Asian Journal of Chemistry Vol. 22, No. 4 (2010), 3159-3168

Elemental Analysis of TSP and PM_{10} in The Ambient Air of Aleppo City, Syria

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Determination of TSP and PM_{10} of aerodynamics particle sizes larger than 0.3 μm and heavy metals (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) by atomic absorption spectroscopy in Aleppo city, Syria were studied. The mean TSP and PM_{10} levels in residential sites were at 73 to 241 and 37 to 110 $\mu g/m^3$, respectively and 256 to 961 and 123 to 585 $\mu g/m^3$ in industrial-residential sites, respectively. The above mentioned heavy metal concentrations were at 297 to 1112 and 201 to 734; 0.97 to 4.73 and 0.41 to 2.46; 312 to 1837 and 158 to 963; 0.14 to 1.94 and 0.08 to 0.79; 68 to 223 and 33 to 120; 0.28 to 1.87 and 0.17 to 1.22; 1116 to 4604 and 780 to 2538; 179 to 270 and 113 to 170; 370 to 1039 and 240 to 710 ng/m^3 in industrial-residential sites using TSP and PM_{10}, respectively. The results showed that, the values of TSP, PM_{10}, Pb, Ni and Mn in industrial-residential sites atmosphere were more than the recommended maximum by World Health Organization (WHO), while the value levels of all metals in residential sites were lower than the guideline values specified by WHO.

Key Words: Airborne particulates (TSP and PM_{10}), Heavy metals, Aleppo city, Syria.

INTRODUCTION

Atmospheric particulate pollution has imposed a great burden on the terrestrial environment on a regional scale and even in a global context. Epidemiological studies have indicated that elevated concentrations of fine-particulate matter are associated with increased mortality and morbidity, especially in children and elderly people[1-4]. Heavy metals are non-degradable and can accumulate in the human body system, causing damage to a person's nervous system and internal organs. They also act as confounding factors of cardiovascular diseases, reproductive impairments and cancer[3,5]. Metals in the ambient air can catalyze the oxidative stress in the body cells, eliciting inflammatory injuries in the airway and lungs. The inhalation of airborne trace metals can therefore have a long-term and serious impact on human health[3,6].

The arithmetic average for the concentration of some heavy metals together with the arithmetic average TSP or PM_{10} in many cities in the world were determined, among them the following: Seoul, Korea[7]; Rio de Janeiro, Brazil[8]; Hong Kong[3];

Tokyo, Japan[9]; Ho Chi Minh city, Vietnam[10]; Taichung, Taiwan[11]; Biejing, China[12]; Baghdad, Iraq[13]; Niteroi, Brazil[14]; Kanazawa, Japan[15]; Los Angeles, USA[16] and Athena, Greece[17].

Environmental and biological monitoring of lead in acid batteries and liquid gases in Aleppo-Syrian company using total suspended particulates (TSP) of aerodynamics particle sizes larger than 0.3 μm and chemical trap (CT) for total lead in air were studied. The results showed that, high mean of lead concentration in air in all different sections of the factory were more than the recommended maximum by National Ambient Air Quality Standards (NAAQS)[18]. Determination of Al, Cu and Pb in Aleppo Company for cable industry-Syria using TSP and PM_{10} of aerodynamics particle sizes larger than 0.3 μm and chemical trap (CT) were studied. The results showed that, the values of TSP, PM_{10}, Al and Cu in working atmosphere much lower than the guideline values specified by the Occupational Safety and Health Administration (OSHA), while high levels of lead were more than the recommended maximum by (OSHA); due to the fact that lead acid batteries and liquid gases plant adjacent to this factory from the western side and the wind direction often from west to east[19].

