RESEARCH PAPER:

A preliminary assessment of the heavy metals around two municipal solid waste (MSW) dumpsites

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SUMMARY

Heavy metals and physico-chemical characteristics of the different sites of the municipal solid waste dumpsite at two Municipal Solid Wastes (MSW) dumpsites, Alexandria, Egypt were investigated. The levels of heavy metals were measured at different sites with different distances and directions from two dumpsites in Alexandria for the ambient air and soil. 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 1.43, 2.95, 2.71, and 2.95 and 2.35 μg m^{-3} for Cd, Cu, Ni, Cr and Zn, respectively, while the minimum levels were 0.10, 0.32, 0.41, 0.30 and 2.10 μg 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 closed to the (MSN) dumpsite at Abis contained the highest levels of total metals which were 4.90, 95.20, 11.80, 10.20 and 110.0 ìg g^{-1} for Cd, Cu, Ni, Cr and Zn, respectively. Similar trend was found at El-Montaza district.

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Atmospheric pollution is of a major public health concerns in many large cities worldwide. 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 included deposition of compost and incineration of MSW, which contained 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 (James *et al.,*1990; Jaffe *et al.,* 1993).

Municipal Solid Waste management depends on the characteristic of the solid waste including the gross composition, moisture contents, average particle size, chemical composition and density, in which knowledge of these, usually helps in disposal plans (Sally, 2000; Ogundiran, 2008).

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 (Howard, 1987).

Soil constitutes part of vital environmental, ecological and agricultural resources that have to be protected from further degradation as on 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 (Elsokkary and Lag, 1980; Alloway, 1990).

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 [8]. High 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 [9]. Some of the metals are toxic to both plants and animals through their entry into the food chain [10].

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 [11, 12].

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 pollution levels between population units [13].

The objectives of this study were to: (i) Assessing the levels of heavy metals in air, soil 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.

EXPERIMENTAL METHODOLOGY

Studied areas:

There are two main dumpsites for Municipal Solid Waste MSW at Alexandria city:

– Abis dumpsite.

– El-Montaza dumpsite.

Both are surrounded by an agricultural area as shown in Fig. A and B.

Fig. A : Location of different soil and air samples collected at Abis area near and around the municipal solid waste dumpsite, Alexandria, Egypt

Fig. B : Location of different soil and air samples collected at El-Montaza area near and around the municipal solid waste dumpsite, Alexandria, Egypt

– 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. C).

Fig. C : The self ignition at the municipal solid waste dumpsite in Abis area, Alexandria, Egypt, and its impact on the surrounding environment

– 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. A yearly average wind direction in Alexandria city is northwest, so the anticipated affected area at the two dumpsites is the southeast as, shown in (Fig. 1.), Self -ignition has been frequently occurred and a lot of pollutants were dispersed near by the surroundings as shown in (Fig. D).

Fig. D : The self ignition at the municipal solid waste dumpsite in El-Montaza area, Alexandria, Egypt, and its impact on the surrounding environment

Sampling programme:

Ambient air sampling:

This was carried out as follows:

–Five sites have been selected closed to the dumpsite, south and southeast the dumpsite in Abis as shown in Fig. A.

–Four sites have been selected at El-Montaza dumpsite closed to the dumpsite at different distances southeast direction from the dumpsite as shown in Fig B. The air sampling method was designed to collect atmospheric particles in from suitable for heavy metals analysis. Aerosol samples were collected using a high volume air samplers with flow rates of 1.0 and 2.0 m^3/min., and used to collect aerosol on whatman -41 glass fibre filter papers (size 20.3 x 25.4 cm^2). The inlet manifold of volume sampler was two meters height of the ground surface. Suspended particulate matter in the ambient air is sampled temperature and pressure [14]. 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. Each site was sampled four times (four successive days) and all samples have been conducted in summer (2009).

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. A. 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 closed to the dumpsite. Six sites have been selected for soil sampling at south El-Montaza downwind the dumpsite. From sites were selected at the southeast, one closed to the dumpsite and the last one was to the north (upwind) for the comparison as shown in (Fig. B). 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.

