Assessing Heavy Metal Pollution in Soils of Damietta Governorate, Egypt

M. I. El-Gammal, R. R. Ali, and R. M. Abou Samra

Abstract**—**This study aims to assess heavy metals pollution in the soils of Damietta governorate by using remote sensing and GIS techniques. To fulfill this objective, surface and subsurface soil samples were collected in soils along ten major road segments in Damietta governorate. Cu, Fe, Ni and Zn concentration in the samples were estimated. The inverse distance weighted (IDW) of Arc-GIS 10.2 software was used to interpolate the heavy metal concentration in soils over the study area. The index of Geo-accumulation was applied to assess of the soil contamination. . According to the study results, the concentrations of Cu in top soils and Ni for the entire region were lower than its background values while the concentrations of Cu in subsurface soils and Zn in all soil samples were higher than the background values.

Keywords**—**Heavy metal, Pollution assessment, spatial pattern, Index of Geo-Accumulation, Damietta governorate, Egypt.

I. Introduction

SOIL contamination by heavy metals (HM) has become a widespread serious problem in any parts of the world (Sofianska et al., 2013). Heavy metals enter the environment as a result of both natural and anthropogenic activities. Naturally heavy metals occur in soils, usually at a relatively low concentration, as a result of the weathering and other pedogenic processes acting on the rock fragments on which the rock develops soil parent materials (Jankaitė et al., 2008 and Mbah and Anikwe, 2010). Anthropogenic sources of heavy metals for soils include commercial fertilizers, liming materials, agrochemicals and other materials used as soil amendment, irrigation waters and atmospheric decompositions (Sofianska et al., 2013 and Senesi et al., 1999). The categorical aspects of pollutants (inorganic and organic) come from different source of industrial activities and vehicle based emission. Inorganic pollutants and its compounds come from vehicle pollution and industrial emission. Trace elemental concentration in dust which is significantly deposited due to anthropogenic stress and ignorance (Rakib et al., 2014).Inter-spherical migration of chemical elements and their accumulation depend on a lot of environmental factors, such as meteorological conditions, the chemical and mineralogical composition of soil-forming rocks, the textured composition of the soil, soil solution pH, sorption, the content of organic matter, etc. (Jankaitė et al., 2008). Accumulation and distribution of anthropogenic heavy metals in soil may depend on wet and dry depositions that convey particles from air to soil (Malizia et al., 2012). The sources of heavy-metal emissions from vehicles include fuel combustion, lubricating oil consumption, tire wear, brake wear, road abrasion. Zn comes from tire wear and galvanized parts such as fuel tanks. Brake wear is the most important source for Cu emissions. Through the atmospheric deposit or road runoff, heavy metals can be transported into the roadside soils (Yan et al., 2013). Nickel is included in various metal alloys, stainless steels, and electroplating. Zinc fertilizers, sewage sludge and atmospheric dust of industrial origin are the principal sources of Zn accumulation in soils (Omran and El Razek, 2012). The waste products from vehicles that ply highways contain some heavy metals inform of smokes. Emissions from exhaust pipes of automobile engine and contacts between different metallic objects in machines contain such heavy metals as Zinc (Zn), Iron (Fe) and Copper (Cu) and are major sources of pollution among soils .The contaminants from automobile either accumulates on the soil surface or are moved down to deeper layers and eventually may change the soil physicochemical properties directly or indirectly. Most commonly heavy metals do not degrade naturally and accumulation of high concentration in soils can be toxic to plants, humans and other living organisms in the surrounding environment (Mbah and Anikwe, 2010).Spatial distribution of some important heavy metals is essential to assess their effects on soil and to delineate contamination (Omran and El Razek, 2012). Geostatistical interpolation is being used to estimate the spatial distribution of pollutants in soil (Baraba et al., 2001; Van Meirvenne and Goovaerts, 2001; He and Jia, 2004; Woo et al., 2009). The spatial interpolation of inverse distance weight was used to produce the spatial patterns of heavy metals and to quantify the probability of heavy metal concentrations higher than their guide values (Parveen et al., 2012).

II. Materials And Methods

A. The Study Area

Damietta governorate is located at the northeast of the Nile Delta between longitudes 31° 28`& 32° 04` and latitude 31° 10` & 31° 30` (Fig. 1). The governorate covers an area of 227575.32 acres, representing 0.1% of the Republic's area, and encompasses 4 districts, 10 cities, 47 rural units and 85 villages. According to the preliminary results of 2006 census, population is about 1.1 million people; 38.4% of them live in urban areas and 61.6% in rural areas. The population natural growth rate is 21.6 per thousand. The governorate cultivated

M. I. El-Gammal, and R. M. Abou Samra, are with Environmental Science Department, Faculty of Science, Damietta University, Egypt

R. R. Ali, Soils and Water Department, National Research Centre, Cairo, Egypt

area covers 108.8 thousand acres and is famous for growing wheat, maize, cotton, rice, potatoes, lemons, grapes, and tomatoes (CAPMAS, 2011).

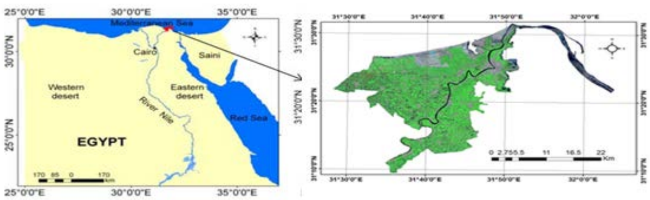

Fig. 1 Location of Damietta Governorate on Egypt Map (to the Left) and Landsat-8 Image of the Governorate acquired in 2013 (to the Right).

