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/m^3 at Ain Sokhna sector and 92, 78 μg/m^3 at Shoubra El-Khaima sector for SO_2 and NO_2, respectively. These levels were less than the Egyptian Permissible limits (125 μg/m^3 in urban and 150 μg/m^3 in industrial for SO_2, 150 μg/m^3 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/m^3 of SO_2 and 234 cases at 120 - 129 μg/m^3 of NO_2. While, in Ain Sokhna, HARD were 18 cases at 50 - 59 μg/m^3 of SO_2 and 15 cases at 60 - 69 μg/m^3 of NO_2. 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. 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 traffic. 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.

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. 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 O_3. Human activities in the urban areas represent the main sources of NO_2 from automobile exhaust emissions to stationary sources such as power plants, agriculture and industrial activities. 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. Population growth, increased vehicles (Traffic), industrialization and etc were the main factors that affecting levels of pollutants in the ambient air. The World Health Organization (WHO) had estimated that annually 800,000 people prematurely die around the world, due to

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cardiovascular and respiratory diseases, and lung cancer which are caused by air pollution. Most of the Epidemiological studies had focused on the health effect of particulate matters. However, criteria gaseous pollutants such as nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) also had adverse effects on human health.

In recent years, several hundred epidemiological studies showed that increase in the air pollutants concentrations could increase cases in hospital admission for respiratory diseases. SO₂ and NO₂ are very soluble in the upper respiratory tract and thus may produce an urgent irritant effect on the respiratory mucosa. There are several models, mainly based on statistical/epidemiological measures, for the assessment of health effects (short-term exposure) attributed to air pollutants. 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. 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.

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 SO₂ and NO₂, and predicts hospital admissions respiratory diseases (HARD) cases attributed to SO₂ and NO₂.

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 SO₂ and NO₂ 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-Khaima sector (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.

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 coastal 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.
**Sampling and analysis**

Gaseous pollutants, sulphur dioxide (SO₂) and nitrogen dioxide (NO₂) 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 SO₂, Jacobs and Hochheiser method for NO₂) were used for gases analysis. The concentration of gaseous pollutants (µg/m³) was calculated from standard curve and the volume of air sampled.

**AirQ2.2.3 Software**

The Air Quality Health Impact Assessment (AirQ2.2.3 model) is software provided by WHO to assess the health outcome of air pollutants. 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. AirQ calculated the short-term potential effects of the exposure to atmospheric pollutants (SO₂ and NO₂) 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.

Relative risks (RR) with 95% confidence interval (CI) for each 10 µg/m³ increase in daily mean concentrations of SO₂ and NO₂ pollutants have been reported. The amount of AP can be calculated by using the Eq. (1):

\[
AP = B \times X - B \times Xo
\]

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. 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). 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.

Relative Risk (RR) was calculated by using the Eq. (2):

\[
RR = \frac{B}{X} - \frac{B}{Xo}
\]

Where B = lower (0.0006), (mean 0.0008) and higher (0.0010)
X = Annual mean concentration (µg/m³)
Xo = Baseline (Threshold) concentration (µg/m³)
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 \(^9,20\):

\[
IE = I \times \frac{NE}{N}
\]

Where IE is the rate of the health impacts attributable to the exposure and I is the 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 \(^80,81\):

\[
NE = N \times \frac{IE}{I}
\]

Where NE is the number of cases attributed to the exposure and N is the size of the population investigated. In this study, 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 admissions 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 (\(\mu\)g/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 \(\mu\)g/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).

**Results and discussion**

Table 1 shows the concentration levels of SO\(_2\) and NO\(_2\) in Ain Sokhna and Shoubra El-Khaima sectors 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 \(\mu\)g/m\(^3\) in urban and 150 \(\mu\)g/m\(^3\) in industrial for SO\(_2\), 150 \(\mu\)g/m\(^3\) 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 \(\mu\)g/m\(^3\) for SO\(_2\) and NO\(_2\), respectively in Ain Sokhna sector; 92 and 78 \(\mu\)g/m\(^3\) for SO\(_2\) and NO\(_2\), respectively in Shoubra El-Khaima sector; which are lower than the Egyptian limit of 125 \(\mu\)g/m\(^3\) in urban and 150 \(\mu\)g/m\(^3\) in industrial for SO\(_2\), 150 \(\mu\)g/m\(^3\) 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 SO₂ and NO₂ exposure in the sampling sites. The attributable proportion (AP) expressed as percentage and number of excess cases for HARD due to SO₂ and NO₂ 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 SO₂ and NO₂ exposure for a concentration interval of 10 μg/m³ 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 by⁸⁷.

