The evaluation of the effect of air pollution on the health status of children in Zonguldak City, Turkey

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The evaluation of the effect of air pollution on the children health status of Zonguldak City, Turkey

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Abstract: Air pollution effects on human health particularly sensitive groups such as children, pregnant women, elderly people and patients with chronic respiratory diseases in many ways, including reduced lung function, increased morbidity and infant mortality. Many epidemiological studies have shown positive association between respiratory health and current level of ambient air pollution. This study tries to assess the associations between Occurrence of Respiratory Symptoms and Diseases (ORSD) and those parameters: Particulate Matter (PM), sulfur dioxide (SO_2), pollen and meteorological variables in the mining city of Zonguldak-Turkey. The finding of the study shows significant association between ORSD, and ambient level of PM, SO_2 and pollen.

Keywords: respiratory disease; children; air pollution; Zonguldak.

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1 Introduction

Globally, the main load of anthropogenic air pollution is concentrated in the urban areas, in particular the metropolitan areas. Whereas in some urban areas exhaust gases from industrial process and/or domestic heating are sources of considerable air pollution, in other places it is the automobile traffic which is the main source of air pollution. Atmospheric dispersion and chemical transformation conditions as well as topographic location have an influence on air quality in urban areas (Baumbach, 1997; Karaca et al., 2004). The scientific and social interest in the effects of air pollution on people's health has notably increased in the past decade as a consequence of the growing evidence of its actual relevance to health of the population and concern about related changes in the near future (Ballester et al., 2002).

Many epidemiological studies have demonstrated the association of environmental air pollution and deterioration of respiratory health. Individuals with chronic respiratory diseases such as asthma and chronic obstructive airway disease are particularly susceptible to the adverse effects of air pollution. Experimental studies in humans have also shown that air pollutants including ozone, sulphur dioxide, inhalable particles <10 μm in aerodynamic diameter (PM10), and nitrogen oxides (NOx) all can aggravate airway pathology by including or enhancing airway inflammation (Moshammer and Neuberger, 2003; Martonen and Schroeter, 2003; Helander et al., 1997; Monn, et al., 1999). Many studies have shown that levels of air pollution are associated with reduced pulmonary function, increased respiratory symptoms and, even increased mortality (Monn, et al., 1999; Williams et al., 2000; Alberini and Krupnick, 1998; Wordley et al., 1997; Lipfert and Morris, 2002; Timonen et al., 2002; Nelson and Tony, 2000). In both adults and children, air pollution has also been founded to be associated with increased visits to emergency and admissions to hospitals due to respiratory complaints or asthma exacerbation (Boezen et al., 1999; Duhme et al., 1998; Brunekreef and Holgate, 2002; Gomzi, 1999; Wong et al., 2001; Qian et al., 2000; Roemer et al., 2000). Zonguldak is the main mining centre of Turkey with many underground coalmines, mainly run by the government. The development of the city is largely based on mining and industry. Underground mining impacts directly on the health of those working underground, but opencast mining create wider air quality deterioration due to dust and gaseous pollutants in and around the mining complexes (Ghose and Majee, 2001). In Zonguldak, chronic respiratory asthma, chronic bronchitis diseases are prevalent conditions. Epidemiological surveys have shown that children and young adults suffer from asthma (Tomaç et al., 2002).

Public opinion is becoming more concerned about environmental issues and at the same time new regulations are enforced to control pollution deterioration of ambient air quality. In 1997, an Environmental Management Committee was found to investigate the environmental problems resulting from mining, industrial and domestic activities in Zonguldak and to coordinate subsequent environmental protection and improvement activities. The committee consists of representatives from the central government, the municipality of Zonguldak, the industry and the coal company. Therefore, the analysis of the relation between air pollution and health effect is increasingly gaining importance.

