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Geochemical and electrical properties of some Heavy Metals in El-Tabbin area, Egypt

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ABSTRACT

The present work is conducted in the industrial district south of greater Cairo (El-Tabbin area). Some heavy metals such as Mn, Co, Ni, Cu, Zn, Pb, Cr, Ba, Cd, Mo were determined in contaminated soils during May, 2018. The results showed that the average concentrations of the toxic heavy metals in the study area varied significantly and decreased in the order of Mn>Ba >Zn > Cr > Ni > Co > Pb > Cu> Mo>Cd. The average concentration of some selected heavy metals ranges as follows: Mn (255.8-31448.2 ppm); Ba (145.2-17545.6 ppm); Zn (53.3-1589.9 ppm); Cr (26.7-311.3 ppm); Ni (29.7-114.1 ppm); Co (13.2-39.8 ppm); Pb (5.7-77.4 ppm); Cu (7.6-35.2 ppm); Mo (0.1-15.9 ppm) and Cd (0-1.5 ppm), respectively. Electrical properties were taken and measured in the frequency range (100 to 100 kHz).

Keywords: Electrical resistivity; Permittivity; impedance; Geochemistry; Mineralogy.

Introduction

The alluvial soils in Egypt are formed from disintegration of the eruptive and metamorphic rocks from the Ethiopian Highlands (Blokhuis *et al.,* 1964). The mega cities in the world are facing many serious environmental problems (Molina and Molina 2004).

The field mapping of the fluviatile and associated sediments in the Nile Valley and the examination of a large number of boreholes show that it is possible to conceive the Nile as having passed through five main episodes since the valley was cut down in the late Miocene time (Said 1981). These are from the oldest to the youngest as follows: Eonile (Late Miocene), Paleonile (Late Pliocene), Neonile (Pleistocene). The local geology of the River Nile consists of quaternary deposits, floodplain sediments (Yousef, 1968) and (Said, 1990 and 1993).

The contamination soils due to deposition of heavy metals from various sources have engrossed a great attention worldwide through the recent years. Heavy metals leached into ground water and enter into the growing food crops (Janos *et al.,* 2010). Industrializations have increased very rapidly, especially in the second half of the last century and causing increased levels of environmental hazards (Robaa, 2003). The use of remediation as a cleanup strategy for contaminated environments has increased due to its viability and cost-effectiveness (Alam *et al.,* 2018).

El-Tabbin area is located in southern part of Cairo. Melegy et al. (2005) reviewed the man-made impacts upon water quality of the River Nile of Egypt. The previous work has shown that El-Tabbin region is characterized with relatively high level of anthropogenic contamination of soils and stream sediments by potentially toxic elements (Cd, Se, As, Zn, Ba and Pb) (Melegy *et al.,* 2010). The analysis of the extractable organic matter in soil and sediments from El-Tabbin showed contamination by anthropogenic impacts (Havelocova *et al.,* 2014).

The aim of this study was to study the relationship between geochemical distribution of some selected heavy metals and electrical properties in contaminated El-Tabbin soil.

Materials and Methods

For determination of level of pollution 10 soil samples and were taken in spring period (May) in 2018 (Fig. 2). The sampling sites are described in Table 1.

In each of the selected sites, six quadrates were marked. In each quadrat, soil samples were collected randomly at depth 0–30 cm and put together to form a composite sample. The soil samples

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were kept in zip-locked plastic bags, labelled and transported to the laboratory for making further analysis. The soil samples were dried at room temperature for 4 days, and ground to fine powder. They were then sieved with a 2 mm sieve to remove the coarse soil materials. Sub-samples of the sieved soils were taken for heavy metals analyses and electric properties.

Major elements and heavy metals were measured using X-ray fluorescence (XRF). LCR Hitester Impedance Analyzer (Hioki 3522-50) was used to measure the electrical properties (conductivity, dielectric constant, and impedance).

LCR Hitester Impedance Analyzer (Hioki 3522-50) was measured the electrical properties. The electrical properties were measured at room temperature (~20 °C) and at relative humidity of (~65 %), in the frequency range from 100 Hz up to 100kHz, with 1 volt (Gomaa and Alikaj 2009, Gomaa and Kassab 2016, 2017).

