Evaluation of Chronic Obstructive Pulmonary Disease (COPD) attributed to atmospheric O₃, NO₂, and SO₂ using Air Q Model (2011-2012 year).

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Abstract

Chronic obstructive pulmonary disease (COPD) is an important disease worldwide characterized by chronically poor airflow. The economic burden of COPD on any society can be enormous if not managed.

We applied the approach proposed by the World Health Organization (WHO) using the AirQ2.2.3 software developed by the WHO European Centre for Environment and Health on air pollutants in Tabriz (Iran) (2011-2012 year). A 1h average of concentrations of ozone (O₃), daily average concentrations of nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) were used to assess human exposure and health effect in terms of attributable proportion of the health outcome and annual number of excess cases of Hospital Admissions for COPD (HA COPD).

The results of this study showed that 2% (95% CI: 0.8–3.1%) of HA COPD were attributed to O₃ concentrations over 10 µg/m³. In addition, 0.7 % (95% CI: 0.1- 1.8%) and 0.5% (95% CI: 0–1%) of HA COPD were attributed to NO₂ and SO₂ concentrations over 10µg/m³ respectively. In this study, we have shown that O₃, NO₂ and SO₂ have a significant impact on COPD hospitalization. Given these results the policy decisions are needed in order to reduce the chronic pulmonary diseases caused by air pollution and furthermore better quantification studies are recommended.

Keywords: AirQ software; Ozone; Nitrogen dioxide; Sulfur dioxide; COPD, Air Pollution, Hospitalization.

1. Introduction

Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects (Pascal et al., 2013; Schnell et al., 2015). The acute effects of air pollution on human health were amply proven in the 20th century, when severe air pollution in Europe (Meuse Valley and London) and in the United States (Donora, Pa) caused deaths and disease in hundreds of thousands of people. These episodes have demonstrated that high concentrations of air pollutants cause an increase in mortality and morbidity (Hassanvand et al, 2012).

Chronic obstructive pulmonary disease (COPD) is an important worldwide disease in both high-income and low-income countries (Polosa et al., 2013; Buist et al., 2008; Ko et al., 2012; Ko et al., 2008; Menezes et al., 2008) characterized by chronically poor airflow. The main symptoms include shortness of breath, cough, and sputum production (Vestbo, 2014; Vestbo and Wedzicha, 2013). By the year 2020, it has been estimated that COPD will rank fifth among the conditions with a high burden to society (Murray and Lopez, 1997) and third among the most important causes of death humans worldwide (Chapman et al., 2006; Vestbo, 2014). Air pollution has been recognized as a trigger for intensification of COPD (Ko et al., 2007) and has led to the development of air quality standards in many countries resulting in substantially decreased levels of various atmospheric pollutants derived from the burning of different fossil fuels (Adar et al., 2015; Schikowski et al., 2010). However, some pollutants such as ozone (O₃), sulfur dioxide (SO₂), and nitrogen dioxide (NO₂) continue to increase because are linked to increased urban traffic (Ferrante et al., 2012; Schikowski et al., 2014).

The ambient air pollutants concentrations however are strictly related to changes in pollutant emissions and to climate conditions (Hassan et al., 2015). Results of several studies show a direct associations between combustion of several fuels and COPD, but also, there is strong evidence of associations between traffic-related air pollution and adverse effect (Bravo et al., 2015) on lung development (Goldizen et al., 2015) in children aged 10–18 years (Thurston and Ito, 1999; Fattore et al., 2011) and on other organs (Dong et al., 2015). Especially O₃, NO₂ and SO₂ pollutants can all produce deleterious effects on the airway (Ferrante et al., 2012) such as an increase in bronchial reactivity (Ko et al., 2012; Happonen et al., 2010), airway oxidative stress (Antus et al., 2015; Patel et al., 2013; Medina-Ramón et al., 2006; Wong et al., 1999; Corradi et al., 2002; Gilmour et al., 2003), pulmonary and systemic inflammation (Ji et al., 2014; Happonen

et al., 2010; Anderson et al., 1997), amplification of viral infections, (Kesicet al., 2012) and reduction in airway ciliary activity (Ierodiakonou et al., 2015; Gilley et al., 2014).

