



## Assessment of air pollution elements concentrations in Baghdad city from periods (May-December) 2010

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### Abstract

Air pollution in developing countries has recently become a serious environmental problem, which needs more active air quality monitoring and analyses. To assess air quality characteristics over the city of Baghdad, temporal variations in CO, NO, NO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub> and PM<sub>10</sub> Concentrations measured between May-December 2010 (245 days), at period from 8:00-16:00 daily hour from location called AL-Jadriyah station (44.1E -33.3N, 38.5m above sea level). From diurnal variability of these concentration, we see high daily values of CO and CH<sub>4</sub> 3.25, 1.9 PPM at November while NO<sub>x</sub> record 0.23 PPM at December that consider as highest daily value. While other pollutant concentration don't have large variation have 0.14-0.18 PPM. Particular matter at 10um (PM<sub>10</sub>) have 1.6g/m<sup>3</sup> at 21/7/2010. At winter season and specifically at December month, there is good relation between the hourly concentration of PM<sub>10</sub> and other chemical pollutant concentration such as CO,SO<sub>2</sub>, NO, NO<sub>x</sub> this can be putting by correlation coefficient  $r = 0.7-0.5$ . The monthly mean concentration of pollutant CO, NO<sub>x</sub>, CH<sub>4</sub>, NO, NO<sub>2</sub> recorded high value at August Month. While O<sub>3</sub> have large mean concentration in November, while PM<sub>10</sub> have large monthly mean concentration at June and July months where there is most frequent dust-storm events. High concentration and its frequency distribution shifts towards large values concentrated at summer seasons June, July, Aug. about 0.25-1.25 PPM and have frequency percent about 82.6%. In winter the frequency distribution shifts towards large values of O<sub>3</sub> even above 61.2% in range 0.085-0.105 PPM. Regarding the frequency distribution of SO<sub>2</sub> all season where shifts towards lower except spring (May) 88.2% at range concentration 0.025-0.125 PPM. Nitrate oxide have different concentration an frequency at several season but NO<sub>x</sub> have large frequency at summer, other pollutant concentration CH<sub>4</sub> and PM<sub>10</sub> have high concentration frequency at this period.

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**Keywords:** Air pollution; Air quality; Frequency of occurrence; Temporal variations.

### 1. Introduction

Air pollution is defined as the emission of particulate toxic elements in to the atmosphere by natural or anthropogenic sources [1]. These sources can be further differentiated in to either mobile or stationary sources [2]. Anthropogenic air pollution commenced with human s systematic use of fire. Its historical development has been characterized by steadily increasing amounts of total emissions. The inversion of new sources of pollution emission as well as the emission of pollutants that had not formerly been emitted by man-made sources. This development has had the greatest impact on the air quality of so-called Mega-cities (cities with over 10000000 inhabitants). Today the major sources of man –made air pollution are motorized street traffic (especially exhaust gases and tire abrasion). The burning of fuels,

and larger factory emissions. Depending on the pollutant particles size, they can be carried for distances of several thousand miles. With decreasing diameter, they are able to infiltrate finer lung structures [3]. The world health organization (WHO) estimate 2.4 million fatalities due to air pollution each year [4]. Since the breathing of polluted air may have severe health effects such as asthma, or increased cardiovascular risks [5, 6]. Thus air pollution has presented one of the major environmental issues and is becoming a very important factor of the quality of life in urban areas, posing a risk both to human health and to the environment. According to the directive on ambient air quality assessment and management, ozone ( $O_3$ ) nitric oxide, nitrogen dioxide ( $NO_2$ ), sulfur dioxide ( $SO_2$ ), carbon monoxide (CO) and particulate matter with diameter  $<10\mu m$  ( $PM_{10}$ ) are target species, due to their negative effects on human health and vegetation [7]. Ozone a secondary air pollutant has gained extensive attention in the literature due to its harmful effects in vegetation during the growing period. Emission of nitrogen oxides ( $NO_x = NO + NO_2$ ), volatile organic compounds (VOCS) and sulfur compounds (including  $SO_2$ ) can lead to complex series of chemical and physical transformations such as the formation of  $O_3$  in urban and regional areas [8]. Meteorological conditions (temperature, relative humidity, wind speed, rainfall and atmospheric pressure) strongly influence the efficiency of photochemical processes leading to the ozone formation and destructions [9, 10]. The understanding of the  $O_3$  behavior near surface layers is essential for a study of pollution oxidation processes in urban areas. Concentration of atmospheric trace gasses involved in forming  $O_3$  and  $NO_x$  change rapidly accompanied by a change of wind speed and wind direction, temperature, humidity and solar radiation. All these factors play crucial role in production and destruction of  $O_3$  [11]. Usually  $NO_2$  in the atmosphere comes from two sources, either directly from emission sources (primary pollutant) or from chemical reactions in the atmosphere [12]. Nitrogen monoxide (NO), in turn, is converted to  $NO_2$  by reactions with proxy radicals ( $RO_2$ ) or  $O_3$ . Proxy radicals are produced mostly by the reactions of hydroxyl radical (OH) with reactive hydrocarbons and CO and photolysis of aldehydes which have both natural and anthropogenic origins.