**Table 1:** The monthly mean concentrations (µg/m³) of Pollutants (SO₂ and NO₂) in sampling sites (December 2015 – November 2016)

| Month | Ain Sokhna | Shoubra El-Khaima |
|-------|------------|-----------------|
|       | SO₂        | NO₂  | SO₂ | NO₂  |
| Dec-15 | 6          | 8    | 93  | 72   |
| Jan-16 | 3          | 5    | 90  | 33   |
| Feb-16 | 7          | 7    | 60  | 65   |
| Mar-16 | 9          | 12   | 79  | 73   |
| Apr-16 | 16         | 17   | 89  | 82   |
| May-16 | 17         | 18   | 78  | 86   |
|       |            |      |     |      |
| Jun-16 |            | 31   | 29  | 111  |
| Jul-16 |            | 29   | 38  | 113  |
| Aug-16 |            | 52   | 54  | 116  |
| Sep-16 |            | 41   | 46  | 92   |
| Oct-16 |            | 17   | 18  | 83   |
| Nov-16 |            | 7    | 9   | 73   |

**Table 2:** Summary of Pollutants (SO₂ and NO₂) concentration in sampling sites (December 2015 – November 2016)

| Site / Pollutant (µg/m³) | Ain Sokhna | Shoubra El-Khaima |
|-------------------------|------------|-----------------|
|                         | SO₂        | NO₂  | SO₂ | NO₂  |
| 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 SO₂ and NO₂ exposure in sampling sites

| Health impacts /Site/ Pollutant | I | RR (95% CI) per 10 µg/m³ |
|---------------------------------|---|--------------------------|
| Hospital Admissions Respiratory Diseases (HARD) | | |
| AinSokhna SO₂ | 37 | 1.0330 (1.0246 - 1.0414) |
| AinSokhna NO₂ | | 1.0229 (1.0171 - 1.0287) |
| Shoubra El-Khaima SO₂ | 77 | 1.0261 (1.0195 - 1.0327) |
| Shoubra El-Khaima NO₂ | | 1.0226 (1.0169 - 1.0283) |
Table 4: The attributable proportion (AP) expressed as percentage and number of excess cases for HARD due to SO₂ and NO₂ exposure in sampling sites

| Site / Pollutant | AinSkhona | Shoubra El-Khaima |
|-----------------|-----------|-------------------|
| AP (%)          | 0.007     | 0.026             |
| NO₂             | 0.008     | 0.024             |
| NO₂             |           |                   |
| Number of excess cases (persons/year) | 45 | 47 |
| SO₂             | 1337      | 1247              |

Table 5: Number of excess for HARD due to SO₂ and NO₂ exposure in sampling sites

| Concentration (µg/m³) | Cumulative number per 100,000 person | Concentration (µg/m³) | Cumulative number per 100,000 person |
|----------------------|--------------------------------------|----------------------|--------------------------------------|
|                      | AinSkhona   | Shoubra El-Khaima    | AinSkhona   | Shoubra El-Khaima                  |
| < 10                 | 0           | 0                    | 130 – 139   | 0                                   |
| 10 – 19              | 2           | 1                    | 140 – 149   | 0                                   |
| 20 – 29              | 4           | 4                    | 150 – 159   | 0                                   |
| 30 – 39              | 8           | 5                    | 160 – 169   | 0                                   |
| 40 – 49              | 14          | 9                    | 170 – 179   | 0                                   |
| 50 – 59              | 18          | 14                   | 180 – 189   | 0                                   |
| 60 – 69              | 0           | 15                   | 190 – 199   | 0                                   |
| 70 – 79              | 0           | 0                    | 200 – 249   | 0                                   |
| 80 – 89              | 0           | 0                    | 250 – 299   | 0                                   |
| 90 – 99              | 0           | 0                    | 300 – 349   | 0                                   |
| 100 – 109            | 0           | 0                    | 350 – 399   | 0                                   |
| 110 – 119            | 0           | 0                    | >= 400      | 0                                   |
| 120 – 129            | 0           | 0                    | 311 234     | 0                                   |