Stieb and colleagues (2009) showed how an increase of 18.4 ppb level of O₃ concentration was associated with an increased of emergency room visits for asthma 3.2% (95% CI: 0.3–6.2%) and COPD 3.7% (95% CI: –0.5–7.9%). This association are stronger for children (5-17 years) compared with other age groups (Sacks et al. 2014; Delfino et al., 2014).

Tabriz is the fourth most populous city in Iran following Tehran, Mashhad and Isfahan. Tabriz is also the second most polluted city of Iran (Heidarnazhad et al., 2004) and one of the seven most polluted Iranian metropolises since last decades as a result of: population growth, urbanization, substandard gasoline use and increased of urban traffic (Gharehchahi et al., 2013).

The predictive models of concentration and of effect of air pollutants can be useful and these are classified into categorical and statistic groups (Krzyzanowski et al., 1997; Goudarzi et al., 2013).

AirQ software, developed by the WHO European Centre for Environment and Health (WHO, 2004), was proved to be a valid and reliable tool to estimate the potential effects of air pollution, predicts health and points attributed to criteria pollutants and finally allows the examination of different scenarios in which emission rates of pollutants are varied (Colls, 2006). There is only a paper with published data on COPD attributed to O₃, NO₂ and SO₂ in urban air of Tabriz city but related to the year 2008-2009 (Ghozikali et al., 2014).

In our study, carried out in year 2011 - 2012, we have examined the COPD attributed to O₃, NO₂ and SO₂ in ambient air of Tabriz using Air Q 2.2.3 Software to plot the trend respect to 2009.

This study was aimed to:

- 1) examine the COPD attributed to O₃, NO₂ and SO₂ in ambient air using Air Q 2.2.3 Software to assess Hospital Admissions for COPD (HA COPD) in people living in Tabriz, where the geographical features make the air quality among the worst in the Iran;
- 2) plot the trend of this air pollutants and AH COPD between 2009 and 2012;
- 3) provide the scientific basis for formulating suggestions or policy actions aimed to improve air quality and reduce so the burden of disease associated with air pollution in Tabriz.

2. Materials and Methods

2.1 Study area

Tabriz is the capital city of East Azerbaijan Province in Northwest of Iran (Fig. 1). It is located in the latitude of 38°04' N and the longitude of 46°17' E with average elevation of 1415 m above sea level. This city is located in a valley to the north of the long ridge of the volcanic cone of Sahand. According to the latest census report by Statistical Centre of Iran the population is about 1.5 million people. It is a major hub for heavy industries including automobile, machine tools, oil and petrochemical and cement production. Due to the growth of urban vehicular traffic and of new heavy industries (thermal power plant, petrochemical complex, and the oil refinery) in the west of the city, the air pollution levels have increased continuously, since the second half of the 20th century (AMAR, 2012).

2.2 AirQ software

We applied the approach proposed by the World Health Organization (WHO) using the AirQ2.2.3 software developed by the WHO European Centre for Environment and Health, Bilthoven Division (Fattore et al., 2011; Ghozikali et al., 2014).

First aim of this study was the study of COPD as a main item of health impact assessment (HIA) of air pollution on the target population using AirQ 2.2.3 software. This software has been developed to estimate the health impacts of exposure to specific air pollutants on a resident population in a certain area for 1 year (according its default). AirQ software permits the assessment of health effects related to a specific air pollutant short-term exposure in a specific population after a 1 year of monitoring. The assessment is set up on attributable proportion (AP) defined as the fraction of the health outcome in a certain population attributable to certain atmospheric pollutant's exposure.

The AP is calculated as described by Ghozikali and colleagues (2014), briefly

$$(1) \quad AP = \text{SUM} \{ (RR(c)-1) \times p(c) \} / \text{SUM} (RR(c) \times p(c))$$

Where:

AP is the attributable proportion of the health outcome, assuming a proven causal relation between exposure and health outcome and no major confounding effects in that association (Héroux et al., 2015; Gharehchahi et al., 2013; Gholampour et al., 2014; Naddafi et al., 2012; Fattore et al., 2011).