Nitrogen dioxide is then photolysis in the atmosphere, and the released atomic oxygen combines with molecule  $O_2$  to form  $O_3$  [13]. High concentrations of CO generally occur in areas with heavy traffic and congestions. The point sources of CO emission also include industrial processes. Non transportation fuel combustion 2006) [12]. The present of sulphur dioxide in air is related to the fuel combustion and industrial processes. Primary pollutant (CO,  $SO_2$ ) concentrations are usually higher in cold months (winter) than in hot months. Where the concentrations of the secondary pollutants ( $NO_2$  and  $O_3$ ) are higher in summer than in winter months [14]. Overall all these pollutant concentrated in crowded street where the United Nation estimated that over 600 million people worldwide in urban areas are exposed to dangerous levels of traffic-generated air pollutants [15]. Methane is invisible, odorless, and combustible gas present in trace concentrations in the atmosphere, it enters the atmosphere from both natural (30 percent) and anthropogenic (70 percent) sources. Methane is twenty three times more potent as a greenhouse gas than carbon dioxide. Both gases are targeted for emissions reduction in the Kyoto Protocol [16, 17]. Particulate matter (PM) in urban areas is mainly made up of metals, organic compounds, materials of biological origin and elemental carbon [18]. The particle core, which often forms bulk of the urban particulate matter, mainly comprises elemental carbon. Many organic compounds can lead to mutations and can be cancerous. The effects of air pollutions on health are very complex, after being inhaled, they affect human health severely damaging the lungs and respiratory system [19]. In present work analyzes the temporal variation of measurements CO,  $SO_2$ , NO,  $NO_2$ ,  $NO_x$ ,  $O_3$ ,  $CH_4$ ,  $PM_{10}$  concentrations were performed for the first time in may – December 2010 and the results are present in this paper to find simple evaluate the state of ambient air in urban area of Baghdad city middle – east of Iraq, and focusing mainly on the following five objectives:

1. Establishing baseline pollutant concentration levels at daytime, which could be used in the future to assess the effectiveness of any implemented emission control strategies at this period.
2. Comparing the observed pollutant concentrations levels to the corresponding would ambient air standards.
3. Revealing the role of wind speed and other atmospheric element, especially in hot and cold months, to the pollutant levels.
4. Examine the domain concentrations of these pollutants through the frequency of occurrence.
5. Test the relationship between several pollutant, this can be used in interpreted the origin of these elements.

It should be noted that such studies are lacking from this region and is the first that examines pollutant concentrations because there is not continues record through 24 hours of pollutant concentration in this city, especially in the previous years.

## 2. Data collection

Baghdad city located in the middle –east part of Iraq has a population of more than 8000000 (according to 2010 estimation) and is regarded as a urbanized area with several industries, a large number of automobile and huge number of small and large electric generator, spread in different parts it, specifically after 2003 where there luck in electric generated, all of these can contribute to the production of local pollutant. The climate of this city is semiarid to arid (specifically 2010 year), with a low annual average precipitation of 0.7mm occurring mainly in winter months (November to April). Monthly mean values of temperature, relative humidity (RH%), atmospheric pressure, and accumulated precipitation in Baghdad during the year of period study (May-December 2010) are plotted in Figure 1. The monthly mean temperature exhibits a clear annual pattern with low values in winter 13°C and high values 38°C in summer following the common pattern found in the northern mid-latitudes. RH% illustrates an inverse annual variation with larger values in winter 56% and very low values in summer below 20%, which are indicative of an arid environment. The atmospheric pressure is generally steady 1015 hpa from January to April, and then decreases significantly during summer and increases again in autumn, see Figure 1, The summer low pressure 999.5 hpa in July is attributed to the Indian thermal low that extends further to the west over the arid environment of Iraq and middle east as a consequence of the south Asian monsoon system.

