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SPATIAL AND TEMPORAL VARIATIONS OF GASEOUS POLLUTANTS INTENSITY IN COSTAL AND COMPLEX SECTORS IN EGYPT

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Abstract

The current study was a comparative study between two different sectors in Egypt, the first is Shoubra El-Khaima (complex: residential, heavy traffic, industrial and agriculture sector) and the second is Ain Sokhna (costal tourist sector) to evaluate some common gaseous pollutants (SO_2, NO_2, NH_3 and H_2S) intensity using one-year (December 2015 - November 2016). Monthly mean concentrations of gaseous pollutants in Shoubra El-Khaima were 92, 78, 68, and 61 µg/m³ for SO_2, NO_2, NH_3 and H_2S, respectively. While in Ain Sokhna the monthly mean concentrations were 19, 22, 24 and 24 µg/m³ for SO_2, NO_2, NH_3 and H_2S, respectively. The concentration levels of all gaseous pollutants in summer months were significantly higher than in the other seasons, while the minimum concentrations were detected in winter months. Generally, very high air gaseous pollutant concentrations were observed in Shobra El-khema for all months compared to Ain Sokhna. The annual mean concentrations in Shoubra El-Khaima sector were about 5, 4, 3 and 3 times higher than that found in Ain Sokhna sector for SO_2, NO_2, NH_3 and H_2S, respectively. Strong positive correlations ranging from 0.93 to 0.986 were found at Ain Sokhna sector suggesting that the gaseous pollutants emit from the same source. While at Shoubra El-Khaima sector, weak to strong positive correlations ranging from 0.206 to 0.798 were observed. Levels of investigated gases at Ain Sokhna sector were lower than the annual Egyptian and international permissible average limit. Ain Sokhna (as costal tourist area) could be considered as a background site with only negligible amounts of local gaseous pollution.

Key words: *Gases pollutants, Complex sector, Costal tourist sector, sulphur dioxide, Nitrogen dioxides, Hydrogen sulfide, Ammonia.*

INTRODUCTION

Gaseous pollutants are originated by combustion of fossil fuels and the vaporization of volatile fuels. Because of their impacts on the atmospheric environment, materials, vegetation and human health, gaseous pollutants have received considerable research and attention. About 90% of the anthropogenic emissions to the atmosphere are gaseous pollutants (Godish, 1997). The anthropogenic sources of gaseous pollutants include thermal power stations, industrial activities, open burning of municipal and hazardous solid wastes, in addition to vehicles emissions (Waked and Afif , 2012). Excessive use of fossil fuel has caused a significant increase of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions (Streets et al., 2003). SO_2 and NO_x pollutants have damaged public health and regional air quality, photochemical smog (Wang and Kwok, 2003), and heavy haze (Liu et al., 2013; Zhao et al., 2016 and Bao et al., 2017). SO_2 and NO_x can be transported away from source areas in association with air flows or dust storms (Bao et al., 2017).

Fuel combustion is the main source of man-made NO_x, it is formed during high-temperature combustion from the oxidation of nitrogen contained in fuels. The other sources of NOx emissions are vehicles, thermal power plants, and industrial activities (Bao et al., 2017). All NO_x is emitted as nitric oxide (NO), which is rapidly oxidized to NO_2 (Kean et al., 2000). NO_2 is an irritating gas, which absorbed into the mucous membrane of respiratory system. Exposure to NO_2 is can increase susceptibility to respiratory diseases (Khare and Nagendra, 2007). Ammonia (NH_3) is originated from decomposition and volatilization of animal wastes, in addition to increases in agricultural livestock and nitrogen fertilization (Sutton et al., 2001). Exposure to low concentration levels of NH_3 can cause irritation of the eyes, nose, and throat of some people. Moreover, exposure to high concentration levels can cause headaches and intense burning of the eyes, nose, throat and skin (Abdel-Latif et al., 2006; Ibrahim et al., 2006). Hydrogen sulfide (H_2S) is originated from the bacterial breakdown of organic matter in the absence of oxygen (anaerobic digestion) (CalEPA, 1999; Gerasimon et al., 2007).

Almost all the released H_2S are to the air, where it exists in the gas phase. H_2S is one of the most commonly occurring toxic air pollutants that at high concentrations (>800 ppm ≈ 1120 ug/m^3) may be fatal if inhaled or absorbed through skin. H_2S is a mucous membrane and respiratory tract irritant and affects all organs, particularly the nervous system. Exposure to typical environmental concentrations of H_2S range from 0.00011 to 0.0003 ppm (0.154 – 0.420 μg/m^3) caused no effect on human health (ATSDR, 2004 ; Abdel-Latif et al., 2006; Zhao et al., 2016). Egypt is currently facing serious air pollution problems. It has experienced rapid growth of populations and economies in recent years. Rapid population growth, economic expansion and high rate of urbanization in Egypt, leads to highly increases of gaseous pollutants in the atmosphere.

