

## Geo-Environmental Assessment of Al-Ramtha Soils, Jordan

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### ABSTRACT

This study aims to characterize the pollution conditions by measuring the concentrations of selected heavy metals. It also intends to investigate the relations between soil genesis and lithology. This provides knowledge about the future of the agricultural development in the area and helps decision makers in the land use planning.

**Key words:** Al-Ramtha soils, Heavy metals, Geo-environmental assessment.

### INTRODUCTION

Soils are fundamental components of the ecosystem, the backbone of terrestrial ecosystems and contribute in several biogeochemical processes at air, soil and water Interfaces. Soils can absorb and degrade many types of extremely toxic substances (ETS) such as heavy metals. However its capacities are limited and sometimes may become contaminated (Wahsha *et al.*, 2014a). Therefore, the soil quality and its productive capacity must be preserved and improved. The levels and spatial distribution of ETS in soils depend on several factors such as parent material, climate, topography, soil type and land use (Wahsha *et al.*, 2012a). Three main sources of pollution can be identified: industrial activities and agricultural practices. The mismanagement of these anthropogenic activities could strongly increase the normal concentration level of ETS in soils, causing contamination, environmental troubles and health concerns. Soil contamination by heavy metals may influence negatively soil health, which often limits and sometimes disqualifies soil biodiversity and decreases plant growth (Nadimi-Goki *et al.*, 2014). Within soils, all biological, geological and chemical

processes of the different ecosystem components are combined (Maleci *et al.*, 2014). A common criterion to evaluate long term sustainability of ecosystems is to assess the quality of soil (Wahsha *et al.*, 2014b)

Therefore it is important to understand the soil composition, properties and dynamics to make sustainable protection and reclamation if required. There is a growing need to apply more sustainable and geo-environmental assessment to soils which may become or have become polluted (Wahsha *et al.*, 2014c).

The major characteristic of the climate in Jordan is the contrast between sub-humid Mediterranean in the northwestern and arid to extremely arid in the east and southeastern Jordan. In addition to altitudinal and geologic variations, these factors have played a major role in soil development and genesis (Wahsha *et al.*, 2014b). Soil Survey in Jordan dates back to 1950s using the US classification system of 1938 (Al-Qudah, 2001). In northwestern Jordan, five are common; Aridisols, Entisols, Inceptisols, Vertisols and Mollisols (Ministry

of Agriculture, 1993). These soils have been developed from different parent materials including Quaternary alluvium, colluvium and loess deposits (Khresat *et al.* 1998).

The study area is the eastern extension of the northern plateau; a fertile soil known for cereal planting. It is actually of less productivity compared to soils of the western part. However, in the last few decades, this area has observed rapid expansion in urban development. The area hosts a major highway between Irbid and the eastern cities including Al-Ramtha, which facilitated the eastward expansion of human settlement. Soil in northeastern Jordan is mainly of Aridisols order, where it was developed under conditions of low rainfalls and high temperatures. Soils cover about 70% of the study area with a moisture regime of xeric aridic transition (Khresat *et al.* 1998).

This study aims to characterize the pollution conditions by measuring the concentrations of selected heavy metals. It also intends to investigate

the relations between soil genesis and lithology. This provides knowledge about the future of the agricultural development in the area and helps decision makers in the land use planning.

### Study area

The study area is located in the northern part of Jordan, about 2 km south of Al-Ramtha city (east of Irbid) between  $32^{\circ}31' - 32^{\circ} 32'$  longitude and  $35^{\circ}59' - 36^{\circ}3'$  latitude (Fig. 1). The main geologic outcroppings in the study area are: Muwaqqar Chalk Marl Formation (B3) which is composed of marl and marly limestone, and Umm Rijam Chert Limestone Formation (B4) of lower-middle Eocene age. The B4 Formation is mainly composed of alternations of limestone, chalk and chert. Holocene calcrete occurs in limited parts within the study area (Fig. 2). The calcrete is randomly distributed in different parts of semi-flat and gently sloping plains, where evaporation exceeds annual rainfall. Most rocks in this area are covered with soil of variable thicknesses that range from 1-6 m. This soil was developed by weathering of the carbonate rocks exposed

