Risk assessment of NH_3 and H_2S in costal and Complex sectors in Egypt by using $AirQ^+$ software

Abstract

The aim of the present study is to assess the health risks of NH_3 and H_2S gases in two different sectors in Egypt, one of them is a complex sector (represents a residential, industrial and agriculture sector) and the other is a costal tourism sector. Hospital admissions respiratory disease (HARD) cases living in the two Sectors was also estimatedduring one year, due to exposure to NH_3 and H_2S gases using the $AirQ^+$ Software. Concentration levels of gaseous pollutants (NH_3 and H_2S)were measured from December 2019 to November 2020.

Daily mean concentrationsof NH_3 and H_2S at the mixed sector (68.15, and 50.06 $\mu g/m^3$, respectively) were higher than those in the coastal sector (23.92 and 24.10 $\mu g/m^3$, respectively). The daily mean concentrations of NH_3 in both sectors were less than the Egyptian and international Permissible limits.

Non-carcinogenic risk (HQ) of H_2S in the mixed regionwas higher than 1; indicating high adverse chronic health effects occur due to exposure to H_2S according to US EPA. In addition, the estimatednumber of hospital admissions respiratory diseases (HARD) Cases per 100,000 population living were 3 (1 - 6) and 4 (2 - 7) for NH_3 and H_2S, respectively in the coastalsector, while they were 392 (358 - 410) and 569 (347 - 576) for NH_3 and H_2S, respectively in the mixed sector. Finally, Air Q+ Software is a valid and reliable tool for estimating short-term risk effects of NH_3 and H_2S, and can predicts hospital admissions respiratory diseases (HARD) cases attributed to NH_3 and H_2S gases.

Keywords: $AirQ^+$ software, Complex sector, Costal tourist sector, Ammonia, Hydrogen sulfide.

Introduction

Ambient air pollution is considered to be one of the most important environmental risk factors for public health. According to the World Health Organization report, about 4.2 million deaths worldwide are associated with exposure to air pollution (Stosic et al., 2021). Gaseous pollutants arise from the combustion of fossil fuels and the evaporation of volatile fuels. Because of their impacts on the atmospheric environment, human health, plants, and materials, gaseous pollutants have received a great deal of research and attention.About 90% of anthropogenic emissions into the atmosphere are gaseous pollutants (Godish, 1997). Anthropogenic sources of gaseous pollutants include thermal power plants and industrial activities; Open burning of municipal and hazardous waste, as well as vehicle emissions (Waked and Afif, 2012).

Ammonia (NH_3) gas arises mainly from the decomposition and volatilization of animal waste, in addition to the increase in agricultural livestock and nitrogen fertilization (Sutton et al., 2001). The risks of exposure to ammonia depend on the duration of exposure, the concentration of the gas, and the depth of inhalation.Exposure to low levels of NH_3 may cause eye, nose, and throat irritation in some people. The Agency for Toxic Substances and Disease Registry reported that "at a concentration level of 50 ppm, inhalation of ammonia can cause eye, nose, and throat irritation, coughing, and narrowing of the bronchi (ATSDR, 2017).

Hydrogen sulfide (H_2S) arises from the bacterial breakdown of organic matter in the absence of oxygen (anaerobic digestion) (CalEPA, 1999). Almost all H_2S is released into the air, where it is found in the gas phase.H_2S is one of the most common toxic air pollutants that may be fatal at high concentrations (>800 ppm ≈ 1120 ug/m^3) if inhaled or absorbed through the skin (Gerasimon et al., 2007; ATSDR, 2014; ATSDR, 2017).

Several epidemiological studies have demonstrated a positive association between air pollution and the risk of human diseases, especially respiratory and cardiovascular diseases (Ghaffari*et al.*, 2017; Weichenthal*et al.*, 2017; Khattak et al., 2021; Stosic et al., 2021; Tsai *et al.*, 2021; Liu et al., 2022). Toxicological studies have also found that exposure to air pollutants might induce airway inflammation and elevated inflammatory biomarkers (Katsouyanni*et al.*, 2001; Penget al., 2005; Bell et al., 2008; Rich et al., 2012; Dadvand*et al.*, 2014; Lin *et al.*, 2018; Ho *et al.*, 2021). Some studies in Hawaii, New Zealand and the Azores have indicated that short-term changes in levels of air pollutants (such as: NH_3 and H_2S) have been positively associated with respiratory effects such as hospital admissions respiratory diseases (Carlsen et al., 2012; Morphew et al., 2021).

