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Dispersion and Deposition of Heavy Metals Around Two Municipal Solid Waste (MSW) Dumpsites, Alexandria, Egypt

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Abstract: The levels of heavy metals were measured at different sites with different distances and directions from two dumpsites in Alexandria for the ambient air, soil and vegetation. The results indicated a steady decrease in the concentrations of total Cd, Cu, Ni, Cr and Zn in the ambient air at Abis area with distance from the municipal solid waste (MSW) dumpsite. The mean maximum recorded levels were 1.35, 3.17, 2.85, 3.05 and 2.40 $\mu g\ m^{-3}$ for Cd, Cu, Ni, Cr and Zn respectively, while the minimum levels were 0.20, 0.35, 0.31, 0.35 and 2.10 $\mu g\ m^{-3}$ respectively in Abis area. Similar trends were found at El-Montaza district. Levels of heavy metals in soil were measured in 19 sites near and around the old (MSW) dumpsite at four directions. It was found that the sites located in the southeast direction from (MSW) dumpsite had the highest levels of total metals in soils. The soil of site close to the (MSW) dumpsite at Abis contained the highest levels of total metals which were 5.10, 97.10, 12.20, 11.20 and 110.0 $\mu g\ g^{-1}$ for Cd, Cu, Ni, Cr and Zn respectively. Similar trend was found at El-Montaza district. The concentrations of metals in leaves and roots of tomatoes, carrots and potatoes plants were higher in plants grown at the site close to Abis (MSW) dumpsite and decreased with increasing distance. The results obtained in this study clearly showed that heavy metals are dispersed with the aerosol in the ambient air and transported by wind then deposited onto the surrounding environment.

Key words: Aerosol · heavy metals · municipal solid waste · soil · vegetation

INTRODUCTION

Atmospheric pollution is of a major public health concern in many large cities world wide. However, in many cases only a little attention has been given to this issue in developing countries. Example is the case of Alexandria city in Egypt where two municipal solid waste (MSW) dumpsites were located at the east and west directions of the city. One of the main activities leading to this problem includes deposition of compost and incineration of MSW, which contain high levels of heavy metals. Such activities tend to increase the elemental background levels in the surrounding agricultural land driving to adverse temporal and/or spatial variations of heavy metals levels in soils.

Atmospheric deposition of anthropogenic derived chemicals is an important source of environmental pollution. It contributes to the load of pollutants in urban runoff [1, 2]. In some areas, the atmospheric deposition of pollutants has reached levels which are toxic to human and organisms. Therefore, the measurements of the fluxes of pollutants from the atmosphere in urban and non urban environments can aid in the assessment of air quality and can be used to determine spatial, temporal and seasonal variability of pollution sources [3].

Soil constitutes part of a vital environmental, ecological and agricultural resources that have to be protected from further degradation as an adequate supply of healthy food needed for the world's increasing population. Heavy metals can affect both the yield of crops and their composition. Thus determination of the elemental status of a cultivated land has to be made in order to identify yield-limiting deficiencies of essential micronutrients of plants grown on polluted soils [4, 5].

Some heavy metals are essential in trace amounts, namely Zn, Cu and Mn for plants and in addition Co and Ni for animals. On the other side, Cd, has not been known to have any function for either plants or animals [6]. High

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concentrations of metals become toxic to plants and possibly are dangerous to human health. A number of cases of health problems related to environmental Cd poisoning have been reported [7]. Some of the metals are phytotoxic and some are toxic to both plants and animals through their entry into the food chain [8].

Baseline data for the occurrence of heavy metals as contaminants are needed as one of the criteria for assessment of critical heavy metals levels in agricultural soils. Over the last two decades, the study of the sources, fluxes and pathways of heavy metals on both national and international research communities is a response of a great concern about pollution and possible health impacts [9, 10].

Environmental pollution data tend to vary extensively and to be subjected to various types of uncertainties due to several factors such as distance from pollution sources and pathways, natural background variation, pollution buildup or degradation over time. Environmental variability depicts the exact variant in pollution levels between population units [11].