Tourism is an important economic sector for Egypt. For tourism-reliant areas it would be useful to know Gaseous pollutants concentration levels. Importance of tourism as well as its impacts on the environment should be studied and measured. However, tourism also contributes to climate change through the emission of gases pollutants through transport, accommodation and other tourist activities. Environmental impacts of tourism and their measurement have also received wide-spread attention.

Impacts have been described on local, regional, national and global concentration levels around the world (Nielsen et al., 2010).

The aim of the present study was a comparative study between two different sectors in Egypt, the first is Shoubra El-Khaima (complex: residential, heavy traffic, industrial and agriculture sector) and the second is Ain Sokhna (costal tourist sector) to evaluate some common gaseous pollutants intensity using one-year (December 2015 - November 2016). Quantification of gaseous pollutants in these regions are of great importance for developing emissions reductions strategies in order to reduce the adverse impacts of gaseous pollutants on human health and environment and improve air quality, especially at tourism regions.

MATERIALS AND METHODS

Sample site description: Field measurements for gaseous pollutants were conducted in two locations in Egypt (Fig. 1).

(i) Shoubra El-Khaima located at north of Greater Cairo (30◦08_N, 31◦34_E) and represents as a complex sector (residential, industrial and agriculture), and it can be regarded as seriously anthropogenic polluted area (El-Dars et al., 2004; Hassanien and Abdel-Latif, 2008; Hassan and Khoder, 2011). Shobra El-khema is located in a high population density section and it is representative of Greater Cairo City metropolitan area. However, it is also affected by heavy road traffic and emissions from industry and -energy power plants.

(ii) Ain Shokna located on the coast of the Gulf of Suez in the Red Sea , 55 kilometers from the city of Suez Governorate in Egypt, surrounded by mountains and represent as one of a costal Tourist site in Egypt. The importance of this city that it is a touristic destination for both internal and external tourism, and has several beaches with tourist villages, hotels and chalets.

Ain Shokna area has oil and gas fields, refining and liquefaction project . In addition to the 22.3 km^2 sea port of Al-Ain Shokna, near the port there is a large refinery for refining sugar and vegetable fuel and an ammonia plant. So, it is important to measure the levels of gaseous pollutants as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ammonia (NH_3) and hydrogen sulfide (H_2S) that can emit from these different industries.

Sampling and analysis: Gaseous pollutants, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ammonia (NH_3) and hydrogen sulfide (H_2S), were measured in ambient air at two sectors (one/week) in the period from December 2015 to November 2016. Reference methods were used for the gases measurement. The absorption method was used for collecting the gaseous samples on a 24-h basis at the two stations.

The sampling equipment consisted of gas bubblers through which the gas sample was drawn, calibrated vacuum pump with flow rate set at 1 L/min and dry gas-meter are connected. The concentration of gaseous pollutants (µg/m^3) was calculated from standard curve and the volume of air sampled.

Sulphur dioxide (SO_2): Modified West and Gaeke method was used for SO_2 analysis in the concentration range from about 0.005 to 5 ppm (13 - 13115 µg/m^3) (West and Gaeke, 1986; Stern, 1986; Harrison and Perry, 1986; CPCB, 2011). The concentrations (µg/m^3) were measured by means of a UV–Visible spectrophotometer at 560 nm, using Novaspec – LKB model 4049 – Biochrom, Cambridge, England, with a blank reagent as reference.

