Estimation of hospital admission respiratory disease cases attributed to exposure to SO_2 and NO_2 in two different sectors of Egypt

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Abstract

Air Q $_{2.2.3}$ was used to predicted hospital admissions respiratory disease cases due to SO_2 and NO_2 exposure in two sectors of Egypt during December 2015 to November 2016. Levels were 19, 22 μg/m³ at Ain Sokhna sector and 92, 78 μg/m³ at Shoubra El-Khaima sector for SO_2 and NO_2, respectively. These levels were less than the Egyptian Permissible limits (125 μg/m³ in urban and 150 μg/m³ in industrial for SO_2, 150 μg/m³ in urban and industrial for NO_2). Results showed that relative risks were 1.0330 (1.0246 - 1.0414) and 1.0229 (1.0171 - 1.0287) at Ain Sokhna sector while they were 1.0261 (1.0195 -1.0327) and 1.0226 (1.0169 - 1.0283) at Shoubra El-Khaima sector for SO_2 and NO_2, respectively.

The highest cases of HARD were found in Shoubra El-Khaima sector; 311 cases at 120 - 129 μg/m3 of SO_2 and 234 cases at 120 - 129 μg/m³ of NO_2. While, in Ain Sokhna, HARD were 18 cases at 50 - 59 μg/m³ of SO_2 and 15 cases at 60 - 69 μg/m³ of NO2. The excess cases found in Shoubra El-Khaima sector as compared to those in Ain Sokhna sector, may be attributed to the higher density of population and industries in Shoubra El-Khaima sector.

Keywords: AirQ$_{2.2.3}$ model; Hospital admissions respiratory disease (HARD); Nitrogen dioxide (NO_2); Sulfur dioxide (SO_2); Coastal Sectors.

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Introduction

Air is an important factor for the living organisms and without air there is no life on earth. Thus, breathing clean air, and study air which entering the human body through inhalation is of utmost importance[1]. Air pollution is one of the most important issues in the urban areas that eclipsed the human's life. Atmospheric pollutants (as SO_2 and NO_2) were emitted into ambient air by natural and man-made emission sources; including volcanoes, sea spray, industrial activities, power plants and road traffics[2-4]. Sulfur dioxide (SO_2) is a colorless gas that is released from burning of diesel fuel. SO_2 may cause irritation, decrease of visibility and some respiratory illness[5].

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The main sources of sulfur dioxide (SO_2) are various industrial processes, transportation and vehicles, economic development through the use of excess energy, power plants and fuel burning. Several previous studies showed a connection between sulfur dioxide exposure and hospital admissions respiratory diseases[6-8]. Nitrogen dioxide (NO_2) is a gas with oxidant properties capable of contaminating ambient air in many urban and industrial contexts. NO_2 is mainly derived from oxidation of nitrogen oxide (NO) by atmospheric oxidants such as O3. Human activities in the urban areas represent the main sources of NO_2; from automobile exhaust emissions to stationary sources such as power plants, agricultures and industrial activities[9-10]. SO_2 and NO_2 might be absorbed into body through the nose and mouth to reach the lungs.

The previous studies on health effects of traffic emissions and criteria air pollutants confirmed the harmful health effects of air pollutants, even at low concentrations[3,11-12]. Population growth, increased vehicles (Traffic), industrialization and etc were the main factors that affecting levels of pollutants in the ambient air[13]. The World Health Organization (WHO) had estimated that annually 800,000 people prematurely die around the world, due to cardiovascular and respiratory diseases, and lung cancer which are caused by air pollution[14]. Most of the Epidemiological studies had focused on the health effect of particulate matters. However, criteria gaseous pollutants such as nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) also had adverse effects on human health[15-21].

In recent years, several hundred epidemiological studies showed that increase in the air pollutants concentrations could increase cases in hospital admission for respiratory diseases[22-35]. SO_2 and NO_2 are very soluble in the upper respiratory tract and thus may produce an urgent irritant effect on the respiratory mucosa[36-40]. There are several models, mainly based on statistical/epidemiological measures, for the assessment of health effects (short-term exposure) attributed to air pollutants[20,38,41-61].

