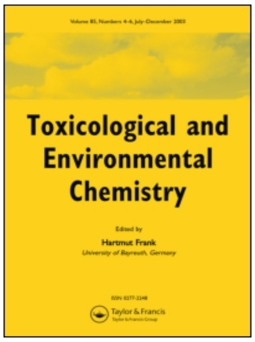

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It is well known that air pollution exerts adverse effects on health and environment. Balıkesir located in the Marmara region (Turkey) has serious air pollution problems produced by heating in the months of winter. In this study, the effect of exposure to air pollution on hospital admission for respiratory illnesses among children and adults was examined. Epidemiological data from records of hospitals, air pollutants and meteorological data were used. During July 2005–July 2007 period, there was a total of 280,426 hospital admissions for respiratory diseases. In a population-based analysis, 9 children were admitted for asthma, 17 children for acute bronchitis, and 20 children for lower respiratory diseases out of 100 children. There was a significant increase in the hospital admissions for respiratory diseases and air pollutants from October to March. It was concluded that children living in the city suffer from respiratory diseases such as asthma, pneumonia, and lower respiratory diseases. Three factors that account for approximately 90% of total variance of hospital admissions, air pollution, and meteorology were identified by means of principal component factor analysis.

Keywords: urban air pollution; meteorology; health effects; factor analysis; Balıkesir

Introduction

Major anthropogenic air pollutants are concentrated in city centers. Traffic, industry, and heating systems are the main sources of urban air pollution. Meteorology, topographic structure, and urban settlement issues are significant factors influencing dispersion, accumulation, and chemical transformation processes of air pollutants. It is well known that various air pollutants exert adverse effects on environmental and human health. Clinical studies conducted on human health demonstrated that pollutants like ozone (O_3), SO_2, particulate matters (PM), NO_x, and biogenic antigens like pollen produce an increase in the frequency of respiratory diseases (Helander, Savolainen, and Ahlholm 1997; Monn et al. 1999; Martonen and Schroeter 2003; Moshammer and Neuberger 2003). In many epidemiological studies, environmental air pollution was shown to produce adverse effects on the respiratory system resulting in diseases, especially like asthma (Alberini and Krupnick 1998; Williams et al. 2000). Similar studies indicate the existence of a relationship between the rise in frequency of respiratory related symptoms and increase in mortality (Wordley, Walters, and Ayres 1997; Timonen et al. 2002). A correlation was detected in adults and children between air pollution and hospital admissions or the need

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for emergency services due to respiratory system or severe asthma complaints (Gomzi 1999; Wong et al. 2000; Brunekreef and Holgate 2002).

In contrast, parallel to epidemiological studies, a series of investigations concentrated on the perception of environmental risks by the public regarding the relationship between air pollution and health issues. Studies were conducted on the perception of risk posed on human health by air pollution (Elliott et al. 1999; Moffatt et al. 2000; Wakefield and Elliot 2000). It was emphasized that the perception of risk between air pollution and human health issues were associated with factors like personal exposure, habitation near to industrial regions, and socio-economical status (Elliott et al. 1999; Bickerstaff and Walker 2001; Howel et al. 2003). Similarly, many environmental epidemiologists have been involved in research studies on the development of air pollution: human health perception considering the relationships between regional distribution and trend of air pollution and changes in health conditions like complaints of asthma and heart diseases (Brauer et al. 2002; Lin et al. 2002; Annesi-Maesano et al. 2003). It is necessary to control and reduce these risks by controlling air pollution. Policies that control air pollution will have an in-depth effect on our future life and our lifestyles with regard to traveling and working conditions; but implementation of such policies is not possible without the support of the public. This study aims at determining the trends in air pollution and meteorological variables while examining health related effects in the city.