Analytical procedures:

Aerosol:

The fibre glass filter paper was placed in a dessicrator 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 per-chloric acid and heated (80-120^{0}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 per cent 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, [15].

Soil:

The soil particulates samples were air dried and then passed through a 1 mm stainless steel sieve. One gram of each soil sample was put into 150 ml conical flask, a mixture of HNO_3: $HCLO_4$: HF the ratio 3:1:3 was added [16].The mixture was placed on a hot plate for three hours at 80°C. The digest was filtered into 100 ml standard flask and made to mark with de-ionized water. 2 g of plant samples were dry-ashed in an oven. The ash content was completely dissolved in 15 ml of 20 per cent HNO_3 [17]. The digest was filtered into 100 ml standard flask and made up to mark with de-ionized water. Heavy metals were analyzed for both in the sediment and plant samples using atomic absorption spectroscopy, AAS (Perkin-Elmer model 5000).

Experimental Findings and Discussion

The results are summarized below according to objectives of the study:

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 closed to the dumpsite at Abis and El-Montaza. The mean maximum recorded levels were

1.43, 2.95, 2.71, 2.95 and 2.35 ìg m^{-3} for Cd, Cu, Ni, Cr and Zn, respectively in Abis area and were 0.73, 2.01, 1.85, 2.10 and 2.35 ìg m^{-3}, respectively, for the same metals in El-Montaza area. These levels were high and could be originated from anthropogenic and industrial activities [18, 19]. These high recorded levels found in the present study are hundred times higher than the levels of these metals in an unpolluted remote area and reached 76 times in the case of Cr in the rural area. A steady decrease in the concentrations of Cd, Cu, Ni, Cr and Zn was found with distance from the MSW dumpsite. The highest concentrations were found closed to the MSW dumpsites for all the measured metals, while the lowest levels were recorded for the sites located for 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 their 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 dumpsites. 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 [20]. 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 Petro jet 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 mentioned 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 closed 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 closed to the dumpsite and was the highest among the other metals while Zn was

Table 1: The average values of total heavy metals concentration (µg m^{-3}) in the suspended particulate matter (aerosol) at Abis in air samples of MSW dumpsite

Site description	Heavy metals concentrations, (µg m^{-3})				
	Cd	Cu	Ni	Cr	Zn
Close to dumpsite	1.43	2.95	2.71	2.95	2.35
200 m, southeast the dumpsite	1.30	2.10	2.15	1.75	2.15
500 m, southeast the dumpsite	0.55	0.86	0.73	0.66	2.20
200 m, south the dumpsite	0.60	1.65	1.35	1.20	2.40
300 m, south the dumpsite	0.10	0.32	0.41	0.30	2.10

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 of MSW dumpsite

Site description	Heavy metals concentrations, (µg m^{-3})				
	Cd	Cu	Ni	Cr	Zn
Close to dumpsite	0.73	2.01	1.85	2.10	2.30
200 m, southeast the dumpsite	0.44	1.40	1.35	1.55	2.20
300 m, southeast the dumpsite	0.15	0.90	1.00	0.95	1.90
500 m, southeast the dumpsite	0.08	0.20	0.20	0.25	0.55

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

Site description	Heavy metals				
	Cd	Cu	Ni	Cr	Zn
Close to dumpsite	1.96	1.47	1.46	1.40	1.02
500 m, southeast the dumpsite	6.88	4.3	3.65	2.64	4.00

the least (1.02). The ratios of Cu, Ni and Cr metals varied from 1.43 to 1.47. The same trend occurred at the site 500 m downwind the dumpsite, but the ratios were much higher and reached 6.88 times for Cd in Abis compared to El-Montaza. The ratios of Cu, Ni, Cr and Zn metals varied between 2.64 to 4.30 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 closed 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 the dumpsite at Abis area where the Petro jet Company is and the Mixers are existing active. However, the MSW dumpsites are still the main sources and main contributor of heavy metals load especially for the sites closed to the dumpsite.

