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Environmental Study on Atmospheric Suspended Particulate Matter and Heavy Metals in Sandoub Area, Al-Mansoura, Egypt

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Abstract

Air quality of urban areas has deteriorated as a result of rapid industrialization and increased vehicle emissions. The aim of the study was conducted to evaluate the levels of ambient particles and some heavy metals (lead, zinc, cadmium and manganese) in Sandoub area, Al-Mansoura, Egypt. The main sources of these heavy metals in the sampled area could be attributed to anthropogenic activities like open incineration of waste and vehicular traffic. Lead was the dominated metal at all studied sites. Pb had been reported to be traffic related as a constituent of leaded gasoline. Mean of PM10 and heavy metals were higher than the ambient air quality limits recommended by EEAA. Therefore efforts should be taken to control the atmospheric pollution from hazardous toxic effects on the environment and human health. So far, the data generated in the study will be helpful for proper planning and management in this area as well as other part of the country.

***Keywords*:** Air Quality; PM_{10}; Heavy Metals; Pollution sources; open burning.

Introduction

In recent years, anthropogenic activities including industrial discharges, vehicle emissions and other activities critically affected the atmospheric environment. The ambient air quality has deteriorated to such an extent that it adversely affects the health and welfare of human beings (**Das *et al.*, 2015**). PM_{10} are more likely to increase the frequency of respiratory and cardiovascular diseases (**Padoan *et al.*, 2016**).

North Africa is one of the world's major dust-emitting regions. Consequently, a wide range of nature and emission sources contribute to particulate matter concentrations in the atmosphere **(El-Fadel and Massoud, 2000).**The major anthropogenic air pollution sources in African cities include industrial activities, emissions from waste and biomass burning for household and commercial needs, and emissions from vehicles as well as suspension from unpaved roads (**Engelstaedtera e*t al.*, 2006**).

Heavy metals are one of the most important pollutants emitted to the atmosphere due to their toxic effects on the environment and human health (**Fang *et al.*, 2015)**. Heavy metals

may come from many different sources in urbanized areas, including vehicle emissions, industrial discharges and other activities **(Talebi and Abedi, 2004)**.

Sandoub is considered as one of the major industrial areas in Mansoura. Industrial activities, heavy traffic missions and biomass burning are considered to be the major pollution sources in Sandoub. The aim of this study is to evaluate the levels of ambient particles and some heavy metals; lead (Pb), Zinc (Zn), Cadmium (Cd) and Manganese (Mn) in Sandoub area, Al-Mansoura, Egypt.

Material and Methods

Study area

Sandoub is located at the south of Al-Mansoura city, the capital of Al-Dakhlia Governorate, Egypt. It extends between 31° 01' 15 " N and 31° 38' 8" E (Fig 1). Sandoub area hosts many industries namely; Al-Mansoura for resin and chemical industries Company; Al-Dakhlia spin and wear Company; Soap, oil and animal fodder industry; and Al-Dakhlia treatment and disposal project (the open burning of Garbage).Location of the six sampling sites in Sandoub area is presented in Table 1 and Fig. 2.

Table (1): Location of the six sampling sites in Sandoub area.

Site	Location
Site 1	behind Al-Mansoura for resin and chemicall industries Company and is surrounded by low residential area
Site 2	beside the sub gate of Al-Mansoura for resin and chemical industrial Company along the highway of Al-Mansoura and Mit-Ghamr
Site 3	beside the primary gate of El-Mansoura for resins and Chemical Industries Company along the main road between Al-Mansoura and El-Sinballaween
Site 4	beside the primary Gate of Al-Dakhlia spin and wear Company along the highway between El-Mansoura and El-Sinballaween
Site 5	beside the primary Gate of Soap, oil and animal fodder industry along the highway between Al-Mansoura and El-Sinballaween. It is surrounded with Shawa residential area.
Site 6	beside Al-Dakahlia treatment and disposal project. It is surrounded by agriculture and low residential areas.

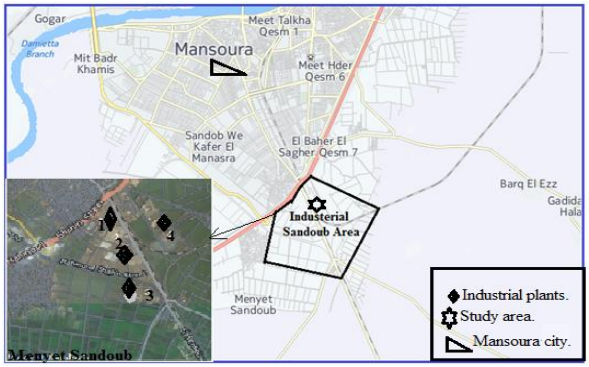


Fig (1): Location of Sandoub area, El-Mansoura, Egypt.