B. Soil Sampling And Analysis

Soil samples were collected from ten sites representing Damietta governorate during April 2013. We paid special attention to the criteria such as traffic density and road section while selecting the sample points. Locations of the studied sites were identified using a "GPS" (Model German) as shown in Fig.2. Two soil samples were taken from each site: the first from the surface soil layer at depth 0 – 30 cm (top soil) and the second represented the subsurface soil layer at depth 30– 60 cm (sub soil). All samples were put in airtight polyethylene bags and taken back to the laboratory. Cu, Fe, Ni and Zn concentration were estimated in the Desert Research Center, Cairo. Collected samples were air-dried, crushed and stored in plastic bottles. The samples were acid digested with concentrated sulfuric acid and hydrogen peroxide added as drops as an oxidizing agent and an accelerator for digestion process and heated until samples being clear .Cu, Fe, Ni and Zn concentration in the extracts were estimated using atomic absorption Unicam 929 AA spectrometer by hollow cathode lamp 10 mA in the Desert Research Center, Cairo according to (Cook, 1997).

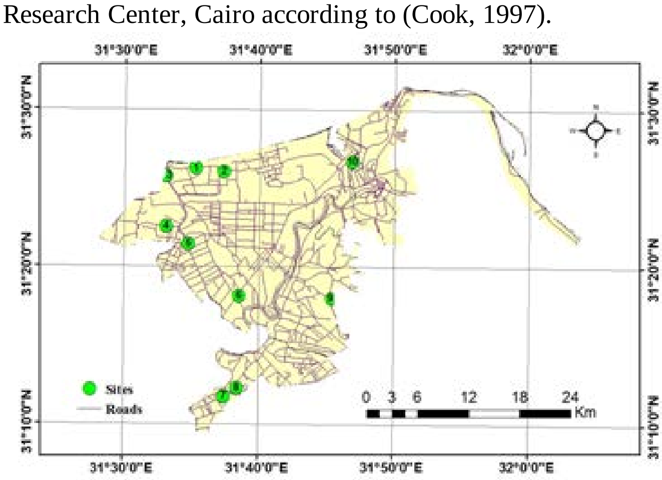

Fig. 2 Location Map of collected Samples, Damietta Governorate

C. Spatial Distribution Of Heavy Metals

Spatial interpolation is commonly used for producing continuous information when data are collected at distinct locations (e.g. soil profiles). The inverse distance weighted (IDW) is an interpolation method, which weighs the surrounding known values to derive estimations for an unmeasured location (Ali and Moghanm, 2013). The inverse distance weighted (IDW) of Arc-GIS 10.2 software has been used to interpolate the heavy metal concentration in soils over the study area.

III. Assessment Of Contamination

A. Index Of Geoaccumulation.

The index of Geoaccumulation (Igeo) means the assessment of contamination by comparing the levels of heavy metal obtained to a background levels originally used with bottom sediments (Awadh, 2013). Gowd et al. (2010) has applied the index of Geo-accumulation to assess of the contamination. The evaluation of contamination with heavy metals was made using the index of Geoaccumulation (Igeo) using the following equation

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n}$$

Where C_n is the measured concentration of the heavy metal in road dust and B_n is the geochemical background concentration of the heavy metal (crustal average). Lu et al., 2009 defined the constant 1.5 in equation 1 as a constant introduced to minimize the effect of possible variations in the background values which may be attributed to lithologic variations in the sediments. Here the focus is between the concentration obtained and the concentration of elements in the Earth's crust, because soil is a part of the layer of the Earth's crust and its chemical composition is related to that of the crust (Rahman et al., 2012). The index of Geoaccumulation (Igeo) is shown in Table 1.

TABLE I
INDEX OF GEOACCUMULATION (IGEO) FOR CONTAMINATION LEVELS IN SOIL (RAHMAN ET AL., 2012)

Igeo Class	Igeo Value	Contamination Level
0	Igeo ≤ 0	Uncontaminated
1	0 < Igeo < 1	Uncontaminated/moderately contaminated
2	1 < Igeo < 2	Moderately contaminated
3	2 < Igeo < 3	Moderately/strongly contaminated
4	3 < Igeo < 4	Strongly contaminated
5	4 < Igeo < 5	Strongly/extremely contaminated
6	5 < Igeo	Extremely contaminated

B. Statistical Analysis

The statistical analysis was performed using Excel Microsoft 2010 and SPSS version 17 programs. This represents the descriptive statistics. A probability of 0.05 or less was considered as significant. Correlation coefficients as well as the derived equations from the relationship between the related parameters were also calculated.

IV. Results And Discussion

A. Assessment And Mapping Of Heavy Metal In Soils

The influence of anthropogenic activities as a major source of heavy metals contamination in the soil, dust, plants and sediments was observed by many studies (Senesi et al., 1999; Fagbote and Olanipekun, 2010; Mbah and Anikwe, 2010; Omran and El Razek, 2012; Yan et al., 2013; Sofianska et al., 2013 and Yadav et al., 2013). The guidelines of some pollutants elements in soil not settled. Egyptian law 4/94 did not include standard limit in dust and soil, or also in air except for lead in air (El -Gammal et al., 2011). The concentration of heavy metal published in some of these studies showing threshold of heavy metal concentrations (mg kg-1) found in the European Union Standards (EU 2002) as shown in Table 2.

TABLE II
THE THRESHOLD OF HEAVY METAL CONCENTRATIONS IN SOIL AS (MG KG-1) DRY SOIL

Parameters	Threshold concentration *EUS
Zn	300
Cu	140
Ni	75
Fe	-

Adopted from Baize, 1997; * EUS= European Union Standards (EU 2002).

