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## Gaseous Pollutants in Basra City, Iraq

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**Abstract:** This study aimed to detect the present levels and distribution of CO, CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>2</sub>, and total hydrocarbons gases (HCs) produced from different industrial plants in Basra city, Iraq. Measurements were carried out in the winter and summer of 2011. CO, SO<sub>2</sub>, NO<sub>2</sub>, and HC concentrations were measured using a Dräger CMS portable detector, while CO<sub>2</sub> concentrations were measured using a RI-411A portable detector. The average minimum concentrations of CO, CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>2</sub>, and HCs were 2.0 mg/L, 250.0 mg/L, 4.0 mg/L, 0.4 mg/L, 0.5 mg/L, and 0.3 mg/L, respectively. Their average maximum concentrations were 18.0 mg/L, 280 mg/L, 0.9 mg/L, 1.3 mg/L, and 1.3 mg/L, respectively. The results indicate that stations close to the electrical power plant and oil refinery have higher levels of pollutants when compared to the urban station. According to the standards guidelines reported by the World Health Organization's Environmental Protection Act, the detected concentrations of CO for short-term exposure and the average concentrations of NO<sub>2</sub> and SO<sub>2</sub> for short-term and long-term exposure pose serious health hazards, especially in the industrial areas.

**Keywords:** gaseous pollutants, air quality, Basra city, health hazards

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## Introduction

The atmosphere is generally defined as a complex, dynamic, natural gaseous system that is important in order to support life.<sup>1</sup> The quality status of air is of crucial importance not only to healthy human life but also for wildlife, vegetation, water, and soil.<sup>2,3</sup> Generally, air quality is rated and can be ranked as being good quality (which refers to clean, clear, unpolluted air) or poor quality (which occurs when pollutants are present at a level considered to be dangerous for the health of humans and the environment).<sup>4,5</sup> Bad air quality generally results from increasing levels of gaseous pollutants, which are mainly considered toxic for humans and other living organisms due to their extensive natural or anthropogenic activities.<sup>6</sup> Natural gaseous pollutants are classified as natural-primary pollutants (which are released mostly from volcanic eruption), carbon monoxide gas from motor vehicle exhaust, and as sulfur dioxide released from factories, or they can be natural-secondary pollutants like ground-level ozone.<sup>6</sup> These pollutants can also be released as primary or secondary pollutants from different anthropogenic activities.<sup>7</sup> The most common primary anthropogenic pollutants produced by human activity are: (1) sulfur oxides ( $\text{SO}_x$ ), especially sulfur dioxide ( $\text{SO}_2$ ), which is produced mainly in power stations; (2) nitrogen oxides ( $\text{NO}_x$ ), especially nitrogen dioxide ( $\text{NO}_2$ ), which is released primarily via high temperature combustion; (3) carbon monoxide ( $\text{CO}$ ), which is the major product of incomplete fuel combustion; (4) carbon dioxide ( $\text{CO}_2$ ), which is released from combustion, cement production, and respiration; and (5) ammonia ( $\text{NH}_3$ ), which is released primarily via agricultural processes.<sup>8</sup>

According to both environment protection agency and global World Health Organizations, air pollution can be a serious cause of different health conditions, including respiratory infections and lung cancer.<sup>8–12</sup> Gehring et al<sup>13</sup> indicated that long-term exposure to traffic-related air pollution can cause allergies and that individuals—especially children under the age of 8—are more susceptible to developing asthma.<sup>14</sup> Other studies have also indicated that the risk of developing lung cancer is highly related to air pollution caused by high traffic<sup>15</sup> or long-term exposure to nitrogen dioxide.<sup>16</sup> Gaseous pollutants are also considered to be risk factors for stroke<sup>17</sup> and are associated with an increased incidence of and mortality from coronary

artery disease. The early indication of air pollution goes back to the twelfth century, when smoke from burning coal (mainly  $\text{CO}$  and  $\text{CO}_2$ ) caused serious health problems in England. The discovery led King Edward to become the first to ban the use of coal in lime kilns in London in 1307.<sup>18</sup> Along with the increase in number of industrial zones within cities and urban areas, it has been noted that their impacts have significantly affected the surrounding air quality.<sup>1</sup> In 1948, one of the most dramatic air inversions occurred in Donora, Pennsylvania, when a wall of smog killed 20 people and sickened 7,000 more.<sup>18</sup> Additionally, in England two episodes of “killer fogs” claimed the lives of more than 6,000 people in 1952.<sup>19</sup> On the other hand, some environmental variables intensified the dangers of certain gases; for example, in Meuse Valley, Belgium in 1930, the high humidity concentrated the  $\text{SO}_2$  gas and increased its release levels, leading to the deaths of 63 people in a space of 5 days.<sup>19</sup>