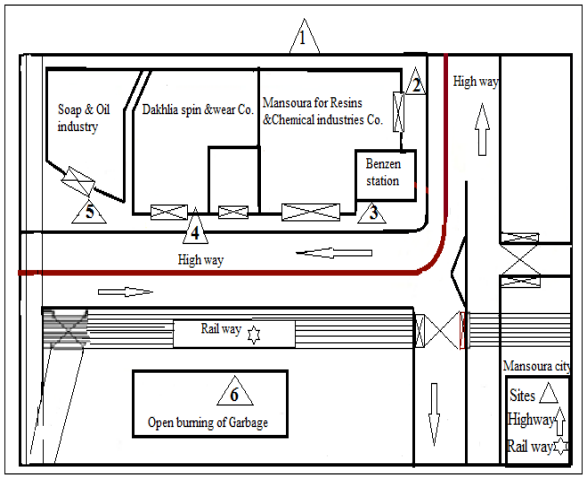


Fig (2): Location of the six sampling sites in Sandoub area.

Sampling Protocol

Sampling of $PM_{10}$was carried out simultaneously at the six sites twice a month from January to December 2015. Sampling was carried out for 8 hrs with a mean flow rate of 1.5 l/min. The sampling equipment was located on a building at about 5 m from the ground. Particles were collected on Whatman 47 mm membrane filters with 0.45 µm pores size. Filters were weighed in temperature and relative humidity control. PM_{10} concentrations were measured using the filtration method (Harrison and Perry, 1986).A definite section of the filter on which suspended particles were accumulated was cut and digested in 3 M nitric acid. The concentration of some metals including Pb, Zn, Cd and Mn were measured following well-established techniques (**Lodge and Editor, 1998**) using flame atomic absorption spectrophotometer.

Statistical Analysis

The descriptive statistics (means, minima and maxima) were used. In addition, the

relationship among heavy metals in water was assessed using Pearson's correlation coefficient. All statistical analyses were done using the computer program of Minitab program, version 16.1.

Results and Discussion

Summary statistics of particulate matter (PM_{10}) and heavy metal; Pb, Zn, Cd and Mn concentrations in the six sampling sites of Sandoub area during the study period from January to December 2015are presented in Table (1).

PM_{10} in the Atmosphere of Sandoub Area

The monthly mean concentrations of particulate matter (PM_{10}) as mg/m^3 in Sandoub area from January to December 2015 are represented in Fig (3). The results show that the mean concentration of PM_{10} varied at site 1 from 122µg/m^3 in December to 7.89µg/m^3 in April and at site 6 from 1.27 µg/m^3 in July to 4.78 µg/m^3 in October; comparing with the sites 2, 3, 4 and 5 the mean concentration ranges were (1.41-5.17), (1.17-4.99), (1.44 - 5.56) and (1.25 - 4.79) µg/m^3 in (June - October), respectively (Table 2). The annual mean concentrations of particulate matter (PM_{10}) in Sandoub area were exceeded the annual permissible limit (125 µg/m^3) established by the Egyptain Environmental Affairs Agency (**EEAA, 1995**). Large numbers of vehicles, as well as a substantial concentration of industrial facilities, contribute to high levels of PM_{10}. In addition to industrial and mobile sources, open waste burning contributed substantially to particulate matter pollution levels, particularly during the winter months.

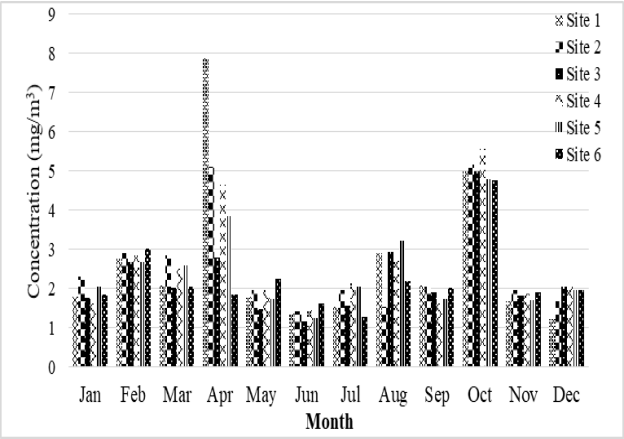


Fig (3): Concentrations of PM_{10} in the air of Sandoub area.