RR or relative risk for a given health outcome is defined as a risk of an event or of developing a disease relative to exposure and it is calculated through the ratio (Probability of event When exposed) / (Probability of event When non-exposed).

$P(c)$ is the population of exposure.

If the baseline frequency of the health outcome in the population under investigation is known, the rate attributable to the exposure can be calculated as

$$(2) IE = I \times AP$$

Where *IE* is the rate of the health outcome attributable to the exposure and *I* is the baseline frequency of the health outcome in the population under investigation.

Knowing the size of the population, the number of cases attributable to the exposure can be estimated as follows:

$$(3) NE = IE \times N$$

NE is the number of cases attributed to the exposure and *N* is the population's size investigated (in our case is 1.5 million of people).

In this research, air quality data (O_3 , NO_2 , and SO_2 levels), COPD as a health outcome, and exposed population data were entered to the software for the period of 2011 to 2012. Moreover, estimation of the excess hospitalizations due to COPD disease in exposed population as a result of short-term (daily) exposure to O_3 , SO_2 , and NO_2 were calculated by using *RR* and baseline incidence (*BI*) of WHO.

Three ranges of relative risk based on model's default were considered for assessing health effects of O_3 , NO_2 and SO_2 . Furthermore, baseline incidence (*BI*) values were also taken from default of the model and it is of 101.4 per one hundred thousand people each year.

In fact, when the local incidence data are not accessible or available at the time of the study (this is our case), is possible to use the WHO default values, this approach was reported in several published studies (Gharehchahi et al., 2013; Naddafi et al., 2012a; Gholampour et al., 2014; Fattore et al., 2011; He'roux et al, 2015).

2.3 Exposure assessment

Levels of O_3 , NO_2 and SO_2 were measured (hourly) in one year (21th March 2011 to 21th March 2012) by the Eastern Azerbaijan's Department of Environment (EA-DoE) using fixed ambient monitors in main urban and commercial roads.

Abrasan (residential-commercial area in the east city), Baqshomal (residential-commercial area in the city center), Health center (residential area in the north city), Hakim nezami (residential area in the south city), Rah ahan (Commercial Industrial area in the west city) and Rastekouche (commercial area in the city center) were the monitored stations.

In the station of Abrasan was used HORIBA model AP360 air pollution continuous monitoring system whilst, in all other stations, were used Environ tech model M200 continuous monitoring system. Both the monitoring systems are capable of stable and simultaneous measurement O_3 , NO_2 and SO_2 . In particular, both systems continuously monitors atmospheric O_3 concentrations through a cross multi-flow Ultraviolet Absorption method, NO_2 concentrations through a cross-flow modulated semi decompression chemiluminescence method and finally, SO_2 concentrations through an Ultra Violet Fluorescence method.

All data were collected on a volumetric base. Because the Air Q model was on gravimetric basis, we converted EA-DoE data in gravimetric units for their use on AirQ model. All processing mechanisms for conversion between volumetric and gravimetric units, such as correction of temperature and pressure, coding, averaging and filtering were performed using AirQ2.2.3 software.

For estimating the amount of O_3 , NO_2 and SO_2 , the procedure was designing input file for the model from the raw data. For this purpose, the following steps were performed successively:

1. Modification of temperature and pressure, and the conformation of dosages with the model;
2. Primary processing (this stage included deletion, spreadsheet of the pollutants and synchronization for the estimated average);
3. Secondary processing (this stage involved three parts of code writing mean calculation and condition correction);
4. Primary filtering;
5. Secondary filtering;
6. Quantifying of the health effects (COPD) of exposure to O_3 , NO_2 and SO_2 by means of AirQ software.

