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Assessment of Air Pollution by Suspended Particles and Some Heavy Metals for Selected Areas in Baghdad City

[1]Muhannad Kh. Mohammed, [1]Majed Hassan Karbon, [1]Raheem Jafer Aziz,
[2]Nabeel Hashim Ameen and [3]Huda Nassar Karkosh
[1]College of Basic Education, Al-Mustansiriyah University, Baghdad, Iraq
[2]Ministry of Science and Technology, Radiation and Nuclear Safety Directorate, Baghdad, Iraq
[3]Iraqi Radioactive Sources Regulatory Authority, Baghdad, Iraq

Abstract: The high rate of urbanization in Baghdad City is associated with environmental degradation such as air pollution. In the present study, atmospheric samples of suspended particles were collected using low volume air sampler (Sniffer) at 18 selected locations in Baghdad City during the period from October 2017 to January 2018. Dust samples collected on fiberglass filter were analyzed for Zinc (Zn), Cupper (Cu), Chromium (Cr), lead (Pb) and Cadmium (Cd) using flame atomic absorption spectrophotometer model AA-6200. The average total suspended particles concentration estimated for urban areas (518.38 $\mu g/m^3$) was about 9 times higher than the value estimated for suburban/agricultural areas (57 $\mu g/m^3$). The ranges of heavy metal concentrations in the investigated areas were ranged from 8.76-29 $\mu g/m^3$ for Zn, 0.014-0.142 $\mu g/m^3$ for Cu, 0.31-2.923 $\mu g/m^3$ for Cr, 0.09-1.3 $\mu g/m^3$ for Pb and 0.38-1.656 $\mu g/m^3$ for Cd. Average levels of Cr (1.51 $\mu g/m^3$) and Pb (0.59 $\mu g/m^3$) show higher levels than corresponding international limits (0.04 and 0.5 $\mu g/m^3$, respectively). The estimated Hazard index value for all studied metals (1.5) was higher than the safe level (1), indicating that some investigated heavy metals reach levels of public health concern.

Key words: Air pollution, suspended particles, heavy metals, limits, hazard index, public health concern

INTRODUCTION

Air pollution may be defined as any atmospheric condition in which certain substances are present at concentration well above normal limits in such concentrations that they may cause undesirable effects on human and his environment. These substances include gases (SOx, NOx, CO, HCs, etc), particulate matter (smoke, dust, fumes, aerosols), radioactive materials and many others (Admassu and Wubeshet, 2006). The substance can be solid particles, liquid droplets or gases. A pollutant can be of natural origin or man-made (Al-Azzawi and Al-Dulaimi, 2015).

Atmospheric Particulate Matter (PM) or fine particles are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation and sea spray. Human activities, due to burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols (Al-Azzawi and Al-Dulaimi, 2015).

Averaged worldwide, anthropogenic aerosols (those made by human activities) currently account for approximately 10% of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer (Anonymous, 2010). The suspended particle with a diameter larger than (10 μm) tends to deposition near the surface of the ground while suspended particle of light with a diameter smaller than (1 μm) remain stuck in the lower part of the atmosphere for up to several weeks. The suspended particles with diameter confined between (1-10 μm) constitute a significant health risks as they are small enough to penetrate the lungs and cause acute respiratory disease such as asthma (Ahrens, 2005).

The lead (Pb) is the most common toxic elements in the air and pollutants dangerous to human health and the environment. It is possible that Pb accumulates in the human body and leads to general weakness and prejudice to the nervous system and may lead to mental retardation in children. The automobiles and electrical generators exhaust represent the most important source of lead, since, it is being added to gasoline from the fourth ethyl

Corresponding Author: Muhannad Kh. Mohammed, College of Basic Education, Al-Mustansiriyah University, Baghdad, Iraq

lead as additives for improving fuel. Natural sources of Pb include emissions of volcanic and forest fires. The estimated normal level of Pb in the air about (5×10^{-5} μg/m^3) (Hutton *et al*., 1988).