Heavy Metals in the Atmosphere of Sandoub Area

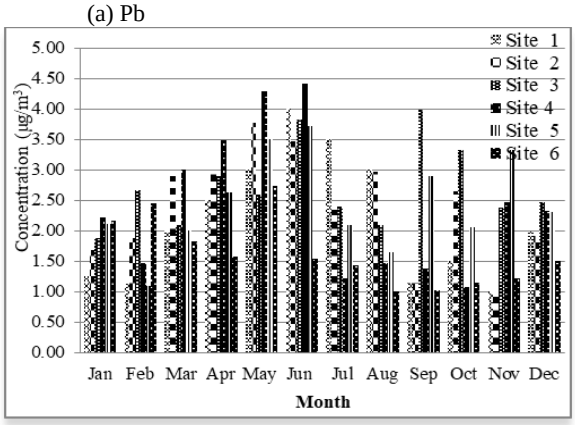
The monthly mean concentrations of heavy metals as µg/m^3 in Sandoub area are represented in Fig (4). It is noticed that Pb varied at site 1from 1.01 µg/m^3 in Novembe rto 4.0 µg/m^3 in June, at site 2 from 1.0µg/m^3 in November to 3.77 µg/m^3 in May, at site 3from 1.87 µg/m^3 in January to 3.99 µg/m^3 in September, at site 4from1.07 µg/m^3 in October to 4.42 µg/m^3 in June, at site 5from1.10 µg/m^3 in February to 3.71µg/m^3 in June, and at site 6 from1.01 µg/m^3 in August to 2.73µg/m^3 in May (Table 2 and Fig 4a). The annual mean concentrations of Pb in Sandoub area were exceeded the annual permissible limit (1.0 µg/m^3) recommended by the Egyptain Environmental Affairs Agency (**EEAA, 1995**). The high pollution of Pb metal may be associated with heavy traffic intensity (Oil leakage from car and vehicle exhaust).

Table (2): The summary statistics of particulate matter (PM_{10}) and heavy metals in Sandoub area

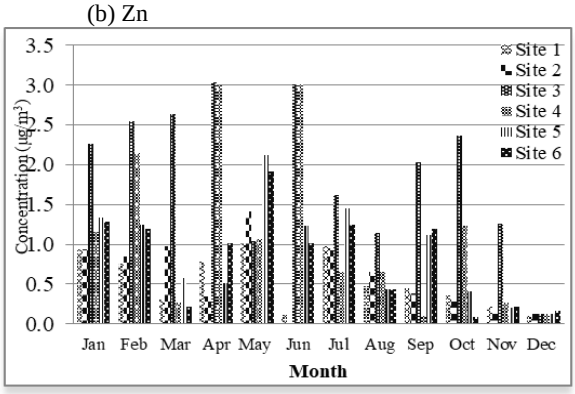
		Concentration *					
		Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
PM_{10}	**Mean**	2.68	2.57	2.26	2.59	2.47	2.23
	Range	1.22- 7.89	1.41- 5.17	1.17- 4.99	1.44- 5.56	1.25- 4.79	1.27- 4.78
Pb	**Mean**	2.17	2.39	2.72	2.4	2.45	1.63
	Range	1.01- 4	1- 3.77	1.87- 3.99	1.07- 4.42	1.1- 3.71	1.01- 2.73
Zn	**Mean**	0.54	0.6	1.92	1.14	0.9	0.83
	Range	0.1- 1.01	0.01- 1.41	0.12- 3.04	0.1- 3.01	0.13- 2.12	0.09- 1.91
Cd	**Mean**	0.91	0.85	1.24	1.36	1.64	1.17
	Range	0.001- 1.79	0.001- 1.93	0.36- 1.89	0.86- 2.23	0.96- 2.36	0.01- 2.64
Mn	**Mean**	0.69	0.73	0.49	0.93	0.72	0.69
	Range	0.1- 2.31	0.16- 2.17	0.05- 1.04	0.13- 2.42	0.09- 1.65	0.13- 0.99

