

HEAVY METALS POLLUTION AND RISK ASSESSMENT OF SOIL AND AIR IN THE VICINITY OF ELECTRIC POWER STATION WEST OF ALEXANDRIA CITY, EGYPT

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ABSTRACT

Levels of total amounts of heavy metals (As, Cd, Cu, Cr, Ni, Hg and Zn) have been measured in both soil and air samples in the vicinity of electric power station (EPS) at Sidi Kirayer, west of Alexandria, to assess the quality of soil and air at this area. The chemical fractions of these metals in soils has been measured. The risk assessment has been carried out to define the impact of the present levels of these metals on human health.

The analytical data showed that the air of the studied area is highly polluted by Cr, Cd and Cu as compared with the unpolluted air.

The results indicated that there were marked decreases in the levels of metals with the distance from the electric power station (EPS). The highest recorded levels of total As, Cd, Cu, Cr, Ni, Hg and Zn were found in the soil of the upper layer (0-25cm) of site No. 1 and were, on the average, 0.5, 1.4, 1.8, 3.5, 6.4, 0.9 and 58 mg/kg soil, respectively. The results also indicated that most of metals are accumulated in the surface soil layer and the downward mobility of metals in the soil profile is negligible. The lowest recorded levels of total metals in soils were found in the deepest layer (50-100 cm) of site No. 4 and were 0.008, 0.11, 0.085, 0.08, 0.5, 0.03 and 10.5mg kg⁻¹ soil for As, Cd, Cu, Cr, Ni, Hg and Zn, respectively. These value are considered the background levels of total metals in the studied soil. The metals fractionation of the studied soils showed that most of Cd, Ni and Zn occurred in the carbonate fraction, while Cu and Cr occurred in the organic and sulfide fraction.

Risk assessment of heavy metals in air and soil indicated that the inhalation pathway is the most effective for carcinogenic hazardous metals. Cadmium was the highest regarding the non-carcinogenic effects which had Health quotient of 60 in air. On the other hand, chromium was the highest among the measured carcinogenic metals in this work. The risk estimated, due to the recorded Cr level, was 53.040 cases per million.

INTRODUCTION

In spite of the recent increase in awareness and concern with respect to the industrialized countries, contaminated land is well recognized problem. In developing countries, this problem has early begun to recognize as a potential issue. Land contamination can have serious consequences both to the environment and to human health. It can hinder future land use, such as residential development or agriculture projects. There are two types of land contamination; "site" and "diffuse". The first type is the result of direct introduction of contaminants into soil from a point source. The second type results from indirect transfer of contaminants to soil and affects large scale

(Pacyna, 1987, Migon and Caccia, 1990, Jaffe *et al.*, 1993, Elsokkary, 1996; and Van den Hout *et al.*, 1999).

Atmospheric fluxes of contaminants, from coal and oil combustion and from electric power stations, emit several pollutants, especially those being easily volatile such as As, Cd, Pb and Hg (Pacyna, 1987 and Garty *et al.*, 1998). As a result, atmospheric deposition of chemicals such as heavy metals (Pb, Cu, Ni, Zn & Cd) and aliphatic and aromatic hydrocarbons (Jaffe *et al.*, 1993 and van den Hout *et al.*, 1999) are important sources of pollutants in the environment.

Heavy metals, particularly Cd and Cr in the soils, were intensively studied by several workers because of their long resistance time and its potential toxicity to the ecosystem. Heavy metals storage and remobilization are key areas of inquiry in furthering our understanding of pollution potential, possible human health effects, and ecological system disturbance.

Based on accumulation mechanism of heavy metals in sediments, metals in soil can be classified into five categories: (i) water soluble and exchangeable, (ii) bound to carbonate, (iii) bound to Fe and Mn oxides, (iv) bound to organic matter and sulfides, and (v) residual or lattice metals (Tessier *et al.*, 1979, Elsokkary, 1992 and Ma and Rao, 1997).

Environmental health risk assessment or health impact assessment, as it is coming to be known, is increasingly being used to develop the environmental health policy and to assist the decision makers by providing estimates of health effects. In the past decade, varieties of efforts have been undertaken to extend the use of this techniques (Larissa *et al.*, 2001). Decision makers receive valuable information about the relative magnitude of risk assessment, sources of risk and population at risk. In this work, risk assessment is included and emphasized the expected health impacts on population in the vicinity of the power station from the air emission and from soil exposure.

The objectives of this study, therefore, were to (i) evaluate the total concentration levels of heavy metals in the soils and air at Sidi Kirayr, located west of Alexandria City, as influenced by the atmospheric deposition from the Electric Power Station in the area, (ii) investigate the chemical fractionation of metals in soils and, (iii) carry out risk assessment of these metals in air and soil of this area.

MATERIALS AND METHODS

1. Studied area

The area surveyed is located west of Alexandria city, at Alexandria Mersa Matrouh road, and about 29 Km from Alexandria city centre (Fig. 1). The soil of this area is influenced by emission of metals from the electric power Station (EPS) of Sidi Kirayr which is located at the Mediterranean sea. This station was constructed in 1989 and the coal and mazout is being the source power. The studied area is extending south and south-east the EPS and planned to be a residential area (housing and gardens) for the staff members of the EPS. This area comprises a flat coastal plain. The soil

formation reflects the marked influence of its arid climatic conditions. It has developed from highly calcareous parent material with column ranges between 25 to 120 cm thick and therefore the depth of leaching is limited. The accumulation of organic matter in the surface horizon is very small and ranging between 0.19 and 0.81 %. The morphological characteristics of the soils show the presence of calcic and gypsum horizons (Abd El-Rahman *et al.*, 1987). The main land use of this area is cultivation of fig trees and is planned to be small house gardens and housing.