Chromium (Cr) is a grey, hard metal most commonly found in the trivalent state in nature. Chromium in the air may originate from wind erosion of shales, clay and many other kinds of soil. In countries where chromite is mined, production processes may constitute a major source of airborne chromium. The bronchial tree is the primary target organ for carcinogenic effects of chromium. Inhalation of chromium-containing aerosols is therefore a major concern with respect to exposure to chromium compounds (WHO., 2000).

Cadmium (Cd) has been widely dispersed into the environment through the air by mining and smelting as well as by other human activities. Many studies have found that even very low-levels of cadmium may have adverse effects on the kidney. WHO currently states that 200 μg/g levels wet weight in kidney causes adverse changes in 10% of the population (Anonymous, 2008).

Copper (Cu) is a reddish metal that occurs naturally in rock, soil, water, sediment and at low levels in air. It is an essential element for all known living organisms including humans and other animals at low levels of intake. At much higher levels, toxic effects can occur (ATS., 2004).

Zinc (Zn) and its compounds have been found to be toxic under certain conditions. High concentrations of certain Zn compounds can produce harmful effects on humans, animals and plants. Zn is commonly associated with other metals such as Pb, Cu and Cd. The most common effect of Zn air pollution is the occurrence of "metal-fume fever" which results from inhalation of Zn oxide fumes (Athanassiadis, 1969).

In this study, air pollution was studied in selected regions from Baghdad City. Heavy metals (Zn, Cu, Cr, Pb and Cd) concentrations in air were analyzed for comparison with permissible limits.

MATERIALS AND METHODS

Study area: Baghdad is the capital of Iraq. The population of Baghdad as of 2011 is approximately 7, 216, 040, making it the largest city in Iraq. The city includes 457 sectors. Located along the Tigris River which divided into two main parts: the Eastern side (Al-Rusafa) and the western side (Al-Karkh). The area is characterized by arid to semiarid climate with dry, hot Summers and cold Winters. The mean annual rainfall is about 151.8 mm (Al-Obaidy *et al*., 2016). Suspended particles were sampled at 18 locations (Fig. 1). These locations involve suburban/agricultural areas (Al-Rashidiya, Al-Boaitha, Al-Tarmiya, Al-Yousifiya and Al-Husainiya) and urban areas with residential, commercial and local industrial activities (Al-Salihiya, Hay Al-Kahira, Al-Zaafaraniya, Hay Our, Hay Al-Adil, Al-Aadamiya, Palestine street, Al-Saidiya, Al-Karada, Al-Kiyara, Al-Obaidi, Madenat Al-Sader and Al-Shoala). The 18 sampling locations were selected to reflect the influences from urban, suburban, residential, heavy traffic areas in the air contamination levels.

Suspended particles sampling: Suspended particles sampling were conducted during the period from October 2017 to January 2018. The samples were collected for 3 h at 1.5 m elevation above ground surface (which represents the average human height (Al-Azzawi and Al-Dulaimi, 2015) using portable dust sampler (Sniffer, Rotheroe and Mitchel Ltd., Fig. 2a). The suspended particles were collected on fiberglass filter. Concentrations of Total Suspended Particles (TSP) in μg/m^3 were estimated using equation below (Al-Azzawi and Al-Dulaimi, 2015):

$$TSP = \frac{w_a - w_b}{V} \quad (1)$$

Where:

w_a and w_b = (μg) represent weights of the filters after and before sampling, respectively

V = The total volume of air sample (m^3)

Samples preparation and analysis: Samples were prepared for analysis using Melaku standard method (Sabourmoghaddam, 2017) with minor modifications. HNO_3 and $HClO_4$ acids were utilized for digestion of the fiberglass filters. Deionized water was employed for extraction and making solutions of the samples. For each sample, HNO_3 and $HClO_4$ acids were added at a ratio of 4:1 to a beaker of 50 mL capacity and then heated up to 60°C for 5 h. Once the solution's volume decreased in response to evaporation, deionized water was added to the solution. The digested samples were then filtered and analyzed using flame atomic absorption spectrophotometer model AA-6200 (Shimadzo, Japan) (Fig. 2b) for determination of Zinc (Zn), Cupper (Cu), Chromium (Cr), lead (Pb) and Cadmium (Cd) in sampled air.