Recently, the general quality of ambient air in Basra city (southern Iraq) has been decreasing because of an increase in the city's population and high traffic levels, as well as the expansion and establishment of several industrial plants, including petrochemical plants, oil refineries, burned natural gas flames, fertilizer plants, paper and pulp mills, power generation stations, and industrial workshops.<sup>21</sup> These have put the local population in direct daily contact with the different gaseous pollutants that are caused by daily urban activities, mostly by increasing the use of fossil fuel combustion from electrical generators and motors vehicle, as well as exposing the population to industrial activities. Previous studies have indicated high concentrations of  $\text{CO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$ , and HCs within the industrial area in Basra city,<sup>21–23</sup> and given that concentrations from these emissions are constantly increasing, these high levels have become hazardous to human health. The lack of management and control of the gaseous discharges and residues in urban and industrial areas has increased the possibility that the air quality has become worse. This study aims to detect the present levels and distribution of  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{SO}_2$ ,  $\text{NO}_2$ , and total hydrocarbons gases (HCs) that are produced from different industrial plants in Basra city in southern Iraq. This survey will also serve as background information to help future environmental assessment studies within the region.



**Figure 1.** Sampling locations for air pollution in Basra city, southern Iraq.

## Materials and Methods

Seven stations were chosen in Basra city—Al-Qurna, Al-Deer, Garmatt Ali, Al-Ashar, Abu Al-Khaseeb, Al-Seeba, and Al-Faw (Fig. 1). These stations were selected in order to monitor the concentrations of CO, CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>2</sub>, and HCs in the ambient air during the winter and summer months of 2011. CO, SO<sub>2</sub>, NO<sub>2</sub>, and HC concentrations were measured using the portable detection instrument Drager Chip-Measurement-System (Dragerwerk AG & Co, Lubeck, Germany), while CO<sub>2</sub> concentrations were measured using the portable detection instrument RI-411A (RKI Instruments, Inc., Union City, California, USA). The instruments used were calibrated and certified every six months by sending them to the manufacturing company.

The survey took seven days (one day per station) for every season. The gaseous probe detector was fixed to a 1.5 meter stand, which represents the

average human height, to ensure that it was possible to measure the average concentrations that most people inhale. The average of two readings was taken between late afternoon and sunset under low to moderate wind speed, in order to capture the amount of traffic during rush hours.

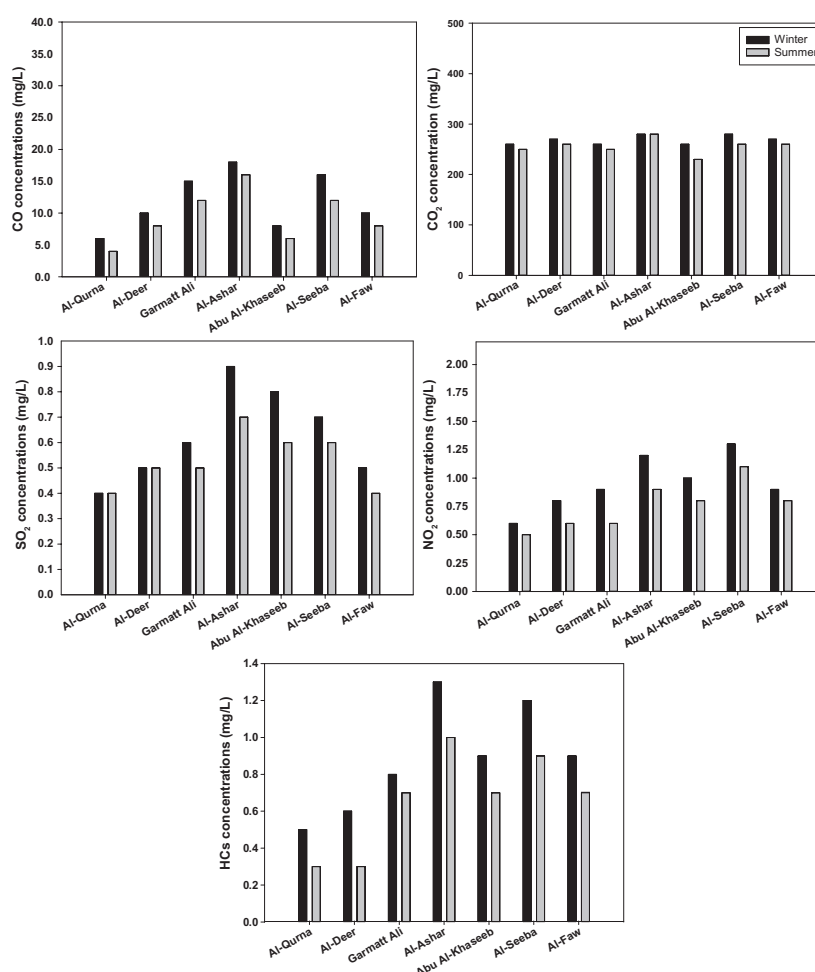
A principal component analysis (PCA) was constructed using the average seasonal reading of each pollutant at each station. PCA plot was developed using the CANOCO program for Windows 7<sup>24</sup> to examine the differences in average levels of gaseous pollutants in the atmosphere across the seven selected stations during the study period. Focus scaling of the data was set on inter-species correlation and the species scores were divided by the standard deviation.