Finnbjornsdottir et al. (2016) in the Reykjavik capital area, in Iceland mentioned that "increasing H_2S to concentration levels of 140 μg/m^3 may cause: eye irritation, neurological symptoms, headache and nausea. Furthermore, pulmonary edema, respiratory arrest, and death can be caused at exposure to levels of 700 μg/m^3".

Egypt is currently facing serious air pollution problems. It has experienced rapid growth in population and economies in recent years. Rapid population growth, economic expansion and high rate of urbanization in Egypt lead to a significant increasein gaseous pollutants in the atmosphere.

Egypt has different complex sectors which are residential, industrial and agriculture regions.They can be regarded as seriously anthropogenic polluted areas. In addition, tourism is an important economic sector for Egypt. For tourism-reliant areas, it would be useful to know the levels of pollutants concentration in these areas and their effects. On the other hands, tourism also contributes to the emission of gaseous pollutants through transportation, accommodation and other tourism activities.

The environmental impacts in tourism areas and their risk assessment have received widespread attention. These impacts should be described at the local, regional, national and global scales around the world (Nielsen et al., 2010). In a previous study, an estimate of hospital admission respiratory disease due to SO_2 and NO_2 exposure was performed in Egypt by Mohammed et al (2019).Therefore, the current study was conducted to assess the health risks of other gaseous pollutants (such as NH_3 and H_2S) in two different sectors in Egypt, the first is a complex sector (Shoubra El-Kheima which is a residential, heavy traffic, industrial and agriculture sector) and the second is a costal tourism sector (Ain Sokhna). And to estimate the hospital admissions respiratory disease (HARD) casesliving in the two Sectors inEgypt during one year (December 2019 to November 2020) due to exposure toNH_3 and H_2S gases using the AirQ$^+$ Software.

Materials and methods

Sites description

The current study was conducted in Shoubra El-Kheima and Al-'Ain al-Sokhna sectors in Egypt (Fig. 1), wherefield measurements of gaseous pollutants were carried out at the two locations. Shoubra El-Kheima is located north of Greater Cairo (30°08N, 31°34 E). It has an area of 270.68 km^2 and represents a complex sector (residential, industrial and agricultural) (El-Dars et al., 2004; Hassanien and Abdel-Latif, 2008).

Figure 1: Maps showing the two sampling sectors (Shoubra El-Kheima and Ain Sokhna)

Shoubra El-Kheima is characterized by a high population density (about 1,600,000 people) and is representative of the metropolitan area of Greater Cairo (CAPMAS, 2022). In addition, it is also affected by heavy road traffic and emissions from industry and energy power plants.

Al-’Ain al-Sokhna is a town in the Suez Governorate in Egypt, lying on the western shore of the Red Sea's Gulf of Suez. It is situated 55 kilometers south of Suez and approximately 120 kilometers east of Cairo. It is surrounded by mountains and represents as one of the costal tourist sites in Egypt. The population density is equivalent to about 49,887 people according to the statistics of 2022 (CAPMAS, 2022). Al-’Ain al-Sokhna has oil and gas fields as well as refining and gas liquefaction projects. In addition, it has the sea port of Sokhna, which has an area of 22.3 square kilometers. Near the port there is a large refinery for sugar refining and vegetable fuel, and a plant for ammonia production. Recently, huge urban expansions took place in Al-’Ain al-Sokhna town, which now includes residential communities, universities, hospitals and hotels, as the area of Jabal Al-Jalalah.

Therefore, this research is concerned with measuring the levels of gaseous pollutants such as ammonia (NH_3) and hydrogen sulfide (H_2S) that could be emitted from these different industries and assessing the health risks from exposure to these gases.