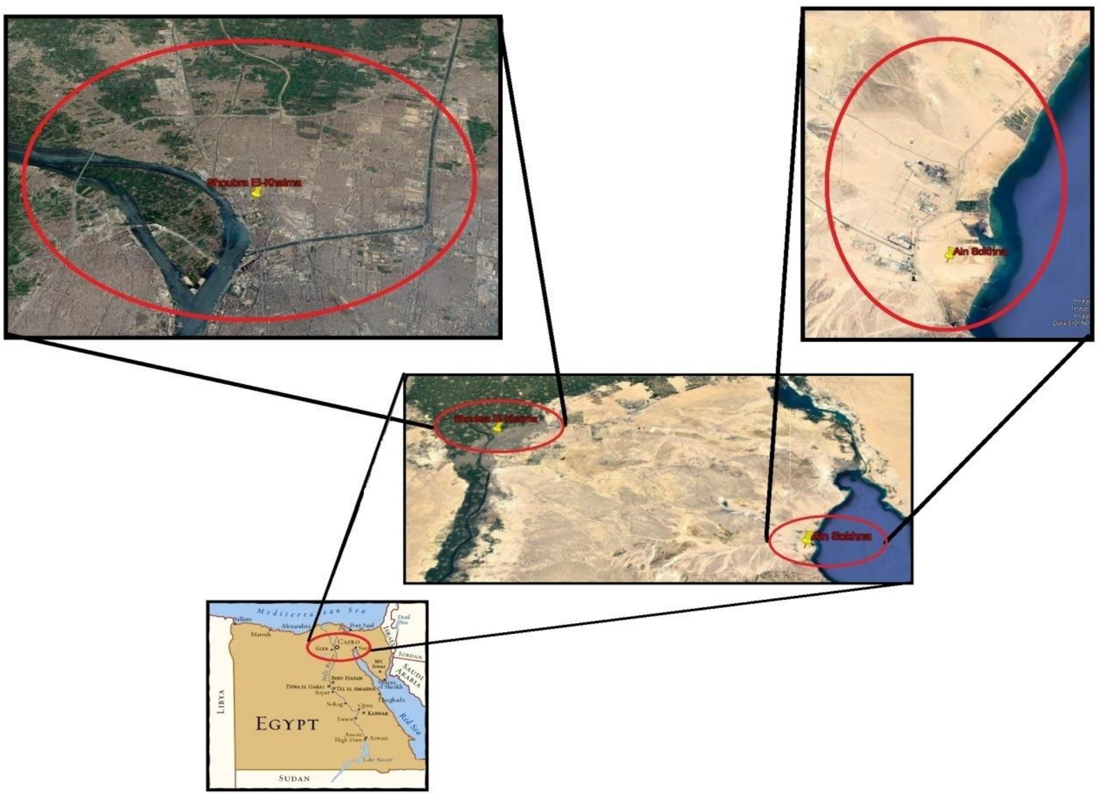

Fig.(1): Map showing the two sampling sectors (Shoubra El-Khaima and Ain Shokna)

Nitrogen dioxide (NO_2): Jacobs and Hochheiser method was used for NO_2 analysis (Stern, 1986; CPCB, 2011). NO_2 was collected by bubbling air through a solution of 0.1N sodium hydroxide.

Ammonia (NH_3): The colorimetric Nessler's method was used for the determination of ammonia (Marr and Cresser, 1983; Patnaik, 1997). Air was aspirated (1 liter/minute) through a glass bubbler sampler containing 50ml of absorbing solution (dilute sulfuric acid) forming ammonium sulfate.

Hydrogen sulfide H_2S: The methylene blue method was used to measure the H_2S levels (Stern, 1986; Alizadeh-Choobaria et al., 2016). Air was aspirated (1 liter/minute) through a glass bubbler sampler containing alkaline suspension of cadmium sulfate hydrate and sodium hydroxide as absorbing solution. Hydrogen sulfide was determined by adding coloring reagent to discharge the yellow colour of ferric ion according to the concentration of hydrogen sulfide.

RESULTS AND DISCUSSION

Fig.(2) shows, monthly mean concentrations of gaseous pollutants in ambient air of the investigated sectors compared to the Egyptian law 4# 1994 (EEAA, 1994) . It shows that, very high air gaseous pollutant concentrations were observed in Shobra El-khaima sector at all months compared to Ain Sokhna sector. Maximum monthly concentrations of all the detected gases at Ain Sokhna sector were 52, 54, 45 and 44 µg/m³ for SO_2, NO_2, NH_3 and H_2S, respectively, found during August 2016. While the minimum levels for SO_2 and NO_2 were 3 and 5 µg/m³ respectively, found during January 2016 and during December 2015, for NH_3 and H_2S (13 and 16 µg/m³, respectively). At Shoubra El-Khaima sector, the higher monthly concentrations of SO_2 (122 µg/m³) were found during September 2016, during August 2016 for NO_2 and NH_3 (120 and 88 µg/m³, respectively), and during June 2016 for H_2S (181 µg/m³). While minimum concentrations were found during February 2016 for SO_2 (181 µg/m³), during January 2016 for NO_2 (33 µg/m³), during December 2015 for NH_3 (47 µg/m³) and during July 2016 for H_2S (36 µg/m³) (as shown in Fig. 2). All the detected concentrations of the investigated gaseous pollutants are less than the Egyptian Permissible Daily (24 Hours) average limit in Annex No. 5 of the Executive Regulations of Law No. 4/1994 amended by Law 9/2009 that were 125 µg/m³ in urban areas and 150 µg/m³ in industrial areas for SO_2, 150 µg/m³ in urban and industrial areas for NO_2, and 120 µg/m³ in urban and in industrial areas for NH_3 (EEAA, 1994) and less than Recommended Exposure Limit (REL) for H_2S amended by The National Institute for Occupational Safety and Health (NIOSH): 10 ppm, for 10-minute (NIOSH, 2016).