The statistical/epidemiological models integrate the air quality data at concentration intervals with epidemiological parameters such as relative risk (RR), baseline incidence (BI) and attributable proportion (AP) for the quantification of morbidity due to exposure to the air pollutants[62-63]. The AirQ2.2.3 software has been used in several epidemiological studies in the world to assess the short-term and long-term health impacts of atmospheric pollutants on morbidity and mortality cases[9,54,64].

In the present study, Air Q 2.2.3 Software was proven to be a valid and reliable tool to the quantification of the potential short-term effects of SO_2 and NO_2, and predicts hospital admissions respiratory diseases (HARD) cases attributed to SO_2 and NO_2.

The main objective of this study was the assessment of health impacts (hospital admissions respiratory diseases (HARD)), by using Air Q 2.2.3 Software, attributed to SO_2 and NO_2 in ambient air of two different sectors in Egypt (Shoubra El-Khaima and Ain Sokhna sectors) during the period from December 2015 to November 2016.

Material and methods

Investigated sectors description

This study was carried out in Shoubra El-Khaimasector (30° 7' 43" N, 31° 14' 32" E) and Ain Sokhna sector (29° 36' 0" N, 32° 19' 0.1" E) (Fig. 1). Shoubra El-Khaima is located in Qalyubia Governorate along the Northern edge of Cairo Governorate. It forms part of the Greater Cairo agglomeration. In addition, it is residential sector with high population density. Also, it contains energy power plants, highly traffic density, industrial and agriculture activities[65-67].

Ain Sokhna is a town in Suez Governorate, lying on the western shore of the Red Sea's Gulf of Suez. It is situated 55 km South of Suez and approximately 120 km East of Cairo. It is surrounded by mountains and represents one of the remote or costal tourist sites in Egypt. It has several beaches and tourist villages, with hotels and chalets. Also, it has oil and gas fields, refining and liquefaction projects, AinSokhna port have a large refinery for refining sugar and vegetable fuel and an ammonia plant.

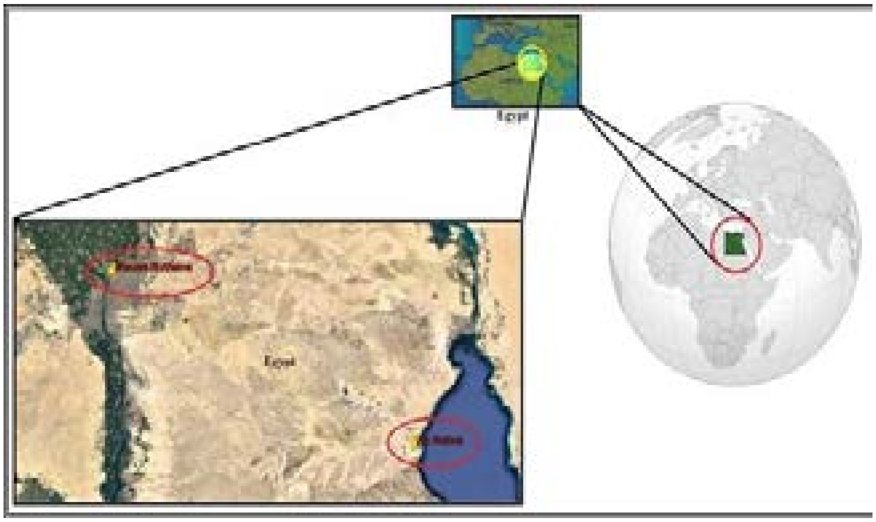

Fig. (1): Investigated sectors

Sampling and analysis

Gaseous pollutants, sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) were measured in ambient air at two sites biweekly in the period from December 2015 to November 2016. The absorption method was used for collecting the gaseous samples on a 24-h basis at the two sites. 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. Reference methods (Modified West and Gaeke method for SO_2; Jacobs and Hochheiser method for NO_2) were used for gases analysis. The concentration of gaseous pollutants (µg/m^3) was calculated from standard curve and the volume of air sampled[68-70].