The objectives of this study were to, (i) assessing the levels of heavy metals in air, soil and vegetables distributed in the surrounding environment of two old MSW dumpsites at Alexandria city in Egypt, (ii) comparing these levels at both MSW dumpsites in west and east of Alexandria, (iii) assessing the relationship between heavy metals in soils and corresponding vegetations and (iv) defining the contribution of air pollution on soil pollution.

MATERIALS AND METHODS

Studied areas: There are two main dumpsites for Municipal solid waste MSW at Alexandria city: (i) Abis dumpsite and (ii) El-Montaza dumpsite. Both are surrounded by an agricultural area as shown in Fig. 1 and 2. (i) Abis dump site has an area approximately 100.000 m^2 and is surrounded by Maryout Lake from the northwest and northeast. The agricultural area lies to the south, southwest and southeast of the dumpsite. Some private Mixer and Project Company are located on the main road leading to the dumpsite. Alexandria-Cairo desert road is located about one km to the north of the dumpsite. The maximum height above the ground of municipal solid on site is about 5 meters. The waste is usually subjected to primitive and random sorting by Scavengers. Self ignition has been frequently occurred and a lot of pollutants were dispersed near by the surroundings as shown in (Fig. 3). (ii) El-Montaza dumpsite is located to the east of Alexandria city as shown in (Fig. 2). It is surrounded by the agricultural area from most directions except some scattered buildings and schools to the north. An old compost plant is located close to the dumpsite. Yearly average wind roses showed that the dominant wind directions in Alexandria City is Northwest, so the anticipated affected area at the two dumpsites is the southeast as, shown in Fig. 1.

Sampling program

Ambient air sampling: This was carried out as follows: (i) five sites have been selected close to the dumpsite, south and southeast the dumpsite in Abis as shown in Fig. 1 and (ii) four sites have been selected at El-Montaza dumpsite close to the dumpsite at different distances southeast direction from the dumpsite as shown in Fig 2. The air sampling method was designed to collect atmospheric particles in a form suitable for heavy metals analysis. Aerosol samples were collected using a volume samplers type L-2SF. MK3 from Rotheroe & Michael, with a fiber glass filter paper (47 mm 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 [12]. Sampling period was approximately 24 hrs and the flow was measured at the beginning and at the end of each sampling to obtain an average flow rate. Average flows ranged from 70 to 100 m^3 hr^{-1}. Each site was sampled four times (Four successive days) and all samples have been conducted in summer (2004).

Soil sampling: Surface soil samples (0–10 cm) from Abis area have been collected from 19 sites from the agricultural area as shown in Fig. 1. The sampling sites covered the following directions: west, east, south, southwest and southeast. The samples were collected at different distances from the dump site, the longest distance was 2000 m southwest the dumpsite, in addition to one site very close to the dumpsite. Six sites have been selected for soil sampling at south El-Montaza downwind the dumpsite. Four sites were selected at the southeast, one close to the dumpsite and the last one was to the north (upwind) for the comparison as shown in (Fig. 2). The collected soil samples were air dried in a clean room to avoid contamination and ground to pass through 2 mm sieve and stored in polyethylene bags for analysis.