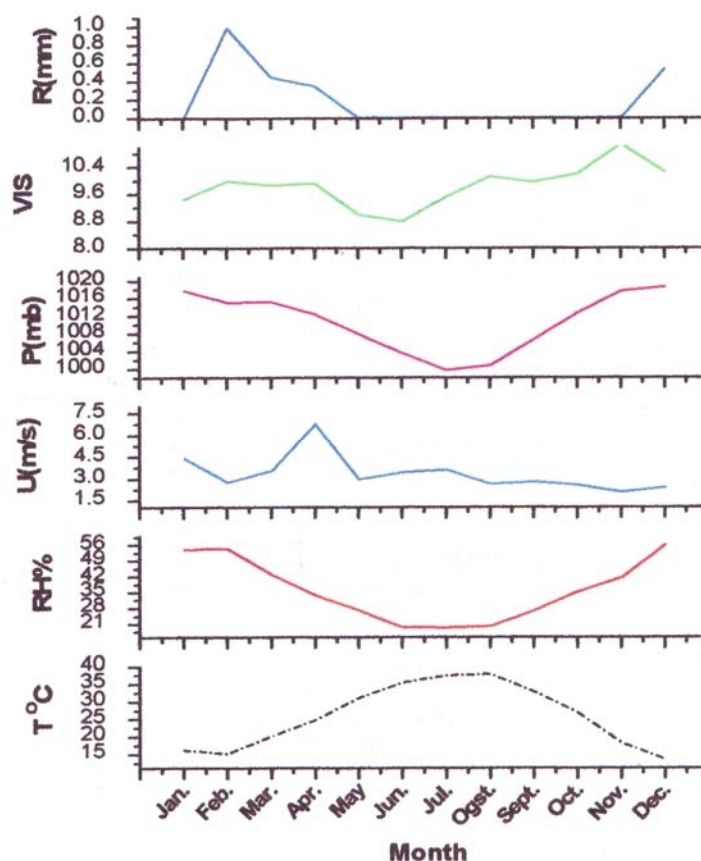


Figure 1. Monthly mean variation of meteorological variables in Baghdad, Iraq covering the period (January – December) 2010

In this study we taken the local recorded of daily hourly concentrations of  $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{CH}_4$ ,  $\text{CO}$ ,  $\text{PM}_{10}$  and  $\text{O}_3$  at near-surface level in city of Baghdad that have been systematically measured using environment pollution, AL-Jadriyah station (44.1 east, 33.3 north, 38.5m a.m.s.l where it located near residential site). The present measurements were carried out during the period May-December 2010

(total of 245 days). The measures of  $PM_{10}$  concentration were in milligrams per cubic meter, with a relatively high temporal resolution (1 hour) of recording. But the measurement of other chemical pollutions is recorded in ppm (part per millions) and the period of recorded is 30min, All center of the city, in a sparsely populated area without daily hour. The station is located at the outskirts center of city, in a sparsely populated area without any industries and direct influence by anthropogenic emissions. All the hourly measurement of this pollution was converted to daily average from which the monthly values and variations were obtained.

### 3. Result and discussion

#### 3.1 Diurnal variability of pollutant concentrations

Daily mean pollutant concentration at period's daytime and from 2 May 2010 to 1 January 2011 are shown in Figure 2. We see that highest daily maximum values of the pollutant elements such as CO and  $CH_4$  were 3.25, 1.9 ppm respectively this was at November 7/11/2010. On the other hand  $NO_x$  has highest concentration value at December 5/12/2010 about 0.23 ppm. But other pollutant element such as NO,  $NO_2$ ,  $SO_2$ ,  $O_3$  have maximum values lived between (0.14 -0.18ppm), this refer to the changes of mean daily concentration of these element pollutant through period study is very low. Particular matter at diameter 10um ( $PM_{10}$ ) make high mean daily value at 21/7/2010 about  $1.6mg/m^3$ .

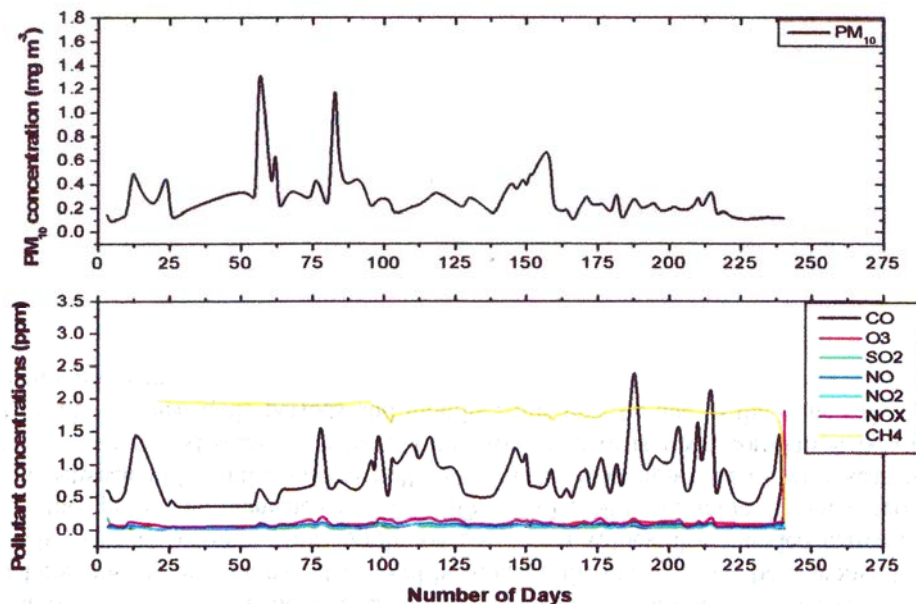


Figure 2. Daily pollutant concentrations at Baghdad during the period 1 May 2010 to 31 December 2010