AirQ$_{2.2.3}$ Software

The Air Quality Health Impact Assessment (AirQ2.2.3 model) is software provided by WHO to assess the health outcome of air pollutants[20,71-72]. The tools to model health impacts assessment combine the data of air quality and epidemiological parameters including relative risk (RR), attributed proportion (AP), and baseline incidence (BI) and present the results in the form of the morbidity rate[9,73]. AirQ calculated the short-term potential effects of the exposure to atmospheric pollutants (SO_2 and NO_2) on health of human living in the sampling sites during one-year (December 2015 - November 2016). The assessment was based on attributable proportion that is identified as the portion of the health effect in a particular population attributable to a certain air pollutant[20,74]. Attributable Proportion (AP), Relative Risk (RR) and Based Incidence (BI) used for each health consequences. Relative risks (RR) with 95% confidence interval (CI) for each 10 µg/m^3 increase in daily mean concentrations of SO_2 and NO_2 pollutants have been reported. The amount of AP can be calculated by using the Eq. (1)[20,39,75].

Where, AP: the attributable proportion of the health impacts.

RR: the relative risk for a given in category "c" of exposure, obtained from the exposure–response functions derived from epidemiological studies

P(c): represented the exposed population.

Relative risk (RR) was the attributable health risk attributed to people who have defined exposures. If the baseline incidence and population number of the health impact in the population under study were known, the number of excess cases attributable to exposure could be calculated[76]. It was worth mentioning that the AirQ was one of the best methods to quantify the effects of pollutants on the basis of "risk assessment"; it was mostly an epidemiological statistics and was presented in 2004 by the World Health Organization (WHO)[77]. This model being a valid and reliable tool for predicting short-term effects of air pollutants and enables the user to evaluate the potential effects of human exposure to an identified contaminant in urban areas during a specific time[64,74,78].

Relative Risk (RR) was calculated by using the Eq. (2) [55,77,79-81]:

Where B = lower (0.0006), (mean 0.0008) and higher (0.0010)

X = Annual mean concentration (µg/m^3)

Xo = Baseline (Threshold) concentration (µg/m^3)

If the baseline frequency of the health impacts in the population under investigation was known, the rate attributable to the exposure can be calculated as follows [9,20]:

Where IE is the rate of the health impacts attributable to the exposure and I isthe baseline frequency of the health impacts in the population under investigation. Finally, knowing the size of the population, the number of cases attributable to the exposure can be estimated as follows [80-81]:

Where NE is the number of cases attributed to the exposure and N is the size of the population investigated.
In this studied the population equivalent to 1,142,949 and 5725 people in Shoubra El-Khaima and Ain Sokhna sectors, respectively[82].

Input adjustment
AirQ2.2.3 model was used to assess the Hospital admission respiratory diseases (HARD) related to the daily data for SO_2 and NO_2 concentrations during December 2015 to November 2016. The AirQ software tool required the data based on gravimetric unit (μg/m^3). The required statistical indicators including the annual mean, the seasonal mean for warm (spring and summer) and cold (autumn and winter) seasons, the annual and seasonal maximum of SO_2 and NO_2, were extracted. Concentrations were divided into 10 μg/m^3 categories. The data for the population, which were taken from the Central Agency for Public Mobilization & Statistics of Egypt[82]; relative risk; and baseline frequency of the health effect, were entered into AirQ2.2.3 software to estimate the number of cases of HARD attributable to SO_2 and NO_2 exposure. Note that the relative risk and baseline frequency parameters and the attributable proportion are different for different pollutants. Finally, the association between air pollution and hospital admissions respiratory diseases (HARD) was assessed using AirQ2.2.3 Software (Fig. 2).