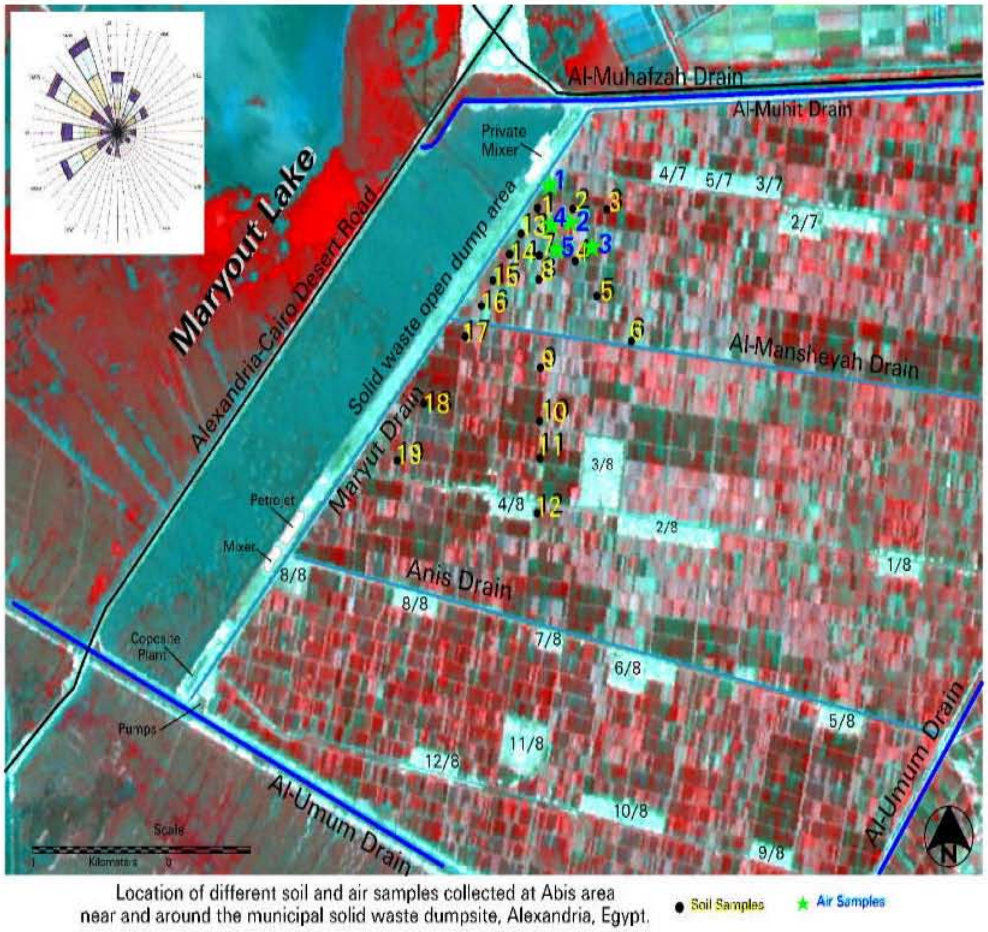

Fig. 1: Location of diffrent soil and air samples collected at Abis area near and around the municipal soil wast dumpsite, Alexandria, Egypt

Fig. 2: Location of diffrent soil and air samples collected at Elmontaza area near and around the municipal solid wast dumpsite, Alexandria, Egypt

Fig. 3: The self ignetion at the municipal solid wast dumpsite in Abis area Alexandria, Egypt and its impact on the surrounding Environmental

Vegetables sampling: Tomato leaves and roots, carrot roots and potatoes roots were collected from sites No. 1 and 18 at Abis area, washed with tap water then with distilled water. The plant materials were air dried in a dust free room then in an oven at 70°C for 48 hrs. The plant samples were ground in a stainless steel mill and passed through a 0.5 mm sieve and stored in polyethylene bags for analysis.

Analytical procedures

Aerosol: The fiber glass filter paper was placed in a desecrator for 48 hrs then its weight was measured. For the determination of the concentration of total Cd, Pb, Ni, Cr and Zn, the pre-weighed filter paper was treated with one ml concentrated Hydrofluoric acid then 10 ml concentrated nitric acid and 5 ml perchloric acid and heated (80-120°C) for 5 hrs. 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 50 ml in a volumetric flask with glass double distilled water. A blank filter paper was similarly digested and the same procedure was carried out. The concentrations of heavy metals were measured by, Perkin-Elmer model 5000, an atomic absorption spectrophotometer, AAS, [13].

Soil: The main chemical characteristics of the soils: EC, pH, total carbonate and the distribution of the particle size (sand, silt and clay) were determined according to standard methods [14]. The amounts of total heavy metals in soils were determined by the same method used for digesting the aerosol samples.

Plant leaves: The same procedure, carried out for digesting the soil and aerosol samples, has been used for digesting the plant material of the different vegetables. The concentrations of Cd, Pb, Ni, Cr and Zn in plant material were measured by AAS.