This a threshold value of  $1.62mg/m^3$  was chosen for the city of Baghdad in order to identify days with severe  $PM_{10}$  levels, while lowest daily value noted is at 2/11/2010. This mean that most highest value of  $PM_{10}$  is measured at summer season period (hot months) while lowest value is noted at winter season (cold days) this is parallel with domain atmospheric condition that is makes high frequency of dust storm mostly at summer season where its loaded by high concentration of  $PM_{10}$  because active wind through is period, days with severe  $PM_{10}$  concentrations are observed mainly in summer months on 21/7/2010, significant daily variability is observed especially for  $PM_{10}$  with several peaks and gaps attributed to the intensity of local emissions, regional meteorology, boundary layer dynamics, and long-range transported aerosols. This value can comparable in magnitude to those observed during an intense dust storm in Beijing [20]. This situation is different in the chemical pollutant element where we see that most of high concentration is domain in cold daily period, where wind speed is nearly calm. More explain to this circumstance we will take linear correlation coefficient between all the hourly concentration pollutant element at periods that represent winter, April, summer and autumn that extracted from period study, Table 1. At winter and specifically at December month, we see that there is a good values to correlation coefficient between  $PM_{10}$  and other chemical pollutant concentration such as CO,  $SO_2$ , NO,  $NO_x$ ,  $PM_{10}$  levels in these seasons. This correlation coefficient values also founded between concentration of  $NO_x$  and other pollutant element such as  $SO_2$ , NO,  $NO_2$  see Table 1 (winter period). Correlation coefficient

between PM<sub>10</sub> and chemical pollutant element is disappeared in other seasons period, April, summer, autumn period season see Table 1. But overall there is good correlation between NO<sub>x</sub>, SO<sub>2</sub>, NO, NO<sub>2</sub> in all seasonal daily periods and months, this may be due to the same references emission of this elements pollutant.

Table 1. Linear correlation coefficient among different pollutants in Baghdad urban area through the periods represents Winter, Spring, Summer and Autumn

		Pollutant concentrations							
		CO	O <sub>3</sub>	SO <sub>2</sub>	NO	NO <sub>2</sub>	NO <sub>x</sub>	CH <sub>4</sub>	PM <sub>10</sub>
Winter (Dec.)	CO	1	0.0556	0.5792	0.7780	0.8090	0.91541	0.4590	0.92497
	O <sub>3</sub>		1	0.1169	-0.2685	0.30701	-0.07181	-0.28825	0.36641
	SO <sub>2</sub>			1	0.25768	0.38534	0.59269	0.48941	0.81566
	NO				1	0.44406	0.92865	0.60292	0.65398
	NO <sub>2</sub>					1	0.74423	0.12788	0.90042
	NO <sub>x</sub>						1	0.54071	0.88528
	CH <sub>4</sub>							1	-0.43833
	PM <sub>10</sub>								1
Spring (April, May)	CO	1	-0.39861	0.25443	0.2544	0.60755	0.40598	0.23456	0.276
	O <sub>3</sub>		1	-0.32433	-0.33192	-0.46832	-0.38853	0.04009	-0.16735
	SO <sub>2</sub>			1	0.23768	0.31123	0.23752	0.70193	-0.24429
	NO				1	0.69567	0.87103	0.52626	-0.24098
	NO <sub>2</sub>					1	0.78555	0.61677	-0.1137
	NO <sub>x</sub>						1	0.55213	-0.22242
	CH <sub>4</sub>							1	-0.35493
	PM <sub>10</sub>								1
Summer (June, July, Aug.)	CO	1	0.10117	0.61214	0.57508	0.82317	0.69975	0.15713	-0.0434
	O <sub>3</sub>		1	0.29566	-0.1311	0.14192	-0.06776	0.27855	-0.23331
	SO <sub>2</sub>			1	0.57266	0.6731	0.64087	0.07754	-0.09658
	NO				1	0.68767	0.94615	-0.16564	0.02888
	NO <sub>2</sub>					1	0.86232	0.00885	-0.26906
	NO <sub>x</sub>						1	-0.14442	-0.08473
	CH <sub>4</sub>							1	0.27479
	PM <sub>10</sub>								1
Autumn (Sep., Oct., Nov.)	CO	1	0.10169	0.26392	0.39961	0.77345	0.60138	0.34074	0.26123
	O <sub>3</sub>		1	0.00316	-0.25319	0.08903	-0.16759	0.06095	-0.23932
	SO <sub>2</sub>			1	0.5709	0.52155	0.61913	0.15172	0.18205
	NO				1	0.49687	0.94048	-0.01066	0.07307
	NO <sub>2</sub>					1	0.7571	0.19261	0.31387
	NO <sub>x</sub>						1	0.05295	0.18013
	CH <sub>4</sub>							1	0.1261
	PM <sub>10</sub>								1