B. Evaluation Of Nickel (Ni) In Soil

The concentrations and geographical distribution of Ni in soil were given in Tables 3 and 4 and Figs. 3 and 4. Nickel concentrations in the surface layers of soil (0-30 cm) ranged from 1.85 to 47.79 with a mean value of 15.9 mg kg-1 soil. The highest nickel concentration (47.79 mg kg-1) in the top soil samples has been found at location 4 (Nabaruh - Kafr Al – Ghab Road). Corresponding values for the subsurface layers were from 12.48 to 47.86 with an average value of 29.7 mg kg-1 soil. The highest nickel concentration (47.86 mg kg-1) in the subsurface soil samples has been found at location 3 (Jamasah - Kafr Al – Wustani Road). These results indicated that the subsurface layers of Damietta governorate soils contain greater amounts of Ni in comparison with surface layers. The major sources of nickel contamination in the soil are metal plating industries, combustion of fossil fuels, and nickel mining and electroplating. It is released into the air by power plants and trash incinerators and settles to the ground after undergoing precipitation reactions (Raymond and Okieimen, 2011). Anthropogenic activity has resulted in the widespread atmospheric deposition of nickel from the burning of oil and coal. Agricultural fertilizers, especially phosphates, are also a significant source of nickel in soil (McGrath, 1995). Nickel phytotoxicity in soil includes chlorosis followed by yellowing and necrosis of leaves, restricted growth, and tissue injury (Rooney et al., 2007). For evaluating of the degree of soil contamination in Damietta governorate, the obtained results of the nickel element concentrations were compared with the European Union Standards (EU 2002) and permissible critical limits. De Vries and Bakker (1998) reported that the critical soil total contents of Ni according to some environmental regulations all over the world are 10 ppm in Denmark; 15 for clay soils and 70 ppm for sandy soils in Germany; 20 ppm in Canada; 30 ppm in Ireland; 35 ppm in Netherlands; 40 ppm in Finland; 50 ppm in Switzerland; 60 ppm in both Taiwan and Czech Republic; and 85 ppm in Eastern Europe. In comparison with European Union Standards (EU 2002) limits (75 ppm), it could be observed that the Ni values of the top and subsurface soils were generally lower than this standard. Depending upon the origin of the soil and pedogenic processes, the surface, or the subsoil may be relatively enriched or have the same Ni concentrations (Parth et al., 2011). The lowest Ni concentration (1.8 was found mg kg-1) was found at location 1(Jamasah- Dumyat Al – Jadidah Road) among all road side soil samples.

C. Evaluation Of Copper (Cu) In Soil

The concentrations and geographical distribution of Cu in soil were given in Tables 3 and 4 and Figs. 5 and 6. Copper concentrations in the surface layers of soil (0-30 cm) ranged from 19.8 to 101 with a mean value of 33.9 mg kg-1 soil. The highest copper concentration (101 mg kg-1) in the top soil samples has been found at location 10 (Ras Al - Barr - Dumyat Al – Jadidah Road). Corresponding values for the subsurface layers were from 15.41 to 433. 6 with an average value of 118.4mg kg-1 soil. The highest copper concentration (433. 6 mg kg-1) in the subsurface soil samples has been found at location 3 (Jamasah - Kafr Al - Wustani Road). These results indicated that the subsurface layers of Damietta governorate soils contain greater amounts of Cu in comparison with surface layers. Major sources of copper in the atmospheric environment are coal and oil combustion as well as, some industrial processes (El -Gammal et al., 2011). Copper normally occurs in drinking water from Cu pipes, as well as from additives designed to control algal growth. In plants, Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in high doses it can cause anaemia, liver and kidney damage, and stomach and intestinal irritation. (Raymond and Okieimen, 2011). For evaluating of the degree of soil contamination in Damietta governorate, the obtained results of the copper element concentrations were compared with the European Union Standards (EU 2002) and permissible critical limits. In comparison with European Union Standards (EU 2002) limits (140 ppm), it could be observed that the Cu values of the top soils are generally lower than this standard but the subsurface soils contain greater concentrations than this standard. The lowest copper concentration (15.41 mg kg-1) was found at location 5(Kafr Sad Al - Balad - Kafr Al – Wusrani Road) among all road side soil samples.

D. Evaluation Of Zinc (Zn) In Soil

The concentrations and geographical distribution of Zn in soil were given in Tables 3 and 4 and Figs. 7 and 8. Zinc concentrations in the surface layers of soil (0-30 cm) ranged from 7.72 to 1022 with a mean value of 258.7 mg kg-1 soil. The highest zinc concentration (1022 mg kg-1) in the top soil samples has been found at location 10 (Ras Al - Barr - Dumyat Al – Jadidah Road). Corresponding values for the subsurface layers were from 60 to 958 with an average value of 343.3 mg kg-1 soil. The highest zinc concentration (958 mg kg-1) in the subsurface soil samples has been found at location 3 (Jamasah - Kafr Al - Wustani Road). This could be attributed to the use of zinc during industrial activities, such as mining, coal, and waste combustion and steel processing. This is in agreement with El-Gammal et al., 2005 who detected the high zinc concentration in Damietta city was emitted from the urban activities, mainly motor vehicles. The chief pollution sources of Zn in soils are metalliferous mining activities, agricultural use of sewage sludge and the use of agro-chemicals such as fertilizers and pesticides. Large concentrations of Zn in the soil have adverse effects on crops, livestock and human (Parth et al., 2011). For evaluating of the degree of soil contamination in Damietta governorate, the obtained results of the Zn element concentrations were compared with the European Union Standards (EU 2002) and permissible critical limits. In comparison with European Union Standards (EU 2002) limits (300 ppm), it could be observed that the Zn values of the top soils and the subsurface soils are generally higher than this standard. The lowest zinc concentration (7.72 mg kg-1) was found at location 5(Kafr Sad Al - Balad - Kafr Al – Wusrani Road) among all road side soil samples, this may be due to the low traffic density there with low work activities and atmospheric conditions.

E. Evaluation Of Iron (Fe) In Soil

The concentrations and geographical distribution of Fe in soil were given in Tables 3 and 4 and Figs. 9 and 10. Iron concentrations in the surface layers of soil (0-30 cm) ranged from 4.24 to 41.56 with a mean value of 19.2 mg g-1 soil. The highest iron concentration (41.56 mg g-1) in the top soil samples has been found at location 9 (Dumyat - Kafr Al - Arab Road). The lowest iron concentration (4.24 mg g-1) in the top soils was found at location 2(Umm Rida Al - Jadidah - Dumyat Al – Jadidah Road) among all road side soil samples, this may be due to lack of iron in the soil, excess soil moisture or root diseases. Corresponding values for the subsurface layers were from 6.59 to 93.27 with an average value of 28.9 mg g-1 soil. The highest iron concentration (93.27 mg g-1) in the subsurface soil samples has been found at location 4 (Nabaruh - Kafr Al - Ghab Road). The highest deposition of Fe in soil might be due to its long-term use in the production of machine tools, paints, pigments, and alloying in various industries that may result in contamination of the soil and a change to the soil structure thus making it risky for use in cultivation (Rahman et al., 2012). Iron is very insoluble under oxidizing condition in soil, the organic matter in the soil may form chelate complex by keep considerable amount of Fe (III) in a mobile form (Deka and Sarma, 2012).In other words, the soil in the investigated area is being rich in iron; there is no limit to the concentration of iron in soil because it is abundant in soil.