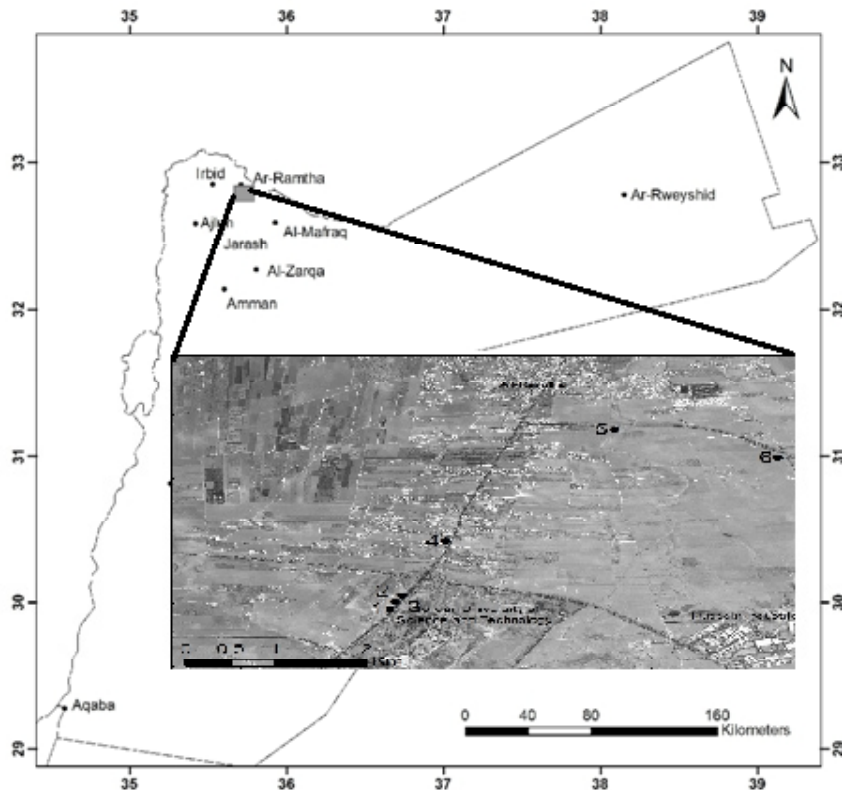


Fig. 1: Location of the studied area and sampling sites

in the surrounding area (Abed, 2003; Ministry of Agriculture, 1993).

## MATERIALS AND METHODS

The area under consideration in this study is located in Al-Ramtha city. Seven sites were selected according to homologous geological, morphological, vegetation coverage and anthropogenic impact and the same pedoclimate conditions (Fig. 1). Each site was sampled at 5, 15 and 30 cm depths. Samples were tightly wrapped with aluminum foil and placed in sealed plastic bags to preserve soil moisture content. Once carried to the lab, routine soil analyses were carried out following the procedures described by Wahsha *et al.* (2012b). Samples were initially analyzed for moisture content, and grain size distribution to determine soil texture. Soil samples were also subjected to mineralogical analysis involving x-ray diffraction. The XRD analysis for random samples was accomplished using Phillips TW 1729 diffractometer with Cu-K-alpha radiation generated at 40 kV and 20mA. The samples were crushed gently using a wooden rod in order to separate the grains without damaging the crystal lattices. One sample from each sampling site was

analyzed for XRD. In addition, soil samples were oven-dried at 105°C for 24 hours, extracted with deionized water (1:5 soil-to water mixtures), shaken for 90 minutes, centrifuged and filtered through a 0.45 micron filter. The extract was analyzed for  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$  (by spectrophotometer), EC and pH. The bulk chemical composition of the samples was determined using both atomic absorption spectrophotometry (AAS) and gravimetric method.

For the analysis of pseudo-total metal content (Cu, Fe, K, Mg, Mn, Na, Pb and Zn) in soils, 0.2 g of powder soil sample was subjected to a complete digestion in 5 mL of *aqua regia* in the microwave in closed containers made of Teflon. After digestion, soil samples were analyzed by flame atomic absorption spectrometry (AAS) according to Fontana *et al.* (2010).

## RESULTS AND DISCUSSION

### Origin of surface soils

The grain size distributions of most hydraulic and aeolian soils are considered are polymodal and represent different transport or depositional processes (Bagnold and Barndorff-Nielsen, 1980).