Materials and methods

Description of the region of study

The province of Balıkesir consists of the Aegean Region, although it is situated in Marmara Region and is surrounded by Bursa and Kütahya in the east, Izmir and Manisa in the south, Aegean Sea, and Çanakkale in the west and the Marmara Sea in the north (Figure 1). Population of the city center is 215,436 according to the general census in the year 2000. Balıkesir is in a transitional region between Mediterranean climate and Black Sea climate. Thus, it is possible to face climatic characteristics of both these climates from place to place. Aegean coasts are generally hot and arid in summer and warm and rainy in winter, while the summer along Marmara Sea coasts is relatively cool as affected by the Black Sea climate conditions. Continental climate tendencies increase towards terrestrial regions where it is cold in winter. Effective fog occurrences in terrestrial zones during cold winter times may result in relative humidity of 95–100% from time to time. High pressure in cold periods of time produces excessive fuel consumption due to low temperatures and accompanying fog occurrences lead to heavy air pollution episodes to be experienced (Çevre ve Orman Bakanlıgı 2004).

The province of Balıkesir is under the influence of air pollution in winter, which result from heating systems. The provincial center is considered among the Group I of Polluted Provinces with its pollution according to its SO_2 and total particulate matter (TPM) figures in winters during 2002–2003 and 2005–2006 periods. The provincial center of Balıkesir was generally listed among the most polluted provinces with its winter-season pollution levels which were usually above limit values during long years in which conventional SO_2 and TPM measurements were made. Topographical structure, urban settlement plan and adverse meteorological conditions contribute to this pollution profile to those living in the city center besides existing heating, industrial and traffic conditions. The bowl-shaped structure of the city center, the decrease in speeds of dominating winds, high pressure and decrease in air temperatures as well as high

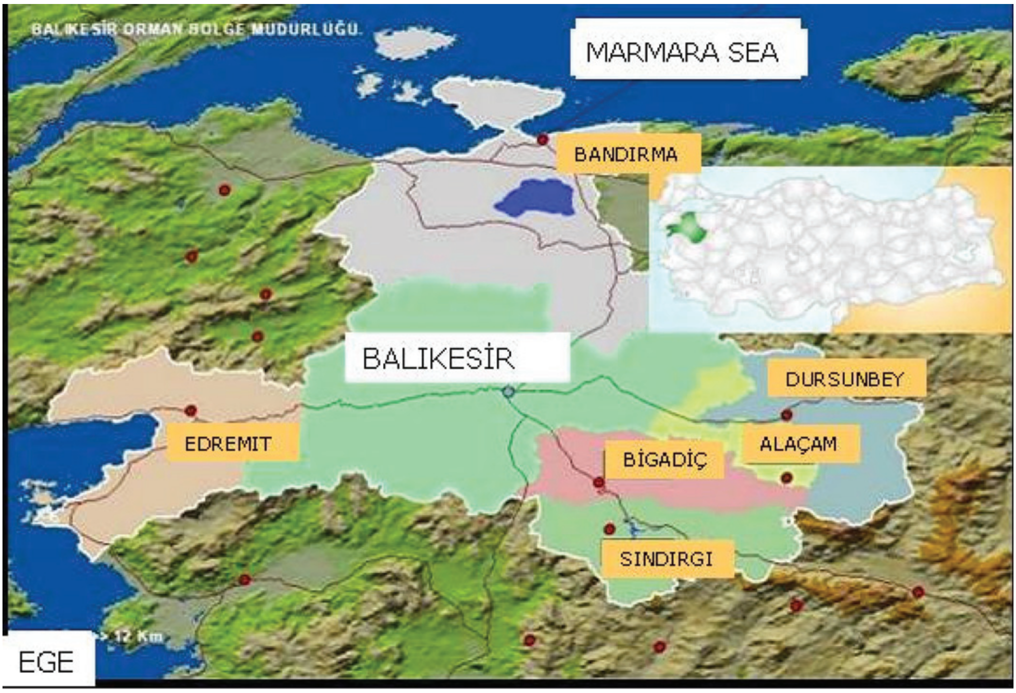

Figure 1. (Color online). The study region.

humidity and frequently observed foggy days in winter months are increasing the effects of pollution.

Data and analysis

Air pollution data (TPM, SO_2) were received from the measurement station established by Provincial Health Administration in 1996. Long-range analysis of air pollution observed in the city was realized using 24 h averages of pollutants in the period 1996–2006. Data related to the period 2005–2006 were used in analysis regarding the relations between hospital admissions due to respiratory system diseases and the air pollution in the city.