TABLE IV
SUMMARY STATISTICS OF HEAVY METALS CONCENTRATIONS

Soil						
Depth	Top soil (0-30 cm)			Subsoil (30-60 cm)		
Parameters	Mean	Min.	Max.	Mean	Min.	Max.
Ni (mg kg-1)	15.9	1.8	47.8	29.7	12.4	48
Cu (mg kg-1)	33.9	19.8	101	118.4	15.4	433.6
Zn (mg kg-1)	258.7	7.72	1022	343.3	60	958
Fe(mg g-1)	19.2	4.24	41.56	28.9	6.59	93.27

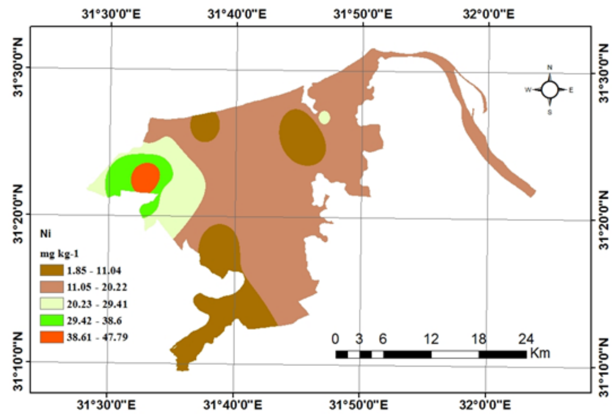

Fig. 3 Spatial Distribution of Nickel in the Soil Top-layer

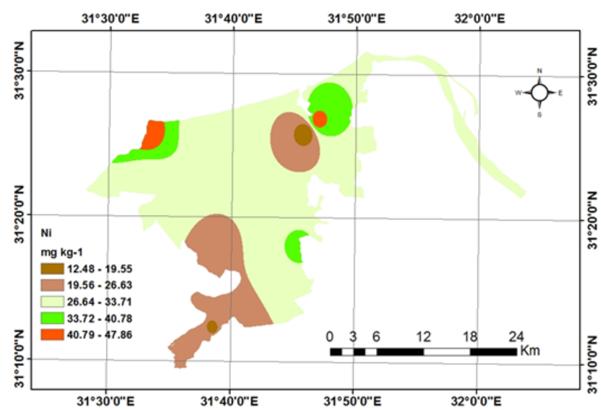

Fig. 4 Spatial Distribution of Nickel in the Subsurface Soils

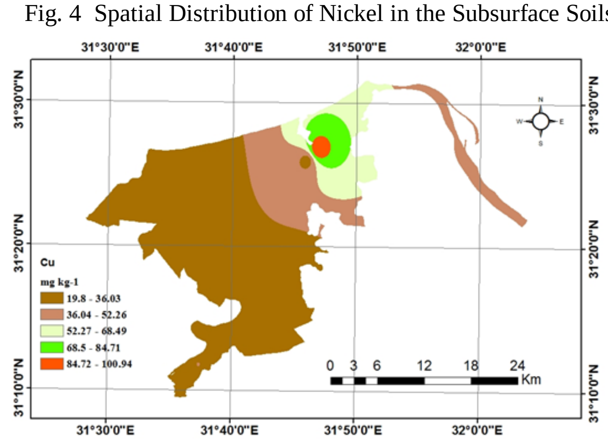

Fig. 5 Spatial Distribution of Copper in the Soil Top-layer

TABLE III
HEAVY METAL CONCENTRATIONS IN SOIL SAMPLES

Site No.	depth)cm(	Road name	Ni(mg kg-1)	Cu)mg kg-1(	Zn)mg kg-1(	Fe)mg g-1(	NDVI value
1	0-30	Jamasah- Dumyat Al – Jadidah	1.8	28.4	218	11.45	
	30-60		12.4	74.8	392	12.26	
2	0-30	Umm Rida Al - Jadidah - Dumyat Al – Jadidah	8.4	25.8	444	4.24	0.1817
	30-60		30	109.4	380	6.59	
3	0-30	Jamasah - Kafr Al - Wustani	17.4	25.8	254	11.30	0.1762
	30-60		48	433.6	958	12.73	
4	0-30	Nabaruh - Kafr Al - Ghab	47.8	21	42.4	18.29	0.127257
	30-60		27.6	27.6	60	93.27	
5	0-30	Kafr Sad Al - Balad - Kafr Al - Wusrani	27.2	19.8	7.72	20	0.4483
	30-60		29.4	15.4	79.6	26.59	
6	0-30	Kafr Sad Al - Balad - Kafr Mit Abu Ghalib	8	29.8	95	39.65	0.1025
	30-60		23.8	30.6	70.2	39.88	
7	0-30	Al - Zarqa - Dumyat	4.2	36.2	91	30.51	0.1859
	30-60		26.2	39.4	75.8	32.61	
8	0-30	Al - Zarqa - Dumyat	2.32	25.4	340	6.96	0.1946
	30-60		18.6	376.8	724	7.97	
9	0-30	Dumyat - Kafr Al - Arab	20	25.6	73	41.56	0.3855
	30-60		34.6	33.8	71.8	50	
10	0-30	Ras Al - Barr - Dumyat Al – Jadidah	22.4	101	1022	8.22	0.2117
	30-60		46	42.2	622	7.44	