Aleppo is a city in northern Syria, the first industrial Syrian city. Because of the rapid population growth has interfered the residential areas with industrial zones, which were located on the outskirts of the city. The studied industrial-residential sites in Aleppo city are as follows: **Sheikh-Said:** Industrial residential site is located about 6 kilometers from the city center on the north having grand cement factory and several non-formal centers for mining of lead and acid batteries. **Hullok:** Industrial residential site is located about 5 kilometers from the city to the north-east of the city having many textile industries, laundries, dye houses, workshops apparel, many workshops for machinery, engines and cars maintenance, painting of cars and various spare parts. **Shkaeif:** Industrial residential site is located about 7 kilometers from the city center on the north of the city, accommodates a variety of industries as laundries, dye houses, workshops apparel and too many workshops for machinery, engines and cars maintenance, painting of cars and various spare parts. **Kafr-Hamra:** Industrial residential site is located about 8 kilometers from the city center on the north-west having many textile industries, laundries, dye houses, malls and oils factory. The studied residential sites in Aleppo city are as follows: **Aleppo University:** The university camps and student residential site is located about 4 kilometers from the city center on the west of the city containing a variety of faculties and institutes. **Almuthaf (Museum):** Residential and commercial area in general is located at the center of the city, a crowded and traffic jam. **Muhafaza:** Residential site is located at 3 kilometers from the city center on the west of the city with a busy traffic.

An investigation was carried out of air pollution in some sites of Aleppo with the framework of the project of Integrated Pollution Control in Aleppo, where is financed by the European Union (EU), monitored by the United Nations Development

Program (UNDP) and implemented by the Aleppo Directorate of the Environment in Governorate of Aleppo. It was found that, the hourly concentrations of NO_x, SO_2 and TSP were higher than the WHO permissible limits by up to 3-10 times.

EXPERIMENTAL

In the present study, the determination of TSP and PM_{10} of aerodynamics particle sizes larger 0.3 μm and metal composition (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) in industrial-residential sites and residential sites only in Aleppo city, Syria were carried out. All elements were determined using atomic absorption spectroscopy. The different investigated sites were Sheikh-Said, Hullok, Shkaeif, Kafr-Hamra (industrial-residential sites), Aleppo University, Almuthaf and Almuhafaza (residential sites only). A high flow TSP air sampler system (HVAS, Instrument No. AS-16, USA) and TE-6070 high volume MFC PM_{10} MFC monitor reference method (TISCH Environmental, INC. 145 MIAMI AVE USA) were used to collect samples for 24 h using a glass filter Whatman EPM 2000 High-Volume 1882-866 and Micro-Quartz filter media 8" × 10" for TSP and PM_{10}, respectively.

Atomic absorption spectrometer (AAS) used for analysis was manufactured by Shimadzu type AA-6601 equipped with lamps type HCL particular of analysis studied elements and corrected for background reference BGC-D2K with flame (Air-C_2H_2). The analytical used line of Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn were at 217.0, 228.8, 324.75, 240.73, 357.87, 232.0, 248.33, 279.48 and 213.86 nm, respectively.

Samples preparation: Samples were taken from different mentioned sites in Aleppo city, Syria for determination of TSP, PM_{10}, Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn pollutants. Samples were collected using the TSP and PM_{10}, dried at 105 ºC, followed by crushing in a porcelain mortar, then dried again and mixed once again and kept in polyethylene packages for next procedures. A 0.5 g of the previous sample was treated with 20 mL solution content 5 M of HNO_3 and H_2O_2 concentrations. The mixture was boiled on an electric heater for 0.5 h, filtrated and transferred into 25 mL volumetric flask and the final volume was completed to 25 mL using distilled water.

Environmental study

Total suspended particulates (TSP) monitoring: Total suspended particulates samples were collected continuously in the different sites of Aleppo city through the autumn 2008, spring and summer 2009. The particulate collected using filters with a pore size of 0.3 μm.

Inhaled particulates PM_{10}: The inhaled particulates were measured using PM_{10} sampler in the different sites of Aleppo city. Inhaled dust is a new term used to describe dust that is hazardous when they deposited anywhere in the respiratory track including the nose, mouth and lungs. Researchers generally recognize that these particulates < 10 μm and > 0.3 μm may cause significant adverse effects.