Data on hospital admissions due to respiratory system diseases (HARSD) related to the July 2005–2007 were collected on patients applying to the clinics for children and adults at three hospitals in the city due to respiratory system complaints on the basis of the following criteria;

> age, gender, hospital registration number, hospital application date, ICD10 (WHO 2005), payment type (to determine the socio-economic condition), and information on the region of residence.

Records in all the hospitals from which the above-mentioned data were collected have been kept in an ICD10-based computer environment since the middle of the year 2005. These data are sent to the Ministry of Health in certain periods of time. This system of records provided us with the chance to collect data for the study realized in a healthy manner.

Long-range meteorological data for Balıkesir were collected from General Directorate of State Meteorological Services Administration. Averages, changes and general statistics of temperature, relative humidity, wind speed, pressure, and total precipitation parameters were determined over a 26-year period since 1980. Meteorological data were analyzed as it is another factor influencing hospital admissions due to respiratory system diseases.

Statistical analysis

The changes and trends of the air quality in the city and related meteorological data were detected by making use of central tendency and distribution criteria as well as other determining statistical methods. Records regarding patients of asthma, pneumonia, acute and chronic bronchitis, LRD (lower respiratory diseases), URD (upper respiratory diseases) and COPD (chronic obstructive pulmonary disease) were statistically analyzed on the basis of demographical structure information like ages, genders, and related data. Factor analysis was made to determine effective factor quantities of air pollution levels and meteorological conditions known to exert influences on hospital admissions due to the respiratory system. This technique examines and classifies the changes, trends and variants of all data group parameters, and determines the effective factor quantities.

Results

Air quality and local meteorology

Ten-year statistics on air pollutants (TPM, SO_2) in the period 1996–2006 are given in Table 1. Figure 2 indicates, on the basis of 10-year observation results, that SO_2 trend is decreasing while there is an increasing trend in TPM values.

Average SO_2 concentration was 78.4 $\mu g\,m^{-3}$ and showed a considerably large variance in this 10-year period. The difference between maximum and minimum values was 666 $\mu g\,m^{-3}$, and this change points to the fact that periodical episodes were experienced in this period. Furthermore, it is clear from the frequency distribution of measured SO_2 concentrations that 25% of daily averages are greater than 101 $\mu g\,m^{-3}$. SO_2 concentrations in 10% of the 3549-day period in which the measurements were made (nearly 355 days) were at levels equal to or higher than 213 $\mu g\,m^{-3}$. This exceeded the concentration of 455 $\mu g\,m^{-3}$ in a time segment of about 1% (approximately 35 days).

In contrast to SO_2 concentrations, TPM concentrations showed an increase in the period 1996–2006. The average of the 10-year period was 53.46 $\mu g\,m^{-3}$. TPM pollution above the level of about 113 $\mu g\,m^{-3}$ was experienced within a period of 3529 days. TPM concentrations under 241 $\mu g\,m^{-3}$ were measured in a time segment of 1% of the measured period. Although there are days with peak values measured from time to time, 75% of measurements are under the level of 66 $\mu g\,m^{-3}$. The general trend of increase is important for TPM. The increase in the number of vehicles may be among the important causes of the above-mentioned increase.

Meteorological data

Statistics showing the long-range distribution of meteorological parameters comprised of daily observation values over a period of 26 years (1980–2006) are given in Table 1. When evaluations regarding the course of local meteorological conditions based on the data received from meteorological stations in the city center are made for each parameter, it is seen that the wind speed in the city is 1.64 $m\,s^{-1}$ on average, while 75% of daily wind speed averages are below 2.3 $m\,s^{-1}$ and only 10% of these wind speed averages (approximately 983 days) are above 3.9 $m\,s^{-1}$.

Table 1. Air pollutants and meteorological variables.