To clarify the possible role of the air pollution, meteorological conditions and biologic pollen gains on respiratory health of asthmatic children, this has been performed to investigate the temporal relationship between the ambient level of the air pollutants (PM, SO_2), meteorological parameters and pollens – on hospital admission due to asthma and respiratory diseases in children living in Zonguldak.

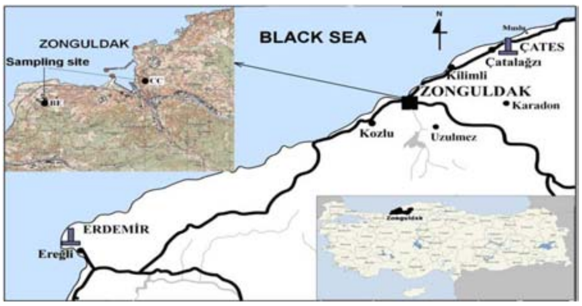
Aims of this study are to evaluate the effect of air pollution on the health status of Zonguldak City population and to study the relation between exposure to air pollution and the Occurrence of Respiratory Symptoms and Diseases (ORSD).

2 Data and method

2.1 The study area

Zonguldak is a coastal city located in the western Black Sea region at position 41027′ N, 31046′ E (Figure 1). It has a current population of about 1,08,000. The city is characterised by 'black diamond', the name which signifies the importance attached to the coal produced in the area. In fact, the local economy has heavily relied on coal mining and coal industry for decades. At present, the decline in the industry has already started to impose its adverse repercussions upon the local economy (Zonguldak Local Agenda 21). The development of the city and rapid rise in the population were associated with the growth of this coal industry after the 19th century. Turkey's hard coal is mined in the only in one location – the Zonguldak basin of Northwestern Turkey. State-owned coal company, TTK, produces, processes, and distributes hard coal (1.5–2 million ton per year) at Kozlu, Uzulmez, Karadon coal mining site. Producted coal, which is used mainly for power generation, steel plant and combustion, is generally of poor quality and highly polluting. Kozlu, Uzulmez and Karadon coal mining site were located 5 km west, 7 km south and 12 km east of Zonguldak centre, respectively (Figure 1). The adverse consequence for the population and industrialisation is the increase of environmental degradation, namely air quality in Zonguldak. In the Zonguldak, sulphur dioxide has been emitted into the atmosphere with no controls particularly in hard coal mining region. In addition to SO_2 emission, the hard coal mines emits particulate matter which contains hazard heavy metals, into the city's atmosphere. Measured monthly average concentrations of SO_2 and PM (μg/m^3) are shown in Figure 2. Yearly average concentrations of SO_2 and PM have not significant differences, 65.55 μg/m^3, and 72.21 μg/m^3, 70.65 μg/m^3 for SO_2 and 84.35 μg/m^3, 79.68 μg/m^3, 73.09 μg/m^3 for PM from 1999 to 2001. The Turkish Health Ministry, air pollution control regulations annual mean concentration standard and criteria are 150 μg/m^3 and 60 μg/m^3 for both SO_2 and PM, respectively. All this records are higher than 60 μg/m^3.

Figure 1 Map of Zonguldak City showing the locations of monitoring stations (see online version for colours)



M: Meteorological Station; BE: Bahçelievler Station; CC: City Centre Station

2.2 The data

The data are provided from the two air quality measurement stations established by Ministry of Health. SO_2 and PM concentrations data for January–December 2002 season are monitored for 24 hour period at two sites. One of the stations is Bahçelievler station, surrounded by the hospital, houses and some social clubs. The other is City Centre station which was placed directly on the city's main traffic road close to schools and other offices in Zonguldak. Allergic daily pollens were collected by Burkard pollen uptake apparatus in Zonguldak city at Karaelmas University campus area near the Bahçelievler station. Counting pollens will be carried out by optical microscopy. The input parameters for the model include the meteorological variables which were provided by the Governmental Meteorology Office. The meteorological station is also very close to Bahçelievler station with a distance of about 100 metres.