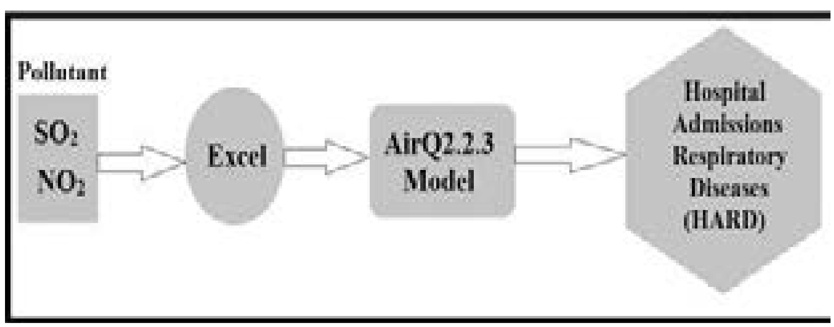

Fig. (2): Schematic plane of study

Results and dissucion
Table 1 shows the concentration levels of SO_2 and NO_2 in Ain Sokhna and Shoubra El-Khaimasectors during December 2015 – November 2016. Environmental Data were classified into two seasons: warm seasons (i.e. spring and summer) and cold seasons (i.e autumn and winter). According to (Table 1), the mean concentration of SO_2 and NO_2 in warm seasons was higher than that of cold seasons. The higher concentration levels were attributed to the impact of weather conditions, geographical locations and anthropogenic activities. All the detected concentrations of the investigated gases (SO_2 and NO_2) were 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 and 150 μg/m³ in industrial for SO_2, 150 μg/m³ in urban and industrial for NO_2[83-84].
This study attempted to carry out an estimation of hospital admission respiratory diseases (HARD) cases related to the investigated gases (SO_2 and NO_2) in Ain Sokhna and Shoubra El-Khaima sectors during (December 2015 – November 2016). Table 2 shows the summary of the statistics of SO_2 and NO_2 concentration levels in sampling sites. The results showed that annual mean were 19 and 22 μg/m^3 for SO_2 and NO_2, respectively in Ain Sokhna sector; 92 and 78 μg/m^3 for SO_2 and NO_2, respectively in Shoubra El-Khaimasector; which are lower than the Egyptian limit of 125 μg/m³ in urban and 150 μg/m³ in industrial for SO_2, 150 μg/m³ in urban and industrial for NO_2[83-84] (EEAA, 1994 and 2009). Table 3 presents

the values of relative risks (RR) and baseline frequency (I) used to estimate HARD attributable to SO_2 and NO_2 exposure in the sampling sites.

The attributable proportion (AP) expressed as percentage and number of excess cases for HARD due to SO_2 and NO_2 exposure in the sampling sites were quantified by AirQ2.2.3 model based on the above environmental data (Table 4). The numbers of excess HARD due to SO_2 and NO_2 exposure for a concentration interval of 10 μg/m^3 were summarized in Table (5). The results may be attributed to high density of population and industries in Shoubra El-Khaima sector than in Ain Sokhna costal sector, which agreement with that found by[87].

Table 1: The monthly mean concentrations (μg/m^3) of Pollutants (SO_2 and NO_2) in sampling sites (December 2015 – November 2016)

Month	Ain Sokhna		Shoubra El-Khaima		Month	Ain Sokhna		Shoubra El-Khaima	
	SO_2	NO_2	SO_2	NO_2		SO_2	NO_2	SO_2	NO_2
Dec-15	6	8	93	72	Jun-16	31	29	111	86
Jan-16	3	5	90	33	Jul-16	29	38	113	85
Feb-16	7	7	60	65	Aug-16	52	54	116	120
Mar-16	9	12	79	73	Sep-16	41	46	92	94
Apr-16	16	17	89	82	Oct-16	17	18	83	73
May-16	17	18	78	86	Nov-16	7	9	73	66

Table 2: Summary of Pollutants (SO_2 and NO_2) concentrationin sampling sites (December 2015 – November 2016)

Site / Pollutant (μg/m^3)		Ain Sokhna		Shoubra El-Khaima	
		SO_2	NO_2	SO_2	NO_2
Cold seasons*	Mean	13	16	82	67
	Maximum	45	57	136	100
	Day Count	24	24	24	24
Warm seasons**	Mean	26	28	98	89
	Maximum	56	60	130	130
	Minimum	24	24	24	24
Annual mean	Mean	19	22	92	78
	Maximum	56	60	136	130
	Day Count	48	48	48	48
98th percentile		56	57	115	123

* Cold seasons in Egypt are winter and autumn seasons.

** Warm seasons in Egypt are summer and spring seasons.

Table 3: The values of relative risk (RR) and baseline frequency (I) used to estimate hospital admissions respiratory diseases (HARD) attributable to SO_2 and NO_2 exposure in sampling sites

Health impacts /Site/ Pollutant			I	RR (95% CI) per 10 μg/m^3
Hospital Admissions Respiratory Diseases (HARD)	AinSokhna	SO_2	37	1.0330 (1.0246 - 1.0414)
		NO_2		1.0229 (1.0171 - 1.0287)
	Shoubra El-Khaima	SO_2	77	1.0261 (1.0195 -1.0327)
		NO_2		1.0226 (1.0169 - 1.0283)

Table 4: The attributable proportion (AP) expressed as percentage and number of excess cases for HARD due to SO_2 and NO_2 exposure in sampling sites