2. Sampling program

2.1. Air sampling

The air sampling method was designed to collect atmospheric particles in a form suitable for heavy metals analysis. A site at 500m to the south east downwind the electric power station was selected to collect the aerosol sample. These samples were collected using a volume samplers type L-2SF, MK3 from Rotheroe & Michael, with a fiber glass filter paper (47mm in diameter) at a flow rate 100 l/min for 24 hrs. The inlet manifold, of volume sampler, was two meters height of the ground surface. Suspended particulate matter, in the ambient air, is sampled at standard temperature and pressure (Garland and Nicholson, 1991). Sampling period were approximately 24 hrs. The flow was measured at the beginning and at the end of each sampling to obtain an average flow rate. The site was sampled five times (five successive days) and all sampling have been conducted in summer.

2.2. Soil sampling

Surface (0-25cm) and subsurface (25-50cm) and (50-100cm) soil samples were collected from selected sites (7sites) at different distances from the "EPS" as shown in Fig. 1. Sixty five samples have been collected representing these 7 sites. The soil samples were air-dried and ground in wooden mortar and passed through 2mm sieve and stored for analysis. Subsamples of soils were finely ground for the determination of total heavy metals contents in soils, and for chemical fractionation.

3. Sample analysis

3.1. Air analysis

Analysis of heavy metals in air samples: The fiber glass filter paper was placed in a dessicator for 48hrs then its weight was measured. For the determination of the concentration of total Cd, Pb, Ni, Cr and Zn, after sampling the pre-weighed filter paper was treated with one ml concentrated Hydrofluoric acid then 10ml concentrated nitric acid and 5ml perchloric acid and warmed for 5hrs. To complete the digestion process, the matrix was digested three times and the sample was evaporated to dryness. The residues were dissolved in 1% nitric acid, cooled, filtered and made to 50ml in a volumetric flask with glass double-distilled water. A blank filter paper was similarly digested and the same procedure was carried out. The concentration of heavy metals were measured by an atomic absorption spectrophotometer (Tripathi, 1994).

3.2. Soil analysis

The determinations of the main chemical and physical characteristics of the soils were carried out according to the methods outlined by Page *et al.* (1982) and presented in Table 1.

The total amounts of heavy metals were determined after digesting 5.0 grams of soil with HNO₃/HClO₄ acids and filtrated through Whatman filter paper No. 42 (Page *et al.*, 1982). The concentrations of heavy metals were measured by atomic absorption spectrophotometer using hydrogen lamp for matrix correction.

The chemical fractionation of heavy metals was carried out according to the method outlined by Tessier *et al.* (1979) and Elsokkary (1992) as follows; 10 grams of soil were placed in 50ml PVC centrifuge tube and successively extracted with different chemicals to obtain the following metal fractions: (i) water soluble plus exchangeable (extraction with NaOAc pH 8.2, 2 hrs shaking), (ii) carbonate-bound (the residue from ext. No i. was extracted with NaOAc pH5 for 30 min shaking, three successive extractions), (iii) Fe-Mn-bound (the residue from ext. ii was extracted with NH₂ OH-HI, pH 3 by HOAc, 3hrs Shaking, (iv) Organic and sulfide-bound (the residue from ext. No. iii was extracted with 30% H₂O₂+0.02M HNO₃, pH 2, at 85°C intermittent agitation for 3 hrs, then extracted with NH₄OAc pH 2 by HNO₃) (v) Residual (the residue from ext. No. iv was digested with HNO₃/HClO₄ acids. After each successive extraction, separation was carried out by centrifuge, the supernatant was taken carefully for the measurement of metal concentration by AAS.

Table 1: The main chemical and physical characteristics of the soils of the studied area (range values).

Soil parameter	Soil Depth, Cm		
	0 - 25	25 - 50	50 - 100
EC (dS/m)*	0.80 - 0.84	1.30 - 1.46	1.20 - 1.80
pH**	8.20 - 8.50	8.40 - 8.40	8.10 - 8.30
Total CO ₃ (%)	38.00 - 96.00	28.00 - 90.00	50.00 - 57.00
O.M. (%)	0.10 - 0.29	0.12 - 0.65	0.16 - 0.59
Particle Size:			
Sand (%)	85.0 - 94.0	72.00 - 96.00	50.00 - 86.00
Silt (%)	2.00 - 11.00	2.00 - 18.00	6.00 - 23.00
Clay (%)	5.00 - 8.00	6.00 - 14.00	8.00 - 20.00
Soil texture	loamy sand	sand clay loam	sand clay loam

* In 1:1 Soil - Water extract.

** 1: 2.5 Soil - Water suspension.

4. Health Risk Assessment (HRA)

In the present study, HRA was carried out for heavy metals in air and in soil in the area under investigation. HRA was preformed according to US EPA, (1991). The 4-steps method involves the following to carry out the risk assessment:

- 1- Hazard identification; this is concerning with the health problems which are caused by the pollutant.