RESULTS AND DISCUSSION

Heavy metals in the ambient air: The average concentrations of heavy metals ($\mu g\ m^{-3}$) in atmospheric particulate matter near and around the two MSW are shown in Tables 1 and 2. The results indicated that the highest concentration levels were recorded for the site close to the dumpsite at Abis and El-Montaza. The mean maximum recorded levels were 1.35, 3.17, 2.85, 3.05 and 2.4 $\mu g\ m^{-3}$ for Cd, Cu, Ni, Cr and Zn, respectively in Abis area and were 0.65, 1.92, 1.83, 2.13 and 2.4 $\mu g\ m^{-3}$ respectively, for the same metals in El-Montaza area. These levels are high and could be originated from anthropogenic and industrial activities [15, 16]. These high recorded levels found in the present in study are hundred times higher than the levels of these metals in an unpolluted remote area and reached 76 times in the case

Table 1: The average values of total heavy metals concentration (μg m^{-3}) in the suspended particulate matter (aerosol) at Abis in air samples collected at different sites downwind direction of the soil municipal solid waste dumpsite

Site description	Cd	Cu	Ni	Cr	Zn
Close to dumpsite	1.35±0.10	3.17±0.12	2.85±0.20	3.05±0.27	2.40±0.18
200 m, southeast the dumpsite	1.20±0.08	2.50±0.08	2.25±0.09	1.95±0.20	2.75±0.17
500 m, southeast the dumpsite	0.40±0.07	0.85±0.01	0.63±0.015	0.85±0.12	2.20±0.19
200 m, south the dumpsite	0.50±0.07	1.65±0.04	1.25±0.09	1.35±0.08	2.30±0.10
300 m, south the dumpsite	0.20±0.03	0.35±0.01	0.31±0.01	0.35±0.02	2.10±0.11

Table 2: The average values of total heavy metals concentration (μg\m^3) in the suspended particulate matter (aerosol) at El-Montaza in air samples collected at different sites at the municipal solid waste dumpsite

Site description	Cd	Cu	Ni	Cr	Zn
Close to dumpsite	0.65±0.08	1.92±0.12	1.83±0.10	2.13±0.19	2.40±0.15
200 m, southeast the dumpsite	0.42±0.07	1.35±0.10	1.45±0.09	1.52±0.12	2.35±0.12
300 m, southeast the dumpsite	0.20±0.04	0.85±0.09	0.92±0.09	1.10±.08	2.10±0.09
500 m, southeast the dumpsite	0.07±0.01	0.20±0.01	0.25±0.01	0.27±0.01	0.57±0.08

Table 3: The ratios of heavy metal between that of Abis and that of El-Montaza at site close to the dumpsite and at 500m southeast downwind direction

Metal	Close to dumpsite	500 m downwind site
Cd	2.07	5.70
Cu	1.65	4.25
Ni	1.55	2.52
Cr	1.43	3.14
Zn	1.14	1.28

of Cr in the rural area. A steady decrease in the concentrations of Cd, Cu, Ni, Cr and Zn were found with distance from the MSW dumpsite. The highest concentrations were found close to the MSW dumpsites for all the measured metals, while the lowest levels were recorded for the sites located far away from the dumpsites. It is clear that the MSW dumpsite is the main source of these heavy metals in this area. The suspended particles and the self ignited products with its contents of metals are transported and deposited on soil with the distance. There are two possible pathways for metals to be suspended in the aerosol. The first one is the transport of the fine material enriched with metals from MSW dumpsite. The second is the emission of heavy metals from the uncontrolled self ignition and the incineration products from the MSW dumpsite. The incineration residue including metals is suspended to the aerosol and transported by winds. The MSW consists of a wide variety of organic (combustible) and inorganic (non-combustible) products ranging in size and composition from dust particles to old furniture and appliances [17]. The percentage of combustible material in MSW reaches about 75% of the total. It is obvious that the main air pollutants from municipals solid waste are acid gases, dioxins and heavy metals. Although a great deal of these pollutants are released in the form of fly ash as a product of incineration, there is a minor contribution from the other scattered sources such as the Petrojet activity and the Mixers at Abis. It is therefore, expected to find these metals enriched in the atmosphere at these two areas; (Abis and El-Montaza) as a result of the presence of the MSW dumpsites.