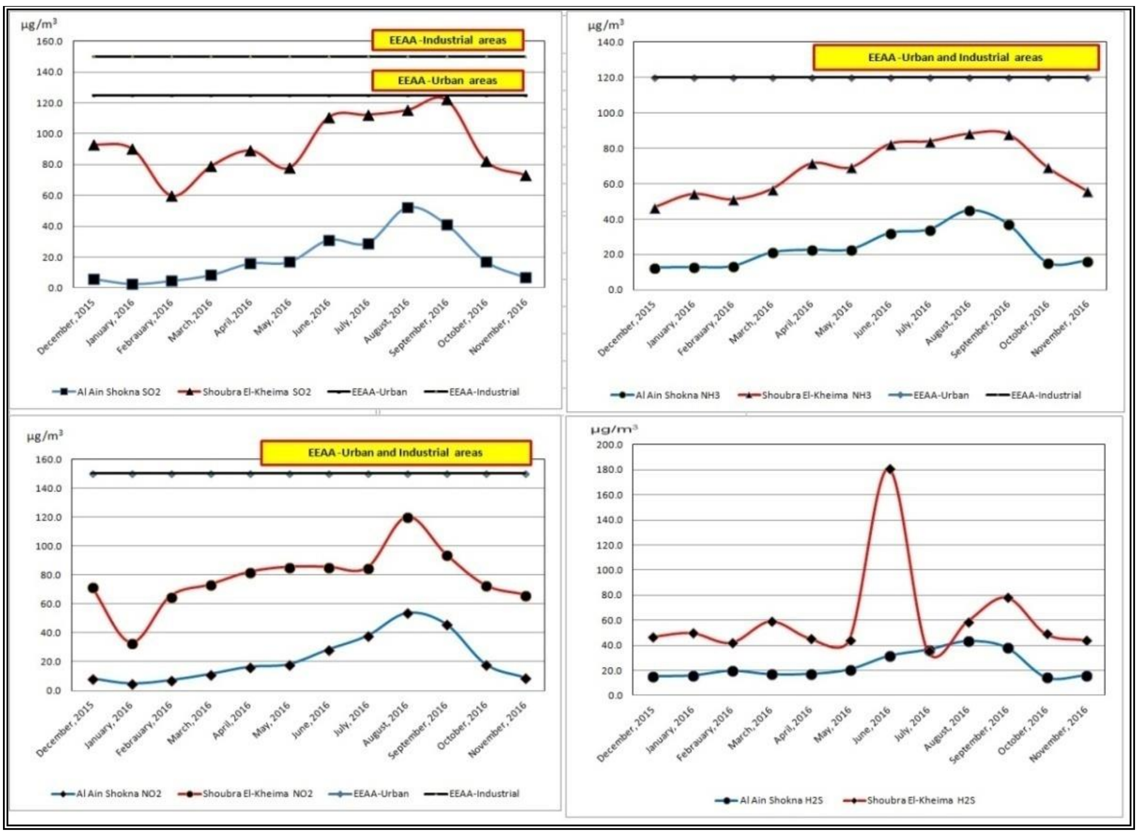

Fig. (2): Monthly mean concentrations of investigated gases in ambient air over the investigated sites.

Fig.(3) and Fig.(4) show maximum, minimum and mean concentrations of each season for the different gaseous pollutants. We can notice that, the concentrations of all measured gases in summer months were significantly higher than those in other seasons, while the minimum concentrations were detected in winter. Seasonal mean concentrations of gaseous pollutants (± SD) and their ratio (summer/winter) in ambient air over the investigated sectors, are represented in Table-1. At Ain Sokhna sector, the mean concentrations show great differences of measured gases during the investigated seasons. SO_2 and NO_2 concentrations at costal tourist sector show high seasonal variations, with ratios of 8 and 6 between their maximum and minimum values (summer/winter ratio) (Table 1). These results are related to two main factors, i.e., anthropogenic emission, as in touristic periods (the summer season), traffic intensity increases, and meteorological conditions (Zhang et al., 2012; Bao et al., 2017). While at Shoubra El-Khaima sector, low seasonal variations, with ratios of 1 and 2 between their maximum and minimum values for SO_2 and NO_2 respectively, due to the main sources are industrial and traffic emissions (Zhang et al., 2009; Bao et al., 2017**).**