- 2- Exposure assessment; this is concerning with the amount of the pollutant reaching the people through inhalation pathway.
- 3- Dose-response assessment which represents the effects of pollutants on health. The non-cancer chronic effects were evaluated using the Reference Exposure Levels (REL) which is defined as an estimate of a daily exposure to human population that is likely to be without appreciable risk of deleterious effects. It is derived from non or low adverse effect level from human or animal exposure to which safety factors are applied. For cancer effects, the cancer potency factor was used; it is defined as the upper bound probability cancer cases occurring in an exposed population assuming a lifetime exposure when the chemical dose is expressed in exposure units of mg/kg.day. The average concentration of investigated substances in addition to their REL and cancer potency factors are used to perform HRA (OEHHA, 1991a, 1991b)
- 4- Risk characterization, in this step, is the health effect of non-carcinogenic and is expressed in "Health Quotient (HQ)" which is defined as the ratio of single contaminant exposure level over a specific period to the REL or RfC. The carcinogenic effects were expressed using the expected number of cancer cases per million of exposed population.

RESULTS AND DISCUSSION

1. Main soil characteristics

Data in Table 1 show that the studied soils are highly calcareous containing high levels of total carbonate especially in the surface layer (0-25m) which decreased with soil depth. The pHs of the soils are higher than 8.0. On the other hand, the salinity is almost low in the surface soil layer and increases with soil depth. In addition, the organic matter contents in soils are generally low. The textures of the investigated soils are generally in the range of loamy sand, in the surface soil layer, and in the range of sandy clay loam, in the subsurface layer (Table 1). According to Abd El-Rahman *et al.*, (1987), these soils consist of loose and calcareous oolitic of medium to coarse sand size of marine origin and almost free from soluble salts with CaCO₃ over 90%.

2. Heavy metals in ambient air

The levels of heavy metals in the suspended particulate matter of the ambient are presented in Table 2. The results indicated that metals concentrations levels are very high compared to these of unpolluted air of the Antarctic as reported by Puxbaum (1999) for Cd, Cu, Cr, Ni and Zn which were 0.01, 0.012, 0.011, 0.03 and 0.11 µg/m³. It could be suggested that the electric power station (EPS) is considered the main source of these metals in the ambient air. These metals are supposed to be carried by suspended particulate matter, part of them are deposited locally near by the (EPS) and the remaining are transported for a longer distances (Davidson and Osborn, 1986; Pacyna, 1987 and Van den Hout *et al.*, 1999).

Table 2: Levels of heavy metals ($\mu\text{g}/\text{m}^3$) in the ambient air at Sidi Kirayer area 500 m downwind the Electric Power Station.

Sample No	Site description	Concentration $\mu\text{g}/\text{m}^3$				
		Cd	Cu	Cr	Ni	Zn
1	The site is located 500m to the south east downwind the Electric Power Station	1.1	3.00	2.75	1.85	2.5
2		1.2	3.05	2.75	1.85	2.5
3		1.0	3.00	2.70	1.80	2.4
4		1.1	2.95	2.70	1.85	2.3
5		1.1	3.00	2.70	1.85	2.4

Taking into consideration the background levels of metal concentration in Antarctic air (Puxbaum, 1999) and calculating the enrichment ratio of metal, it is clear that the air of the studied site is highly polluted by metals (Table 3). It is clear that the air is highly polluted by Cu, Cr and Cd. The magnitude of air pollution by metals can be arranged, according to the values of enrichment ratio (ER), in the order: $\text{Cu} = \text{Cr} > \text{Cd} > \text{Ni} > \text{Zn}$.

Table 3: Values of the enrichment ratio (ER) of metals in the air of the studied site.

Sample No	Cd	Cu	Cr	Ni	Zn
1	110	250	250	61.7	22.7
2	120	254	250	61.7	22.5
3	100	250	246	60.0	21.8
4	110	246	246	61.7	20.9
5	110	250	246	61.7	21.8
Background levels(Puxbaum, 1999)	0.01	0.012	0.011	0.03	0.11

3. Heavy metals in soil

Total amount:

Data in Table 4 show marked decrease in the total amounts of heavy metals in soil with depth. This indicates that most of metals are accumulated in the upper soil layer (0-25 cm) and its mobility downward in the soil profile is very limited. This is attributed to both high pH and high total carbonate in the soils (Alloway, 1995). The amounts of total metal in soils varied from site to another according to proximity from the emission source of Sidi Kirayer Electric Power Station (EPS).

Haiyan and Stuanes (2003) found that heavy metals accumulated mainly in the topsoil with little downward movement in polluted Chinese soils.

Source of metal pollution:

It is obvious that coal and oil are the main fossil fuels used to produce electricity. Also, it is well known that coal and oil power plants create serious environmental hazardous due to the emission of pollutants such as As, Cd and Hg through combustion (van den Hoat *et al.*, 1999). It is reported that the total amount of As, Cd and Hg in coal and crude oil are within the range 0.34-130, 0.01-300.0, and 0.01-1.6 mg kg^{-1} coal and within the range 0.0024-1.63, 0.03-2.10, 0.014-30.0 mg kg^{-1} crude oil, respectively (Pacyna,

1987). This points out to high possibility of soil pollution by metals emitted from the Electric Power Station (EPS). Considering the volatility of As, Cd and Hg compounds which are condensed on small particles in the flow gas stream, from high temperature source, these metals can be transported over long distance up to 3 km. It is reported that from the total emitted metals; 5-11% is locally deposited (Pacyna, 1987). According to Davidson and Osborn (1986) and Pacyna (1987), the rate of metal transport is related to metal-mass medium diameter which can be arranged in the order Hg > As > Zn = Ni < Cu < Cd < Cr. This points out to the magnitude of different metals transported in the atmosphere. As a result, local deposition of Hg is the least and that of Cr is the highest.