	1996–2006		1980–2006					
	TPM ($\mu g\,m^{-3}$)	SO_2 ($\mu g\,m^{-3}$)	Wind ($m\,sn^{-1}$)	Temp. (°C)	R.H (%)	Press. (mb)	Cloud. (×/10)	Rain (mm)
N	3529	3549	9826	9857	9857	9857	9862	3821
Mean	53.46	78.40	1.64	14.57	70.56	1000.79	4.28	3.79
SD	51.85	95.71	1.66	8.10	12.70	6.40	3.29	7.53
Minimum	0	1	0.0	−9.2	27.3	973.6	0.0	0.0
Maximum	1119	666	19.4	32.6	99.7	1024.5	10.0	126.8
Percentiles								
25	22.00	16.70	0.50	7.80	61.70	996.40	1.00	0.00
50	36.00	38.00	1.10	14.80	70.30	1000.10	3.70	0.50
75	66.00	101.00	2.30	21.70	80.30	1005.00	7.00	4.40
90	113.20	213.00	3.90	25.00	87.70	1009.50	9.00	11.98
95	154.70	284.00	5.10	26.30	91.00	1012.00	10.00	18.20
99	241.38	455.50	7.400	28.500	95.700	1017.000	10.000	34.690

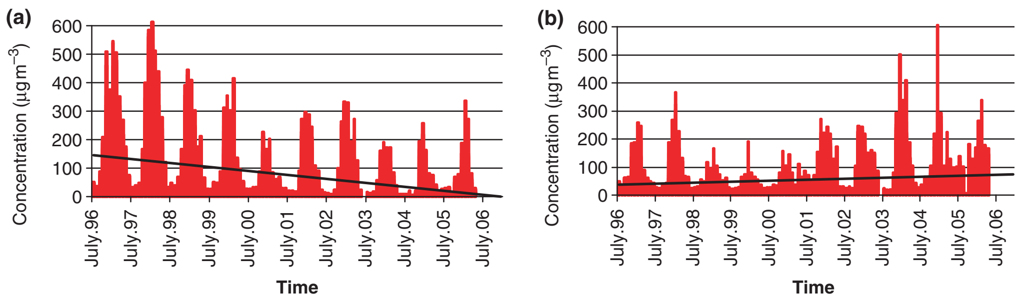

Figure 2. For the period 1996–2006, (a) SO_2, (b) TPM daily mean and trends.

Average temperature is 14.57°C while the temperature changed within a range of lowest and highest temperatures of −9.2°C and 32.6°C. During the period of the said 26 years corresponding to a total of 9857 days, average temperatures recorded in the coldest 25% segment were below 7.8°C, while average temperatures recorded in the warmest 25% segment were above 21.7°C. It is possible to express the temperature median value of 14.8°C which is a heating requirement in the city for about half of the entire period in question.

Relative humidity, which has a mean of 70.56%, has a standard deviation of 12.70. A 25% portion of relative humidity measured as 27.3% in minimum and 99.7% in maximum has been realized as equal to and above 80.3%. These values indicate that the relative humidity in the city is high. Statistical values of precipitation, cloud, humidity, and pressure parameters indicate the existence of periods with stable weather conditions where a good mix of air pollutants could not be established to allow their uniform distribution in the city's atmosphere. It is known that there are such adverse conditions experienced in all urban settlements in general from time to time.

Epidemiological data

There was a total of 280,426 patients applying to the three hospitals in the city (Atatürk State Hospital, Balıkesir SSK Hospital and Hospital for Chest Diseases) due to respiratory system diseases in the period between July 2005 and July 2007 (Table 2). This figure also covers more than one admission per person. It is clear from HARSD details expressed in ICD10: J00-J99 codes that daily average, standard deviation and daily maximum figures are 368, 284, and 1538 people, respectively. Lower respiratory diseases (LRD), acute bronchitis, chronic obstructive pulmonary diseases (COPD), and asthma related diseases were more common among the admissions.

Considering the HARSD counts on the basis of age groups, it was found that there were a total of 103,968 admissions from children of age 0–14 years with all types of respiratory system complaints comprised mainly of acute bronchitis, LRD problems and asthma related diseases. Children of the age 0–14 years constitute 23% within the demographical structure of the population at Balıkesir (www.tuik.gov.tr). When hospital admissions are examined in consideration of the age groups 166.222 for adults (age 15 years and above) and 49.193 for children (age group 0–14), the number of children admitted to hospital was higher than the number of hospital admissions for adults, with the exception of COPD and acute bronchitis diseases (Figure 3).