It should be mention that the levels of heavy metals in the aerosol of Abis were higher than in those recorded of El-Montaza. A ratio between the levels of heavy metals in the aerosol of the site close to the dumpsite and at 500 m downwind the dumpsite, of Abis and El-Montaza, are shown in Table 3. Abis had Cd level two times higher than El-Montaza at the site close to the dumpsite and was the highest among the other metals while Zn was the least (1.14). The ratios of Cu, Ni and Cr metals varied from 1.14 to 1.65. The same trend occurred at the site 500 m downwind the dumpsite, but the ratios were much higher and reached 5.7 times for Cd in Abis compared to El-Montaza. The ratios of Cu, Ni, Cu and Zn metals varied between 1.28 to 4.25 times. The increase in the ratio between the levels of heavy metals of both areas at 500 m downwind the dumpsite revealed that there may be another sources contributing at Abis area. The obtained results showed that the aerosol which originated from the municipal solid waste were deposited close to the dumpsite while which are transported to longer distances are originated from the residue of the self incineration and from the other activities found near by the dumpsite at Abis. The differences in the levels of heavy metals, at both areas, were attributed to other sources found around

Tale 4: Average values of the main chemical and physical properties of the cultivated soils at Abis area

Plant type	pH*	EC** dsm^{-1}	Ca^{2+}	Mg^{2+}	Na^{+}	SO^{4-}	Cl^{-}	Total $CaCO_3$ %	Sand	Silt	Clay	Soil texture
			meq/1						%			
Tomato	8.1	1.38	3.7	2	7.7	6.3	5.4	24.2	5.5	19	26	Sandy Clay Loam
Carrot	8.1	2.00	4.5	3	11.8	0.5	7.3	23.3	60	16	24	
Potato	8	2.78	7.7	4.2	15	15	11	25.1	52	18	30	

*Measured in 1:2.5 soil water suspension **Measured in 1:1 soil water extrac.

Table 5: Average values of the amounts of total heavy metals in soils ($\mu g\ g^{-1}$) collected at different sites downwind old MSW dumpsite in Abis

Site No.	Site description	Cd	Cu	Ni	Cr	Zn
1	Close to dumpsite	5.1	97.1	12.2	11.2	110
2	200 m, east of the dumpsite	4.6	82.5	9.3	9.0	98
3	500 m, east of the dumpsite	4.3	74.8	8.4	8.2	90
4	500 m, southeast of the dumpsite	4.5	82.8	8.4	9.0	89
5	700 m, southeast of the dumpsite	3.4	60.0	7.9	8.3	87
6	1000 m, southeast of the dumpsite	2.7	55.6	7.5	8.0	86
7	300 m, south dumpsite	4.2	80.2	8.2	8.9	91
8	500 m, south dumpsite	4.1	73.5	7.9	8.7	87
9	1200 m, south dumpsite	1.2	49.5	7.2	8.6	80
10	1500 m, south dumpsite	1.5	45.2	7.2	8.4	80
11	1700 m, south dumpsite	1.2	43.4	7	8.2	80
12	2000 m, south dumpsite	0.6	41.2	7	8.0	78
13	200 m, southwest dumpsite	4.2	80.5	8.8	9.9	89
14	300 m, southwest dumpsite	3.9	78.0	8.2	4.0	87
15	500 m, southwest dumpsite	3.8	74.0	7.7	8.6	82
16	700 m, southwest dumpsite	2.8	74.1	7.6	8.1	80
17	1000 m, southwest dumpsite	1.45	61.2	7.2	7.8	72
18	1500 m, southwest dumpsite	1.0	49.0	7.2	7.6	70
19	2000 m, southwest dumpsite	0.25	43.0	6.9	7.5	70

the dumpsite at Abis area where is the Petrojet Company and the Mixers are existing active. However, the MSW dumpsites still the main sources and main contributor of heavy metals load especially for the sites close to the dumpsite.