## Results and Discussion

The average concentrations of gaseous pollutants measured in the seven stations are listed in Table 1 and are shown in Figure 2. The results indicate that average concentrations of CO, NO<sub>2</sub>, and HCs are significantly different ( $P < 0.005$ ) among the studied stations. The results also indicate that the average concentrations of the monitored gaseous pollutants were higher in the winter than those recorded in the summer. This may be primarily attributed to the differences in weather conditions, especially wind speeds and directions,<sup>23</sup> air temperature,<sup>21</sup> and humidity;<sup>22</sup> however, these variation were not statistically significant ( $P > 0.005$ ). During the study period, the concentration of CO ranged from 4.0 mg/L to 18.0 mg/L, with mean concentration at 10.6 mg/L. The concentration of CO<sub>2</sub> ranged from 230.0 mg/L to 280.0 mg/L, with mean concentration at 262.1 mg/L. The concentration of SO<sub>2</sub> ranged from 0.4 mg/L to 0.9 mg/L, with mean concentration at 0.6 mg/L. The concentration of NO<sub>2</sub> ranged from 0.5 mg/L to 1.3 mg/L, with mean

**Table 1.** Average concentrations (mg/L  $\pm$  SD) of the selected gaseous pollutants in Basra city during winter and summer of 2011.

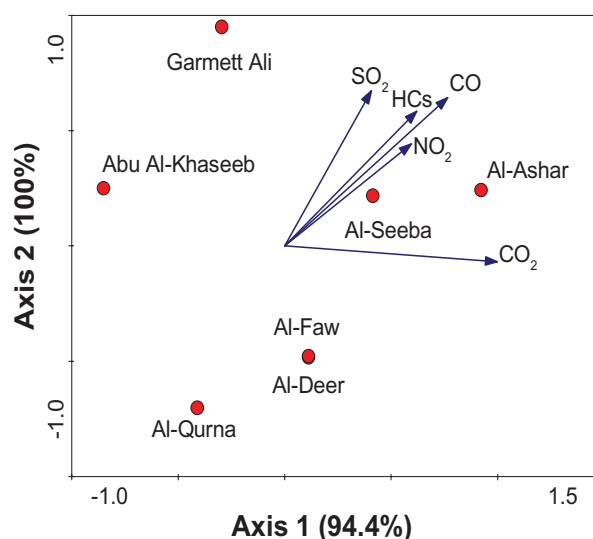
Sampling stations	CO	CO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>	HCs
Al-Qurna	5.0 ( $\pm$ 1.0)	255.0 ( $\pm$ 5.0)	0.6 ( $\pm$ 0.1)	0.4 ( $\pm$ 0.0)	0.4 ( $\pm$ 0.1)
Al-Deer	9.0 ( $\pm$ 1.0)	265.0 ( $\pm$ 5.0)	0.7 ( $\pm$ 0.1)	0.5 ( $\pm$ 0.0)	0.45 ( $\pm$ 0.2)
Garmett Ali	13.5 ( $\pm$ 1.5)	255.0 ( $\pm$ 5.0)	0.8 ( $\pm$ 0.2)	0.6 ( $\pm$ 0.1)	0.75 ( $\pm$ 0.1)
Al-Ashar	17.0 ( $\pm$ 1.0)	280.0 ( $\pm$ 0.0)	1.1 ( $\pm$ 0.2)	0.8 ( $\pm$ 0.1)	1.15 ( $\pm$ 0.2)
Abu Al-Khaseeb	7.0 ( $\pm$ 1.0)	245.0 ( $\pm$ 15.0)	0.9 ( $\pm$ 0.1)	0.7 ( $\pm$ 0.1)	0.8 ( $\pm$ 0.1)
Al-Seeba	14.0 ( $\pm$ 2.0)	270.0 ( $\pm$ 10.0)	1.2 ( $\pm$ 0.1)	0.7 ( $\pm$ 0.1)	1.05 ( $\pm$ 0.2)
Al-Faw	9.0 ( $\pm$ 1.0)	265.0 ( $\pm$ 5.0)	0.9 ( $\pm$ 0.1)	0.5 ( $\pm$ 0.1)	0.8 ( $\pm$ 0.1)