*PM_{10} values are in mg/m^3; heavy metals values are expressed in µg/m^3

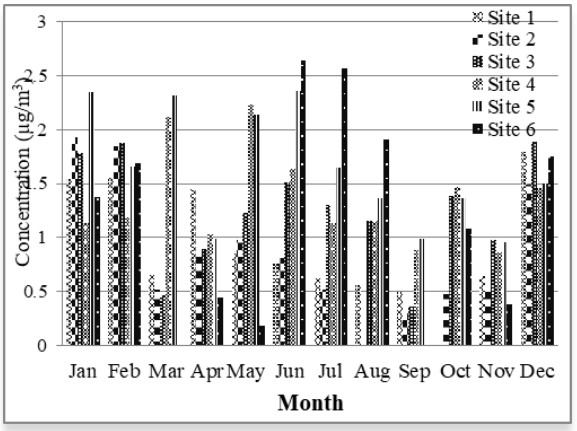
(a) Pb



(b) Zn



(c) Cd



(d) Mn

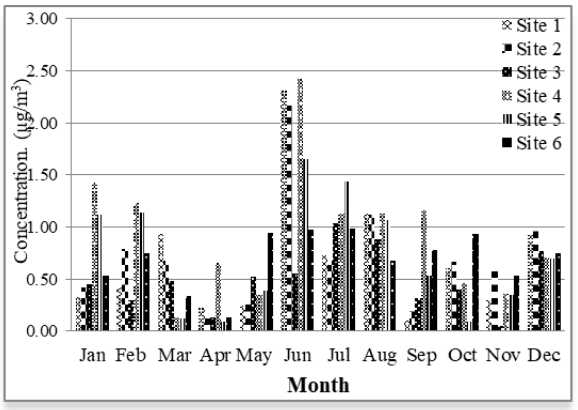


Fig (4): Concentrations of heavy metals; (a) Pb, (b) Zn, (c) Cd and (d) Mn, in the air of Sandoub area.

It is noticed that Zn varied at site 1 from 0.1 µg/m^3 in December to 1.01 µg/m^3 in May, at site 2 from 0.01 µg/m^3 in June to 1.41 µg/m^3 in May, at site 3 from 0.12 µg/m^3 in December to 3.04 µg/m^3 in April, at site 4 from0.1 µg/m^3 in September to 3.01 µg/m^3 in June, at site 5 from0.13 µg/m^3 in December to 2.12 µg/m^3 in May, and at site 6 from0.09 µg/m^3 in October to 1.9 µg/m^3 in April(Table 2 and Fig 5b).

It is noticed that Cd varied at site 1 from 0.001 µg/m^3 in October to 1.79 µg/m^3 in December, at site 2 from 0.001 µg/m^3 in August to 1.93 µg/m^3 in January, at site 3 from 0.36 µg/m^3 in September to 1.89 µg/m^3 in December, at site 4 from0.86 µg/m^3 in November to 2.23 µg/m^3 in May, at site 5 from0.096 µg/m^3 in November to 2.36 µg/m^3 in June, and at site 6 from0.01 µg/m^3 in both March and September to 2.64 µg/m^3 in June (Table 2 and Fig 5c).

Also, Mn varied at site 1 from 0.1 µg/m^3 in September to 2.31 µg/m^3 in June, at site 2 from 0.16 µg/m^3 in April to 2.17 µg/m^3 in June, at site 3 from 0.05 µg/m^3 in November to 1.04 µg/m^3 in July, at site 4 from0.13 µg/m^3 in March to 2.42 µg/m^3 in June, at site 5 from 0.09 µg/m^3 in October to 1.65 µg/m^3 in June, and at site 6 from 0.13 in April to 0.99 µg/m^3 in July (Table 2 and Fig 5d).

Distribution of PM_{10} and Heavy Metals in the air of Sandoub Area

Percentage contribution of each site to PM_{10} in Sandoub areacan be arranged according to the order: site 1 = site 4 > site 2 = site 5 > site 3= site 6 (Fig 5). It was noticed that all sites have source apportionment ranged from 15% to 18 % suggesting influence of the same type/strength emission sources in Sandoub area. Anthropogenic sources of PM_{10} include transportation, industry, fires, mechanical sources **(Salam *et al.*, 2008).**

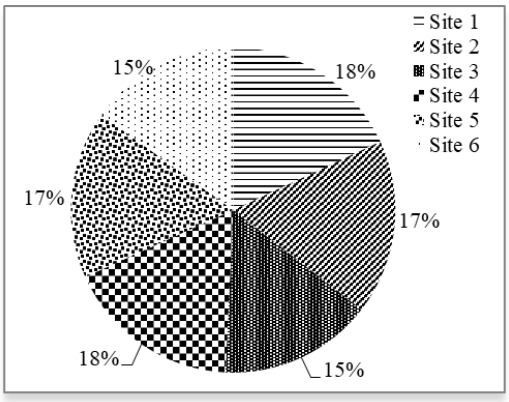


Fig (5): Percentage contribution of each site to PM_{10} in Sandoub area.