Levels of metals in soil

Abis: The main characteristics of Abis soil are presented in Table 4. Levels of heavy metals in soils collected from 19 sites near and around the old MSW dumpsite are presented in Table 5. The samples were taken along four directions: south, southeast, southwest and east from the dumpsite in addition to one sample very close to the dumpsite. The results indicated that this area is highly polluted by heavy metals and is exposed to serious sources of pollution. The results also indicated that there is a decrease in heavy metals concentrations with increasing distance from the dumpsite. It is clear that the sites located at the southeast from the dumpsite had the highest levels of metals as compared with the sites located at the other directions. Site No. 1, which is close to the dumpsite, had the highest levels of metals relative to all other sites and is heavily polluted. These results are highly correlated with the meteorological parameters and with the wind roses which indicated that the dominant wind direction is the northwest, as a result, the affected direction will be the southeast. However, the other two directions are subjected to pollution by this source most of the year as indicated from the current wind roses. This result agreed with other studies, which reported that the concentrations of total heavy metals in soil decreased with increasing distance from the disposal sites of the tannery and the textile industries in Dkaka city, Bangladesh [18]. Similarly, another study showed that surface accumulation of heavy metals in soils may result from atmospheric input in the southwestern region being exposed to air pollution from Great Britain and central Europe [19]. In this respect, it was argued that the soils of southwest France have been received a comparable annual inputs of metals since the dawn of industrialization [20]. Moreover, monitoring of heavy metals deposition onto soils in two locations in UK showed that large amount of metals are entering the soil annually [21]. The results of our study indicted that the lowest recorded levels were found in soils at Site No. 19 (2000 m southwest the dumpsite) while the highest recorded levels were found in soils at Site No. 1 (close to the dumpsite). This indicated that the main source is the dumpsite. Comparing these levels with the background levels of heavy metals of unpolluted soils in Egypt and other soils around the world indicated that Cd, for instance, was ten times higher than the background level [4]. In addition, the levels of all other metals were higher than the background levels except for zinc, which was very close to the background levels in the Egyptian soil [4, 9].

Table 6: Avearage values of the main chemical and physical properties of El-Montaza soils

Parameters	Value
pH*	7.9±0.2
EC ds m^{-1}**	4.8±1.2
O.M. %	2.8±0.3
Total carbonate	6.8±1.4
Sand %	36.0±9.0
Silt %	34.0±5.0
Clay %	30.0±7.0

*Measured in 1:2.5 soil water suspension

** Measured in 1:1 soil water extract

Table 7: Average values of heavy metals in soils (μg g^{-1}) collected at different sites downwind El-Montaza-solid waste dumpsite

Site No.	Site description	Cd	Cu	Ni	Cr	Zn
1.	Close to the dumpsite	4.52	73.70	12.40	10.80	108.50
2.	200 m southeast dumpsite	4.10	65.20	9.40	8.50	95.00
3.	500 m southeast dumpsite	3.74	60.50	8.40	8.00	86.00
4.	700 m southeast dumpsite	2.95	52.50	8.00	8.00	81.00
5.	1000 m southeast dumpsite	1.20	40.80	7.00	7.20	78.00
6.	200 m north dumpsite	0.35	38.20	6.70	7.10	75.00

Table 8: Average values of heavy metals (μg g^{-1}) in root and leaves of tomato potato and carrots grown in Abis area

Type of plant	Site No.	Cd	Cu	Ni	Cr	Zn
Tomato, roots	(1)	0.18	21.60	1.80	1.88	22.60
Tomato, leaves	(1)	0.12	12.17	0.81	0.90	11.30
Carrot, roots	(1)	0.32	15.65	1.00	0.95	16.50
Potatoes, roots	(1)	0.73	42.35	0.35	6.50	43.50
Tomato, roots	(18)	0.09	3.05	0.10	0.12	18.25
Tomato, leaves	(18)	0.08	2.35	0.09	0.09	8.20
Carrot, roots	(18)	0.09	0.30	0.02	0.01	4.50
Potatoes, roots	(18)	0.15	3.50	0.18	2.20	6.50