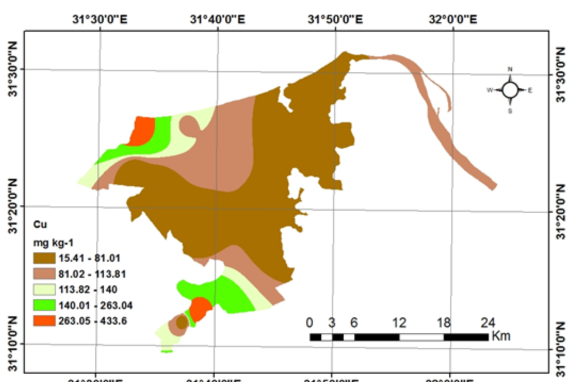

Fig. 6 Spatial Distribution of Copper in the Subsurface Soils

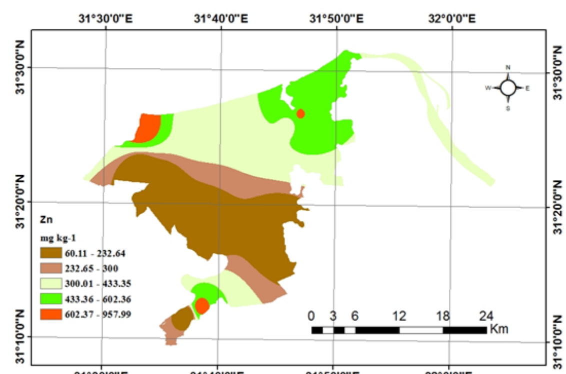

Fig. 8: Spatial Distribution of Zinc in the Subsurface Soils

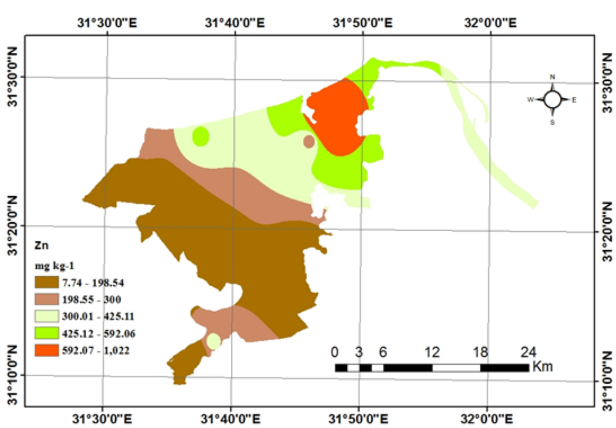

Fig. 7 Spatial Distribution of Zinc in the Soil Top-layer

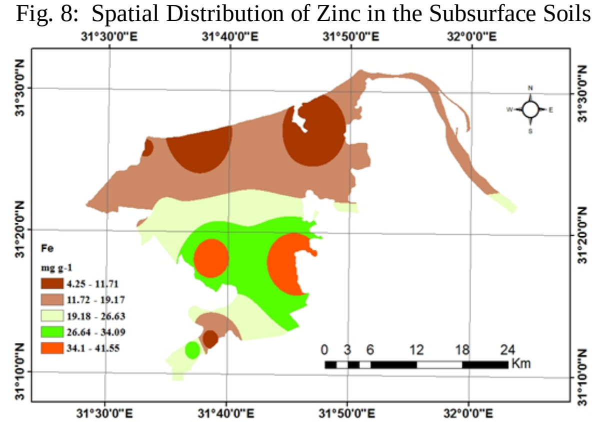

Fig. 9: Spatial Distribution of Iron in the Soil Top-layer

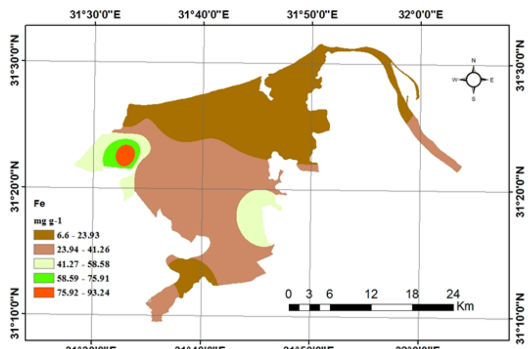

Fig. 10: Spatial Distribution of Iron in the Subsurface Soils

V. Vulnerability Mapping Of Heavy Metals

Soil resources degradation is an issue of significant societal and environmental concern in Damietta governorate. Soil represents a major sink for heavy metals, which can then enter the food chain via plants or leaching into ground water. In order to prevent soil pollution before it occurs and avoid the future need for costly remediation efforts, GIS can be used to assess the soil pollution potential (Omran and El Razek,2012). The Geostatistical Analyst can be used to map the probability that any heavy metals values exceed the threshold. Heavy metals vulnerability maps in soil are shown in Figs. 11 and 12. The whole area is divided into two classes on the basis of hazard, low (below European Union Standards (EU 2002) limits of Zn, Ni and Cu concentration in roadside soil and high (above European Union Standards (EU 2002) limits. The results indicated that, most of Ni and Cu concentration in soil samples fall in the low hazard classes. Cu and Ni metals concentrations of the top soil samples are under the threshold value which falls in the low hazard category. However, Cu of the subsurface soils and Zn of top soil and subsurface soil fall in the high hazard category.