### 3.2 Monthly variability in pollutant concentration

Figure 3 illustrate the monthly variation of all pollutant of study that recordings during the period from May to December 2010. The vertical bars in this figure is refer to the standard deviation from the monthly mean and are indicative of the day-to-day variation. Thus, it is observed that the months with the highest pollutant concentration level also have largest standard deviations. This is occurs mainly in summer month specifically in August month where we noted the high mean concentration in pollutant concentration of CO, NO<sub>x</sub>, CH<sub>4</sub>, NO, NO<sub>2</sub> and SO<sub>2</sub> where it have  $1.045 \pm 0.449$ ,  $0.1141 \pm 0.0425$ ,  $1.8144 \pm 0.0914$ ,  $0.07702 \pm 0.0295$ ,  $0.07018 \pm 0.0222$  and  $0.05333 \pm 0.0304$  respectively this month period have high frequency wind speed events, in other hand have high amount of anthropogenic activity that is due to the emission of large amount of pollutant concentration from the vehicles and electric generated specially there is high needed to electricity at this period and the luck of the national electricity that

supplied to the people of Baghdad city, Table 2. Although the wind speed is very active at this period or at this month from every year. On the other hand there is also large mean concentration in the November specifically at the ozone  $O_3$  where its have largest mean value about  $0.1024 \pm 0.0163$ , CO have also large monthly mean and large standard deviation at this month  $1.211 \pm 0.7448$ , Table 2.