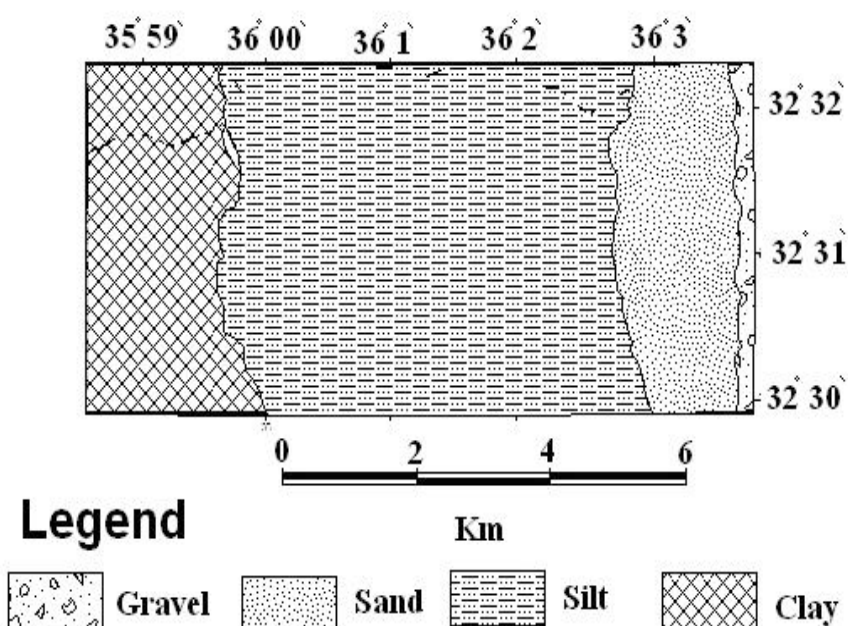


Fig. 2: Pebbly facies map of the study area

Grain-size distribution of collected samples has been commonly used as environmental indicators in soil investigations.

Most of coarse grained soils; particularly sand and gravel deposits in the studied area were transported hedonically during storm wet years as result of flash flood due to wide spread of caliches areas deposits (Fig. 2).

The results of the textural analysis of surface soils are tabulated in Fig.3. Grain size distribution suggests granulometric distribution of the surface were concurrent with distribution of fine and medium grained material, as found in similar flat systems. vast majority of soils showed silty, sandy, clay and pebbly textural granular facies.

These sediments were deposited in the flat watercourse basin. average grain size increases in the north direction, where deposition of the coarser fraction took place. It is likely that sand was transported by saltation, while silt and clay were transported by suspension in the water or by wind action. The pebbly facies is believed to have been deposited after the heavy rains or storm events (Fig. 2).

### Geochemistry

The mean concentrations and standard deviations of the chemical properties and metals concentration for all studied samples are shown in Table 1. In the area of investigation, moisture content of soil samples varied from 7.6-30.8% (averaging about 18.97 (Table 1).

The pH values of the collected soil samples ranged from 7.2 to 8.2 with a mean value of 7.75. These values indicate that the soil is of slightly alkaline nature. The higher pH > 7 plays a role in the removal of metals from aqueous to solid phase and in the plant availability of nutrients. Adsorption-desorption are primarily dependent on pH, for example; it was observed an increase in the adsorption of lead by soil with the increasing of pH from 4 to 7. Generally, heavy metals concentrations in the studied soil are relatively high which could be explained by the increasing of pH (> 8) which increases the ability of soil to adsorb these elements (Nadimi-Goki *et al.* 2014).

The nitrate content ( $\text{NO}_3$ ) of the soil samples ranged between 27 and 108 ppm with an average of 53 ppm (Table 1). The nitrogen concentration increase could be due to the decay of plants residues