Sampling and analysis

Ammonia (NH_3) and hydrogen sulfide (H_2S) were measured in ambient air at the two sectors in Egypt (once/week) in the period from December 2019 to November 2020. Reference methods were used for the gaseous measurements. The absorption method was used for collecting the gaseous samples on a 24-h basis at the two sectors. The sampling equipment consisted of gas bubblers through which the gas sample has been drawn. A calibrated vacuum pump with flow rate set at 1 L/min and a dry gas-meter are connected. The concentration of gaseous pollutants ($\mu g/m^3$) was calculated from standard curve and the volume of air samples (Mohammed, 2012; Bahino et al., 2018).

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 50 ml 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 color of ferric ion according to the concentration of hydrogen sulfide.

Health Risk Assessment

The health risk assessment focused on chronic exposure to Ammonia (NH_3) and hydrogen sulfide (H_2S), which are related to long term health impacts. The main exposure route of interest was inhalation (US EPA, 2017). The inhalation intake dose (D) was calculated by the average daily intake during the exposure period. Table 1 summarizes various exposure and risk assessment factors, used in this study. To calculate the inhalation intake of this study follows the methodology developed by US EPA, 2017 as shown in (Eq. 1A):

$$\mathbf{D = (C \times IR \times EF \times ED) / (AT * BW) \qquad (Eq.\ 1A)}$$

Where D is the inhalation intake dose (mg/kg.day), C is the concentration (mg/m^3) of the gaseous pollutants (NH_3 and H_2S), IR is the inhalation rate (m^3/day), EF is the exposure frequency (days/year), ED is the exposure duration (years), AT is an average time (lifetime in years),and BW is body weight (Kg).The non-cancer risk was expressed in terms of the hazard quotient (HQ) as shown in (Eq. 2A). REL is the reference exposure levels that were used according to US EPA, 2017. The non-cancer health impacts were expressed as the hazard index (HI) as shown in (Eq. 3A), which calculated as the sum of HQs at various locations (US EPA, 2017).

$$\mathbf{HQ = D\ (mg/kg.day) / RELs\ (mg/kg.day) \qquad (Eq.\ 2A)}$$

$$\mathbf{HI = HQ_1 + HQ_2 + HQ_3 + \ldots\ HQ_n \qquad (Eq.\ 3A)}$$

Generally, if HQ ≤ 1 and HI ≤ 1, these indicate that no probability of health risk effects. While if HQ > 1 and HI > 1, these indicate that probability of adverse health risk effects will occur.

Table 1: The exposure and risk assessment factors

Exposure settings	Value	Unit	Reference
concentration (C)		mg/m^3	The current study
Inhalation rate (IR)	20	m^3/day	
Exposure frequency (EF)	365	day/year	
Exposure duration (ED)	70	Year	US EPA, 2017
Average life time : non-carcinogenic (AT)	10950	Day	
Body Weight (BW)	70	Kg	
Chronic inhalation reference dose (RfD)	NH_3:0.277 H_2S: 0.02	mg/kg.day	Wua et al., 2021 ATSDR, 2012

AirQ

<u>$AirQ^+$ software</u>

The Air Quality Health Impact Assessment ($AirQ^+$)is the updated version of WHO AirQ software. Long and short exposures to ambient air pollution from many pollutants can be considered.All computations performed via $AirQ^+$ programming are based on approaches and response functions grounded by epidemiological examinations (Conti et al., 2017).

AirQ+ was used to estimate potential short-term effects of exposure to gaseous atmospheric pollutants, such as NH_3 and H_2S, on the health of humans living at the sampling sites during one year (December 2019–November 2020). In addition, AirQ+ was able to estimate the attributable number of cases per 100,000 populations at risk.