Fig. 1: The location map of the El-Tebbin Area, Egypt.

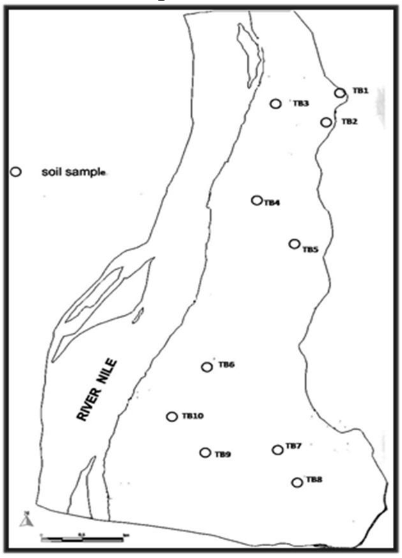

Fig. 2: The sites of soil samples in El- Tebbin Area, Egypt.

Table 1: The key of the studied samples collected from El-Tabbin area, Egypt

No. of samples	Kind of samples	Investigated sites	Major sources of pollution
TB!	Soil	Arab Kafr Ei'llw	Cement factory
TB2	Soil	Arab Kafr Ei'llw	Cement factory
TB3	Soil	Arab Kafr Ei'llw	Cement factory
TB4	Soil	Es El Tebbin	Asfor Co.of Metallorgy and Ceramics
TB5	Soil (school area)	El Tebbin	Industrial Complexes
TB6	Soil (arable land)	El Shobak El-Sharqi	Industrial Complexes
TB7	Soil	El Minya	Coke Factory
TB8	Soil	El Minya, El Shurafa, El-Utaiyat	Coke Factory
TB9	Soil	El-Utaijat	Industrial Complexes
TB10	Soil	El Shobak	Industrial Complexes

Results and Discussion

Based on the chemical analysis of major oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, and P_2O_5); it is observed that El-Tabbin soils are predominantly siliceous type with slight enrichment of alumina component.
The available manganese concentration in soil samples followed the order: TB8>TB4>TB2>TB7>TB1>TB6>TB9>TB5>TB10>TB3.
Maximum concentration of Mn found to be 31448ppm in TB8. The average concentration of Mn of soil sample follows was 3839.7 ppm. Manganese considered as an essential metal, but its high concentration in soil may cause serious problems. Various reports are available which indicate the high application of Mn metal from coke industry causing contamination of soil.
The level of barium in soils ranged from 145.2 ppm in TB3 to 17545.6 ppm in TB8, with an average of 2096 ppm.
Zinc covers the class of essential heavy metals but also toxic if present more than maximum permissible limit. The concentration of zinc in soil ranged from 53.3 ppm to 1589.9 in TB3 and TB8, respectively.

The concentration of chromium also varies from 26.7– 311.3 ppm with an average of 111.04 ppm. The high concentration of Cr recorded at TB8 could be as a result of the steel producing industries in the studied area, chrome plating and pigment production is the main source of chromium contamination in the studied area.

Nickel concentration ranges from 29.7-114.1 ppm with an average of 63.26 ppm. The cobalt concentration in the soils of the study area varies from 13.2–39.8 ppm with an average of 29.71 ppm. The highest concentration is 39.8 in TB9.

Table 2: Major elements in contamined soil in El-Tabbin area.