Air-elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) estimation: The Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn contents in the TSP and PM_{10} samples were subjected to wet mixture digestion (20 mL solution content at 5 M of HNO_3 and H_2O_2 concentrations) on a slow heating hot plate. The digested matter was filtered, made up to 25 mL using quartz double distilled water. The final analysis for Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn estimation were performed by flame AAS.

RESULTS AND DISCUSSION

Environmental monitoring: In the present study, personal monitoring of the TSP, PM_{10} were carried out in different sites of Aleppo city. The TSP, PM_{10} and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) in studied atmosphere noted in the different sites are presented in Tables 1-4.

TABLE-1
PARTICULATE ELEMENT CONCENTRATION IN ATMOSPHERE OF INDUSTRIAL AND RESIDENTIAL SITES FOR ALEPPO CITY IN AUTUMN 2008, SPRING AND SUMMER 2009 USING TOTAL SUSPENDED PARTICULATE (TSP)

Site	Time	TSP* ($\mu g\ m^{-3}$)	Mean* concentration ($ng\ m^{-3}$)								
			Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Sheikh-Said	Autumn	520	952	4.60	564	0.28	97	0.43	1807	214	640
	Spring	298	640	3.14	312	0.14	83	0.39	1116	179	431
	Summer	612	1112	4.73	594	0.30	102	0.64	2391	224	657
Hullok	Autumn	795	497	1.37	228	0.88	74	1.73	2215	247	765
	Spring	630	308	0.97	196	0.85	68	1.52	1586	201	640
	Summer	810	567	1.52	445	0.91	78	1.87	2393	256	815
Shkaeif	Autumn	899	876	2.97	1720	1.80	191	1.27	3001	259	988
	Spring	693	631	2.07	1645	1.62	182	1.13	2917	218	894
	Summer	961	986	3.04	1837	1.94	203	1.29	3028	270	1039
Kafr-Hamra	Autumn	486	402	1.07	410	0.52	214	0.32	3887	200	486
	Spring	256	297	0.98	324	0.41	199	0.28	2766	182	370
	Summer	585	416	1.20	418	0.54	223	0.37	4604	211	552

*Average of five measurements.

TABLE-2
PARTICULATE ELEMENT CONCENTRATION IN ATMOSPHERE OF RESIDENTIAL SITES FOR ALEPPO CITY IN AUTUMN 2008, SPRING AND SUMMER 2009 USING TOTAL SUSPENDED PARTICULATE (TSP)

Site	Time	TSP* ($\mu g\ m^{-3}$)	Mean* concentration ($ng\ m^{-3}$)								
			Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Aleppo university (Student housing)	Autumn	122	110	0.86	187	0.23	27	0.18	897	18	203
	Spring	73	94	0.60	102	0.19	23	0.14	689	16	184
	Summer	154	116	0.92	210	0.28	31	0.19	964	20	210
Almuthaf (Museum)	Autumn	161	254	1.28	213	0.34	48	0.34	1187	68	510
	Spring	140	204	1.07	190	0.28	43	0.25	1043	61	435
	Summer	241	263	1.37	262	0.36	51	0.41	1249	76	545
Almuhafaza	Autumn	164	115	0.91	160	0.16	30	0.08	472	25	97
	Spring	146	98	0.68	145	0.12	26	0.06	412	22	86
	Summer	172	128	0.97	162	0.18	34	0.10	498	28	103
Kafr-Hamra	Autumn	486	402	1.07	410	0.52	214	0.32	3887	200	486
	Spring	256	297	0.98	324	0.41	199	0.28	2766	182	370
	Summer	585	416	1.20	418	0.54	223	0.37	4604	211	552

*Average of five measurements.