Percentage contributions of each site to heavy metals in Sandoub area were presented in Fig (6). Percentage contribution of each site to Pb in Sandoub areacan be arranged according to the order: site 3 > site 5 > site 4 = site 2 > site 1 > site 6 (Fig 6a). It was noticed that all sites have source apportionment ranged from 12 % to 20%. The Percentage contribution of site 3 was 20 % of the total concentration from the Sandoub area as it is located along the highway adjecent to oil station. Pb used to be one of the trace elements considered as a marker of vehicle traffic **(Cheng *et al.*, 2014)**.

Percentage contribution of each site to Zn metal in Sandoub areacan be arranged according to the order: site 3 > site 4 > site 5 > site 6 > site 2 > site 1(Fig 6b). All sites have source apportionment ranged from 9 % to 19 % except site 3 (33 %). site 3 is subjected to heavy traffic intensity along the year.Zinc may come from lubricating oil and tire of motor vehical **(Awan *et al.*, 2013).** Concentration of Zn metal in the atmospheric particulate matter was very high enrichment by the anthropogenic activities **(Shah *et al.*, 2012)**.

Percentage contribution of each site to Cd in Sandoub areacan be arranged according to the order: site 5 > site 4 > site 3 > site 6 > site 1 > site 2(Fig 6c). It was noticed that allsites have source apportioment ranged from 12 % to 23 %. This may indicate that Sandoub area was polluted with Cd. Industrial processes, high number of vehicles and combustion sources are the main sources for Cd **(Pal *et al.*, 2014).**

Percentage contribution of each site to Mn in Sandoub areacan be arranged according to the order: site 4 > site 5= site 2 > site 6= site1 > site 3(Fig 6d). It was noticed that allsites have source apportioment ranged from 12 % to 22 %. This may indicate that Sandoub area was polluted with Mn.This may be as a result of anthropogenic activities around the sites that result in high temperature combustion of manganese rich-fuel enhancers or open burning of wastes and industrial processes. Mn also related to industrial processes and brake-drum abrasion (**López *et al.*, 2005**).

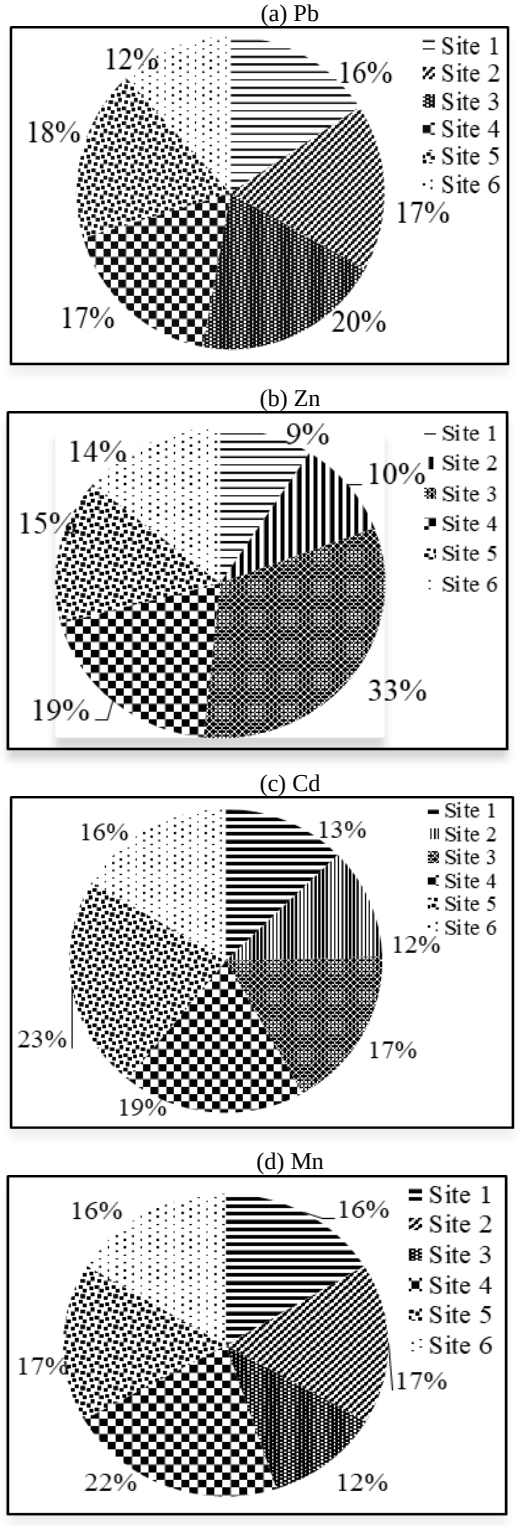


Fig (6): Percentage contribution of each site to heavy metals; (a) Pb, (b) Zn, (c) Cd and (d) Mn, in Sandoub area.