Table 4: The range and average values of total contents of heavy metals in soils (mg kg⁻¹).

SiteNo.	Soil depth,cm	As	Cd	Cu	Cr	Ni	Hg	Zn
1	00-25	0.4-0.6 (0.5)	0.2-2.25 (1.4)	0.6-6.2 (1.8)	3.2-3.8 (3.5)	5.8-7.0 (6.4)	0.9-1.9 (0.9)	27-75 (58)
	25-50	0.1-0.3 (0.15)	0.25-2.25 (0.9)	0.6-1.5 (0.9)	0.4-1.9 (0.7)	3.5-6.4 (4.8)	0.1-1.8 (0.65)	17-61 (50)
	50-100	0.01-0.04 (0.025)	0.1-0.75 (0.24)	0.05-1.85 (0.60)	0.4-0.75 (0.55)	1.0-2.6 (1.7)	0.05-0.12 (0.08)	12-56 (46)
2	00-25	0.3-0.5 (0.4)	0.2-2.5 (0.9)	1.35-5.3 (2.3)	0.9-4.0 (2.9)	1.4-7.8 (3.46)	0.19-1.8 (0.66)	25.0-30.5 (70)
	25-50	0.08-0.20 (0.10)	0.1-0.25 (0.15)	0.32-1.3 (0.6)	0.4-0.8 (0.45)	1.0-1.8 (1.1)	0.04-0.15 (0.09)	7.0-23.0 (12.6)
	50-100	-- (0.020)	--	-- (0.1)	--	--	-- (0.08)	-- (12)
3	00-25	0.18-0.30 (0.24)	0.5-1.25 (0.55)	0.71-2.3 (1.1)	0.4-4.2 (1.5)	1.4-5.0 (1.9)	0.15-1.5 (0.60)	35.0-45.0 (40.0)
	25-50	0.04-0.10 (0.07)	0.25-0.27 (0.28)	0.71-0.85 (0.81)	--	1.4-1.5 (1.45)	0.04-0.10 (0.07)	7.0-22.0 (16)
	50-100	-- (0.1)	-- (0.1)	-- (0.1)	-- (0.08)	-- (1)	-- (0.08)	-- (10)
4	00-25	0.1-0.20 (0.15)	0.5-1.5 (1.17)	3.1-8.3 (4.1)	5.8-7.0 (6.4)	1.1-8.5 (4.35)	0.10-1.0 (0.55)	7.0-81.0 (55.3)
	25-50	0.02-0.08 (0.04)	0.3-0.6 (0.46)	0.9-14.0 (1.3)	0.1-3.1 (1.6)	1.1-1.8 (1.7)	0.04-0.08 (0.06)	15-17 (15.8)
	50-100	0.004-0.012 (0.008)	0.1-0.12 (0.11)	0.08-0.09 (0.085)	-- (0.08)	0.3-0.7 (0.5)	0.02-0.04 (0.03)	8-13 (10.5)
5	00-25	0.06-0.1 (0.08)	0.5-1.7 (1.3)	0.6-3.5 (2.1)	0.4-1.0 (0.9)	1.1-6.3 (4.1)	0.08-0.4 (0.20)	7.0-83.0 (34)
	25-50	0.01-0.04 (0.025)	0.4-0.55 (0.45)	0.7-0.8 (0.75)	0.4 (0.4)	1.2-5.5 (3.1)	0.04-0.06 (0.05)	12-13 (12.5)
	50-100	-- (0.005)	0.1 (0.1)	-- (0.08)	--	0.55 (0.55)	-- (0.009)	9-10 (9.5)
6	00-25	0.05-0.09 (0.07)	0.4-0.5 (0.45)	0.6-1.1 (0.55)	--	0.9-3.0 (1.95)	0.04-0.10 (0.07)	17-34 (25.5)
	25-50	0.01-0.04 (0.025)	0.4-0.5 (0.45)	0.06-0.08 (0.075)	--	0.6-1.5 (1.1)	0.03-0.05 (0.04)	7.2-12.2 (8.2)
	50-100	-- (0.00)	0.08-0.1 (0.065)	0.05-0.07 (0.055)	--	0.6-1.5 (1.1)	-- (0.008)	7-9 (7.5)
7	00-25	0.04-0.09 (0.06)	0.3-0.5 (0.4)	1.8-2.3 (2.05)	--	2.0-2.2 (2.1)	0.04-0.06 (0.05)	55-80 (66.5)
	25-50	0.01-0.04 (0.02)	0.1-0.39 (0.21)	0.06-0.9 (0.085)	--	0.9-3.0 (1.95)	0.02-0.03 (0.02)	7.0-42.7 (24.30)
	50-100	-- (0.005)	0.1 (0.1)	-- (0.07)	--	0.3 (0.3)	-- (0.005)	-- (7)

It is also obvious that metals can reach the soil from the atmosphere by dry deposition (sedimentation, interception, impaction and turbulent diffusion) and by wet deposition (rainout, washout). The relative importance of dry and wet deposition depends on the transport distance from the source and wind velocity. In a heavily polluted area, the amounts of metals removed by dry deposition seem to be larger than by wet deposition. (Van den Hout *et al.*, 1999).