Main Constituents (wt%)	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8	TB9	TB10
SiO_2	42.00	39.95	42.89	40.90	27.10	45.46	44.49	10.46	36.71	34.80
TiO_2	1.97	2.03	1.17	1.96	0.71	1.76	1.84	0.22	1.31	1.29
Al_2O_3	12.07	12.34	6.74	12.80	4.79	12.69	13.73	3.22	9.86	7.57
$Fe_2O_3^{tot.}$	11.22	12.41	4.73	12.96	5.97	12.85	13.66	49.89	8.75	8.18
MgO	2.89	2.71	1.54	2.54	2.00	2.43	2.56	1.20	3.44	2.19
CaO	13.00	12.52	25.54	11.51	29.18	9.24	8.91	11.81	9.43	18.48
Na_2O	1.10	0.80	0.70	0.82	1.05	0.81	0.75	0.89	4.57	2.34
K_2O	1.24	1.11	1.09	1.08	1.11	1.45	1.53	0.38	1.75	1.81
P_2O_5	0.56	0.51	0.34	0.34	0.36	0.55	0.59	0.34	0.46	0.46
LOI	12.50	14.62	13.27	13.61	22.27	11.30	10.75	16.68	12.36	14.49
SO_3	0.65	0.41	0.99	0.67	3.04	0.46	0.34	1.52	6.53	4.84
Cl	0.29	0.06	0.49	0.14	1.69	0.33	0.24	0.75	4.38	2.91
Total	99.49	99.47	99.49	99.33	99.27	99.33	99.39	97.36	99.55	99.36

The average concentration of lead in top soil is 27.98 ppm. The concentration of lead of the area ranges from 5.7-54 ppm.Main source of lead pollution in the area is due to electroplating of metals, excessive traffic and corrosion of lead pipes.

Copper concentration varies from 7.6 ppm to 35.2 ppm with an average of 17.94 ppm. Copper accumulation in the studied soil of the study area is due to the industries like steel manufacture and application of agrochemicals in the agro-based industry.

Similarly, the concentration of Cd ranged from <0.001 ppm at TB1 to 1.5 ppm at TB9 with an average value of 0.6 ppm. The mean concentrations of Cd recorded in soil at all studied sites were below the WHO/FAO permissible limit.

Electrical properties

Really, the previous concentrations are not the only dominant factor in controlling the resistivity values. There are another dominant factor, which is called the texture and tortuosity of all these elements and the way that they are arranged together. Another factor is the minor elements (Table 3) of these heavy elements in the samples. TB8 (Group A) has very high concentration of Mn, Ni, and Zn heavy elements (decreases resistivity), while the other group samples (TB9 and TB10) has relatively high values of these elements in addition to the relatively high values of the Pb and Cu heavy elements (increases resistivity). Similarly, TB3 (Group C) has the lowest concentration values of Mn, Ni, and Zn heavy elements (decreases resistivity), while the other group samples (TB7 and TB2) has relatively high values of these elements in addition to the relatively high values of the Pb and Cu heavy elements (increase resistivity). The mixing up of these different minor and major elements and minerals in the sample may lead to the change of resistivity values at these samples. The main controlling factors of the major elements are the Fe_2O_3 and SiO_2, while the main controlling factors of the minor elements are the Mn and Pb.

Table 3: Heavy metals in contamined soil in El-Tabbin area

Trace elements (ppm)	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8	TB9	TB10	Min	Max	Av
Mn	989.6	1051.4	255.8	1158.3	547.9	930.6	991.9	31448.2	548.9	471.6	255.8	31448.2	3839.4
Ba	420.1	411.4	145.2	737.6	414.3	387.4	378.6	17545.6	251.0	269.3	145.2	17545.6	2096
Zn	121.9	130.8	53.3	188.0	163.6	136.1	136.7	1589.9	79.7	96.5	53.3	1589.9	269.65
Cr	131.2	101.1	31.7	204.3	26.7	86.8	91.2	311.3	72.3	53.8	26.7	311.3	111.04
Ni	77.6	74.0	29.7	80.6	37.1	58.8	66.5	114.1	53.6	40.6	29.7	114.1	63.26
Co	35.3	25.0	26.6	38.3	13.2	25.9	28.7	-	39.8	34.6	13.2	39.8	29.71
Pb	12.2	17.3	5.7	54.0	48.7	19.2	21.3	77.4	9.6	14.4	5.7	77.4	27.98
Cu	16.2	18.5	7.6	35.2	12.7	16.6	19.2	27.9	12.8	12.7	7.6	35.2	17.94
Mo	0.1	1.1	-	0.6	1.1	0.3	0.1	15.9	1.6	0.6	0.1	15.9	2.38
Cd	<0.001	0.3	-	0.002	0.4	0.0	0.6	1.2	1.5	0.2	-	1.5	0.60

Figure (3) shows three different regions for the variation of the resistivity with frequency. The first region is characterized by a steep decrease of resistivity with the increase of frequency at relatively low frequencies (slope ~0.25). The second region is characterized by very low or nearly no decrease of resistivity with the increase of frequency at relatively moderate frequencies. Finally, the third region is characterized, again, by a more or less decrease of resistivity with the increase of frequency at relatively high frequencies (slope ~0.35).These three regions are very clear at sample TB3 but they are changed from sample to another according to its combinations. Also, these three regions changes by decrease or increase (in frequency range) from one sample to another.