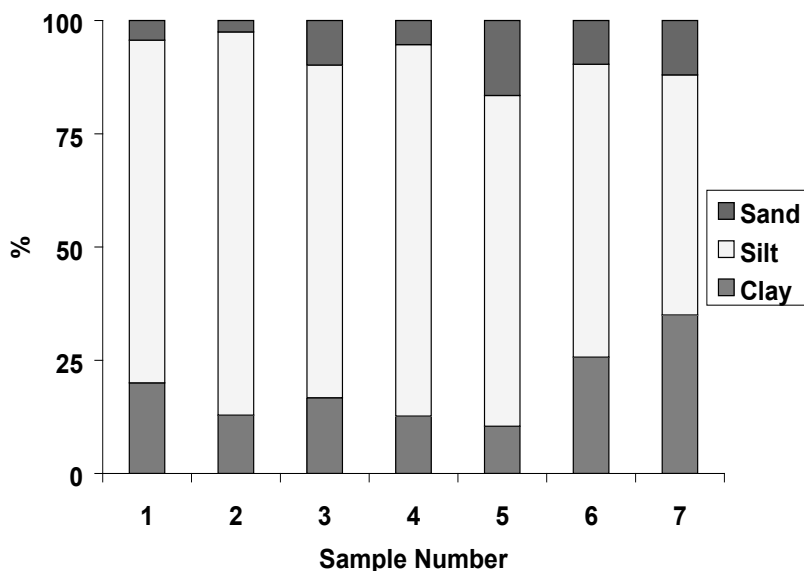


Fig 3: Grain size analysis (average given in percentage) of soils of the studied area.

Table 1: Selected chemophysical properties and the concentrations of heavy metals of the studied soils.

Sample ID	Moisture content %	EC $\mu\text{s/cm}$	pH	Po <sub>4</sub> %	NO <sub>3</sub> %	Cu	Fe	K	Mg	Mn ppm	Na	Pb	Zn
A1	13.5	183	7.6	0.28	84.10	388.71	40828	1079.2	1077.8	290.86	600	145.55	180
A2	17.9	253	7.9	0.18	41.29	700	43637	1510.95	1275.05	1369.2	789	220	230
A3	15.2	212	7.7	0.23	41.78	656.7	37318.5	1307.05	1150.6	841.2	642.2	189.47	190.52
B1	18.5	265	7.6	0.26	108.83	154.44	43095	1486.75	1165.65	1027.5	677.35	195	135
B2	16	178	8	0.21	59.29	130	30930	1118.75	1084.95	395.22	567.7	175.39	120
B3	20.9	252	7.8	0.18	38.84	180	44891	1673.75	1422.95	952.95	745.45	205	150
C1	11.9	295	7.9		72.68	183.75	48300.5	1803.75	1105.15	458.58	832	107.64	99.36
C2	16.7	182	7.8	0.20	47.14	211.47	47745	1726.55	1068.25	628.7	777.5	132.31	120
C3	9	215	7.5	0.27	37.86	439.85	36242.5	1303.4	957	908.3	759.7	147	163.77
D1	18.3	293	8.2	0.37	52.70	429.3	32605	1106.85	1078.1	620.75	679.85	161.72	72.53
D2	30.8	436	7.6	0.25	33.40	490	46244.5	1662.05	1448.8	1017.55	707.6	106.17	45
D3	7.6	357	7.9	0.24	35.74	234.27	46383	1508.05	1250.2	489.22	770.3	128.41	59.07
E1	21.9	194	7.2	0.21	93.35	1330.7	34121	1201.45	1267	496.65	579.55	207.06	465.37
E2	24.6	174	7.8	0.28	34.33	297	33671.5	1207	1280.15	765.95	607.2	109.89	160.39
E3	21.1	216	8	0.21	47.66	315.94	22696	745.45	1170	832	449.64	151.51	50
F1	26.9	1908	7.7	-	83.56	747.7	31189	1070.1	985.65	1213.4	578.2	161.12	241.04
F2	27.6	323	7.8	-	43.39	267	56315	1809.35	1146.7	1342.15	739.15	142.11	122.09
F3	27.4	460	7.6	-	36.69	291.93	32010	1436.4	511.5	1463	640.85	155.65	43
G1	17.9	243	7.7	0.22	77.60	599.8	34367.5	1840.2	1344.9	593.15	793.5	193.68	211.58
G2	21.4	193	7.6	0.24	25.26	500	47894	1157.45	1099.15	530	621.65	171	187.21
G3	13.3	185	7.8	0.25	27.34	457.35	28435	665.5	859.9	425	508.8	70	54.73

or from irrigation with treated wastewater. The increased usage of nitrogen fertilization and manure application in the adjacent cultivated lands as well as effects of man and livestock wastes also attribute to the increase in  $\text{NO}_3^-$ .