The atmospheric behavior of Hg appears to be a combination of deposition and resuspension or volatilization. After emission into the atmosphere, a part of Hg can be scavenged by even light precipitation, deposited on land, and can be re-vaporized within 1-2 days. It has been reported also that most of Hg in the atmosphere is transported over long distance from the source (Elsokkary, 1996).

Soil pollution by heavy metals:

It has been recognized that the atmosphere is an important pathway for transport of metals to soils. As shown in Table 4, on the average, metal contents in the soil of the deeper layer (50-100 m) are extremely low as compared with their contents in normal soils as outlined by Alloway (1995). Accordingly, in this study, total metals contents in soils of the deeper layer (50-100 cm) can be considered as the background levels of total heavy metals in the investigated soils. The background levels of heavy metals of the studied soil and those recorded by other authors are reported in Table 5. These background levels shown in Table 5 are used for calculating the enrichment ratio (ER) of heavy metals of the surface soil layer (0-25m), and the data obtained are given in Table 6. It is clear that the values of ER of heavy metals in each site varied markedly. The magnitude of "ER" of the different metals in the different sites can be arranged in the following order:

Site No. 1: Cr > Hg > As > Cd > Cu > Ni > Zn
Site No. 2: Cr > Hg > As > Cu > Cd > Ni > Zn
Site No. 3: Hg > Cr > As > Cu > Cd > Ni = Zn
Site No. 4: Cr > Cu > Hg > Cd > Ni > As > Zn
Site No. 5: Cu > Cd > Ni = Cr > Hg > Zn > As
Site No. 6: Cd > Cu > Ni > As > Zn > Hg
Site No. 7: Cu > Zn > Cd > Ni > As > Hg

According to these orders, Table 6 and Fig. 1, it is clear that soils of sites No. 1 and 2 are highly polluted by Cr as compared with sites No. 6 and 7 which are located at longer distances from the "EPS". It is also clear that the magnitude of pollution by metals decreases with increasing distance from the source of pollution. Generally, the studied soils of sites No. 1, 2 and 3 are highly polluted by Cr, Hg and As and the least by Cu, Ni and Zn. With respect to pollution, the soil of site No.1 was highly polluted while that of No 7 was the least and could represent normal agricultural soils. On the other hand, soils of site No 4 was highly polluted by Cr, Hg and Cu, and those of site No 7 was the least.

5: The values of total heavy metals in soil (mg kg^{-1}) of the deepest layer (50-100cm) as compared with other values reported in the literature (Alloway, 1995 and Kabata Pendias and Pendias, 1995).

	Ni	Cr	Cd	Zn	Cu	Hg	As
Studied soil No. 1	1.70	0.55	0.24	46.00	0.60	0.08	0.025
Studied soil No. 3	1.00	0.08	0.10	10.0	0.10	0.08	0.1
Studied soil No. 4	0.50	0.08	0.11	10.50	0.085	0.03	0.008
Range of the studied soils	0.5-1.7	0.08-0.55	0.1-0.24	10.00-46.00	0.085-0.6	0.03-0.08	0.008-0.1
Average of the studied soils	1.07	0.23	0.15	22.16	0.25	0.053	0.044
Normal Soil (Alloway, 1995)	2.0-750	5.0-100.0	0.01-2.0	1.0-900.0	2.00-250.00	0.01-0.05	0.1-40
Very light Sandy Soil (Kabata Pendias and Pendias, 1995)	3.7	8.0	0.19	0.19	4.6	---	---

Table 6: Enrichment ratio (ER) of heavy metals in the surface soil layer (0-25m).

Metal	Site No.						
	1	2	3	4	5	6	7
Ni	5.99	3.23	1.77	4.06	3.83	1.82	1.96
Cr	15.20	12.60	6.52	27.82	3.90	--	--
Cd	9.33	6.00	3.66	7.80	5.18	3.00	2.66
Zn	2.61	0.73	1.80	2.49	1.53	1.15	3.00
Cu	6.92	8.84	4.23	15.76	8.00	2.11	7.88
Hg	14.28	10.47	9.52	8.73	3.17	1.11	0.79
As	11.36	9.09	5.45	3.40	1.18	1.59	1.36

These data show that atmospheric deposition is assumed to be significant source of metals input into the soil of the studied area. It has been reported by Haugland *et al.*(2002) and Sterckeman *et al.*(2002) that the concentration of heavy metals in the contaminated soils are decreasing with increasing distance from the pollution sources.

Metals fractionation in soils:

Data in Table 7 show the average distribution of metals in the different chemical fractions of the metals in the surface soils No. 1 and 2. It is clear that the amounts of metals in the water soluble plus exchangeable fractions are lower than the detected limits of measurements by AAS. However, most of the total metal in soils are existing in the carbonate, Fe and Mn oxides, organic and sulfide and residue fractions. The magnitudes of each metal fraction in soils are dependent on metals type. Thus, most of Cd, Ni and Zn occurred in the carbonate fraction while those of Cu and Cr occurred in the organic and sulfide fraction (Table 7 and Fig. 2).

Table 7: Average values of metals concentrations into the different chemical fractions of soils No. 1 and 2 (mg kg⁻¹).