Levels of metals in soil:

Abis:

Levels of heavy metals in soils collected from 19 sites near and around the old MSW dumpsite are presented in Table 4. The samples were taken along four directions: south, southeast, southwest and east from the dumpsite in addition to one sample very closed to the dumpsite. The results indicated that this area was highly polluted by heavy metals and was exposed to serious sources of pollution. The results also indicated that there was 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 closed 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 which 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 [21]. 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

Table 4: The average values of the amounts of total heavy metals concentration (µg g^{-1}) in the soils collected at different sites of MSW dumpsite

Site No.	Site description	Heavy metals concentrations, (µg g^{-1})				
		Cd	Cu	Ni	Cr	Zn
1.	Close to dumpsite	4.90	95.20	11.80	10.20	110.00
2.	200 m, east the dumpsite	4.20	82.00	9.30	9.10	95.00
3.	500 m, east the dumpsite	3.85	73.8	8.40	8.25	90.00
4.	500 m, southeast the dumpsite	3.95	81.8	8.35	9.15	89.10
5.	700 m, southeast the dumpsite	3.55	59.50	7.85	8.30	87.00
6	1000 m, southeast the dumpsite	2.50	54.60	7.50	8.00	86.00
7.	300 m, south the dumpsite	3.80	80.10	8.20	8.80	91.00
8.	500 m, south the dumpsite	3.70	74.50	8.00	8.60	87.50
9.	1200 m, south the dumpsite	1.00	48.20	7.20	8.50	80.00
10.	1500 m, south the dumpsite	1.35	44.50	7.15	8.40	80.00
11.	1700 m, south the dumpsite	1.00	42.80	6.95	8.20	80.00
12.	2000 m, south the dumpsite	0.50	40.20	7.00	8.00	77.50
13.	200 m, southwest the dumpsite	3.95	80.50	8.90	10.00	90.00
14.	300 m, southwest the dumpsite	3.45	77.80	8.10	4.10	86.00
15.	500 m, southwest the dumpsite	3.40	73.50	7.70	8.65	81.50
16.	700 m, southwest the dumpsite	2.15	74.10	7.60	8.00	80.00
17.	1000 m, southwest the dumpsite	1.10	61.10	7.20	7.80	72.00
18.	1500 m, southwest the dumpsite	0.85	50.00	7.00	7.60	70.15
19.	2000 m, southwest the dumpsite	0.20	42.50	6.75	7.45	69.50

Table 5 : The average values of heavy metals concentration (µg g^{-1}) in the soils collected at different sites downwind municipal solid waste dumpsite (MSW) in El-Montaza

Site No.	Site description	Heavy metals concentrations, (µg m^{-3})				
		Cd	Cu	Ni	Cr	Zn
1.	Close to dumpsite	4.50	71.90	11.50	10.65	105.90
2.	200 m, southeast the dumpsite	4.15	65.20	9.20	8.65	96.00
3.	500 m, southeast the dumpsite	3.60	60.10	8.40	8.15	86.50
4.	700 m, southeast the dumpsite	2.90	51.60	7.95	8.00	79.90
5.	1000 m, southeast the dumpsite	1.15	40.50	7.00	7.25	77.90
6.	200 m, north the dumpsite	0.30	37.50	6.25	7.10	73.60

Europe [22]. In this respect, it was argued that the soils of southwest France have been received comparable annual inputs of metals since the dawn of industrialization [23]. Moreover, monitoring of heavy metals deposition onto soils in two locations in UK showed that large amount of metals are entering the soil annually [24]. The results of our study indicated 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 (closed 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 [6]. In addition, the levels of all other metals were higher than the background levels except for zinc, which was very closed to the background levels in the Egyptian soil [6, 11].

El-Montaza:

Six sites have been selected for soil sampling and the obtained levels of heavy metals are shown in Table 5. The highest levels were recorded in soils of the Site No. 1 closed to the dumpsite and the lowest levels were found in soils of site No. 6, (200m north the dumpsite). In general, there was a tendency for decreasing the levels of heavy with increasing distance from the dumpsite as shown in Table 5. Comparing the obtained results with those obtained with Abis area, showed similar patterns where the highest level was found closed to the dumpsite and these was 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 [6, 11]. 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 was 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 their metals [25].

Conclusion:

– 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 are surrounding the municipal solid waste dumpsites in Abis and El-Montaza districts and 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.

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 otherwise burning can result in emission 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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