Figure (4) shows the distribution of the permittivity with frequency of El Tabbin area. The values of the permittivity curves behave nearly as one group of levels. TB10, TB9 and TB8 samples have the highestpermittivity value.TB7, TB2 and TB3 samples have the lowest permittivity values. TB6, TB5, TB4 and TB1 samples have moderate permittivity values. The combinations of minor and major elements in the samples lead to the present values of permittivity. The arrangement of the samples according to resistivity values is nearly the same as their values according to permittivity (group A, B and C has the same arrangements). TB10 at Group (A) has the lowest permittivity value. TB3 at Group (C) has the lowest permittivity value.

Generally, as the frequency increases the permittivity decreases as a direct result of the decrease of distance between semi-conducting cluster, which decrease with the increase of the activity of charged particles with the increase of frequency. Frequency increase and accordingly, charged particles are activated to overcome energy barriers between clusters or grains to become more close to each other's and, finally, permittivity values increase (Gomaa *et al.,* 2018).

The small insulating distances between semi-conducting clusters or grains motivate high values of permittivity.

Concentrations of major and minor elements control the complex impedance values (Table 3). Mixing up of elements and minerals in samples changes the texture that changes the complex impedance of these samples.

Figure (5) shows the distribution of all samples. There are arcs (or lines) for all the samples for the low frequency impedance. This arc (or line) is an indicator of the ratio of the real to the imaginary components in the samples. When the angle (with the X-axis) decreases, then the sample is more conductor (increase of total conductor conduction paths between electrodes) and vise verse (Shaltout *et al.,* 2012).The second region is the high frequency region, which is represented by a semicircle at the end of the arcs (or lines). The semicircles are a representation of the bulk material of the samples (Gomaa and Abou El-Anwar 2015).

Generally, semicircles mean that there is DC in addition to the AC conduction of the resistivity (Kassab *et al.,* 2017). Arcs decrease in size to be a fraction of semicircle due to the increase of conductor minerals (Gomaa and Abou El-Anwar 2017). The minor and major compositions (and texture) change and the electrical properties are changed and accordingly we can follow the contamination effect of minor and major compositions at the electrical properties.