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 SO₂ and NO₂ exposure were found in Shoubra El-Khaima sector; 311 cases attributed to exposure to SO₂ occurred in concentrations range of 120 - 129 µg/m³ and 234 cases attributed to exposure to NO₂ occurred in concentrations range of 120 - 129 µg/m³. While in Ain Sokhna sector, the excess cases of HARD due to SO₂ and NO₂ exposure were 18 cases (attributed to exposure to SO₂ occurred in concentrations ranges of 50 - 59 µg/m³) and 15 cases attributed to exposure to NO₂ occurred in concentrations ranges of 60 - 69 µg/m³. 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 SO₂ and NO₂ 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\textsubscript{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\textsubscript{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\textsubscript{2} exposure in Shoubra El-Khaima sector during December 2015 – November 2016
Fig. 5: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) attributable to SO₂ 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 exposed to different levels of SO₂ and NO₂ during December 2015 to November 2015 and number of cases per 100000 people. Also, these figures showed that, the highest percentage of person-days occurred in concentration interval of (< 10 μg/m³) for SO₂ and NO₂, 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 SO₂ and NO₂ in Shoubra El-Khaima sector were detected in the interval concentrations of (70 – 79 μg/m³) and (60–69 μg/m³), for SO₂ and NO₂ 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 SO₂ and NO₂ 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 SO₂ and NO₂ in Ain Sokhna sector were similar to that found in cities of Iran, Spain, UK, Italy, Netherlands, and France.

Fig. 6: Cumulative number of cases in hospital admissions for respiratory diseases (HARD) attributable to NO₂ exposure in Shoubra El-Khaima sector during December 2015 – November 2016

Fig. 7: Percentage of times that people were exposed to different concentrations of air pollutant (SO₂ and NO₂) in investigated sectors
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 SO2 and NO2, and predicts hospital admissions respiratory diseases (HARD) cases attributed to SO2 and NO2. The main objective of this study was the assessment of health impacts (HARD) attributed to SO2 and NO2 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 SO2 and NO2 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 SO2 and NO2, respectively in Ain Sokhna sector; 92 and 78 µg/m3 for SO2 and NO2, respectively in Shoubra El-Khaima sector. The concentrations of the investigated gases (SO2 and NO2) were less than the Egyptian permissible daily (24 Hours) average limits (125 µg/m3 in urban and 150 µg/m3 in industrial for SO2, 150 µg/m3 in urban and industrial for NO2). The mean concentrations of SO2 and NO2 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 SO2 and NO2, respectively in Ain-Sokhna sector, while they were 1.0261 (1.0195 -1.0327) and 1.0226 (1.0169 - 1.0283) for SO2 and NO2, respectively in Shoubra El-Khaima sector. The attributable proportion (AP) were 0.007 and 0.008 for SO2 and NO2, respectively in AinSokhna sector, while it were 0.026 and 0.024 for SO2 and NO2, respectively in Shoubra El-Khaima sector.

The highest excess cases of HARD due to SO2 and NO2 exposure were found in Shoubra El-Khaima sector (311 cases attributed to exposure to SO2 occurred in concentrations range of 120 - 129 µg/m3; and 234 cases attributed to exposure to NO2 occurred in concentrations range of 120 - 129 µg/m3). While, in Ain Sokhna HARD were 18 cases, attributed to exposure to SO2 occurred in concentrations range of 50 - 59 µg/m3, and 15 cases attributed to exposure to NO2 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 SO2 and NO2 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 SO2 and NO2 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 in-

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

| Country     | SO2 Conc. (µg/m³) | HARD HARD (case)* | NO2 Conc. (µg/m³) | HARD (case)* |
|-------------|-------------------|------------------|-------------------|-------------|
| Egypt       |                   |                  |                   |             |
| Ain Sokhna  | 19                | 45               | 20                | 47          |
| Shoubra El-Khaima | 92                | 1337             | 78                | 1247        |
| Iran        |                   |                  |                   |             |
| Tabriz      | 34                | 32               | 19                | 15          |
| Tehmar      | 58                | 298              | 89                | 247         |
| Kermanshah  | -                 | -                | 76                | 497         |
| Ahvaz       | 37                | 24               | 160               | 13          |
| Bushehr     | 56                | 67               | 47                | 27          |
| Shiraz      | 74                | 115              | 63                | 43          |
| USA         |                   |                  |                   |             |
| New York    | 10                | 4                | 23                | 12          |
| Spain       |                   |                  |                   |             |
| Barcelona   | -                 | -                | 95                | 36          |
| 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.
terval of $(< 10 \mu g/m^3)$ for $SO_2$ and $NO_2$, led to minimize the HARD among the inhabitants of Ain Sokhna coastal 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 $(70 – 79 \mu g/m^3)$ and $(60–69 \mu g/m^3)$, for $SO_2$ and $NO_2$ respectively, which resulted to HARD among the inhabitants.