**Figure 2.** CO, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and HCs concentrations of Basra city's ambient air during winter and summer of 2011.

concentration at 0.9 mg/L. Moreover, the concentration of HCs gases ranged from 0.3 mg/L to 1.3 mg/L, with mean concentration at 0.8 mg/L.

The PCA analysis indicated that Al-Ashar and Al-Seeba stations were highly polluted when compared to the other monitored stations, while Al-Qurna, Al-Deer, and Al-Faw stations were less polluted (Fig. 3). However, according to the standard guideline concentrations of CO, CO<sub>2</sub>, NO<sub>2</sub>, and SO<sub>2</sub> reported by the global health organizations listed in Table 2, CO<sub>2</sub> concentrations were within acceptable limits. Among the studied areas, average CO concentrations were higher than the levels permitted for short-term exposure, as previously reported.<sup>9,11,20,23</sup> The SO<sub>2</sub> concentrations within the studied locations were also higher than the global limit concentrations allowed for long-term and short-term exposure, also previously reported.<sup>8–11,20,23</sup> The average concentration of NO<sub>2</sub> was higher than the allowable limit recommended for



**Figure 3.** PCA of the average concentrations of CO, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and HCs in the ambient air of the seven selected stations in Basra city during the study period.

**Notes:** Axis 1 accounted for 94.4%, axis 2 accounted for 100.0%, and axis 3 accounted for 100.0% of the total variance. Chloride (Cl<sup>-</sup>) had strong positive loadings on axis 1, while sulfate (SO<sub>4</sub><sup>-2</sup>) had negative loading on Axis 2.



**Table 2.** Review of guidance intended to limit ambient air concentrations of CO, CO<sub>2</sub>, NO<sub>2</sub>, and SO<sub>2</sub> concentrations (mg/L).