For all pollutants, the parameters required by the software (annual and seasonal averages, maximum and annual 98th percentiles) were obtained and the concentrations were divided into 10 $\mu g/m^3$ categories, corresponding to equivalent exposure categories. For O_3 , data were expressed as a hourly “moving average” whilst, for NO_2 and SO_2 as daily average concentrations.

AirQ2.2.3 software assumes that concentrations measured are representative of the average exposure of the people. Finally, the association between air pollution and COPD was assessed using AirQ2.2.3 Software, as also well described by Ghozikali and colleagues (2014).

3. Results

The maximum annual 1h average, maximum summer 1h average, maximum winter and 1h 98th percentile of O₃ concentrations of all stations have been listed in Table 1. For O₃ the maximum summer 1h average concentration was 43 µg/m³ while, the maximum winter 1h average concentration was 50µg/m³. The O₃ mean concentration was high both in the winter and in the summer (107µg/m³) (see Tab.1).

The annual average, summer average, winter average and 98th percentile of NO₂ and SO₂ concentrations in these stations have been presented in Tables 2 and 3.

The annual mean of NO₂ and SO₂ concentrations in Tabriz were 29 and 21µg/m³ respectively. The annual maximum of NO₂ and SO₂ concentrations were 80 and 116µg/m³ respectively. As the daily averages and daily maximum concentrations respectively of NO₂ (see Tab.2) and SO₂ (see Tab. 3) were all high in the winter.

The relationship of single air pollutants and percentage of attributed proportion, relative risk and number of persons suffering from COPD due to O₃, NO₂ and SO₂ exposure (as rate per 100,000 inhabitants) are shown in Table 4.

The estimated attributable proportion (AP) of HA COPD in a year due to short-term exposure above 10µg/m³ were 1.96, 0.74 and 0.52%, per 100,000 inhabitants for O₃, NO₂ and SO₂, respectively, in otherwise, estimated number of excess cases as a HA COPD were 31, 12 and 8 persons.

Also, Table 4 shows the Cumulative number of HA COPD (related to O₃, NO₂ and SO₂) in relation to respective concentrations of the pollutants in the upper, central and lower domains of the relative risk. The assessment of health effect of COPD by exposure to O₃, NO₂ and SO₂ in Tabriz obtained in percentage from the software and the numbers of consequences are shown in Figure 2. Figure 2 showed number of cases in 5, 50 and 95 percent relative risk respectively. Cumulative number of HA COPD due to O₃ in rr5=1.0022, rr50=1.0058 and rr95=1.0094 was 12, 31 and 49 persons respectively. Cumulative number of HA COPD due to NO₂ in rr5=1.0004, rr50=1.0038 and rr95=1.0094 was 1, 12 and 29 persons respectively. Cumulative

number of HA COPD due to SO₂ in rr5=1, rr50=1.0044 and rr95=1.011 was 0, 8 and 21 persons respectively.

In Figure 2 the mid curve corresponds to the central relative risk and cumulative number of HA COPD due to exposure O₃, NO₂ and SO₂ in based on mid curve was 31, 12 and 8 persons respectively. The data of first monitoring (2008-2009) about O₃ showed that, maximum summer 1h average and maximum winter 1h average concentration were 66.82 µg/m³ and 67.05 µg/m³ respectively, it was higher respect to recent study. Also, based on the data of previous study (2008-2009), the annual mean of NO₂ and SO₂ concentrations were 33.54 and 19 µg/m³, respectively. The annual maximum of NO₂ and SO₂ concentrations were 78.52 and 88 µg/m³, respectively (Ghozikali et al., 2014).

The results of this study showed that 2% (95% CI: 0.8–3.1%) and 0.7 % (95% CI: 0.1- 1.8%) of HA COPD were attributed to O₃ and NO₂ concentrations over 10 µg/m³ respectively, that are slightly decreased compared to 2009. In addition, 0.5% (95% CI: 0–1%) of HA COPD were attributed to SO₂ concentrations over 10µg/m³ that, instead, are increased compared to 2009.

4. Discussion

In this research, the authors have estimated the excess hospitalization cases for COPD due to short-term exposure to O₃, NO₂ and SO₂ air pollutant using AirQ model and in particular the WHO AirQ2.2.3 software. O₃, NO₂ and SO₂ are the major atmospheric pollutants in Tabriz.