Air quality assessment: The TSP is one of the environmental indicators used to express air quality and

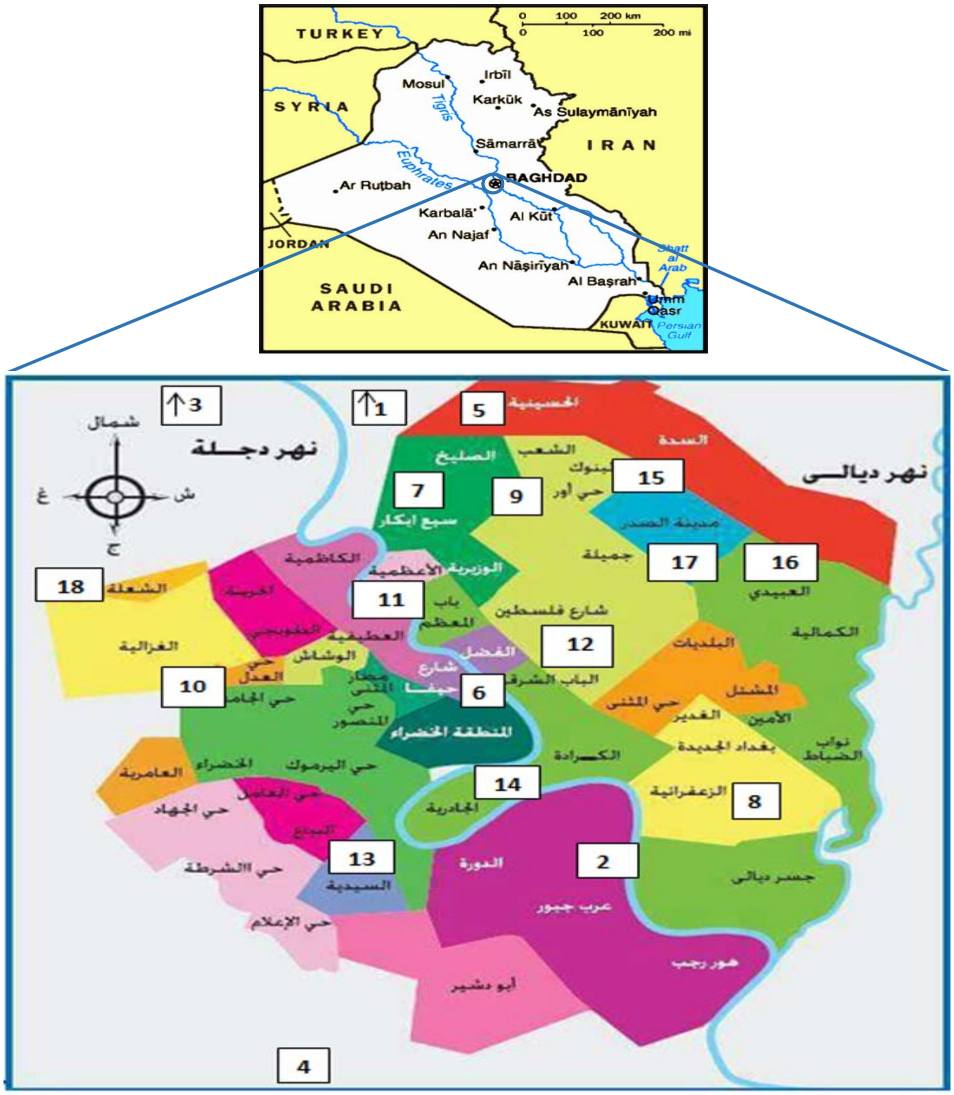

Fig. 1: Map of Baghdad City shows suspended particles sampling locations

(a) (b)