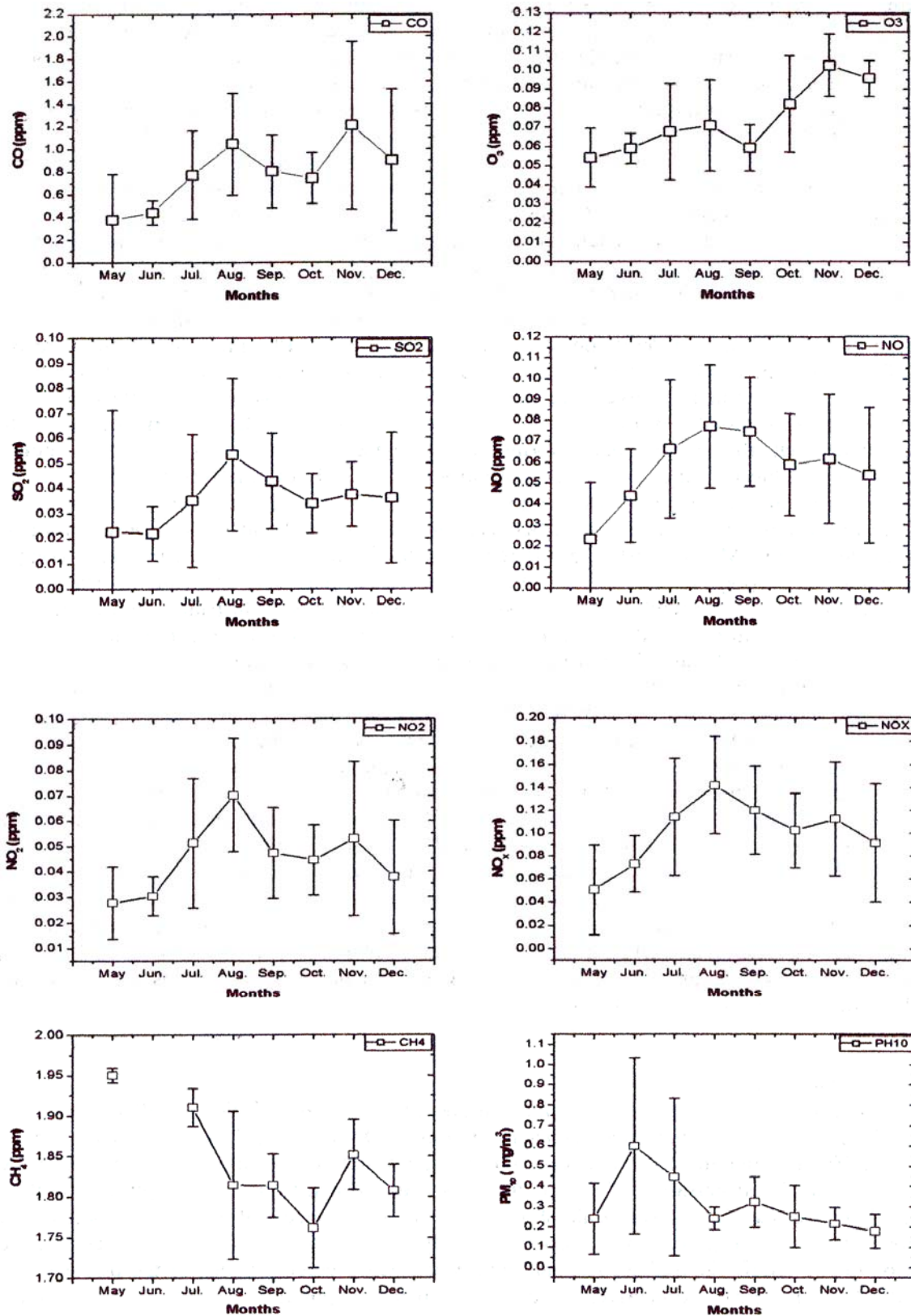


Figure 3. Monthly mean variation values of CO,  $O_3$ ,  $SO_2$ , NO,  $NO_2$ ,  $NO_x$ ,  $CH_4$  and  $PM_{10}$  at Baghdad during period May-December 2010

Table 2. Monthly mean, maximum and minimum pollutant concentration in Baghdad during period 1 May to 31 December 2010

		MONTHS							
		May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
CO (ppm)	mean	0.37549	0.4392	0.77265	1.04562	0.8049	0.7425	1.211	0.9047
	min	0.29375	0.10619	0.39047	0.4497	0.3243	0.225	0.393	0.353
	max	1.735	0.64118	1.98163	1.8433	1.3949	1.183	3.230	2.8131
O <sub>3</sub> (ppm)	mean	0.05421	0.05903	0.06774	0.0709	0.0592	0.0821	0.102	0.0956
	min	0.01531	0.00797	0.02526	0.0238	0.01206	0.0253	0.0163	0.00939
	max	0.0965	0.07388	0.13413	0.1157	0.0796	0.1208	0.147	0.1099
SO <sub>2</sub> (ppm)	mean	0.02262	0.02198	0.03506	0.05336	0.04284	0.0338	0.0373	0.0360
	min	0.00975	0.01033	0.0063	0.0225	0.0163	0.0117	0.0128	0.0101
	max	0.18456	0.0432	0.10663	0.1133	0.0864	0.0613	0.068	0.1044
NO (ppm)	mean	0.02311	0.04385	0.0663	0.07702	0.0745	0.0587	0.0615	0.0537
	min	0.00318	0.02089	0.00843	0.023	0.0261	0.0243	0.0065	0.01
	max	0.0969	0.08515	0.13575	0.1251	0.1138	0.1204	0.120	0.1203
NO <sub>2</sub> (ppm)	mean	0.02778	0.03045	0.05125	0.07018	0.0473	0.0444	0.0529	0.0378
	min	0.01009	0.00762	0.02559	0.02229	0.0180	0.0138	0.023	0.0222
	max	0.0684	0.04413	0.1181	0.1135	0.0836	0.0765	0.143	0.1081
NO <sub>x</sub> (ppm)	mean	0.05089	0.07342	0.1142	0.14186	0.1199	0.1024	0.112	0.0916
	min	0.01327	0.02435	0.04286	0.0425	0.0383	0.0323	0.0295	0.04
	max	0.1653	0.1133	0.2245	0.20975	0.1737	0.196	0.2048	0.228
CH <sub>4</sub> (ppm)	mean	1.95017		1.91048	1.81441	1.8139	1.7618	1.851	1.807
	min	0.00914	0	0.02337	0.09148	0.03942	0.0491	0.0433	0.0321
	max	1.966	0	1.93386	1.9547	1.8915	1.836	1.9057	1.867
PM <sub>10</sub> (mg/m <sup>3</sup> )	mean	0.23983	0.599	0.4452	0.2408	0.3218	0.2504	0.215	0.179
	min	0.089	0.165	0.1784	0.05567	0.1249	0.091	0.072	0.0839
	max	0.60017	1.4	1.62	0.3455	0.5056	0.814	0.3306	0.4012