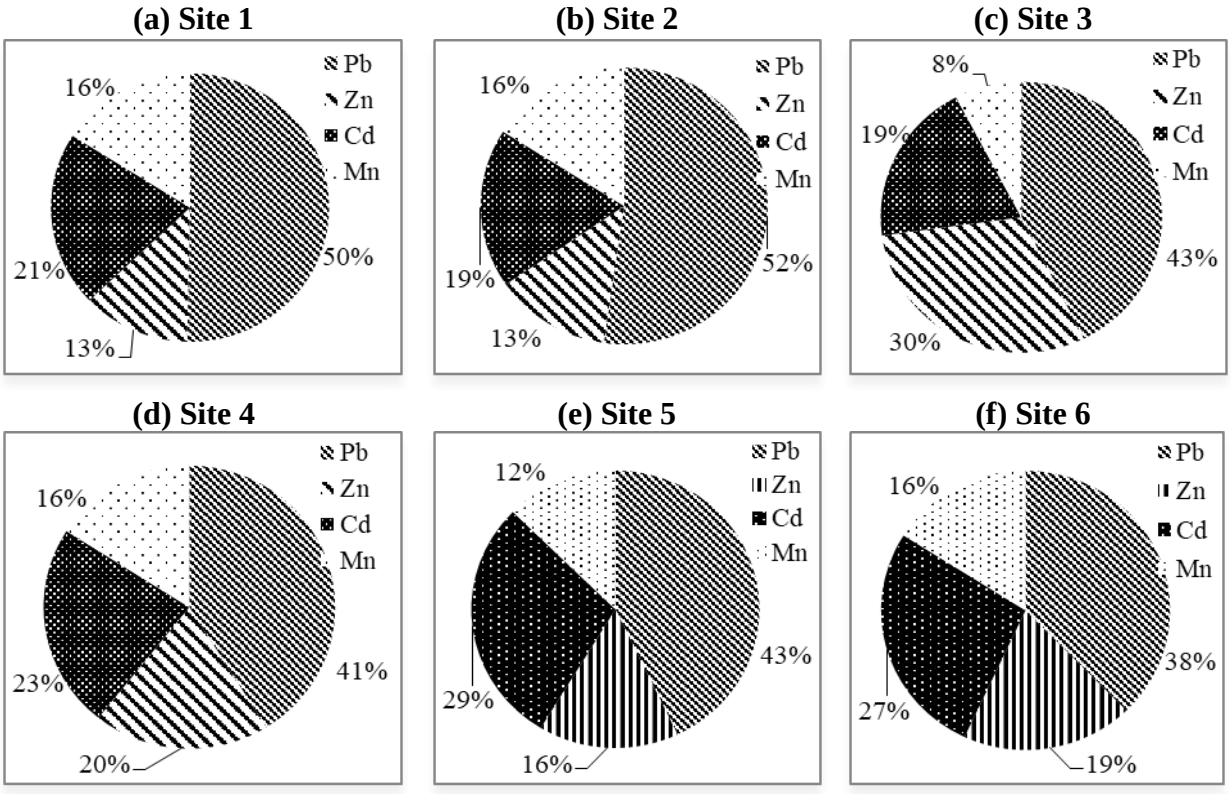


Fig (7): Percentage contribution of Pb, Zn, Cd and Mn for each site in Sandoub area during 2015.

Percentage contribution of Pb, Zn, Cd and Mn for each site in Sandoub area during 2015 was represented at Fig (7). Heavy metals can be arranged according to the order: Pb (50 %) □ Cd □Mn □ Zn; Pb (52%) □ Cd □Mn □ Zn; Pb(43 %) □Zn □ Cd □ Mn; Pb (41 %) □ Cd □Zn □ Mn; Pb (43 %) □ Cd □Zn □ Mn and Pb (38%) □Cd □ Zn □ Mn at site 1, site 2, site 3, site 4, site 5 and site 6, respectively.