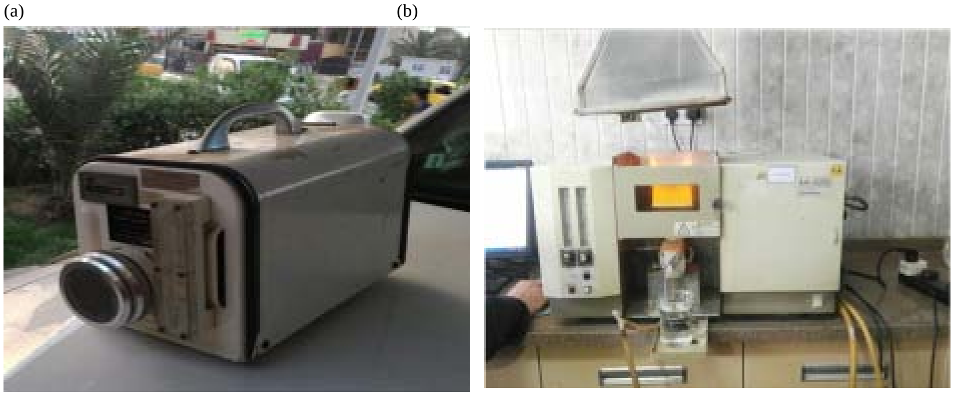

Fig. 2: Equipment and apparatus used for suspended particles sampling and analysis: a) Portable dust sampler and b) Flame atomic absorption spectrophotometer model AA-6200

can be used to inform the public about potential health effects due to air quality. In Table 1, air quality is categorized into six types on the basis of dust concentration according to US.EPA guidelines (Anonymous, 1998).

Health risk assessment: The Average Daily Intake (ADI) of heavy metals by the human through inhalation was calculated using the following equation (Qu *et al*., 2012):

$$ADI = \frac{C \times IR}{BW} \quad (2)$$

Where:

ADI = The average daily intake or dose through inhalation (mg/kg-day)
C = The chemical concentration in the air (mg/m^3)
IR = The inhalation rate (20 m^3/day) and BW is the body weight (70 kg)

The human health risks posed by heavy metal exposure were characterized by the Hazard Quotient (HQ) (Du *et al*., 2013):

Table 1: TSP concentrations and its corresponding to air quality categories (Anonymous, 1998)

TSP (µg/m^3)	Category
0-54	Good
55-154	Moderate
155-254	Unhealthy for sensitive groups
255-354	Unhealthy
355-424	Very unhealthy
425-604	Hazardous

$$HQ = \frac{ADI}{RfD} \quad (3)$$

The Reference Dose (RfD) is an estimation of maximum permissible risk on human population through daily exposure taking into consideration of sensitive group during a lifetime. HQ = 1 indicates no adverse health effects from that element and HQ>1 indicates likely adverse health effects on human health from that element. To assess the overall potential for health effects posed by more than one metal, summing HQs across metals can serve as a conservative assessment tool to estimate health risk as shown in equation (Du *et al*., 2013):

$$HI = \sum_{i=1}^{i=n} HQ_i \quad (4)$$

Where:

HI = The hazard index
n = The number of heavy metals present

If the value of HI = 1, it will be considered that there is no significant risk of non-carcinogenic effects. HI>1 means that there is a great chance of non-carcinogenic effects and the probability increasing with the increasing value of HI (Du *et al*., 2013).

RESULTS AND DISCUSSION

The results of suspended particles sampling and analysis are shown in Table 2. Highest TSP value was