The assessment was based on the attributable proportion identified as the fraction of the health effect in a given population that is attributable to a certain air pollutant (Mohammed et al., 2019). Relative risks (RR) with 95% confidence interval (CI) for each 10 $\mu g/m^3$ increase in daily mean concentrations of NH_3 and H_2S pollutants have been reported. $AirQ^+$ software used the following equations(WHO, 2017; WHO, 2020):

$$AP = \Sigma \frac{[RR(c) - 1] \times p(c)}{[RR(c) \times p(c)]} \text{ ---------(Eq. 1)}$$

$$RR = \exp[B(X - Xo)] \quad \text{(Eq. 2)}$$

$$IE = I \times AP \quad \text{(Eq. 3)}$$

$$NE = IE \times N \quad \text{(Eq. 4)}$$

Where:

AP: is the attributable proportion of the health impacts.

RR: is 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

B: is base constant, (lower (0.0006); mean (0.0008); and higher (0.0010) WHO, 2017; WHO, 2020)

X: is annual mean concentration ($\mu g/m^3$)

Xo: is baseline (Threshold) concentration ($\mu g/m^3$)

IE: is the rate of the health impacts attributable to the exposure

I: is the baseline frequency of the health impacts cases in the population under investigation

NE: is the number of cases attributed to the exposure

N: is the population number of the investigated area

Input adjustment

AirQ$^+$software was used to assess the Hospital admissions respiratory diseases (HARD) related to the daily data for NH_3 and H_2S concentration levels from December 2019 to November 2020. The AirQ$^+$ software tool required the data based on gravimetric unit ($\mu g/m^3$). The required statistical indicators including the annual mean of NH_3 and H_2S, concentration levels were divided into 10 $\mu g/m^3$ categories (Stosic et al., 2021). The populationdata was obtained from the Central Agency for Public Mobilization & Statistics of Egypt (CAPMAS, 2022). The relative risk and baseline frequency of the health effects were entered into AirQ$^+$ software to estimate the number of cases of HARD attributed to NH_3 and H_2S exposure.

Results and Discussion

Concentration Levels of NH_3 and H_2S

Figure 2 shows, daily mean concentrations, maximum and minimum levels of NH_3 and H_2S in ambient air over the investigated areas. The figure shows that, high concentration levels were observed in Shoubra El-Kheima sector compared to Al-'Ain al-Sokhna sector during the period of the study. Maximum concentration levels at Al-'Ain al-Sokhna sector were 59 and 52 µg/m³ for NH_3 and H_2S, respectively. While the minimum levels were 8 and 12 µg/m³ for NH_3 and H_2S, respectively. At Shoubra El-Kheima sector, the highest concentration levels of NH_3 and H_2S were 130 and 90 µg/m³, respectively. While the minimum levels were 13 and 22 µg/m³ for NH_3 and H_2S, respectively. The daily mean concentrationsof NH_3 and H_2S at Al-'Ain al-Sokhna sector were 23.92 and 24.10 µg/m³, respectively; while at Shoubra El-Kheima, they were 68.15 and 50.06 µg/m³, respectively. The daily mean concentrations of NH_3 in both sectors were less than the Egyptian Permissible (24 Hours) limit in Annex No. 5 of the Executive Regulations of Law No. 4/1994 amended by Law 9/2009 which is 120 µg/m³ in urban and industrial areas (EEAA, 2015).Also, levels of H_2S concentrations were below the threshold limit value (TLV) of 1 ppm (1394 µg/m^3) for 8 hours of exposureadjusted by the American Conference of Governmental Industrial Hygienists (ACGIH) (NIOSH, 2016). These results may be attributed to anthropogenic activities in Shoubra El-Kheima sector, which were among the most important factors causing air pollution. Furthermore, the serious increase in air pollution occurred in Shoubra El-Kheima due to rapidpopulation growth in urban areas and concentration of industrial sites (Sharma and Kulshrestha, 2014). Besides, the presence of two electric power stations in this region; one of which was a very large thermal power station that used heavy oil most of the time, and consequently emitted excessive amounts of gases during combustion processes. In addition tothe contributions from petroleum refineries and industry in Mostorod (industrial region northeast of this sector), traffic problems on the Ring Road and the Cairo-Alexandria Ring Road.