The population of all ages at Balıkesir is comprised of 48% women and 52% men. It was shown from gender distribution from HARSD that the number of boys (age 0–14 years) applying to hospitals was higher than the number of girls (Table 2). Considering the adults, on the other hand, the situation was different as the number of female admissions was higher than male admissions with HARSD complaints. The number of male patients was higher in admissions regarding COPD and pneumonia diseases.

Table 2. HARSD in the period of July 2005–July 2007.

	All ages						
	Sum HARSD	Asthma	COPD	Pneumonia	Acute bronchitis	Lower RD	Chronic bronchitis
N	761	761	761	761	761	761	761
Mean	368.50	31.94	42.53	6.61	54.35	60.96	13.87
SD	294.51	31.37	36.62	6.85	54.75	60.74	13.26
Minimum	0	0	0	0	0	0	0
Maxmum	1538	147	196	42	319	350	73
Age (years)							
0–6	60.284	3.492	232	1.354	8.117	9.471	192
7–14	43.684	2.582	193	780	3.549	4.329	152
0–14	103.968	6.074	425	2.134	11.666	13.800	344
15–64	144.615	15.445	17.270	2.123	24.288	26.411	7.705
> 64	31.843	2.785	14.674	771	5.409	6.180	2.503
Gender							
Girls	47.804	2.410	189	979	5.145	6.124	156
Boys	56.164	3.664	236	1.155	6.521	7.676	188
Women	97.922	14.099	11.495	1.253	16.573	17.826	5.420
Men	78.536	4.131	20.449	1.641	13.124	14.765	4.788

Relationship between air pollution and epidemiology

The relationship between air pollution and epidemiology was examined in this study on the basis of HARSD (ICD10: J00-J99). HARSD include the entire emergency service admissions and repetitive admissions as well as all the out-patient and/or in-patient treatments. Evaluations on the relationship between air pollution and epidemiology were made on the basis of records in the period July 2005–April 2006 covering also the winter season where intensive air pollution occurred. Since the regular ICD10-based records were started in July 2005 and only the measurements on air pollutants until April 2006 could be found, our study was limited to this time period. The period between the months of October and March represents the heating period in the city. Data from the period July 2005–April 2006, of air pollutants (TPM, SO_2) as well as the epidemiological and meteorological results are given in Table 3.

According to the figures for this period, it is clear that average TPM concentrations are higher than SO_2 concentrations. It is known that from 10-month variations of pollutants within the period July 2005–April 2006, high concentrations were present during the winter season (Figure 4). Concentrations started to increase in October and reached peak values around January and then decreased after that point. Pollution above the average was experienced in the months of February and March and concentrations decreased in April, which represents the end of the heating period.

A similar trend of air pollutants is also observed in the distribution of monthly averages of HARSD figures in the same period. There are many factors affecting periodical increases in respiratory system diseases; and air pollution and local meteorology, which are environmental factors, play important roles in increasing the prevalence of such diseases.

A principal component analysis (PCA) was undertaken in order to determine the degree of influence of hospital admissions, air pollution and local meteorology as the factors in this period (July 2005–April 2006).