TABLE-3
PARTICULATE ELEMENT CONCENTRATION IN ATMOSPHERE OF INDUSTRIAL-RESIDENTIAL SITES FOR ALEPPO CITY IN AUTUMN 2008, SPRING AND SUMMER 2009 USING PM_{10}

Site	Time	PM_{10}* ($\mu g\ m^{-3}$)	Mean* concentration ($ng\ m^{-3}$)								
			Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Sheikh-Said	Autumn	280	609	2.38	226	0.11	42	0.28	1265	142	442
	Spring	204	397	1.50	158	0.08	38	0.24	780	113	295
	Summer	339	734	2.46	295	0.14	48	0.39	1722	149	456
Hullok	Autumn	470	318	0.76	124	0.42	41	1.12	1440	165	523
	Spring	368	195	0.42	100	0.40	33	0.97	1026	130	438
	Summer	480	365	0.79	203	0.46	45	1.22	1568	170	568
Shkaeif	Autumn	549	631	2.10	890	0.75	74	0.84	1802	153	670
	Spring	418	450	1.42	851	0.60	68	0.71	1740	120	602
	Summer	585	714	2.26	963	0.79	78	0.86	1811	161	710
Kafr-Hamra	Autumn	238	278	0.68	203	0.22	113	0.21	2136	125	323
	Spring	123	201	0.41	160	0.17	101	0.17	1505	118	240
	Summer	246	286	0.73	210	0.23	120	0.25	2538	141	367

*Average of five measurements.

TABLE-4
PARTICULATE ELEMENT CONCENTRATION IN ATMOSPHERE OF RESIDENTIAL SITES FOR ALEPPO CITY IN AUTUMN 2008, SPRING AND SUMMER 2009 USING PM_{10}

Site	Time	PM_{10}* ($\mu g\ m^{-3}$)	Mean* concentration ($ng\ m^{-3}$)								
			Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Aleppo university (Student housing)	Autumn	49	87	0.46	94	0.09	12	0.12	501	9.6	135
	Spring	37	73	0.31	53	0.08	10	0.09	380	8.4	120
	Summer	54	94	0.48	108	0.10	14	0.14	527	10.9	139
Almuthaf (Museum)	Autumn	72	210	0.68	112	0.14	22	0.23	660	36	338
	Spring	63	161	0.54	93	0.10	18	0.14	570	31	285
	Summer	110	213	0.72	134	0.15	23	0.27	688	39	360
Almuhafaza	Autumn	68	93	0.48	84	0.07	14	0.05	252	13	65
	Spring	61	81	0.35	70	0.05	12	0.04	220	11	55
	Summer	72	105	0.52	86	0.07	16	0.07	270	15	68
Kafr-Hamra	Autumn	486	402	1.07	410	0.52	214	0.32	3887	200	486
	Spring	256	297	0.98	324	0.41	199	0.28	2766	182	370
	Summer	585	416	1.20	418	0.54	223	0.37	4604	211	552

*Average of five measurements.

Sheikh-Said: The mean TSP and PM_{10} were at 477 and 274 $\mu g/m^3$, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 901 and 580; 4.16 and 2.11; 490 and 226; 0.24 and 0.11; 94 and 43; 0.49 and 0.30; 1771 and 1256; 206 and 135; 576 and 398 ng/m^3 using TSP and PM_{10} respectively (Tables 1 and 3). The sequence for heavy metal concentrations in ambient air were Fe > Pb > Zn > Cu > Mn > Cr > Cd > Ni > Co. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.19 and 0.21 %; 0.0009 and 0.0008 %; 0.10 and 0.08 %; 0.00005 and 0.00004 %; 0.020

and 0.016 %; 0.00010 and 0.00011 %; 0.37 and 0.46 %; 0.043 and 0.049 %; 0.12 and 0.145 %, respectively. This site contains the highest quantity of Pb and Cd.