On the other hand, it was interesting to note that Al-'Ain al-Sokhna region located in the coastal sector has low values of gases concentration. This may be due to the wet weather conditions that leachingthe pollutants and aerosol loads, and also the place has low population density. Population density can be treated as a surrogate variable for anthropogenic pollution (Liu and Zhang, 2009).

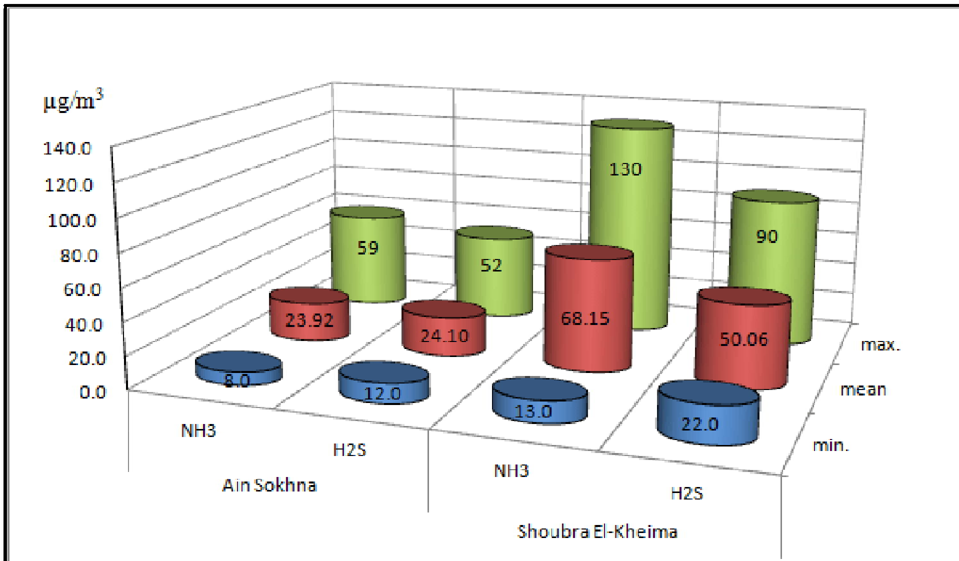

Figure 2: Annual concentration levels of NH_3 and H_2S atthe investigated areas.

Table 2 shows the mean concentration levels of NH_3 and H_2S at Shoubra El-Kheima and Al-'Ain al-Sokhna in comparison with the concentrations of other cities around the world. The table shows that the mean concentration levels of NH_3 at Shoubra El-Kheima and Al-'Ain al-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.On the other hand, the mean concentration levels of H_2S at Shoubra El-Kheima and Al-'Ain al-Sokhna were lower than that found in Cairo and Greece (Table 2).

Table 2: Comparing the results of NH_3 and H_2Sconcentration levels in the current study with those mentioned in previous studies

Country		NH_3	H_2S	Reference
Egypt	Shoubra El-Kheima	68.15	50.06	The current study
	Ain Sokhna	23.92	24.10	
	Cairo	189.9-237.2	95-252	Hassanien, 2009; Hu et al., 2009; EEAA, 2015
United Arab Emirates	Al-Ain	9.65	-	Salem et al., 2009; Waked and Afif, 2012
China	Pearl river Delta	7.3	-	Huet al., 2009; Meng et al., 2010
India	Agra	11.3	-	Parmar et al., 2001
Korea	Seoul-South	4.43	-	Lee et al., 1999
Japan	Kanto	10	-	Sakurai et al., 2003
Greece	Thessaloniki	-	8-20	Kourtidis et al., 2008
USA	California	1.6 - 4.5	-	Bytnerowiez et al., 2002
	Dakota	-	55.71 - 125.36	Campagna et al., 2004
	American cities	-	59.89 - 590.56	
	Clairton, Pennsylvania	-	11.14 - 30.64	Morphew et al., 2021
Iceland	Reykjavik area, 2012	-	7.2 (0.1 - 92.5)	Carlsen et al., 2012
	Reykjavik area, 2016	-	2.46 - 11.68	Finnbjornsdottir et al., 2016

Health Risk Assessment

The inhalation intake dose (D) for both NH_3 and H_2S gases in the current study was calculated from the average daily intake over the exposure period. The calculations revealed thatthe inhalation intake at Al-'Ain al-Sokhna region for both NH_3 and H_2S was 0.016 mg/kg per day as the average concentrations of the two gases were approximately similar. While the inhalation intake values at Shoubra El-Kheima region were 0.045 and 0.033 mg/kgper dayfor NH_3 and H_2S, respectively.