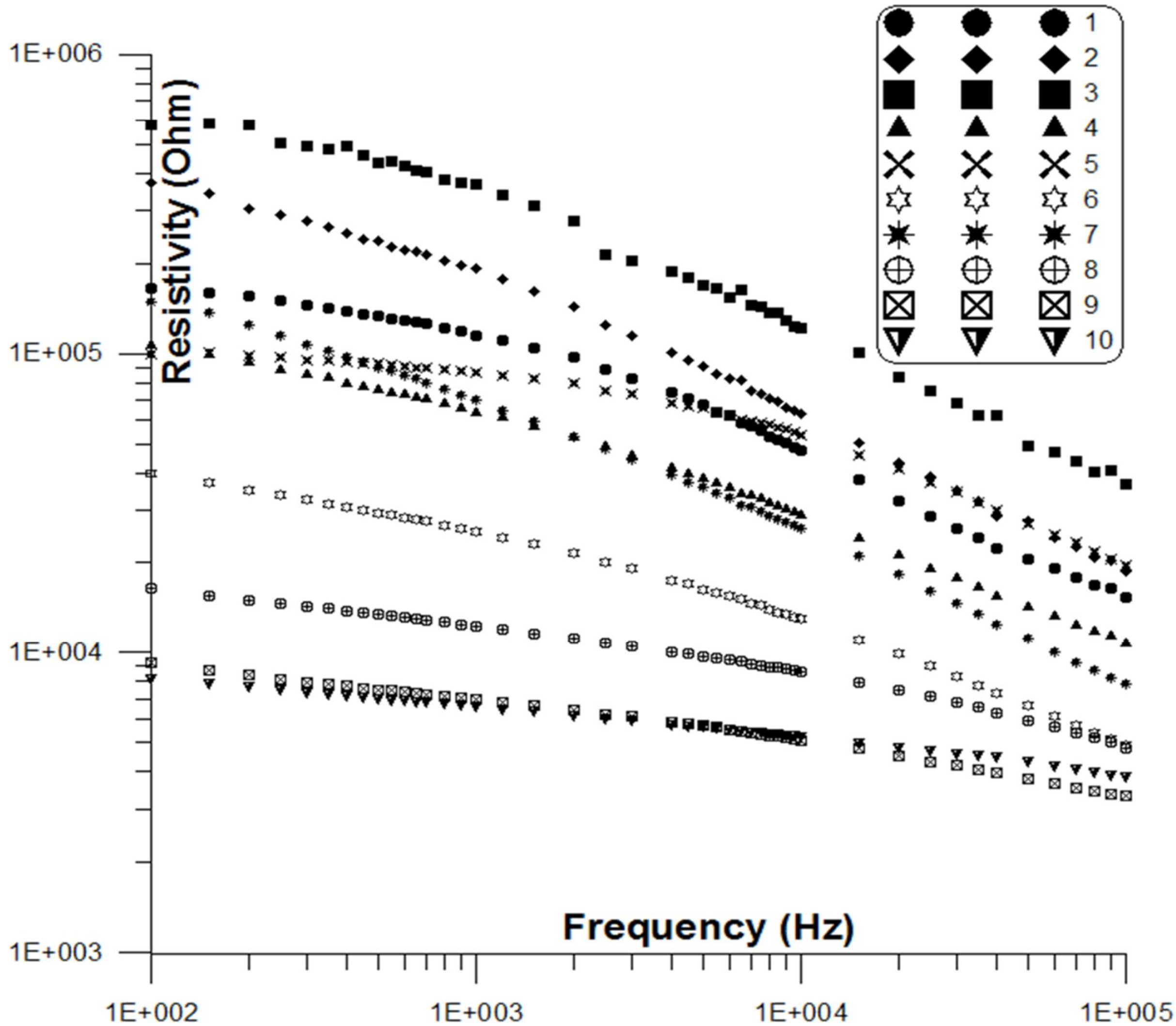

Fig. 3: Shows the variation of the resistivity of samples as a function frequency of the El-Tebbin Area, Egypt.