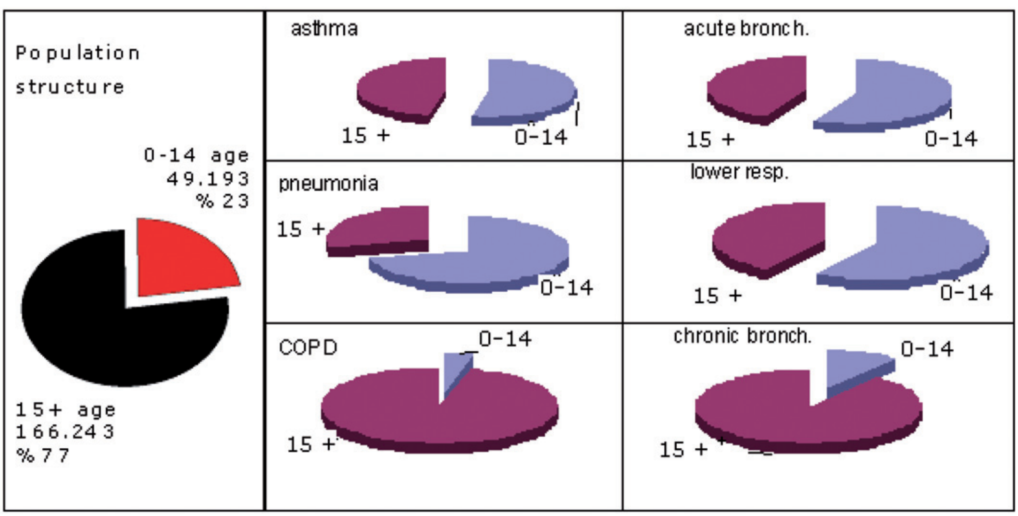

Figure 3. HARSD distribution as per age groups.

Table 3. Air pollutants and epidemiological and meteorological data for the period July 2005–April 2006.

Variables	Day	Mean	Med.	SD	Sum	Percentiles Min	25	50	75	Max
SSHB (*n*)	304	246.21	217	171.14	74848	0	105.7	217	349.5	946
Asthma	304	17.30	13	18.50	5258	0	2	13	22	81
COPD	304	26.40	18	26.43	8025	0	7	18	33.7	140
Pneumonia	304	3.58	2	4.02	1088	0	1	2	5	20
Acute bronchitis	304	32.32	19.5	35.39	9825	0	7	19.5	43	243
Lower RD	304	35.90	22	38.61	10913	0	8	22	47	254
Chronic bronchitis	304	10.57	7	11.79	3213	0	1	7	15	63
Air pollutants										
TPM ($\mu g\,m^{-3}$)	290	76.20	67.7	54.12		2	37.15	67.70	104.3	337
SO_2 ($\mu g\,m^{-3}$)	302	35.12	22.7	41.21		5	10.45	22.75	42.82	337
Meteorology										
Wind speed ($m\,sn^{-1}$)	304	2.05	1.3	2.33		0	0.5	1.35	3.20	19
Temperature (°C)	304	13.40	12.2	8.83		−7	8.12	12.25	21.50	30
Relative humidity (%)	304	71.45	71	11.66		38	63	71	80.22	96
Pressure (mb)	304	1003.8	1003	5.92		989.6	999.4	1003	1007	1019
Cloudiness (×/10)	304	4.60	4.30	3.08		0	2	4.30	7.70	10
Rainfall (mm)	96	4.55	1.05	6.74	437	0	0.30	1.05	5.40	27

Principal component analysis

Factor analysis is used in the analysis of data groups with values belonging to many variables measured on various samples. This technique examines and classifies the changes, trends and variants of all parameters in all data groups and determines the impact quantity figures. PCA establishes a new relationship set of variables that may explain variations in the original data set (Gonçalves et al. 2005). A PCA was conducted in this study for determining the factors in relation with each other as well as the impact quantities on the basis of the monthly averages of HARSD values, measured air pollution concentrations and local meteorological parameters. Results of this analysis are provided in Table 4. A smoothing operation was obtained on data with noise to eliminate the irregularities developed in daily HARSD values due to variations in the days of the week as well as seasons. Therefore, irregularities depending on weekends, vacations, and seasonal periods were eliminated (Jamason, Kalkstein and Gergen 1997).

There were three factors determined in total for HARSD throughout the period of our study and these factors explain 89% of variations. The first factor best explaining the change (41%) is comprised of the group of humidity, pressure, temperature, cloudiness, and SO_2 parameters. This factor represents meteorological parameters. All of these meteorological parameters have more or less the same powerful effect. SO_2 has a relatively smaller effect, but it showed a positive association with humidity, pressure, and cloudiness parameters and a negative correlation with temperature. It is an expected situation and may be important.