Noncarcinogenic riskswere assessed as a hazard quotient (HQ) and a hazard index (HI). The results in Figure 3 show that theHQ of NH_3 and H_2S at Al-'Ain al-Sokhna and the HQ of NH_3 at Shoubra El-Kheima region are less than 1. This indicates that there are no chronic adverse healths effects occur due to exposure to these pollutants according to the US Environmental Protection Agency (US EPA, 2017). However, the HQ of H_2S at Shoubra El-Kheima region is higher than 1; this indicateshigh chronic adverse health effects occur due to exposure to H_2Sgas according to the US EPA (2017). Figure 3 also shows that, hazard index(HI) at Al-'Ain al-Sokhna and Shoubra El-Kheima region was 0.86 and 1.83, respectively.HI is lower than 1 at Al-'Ain al-Sokhna region indicating that there are no chronic adverse health effects that occur due to exposure to these air pollutants according to US EPA (2017). In contrast, at Shoubra El-Kheima region, the HI is higher than 1, indicatinghigh chronic adverse health effects that occur due to exposure to these air pollutants (US EPA, 2017).

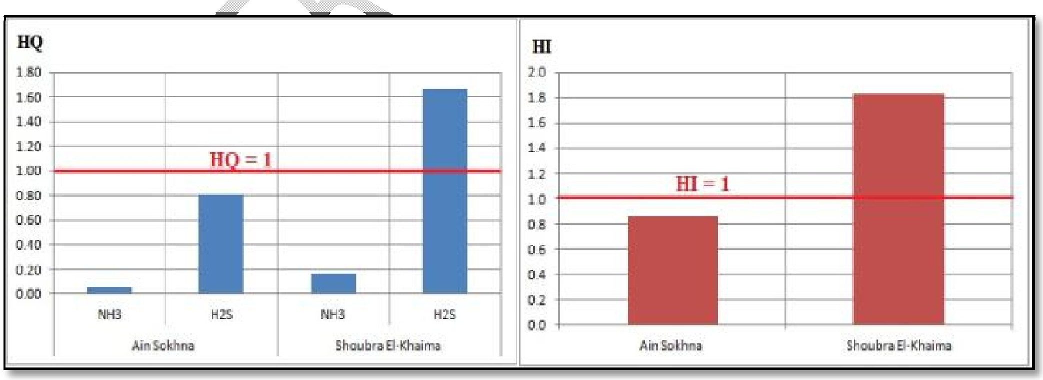

Figure 3: Hazard Quotient (HQ) and Hazard Index (HI) of NH_3 and H_2S at Shoubra El-Kheima and Al-'Ain al-Sokhna regions.

AirQ$^+$ software

One of the outputs of the AirQ$^+$program was a table in which the cumulative number of hospital admissions respiratory disease (HARD) cases per 100,000 populations at risk was estimated. Table 3 shows the estimated number of HARD cases per 100,000 populations at Risk attributable to NH_3 and H_2S exposure in Shoubra El-Kheima and Al-'Ain al-Sokhna sectors. The Estimated number of HARD Cases per 100,000 population at Risk, were 3 (1 - 6) and 4 (2 - 7) for NH_3 and H_2S, respectively, in Al-'Ain al-Sokhna sector, while they were 392 (358 - 410) and 569 (347 - 576) for NH_3 and H_2S, respectively, in Shoubra El-Kheima sector.

The results showed an increase in HARD cases in Shoubra El-Kheima sector compared to those estimated in Al-'Ain al-Sokhna sector; this may be attributed to the high concentration levels of both NH_3 and H_2S in Shoubra El-Kheima sector due to population increase and excess anthropogenic activities that cause increased emissions, such as industrial activities and increased traffic density.