In the analyzed samples electrical conductivity (EC) ranged from 174  $\mu\text{s}/\text{cm}$  to 1908  $\mu\text{s}/\text{cm}$  with a mean of 334.14  $\mu\text{s}/\text{cm}$  (Table 2). The variation in EC values can be explained, as being due to the source of irrigation water, where irrigation with treated wastewater resulted in significantly higher values for EC. The use of pesticide Pyrozone which contain Zinc ethylene, Diyathogarbmiter and Seymezal with 88% viscous sulfur content and the use of Ammonic ( $\text{NH}_4$ )  $\text{SO}_4^-$  fertilizer, may explain

the increase in EC (Abu- Rukah and Samawi, 2000).

The soil content of phosphate ( $\text{PO}_4$ ) ranged between 5.78% and 34.86%, with an average content of 12.96 (Table 1). The variation in soil  $\text{PO}_4$  is attributed to variation in agricultural intensity in the study area. The upper-Cretaceous phosphate in the surrounding, is another contributing cause to the  $\text{PO}_4$  content in soil. The continuous use of phosphate fertilizers in agricultural land are another source of the phosphate in the study area (Bini and Wahsha 2014).

Nitrate has been observed in relatively high levels, although soils in the study area are devoid

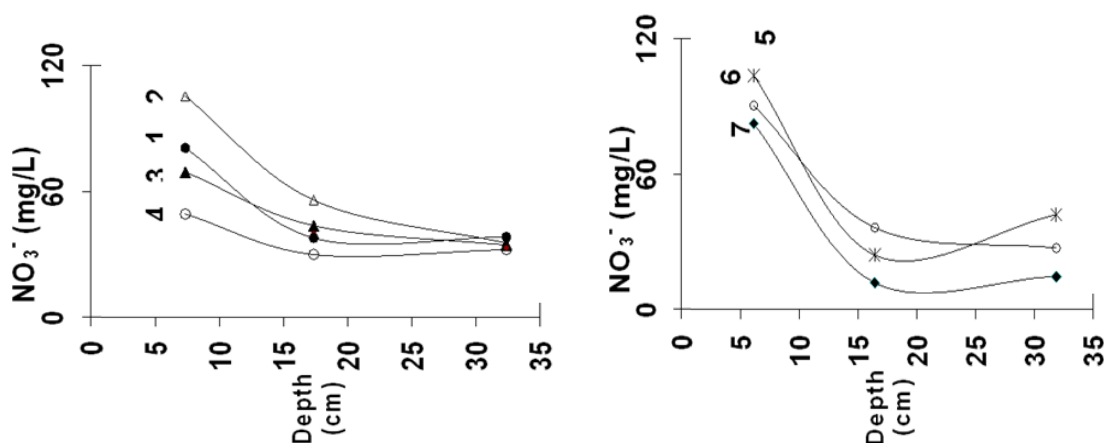


Fig. 3: Nitrate distribution within the soil profiles for different soil samples.

Table 2: The average concentrations of heavy metals in the earth's crust (Rule, 1986) and in soil (ppm) (Adriano, 2001), and normal range in soils and critical soil total concentration (Alloway, 1990), compared with the results obtained from the analyzed soil samples

Metal	Ave. crustal abundance	Normal range in soils	Critical soil total conc	Average world soil	Soil in the study area
Pb	12.5	2-300	100-400	20	145.56
Zn	70	1-900	70-400	95	116.16
Cu	70	1-20	2-100	45	330.79
K	-	-	-	96600	1353.33
Fe	-	-	-	47200	38996.14
Mn	-	20 -10000	1500-3000	850	684.16
Na	-	-	-	9600	671.47
Mg	-	-	-	1500	1157.25

Table 3: Correlation coefficient and significant test between the measured heavy metals and associate physico-chemical parameters.