Table 2: Results of suspended particles sampling and analysis

		Heavy metal concentration (µg/m^3)				
Site	TSP (µg/m^3)	Zn	Cu	Cr	Pb	Cd
Al-Rashidiya	32	8.76	0.014	0.47	0.16	0.424
Al-Boaitha	38	10.2	0.021	0.34	0.21	0.57
Al-Tarmiya	52	13.4	0.022	0.469	0.21	0.38
Al-Yousifiya	67	18.9	0.031	0.31	0.31	0.62
Al-Husainiya	96	25.80	0.0469	1.656	0.09	1.16
Al-Salihiya	150	25.86	0.053	2.566	1.146	1.28
Hay Al-Kahira	274	25.02	0.056	2.43	0.179	1.03
Al-Zaafaraniya	295	23.46	0.0826	2.923	1.114	1.427
Hay Our	424	27.74	0.118	0.787	0.8	0.655
Hay Al-Adil	392	22.76	0.142	1.21	0.94	0.762
Al-Aadamiya	462	21.5	0.048	1.9	0.462	1.15
Palestine street	438	25.25	0.022	1.242	0.832	1.064
Al-Saidiya	439	26.22	0.1264	2.47	0.711	1.566
Al-Karada	672	27.19	0.1382	0.904	0.380	0.655
Al-Kiyara	737	26.14	0.035	2.333	1.262	0.677
Al-Obaidi	694	27.33	0.13	2.4	0.2946	1.656
Madenat Al-Sader	797	29	0.0234	1.613	1.3	1.15
Al-Shoala	965	26.14	0.07	1.228	0.29	0.987
Average	390.2	22.81	0.065	1.51	0.59	0.956
Standard deviation	290.7	6	0.04	0.86	0.41	0.38
Minimum	32	8.76	0.014	0.31	0.09	0.38
Maximum	965	29	0.142	2.923	1.3	1.656
Iraqi National standards (Al-Obaidy *et al*., 2016; Sabourmoghaddam, 2017)	350	*NA	NA	NA	3	NA
International limits (Al-Obaidy *et al*., 2016; Sabourmoghaddam, 2017)	60-90	NA	0.257	0.04	0.5	0.05

*NA: Not Available

reported in Al-Shoala (965 μg/m^3) due to relatively heavy population density and high traffic intensity at this area, while the lowest value (32 μg/m^3) was reported at Al-Rashidiya (agricultural area). The average concentration of TSP (390.2 μg/m^3) was higher than the permissible limit recorded in the Iraqi National Standard (350 μg/m^3) and significantly higher than the international limit of 60-90 μg/m^3. Heavy metals concentrations ranged from 8.76-29 μg/m^3 for Zn, 0.014-0.142 μg/m^3 for Cu, 0.31-2.923 μg/m^3 for Cr, 0.09-1.3 μg/m^3 for Pb and from 0.38-1.656 μg/m^3 for Cd. Among the five measured heavy metals, Zn with an average concentration of 22.81 μg/m^3 had the highest concentration, followed by Cr, Cd, Pb and Cu with average concentrations of 1.51, 0.956, 0.59 and 0.065 μg/m^3, respectively. The relatively high standard deviations estimated over the observation period (0.04-6 μg/m^3) suggest a high variability for heavy metals contents in the ambient air. Generally, lowest heavy metals concentrations were detected in suburban and agricultural areas (Al-Rashidiya, Al-Boaitha, Al-Tarmiya, Al-Yousifiya and Al-Husainiya) as compared with concentrations reported in residential areas due to lower human contaminating activities in agricultural areas. Only Cr and Pb show average concentrations higher than corresponding international limits, indicating that these elements pose a threat to human health. The air concentrations of the investigated heavy metals were not strongly correlated to each other, except for Cd and Cr which show relatively strong statistical correlation (correlation coefficient R = 82%). The correlation coefficients between Pb, Cu and Zn showed lower values (ranged from 9.6-60.5%).

Table 3 shows classification of air quality for investigated areas on the basis of TSP levels. According to US.EPA air quality criteria Table 1, air pollution problem with TSP is "hazardous" in Al-Aadamiya, Palestine street, Al-Saidiya, Al-Karada, Al-Kiyara, Al-Obaidi, Madenat Al-Sader and Al-Shoala. Millions of people currently live in these residential regions with air pollution with TSP far higher than that thought be "healthy" air. Air quality on the basis of TSP concentrations can be considered "Good" only at agricultural areas (Al-Rashidiya, Al-Boaitha and Al-Tarmiya).

The ADI and HQ values from heavy metals inhalation are shown in Table 4. There is a significant difference between HQs values for Cd, Pb, Cr, Cu and Zn. HI value shown in Table 4 refers to the "sum of more than one HQ for multiple substances". The HQ value of Pb represent 80% of the estimated HI value for all metals, indicating that Pb poses the greatest threat to human health. Estimated HI value (1.5>1) indicating that the chronic daily intake dose from investigated heavy metals exceeds the safe reference dose.