Site / Pollutant	AinSkhona		Shoubra El-Khaima	
	SO_2	NO_2	SO_2	NO_2
AP (%)	0.007	0.008	0.026	0.024
Number of excess cases (persons/year)	45	47	1337	1247

Table 5: Number of excess for HARD due to SO_2 and NO_2 exposure in sampling sites

Concentration (µg/m^3)	Cummulative number per 100,000 person				Concentration (µg/m^3)	Cummulative number per 100,000 person			
	AinSkhona		Shoubra El-Khaima			AinSkhona		Shoubra El-Khaima	
	SO_2	NO_2	SO_2	NO_2		SO_2	NO_2	SO_2	NO_2
< 10	0	0	0	0	130 – 139	0	0	0	0
10 – 19	2	1	0	0	140 – 149	0	0	0	0
20 – 29	4	4	0	0	150 – 159	0	0	0	0
30 – 39	8	5	4	2	160 – 169	0	0	0	0
40 – 49	14	9	7	19	170 – 179	0	0	0	0
50 – 59	18	14	27	29	180 – 189	0	0	0	0
60 – 69	0	15	36	72	190 – 199	0	0	0	0
70 – 79	0	0	92	113	200 – 249	0	0	0	0
80 – 89	0	0	144	166	250 – 299	0	0	0	0
90 – 99	0	0	180	186	300 – 349	0	0	0	0
100 – 109	0	0	254	201	350 – 399	0	0	0	0
110 – 119	0	0	281	225	> = 400	0	0	0	0
120 – 129	0	0	311	234					

One of the outputs of the AirQ2.2.3 model was a graph in which the cumulative number of cases was plotted with some concentration intervals for each health effects attributed to the pollutant (Figs. 3 - 6). According to the results of this study, the highest excess cases of HARD due to SO_2 and NO_2 exposure were found in Shoubra El-Khaimasector; 311 cases attributed to exposure to SO_2 occurred in concentrations range of 120 - 129 µg/m^3 and 234 cases attributed to exposure to NO_2 occurred in concentrations range of 120 - 129 µg/m^3. While in Ain Sokhna sector, the excess cases of HARD due to SO_2 and NO_2 exposure were 18 cases (attributed to exposure to SO_2 occurred in concentrations ranges of 50 - 59 µg/m^3) and15 cases attributed to exposure to NO_2 occurred in concentrations ranges of 60 - 69 µg/m^3). Attributable proportion could be calculated with respect to baseline frequency (37 and 77 cases per 100,000 people in Ain Sokhn and Shoubra El-Khaima sector, respectively). These results indicated that the number of HARD in Shoubra El-Khaima sector was higher than that in Ain Sokhna sector, which attributed to higher levels of SO_2 and NO_2 due to anthropogenic activities and the excess population in Shoubra El-Khaima sector.

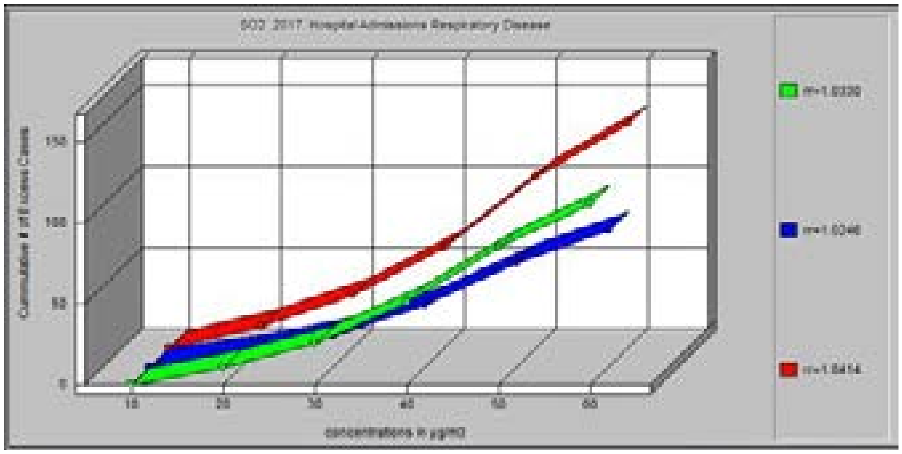

Fig. 3: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) Attributable to SO_2 exposure in Ain Sokhna sector during December 2015 – November 2016