The second factor explains 29% of variations and covers HARSD as well as the TPM, SO_2 and temperature parameters. HARSD showed a positive correlation with air pollutants. TPM is the most effective variable in this factor. SO_2 also displayed

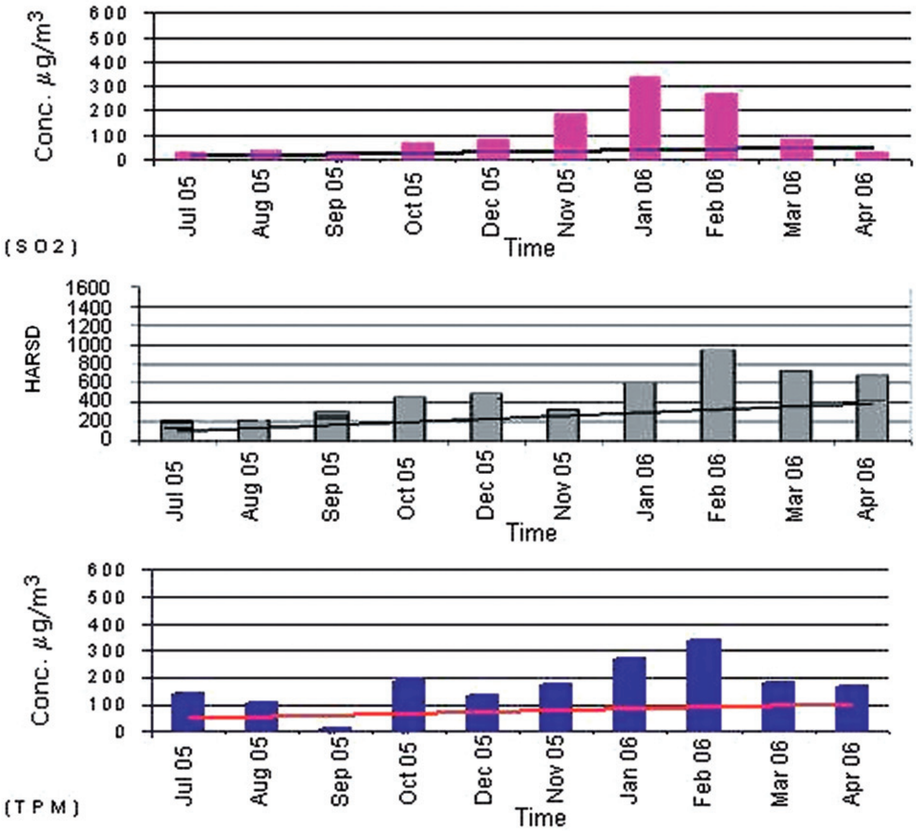

Figure 4. Air pollutants and monthly variations in HARSD.

Table 4. Factor analysis for HARSD.

	Factor 1	Factor 2	Factor 3
Relative humidity (%)	0.946	0.233	0.026
Pressure (mb)	0.936	−0.220	−0.197
Temperature (°C)	−0.837	−0.506	−0.134
Cloudiness (×/10)	0.821	0.476	0.252
TPM ($\mu g\,m^{-3}$)	0.052	0.927	0.063
HARSD (*n*)	0.218	0.781	0.327
SO_2 ($\mu g\,m^{-3}$)	0.637	0.657	−0.098
Wind speed ($m\,sn^{-1}$)	0.144	0.028	−0.922
Rainfall (mm)	0.241	0.403	0.773
Eigenvalues	3.680	2.650	1.694
% of variation	40.884	29.442	18.825
Cumulative %	40.884	70.326	89.151

a positive association with HARSD. It is noteworthy that the temperature shows a negative relationship with all these parameters. Temperature and polluted air are parameters having direct effects on the frequencies of respiratory system disease development. Low temperatures and polluted air conditions produce increases in frequency of respiratory system diseases. The fact that a second effective factor exists and HARSD has a negative correlation with temperature and a positive correlation with pollutants is an expected situation.

The third factor is comprised of wind speed and precipitation parameters and accounts for 19% of variations. Wind speed determines the conditions for distribution and accumulation of pollutants in the city atmosphere, while precipitation provides the washing and removal of pollutants existing in the atmosphere.