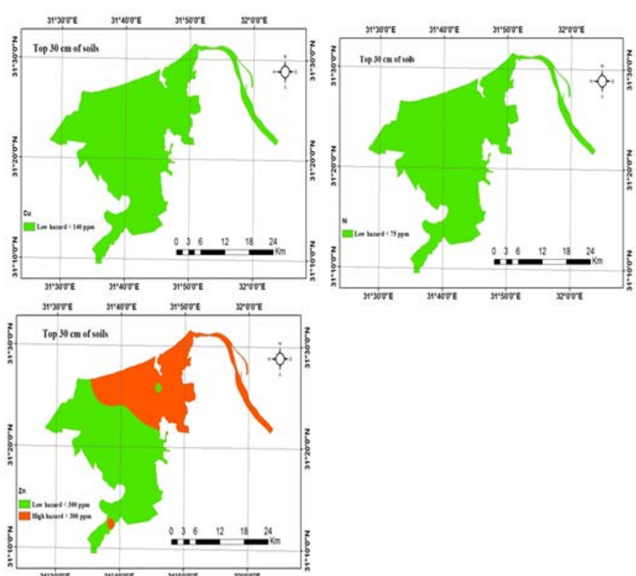

Fig. 11: Heavy Metals (Cu, Ni, Zn) Vulnerability Maps in Top Soils

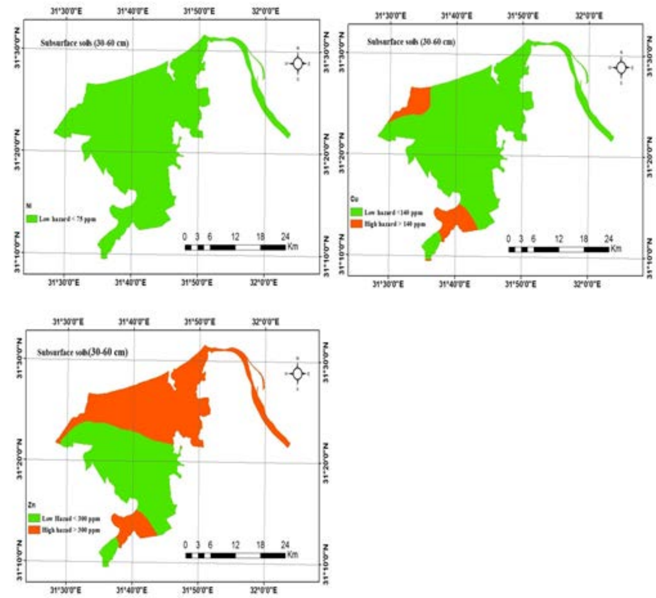

Fig. 12: Heavy Metals (Ni, Cu, Zn) Vulnerability Maps in Subsurface Soils

VI. Assessment Of Contamination Risk

A. *Index Of Geoaccumulation*

Igeo and contamination levels of different metals in soil were given in Tables 5 and 6. Igeo was distinctly variable and suggests that soil around the governorate ranged from uncontaminated to strongly contaminated with respect to the analyzed metals. Igeo revealed that all soil samples in respect of Ni were found negative and fell into class 0-uncontaminated. This indicated that the concentrations of Ni in the soils were unpolluted and lower than the background. Copper showed a negative index for most samples indicating no pollution, but it have positive value 0.29 for one top soil sample (10S) and 2.39 and 2.19 for two subsurface soil samples (3SS and 8SS), respectively and belongs to the class 1 and class 3 indicating uncontaminated /moderately contaminated to moderately /strongly contaminated. Zinc exhibited a positive Geoaccumulation index in many samples and 2 samples fell into class 4 indicating strongly contaminated.

TABLE V
IGEO AND CONTAMINATION LEVELS OF DUST AND SOILS

Sample No	I-geo value Ni	Contamination Level	I-geo value Cu	Contamination Level	I-geo value Zn	Contamination Level
Topsoil (0-30 cm)						
1S	-5.97	Uncontaminated	-1.53	Uncontaminated	1.05	Moderately contaminated
2S	-3.74	Uncontaminated	-1.67	Uncontaminated	2.08	Moderately/strongly contaminated
3S	-2.69	Uncontaminated	-1.67	Uncontaminated	1.27	Moderately contaminated
4S	-1.23	Uncontaminated	-1.97	Uncontaminated	-1.3	Uncontaminated
5S	-2.05	Uncontaminated	-2.05	Uncontaminated	-3.76	Uncontaminated
6S	-3.81	Uncontaminated	-1.46	Uncontaminated	-0.14	Uncontaminated
7S	-4.74	Uncontaminated	-1.18	Uncontaminated	-0.20	Uncontaminated
8S	-5.59	Uncontaminated	-1.69	Uncontaminated	1.69	Moderately contaminated
9S	-2.49	Uncontaminated	-1.68	Uncontaminated	-0.52	Uncontaminated
10S	-2.32	Uncontaminated	0.29	Uncontaminated/moderately contaminated	3.28	Strongly contaminated
Mean	-3.46	Uncontaminated	-1.46	Uncontaminated	0.35	Uncontaminated/moderately contaminated
Subsurface soil (30-60)						
1SS	-3.18	Uncontaminated	-0.14	Uncontaminated	1.9	Moderately contaminated
2SS	-1.91	Uncontaminated	0.40	Uncontaminated/moderately contaminated	1.85	Moderately contaminated
3SS	-1.23	Uncontaminated	2.39	Moderately/strongly contaminated	3.18	Strongly contaminated
4SS	-2.03	Uncontaminated	-1.57	Uncontaminated	-0.80	Uncontaminated
5SS	-1.94	Uncontaminated	-2.42	Uncontaminated	-0.39	Uncontaminated
6SS	-2.24	Uncontaminated	-1.43	Uncontaminated	-0.58	Uncontaminated
7SS	-2.10	Uncontaminated	-1.06	Uncontaminated	-0.47	Uncontaminated
8SS	-2.59	Uncontaminated	2.19	Moderately/strongly contaminated	2.78	Moderately/strongly contaminated
9SS	-1.7	Uncontaminated	-1.28	Uncontaminated	-0.54	Uncontaminated
10SS	-1.29	Uncontaminated	-0.96	Uncontaminated	2.56	Moderately/strongly contaminated
Mean	-2.02	Uncontaminated	-0.39	Uncontaminated	0.95	Uncontaminated/moderately contaminated

TABLE VI
REPRESENTATION OF IGEO OF METALS AT DIFFERENT SAMPLING POINTS

Site No.	Contamination Level Ni	Contamination Level Cu	Contamination Level Zn
Topsoil (0-30 cm)			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			
Subsurface soil (30-60)			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			
	Class 0	Igeo ≤ 0 Uncontaminated	
	Class 1	0<Igeo<1 Uncontaminated/moderately contaminated	
	Class 2	1< Igeo<2 Moderately contaminated	
	Class 3	2< Igeo< 3 Moderately/strongly contaminated	
	Class 4	3< Igeo< 4 Strongly contaminated	

VII. Correlation Analysis

Spearman's correlation analysis was performed between all variables. The level of significance ($P \leq 0.05$ and $P \leq 0.01$) of multi-element correlation for soil samples was determined and the results are given in Table 7. Significant correlations were found in the present study between Cu and Zn ($r = 0.54$ in topsoil and $r= 0.83$ in subsurface soil). The strong association of Zn and Cu indicated common sources, such as industrial activities and contribution of auto-exhaust (El-Gammal et al., 2011 and Parth et al., 2011).