The computerised daily number of hospital admission for respiratory diseases (9th revision of International Classification of Diseases respiratory illness (ICD-9 460–496) in children was collected by researchers form Department of Pediatric Diseases, Faculty of Medicine (University of Karaelmas). Karaelmas University Practice and Research Hospital established in Zonguldak is regional centre at the Northwestern Black Sea region. An approximately average of 1,15,000 patients underwent and evaluated per year at all departments.

2.3 Statistical methods

Some statistical analyses like Regression analysis, *R*-squared values, MSE values and *p*-values are used to explain the relationships between the ORSD and air pollution data. Regression analysis is a mathematical tool that quantifies the relationship between a dependent variable and one or more independent variables. It is the process of estimating the parameters for a model by optimising the value for an objective function, and then testing the resulting predictions for statistical significance against an appropriate null hypothesis model. *R*-squared value is statistic that measures the proportion of the variability in *Y* that a model accounts for. This value ranges between 0% and 100%. MSE is a measure of accuracy computed by squaring the individual error for each item in the set of data, then finding the average or mean value for the sum of those squares. Mallows' *Cp* statistic is a measure of the bias in a model based on a comparison of total Mean Squared Error to the true error variance. Unbiased models have an expected *Cp* value of approximately *n*, where *n* is the number of coefficients in the fitted model. *Cp* is based on the assumption that the model that contains all the candidate variables is unbiased; therefore, the full model will always have *Cp* = *n*. in order to obtain best result one can look for models that have *Cp* values close to *n*. *P*-value is the probability of observing a value for a test statistic that is at least as inconsistent with the null hypothesis as the value of the test statistic actually observed.

3 Results and discussions

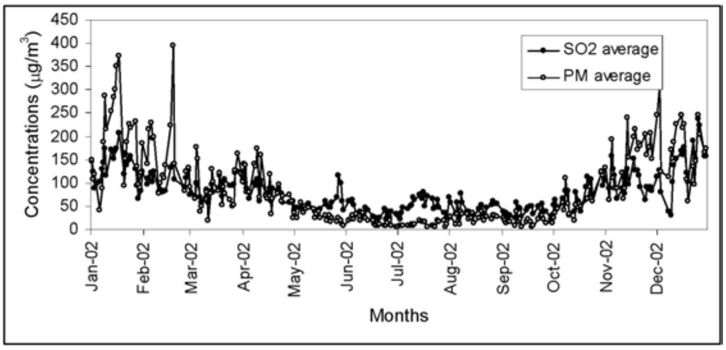
During study periods, data were available on 2456 cases of respiratory illnesses (which includes the asthma cases), and 5607 non-respiratory cases in ZKU hospital (Table 1). With the intention of explain the city's health status firstly we compared the percentages of the respiratory symptoms among all the total symptoms reported by the Turkish Health Ministry (2002). This report was prepared based on urgent symptom calls to 112, the Urgent Health Service during 2002. Turkey has 83 cites. The average value of the percentages of the ORSD values among all the total reported symptoms for Turkey is 6.16%. Zonguldak city's value is 8.1% one of the highest percentage of ORSD values among the all cites of Turkey.

Air pollutants, SO_2 and PM have been monitoring in two stations since 1999 in Zonguldak city. During study period, measured monthly two stations average concentrations of SO_2 and PM (μg/m^3) are shown in Figure 2. Yearly average concentrations of SO_2 and PM have not significant differences, 65.55 μg/m^3, and 72.21 μg/m^3, 70.65 μg/m^3 for SO_2 and 84.35 μg/m^3, 79.68 μg/m^3, 73.09 μg/m^3 for PM from 1999 to 2001. The Turkish Health Ministry, air pollution control regulations annual mean concentration standard and criteria are 150 μg/m^3 and 60 μg/m^3 for SO_2 and PM, respectively. All this records are higher than 60 μg/m^3. In order to understand the relationships between ORSD and this air pollution situation in Zonguldak City, some case studies were carried out.