Table 3 : Estimated number of HARD Cases per 100,000 populations at Risk

Site	Pollutant	HARD number Cases per 100,000 Population		
		Central	Lower	Upper
Ain Sokhna	NH_3	3	1	6
	H_2S	4	2	7
Shoubra El-Kheima	NH_3	392	358	410
	H_2S	569	347	576

Table 4 also outputs of the AirQ$^+$ program that's how the attributable proportion (AP) which expressed as percentage and mean number of excess cases for HARD due to NH_3 and H_2S exposure in Shoubra El-Kheima and Al-'Ain al-Sokhna sectors.

The results showed that the AP %, were0.0047 and 0.0075 for NH_3 and H_2S, respectively in Al-'Ain al-Sokhna sector, while they were 0.0245 and 0.0355 for NH_3 and H_2S, respectively in Shoubra El-Kheima sector. The attributable proportion AP % for both NH_3 and H_2S in Shoubra El-Kheima (mixed sector) was about 5 times more than in Al-'Ain al-Sokhna (coastal sector). In addition, the mean number of excess cases (persons/year)of HARD in Shoubra El-Kheima sector was 392 cases compared to only 3 cases in Al-'Ain al-Sokhna as a result of exposure toNH_3, and 569 cases in Shoubra El-Kheima compared to only 4 cases in Al-'Ain al-Sokhna due to H_2Sexposure.

Table 4 : Attributable proportion (AP) percentage and HARD number due to NH_3 and H_2S exposures in sampling sites

Parameter	Ain Sokhna		Shoubra El-Kheima	
	NH_3	**H_2S**	**NH_3**	**H_2S**
AP (%)	0.0047	0.0075	0.0245	0.0355
Mean number of excess cases(persons/year)	3	4	392	569

The relative risk (RR), with 95% confidence interval (CI) and baseline frequency (I), used to estimate HARD attributable to NH_3 and H_2S exposure in Shoubra El-Kheima and Al-'Ain al-Sokhna regions, are shown in Table 5. The results in this table show that the relative risk (RR), with 95% confidence interval (CI) per 10 µg/m^3, were 1.912 (0.191 - 3.630) and 1.925 (0.193 - 3.660) for NH_3 and H_2S, respectively in Al-'Ain al-Sokhna sector, while they were 5.104 (0.510 -9.700) and 3.799 (0.380 - 7.220) for NH_3 and H_2S, respectively in Shoubra El-Kheima sector. These results of RR in Shoubra El-Kheima sector are in agreement with that found in Reykjavik area, Iceland by (Carlsen et al., 2012).

Table 5: The relative risk (RR), with 95% confidence interval (CI) and baseline frequency (I) used to estimate HARD attributable to NH_3 and H_2S exposures

Health impacts	Site	Pollutant	I	The relative risk (RR), with 95% confidence interval (CI) per 10 µg/m^3
Hospital Admissions Respiratory Diseases (HARD)	Ain Sokhna	NH_3	23	1.912 (0.191 - 3.630)
		H_2S		1.925 (0.193 - 3.660)
	Shoubra El-Kheima	NH_3	401	5.104 (0.510 -9.700)
		H_2S		3.799 (0.380 - 7.220)

Table 6 shows the comparison between the results recorded in the current study and those found in other countriessuch as Iceland and USA. It illustrate that the excess cases of HARD attributed to exposure to H_2Sin Shoubra El-Kheima sector were much higher than thosein cities of Iceland and USA.

Conclusion

The objective of the current study was assessment of hospital admissions respiratory disease (HARD) attributed to NH3 and H_2S exposures in ambient air of two different sectors in Egypt (Shoubra El-Kheima represents a mixed sector and Al-'Ain al-Sokhna represents a costal sector) during December 2019 to November 2020.