**Conflict of interest**
None declared.

**Reference**
1. Kermani M, Jafari AJ, Kalantari RR, Sakhaei FS, Kahe TS, Dowlati M. Evaluation of Chronic Obstructive Pulmonary Disease Attributed to Atmospheric O$_3$, NO$_2$ and SO$_2$ in Tehran City, from 2005 to 2014. Iranian Journal of Health, Safety & Environment. 2004; 4(3): 758-766.
2. Vineis P and Husgafvel-Pursiainen K. Air pollution and cancer: biomarker studies in human populations. Carcinogenesis. 2005; 26(11): 1846-1855.
3. Miller KA, Siscovick DS, Sheppard L, Shepherd K, Sullivan JH, Anderson GL, et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. New England Journal of Medicine. 2007; 356(5): 447-58.
4. Finlay SE, Youssouf H, Annesi-Maesano I. Meteorological conditions and climate change: new emerging factors and bronchial asthma. World Allergy Organisation Journal. 2015; 8(1): 25.
5. Rahila R. K. Review on effects of Particulates; Sulfur Dioxide and Nitrogen Dioxide on Human Health. International Research Journal of Environment Sciences. 2014; 3(4): 70-73.
6. Taiwo A et al. A review of receptor modelling of industrially emitted particulate matter. Atmos. Environ. 2014; 97: 109–120.
7. Geravandi S, Goudarzi G, Mohammadi MJ, Taghavirad SS, Salmanzadeh S. Sulfur and nitrogen dioxide exposure and the incidence of health endpoints in Ahvaz, Iran. Health Scope. 2015a; 4(2):c24318.
8. Neisi A, Goudarzi G, Babaei A, Vosoughi M, Hashemzadeh H, Naimabadi A, Mohammadi M, Hashemzadeh B. Study of heavy metal levels in indoor dust and their health risk assessment in children of Ahvaz City, Iran. Toxins Rev. 2016; 35: 16–23.
9. Fattore E, Paiano V, Borgini A, Tittarelli A, Bertoldi M, Crosignani P, Fanelli R. Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. Environ. Res. 2011; 111: 1321–1327.
10. Vineis P, Hock G, Krzyzanowski M, Vigna-Taglianti F, Veglia F, Airola I, Overvad K, Raaschou-Nielsen O, Clavel-Chapelon F and Lineisen J. Lung cancers attributable to environmental tobacco smoke and air pollution in non-smokers in different European countries: a prospective study. Environmental Health. 2007; 6:7.
11. Downs SH et al. Reduced exposure to PM10 and attenuated age-related decline in lung function. New England Journal of Medicine. 2007; 357(23): 2338-2347.
12. Jerrett M et al. Traffic-related air pollution and asthma onset in children: a prospective cohort study with individual exposure measurement. Environmental Health Perspectives. 2008; 116(10): 1433-1438.
13. Asl FB, Kermani M, Aghaei M, Karimzadeh S, Arjan SS, Shahsavan A, Goudarzi G. Estimation of Diseases and Mortality Attributed to NO2 pollutant in five metropolises of Iran using AirQ model in 2011-2012. J Mazandaran Univ Med Sci. 2015; 24(121): 239-249.
14. Goudarzi, G., et al., (2013). Estimation of number estimation of number of cardiovascular death, myocardial infarction and chronic obstructive pulmonary disease (COPD) from no2 exposure using air q model in Ahvaz city during 2009. 2013.
15. Tominz R et al. Estimate of potential health benefits of the reduction of air pollution with PM10 in Trieste, Italy. Epidemiol. Prev. 2005; 29: 149–155.
16. Wang S et al. A study on variations of concentrations of particulate matter with different sizes in Lanzhou, China. Atmos. Environ. 2009; 17: 2823–2828.
17. Raaschou-Nielsen O, Andersen ZJ, Jensen SS, Ketzel M, Sorensen M, Hansen J, Loft S, Tjønneland A, Overvad K. Traffic air pollution and mortality from cardiovascular disease and all causes: a Danish cohort study. Environ Health. 2012; 11: 60.
18. Castell N et al. Real-World Application of New Sensor Technologies for Air Quality Monitoring. Topic Centre on Air Pollution and Climate Change Mitigation Bilthoven, the Netherlands. ETC/ACM Technical Paper 2013/16 European.
19. Borge R, Ddl P, Lumbreras J, Pérez J, Vedrenne M. Analysis of contributions to NO2 ambient air quality levels in Madrid City (Spain) through modeling. Implications for the Development of Policies and Air Quality Monitoring. Journal of Geoscience and Environment Protection. 2014; 2: 6–11.
20. Nourmoradi H, Goudarzi G, Daryanoosh SM, Omid-Khaniabadi F, Jourvand M, Omid-Khaniabadi Y. Health impacts of particulate matter in air by AirQ model in Khorramabad City, Iran. J. Bas Res. Med Sci. 2015; 2: 44–52.
21. Dobaradaran SGS, Goudarzi G, Idani E, Salmanzadeh S, Soltani F. Determination of cardiovascular and respiratory diseases caused by PM10 exposure in Bushehr, 2013. J. Mazandaran Univ. Med. Sci. 2016; 26: 42–52.