Our study showed that the health consequences related to O₃, NO₂ exposure are declining, while, the health consequences related to SO₂ exposure are increasing (Ghozikali et al., 2014). We think that this relative improvement could be due to the sensitivity and/or attention of the national and regional authorities on air pollution but also to legal requirements, regulations and standards (O₃< 160 µg/m³-1h mean, NO₂< 80 µg/m³- annual mean and SO₂< 400 µg/m³-24h mean) of recent years (Naddafi et al., 2012b).

In this new study, also, NO₂ was the strongest predictor of HA COPD among all gaseous pollutants in single-pollutant models. This finding is consistent with some results of previous studies (Yang et al., 2005; Lin et al., 2003; Burnett et al., 1999). In fact, in a similar study carried out in Sydney, Australia, COPD was strongly associated with NO₂ (Yang et al., 2005; Morgan et al., 1998). NO₂ is not highly soluble, it is most retained in the small airways of lungs, so, NO₂ has a greater airway deposition respect to O₃ and it remains a pollutant of current concern. We found in several experimental studies that patients with COPD are more

sensitive to NO₂ than healthy control subjects (Yang et al., 2005; Sunyer et al., 2002; Morrow et al., 1992). Indicators of relative risk (RR) and Attributable Proportion (AP) for COPD to NO₂ is defined on baseline Incidence (BI) 101.4 at 10⁵ persons by the WHO. For our population of 1.5 millions of people and base on BI of 101.4 per one hundred thousand peoples each year, about 1,567 COPD cases can be expected annually, out of this number, 31, 12 and 8 cases can be attributed to the O₃, NO₂ and SO₂ concentrations above 20µg/m³, respectively. 79.2% of COPD cases occurred in days with pollutant not exceeding 60µg/m³.

For tropospheric O₃ in Tabriz, the maximum annual one hour mean concentration, summer average, winter average and 98th percentile were 44, 43, 50 and 84µg/m³ respectively. Instead, in Ahvaz, Iran, were measured respectively 72.62, 84.38, 60.51 and 121.44µg/m³. So, our results are lower respect to the recent results reported by Goudarzi and colleagues (Goudarzi et al., 2013) in Ahvaz. More than 96.7% of COPD is attributable to days that concentration of O₃ did not exceed the 100 µg/m³ and, in concentration of O₃ below 10 µg/m³ there was not HA COPD. For every increase of 10 µg/m³ in O₃ concentration, the risk of HA COPD rise about of 0.58 %. In a study carried out by Schwartz (1994), O₃ was found to be associated with increased risk of HA COPD. Also in the study carried out in Tehran, Iran, was showed that increasing of 10 µg/m³ of O₃ concentration increases the risk of COPD 0.86% (95% CI: 0.44–1.3%) and 93% of HA COPD is attributable to the days on which O₃ concentration did not exceed the 110 µg/m³. So, the results of both studies are somewhat close together and the O₃ pollution in metropolitan of Tabriz is very similar with that of megacity of Tehran, Iran.

The results of this study showed that 1.96% (95% CI: 0.75-3.14%) of HA COPD were attributed to O₃ concentrations over 10 µg/m³ (Tab. 4). In Europe, the APHEA project (a multicentric and multi-pollutant study) evaluated air pollution (multi-pollutant) and its short-term effects such as HA COPD. The RR for a 50µg/m³ increase in the daily mean level of pollutant was 1.02 (95% CI 0.98–1.06) for SO₂, 1.02 (95% CI 1.00–1.05) for NO₂ and 1.04 (95% CI 1.02–1.07) for O₃ (Anderson et al., 1997).

The results of another study carried out in Ahvaz, Iran, showed that 3.52% (95% CI: 0.05–5.58%) of HA COPD were attributed to O₃ concentrations over 10 µg/m³ (Goudarzi et al., 2013). For every 10 µg/m³ increase in NO₂, O₃ and SO₂ concentrations, the risk of HA COPD increase about 0.38, 0.58 and 0.44% respectively (Tab. 4).