High concentration levels of NH_3 and H_2S concentrations were observed in Shubra El-Kheima sector compared to Al-'Ain al-Sokhna sector during the period of the study. This may be attributed to the anthropogenic activities in Shoubra El-Kheima sector, which were among the most important factors causing air pollution that include: rapid population growth in urban areas, industrial activity such as the presence of two electric power stations in this sector, which use heavy oil most of the time, and the contributions from petroleum refineries and industry in region northeast of this sector, in addition to traffic problems. Average daily concentrations of NH_3in both sectors were lower than theEgyptian Permissible (24 Hours) limit in urban and industrial areas. Also,levelsof H_2Sconcentration werebelow the threshold limit value (TLV) of 1 ppm (1394 µg/m3) for 8 hours of exposureadjusted by the American Conference of Governmental Industrial Hygienists (ACGIH).

Calculations of health risk revealed thatthe inhalation intake dose in Al-'Ain al-Sokhna region for both NH_3 and H_2S was lower than its value in Shoubra El-Kheima. Non carcinogenic risks were assessed as a hazard quotient (HQ) and a hazard index (HI).HQ of NH_3 and H_2S at Al-'Ain al-Sokhna and the HQ of NH_3 at Shoubra El-Kheima region are less than 1, which indicates that there are no chronic adverse health effects occur due to exposure to these pollutants according to the US EPA (2017). However, HQ of H_2S at Shoubra El-Kheima region was higher than 1, which indicates high chronic adverse health effects occur due to exposure to H_2Sgas according to the US EPA (2017). HI at Al-'Ain al-Sokhna region was lower than 1 indicating that there are no chronic adverse health effects that occur due to exposure to these air pollutants according to US EPA. In contrast, at Shoubra El-Kheima region, the HI is higher than 1, indicating high chronic adverse health effects that occur due to exposure to these air pollutants.

The cumulative number of hospital admissions respiratory disease (HARD) cases per 100,000 populations at risk was estimated using $AirQ^+$ program. There were an increase in HARD cases in Shoubra El-Kheima sector compared to those estimated in Al-'Ain al-Sokhna sector; this may be attributed to the high concentration levels of both NH_3 and H_2S in Shoubra El-Kheima sector. The attributable proportion AP % is one of the outputs of $AirQ^+$ program. AP % for both NH_3 and H_2S in Shoubra El-Kheima(mixed sector) was about 5 times more than in Al-'Ain al-Sokhna (coastal sector). The mean number of excess cases (persons/year) of HARD in Shoubra El-Kheima sector was 392 cases compared to only 3 cases in Al-'Ain al-Sokhna as a result of exposure to NH_3, and 569 cases in Shoubra El-Kheima compared to only 4 cases in Al-'Ain al-Sokhna due to H_2Sexposure.

The excess HARD number cases attributed to exposure to H_2S in Shoubra El-Kheima sector were much higher than those in cities of other countries as Iceland and USA.

Finally, Air Q^+ Software was proven to be a valid and reliable tool to the quantification of the potential short-term effects of NH_3 and H_2S, and predicts hospital admissions respiratory diseases (HARD) cases attributed to NH_3 and H_2S.

Table 6: shows the comparison between the results recorded in the current study and those found in other countries.

Site		The relative risk (RR), with 95% confidence interval (CI) per 10 µg/m^3		AP (%)		Mean number of excess cases (persons/year)		References
		NH_3	H_2S	NH_3	H_2S	NH_3	H_2S	
Egypt	Ain Sokhna	1.912 (0.191 - 3.630)	1.925 (0.193 - 3.660)	0.0047	0.0075	3	4	The current study
	Shoubra El-Kheima	5.104 (0.510 -9.700)	3.799 (0.380 - 7.220)	0.0245	0.0355	392	569	
Iceland	Reykjavik area, 2012	-	3.4 (1.3 - 5.6)	-	-	-	-	Carlsen et al., 2012
	Reykjavik area, 2016	-	-	-	-	-	0 - 23	Finnbjornsdottir et al., 2016
USA	Dakota	-	2 (18 – 27)	-	-	-	-	Campagna et al., 2004
	American cities	-	-	-	-	-	-	
	Clairton, Pennsylvania	-	1.79 (1.27 - 2.54)	-	-	-	-	Morphew et al., 2021

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