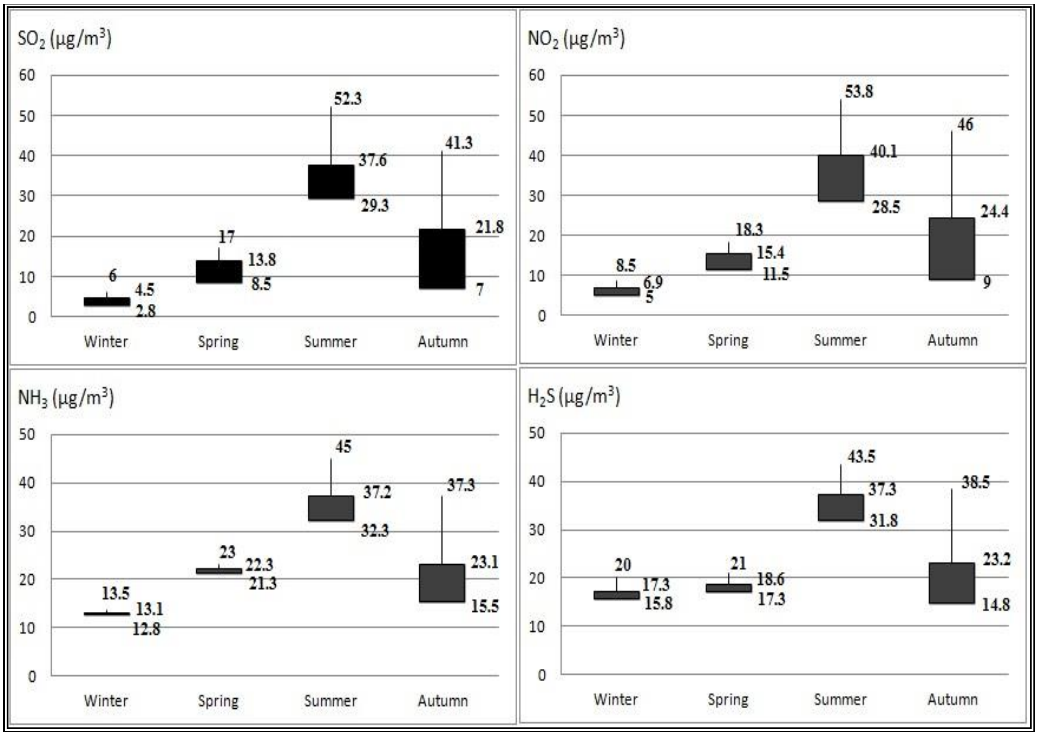

Fig.(3): Seasonal variation of investigated gases in ambient air of Ain Sokhna costal sector.