The monthly mean recorded at the month of CH<sub>4</sub> is large at may and July but June don't have any monthly record. On the other hand the basic monthly of June and July have large monthly mean concentration about  $0.599 \pm 0.435$  and  $0.445 \pm 0.387$  mg/m<sup>3</sup>. In this months is the periods with the most frequent dust-storm evens, one can therefore conclude that the intense dust-storms taking place on specific days during summer are predominantly responsible for large day-to-day variations at all PM concentrations. PM<sub>10</sub> concentrations during winter months are significantly lower with  $0.179 \pm 0.0839$  mg/m<sup>3</sup>, this measured at December. The difference in the monthly mean variation between chemical air pollutant concentration and particular matter at diameter 10um suggests the differences in source regions for these pollutant components. Where the main anthropogenic source of PM<sub>10</sub> and other pollutant element in Baghdad urban environment can be return to vehicle traffic, fossil-fuel combustions, industrial activities that release a large amount of near- surface anthropogenic components. In addition, the boundary layer mixing height is lower in winter and traps the pollutants near the ground as a result of temperature inversions. All the above explain the high concentration of chemical air pollutant at a cold daily period months, in contrast during summer months, thermal heating at the surface and the increase of mixing layer height favors buoyancy and the dilution of anthropogenic pollutant. On the other hand dust storm contribution to the total PM<sub>10</sub> concentration is also expected to originate from Aeolian and traffic-driven resuspension. Some studies conduct in other urban environments, in Turkey [21] and in Athens [22] and other places in world found contrary to our results, in PM<sub>10</sub>, that in winter both PM concentrations and concentration pollutant were high which was attributed to large use of fossil fuels in winter. Where monthly mean PM<sub>10</sub> concentration in Athens have ranging from  $60.3 \mu\text{m}^3$  (January) to  $88.9 \mu\text{g}/\text{m}^3$  (December). Its concluded that the city of Baghdad experiences much higher pollutant concentration levels. This is not only the case for summer element. This emphasizes the fact that air pollutant quality concentrations over Baghdad can be regarded as a real environment problem that possess a serious risk to quality of life and endangering human health.

### 3.3 Frequency of occurrence

Frequency of occurrence for the pollutant CO, O<sub>3</sub>, SO<sub>2</sub> and NO for all period of study is depicted in Figure 4, we see that most concentration of CO is bounded between 0-1 ppm. Where frequency have 300-400 but in O<sub>3</sub> its between 0.05-0.1 PPM and concentrated in frequency between 200-300. SO<sub>2</sub> most of concentration of this pollutant is concentrated from 0-0.05 PPM in NO the matter is different where we see that there is not peak frequency for this concentration its distributed at several concentration from 0-0.1 PPM at this period of study. This concentration can be change between several seasons, the red values in the Table 1 show the highest seasonal hourly frequency percent bands of the pollutant CO, O<sub>3</sub>, SO<sub>2</sub>, NO, NO<sub>2</sub>, NO<sub>x</sub> and PM<sub>10</sub> respectively at each season to compared the situation at each season for example CO that consider important gas to poisons gases and its represent the measured of unhealthy of air quality. We see that most of highest concentration and its frequencies distribution shifts towards larger values concentrated at summer seasons June, July, and Aug. about 0.25-1.25 PPM and frequency percent 82.6%. While other season have smaller than concentration and frequencies at this period, see the red values in the Table 1. In winter the frequency distribution shifts towards large values, of O<sub>3</sub> even above 61.2% in the range concentration about 0.085-0.105 PPM. While in autumn highest percent frequency is 33.6% at 0.11-0.13 PPM, see the red values in the Table 1.