Site description	Cd	Cu	Cr	Ni	Zn
Water soluble +Exch.	N.D.	N.D.	N.D.	N.D.	N.D.
Carbonate	0.9	1.0	1.3	3.0	25
Fe and Mn oxides	0.3	0.7	1.1	0.6	22
Organic and sulfide	0.3	2.6	1.7	1.5	14
Residual	0.1	0.6	0.4	0.8	8

N.D.= not determined and below detection limit

4. Health risk assessment

The exposure through air inhalation:

The inhalation dose was calculated in mg/kg.day using the exposure through inhalation which is function in the respiration rate and the concentration of substance in air:

$$\text{Dose - inhalation} = \frac{C_{air} (DB) E}{T} \quad (1)$$

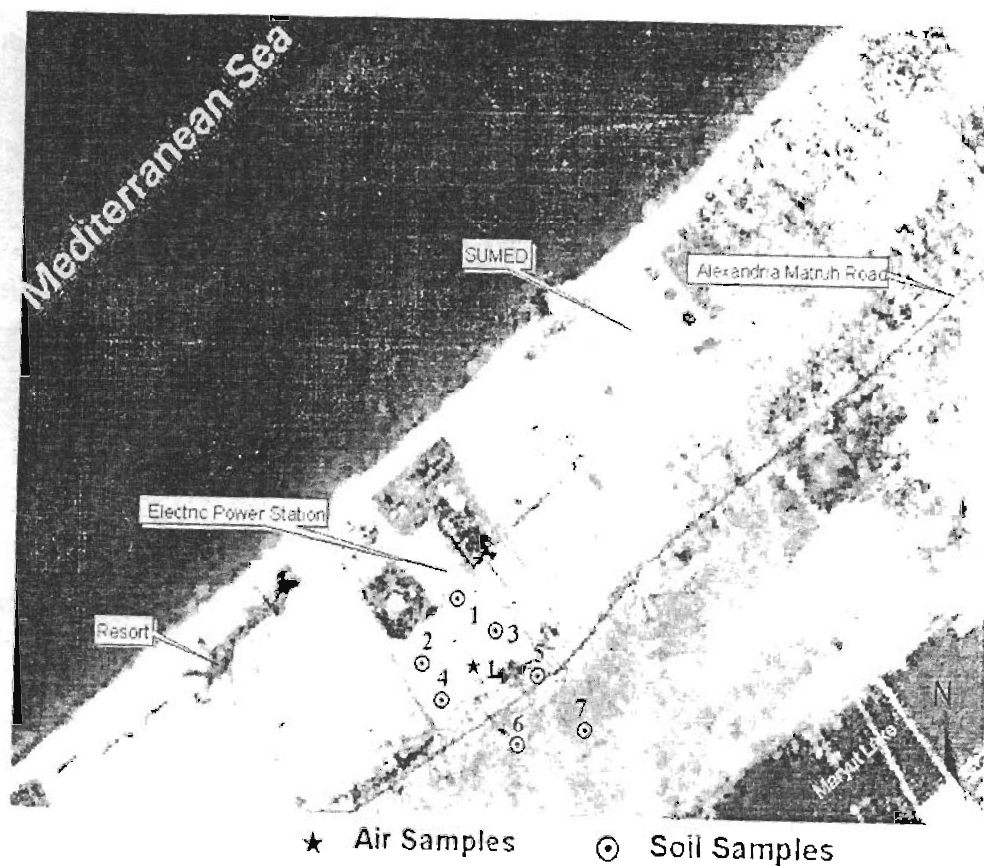


Fig. 1: The location of the selected sites for soil and air samples near and around the Electric Power Station at Sidi Krir area, west of Alexandria, Egypt
Source: SPOT Satellite image, Date 2002