Hullok: The mean TSP and PM_{10} were at 745 and 439 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 457 and 293; 1.29 and 0.66; 290 and 142; 0.88 and 0.43; 73 and 40; 1.71 and 1.10; 2065 and 1345; 235 and 155; 740 and 510 ng/m^3 using TSP and PM_{10}, respectively (Tables 1 and 3). The sequence for heavy metal concentrations in ambient air were Fe > Zn > Pb > Mn > Cu > Cr > Ni > Cd > Co. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.061 and 0.068 %; 0.00017 and 0.00015 %; 0.039 and 0.032 %; 0.00012 and 0.000098 %; 0.0098 and 0.0091 %; 0.0144 and 0.023 %; 0.28 and 0.31 %; 0.032 and 0.035 %; 0.099 and 0.12 %, respectively. This site contains the highest quantity of Ni and Mn.

Shkaeif: The mean TSP and PM_{10} were at 851 and 517 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 831 and 598; 2.7 and 1.93; 1734 and 901; 1.79 and 0.713; 192 and 73; 1.23 and 0.80; 2982 and 1784; 249 and 145; 974 and 661 ng/m^3 using TSP and PM_{10}, respectively (Tables 1 and 3). The sequence for heavy metal concentrations in ambient air were Fe > Zn > Cu > Pb > Mn > Cr > Cd > Co > Ni. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.098 and 0.12 %; 0.00032 and 0.00037 %; 0.20 and 0.17 %; 0.00021 and 0.00014 %; 0.023 and 0.014 %; 0.00014 and 0.00015 %; 0.35 and 0.35 %; 0.029 and 0.028 %; 0.11 and 0.13 %, respectively. This region are characterized by large quantities of various studied heavy metals and contains the highest amount of TSP, MP_{10}, Cu, Zn, Mn and Co.

Kafr-Hamra: The mean TSP and PM_{10} were at 442 and 202 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 372 and 255; 1.08 and 0.61; 384 and 191; 0.49 and 0.21; 212 and 111; 0.32 and 0.21; 3752 and 2060; 198 and 128; 469 and 310 ng/m^3 using TSP and PM_{10}, respectively (Tables 1 and 3). The sequence for heavy metal concentrations in ambient air were Fe > Zn > Cu > Pb > Cr > Mn > Cd > Co > Ni. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.084 and 0.13 %; 0.00024 and 0.00030 %; 0.086 and 0.095 %; 0.00011 and 0.00010 %; 0.048 and 0.055 %; 0.000072 and 0.00010 %; 0.084 and 1.02 %; 0.045 and 0.063 %; 0.106 and 0.153 %, respectively. This site contains the highest quantity of Fe and Cr.

Aleppo university: The mean TSP and PM_{10} were at 116 and 47 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 107 and 85; 0.79 and 0.42; 166 and 85; 0.23 and 0.09; 27 and 12; 0.17 and 0.116; 850 and 469; 18 and 9.6; 199 and 131 ng/m^3 using TSP and PM_{10}, respectively (Tables 2 and 4). The sequence for heavy metal concentrations in ambient air were Fe > Zn > Cu > Pb > Cr > Mn > Cd > Co > Ni. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at

0.092 and 0.18 %; 0.00068 and 0.00089 %; 0.14 and 0.18 %; 0.00020 and 0.00019 %; 0.023 and 0.026 %; 0.00015 and 0.00025 %; 0.73 and 1.00; 0.016 and 0.020 %; 0.17 and 0.28 %, respectively.

Almuthaf: The mean TSP and PM_{10} were at 181 and 82 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 240 and 195; 1.24 and 0.65; 222 and 113; 0.33 and 0.13; 47 and 21; 0.33 and 0.21; 1160 and 639; 68 and 35; 497 and 328 ng/m^3 using TSP and PM_{10}, respectively (Tables 2 and 4). The sequence for heavy metal concentrations in ambient air were Fe > Zn > Pb > Cu > Mn > Cr > Cd > Ni > Co. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.13 and 0.24 %; 0.00069 and 0.00079 %; 0.12 and 0.14 %; 0.00018 and 0.00016 %; 0.026 and 0.026 %; 0.00018 and 0.00026 %; 0.64 and 0.78 %; 0.038 and 0.043 %; 0.27 and 0.40 %, respectively.