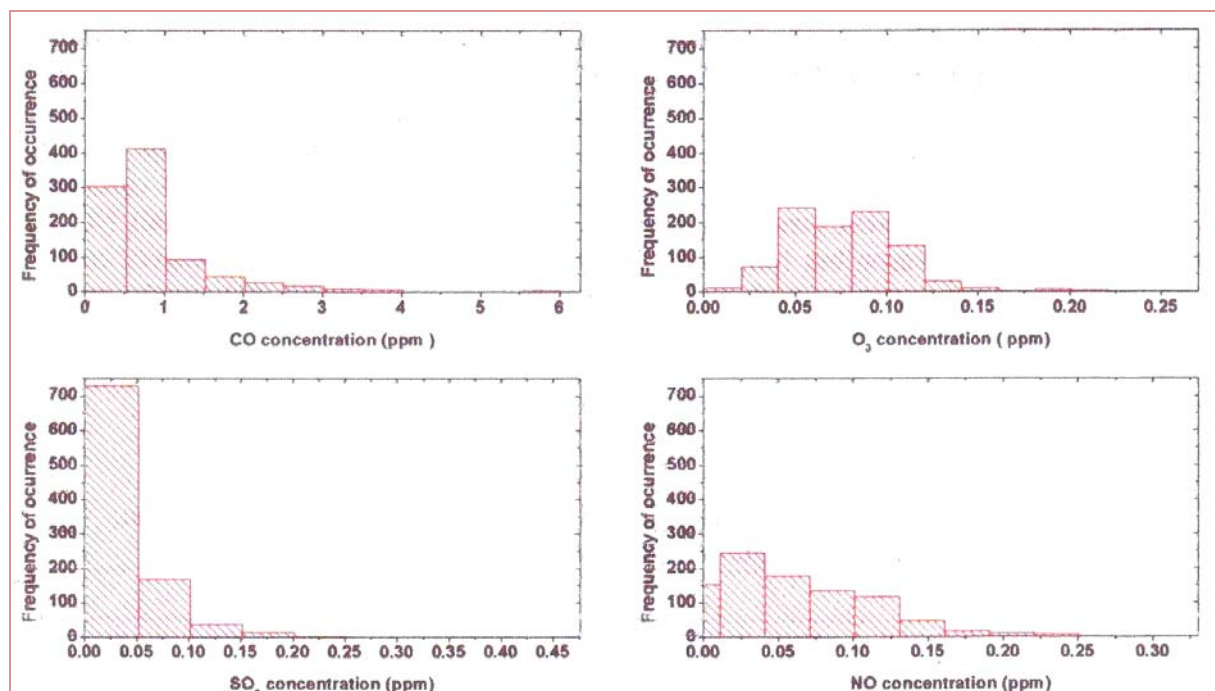


Figure 4. Frequency distribution of CO, O<sub>3</sub>, SO<sub>2</sub>, NO hourly concentration at all period of study in Baghdad (AL-Jadriyah station)

Regarding the frequency distribution of SO<sub>2</sub> all season where shifts towards lower except Spring (May) 88.2% at range concentration 0.025-0.125 PPM. On other hand concentration of nitrate oxide where have different concentration an frequency at several season. Overall NO and NO<sub>2</sub> were nearly similar at all season but NO<sub>x</sub> have large frequency at summer other pollutant concentration CH<sub>4</sub> and PM<sub>10</sub> also have summer month high concentration frequency about 69% at the concentration range 0.1-0.5mg/m<sup>3</sup>.

### 4. Conclusion

Change in population, economic development, energy consumption, and technology can have consequences for air quality in Baghdad city and other megacities. Air pollution occurs as a result of a combination of several factors. Firstly, pollutants need to be emitted in to the atmosphere. Various pollutants may then undergo chemical reactions among themselves and with other species. The pollutants move as a result of transport by the wind, and they diffuse as a result of turbulence in air. The dispersion of the pollutants is a result of two inter-connected factors: local meteorology conditions, and local topography. Severe air pollution occurs when air pollutants are trapped within a region of the lower



atmosphere close to their emission source. Megacities are particularly susceptible to air pollution because of the large quantity of pollutants that industry, motor vehicles and individuals will emit in to the air shed unless stringent control measures are in place. In Asia, cities such as Jakarta, Manila and Bangkok are renowned for their poor air quality, in the Americas, Mexico City has the worst air quality of all the megacities whereas Los Angeles, which is the city in which photochemical smog was first identified, continues to have problems (Earth Watch, 1992). Air pollution also occurs in cities with lower populations than megacities, especially if there is substantial use of motor vehicles with unregulated emissions.

Temperature inversions are conditions in which the temperature of the atmosphere increases with altitude in contrast to the normal decrease with altitude. Strictly, a temperature inversion occurs when the potential temperature gradient is positive. When a temperature inversion occurs, cold air underlies warmer air. The greater density of the cold air inhibits vertical mixing. During a temperature inversion, air pollution released in to the atmosphere's lowest layer is trapped there and can be removed either by strong horizontal winds, or by strong irradiative heating. Temperature inversions may occur during the passage of a cold front or result from the inversion of sea air by a cooler onshore breeze. Overnight irradiative cooling of surface air often results in a nocturnal temperature inversion that is dissipated after sunrise by the warming of air near the ground. A more long-lived temperature inversion accompanies the dynamics of large high – pressure systems. Descending air near the center of the high-pressure system produces a warming (by adiabatic compression), causing air at middle altitudes to become warmer than the surface air, which is isolated within a boundary layer. Rising currents of cool air lose their buoyancy and are thereby inhibited from rising further when they reach the warmer. Less dense air in the upper layers of a temperature inversion. Because high-pressure systems often combine temperature inversion conditions and low wind speeds, their long residency over an industrial area usually results in episodes of severe smog.

## References

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