TABLE XII
SPEARMAN'S CORRELATION MATRIX OF THE ELEMENTS

Topsoil (0-30 cm)				
Ni	1	-0.40	-0.38	0.15
Cu	-0.40	1	0.54	-.012
Zn	-.038	0.54	1	-0.77
Fe	0.15	-.012	-0.77	1
NDVI	0.41	0.17	0.12	-0.19
Subsurface soil (30-60)				
Ni	1	0.12	0.21	-.091
Cu	0.12	1	0.83	-.068
Zn	0.21	0.83	1	-0.78
Fe	-0.09	-0.68	-0.78	1
NDVI	0.15	-0.12	0.26	-0.22

VIII. Conclusion And Recommendations

Soil is a great geochemical reservoir for contaminant as well as a natural buffer for transportation of chemical materials and elements in the atmosphere, hydrosphere, and biomass. For this, it is the most important component of the human biosphere. In this study, we investigated the contents of heavy metals (Cu, Zn, Ni, and Fe) in soils along ten major road segments in Damietta governorate. The extra heavy metals accumulations in soils are almost purely due to traffic activities. According to the study results, the concentrations of Cu in top soils and Ni for the entire region were lower than its background values while the concentrations of Cu in subsurface soils and Zn in all soil samples were higher than the background values. However, the situation in future would become more dangerous if the precautionary environmental requirements are not attended to. These heavy metals have a tendency to bio-magnify and induce long-term adverse impact on ecosystem in terms of biochemical and toxicological effect on human being and other composition of our planet. Moreover different remediation measures should be taking promptly to remove excising metal contamination.

The following recommendations suggest improving soil quality of the city:

- Enhance availability and supply reliability of high-quality fuels (Liquefied Petroleum Gas and kerosene) in all areas, but first in areas with largest exposure.
- Use vapor recovery technology when available, rather than combustion, to further reduce air pollution.
- Forbid the open burning of solid waste inside the city.
- Monitoring activities and regulations should be developed taking into consideration technical characteristics.
- Establish and implement a plan that ensures all trucks used meet emission standards specified in the Clean Fuel Vehicles (heavy trucks) to reduce VOC, and PM emissions.
- Remove the polluted soil and deposit it in landfills or incinerate it.
- Reduce transport sector emissions through a variety of changes to the overall transport system: efficiency improvements in the urban transport system, changes in modal shares through infrastructure investments or land use policy, or through f policies that can affect fuel and vehicle technology choice, fuel consumption, and vehicle use.
- For the removal and recovery of heavy metals various soil washing techniques have been developed including physical methods, such as attrition scrubbing and wet-screening, and chemical methods consisting of treatments with organic and inorganic acids, bases, salts and chelating agents. The problem with these methods, however, is again that they generate secondary waste products that may require additional hazardous waste treatments.
- Constructive city planning by the complete separation of industry and commercial work-shop activities from habitation should receive more attention as a responsible solution for environmental improvement.
- It is possible to improve in situ biodegradation which involves the enhancement of naturally occurring microorganisms by artificially stimulating their numbers and activity. The microorganisms then assist in degrading the soil contaminants.
- Increasing green areas and planting more trees because trees help in cleaning soil, maintaining its fertility and in reducing the level of particulate matter

In order to reduce vehicle emission originated metal pollution in soil, vehicles with catalytic convertors should be preferred and the use of gasoline without lead should be encouraged.

References

[1] Ali, R.R. and Moghanm, F.S. (2013). Variation of Soil Properties over the Landforms around Idku Lake, Egypt. J. Remote Sens. and Space Sci., 16: 91–101.

[2] Awadh, S. M. (2013). Assessment of the Potential Nickel and Lead in the Road-Side Dust in the Karkh City along the Highway between Ramadi and Rutba, West of Iraq, Merit Res. J. Environ. Sci. Toxicol., 1(7): 126-135.

[3] Baraba, S.N.; Goovaerts, P. and Adriaens, P. (2001). Geostatistical Assessment and Validation of Uncertainty for Three-Dimensional Dioxin Data from Sediments in an Estuarine River; Environ. Sci. Techn., 35: 3294–3301. http://dx.doi.org/10.1021/es010568n

[4] CAPMAS, (2011). Mobilization and Statistic of Damietta Governorate. Central Agency for Public Mobilization and Statistics (CAPMAS) Cairo, Egypt

[5] Cook, K.K. (1997). Extension of Dry Ash Atomic Absorption and Spectrophotometric Methods to Determination of Minerals in Soy-Based, Whey-Based and Enteral Formulae (Modification of AOAC Official Methods 985.35 and 986.24): Collaborative Study; J. AOAC Int., 80: 834-44.

[6] De Vries and Bakker. (1998). Manual For Calculating Critical Loads Of Heavy Metals For Terrestrial Ecosystem: Guidelines For Critical Limits, Calculation Methods And Input Data TNO Institute Of Environmental Sciences, Energy Research And Process Innovation. Den Helder, the Netherlands. 144 p.

[7] Deka, J. and Sarma, H. (2012). Heavy Metal Contamination in Soil in an Industrial Zone and its Relation with Some Soil Properties; Arch. Appl. Sci. Res.; 4(2): 831-836.

[8] El-Gammal, M. I.; Ibrahim, M. S.; El-Sonbati, Mervat A. and El-Zeiny A. M. (2011) .Assessment of Heavy Metal Contamination on Street Dust at New Damietta City, J. Environ. Sci.; 40(2): 221-237.

[9] El-Gammal, M.I.; Shakour, A.A.; Ibrahim, M. S. and R. Sh. El-Henawy. (2005). Air Pollution and Suspended Particulate Matter in Atmosphere of Damietta City- Egypt. J. Egypt. Ger. Soc. Zool.; 47(A): 251-281.