It is clear that lead was the dominated metal at all sites in sandoub area. Pb has been reported to be traffic related as constituents of leaded gasoline (**Weckwerth, 2001**). It might be due to oil leakages from cars, vehicular exhaust **(USEPA, 2012)**.Cd was the second metal for all sites except for site 3. Possible sources of Cd include burning of municipal wastes containing discarded Ni-Cd batteries and plastics containing Cd pigments; vehicular emissions including tyre abrasions **(Awan *et al.*, 2011)**. Zn was the second metal at site 3. The occurrences of Zn imply that the particulates originate from weathering of a unique form of local geological materials due to wind erosion, construction work, traffic related and residential activities. Besides, Zn could be released from tires due to the friction and heating (**Ramadan *et al.*, 2000**).

Evaluation of Air Quality in Sandoub Area

The annual concentrations of PM_{10} and heavy metals (Pb, Zn, Cd and Mn) as in the six sampling sites of Sandoub area during 2015are presented in Fig (8). It was concluded that site 1 has the highest value of PM_{10} (2677.75 $\mu g/m^3$) (table 2). The high pollution of PM_{10} may be associated with high traffic intensity and industrial emissions. The traffic density was significantly correlated with PM_{10} (**Mao *et al.* 2009**).

Also, it was concluded that site 3 has the highest values of Pb (2.72 $\mu g/m^3$) and Zn (1.92 $\mu g/m^3$). Site 3 is located adjacent to oil station along high way road suggesting contribution primarily from traffic emissions and road dust. Vehicle emissions, industrial processes and road dust are the major source-types affecting the local atmosphere **(Voutsa *et al.*, 2002)**. Moreover, site 4 has the highest value of Mn (0.93 $\mu g/m^3$) and site 5 has the highest value of Cd (1.64 $\mu g/m^3$). Vehicular traffic contributes to Cd, Pb and Zn while fossil fuel combustion contributes to Pb and Cd (**Estrellanand Iino 2010).**

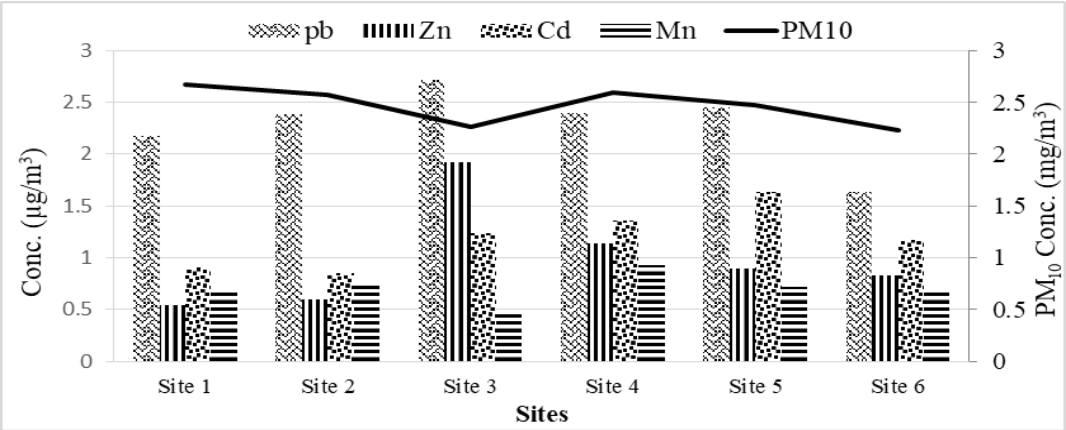


Fig (8): Annual concentrations of PM_{10} and heavy metals in the air of Sandoub area during 2015.

Table (3): Comparison of of PM_{10} and heavy metals in Sandoub area with other industrial areas.