Almuhafaza: The mean TSP and PM_{10} were at 161 and 67 μg/m^3, respectively and air elements (Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn) concentrations were at 114 and 93; 0.85 and 0.45; 155 and 80; 0.15 and 0.06; 30 and 14; 0.08 and 0.05; 461 and 247; 25 and 13; 95 and 63 ng/m^3 using TSP and PM_{10} respectively (Tables 2 and 4). The sequence for heavy metal concentrations in ambient air were Fe > Cu > Pb > Zn > Cr > Mn > Cd > Co > Ni. The concentration of heavy metals Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn relative to the TSP and PM_{10} were at 0.071 and 0.139 %; 0.00053 and 0.00067 %; 0.096 and 0.119 %; 0.000093 and 0.000090 %; 0.019 and 0.021 %; 0.000050 and 0.000075 %; 0.29 and 0.37 %; 0.016 and 0.019 %; 0.059 and 0.094 %, respectively.

The results showed that, the values of TSP, PM_{10}, Pb, Ni and Mn in industrial-residential sites atmosphere were more than the recommended maximum by World Health Organization (WHO), while the value levels of TSP, PM_{10} and all metals in residential sites only were lower than the guideline values specified by WHO (Fig. 1 and 2). Particulate element concentrations in ambient air of industrial-residential sites and residential sites only in Aleppo city at autumn 2008 to summer 2009 using total suspended particulate (TSP) have been determined (Fig. 2).

The arithmetic average for the concentration of all metals together with the arithmetic average TSP and PM_{10} in all studied sites of Aleppo are listed in Tables 1-4. Results determination of TSP, PM_{10} and elements Pb, Cd, Cu, Co, Cr, Ni, Fe, Mn and Zn in Aleppo city and other cities are listed in Table-5 for comparison. It is to be noticed from Table-5 that the average concentration of TSP, Pb, Cu, Cr, Mn and Zn in industrial-residential sites of Aleppo city are higher than they are in other cities. With the exception of Baghdad, it is more polluted by Pb, Cd, Cu and Fe and Rio de Janeiro by Co, Cr, Fe Mn and Zn.

It might be interesting to compare the level of metal in ambient air of Aleppo city ($C_{Aleppo.}$) with level it in ambient air of other cities (C_{city}) using the relationship:

$$R_m = C_{Aleppo.}/C_{city}$$

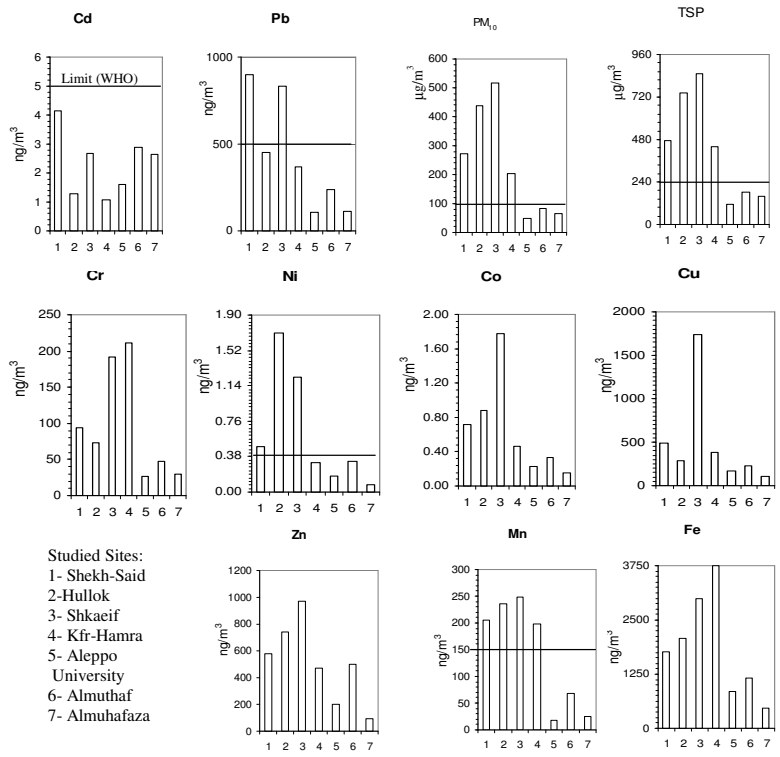

Fig. 1. TSP, PM_{10} (µg/m^3) and metal concentrations (ng/m^3) in atmospheric particulates of Aleppo city, Syria

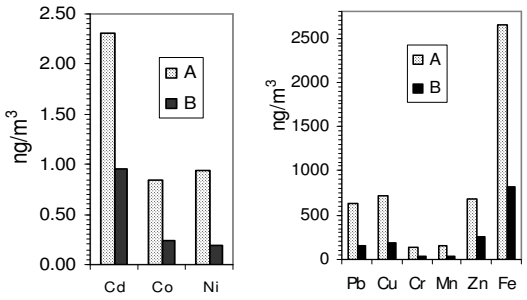

Fig. 2. Particulate element concentrations in air of industrial-residential sites (A) and residential sites only (B) in Aleppo city at autumn 2008 to summer 2009 using total suspended particulate (TSP)

The calculated results of R_m are listed in Table-6. This shows that ambient air pollution by Pb, Cu, Cr, Mn and Zn in industrial-residential sites of Aleppo city more than most other cities, while in the residential sites (where there is no industrial plants) the pollution levels of studied metals are less or similar to levels in other international cities.

TABLE-5
MEAN VALUE OF TSP AND METALS CONCENTRATIONS IN ATMOSPHERE FOR ALEPPO CITY AND OTHER CITIES

City	TSP ($\mu g\ m^{-3}$)	Mean concentration ($ng\ m^{-3}$)								
		Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Syria, Aleppo[a]	629	640	2.31	724	0.85	143	0.94	2643	222	690
Syria, Aleppo[b]	153	154	0.96	181	0.24	35	0.19	823	37	264
Korea, Seoul[7]	-	77	3.10	208	-	15.0	19.0	2397	79.7	-
Brazil, Rio de Janeiro[8]	87	101	0.90	385	1.1	421	0.5	38903	1216	2120
Hong Kong[3]	-	57	1.61	70.8	-	15.3	-	1480	48.3	298
Japan, Tokyo[9]	-	125	-	30.0	-	6.1	-	-	-	299
Vietnam, Ho Chi Minh city[10]	-	146	-	1.82	-	8.6	-	-	-	203
Taiwan, Taichung[11]	-	574	8.5	199	-	29	-	-	-	395
China, Biejing[12]	-	430	6.8	110	-	19	-	-	-	770
Iraq, Baghdad[13]	463	1910	14	752	-	100	-	8270	285	328
Brazil, Niteroi[14]	179	71	1.86	-	-	-	-	3490	51	342
Japan, Kanazawa[15]	1.39	5.7	0.45	18	2.2	-	-	869	35	1386
USA, Los Angeles[16]	-	14	-	52	-	4.9	9.2	-	-	84
Greece, Athena[17]	134	376	0.6	91	-	48	45	1276	-	484

[a]Industrial and residential sites, [b]Residential sites only.