22. Hanno M, Salonen R, Hӓlӓinen A, Jalava P, Pennanen A, Dormans J, Gerlofs-Nijland M, Cassee F, Kosma V-M, Sillanpää M. Inflammation and tissue damage in mouse lung by single and repeated dosing of urban air coarse and fine particles collected from six European cities. Inhal.Toxicol. 2010; 22: 402–416.
23. Wong C, Thach T, Chau P, Chan E, Chung R, Ou C, Yang L, Peiris J, Thomas G, Lam T. Part 4. Interaction between air pollution and respiratory viruses: time-series study of daily mortality and hospital admissions in Hong Kong. Research Report Health Effects Institute. 2010; (154): 283–362.
24. Norval M, Lucas R, Cullen A, De Gruijl F, Longstreth J, Takizawa Y, Van Der Leun J. The human health effects of ozone depletion and interactions with climate change. Photochemical & Photobiological Sciences. 2011; 10: 199–225.
25. Oh SM, Kim HR, Park YJ, Lee SY, Chung KH. Organic extracts of urban air pollution particulate matter (PM2.5)-induced genotoxicity and oxidative stress in human lung bronchial epithelial cells (BEAS-2B cells). Mutat Res/Gene Toxicol Environ. Mutagen. 2011; 723: 142–151.
26. Budinger GS, McKell JL, Urich D, Foiles N, Weiss I, Chiarella SE, Gonzalez A, Soberanes S, Ghio AJ, Nigdelioglu R. Particulate matter-induced lung inflammation increases systemic levels of PAI-1 and activates coagulation through distinct mechanisms. PLoS One. 2011; 6(4): e18525.
27. Ko FW and Hui DS. Air pollution and chronic obstructive pulmonary disease. Respirology. 2012; 17: 395–401.
28. Raaschou-Nielsen O et al. (2013) Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European study of cohorts for air pollution effects (ESCAPE). The lancet oncology 14(8):813– 822. Lave LB and Seskin EP. Air pollution and human health. Routledge. 2013; 6: 350.
29. Hoek G, Krishnan RM, Beelen R, Peters A, Ostro B, Brunekreef B, Kaufman JD. Long-term air pollution exposure and cardiorespiratory mortality: a review. Environ. Health. 2013; 12: 43.
30. Woerman AL and Mendelowitz D. Postnatal Sulfur Dioxide Exposure Reversibly Alters Parasympathetic Regulation of Heart Rate. Hypertension. 2013; 62: 274-280.
31. Jane C and Fanny W. Air pollution: its impact on adult patients with respiratory conditions. The Cover Shot 2015; 20:12.
32. Kariisa M, Foraker R, Pennell M, Buckley T, Diaz P, Criner GJ, Wilkins J. Short-and long-term effects of ambient ozone and fine particulate matter on the respiratory health of chronic obstructive pulmonary disease subjects. Archives of Environmental & Occupational Health. 2015; 70: 56–62.
33. Mraihi R, Harizi R, Mraihi T, Bouzidi MT. Urban air pollution and urban daily mobility in large Tunisia’s cities. Renew Sust Energ Rev. 2015; 43: 315–320.
34. Peng RD, Butz AM, Hackstadt AJ, Williams D, Diette GB, Breysse PN, Matsui EC. Estimating the health benefit of reducing indoor air pollution in a randomized environmental intervention. Journal of the Royal Statistical Society: Series A (Statistics in Society). 2015; 178: 425–443.
35. Pride KR et al. Association of short-term exposure to ground-level ozone and respiratory outpatient clinical visits in a rural location– Sublette County, Wyoming, 2008–2011. Environ Res. 2015; 137: 1–7.
36. Fann N, Lamson AD, Anenberg SC, Wesson K, Risley D, Hubbell BJ. Estimating the national public health burden associated with exposure to ambient PM2.5 and ozone. Risk Anal. 2012; 32(1): 81–95.
37. Geravandi S, Goudarzi G, Mohammadzadeh S, Taghavi-rad SS, Salmanzadeh S. Sulfur and nitrogen dioxide exposure and the incidence of health endpoints in Ahvaz, Iran. Health Scope (Int Q J). 2015; 4(1):e26621.
38. Goudarzi G, Geravandi S, Forouozandeh H, Babaei A, Alavi N, Niri M, Khodayar MJ, Salmanzadeh S, Mohammadzadeh M. Cardiovascular and respiratory mortality attributed to ground-level ozone in Ahvaz, Iran. Environ. Monit. Assess. 2015a; 187(8): 1–9.
39. Mohammadzadeh M, Godini H, Khak MT, Daryanoosh SM, Dobaradaran S, Goudarzi G. An association between air quality and COPD in Ahvaz, Iran. Jundishapur J Chronic Dis Care. 2015; 4(1):e24318.
40. Zallaghi E, Geravandi S, Nourzadeh Haddad M, Goudarzi G, Valipour L, Salmanzadeh S, et al. Estimation of health effects attributed to nitrogen dioxide exposure using the airq model in Tabriz City, Iran. Health Scope. 2015a; 4(4):e30164.
41. Sicard P, Lesne O, Alexandre N, Magin A, Collomp R. Air quality trends and potential health effects—development of an aggregate risk index. Atmos. Environ. 2011; 45: 1145–1153.