Table 5 shows comparison of air pollutants levels investigated in current study with some previous relevant studies in Iraq and some available worldwide values. The TSP results reported in this study were lower than values reported in previous studies in Baghdad but higher than the value reported in Iran. The wide range in air pollutants levels detected in current and previous relevant studies may be attributed to different contaminating activities in investigated areas and different weather conditions (wind speed, precipitation, etc.) which resulted in different air pollutants levels.

Table 3: Classification of air quality for investigated areas on the basis of TSP levels

Category	Areas
Good	Al-Rashidiya, Al-Boaitha, Al-Tarmiya
Moderate	Al-Yousifiya, Al-Husainiya, Al-Salihiya
Unhealthy for sensitive groups	None
Unhealthy	Hay Al-Kahira, Al-Zaafaraniya
Very unhealthy	Hay Our, Hay Al-Adil
Hazardous	Al-Aadamiya, Palestine street, Al-Saidiya, Al-Karada, Al-Kiyara, Al-Obaidi, Madenat Al-Sader, Al-Shoala

Table 4: Average daily intake and hazard quotients of investigated heavy metals

Heavy metal	C (μg/m^3)	ADI (mg/kg-day)	RfD (mg/kg-d) (Anonymous, 1998)	HQ
Cd	0.956	0.000273	1×10^{-3}	0.273
Pb	0.590	0.000169	1.4×10^{-4}	1.2
Cr	1.510	0.000431	1.5	2.88×10^{-4}
Cu	0.065	1.86×10^{-5}	0.04	4.64×10^{-4}
Zn	22.810	0.006517	0.3	0.0217
Total (HI)				1.5

Table 5: Comparison between air pollutants levels detected in current study with some previous relevant studies in Iraq and some worldwide values

		Heavy metal concentration (μg/m^3)					
Country-region	TSP (μg/m^3)	Zn	Cu	Cr	Pb	Cd	References
Iraq-Baghdad	390.2	22.81	0.065	1.51	0.59	0.956	Current study
Iraq-Baghdad	655.5	*NM	NM	18.65	3.1	0.112	(Al-Azzawi and Al-Dulaimi, 2015)
Iraq-Kirkuk	887.87	NM	0.073	0.489	2.30	0.0955	(Al-Dabbas *et al*., 2012)
Iraq-Baghdad	453	NM	NM	NM	NM	NM	(Al-Tameemi and Hohammed, 2011)
Iraq-Baiji	1800.85	NM	NM	NM	NM	0.07	(Al-Hasnawi *et al*., 2016)
Iran-Tabriz	NM	NM	NM	NM	0.662	0.096	(Sabourmoghaddam, 2017)
Iran-Kermanshah	215.13	NM	NM	NM	NM	NM	(Meghdad *et al*., 2014)
USA-Washington	NM	NM	NM	0.8	0.89	0.59	(Al-Tameemi and Hohammed, 2011)
Congo-Kinshasa	NM	NM	NM	NM	0.358	0.003	(Kabamba *et al*., 2016)

*NM: Not Measured

CONCLUSION

Concentrations of suspended particles and heavy metals in ambient air were measured at 18 selected locations in Baghdad City, in the period from October 2017 to January 2018. Significant difference was found between TSP values detected in urban areas (range from 150-965 $\mu g/m^3$) and TSP values detected in sub-rural (agricultural) areas (range from 32-96 $\mu g/m^3$) which imply that anthropogenic sources (traffic, industrial activities, local electrical generators, etc.) are the most sources of heavy metals in this region. The concentrations of Zn, Cu, Cr, Pb and Cd in the investigated areas were found to be vary in the range of 8.76-29 $\mu g/m^3$, 0.014-0.142 $\mu g/m^3$, 0.31-2.923 $\mu g/m^3$, 0.09-1.3 $\mu g/m^3$ and 0.38-1.656 $\mu g/m^3$, respectively, having the order Zn>Cr>Cd>Pb>Cu. The peak concentrations of the 5 heavy metals were observed in the residential areas while agricultural areas reported lowest concentrations. Comparison between heavy metals concentrations in the investigated areas with corresponding international limits indicate that living in Baghdad City is associated with elevated levels of Cr and Pb in ambient air as compared to international limits.

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