Location	PM_{10}	Pb	Zn	Cd	Mn	References
Sandoub	2.47 mg/m³	2.3 µg/m³	0.99 µg/m³	1.2 µg/m³	0.71µg/m³	**Present Study**
Istanbul		3-430 ng/m³	80-429 ng/m³	0.31-36 ng/m³	12.4-53 ng/m³	**Ercan and Dinçer (2016)**
India	74.7 µg/m³	23.0 ng/m³	927.5 ng/m³	1.9 ng/m³	18.2ng/m³	**Police *et al.* (2016)**
Iran	124.6µg/m³	0.02 µg/m³	0.28 µg/m³	-	-	**Mobarakeh *et al.* (2015)**
Egypt	300 µg/m³	0.67 µg/m³	-	-	-	**Lowenthal *et al.* (2014)**
India	204 µg/m³	2.1 µg/m³	21.24µg/m³	0.4µg/m³	-	**Pal *et al.* (2014)**
India	251 µg/m³	-	4.02µg/m³	-	-	**Gajghate *et al.* (2012)**
Egypt	170 µg/m³	-	-	-	-	**Zakey *et al.* (2008)**
Bangladesh	75.5µg/m³	0.204µg/m³	381 ng/m³	13 ng/m³	-	**Salam *et al.* (2008)**
Egypt	360 µg/m³	7 µg/m³	-	-	-	**Abu-Allaban *et al.* (2007)**
Brazil	87 µg/m³	101 ng/m³	2120 ng/m³	0.9 ng/m³	1216 ng/m³	**Quiterio *et al.* (2004)**
Greece	89 µg/m³	71 ng/m³	215 ng/m³	0.70ng/m³	26 ng/m³	**Voutsa et al. (2002)**
Egypt	300 µg/m³	3.2 µg/m³	-	-	-	**Nasralla (2001)**

It is apparent that ambient air of Sandoub area possesses high values of PM_{10} and heavy metal. Generally; these results are similar with those reported for other industrial areas in Egypt (**Nasralla, 2001; Abu-Allaban *et al.*, 2007; Zakey *et al.*, 2008 and Lowenthal *et al.*, 2014)**. On the other hand, the present study revealed higher values than that previously recorded worldwide. The comparison between values of heavy metals of air of Sandoub area of the present study with those results of the previous studies is presented in Table (3).

Pearson's correlation coefficients of heavy metals in PM_{10} of Sandoub area are shown in Table 4. All the metal pairs showed positive relations except for Mn –Pb and Mn – Zn pairs. Pb is significantly positively correlated with Zn (R^2 =0.560), which may suggest a common origin, such as heavily traffic. While Cd showed relatively weak positive correlations with Zn, Pb and Mn varying from 0.397 to 0.147. The source for heavy metals may be industrial activities in this region. A meaningful correlation has not been found between Mn– Pb (-0.198) and Mn–Zn (-0.475) pairs. Mn is mainly of geochemical origin.

Table (4): Pearson's correlation coefficients of heavy metals in PM_{10} of Sandoub area.

	Pb	Zn	Cd	Mn
Pb	1			
Zn	0.560	1		
Cd	0.231	0.397	1	
Mn	- 0.198	- 0.475	0.147	1

Conclusion

Ambient air of Sandoub area is contaminated with PM_{10} and heavy metals. Mean concentration of PM_{10} and heavy metals ranged from 2.23-2.68 mg/m³ for PM_{10},1.63-2.72 µg/m³ for lead, 0.54-192 µg/m³ for Zinc, 0.85-1.64 µg/m³ for Cadmium and 0.49-0.93 µg/m³ for

Manganese. The high concentration of PM_{10}, Pb, Zn, Cd and Mn in Sandoub area may be attributed to the nearby industrial emissions and high traffic density. Therefore, efforts should be taken to control the atmospheric pollution in order to protect humans from hazardous health effects of these potentially toxic pollutants.

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الملخص العربي

عنوان البحث: دراسة بيئية على الجسيمات العالقة وبعض المعادن الثقيلة في منطقة سندوب بالمنصورة

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يحدث تدهور لنوعية الهواء في المناطق الحضرية نتيجة للتصنيع السريع وزيادة انبعاثات المركبات. تهدف الدراسة إلى تقييم مستويات الجسيمات العالقة وبعض المعادن الثقيلة (الرصاص والزنك والكادميوم والمنجنيز) في منطقة سندوب بالمنصورة بمصر من يناير إلى ديسمبر ٢٠١٥. المصادر الرئيسية لهذه المعادن الثقيلة في منطقة أخذ العينات ترجع إلى الأنشطة البشرية مثل الحرق المفتوح للنفايات وحركة المركبات. وكان الرصاص هو المعدن المهيمن في جميع المواقع في منطقة سندوب. وقد تم الإبلاغ عن الرصاص في حركة المرور باعتبارها مكونا من البنزين المحتوي على الرصاص. وكان متوسط PM10 والمعادن الثقيلة أعلى من حدود نوعية الهواء المحيط التي أوصى بها جهاز شئون البيئة. ولذلك ينبغي بذل جهود للسيطرة على التلوث الجوي لحماية البشر من الآثار الصحية المحتملة لهذه الملوثات السامة الخطرة.