	H <sub>2</sub> O	EC	pH	PO <sub>4</sub>	NO <sub>3</sub>	Cu	Fe	K	Mg	Mn	Na	Pb	Zn
H <sub>2</sub> O	1												
EC	0.3688	1											
Ph	-0.183	-0.045	1										
PO <sub>4</sub>	-0.028	0.1428	0.1695	1									
NO <sub>3</sub>	0.0841	0.2733	-0.204	-0.168	1								
Cu	-0.133	0.2289	0.42	0.0112	0.4514	1							
Fe	0.0084	-0.15	-0.089	-0.236	-0.124	-0.521	1						
K	0.153	-0.105	-0.127	-0.303	-0.114	-0.523	0.8995	1					
Mg	-0.067	-0.228	-0.036	-0.257	0.1363	-0.09	0.2147	0.1356	1				
Mn	0.29	0.2982	-0.104	-0.09	0.2905	-0.26	0.5693	0.543	0.4219	1			
Na	-0.202	-0.144	0.0063	-0.116	-0.147	-0.483	0.8483	0.882	0.1637	0.5232	1		
Pb	-0.109	0.0597	0.1201	0.0019	-0.147	0.7979	-0.584	-0.648	-0.176	-0.364	-0.649	1	
Zn	0.0053	0.1577	0.5866	0.0689	0.2872	0.7576	-0.181	-0.208	0.0647	0.0222	-0.236	0.4146	1

of vegetation cover. Despite the variability in nitrate levels, general trends are apparent. The results showed that at each location, nitrate level decreases with depth (Fig. 3).

### Heavy metal concentrations

The concentration of Pb and Zn in the soil samples ranged from 70 to 207 ppm with a mean value of 146 ppm and from 0.0 to 465 ppm with a mean value of 116 ppm, respectively, whereas the mean concentration of Cu, Fe, K, Mg, Mn and Na were 330, 38996, 1353, 1157, 684 and 671 ppm respectively (Table 1).

The variation in the content of Pb, Zn, Na, Cu, Mn, Mg, K and Fe in the soil of the study area makes it difficult to analyze their degree of contamination without taking into account the spatial variability of metals and their content in different world average values. Table 3 shows the average concentrations of heavy metals in the earth's crust in soil (Rule, 1986; Adriano, 1986), normal range in soils and critical soil total concentration (Wahsha *et al.*, 2012b; Alloway, 1990), compared with the results obtained from the analyzed soil samples collected in the study area.

Almost all the locations show high concentrations in various metals in the soil of the study area which exceed the permissible level stated in Mason Moore, 1982. The sources of this increase in the various metal ion concentration could be attributed to the increasing anthropogenic effect from agriculture sources, in addition to the contribution of the natural source.