42. Sicard P, Talbot C, Lesne O, Magin A, Alexandre N, Collomp R. The aggregate risk index: an intuitive tool providing the health risks of air pollution to health care community and public. Atmos. Environ. 2012; 46: 11–16.

43. Dehghani M, Anshiravan A, Hashemi H, Shamsedin N. Survey on air pollution and cardiopulmonary mortality in Shiraz from 2011 to 2012: an analytical-descriptive study. Int. J. Prev Med. 2014; 5: 734–740.

44. Goudarzi G, Geravandi S, Salmanzadeh S, Mohammadi MJ, Zallaghi E. The number of myocardial infarction and cardiovascular death cases associated with sulfur dioxide exposure in Ahvaz, Iran. Arch. Hyg. Sci. 2014a; 3: 112–119.

45. Rezaei M, Salimi A, Taghidust M, Nasrnezadeh P, Goudarzi G, Seydi E, Pourahmad J. A comparison of toxicity mechanisms of dust storm particles collected in the southwest of Iran on lung and skin using isolated mitochondria. Toxicol. Environ. Chem. 2014; 96: 814–830.

46. Taghayirad S, Davar H, Mohammadi MJ. The a study on concentration of BETX vapors during winter in the department of ports and shipping located in one of the southern cities of Iran. Inte J Car Life Sci. 2014; 4(9): 5416–5420.

47. Ghozikali MG, Borgini A, Tittarelli A, Amrane A, Naddafi K, Mohammadyan M. Quantification of the health effects of exposure to air pollution (NO2) in Tabriz, Iran. Fresenius Environ Bull. 2015b; 24: 4142–8.

48. Soleimani Z, Parhizgari N, Dehdari R, Hassan R, Mohammad K, Majid BM, Mohammad G, Hamed G, Hamed GG. Normal and dusty days comparison of culturable indoor airborne bacteria in Ahvaz, Iran. Aerobiologia. 2015; 31 (2): 127–141.

49. Daryanoosh SM, Goudarzi G, Khaniabadi YO, Armin H, Bassiri H, Khaniabadi FO (2016) Effect of exposure to PM10 on cardiovascular diseases hospitalizations in Ahvaz, Khorraramabad and Ilam, Iran during 2014. Iranian Journal of Health, Safety & Environment 3:428–433.

50. Dianat M, Radmanesh E, Badavi M, Goudarzi G, Mard SA. The effects of PM10 on electrocardiogram parameters, blood pressure and oxidative stress in unhealthy rats: the protective effects of vanillic acid. Environ. Sci. Pollut. Res. 2016a; 23(19): 19551–19560.

51. Dianat M, Radmanesh E, Badavi M, Mard SA, Goudarzi G. Disturbance effects of PM10 on iNOS and eNOS mRNA expression levels and antioxidant activity induced by ischemia–reperfusion injury in isolated rat heart: protective role of vanillic acid. Environ. Sci. Pollut. Res. 2016b; 23 (6): 5154–5165. http://dx.doi.org/10.1007/s11356-015-5759-x2016.

52. Geravandi S, Goudarzi G, Soltani F, Salmanzadeh S, Ghomeishi A, Zalaghi E, Aslani Z, Mohammadi M. The cardiovascular and respiratory deaths attributed to sulfur dioxide in Kermanshah. J. Kermanshah Univ. Med. Sci. 2016; 19: 319–326.

53. Geravandi SGG, Yari AR, Idani E, Yousefi F, Soltani F. An estimation of COPD cases and respiratory mortality related to ground-level ozone in the metropolitan Ahvaz during 2011. Archives of Hygiene Sciences. 2016a; 5(1): 15–21.

54. Ghozikali MG, Heibati B, Naddafi K, Kloog I, Conti GO, Polos R, Ferrante M. Evaluation of chronic obstructive pulmonary disease (COPD) attributed to atmospheric O3, NO2, and SO2 using AirQ model (2011–2012 year). Environmental Research. 2016; 144: 99–105.