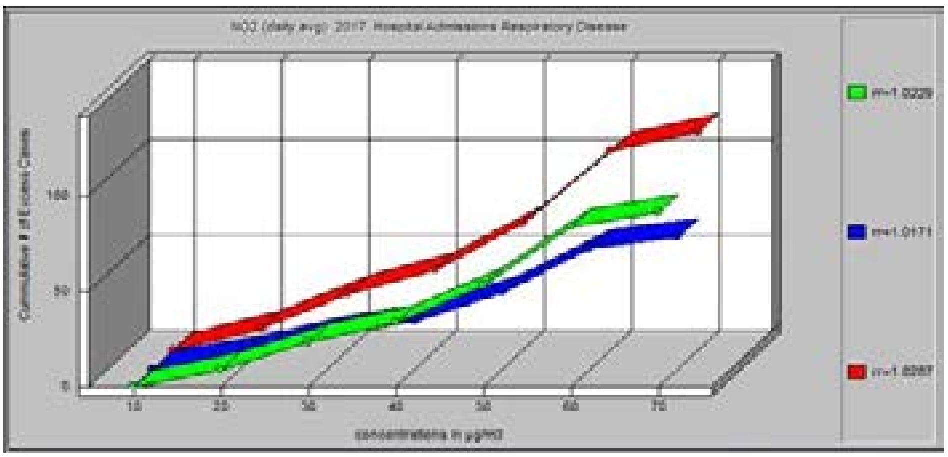

Fig. 4: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) Attributable to NO_2 exposure in Ain Sokhna sector during December 2015 – November 2016

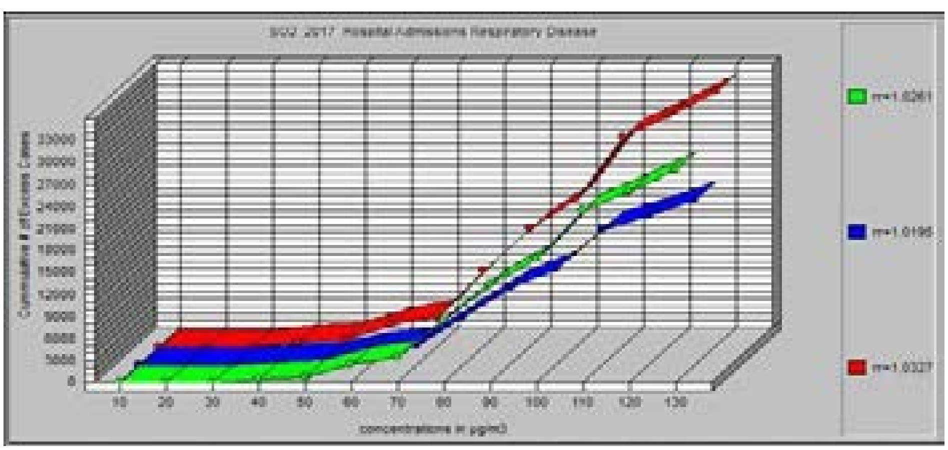

Fig. 5: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) Attributable to SO_2 exposure in Shoubra El-Khaima sector during December 2015 – November 2016

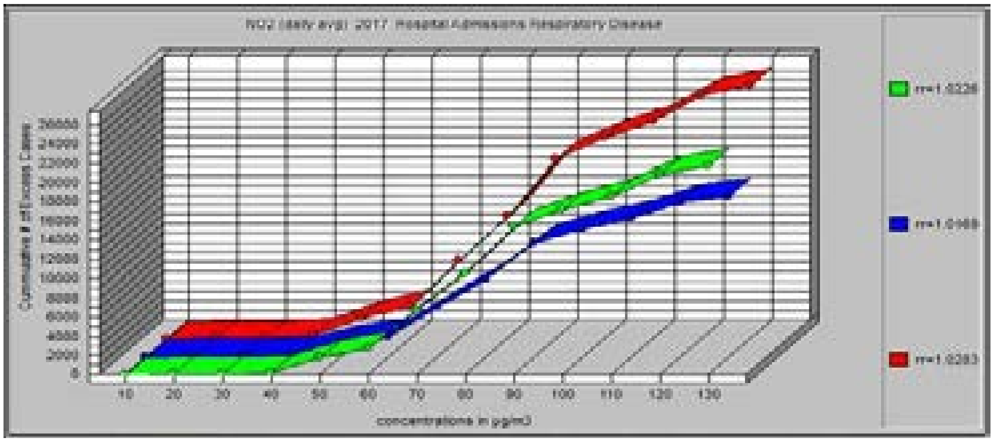

Fig. 6: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) Attributable to NO_2 exposure in Shoubra El-Khaima sector during December 2015 – November 2016