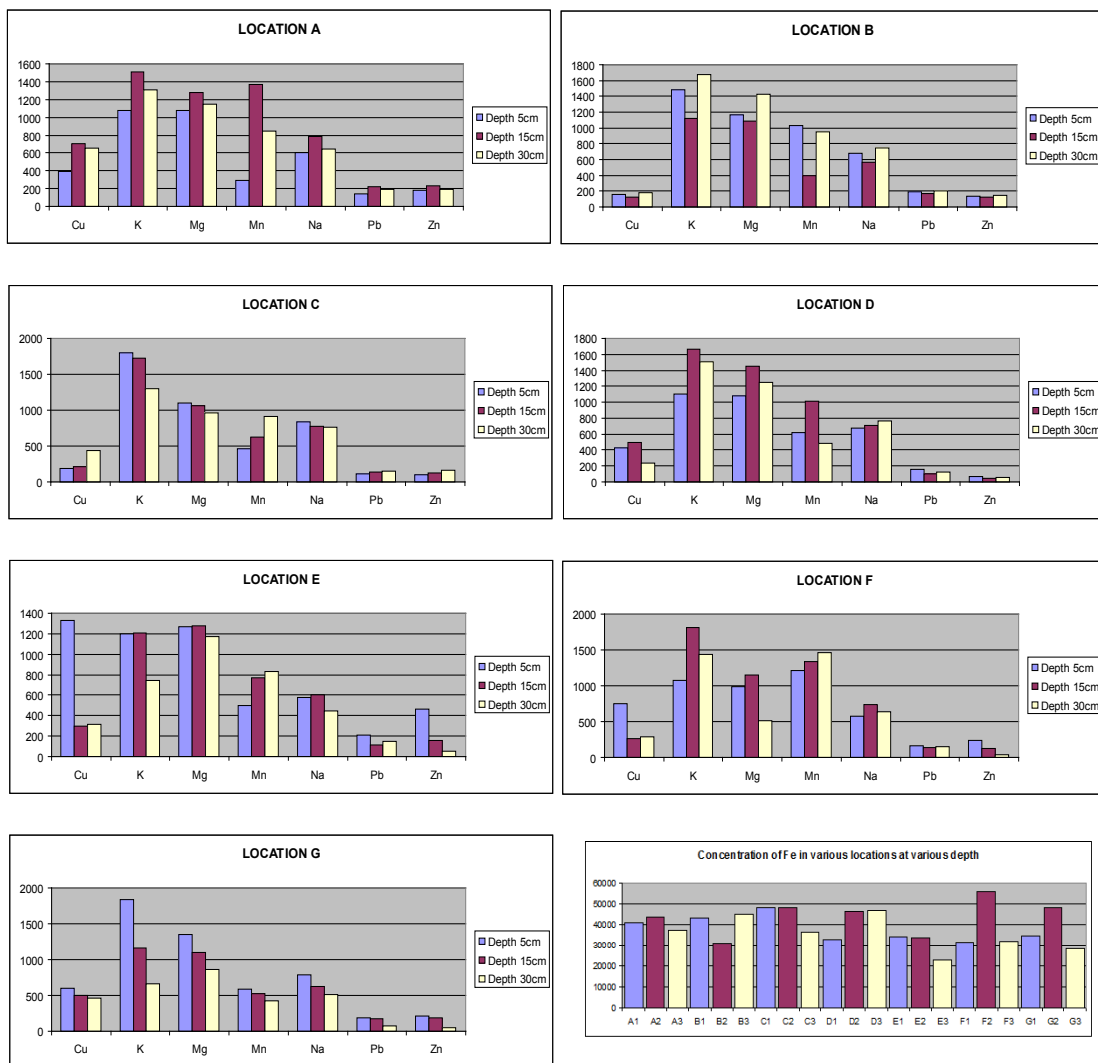
Lead pollution in the environmental samples including soil, dust, sediment and natural water comes from combustion of gasoline that contains tetraethyl lead as an anti-knock agent. Lead concentrations greater than 110 for the total lead content should not occur naturally in soils and must probably reflect the impact of pollution (Kabata-Pendias and Pendias, 1984). According to Bender, (1991), the soils of the study area were : mainly originated from the upper cretaceous carbonate rocks found in the. But carbonates in general have low concentrations of lead. Comparing this with the values obtained in this study, it is clear that the carbonate parent rocks are not the only

source of lead. Other sources contribute most likely anthropogenic ones (Wahsha and Al-Rshaidat, 2014).

The average concentration of Zn in carbonate rocks (Table 2) is about 20 ppm. Alloway (1990) estimated the average concentration of zinc in the carbonate rocks as 20 ppm. and the average concentration, of zinc in normal soil ranges from 1 to 900 ppm. Kabata-Pendias and Pendias, (1984) has found that the average zinc concentration lies between 17 and 125 ppm. Comparing the average concentrations of zinc in the soils of the study area with those given by several authors, it seems that

the relatively higher values of zinc concentrations in the analyzed soil samples may reflect anthropogenic effects (Wahsha and Al-Rshaidat, 2014). This may explain the relatively high concentrations of Zn in the soils of the study area.

Higher concentration of copper in the surface horizon of a soil is an indication of soil additions from smelters, fertilizers, sewage slugs and other wastes, (Alloway, 1990). The levels of copper in the samples were higher than the world-wide values (100 – 300 ppm) (Fergusson and Kim, 1991). The present study found that copper levels were high compared with several regions or areas in the world



**Fig.4: Concentration of major and trace elements in soil sample at various locations and at different depths.**



(Table 2). By analyzing the average concentration of Na, Mn, Mg, K and Fe in the study area, it seems that these contents are similar with those reported by Kabata – Pendias (1984).

### Correlation analysis

The measured total concentration of the heavy metal was positively correlated with the measured physio-chemical properties. The positive correlation between the heavy metal contents and the % PO<sub>4</sub> may be attributed to the use of the phosphate fertilizers in the area under study, which is characterized by intensive agricultural activities.

Alloway *et al.*, (1995) showed that pH was one of the key factors controlling the specific adsorption of heavy metals in different soils. Positive correlation of heavy metals in the sediments is strongly related to the alkalinity of pH (Alloway, 1990, Baker, 1980).