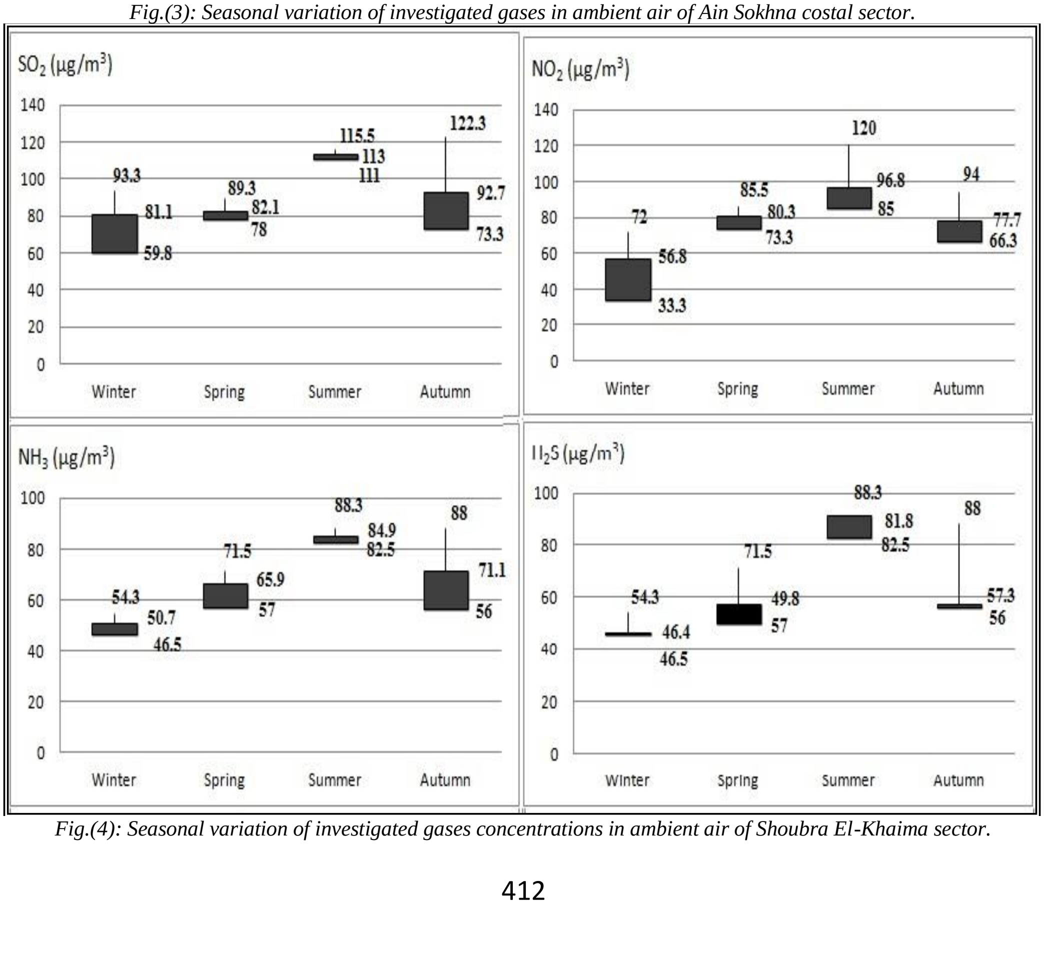

Fig.(4): Seasonal variation of investigated gases concentrations in ambient air of Shoubra El-Khaima sector.

Table (1): Seasonal concentration of investigated gases (± SD) and their ratio in ambient air over the investigated sectors.

Parameter		Dec. 2015– Nov. 2016				
		Winter	Spring	Summer	Autumn	summer/winter ratio
Ain Sokhna	SO_2	5 ± 2	14 ± 5	38 ± 13	22 ± 18	8.3
	NO_2	7 ± 2	15 ± 4	40 ± 13	25 ± 19	5.8
	NH_3	13 ± 0.4	22 ± 1	37 ± 7	23 ± 12	2.8
	H_2S	17 ± 2	19 ± 2	37 ± 6	23 ± 13	2.1
Shoubra El-Khaima	SO_2	81 ± 19	82 ± 6	113 ± 2	93 ± 26	1.3
	NO_2	57 ± 21	80 ± 6	97 ± 20	78 ± 15	1.7
	NH_3	51 ± 4	66 ± 8	85 ± 3	71 ± 16	1.6
	H_2S	46 ± 4	50 ± 8	92 ± 78	57 ± 18	1.9

High concentrations of gaseous pollutants during the heating periods may be due to the relatively low wind speeds and stable conditions leading to strong thermal inversions (Seinfeld and Pandis, 2006). In addition, NO_x emissions from combustion is primarily NO (~90%) and rapidly reacts with O_3 and radicals that increase in hot season, due to strong solar radiation intensity, to form NO_2 (Seinfeld and Pandis, 2006; Masiola et al., 2017). Low gases concentration values in winter could be attributed also to wet weather conditions that clean the pollutants and aerosol loadings (Qu et al., 2016). These results are in contrast to the others in Europe that found higher levels of gaseous pollutants as SO_2 and NO_2 in winter due to coal or biomass burning for domestic heating (Jo et al., 2000; Zhao et al., 2016). As expected, higher summer ammonia and H_2S concentrations were found at the two investigated sectors. These results are consistent with (Ibrahim et al., 2006; Paulot et al.,2014; Masiola et al., 2017).

Fig.(5) shows that the annual mean concentrations in Shoubra El-Khaima were 92, 78, 68, 61 µg/m³ for SO_2, NO_2, NH_3 and H_2S, respectively. While in Ain Sokhna the annual mean concentrations were 19, 22, 24 and 24 µg/m³ for SO_2, NO_2, NH_3 and H_2S, respectively. The comparison obtained between the two investigated sectors show greatly higher concentrations are found in Shoubra El-Khaima sector than Ain Sokhna sector. The annual mean concentrations in Shoubra El-Khaima sector are about 5, 4, 3 and 3 times higher than that found in Ain Sokhna sector for SO_2, NO_2, NH_3 and H_2S, respectively.