In addition, Fig. (7) Illustrates the percentage of time (person - day) that people in investigated sectors were in exposed to different levels of SO_2 and NO_2 during December 2015 to November 2015 and number of caes per 100000 people. Also these figures showed that, the highest percentage of person-days occurred in concentration interval of (< 10 µg/m^3) for SO_2 and NO_2, led to minimize the HARD among the inhabitants of Ain Sokhna costal sector. While, the higher percentage of person-days associated with different levels of SO_2 and NO_2 in Shoubra El-Khaima sector were detected in the interval concentrations of (70 – 79 µg/m^3) and (60–69 µg/m^3), for SO_2 and NO_2 respectively, which resulted to higher HARD among the inhabitants.

Table 6 shows the comparison between the current study and different countries around the world. It illustrated that the excess cases of HARD attributed to exposure to SO_2 and NO_2 in Shoubra El-Khaima sector were much higher than that found in cities of Iran, USA, Spain, UK, Italy, Netherlands, France, and Sweden. While the excess cases of HARD attributed to exposure to SO_2 and NO_2 in Ain Sokhna sector were similar to that found in cities of Iran, Spain, UK, Italy, Netherlands, and France.

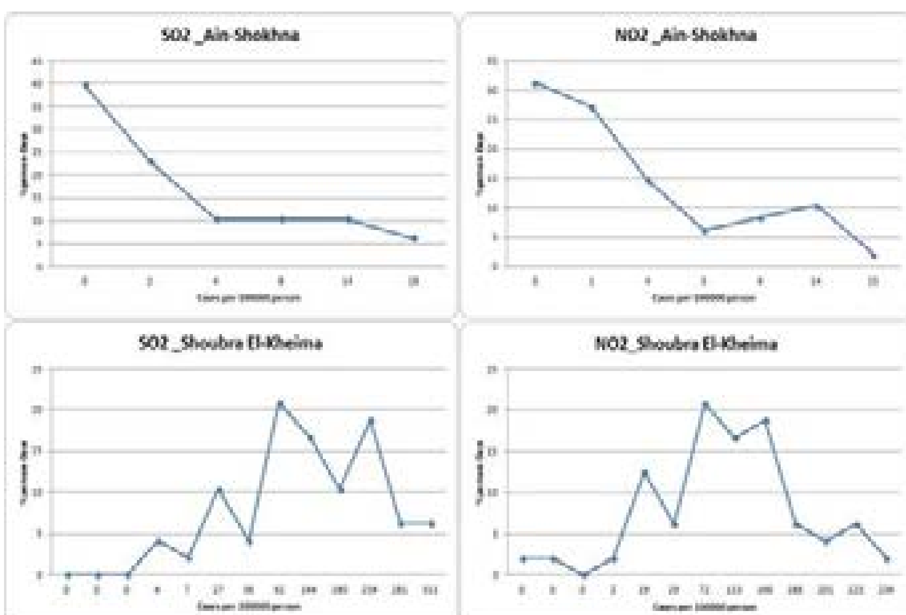

Fig. 7: Percentage of times that people were exposed to different concentrations of air pollutant (SO_2 and NO_2) in investigated sectors

Table 6: Comparison between the current study and different countries around the annual concentration world