55. Maleki H et al. Temporal profile of PM10 and associated health effects in one of the most polluted cities of the world (Ahvaz, Iran) between 2009 and 2014. Aeolian Res. 2016; 22: 135–140.

56. Naimabadi A, Ghadiri A, Idani E, Babaei AA, Alavi N, Shirmandi M, Khodadadi A, Marzouni MB, Ankali KA, Rouhizadeh A, Goudarzi G. Chemical composition of PM10 and its in vitro toxicological impacts on lung cells during the Middle Eastern Dust (MED) storms in Ahvaz, Iran. Environ. Pollut. 2016; 211: 316–324.

57. Radmanesh E, Dianat M, Badavi M, Goudarzi G, Mard SA. The Effect of various LVEDPs on the contractility of heart in ischemia–reperfusion model in rats exposed to PM10. Res. J. Pharm. Biol. Chem. Sci. 2016; 7 (1): 1208–1213.

58. Soleimani Z, Goudarzi G, Sorooshian A, Marzouni MB, Maleki H. Impact of middle eastern dust storms on indoor and outdoor composition of bioaerosol. Atmos. Environ. 2016; 138: 135–143, http://dx.doi.org/10.1016/j.atmosenv.2016.09.017.

59. Yari AR, Goudarzi G, Geravandi S, Dobedararan S, Yousefi F, Idani E, Jamshidi F, Shirali S, Khishdost M, Mohammadi MJ. Study of ground-level ozone and its health risk assessment in residents in Ahvaz City, Iran during 2013. Toxicon. 2016; 35: 201–206.