Other studies have been carried out in US cities, European cities, Milan (Italy) and Hong Kong (China) on the health effects of atmospheric pollution (Tab.5). They found there are association between outdoor pollutants (O_3 , NO_2 and SO_2) and acute exacerbation of HA COPD.

Increases in O_3 , NO_2 and SO_2 were associated with an 11% increase in daily hospital admissions (Burnett et al., 1997). In Vancouver, O_3 and NO_2 were found to be significantly associated with HA COPD and the relative risks (95% CI) were 1.08 (0.97, 1.20) for O_3 , 1.06 (0.95, 1.19) for NO_2 , and 0.96 (0.86, 1.06) for SO_2 . The combined RR for all gases was 1.21 (Yang et al., 2005). A similar multi-pollutant study carried out in USA (three countries) has shown, that also other pollutants (carbon monoxide and particulate matter), besides the O_3 , are strongly associated with HA COPD (Moolgavkar, 2000). In Sao Paulo, Brazil, all measured pollutants, O_3 , NO_2 and SO_2 , were significantly associated with increased HA COPD (Gouveia et al., 2006).

Our study shows high O_3 Maximum level 1h in wintertime than summertime (Tab. 1). Our result is not a rare event. In fact, while vigorous O_3 formation in the summer (high levels of solar irradiance and abundant O_3 precursor concentrations) has long been recognized by several authors, high levels of O_3 production during the winter has only recently been documented (Kalabokas et al., 2013; Ooka et al., 2011). The strong role of meteorology (thermic inversion), topography, and high levels of O_3 precursors from oil refinery activities (with high density in Tabriz) in association to home heating and vehicle traffic have been identified as key drivers of wintertime high O_3 events. In general, O_3 increases with increasing of methane and carbon monoxide (Oltmans et al., 2015; Edwards et al., 2014).

This study has a number of limitations.

The first limitation of this approach is that the health impact focuses on single compounds without considering the simultaneous exposure to several pollutants, which is what actually occurs.

Generally, in quantitative assessments of health effects, the interactions between different contaminants are not well investigated, in fact, these informations are still rarely available.

A further limitation is due to the RR estimates derived in studies of different populations in comparison to that under investigation. Furthermore, because this model is an ecological based approach and not an epidemiological approach, our model does not consider intra-individual differences due to different behaviors inside the population studied (i.e active or passive smoking, mobility during the day, proximity to major roads, etc.).

Finally, another limitation relatively to the exposure assessment (but accepted by all authors on the topic) is that the approach assumes that concentrations measured in specific sampling points are representative of the average exposure of people living in Tabriz.

5. Conclusions

This study has assessed health impacts of air pollution in Tabriz, Iran. The results of this study showed that O_3 and NO_2 concentrations are decreased and instead the SO_2 concentrations are increase compared to 2009. This status suggested that the national and regional authorities have been sensitive on air pollution and most of the people cooperate with the government are trying to reduce air pollutants. With our study we have shown that O_3 , NO_2 and SO_2 have yet a significant impact on HA COPD. Since the geographic, demographic, and climate characteristics are different and not well studied, there is still high need to further studies. The results of our study are in line with those of other researches carried out in other countries, and despite the limitations (similar in all other studies cited), indicate that this method offers an effective and easy tool, helpful in decision-making. The magnitude of the health impacts estimated for this city requires urgent action to further reduce the health burden of air pollution in Tabriz and therefore in Iran.

Given these results, better quantification studies are recommended and the following actions are needed in order to reduce the negative pulmonary health effects caused by air pollution:

- Restricting the use of underground resources and fossil material, raise the level of eco-friendly urban public transport systems, measures necessary to reduce the high traffic urban, traffic correct management applied and effective strategies to improve the quality of the auto industry productions implementing policies to reduce air pollution.
- Quantification for evaluation of the disease burden attributable to air pollution and of the health effects of air pollutants needs epidemiological indices so specialists suggest the identification of these indicators
- Recommended to use this model or other models, to investigate and evaluate effects of air pollution on health of other metropolitan country people and comparisons should be made.