These results may be attributed to anthropogenic activities in Shoubra El-Khaima sector, which are the main contributors of air pollution. Furthermore, the serious increase of air pollution occurred in Shoubra El-kheima due to rapidly growing urban populations and concentrated industrial sites (Waked and Afif, 2012). Besides, the presence of two electric power stations in this region, one of them is very large thermal power station using heavy oil most of the time and consequently emit excessive amounts of gases during combustion processes. As the main important sources of SO_2 emissions are thermal power stations (Alizadeh-Choobaria et al., 2016). In addition, the contributions from the petroleum refiners and industry in Mustorod (industrial sector north east of this area), and traffic problems of ring road and Cairo – Alexandria ring road.

Moreover, the annual mean concentration of SO_2 in Shoubra El-Khaima sector was about 1.5 – 1.8 times higher than the annual Egyptian permissible average limit in Annex No. 5 of the Executive Regulations of Law No. 4/1994 amended by Law 9/2009 that were 50 µg/m³ in urban areas and 60 µg/m³ in industrial areas, while the annual mean concentration of NO_2 was about 1.3 times higher than the limit of 60 µg/m³ in urban areas and similar to the limit of 80 µg/m³ in industrial areas (EEAA, 1994). On the other hand, it was interesting to note that the Ain Sokhna sector located in coastal area has low gases values. This could be due to wet weather conditions that cleans the pollutants and aerosol loadings and the place also has a low population density. population density can be treated as a surrogate variable of anthropogenic pollution (Sharma and Kulshrestha, 2014). Levels of the investigated gases in Ain Sokhna costal sector were lower than the annual Egyptian and international permissible average limit (ATSDR, 2004).

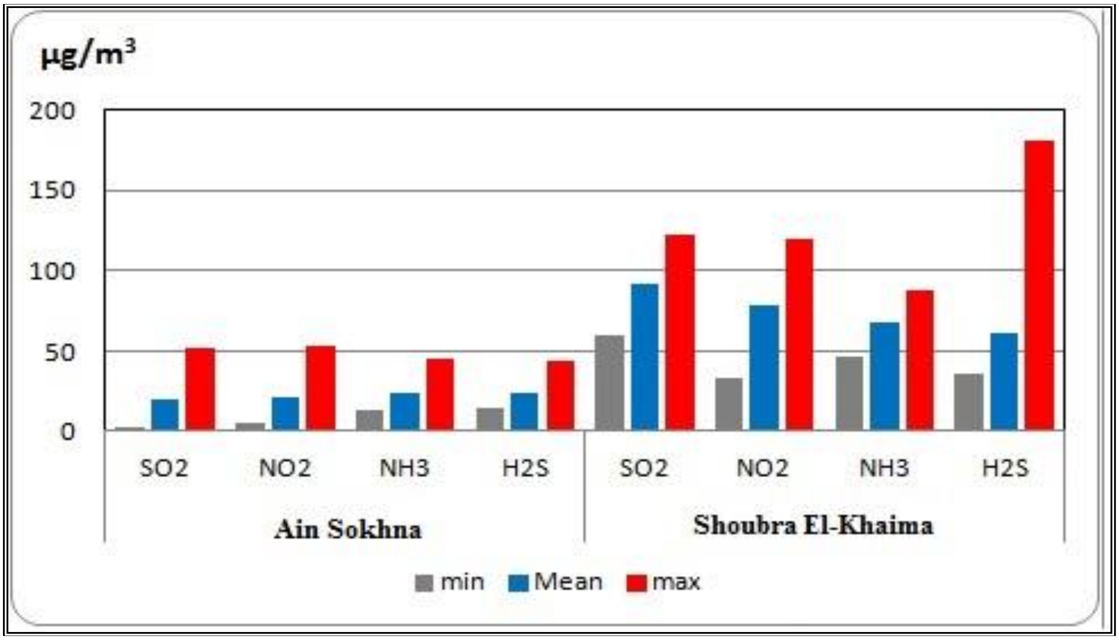

Fig.(5): Annual mean concentrations of investigated gases in ambient air of each sector (Ain Sokhna and Shoubra El-Khaima)

Correlation coefficients of gaseous pollutants (SO_2, NO_2, NH_3 and H_2S) were estimated for concentration levels over the whole sampling campaign at each sector (Table 2) to examine the inter-sector relationships among investigated gases.