60. Moustris KP, Ntourou K and Nastos PT. Estimation of Particulate Matter Impact on Human Health within the Urban Environment of Athens City, Greece. Urban Sci. 2017; 1(6): 2-11.
61. Neisi A, Goudarzi G, Babaei A, Vosoughi M, Hashemzadeh H, Naimabadi A, Mohammadi M, Hashemzadeh B (2016) Study of heavy metal levels in indoor dust and their health risk assessment in children of Ahvaz City, Iran. Toxin Rev 35:16–23.
62. Palit D et al. Assessment of air quality using several bio monitors of selected sites of Durgapur, Burdwan district by air pollution tolerance index approach. Indian Journal of Scientific Research, 2013; 4(1): 149-152.
63. Goudarzi G et al. Health endpoints caused by PM10 exposure in Ahvaz, Iran. Iranian Journal of health, Safety and Environment. 2014b; 1(4): 159-165.
64. Goudarzi G, Geravandi S, Mohammadi MJ, Salmanzadeh S, Vosoughi M, Sahebalzamani M. The relationship between air pollution exposure and chronic obstructive pulmonary disease in Ahvaz, Iran. Chronic Diseases Journal. 2015b; 3(1): 14–20.
65. El-Dars FM, Mohammed AMF and Aly HAT. Monitoring ambient sulfur dioxide levels at some residential environments in the greater Cairo Urban region-Egypt. Environ. Monit. Assess. 2004; 95: 269–286.
66. Hassanien MA and Abdel-Latif NM. Polycyclic aromatic hydrocarbons in road dust over Greater Cairo, Egypt, Journal of Hazardous Materials. 2008; 151(1): 247-254.
67. Hassan SK and Khoder MI. Gas–particle concentration, distribution, and health risk assessment of polycyclic aromatic hydrocarbons at a traffic area of Giza, Egypt. Environ. Monit. Assess. 2012; 184(6):3593-3612.
68. West PW and Gacke GC. Analytical chemistry, 28, 1916.Cited in Stern, A.C. (1968). 2nd Ed, Vol. П, Acad. Press New York, London. 1986.
69. Harrison RM and Perry RH. Hand Book of Air Pollution Analysis. 2nd Ed. Chapman and Hall, London – New York. 1986.
70. CPCB (Central Pollution Control Board). Air quality monitoring, emission inventory and source apportionment study for Indian cities. New Delhi, India: Central Pollution Control Board. 2011.
71. Shahsavani A, Naddafi K, JafarzadeHaghighifard N, Mesdaghinia A, Yunesian M, Nabizadeh R et al. The evaluation of PM10, PM2.5, and PM1 concentrations during the Middle Eastern Dust (MED) events in Ahvaz, Iran, from april through september 2010. J. Arid Environ. 2012; 77: 72–83.
72. Goudarzi G, Geravandi S, Idani1 E, Hosseini SA, Baneshi MM, Yari AR, Vosoughi M, Dobaradaran S, Shirali S, Marzooni MB, Ghomeishi A, Alavi1 N, Alavi SS, Mohammadi MJ. An evaluation of hospital admission respiratory disease attributed to sulfur dioxide ambient concentration in Ahvaz from 2011 through 2013. Environ. Sci. Pollut. Res. 2016; 23(21): 22001-22007.
73. Mohammadi MJ, Godini H, KhakMT, Daryanoosh SM, Dobaradaran S, Goudarzi G. An association between air quality and COPD in Ahvaz, Iran. Jundishapur J. Chronic Dis Care. 2015b; 4: 1–6.
74. Shakour A, El-Shahat M, El-Taieb N, Hassanein M, Mohammed A. Health impacts of particulate matter in greater Cairo, Egypt. J Am. Sci. 2011; 7: 840–848.
75. Nelson SD, Malone D, Lalfeur J. Calculating the baseline incidence in patients without risk factors: a strategy for economic evaluation. Pharmaco Economics. 2015; 33(39): 887–892.
76. Gurjar B, Jain A, Sharma A, Agarwal A, Gupta P, Nagpure A et al. Human health risks in megacities due to air pollution. Atmos. Environ.; 2010; 44: 4606–4613.
77. WHO (World Health Organization). Protection of the human environment, assessing the environmental burden of disease at national and local levels, Geneva 2004.
78. Geravandi S, Goudarzi G, Vosoughi M, JavadMohammadi MJ, Salmanzadeh S, Zallaghi E. Relationship between particulate matter less than 10 microns exposures and health effects on humans in Ahvaz, Iran. Archives of Hygiene Sciences. 2015b; 4(2): 23–32.
79. Ghozikali MG, Mosaferi M, Safari GH, Jaafari J. Effect of exposure to O3, NO2, and SO2 on chronic obstructive pulmonary disease hospitalizations in Tabriz, Iran. Environmental Science and Pollution Research 2015a; 22(4): 2817–2823.
80. Daryanoosh SM, Goudarzi G, Harbizadeh A, Nourmoradi H, Vaisi A, Armin H, Sadeghi S, and Khaniabadi YO. Hospital admission for respiratory and cardiovascular diseases due to particulate matter in Ilam, Iran. Jundisbapur J. Health Sci. 2016b; 9(1): e36106.
81. Daryanoosh, S.M., et al., 2016a. Effect of exposure to PM10 on cardiovascular diseases hospitalizations in Ahvaz, Khorramabad and Ilam, Iran during 2014. Iran. J. Health Saf. Environ. 3, 428–433.
82. CAPMAS (Central Agency for Public Mobilization & Statistics). Egypt in Figures, Booklet. 2016; March. Ref. No. 71-01112-2016.
83. EEAA (Egyptian Environmental Affairs Agency). Egypt Environmental Protection Low No. 4, 1994.
84. EEAA (Egyptian Environmental Affairs Agency). *Egypt State of Environment Report*. 2009.
85. Naddafi K, Hassanvand MS, Yunesian M, Momeniha F, Nabizadeh R, Faridi S, et al. Health impact assessment of air pollution in megacity of Tehran, Iran. *Iranian Journal of Environmental Health Science & Engineering*. 2012; 9(1): 1-7.
86. Khaniabadi YO, Goudarzi G, Daryanoosh SM, Borgini A, Tittarelli A, De Marco A. Exposure to PM10, NO2, and O3 and impacts on human health. *Environmental Science and Pollution Research*. 2016; 24(3): 2781–2789.
87. Geravandi S, Goudarzi G, VousoghiNiri M, Mohammadi MJ, Saeidimehr S, Geravandi S. Estimate of cardiovascular and respiratory mortality related to sulfur dioxide pollutant in Ahvaz. *Journal of Environmental Studies*. 2015c; 41(2): 13–15.
88. Arfaeinia H, Moradi M, sharafi K, Esfahani NM, Do-baradaran S. Evaluation of public health impacts related to urban air. *International Journal of Pharmacy & Technology (IJPT)*. 2015; 7(3): 9811-9824.
89. Mohammadi A, Azhdarpoor A, Shahsavani A, TatabaeH. Investigating the health effects of exposure to criteria pollutants using AirQ2.2.3 in Shiraz, Iran. *Aerosol and Air Quality Research*. 2016; 16: 1035–1043.
90. Lippmann M, Ito K, Nádas A, and Burnett RT. Association of particulate matter components with daily mortality and morbidity in urban populations. *The Health Effects Institute (HEI), Research Report*. 2000; (95): 5-72.
91. Atkinson RW, Anderson HR, Sunyer J, Ayres J, Baccini M, Vonk JM, Boumghar A, Forastiere F, Forsberg B, Touloumi G, Schwartz J, Katsouyanni K. Acute effects of particulate air pollution on respiratory admissions: results from APHEA 2 project. *Air Pollution and Health: a European Approach. Am. J. RespirCrit Care Med*. 2001; 15 (164): 1860-1866.