Table 9: Values of heavy metals contents (μg g^{-1}) in plants [22]

Metals	Sufficient or Normal	Excess or Toxic
Cd	0.05-0.2	5-30
Co	0.02-1.0	15-50
Cr	0.1-0.5	5-30
Cu	5-30	20-100
Mn	30-300	400-1000
Ni	0.1-5.0	10-100
Pb	5-10	30-300
Zn	27-10	100-400

El-Montaza: The main characteristics of El-Montaza soil are presented in Table 6. Six sites have been selected for soil sampling and the obtained levels of heavy metals are shown in Table 7. The highest levels were recorded in soils of the site No. 1 close to the dumpsite and the lowest levels were found in soils of site No. 6, (200 m north the dumpsite). In general, there is a tendency for decreasing the levels of heavy metals with increasing distance from the dumpsite as shown in Table 7. Comparing the obtained results with those obtained with Abis area, showed similar patterns where the highest level was found close to the dumpsite and there is a continuous decrease, of the levels of metals, with increasing distance from the dumpsite at both areas. The recorded levels of Cd, Cu, Ni and Cr were higher than the background levels in the Egyptian soils taking the same trend at Abis area [4, 9]. Zinc levels still similar to that obtained at Abis area and there was no high increase within this area. The only difference between Abis and El-Montaza is that the recorded levels of heavy metals at Abis area were higher than obtained at El-Montaza area. This could be due to the other pollution sources found at Abis area, including the cement company and other petroleum companies near Abis area which is a serious source of there metals.

Levels of heavy metals in vegetables: Two sites were selected for the measurements of total heavy metals in vegetables; one site very close to Abis dumpsite (site No. 6) and the other site (18) located about 1700 m southwest of the dumpsite. The results shown in Table 8 indicate that the distance of the dumpsite is the controlling factor for the distribution of the concentration of metals. Differences were found in the concentrations of these metals at the two sites, where the cadmium levels in the leaves and roots of tomatoes decreased by 50% at site No. 18. The differences were very high in the case of carrot and potato roots where the levels increased several times higher at site No. 1 compared with site No. 18. In all cases, the recorded levels were high when compared to other studies. As reported in previous studies the concentrations of heavy metals were high in the vegetation of tannery area in the vicinity of industries around Dkaka in Bangladesh [17]. As shown in Table 9, the toxic level of Cd, Cu, Ni, Cr and Zn ranged from 5-30, 20-100, 10-100, 5-30 and 100-400 ppm, respectively [22]. In our study, all the results did not reach the toxic levels except in the case of potatoes roots regarding Cu and Cr concentrations at site No. 1 which imply that this soil is containing high amounts of these metals. There is a general tendency for higher metal concentrations in the southern part of Norway compared to central part. The more volatile elements, such as cadmium, which are commonly associated with air pollution, are generally more concentrated in the plant grown on south western region which receives the most rainfall and being more exposed to air pollution from Great Britain and central Europe [19].

CONCLUSIONS

- The uncontrolled burning of municipal solid waste of the two opened MSW dumpsites in Alexandria City creates heavy metals in the ambient air.
- The environmental components air and soil as well as vegetables surrounding the municipal solid waste dumpsites in Abis and El-Montaza districts are highly polluted with heavy metals.
- The magnitude of pollution by metals decreased with increasing distance from the dumpsite.
- Abis area is receiving higher amounts of atmospheric deposited heavy metals than south El Montaza district as a result of the presence of other air pollution sources.
- The levels of heavy metals in tomatoes, potatoes and carrots grown in Abis area were higher than the normal, but did not reach the toxic levels except for Cu and Cr in potatoes roots at the planted area close to the dumpsite.

According to these results, the recommendations urgently required are:

- Solid waste should be carefully incinerated using special facilities and designed to prevent contamination of the soil and plants otherwise burning can result in emissions of hazardous substances such as heavy metals.
- Rehabilitation of the old dumpsites should be started as soon as possible to prevent deteriorations of the surrounding environment.

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