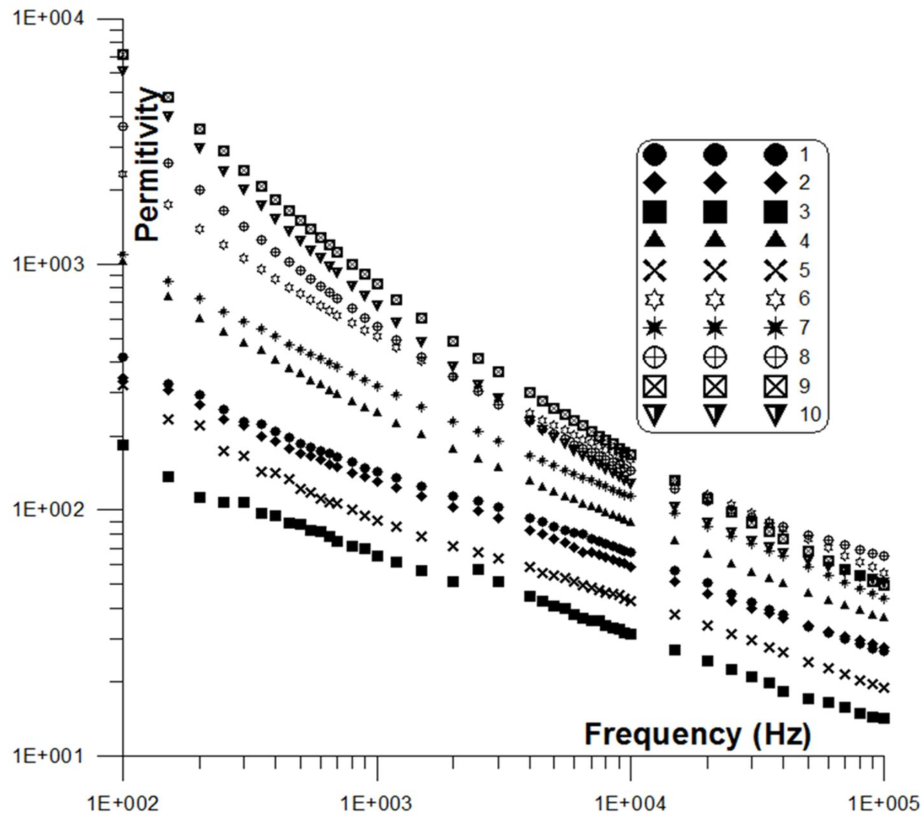

Fig. 4: Shows the variation of the permittivity of samples as a function frequency of the El-Tebbin Area, Egypt.

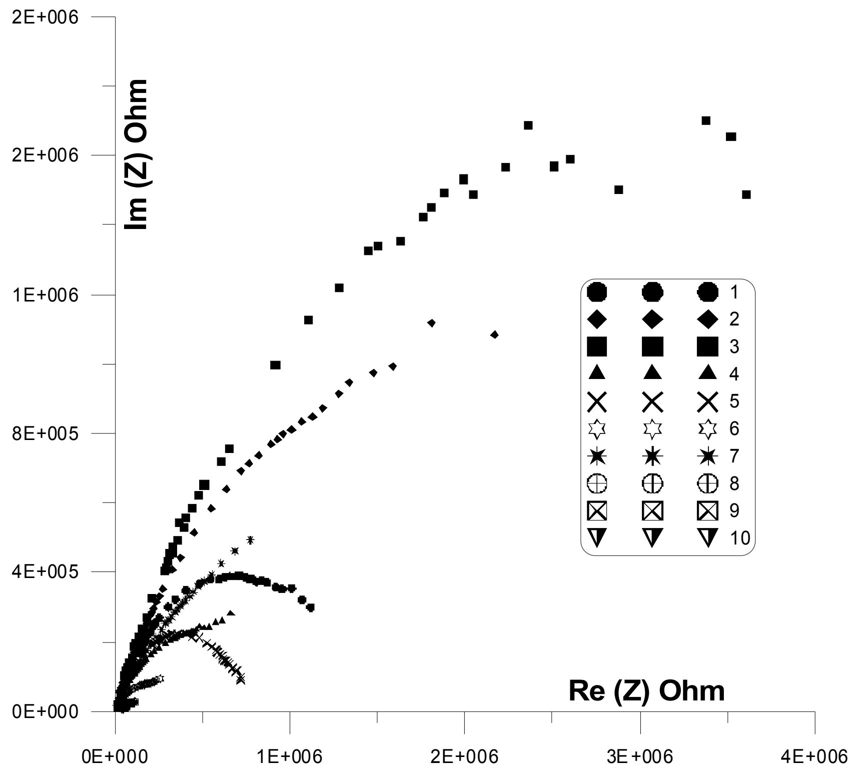

Fig. 5: Shows the variation of the real and imaginary impedance of samples as a function frequency of the El-Tebbin Area, Egypt.

Conculsion

The results presented showed that the average concentrations of the heavy metals in the study area varied significantly and decreased in the order of Mn>Ba > Zn > Cr > Ni > Co > Pb > Cu> Mo > Cd. Maximum concentrations of Mn, Ba, Zn Cr, Ni, Pb and Mo were found to be 31448, 17546.6, 1589.9, 311.3, 114.1, 77.4 and 15.9 ppm, respectively, in TB8, which indicate high application of these metals from, coke the steel industries. Electrical properties of some samples from El- Tabbin area, Egypt, were taken and measured electrically in the frequency range (100 to 100 kHz). The main controlling factors of the major elements are the Fe_2O_3 and SiO_2, while the main controlling factors of the minor elements are the Mn and Pb.

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