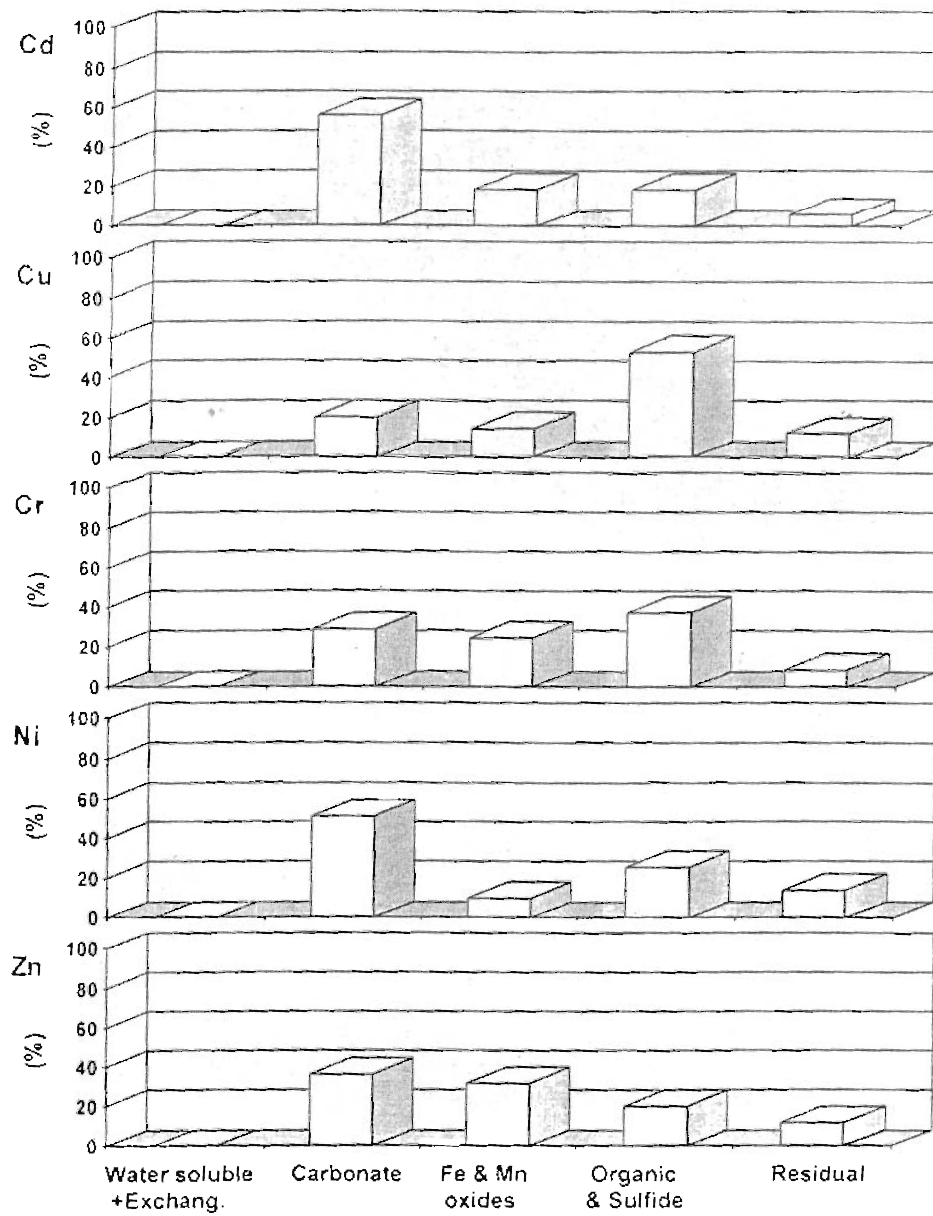


Fig. 2. The distribution of the different chemical fractions of Cd, Cu, Cr, Ni and Zn as average percent of total of soils No. 1 and 2.

Where:

C_{air} : Concentration in air ($\mu\text{g}/\text{m}^3$)

DB : Daily breathing rate $\text{m}^3/\text{kg}\cdot\text{day}$.

E : Exposure duration in days.

T : Averaging time period over which exposure is averaged.

Taken into consideration 70-years for exposure duration (25550 days), the high end of DB is $0.393 \text{ m}^3/\text{kg}\cdot\text{day}$. The exposure duration E was taken to be 70 year should be used in risk estimating for public notification. The obtained values of dose inhalation are listed in Table 8 for the investigated metals.

The exposure through the Ingestion of soil:

The dose in ($\text{mg}/\text{kg}\cdot\text{day}$) from inadvertent soil ingestion was estimated by the point estimate approved using the following equation:

$$\text{Dose} = \frac{C_{\text{soil}} \text{ SI } E}{T} \times 10^{-6} \quad (2)$$

Where:

C_{soil} : Concentration of contaminant in soil ($\mu\text{g}/\text{g}$)

SI : Soil ingestion Rate ($\text{mg}/\text{kg}\cdot\text{day}$)

E : Exposure duration in days

T: Average time: period of time over which exposure is average (days) during 70 years (70×365) day.

The soil ingestion rate for public was taken to be $1.7 \text{ mg}/(\text{kg}\cdot\text{day})$, for exposure duration 70 year. (OEHHA and CARB, 2002)

Data in Table 9 listed the average levels of heavy metals in soil in addition to their ingestion dose, cancer potency factors and Reference exposure Levels (REL).

In this study, risk characterization of heavy metals was performed for both air inhalation and soil ingestion. It is clear that, the health impact due to inhalation is much greater than that of soil ingestion. This may be attributed to the air pathway which is faster than the soil pathway. In the case of soil; the pathway is long and the pollutant may be subjected to several successive dilution processes. In the case of inhalation; the Health Quotient (HQ), which indicates the non-carcinogenic effects, displayed high values for all investigated heavy metals (Table 6). The highest HQ (60) was for Cd and the lowest (1.27) was for Cu. While HQ for Cr and Ni were 13.75 and 37.00 respectively. On the other hand, HQ from soil ingestion was much lower and the values are below 1.00 which is the recommended by EPA as the maximum value (US. EPA, 2002).

Risk characterization of carcinogenic investigated metals was performed for both air inhalation and soil ingestion pathways. For air inhalation Cr, Cd and Ni are known to be carcinogenic. The expected risk was estimated for these metals by multiplication of cancer potency factors by their inhalation doses.

Table 8: The Risk characterization of heavy metals in air

Elements	Average concentration, $\mu\text{g}/\text{m}^3$	Inhalation Dose $\left(\frac{\text{mg}}{\text{kg}\cdot\text{day}}\right)$	Chronic Inhalation Reference Exposure Level (REL) $\mu\text{g}/\text{m}^3$	The inhalation cancer potency factor $\left(\frac{\text{kg}\cdot\text{day}}{\text{mg}}\right)$	Health Quotient HQ	Expected cancer cases per million
Cd	1.20	4.52×10^{-4}	2×10^{-2}	1.5×10^1	60.00	6780.00
Cr	2.75	1.04×10^{-3}	2×10^{-1}	5.1×10^1	13.75	53.040
Cu	3.05	1.15×10^{-3}	2.40	-	1.27	-
Ni	1.85	6.97×10^{-4}	5×10^{-2}	9.1×10^1	37.00	634.27