Average timing	Pollutants standards concentrations (mg/L)				Area	Reference
	CO	CO <sub>2</sub>	NO <sub>2</sub>	SO <sub>2</sub>		
1 hour	—	—	1.2	0.2	Australia	DEH, 2005
8 hours	9.0	—	—	—		
24 hours	—	—	—	0.08		
1 year	—	—	0.03	0.02		
1 hour	20 <sup>a</sup> , 35 <sup>b</sup>	—	0.18 <sup>a</sup>	0.25 <sup>a</sup> , 0.14 <sup>b</sup>	California <sup>a</sup> , US National <sup>b</sup>	CEQA, 2012
3 hours	—	—	—	—		
8 hours	9 <sup>a,b</sup>	—	—	—		
24 hours	—	—	—	0.04 <sup>a</sup>		
1 year	—	—	0.03 <sup>a</sup> , 0.053 <sup>b</sup>	0.03 <sup>b</sup>	Europe	WHO, 2000
10 min	—	—	—	0.2		
15 min	90	—	—	—		
30 min	52.4	—	—	—		
1 hour	26.2	—	0.11	—		
24 hours	—	—	—	0.045		
1 year	—	—	0.02	0.02		
1 hour	—	—	0.11 (not to be exceeded more than 18 times a calendar year)	0.13 (not to be exceeded more than 3 times a calendar year)	UK	EP, 2010
8 hours	9	—	—	—		
24 hours	—	—	—	0.048 (not to be exceeded more than 24 times a calendar year), 0.2 (thresholds value)		
1 year	—	—	0.02 (limited value), 2.13 (thresholds value)	—		
1 hour	35 <sup>b,c</sup>	—	0.11 <sup>a</sup> (not to be exceeded more than 8 times a calendar year)	0.13 <sup>a</sup> (not to be exceeded more than 24 times a calendar year)	Europe <sup>a</sup> , USA <sup>b</sup> , EPA National <sup>c</sup>	DG Environment, 2004
3 hours	—	—	—	0.5 <sup>b</sup> (not to be exceeded more than once a year)		
8 hours	9 <sup>a-c</sup>	—	—	—		
24 hours	—	—	—	0.045 <sup>a</sup> (not to be exceeded more than 3 times a calendar year), 0.14 <sup>b,c</sup> (not to be exceeded more than once year)		
1 year	—	—	0.02 <sup>a</sup> , 0.05 <sup>b</sup> , 0.53 <sup>c</sup>	—	Global	WHO, 2005
10 min	—	—	—	0.2		
15 min	—	30000	—	—		
1 hour	—	—	0.11	—		
8 hours	—	5000	—	—		
24 hours	—	—	—	0.01		
1 year	—	—	0.2	—		

long-term exposure.<sup>9–11,21,23</sup> However, the maximum concentration levels of NO<sub>2</sub> that were recorded in the Al-Seeba station were also higher than the recommended concentrations allowed for short-term exposure, as previously reported.<sup>9,11</sup>

Health hazards associated with total HCs were mostly related to the proportion of petroleum hydrocarbon gases (PAHs) that conceded as carcinogenic pollutants.<sup>25</sup> In terms of daily HC intake, the range

would normally span from less than 10 ng to more than 100 ng.<sup>25</sup> In general, the average concentrations of the HCs among the studied locations were high and fell within the hazard range for human and environment health.<sup>25</sup> Generally, the concentrations of CO, NO<sub>2</sub>, SO<sub>2</sub>, and HCs recorded by the previous studies for the last ten years in the region were high. Al-Mayahi<sup>20</sup> reported that CO concentrations ranged from 10 mg/L to 80 mg/L, while Al-Hassan<sup>23</sup> stated



that the average concentration was 27 mg/L. Al-Saad et al<sup>21</sup> indicated that SO<sub>2</sub> concentrations ranged from 10 mg/L to 15 mg/L. In Al-Hassan,<sup>23</sup> the average concentration of CO<sub>2</sub> and NO<sub>2</sub> were 300 mg/L and 3 mg/L respectively. In addition, Al-Saad et al<sup>21</sup> and Al-Hassen<sup>23</sup> reported that the average HCs concentrations were 5 mg/L and 2 mg/L, respectively.

The current concentrations of measured gaseous pollutants in this study were lower than the levels indicated in the previous studies, especially the studies done during the first and second Gulf War. However, the relative reduction in the current concentrations of gaseous pollutants, which are primarily due to a lack of management and technical support of the secondary power plants, did not—with the exception of CO<sub>2</sub> levels—prevent the temporal risk to human health in the Basra region, this according to European, American, Australian, and WHO guidelines.

## Conclusion

The present data may serve as background levels of gaseous pollutant, as most industries currently are on halt. The survey indicates that the impacts from the remaining working electrical power plant in Al-Najibiya and from Abadan's oil refinery are significantly affecting the air quality in the Al-Ashar and Al-Seeba stations, respectively. The recent improvement of the local economy of Basra can play a significant role in changing the environmental structure of the city by building more industrial plants and expanding the original ones. Thus, these changes can have a direct affect not only on the atmosphere of the region but also on the water and soil.

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## Author Contributions

Conceived and designed the experiments: Sh A, HA. Analysed the data: Sh A. Wrote the first draft of the manuscript: SA. Contributed to the writing of the manuscript: SA, AD. Agree with manuscript results and conclusions: AD, SA, HA, Sh A. Jointly developed the structure and arguments for the paper: SA, AD. Made critical revisions

and approved final version: AD, SA, HA, Sh A. All authors reviewed and approved of the final manuscript.

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