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Figure Captions

Figure 1. Study area and sampling location

Figure 2. Relationship between Cumulative number of HA COPD and atmospheric pollutants concentration

Table 1

O₃ concentrations (µg/m³) 1h by means of the model (Tabriz- Iran, 2011) in all the stations

Station Parameter	Rahahan	Hakimnezami	Behdasht	Abrasan	Rastekouche	Baqshomal	Tabriz
Maximum annual 1h average	69	NA	NA	55	73	44	44
Maximum summer 1h average	61	NA	NA	57	69	49	43
Maximum winter 1h average	65	NA	NA	52	89	73	50
1h 98 th percentile	160	NA	NA	99	159	94	84
Maximum annual1h	288	NA	NA	149	179	110	107
Maximum summer1h	285	NA	NA	149	179	110	107
Maximum winter1h	288	NA	NA	77	107	101	101

Table 2

NO₂ concentrations (µg/m³) daily by means of the model (Tabriz - Iran, 2011) in all the stations.

Station Parameter	Rahahan	Hakimnezami	Behdasht	Abrasan	Rastekouche	Baqshomal	Total stations
Annual mean	17	21	21	22	79	17	29
Summer mean	10	18	14	17	62	16	23
Winter mean	43	30	41	16	98	18	41
Annual 98 th percentile	72	75	80	32	188	32	61
Annual maximum	147	84	91	37	244	57	80
Summer maximum	27	44	22	31	222	37	62
Winter maximum	147	84	91	37	244	28	80

Table 3SO₂ concentrations (µg/m³) daily by means of the model (Tabriz- Iran, 2011) in all the stations

Station Parameter	Rahahan	Hakimnezami	Behdasht	Abrasan	Rastekouche	Baqshomal	Total stations
Annual mean	24	18	NA	26	31	6	21
Summer mean	12	14	NA	22	21	5	15
Winter mean	39	31	NA	36	38	10	31
Annual 98 th percentile	102	62	NA	81	116	19	71
Annual maximum	175	128	NA	168	257	30	116
Summer maximum	39	33	NA	44	53	22	37
Winter maximum	175	128	NA	168	257	30	116

Table 4

Estimated attributable proportion (AP) expressed as number of excess case of Hospital Admissions COPD in a year due to short-term exposure above $10\mu\text{g}/\text{m}^3$ for O_3 , NO_2 and SO_2

Atmospheric pollutants	Index Estimate	RR ^a	Estimated AP (%) ^b	Estimated number of excess cases
O_3	Lower	1.0022	0.7528	12.0
	central	1.0058	1.9606	31.0
	upper	1.0094	3.1393	49.2
NO_2	Lower	1.0004	0.0784	1.20
	central	1.0038	0.7399	11.6
	upper	1.0094	1.8106	28.4
SO_2	Lower	1.0000	1.0000	0.00
	central	1.0044	0.5216	8.20
	upper	1.0110	1.0380	20.3

^aRelative Risk

^bAttributable Proportion

Table 5

Some examples of the association between outdoor pollutants and acute exacerbation of chronic obstructive pulmonary disease admissions (Fattore et al, 2011; Medina-Ramón et al., 2006; Anderson et al., 1997)

Pollutants	Country	RR (%)	95% CI	Reference
O ₃	US cities	0.27	0.08- 0.47	Medina-Ramón et al., 2006
	European cities	1.04	1.02-1.07	Anderson et al., 1997
	Milan (Italy)	1.04	1.03-1.04	Fattore et al, 2011
NO ₂	European cities	1.02	1.00- 1.05	Anderson et al., 1997
	Milan (Italy)	1.03	1.02-1.03	Fattore et al, 2011
SO ₂	European cities	1.02	0.98-1.06	Anderson et al., 1997
	Hong Kong (China)	1.01	1.00-1.01	Ko et al, 2007

Figure 1

Figure 2