Country		SO_2 Conc. (μg/m³)	SO_2 HARD (case)*	NO_2 Conc. (μg/m³)	NO_2 HARD (case)*	Reference
Egypt	Ain Sokhna	19	45	20	47	The current study
	Shoubra El-Khaima	92	1337	78	1247	
Iran	Tabriz	34	32	19	15	Ghozikalia et al.,[79]
	Tehran	58	298	89	247	Naddafi et al. [85]
	Kermanshah	-	-	76	497	Khaniabadi et al., [86]
	Ahvaz	37	24	160	13	Geravandi et al. [7,87]
	Boushehr	56	67	47	27	Arfaeinia et al.,[88]
	Shiraz	74	115	63	43	Mohammadi et al.,[89]
USA	New York	10	4	23	12	Lippmann et al. [90]
Spain	Barcelona	-	-	95	36	Atkinson et al.,[91] Fattore et al.[9] Naddafi et al. [85]
UK	Birmingham	24	18	76	58	
	London	24	55	96	150	
Italy	Milan	29	8	147	38	
	Rome	10	19	140	52	
	Rezzato	-	-	77	4	
Netherlands	Netherlands	9	51	50	206	
France	Paris	18	23	87	64	
Sweden	Stockholm	4	10	36	35	

* The excess cases per 100,000 people.

Conclusion

Air Q 2.2.3 Software was proven to be a valid and reliable tool to the quantification of the potential short-term effects of SO_2 and NO_2, and predicts hospital admissions respiratory diseases (HARD) cases attributed to SO_2 and NO_2. The main objective of this study was the assessment of health impacts (HARD) attributed to SO_2 and NO_2 in ambient air of two different sectors in Egypt (Shoubra El-Khaima and Ain Sokhna sectors) during the period from December 2015 to November 2016.

The concentration levels of SO_2 and NO_2 in Ain Sokhna and Shoubra El-Khaima sectors were classified into two seasons: warm seasons (i.e. spring and summer) and cold seasons (i.e autumn and winter). The results showed that annual mean concentrations were 19 and 22 μg/m³ for SO_2 and NO_2, respectively in Ain Sokhna sector; 92 and 78 μg/m3 for SO_2 and NO_2, respectively in Shoubra El-Khaima sector. The concentrations of the investigated gases (SO_2 and NO_2) were less than the Egyptian permissible daily (24 Hours) average limits (125 μg/m³ in urban and 150 μg/m³ in industrial for SO_2, 150 μg/m³ in urban and industrial for NO_2). The mean concentrations of SO_2 and NO_2 in warm seasons were higher than that of cold seasons. High concentration levels were attributed to the impact of weather conditions, geographical location, anthropogenic activities.

The relative risk (RR), with 95% confidence interval (CI) per 10 μg/m³, were 1.0330 (1.0246 - 1.0414) and 1.0229 (1.0171 - 1.0287) for SO_2 and NO_2, respectively in Ain-Sokhna sector, while they were 1.0261 (1.0195 -1.0327) and 1.0226 (1.0169 - 1.0283) for SO_2 and NO_2, respectively in Shoubra El-Khaima sector. The attributable proportion (AP) were 0.007 and 0.008 for SO_2 and NO_2, respectively in AinSokhna sector, while it were 0.026 and 0.024 for SO_2 and NO_2, respectively in Shoubra El-Khaima sector.

The highest excess cases of HARD due to SO_2 and NO_2 exposure were found in Shoubra El-Khaima sector (311 cases attributed to exposure to SO_2 occurred in concentrations range of 120 - 129 μg/m³; and 234 cases attributed to exposure to NO_2 occurred in concentrations range of 120 - 129 μg/m³). While, in Ain Sokhna HARD were 18 cases, attributed to exposure to SO_2 occurred in concentrations range of 50 - 59 μg/m³, and 15 cases attributed to exposure to NO_2 occurred in concentrations range of 60 - 69 μg/m³. The results may be attributed to high density of population and industries in Shoubra El-Khaima sector than in Ain Sokhna costal sector. The excess cases of HARD attributed to exposure to SO_2 and NO_2 in Shoubra El-Khaima sector were much higher than that found in cities of Iran, USA, Spain, UK, Italy, Netherlands, France, and Sweden. While the excess cases of HARD attributed to exposure to SO_2 and NO_2 in Ain Sokhna sector were similar to that found in cities of Iran, Spain, UK, Italy, Netherlands, and France. The highest percentage of person-days occurred in concentration interval of (< 10 μg/m^3) for SO_2 and NO_2, led to minimize the HARD among the inhabitants of Ain Sokhna costal sector. While, the higher percentage of person-days associated with different levels of SO_2 and NO_2 in Shoubra El-Khaima sector were detected in the interval concentrations of (70 – 79 μg/m^3) and (60–69 μg/m^3), for SO_2 and NO_2 respectively, which resulted to HARD among the inhabitants.

Conflict of interest

None declared.

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