All the above-mentioned factors might account for approximately 90% of variations in HARSD and atmospheric pollution and meteorological conditions. HARSD have been mostly affected adversely from pollutant concentrations compared to meteorological parameters other than temperature in the city.

Discussion

It is seen from HARSD records that the city population of all ages is potentially subject to serious health problems arising from respiratory system diseases. Lower respiratory diseases, acute bronchitis, asthma and pneumonia diseases were more frequently observed in children of ages 0–14 years. Many studies reported that there is a relationship between air pollution and increase in frequency of symptoms regarding failures in function of lungs and respiratory system diseases and hospital admissions (Wilkinson et al. 1999; Nelson and Tony 2000; Williams et al. 2000; Atkinson et al. 2001; Timonen et al. 2002). Various studies reported an association between air pollution and upper respiratory diseases (Boezen et al. 1999), bronchitis (Chauhan and Johnston 2003), asthma (Park et al. 2002), and mortality in children (Hauck et al. 2004). Tecer et al. (2008) demonstrated in Zonguldak children of age 0–14 years that for every 10 $\mu g\,m^{-3}$ increase in PM_{10} concentrations of city atmosphere there was an increase in hospital admissions due to asthma hospital admissions by 14%, lower respiratory diseases by 23% and upper respiratory diseases by 15%. There are several reasons for enhanced sensitivities of children to respiratory system diseases (Mathieu-Nolf 2002; WHO 2006), as follows:

- Children breath more air compared to adults
- Children's lungs are still in a stage of development
- Children spend more of their time running and playing outside;
- Children are generally unaware of the pollution and they are more defenseless.

COPD and chronic bronchitis occur more often in adults. Influences of air pollution on human health are found in humans following both acute and chronic exposure. Breathing polluted air for long periods, especially accumulation of PM in the respiratory tract system results in symptoms affecting heart and respiratory system problems in older ages (Burnett et al. 1999; Loomis 2000; Sheppard 2003).

Adverse meteorological conditions may also result in increases in respiratory system symptoms and admissions to emergency services and hospitals in the same way as air pollution. Lower temperatures and cold weather conditions during winter lead to increases in respiratory diseases (Pope, Schwartz and Ranson 1992; Azevedo, Gonçalves and Leal 2007) while extreme temperatures produce mortality in summer (Chestnut et al. 1998). Strong winds result in the distribution of pollutants while weak winds, cloudy weathers and high pressure systems generate stable weather conditions. Under such conditions, pollutants accumulate in the atmosphere in the region where they have been released creating health related risks.

The PCA that was shown, realized the relationships between HARSD, air pollution and meteorological variables recorded in the city. Analysis results pointed out three factor groups explaining about 90% of variations in hospital admissions. The one with the highest impact amount among these factors comprised of meteorological parameters other than temperature and accounted for 41% of variations. The factor with the second highest impact is comprised of temperature, air pollutants and HARSD records. The fact that HARSD variable has a negative relationship with temperature and a positive relationship with TPM and SO_2 indicates that hospital admissions increase under lower temperatures and polluted air conditions. The decrease in SO_2 concentrations and the increase in TPM concentrations in the city during the last decade were reflected in PCA. Positive correlation between HARSD and TPM concentrations is stronger compared to SO_2. Increases observed in both of these pollutants under cold weather conditions triggered respiratory disease development and resulted in increase of hospital admissions.

Respiratory system diseases are affected by many factors like the individual (genetic, gender, ethnical origin, etc.), triggering (allergens, exercises, etc.) and environmental factors. Air pollution and meteorological conditions are environmental factors in this respect. The relationship defined in the analysis was evaluated as the determination of impact quantities regarding environmental factors. Furthermore, the adverse effects of air pollution and meteorology conditions on human health in the city are also revealed. Further steps of this study must involve relative risk calculations in which exposure-response functions will be determined by making use of epidemiological, air quality and meteorological data. These analyses may reveal the pollution levels and rates of health risks produced by city air pollution.

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