TABLE-6
RATIO OF THE MEAN VALUE OF TSP AND METAL CONCENTRATIONS BETWEEN ALEPPO CITY AND OTHER CITIES

Ratio	TSP	Pb	Cd	Cu	Co	Cr	Ni	Fe	Mn	Zn
Aleppo[a]/Seoul[7]	-	8.31	0.75	3.48	-	9.53	0.050	1.10	2.79	-
Aleppo[b]/Seoul[7]	-	2.00	0.31	0.87	-	2.33	0.010	0.34	0.46	-
Aleppo[a]/Rio de Janeiro[8]	7.23	6.33	2.57	1.88	0.77	0.34	1.880	0.07	0.18	0.33
Aleppo[b]/Rio de Janeiro[8]	1.76	1.52	1.07	0.47	0.22	0.08	0.380	0.02	0.03	0.12
Aleppo[a]/Hong Kong[3]	-	11.23	1.43	10.20	-	9.35	-	1.78	4.60	2.31
Aleppo[b]/Hong Kong[3]	-	2.70	0.60	2.55	-	2.29	-	0.56	0.77	0.82
Aleppo[a]/Tokyo[9]	-	1.23	-	24.13	-	23.44	-	-	-	2.31
Aleppo[b]/Tokyo[9]	-	5.12	-	6.03	-	5.74	-	-	-	0.88
Aleppo[a]/Ho Chi Minh[10]	-	1.05	-	398	-	16.63	-	-	-	3.40
Aleppo[b]/ Ho Chi Minh[10]	-	4.38	-	99.4	-	4.07	-	-	-	1.30
Aleppo[a]/Taichung[11]	-	0.27	0.27	3.64	-	4.93	-	-	-	1.75
Aleppo[b]/Taichung[11]	-	1.11	0.11	0.91	-	1.21	-	-	-	0.67
Aleppo[a]/Biejing[12]	-	0.36	0.34	6.58	-	7.53	-	-	-	0.90
Aleppo[b]/Biejing[12]	-	1.49	0.14	1.64	-	1.84	-	-	-	0.34
Aleppo[a]/Baghdad[13]	1.36	0.34	0.17	0.96	-	1.43	-	0.32	0.78	2.10
Aleppo[b]/Baghdad[13]	0.33	0.08	0.07	0.24	-	0.35	-	0.10	0.13	0.80
Aleppo[a]/Niteroi (Brazil)[14]	3.51	9.01	1.24	-	-	-	-	0.76	4.35	2.02
Aleppo[b]/Niteroi (Brazil)[14]	0.85	2.17	0.52	-	-	-	-	0.23	0.73	0.77
Aleppo[a]/Kanazawa[15]	452	112.3	5.13	40.22	0.39	-	-	3.04	6.34	0.50
Aleppo[b]/Kanazawa[15]	110	27.02	2.13	10.06	0.11	-	-	0.95	1.06	0.19
Aleppo[a]/Los Angeles[16]	-	45.70	-	13.92	-	29.18	0.100	-	-	8.21
Aleppo[b]/Los Angeles[16]	-	11.00	-	3.48	-	7.14	0.020	-	-	3.14
Aleppo[a]/Athena[17]	4.69	1.70	3.85	7.96	-	2.98	0.020	2.07	-	1.43
Aleppo[b]/Athena[17]	1.14	0.41	1.60	1.99	-	0.73	0.004	0.64	-	0.54

[a]Industrial and residential sites; [b] Residential sites only.

Conclusion

The results in this study showed that, the values of TSP, PM_{10}, Pb, Ni and Mn in industrial-residential sites atmosphere of Aleppo city, Syria were more than the recommended maximum by World Health Organization (WHO), while the value levels of all metals in residential sites were lower than the guideline values specified by WHO. Lead concentration in ambient air very large especially in PM_{10}, these inhaled particulates < 10 μm may cause significant adverse effects.

ACKNOWLEDGEMENTS

This work was financially and technically supported by the Ministry of High Education through the University of Aleppo, Faculty of Science, Department of Chemistry. Thanks are also due to the Director, Mr. Ahmad Housam Mkhallati, Environmental Affairs in Aleppo City, Syria and Prof. Abdul Wahab Allaf for technical assistance.

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(*Received*: 27 August 2009; *Accepted*: 2 January 2010) AJC-8253