Nitrate has been observed in relatively high levels, although soils in the study area are low of vegetation cover. Despite the variability in nitrate levels, general trends are apparent. The results showed that at each location, nitrate level increased to a depth of 15 cm where it remained almost constant afterwards.

The semiarid climate conditions of the study area with its relatively limited rainfall allow nitrate to accumulate near the surface. However, over a long period and during events of rainfall, nitrate leaches into soil and accumulates as water evaporates and returns to the atmosphere. In addition, grain size distribution of soil samples showed that soil samples are composed mainly of silt and clay with minor proportion of fine sand. These fine particles can be closely packed together and decrease water infiltration and favor accumulation of nitrates by evaporative concentration. While sources of nitrate have not been investigated, it is believed that both processes; biological or no biological, contribute to soil nitrate. The study area is in a transition zone between arid (eastwards) and sub humid (westwards) and is subjected to dust and sand storm particularly the frequent easterly wind. This suggests that portion of these nitrates is likely associated with aeolian deposits, where nitrate has been transported with atmospheric influx to the area. In addition, the area

is covered with scattered native vegetation which releases nitrate when decomposed. The presence of scattered vegetation also helps trap aeolian dust containing nitrates, which leaches into soil. The soil pH for all samples exhibited alkaline soils, which is mainly related to the presence of calcium carbonate. In addition, the arid and semiarid climate conditions prevailing in the study area help buildup of carbonate in soil profile (Wahsha *et al.*, 2012a and b; Fontana *et al.*, 2010).

### The relation between Soils and Clay content

The soil textural classes depend on the percentage of clay, silt and sand in the soil. Clays are soil particles less than 2µm in size, having a higher surface area than other soil particles like sand and silt. In most cases this specifically includes the clay minerals, but also fine grinded particles of other minerals. Clay minerals are the products of weathering rock and affect both soil physical and chemical properties. Soil chemical properties are impacted by their permanently negatively charged, large surface area. Since much of the cation exchange capacity of soils comes from the negatively charged clay surface sites, clayey soils renders metals much less available than sandy soils. Clay minerals may contain small amounts of trace elements as structural components, but their sorption capacities to trace elements play a very important role. The sorption capacities of different clay minerals vary in the following sequence: montmorillonite, vermiculite > illite, chlorite > kaolinite (Wahsha and Al-Rshaidat, 2014).

### XRD and Organic Matters

Clay minerals such as kaolinite and Fe-oxides are considered variable-charge minerals (Sparks 2002 and 2005). Heavy metals, including Lead (Pb), tend to accumulate in the clay fraction of the soil profile. The Zn concentration in the soil and clay content are positively correlated (Hailu, 2007). Total concentration of heavy metals (Co, Cu, Ni, Pb, and Zn) in soils is dependent on clay content. There are fivefold more Cu, two fold more Zn and Ni, and 1.5-fold more Co and Pb in the clay fraction than in the total soil. The clay fraction of surface horizons contains a greater concentration of Cu, Zn, and Co than subsoil horizons due to biogeochemical cycling of these micronutrients from the subsoil to the surface (Lee *et al.*, 1997).

A general look for the concentrations of some major and trace elements for soil samples at various locations and different depths (Fig. 4) shows that; the concentrations for trace elements are increased with depth at A, B and C locations, while the concentrations are decreased at D, E, F and G locations; this may be controlled by the amount of rainfall and the percentage of sand comparing to silt and clay at these areas. Areas that have more annual rainfall cause more heavy elements leaching and cause accumulation at greater depth and vice versa, beside the percentage of sand comparing to silt and clay at locations D, E, F and G, relatively more than the percentage at the locations A, B, and C, this makes easier infiltration of water and so transport of heavy elements to greater depth.

## CONCLUSIONS

Soil is a fundamental, poorly renewable resource, which provides a number of environmental, social and economic services. Instead, the major short term impacts on soil functioning derive from land use change and its management. The anthropogenic impact in the selected site is evident. Almost all the locations show high concentrations in various metals in the soil of the study area which exceed the permissible levels. The sources of this increase in the various metal ion concentration could be attributed to the increasing anthropogenic effect from agriculture sources, in addition to the contribution of the natural sources in the area.

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