Table 9: The Risk characterization of heavy metals in soil

Metal	Maximum Average concentration, $\mu\text{g}/\text{g}$	Soil ingestion dose $\left(\frac{\text{mg}}{\text{kg}\cdot\text{day}}\right)$	Chronic reference exposure levels (REL) $\left(\frac{\text{mg}}{\text{kg}\cdot\text{day}}\right)$	Oral cancer potency Factor $\left(\frac{\text{kg}\cdot\text{day}}{\text{mg}}\right)$	Health quotient HQ	Expected cancer cases per million
As	0.40	0.68×10^{-5}	3×10^{-4}	1.5	2.27×10^{-3}	0.45
Cd	2.25	3.83×10^{-6}	5×10^{-4}	-	7.66×10^{-3}	-
Cr	6.00	1.02×10^{-5}	2×10^{-2}	0.42	5.1×10^{-4}	24.29
Hg	1.90	3.23×10^{-6}	3×10^{-4}	-	0.01	-
Cu	6.3	-	-	-	-	-
Ni	8.5	1.45×10^{-5}	5×10^{-2}	-	2.9×10^{-4}	-

The obtained values are 53040, 6780 and 634 for Cr, Cd and Ni, respectively. For soil ingestion pathway the estimated values are lower than one per million except Cr, where its risk is 24 cases per million. US. EPA has established the range of generally acceptable risks for known or suspected carcinogenic as 10^{-6} to 10^{-4} (US. EPA, 2002). It is clear that, the inhalation pathways is much sensitive and contribute significantly than that of soil ingestion

CONCLUSIONS

The obtained data and discussion can be concluded into the following:

- 1-The ambient air and soil at the vicinity of EPS in this area are highly polluted by the heavy metals emitted from the EPS.
- 2-The results indicated that most of Cd, Ni and Zn occurred in the carbonate fraction, while those of Cu and Cr had occurred in the Fe and Mn oxides fraction.
- 3-After performing this work, risk assessment for metals released to air or to soil indicated that air inhalation contributes significantly in non-carcinogenic and carcinogenic metals for the population live in the vicinity of power station.
- 4-Soil ingestion gives little contribution to the health impact for both carcinogenic and non-carcinogenic metals.
- 5-Efforts and corrective actions should be taken by the decision maker to reduce the emission from the power station.

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تلوث التربة والهواء بالعناصر الثقيلة وتقييم المخاطر بالقرب من محطة توليد الكهرباء غرب مدينة الإسكندرية - مصر
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تم تقدير الكمية الكلية لعناصر الزرنيخ والكاديوم والنحاس والكروم والنيكل والزنك في كل من عينات التربة والهواء بالقرب من محطة توليد الكهرباء بمنطقة سيدى كريس غرب الإسكندرية وذلك لتقييم نوعية التربة والهواء في هذه المنطقة. وتم قياس هيئة الصور الكيميائية لهذه العناصر في التربة. كذلك أجرى عمل تقييم المخاطر لتحديد تأثير المستويات الحالية لهذه العناصر في الهواء والأرض على الصحة العامة.

أوضحت الدراسة أن الهواء في المنطقة المجاورة لمحطة إنتاج الكهرباء في سيدى كريس ملوثا بنسبة عالية بالكروم والكاديوم والنحاس بالمقارنة بالمناطق الغير ملوثة.

وأوضحت نتائج الدراسة أن هناك انخفاض ملحوظا في مستويات العناصر الثقيلة مع زيادة المسافة عن محطة إنتاج الكهرباء وكانت أعلى القيم المسجلة للتركيز الكلى لكل من الزرنيخ والكاديوم والنحاس والكروم والنيكل والزنك قد وجدت في الطبقة العلي-ا (صفر - ٢٥ سم) في الموقع رقم (١) وكانت المتوسطات هي ٠,٠٥، ١,٤، ١,٨، ٣,٥، ٦,٤، ٠,٩، ٥٨، ٠,٠٨ /مجم كجم تربة على التوالي. وأظهرت النتائج أيضا أن معظم العناصر قد تراكت في الطبقة السطحية للتربة وأن حركة هبوط العناصر في قطاع التربة تعتبر محدودة، وقد وجد أن المستويات الكلية المسجلة للطبقة العميقة (٥٠ - ١٠٠ سم) للموقع رقم (٤) كانت على التوالي ٠,٠٠٨، ٠,٠١١، ٠,٠٠٨، ٠,٠٣، ٠,٠٥، ١٠,٥ /مجم كجم تربة لعناصر الزرنيخ والكاديوم والنحاس والكروم والنيكل والزنك. وقد اعتبرت هذه القيم بأنها القيم المرجعية الموجودة في منطقة الدراسة. وأوضحت دراسة توزيع العناصر في الصور الكيميائية المختلفة من مكونات التربة أن معظم عناصر الكاديوم والنيكل والزنك ترتبط بالكربونات بينما النحاس والكروم ترتبط بكلا من المكونات العضوية وكذا الجزء الكبريتيدى.

وأوضحت الدراسة بالنسبة لتقييم المخاطر لهذه العناصر الثقيلة بالتربة والهواء أن مسهل استنشاق الهواء هو العامل المحدد لكلا من العناصر الخطرة، ويعتبر الكاديوم أعلاها وسجلت ٦٠ في الهواء وكذا الكروم هو أعلاها بالنسبة للتأثيرات المسرطنة حيث سجلت تقييم المخاطر بالنسبة للكروم بمعدل ٥٣٠٤٠ حالة لكل مليون.