Table (2): Correlation coefficients of monthly concentrations between the investigated gases at investigated sectors

Pollutant	Ain Shokna				Shoubra El-Khaima			
µg/m³	SO_2	NO_2	NH_3	H_2S	SO_2	NO_2	NH_3	H_2S
SO_2	1				1			
NO_2	0.986	1			0.566	1		
NH_3	0.963	0.9643	1		0.798	0.758	1	
H_2S	0.93	0.9516	0.0952	1	0.427	0.206	0.39	1

Results in the current study are showed that many of the gaseous pollutants measured have strong positive correlations ranging from 0.93 to 0.986 at Ain Sokhna costal sector suggesting that the investigated gases emit from the same source. While at Shoubra El-Khaima sector, weak to strong positive correlations ranging from 0.20 to 0.80 are observed may be due to there are different common pollutant sources contributing gaseous pollutants mainly from combustion processes of traffic and industries emissions.

Table 3 shows the annual mean concentrations of the selected gaseous pollutants of Shoubra El-Khaima and Ain Sokhna in comparison with other works. The table shows that the annual mean concentrations of SO2 and NO2 at Shoubra El-Khaima were much lower than in many cities in China (Liu and Zhang, 2009) but SO2 was higher than different cities in many countries as Al-Ain in United Arab Emirates (Waked and Afif, 2012), Eskisehir, Ankara and Izmir in Turkey (Özden et al., 2008) and Bucharest in Romania (Zhao et al., 2016), while at Ain Sokhna it was lower than most of those cities.

The annual mean concentrations of NH3 at both Shoubra El-Khaima and Ain Sokhna were higher than that found in Al-Ain in United Arab Emirates, Pearl river Delta in China, Agra in India, Seoul-South in Korea, Kanto in Japan and California in USA (Salem et al.,2009; Bao et al., 2017; Parmar et al., 2001; Lee et al., 1999; Sakurai et al., 2003; and Bytnerowiez et al., 2002).

Table.3: Comparing the current results with other reported ones are represented.

Country		SO_2	NO_2	NH_3	H_2S	Reference
Egypt	Shoubra El-Khaima	92	78	68	61	The current study
	AinSokhna	19	22	24	24	
	Cairo	28-69	36-64	189.9-237.2	95-252	EEAA, 2009 Saleh, 2002 Hassanien, 2009
United Arab Emirates	Al-Ain	60	-	9.65	-	Waked and Afif, 2012 Salem et al.,2009
China	Taiyuan-Shanxi	592	-	-	-	Liu and Zhang, 2009
	Chongqing-Chongqing	364	-	-	-	
	Shenyang-Liaoning	97	-	-	-	
	Pearl river Delta	5.4-186	12.2-238.8	7.3	-	Hu et al., 2008 Meng et al., 2010 Bao et al., 2017
India	Agra	-	-	11.3	-	Parmar et al., 2001
Korea	Seoul-South	-	-	4.43	-	Lee et al., 1999
Japan	Kanto	-	-	10	-	Sakurai et al., 2003
Turkey	Eskisehir	47.13	-	-	-	Özden et al., 2008
	Ankara	30	-	-	-	
	Izmir	38	-	-	-	
Greece	Thessaloniki	-	-	-	8-20	Kourtidis et al., 2008
Romania	Bucharest	10	71	-	-	Zhao et al., 2016
USA	California	-	-	1.6 – 4.5	-	Bytnerowiez et al., 2002
Great Britain	London	23.7	-	-	-	Wonget al., 2002
Hong Kong	Hong Kong	17.7	55.9	-	-	
Brazil	SaoPaulo	18.9	-	-	-	Sharovsky et al., 2004

CONCLUSION

One year-long sampling campaign of gaseous air pollutants SO_2, NO_2, NH_3 and H_2S, were conducted at two different sectors, the first of them taken as representative of complex sector in Cairo City (Shobra El-khaima) and the second sector is taken as representative of costal area (Ain Sokhna) for the purpose of comparison. The paper carried out to study the monthly, annual and seasonal, cycles of gaseous pollutants at the two investigated sectors to study enables some general considerations about air quality status in these sectors. Gaseous emissions need to be quantified and monitored at Ain Sokhna costal sector in order to reduce the negative impact these pollutants on this region as a costal touristic area. Generally, very high air gaseous pollutant concentrations are observed in Shobra El-khaima at all months compared to Ain Sokhna costal sector. Monthly mean concentrations of gaseous pollutants at the two investigated sites are less than the Egyptian permissible daily (24 Hours) average limit in Annex No. 5 of the Executive Regulations of Law No. 4/1994 amended by Law 9/2009. Furthermore, the maximum levels were recorded during summer season, while minimum levels are recorded during winter season. Shobra El-Khaima sector has dominated the emissions of gaseous pollutants and urgently needs to strengthen the control of their emissions, especially SO_2 and NO_2

emissions. Levels of investigated gases at Ain Sokhna sector are lower than the annual Egyptian and international permissible average limit.

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