[10] Fagbote, E. O. and Olanipekun, E. O. (2010). Evaluation of the Status of Heavy Metal Pollution of Soil and Plant (Chromolaena Odorata) of Agbabu Bitumen Deposit Area, Nigeria; American-Eurosian J. Sci. Res. 5(4): 241-248.

[11] Gowd, S.S.; Reddy, M.R. and Govil, P.K. (2010). Assessment of Heavy Metal Contamination in Soils at Jajmau (Kanpur) and Unnao Industrial Areas of the Ganga Plain, Uttar Pradesh, India. J. Hazard. Mater., 174: 113-121.
http://dx.doi.org/10.1016/j.jhazmat.2009.09.024

[12] He, J.Y. and Jia, X. (2004). ArcGIS Geostatistical Analyst Application in Assessment of MTBE Contamination, ESRI User Conference 2004, Fremont, CA.

[13] Jankaitė, A.; Baltrėnas P. and Kazlauskienė, A. (2008). Heavy Metal Concentrations in Roadside Soils of Lithuania's highways. Geologija, 50(4): 237-245.
http://dx.doi.org/10.2478/v10056-008-0049-7

[14] Lu, X.; Wang, L.; Lei, K.; Huang, J. and Zhai, Y. (2009). Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China, J. Hazard. Mater. ; 161: 1058-1062.
http://dx.doi.org/10.1016/j.jhazmat.2008.04.052

[15] Malizia, D.; Giuliano, A.; Ortaggi, G. and Masotti, A. (2012). Common Plants as Alternative Analytical Tools to Monitor Heavy Metals in Soil; Chem. Cent. J. 6: 10p.
http://dx.doi.org/10.1186/1752-153X-6-S2-S6

[16] Mbah, C. and Anikwe, M. (2010). Variation in Heavy Metal Contents on Roadside Soils along a Major Express Way in South East Nigeria., New York Sci.J. 3(10): 103-107.

[17] Mcgrath, S. P. (1995). Nickel. In Heavy Metals in Soils (2nd edn.) (Ed. B.J. Alloway). London: Blackie Academic & Professional, 371p.
http://dx.doi.org/10.1007/978-94-011-1344-1_7

[18] Omran, E., S. and El Razek, A. (2012). Mapping and Screening Risk Assessment of Heavy Metals Concentrations in Soils of the Bahr El-Baker Region, Egypt. J. Soil Environ. Manag. , 6(7): 182-195.

[19] Parth, V., Murthy, N.N. and Saxena, P. R. (2011). Assessment of Heavy Metal Contamination in Soil around Hazardous Waste Disposal Sites in Hyderabad City (India): Natural and Anthropogenic Implications; E3 J. Environ. Res. Manag. ; 2(2): 27-34.

[20] Parveen, N.; Ghaffar. A; Shirazi S.A. and Bhalli, M.N. (2012). A GIS Based Assessment of Heavy Metals Contamination in Surface Soil of Urban Parks: A Case Study of Faisalabad City-Pakistan; J .Geogr .Nat. Disast .2: 5p.

[21] Rahman, S.; Khanam, D.; Adyel T.; Islam, M. Sh.; Mohammad Ahsan, A. and Akbor, M. A. (2012). Assessment of Heavy Metal Contamination of Agricultural Soil around Dhaka Export Processing Zone (DEPZ), Bangladesh: Implication of Seasonal Variation And Indices, Appl. Sci., 2(3): 584-601.
http://dx.doi.org/10.3390/app2030584

[22] Rakib, M.A.; Ali, M.; Akter, M.S. and Bhuiyan.H. M. (2014). Assessment of Heavy Metal (Pb, Zn, Cr and Cu) Content in Roadside Dust of Dhaka Metropolitan City, Bangladesh; Int. Res. J. Environ. Sci.; 3(1): 1-5.

[23] Raymond A. W. and Okieimen, F. E. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation; ISRN Ecology; 20p.

[24] Rooney, C.P.; Zhao, F., J.; McGRATH, S.P. (2007). Phytotoxicity of Nickel in a Range of European Soils: 10 Influences of Soil Properties, Ni Solubility And Speciation. Environ. Pollut. 145, 596 – 605.
http://dx.doi.org/10.1016/j.envpol.2006.04.008

[25] Senesi, G.S., Baldassarre, G., Senesi, N., Radina, B. (1999). Trace Element Inputs into Soils by Anthropogenic Activities and Implications for Human Health. Chemosphere; 39: 343–377.
http://dx.doi.org/10.1016/S0045-6535(99)00115-0

[26] Sofianska, E.; Michailidis, K.; Mladenova, V. and Filippidis, A. (2013). Multivariate statistical and GIS-based approach to identify heavy metal sources in soils of the Drama plain, Northern Greece, Geosci .J. ; 131-132.

[27] Van Meirvenne, M. and Goovaerts, P. (2001). Evaluating the Probability of Exceeding a Site-Specific Soil Cadmium Contamination Threshold, Geoderma; 102:75–100.
http://dx.doi.org/10.1016/S0016-7061(00)00105-1

[28] Woo, K.W.; Jo, J.H.; Basu, P.K. and Ahn, J.S. (2009). Stress Intensity Factor by P- Adaptive Refinement based on Ordinary Kriging Interpolation, Finite Elem. Anal. Des. , 45:227
http://dx.doi.org/10.1016/j.finel.2008.10.002

[29] Yadav, A.; Yadav, P. K. and Shukla D. N. (2013). Investigation of Heavy Metal Status in Soil and Vegetables Grown in Urban Area of Allahabad, Uttar Pradesh, India , Int. J. Sci. . Res. Pub.; 3:1-7.

[30] Yan, X.; Gao, D.; Zhang; F.; Zeng, Ch.; Xiang, W. and Zhang, M. (2013). Relationships between Heavy Metal Concentrations in Roadside Topsoil and Distance to Road Edge Based on Field Observations in the Qinghai-Tibet Plateau, China, Int. J. Environ. Res. Publ. Health. , 10(3): 762-775.
http://dx.doi.org/10.3390/ijerph10030762