Table1 Descriptive Statistics of ORSD, air pollutant and meteorological variables

	N	*Minimum*	*Maximum*	*Sum*	*Mean*	*Std. Deviation*
ORSD	249	1	28	2456	9.86	5.32
SO_2 average	251	20	239.0	19872.0	79.171	42.855
PM average	251	5	395.0	21128.0	84.175	79.772
Pressure	251	982	1018.0	251085.1	1000.339	5.950
Cloudness	251	0	10.0	1228.0	4.892	3.101
Solar radiation	235	0	14	1494	6.36	3.91
Rel. humudity	251	30.0	97.0	18816.0	74.964	13.400
Precipitation	251	–1.0	60.0	1300.0	5.179	9.045
Pollen	251	5	855	24042	95.78	172.23
Temperature	251	–3.0	29.0	3804.2	15.156	7.235

Figure 2 Monthly average concentrations of SO_2 and PM during study period



3.1 Case 1

Whole year air pollution data, ORSD data and, meteorological parameter were statistically analysed. No significant relationships were found for the data. In this case we were analysed monthly averages of whole year data to elucidate the relationship amongst ORSD, air pollution data, and meteorological parameters.

The actual relationship may not be a linear function in some cases, the linear regression can still be performed by transforming the independent and/or the dependent variables. Using regression and graphical methods to determine the parameters that correlated most strongly with fluctuations in ORSD data, an exploratory analysis of the air pollution data was performed. These analyses were carried out to determine suitable functional transformations that may be useful in developing a multiple parameter ORSD model. Firstly we used some functions to define the best curve to fit the relationships between ORSD-SO_2 and ORSD-PM. Best fittings were achieved with cubic functions of both pollutants. Figures 3 and 4 show the best relationship between ORSD-SO_2 and ORSD-PM.

Figure 3 Curve fitting for ORSD-SO_2. ORSD: Monthly average, Person; SO_2: μg/m^3 (see online version for colours)

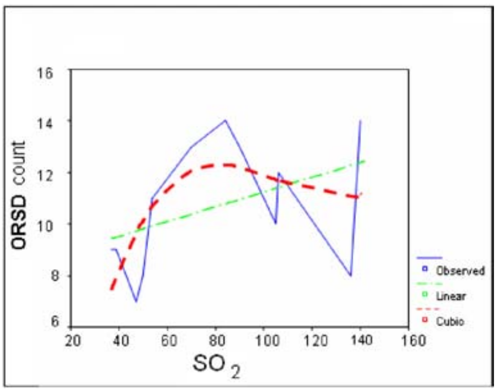
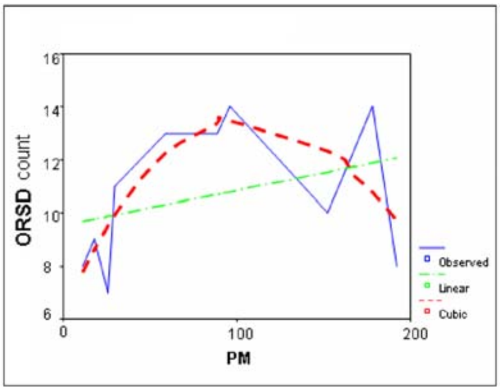


Figure 4 Curve fitting for ORSD-PM. ORSD: Monthly average, Person; PM: µg/m^3 (see online version for colours)



We were used multiple regression models to describe the relationship between ORSD and ten predictor variables. The model equation for ORSD, including the transformation of the SO_2 – PM and independent variables, was formulated as follows:

$$Y_{\text{(montly ORSD)}} = \beta_0 + \beta_1 1/(SO_2\text{^}3) + \beta_2 1/(PM\text{^}3) + \beta_3 \text{ pressure} + \beta_4 \text{ cloudiness} + \beta_5 \text{ solar intensity} + \beta_6 \text{ solar radiation} + \beta_7 \text{ humidity} + \beta_8 \text{ temperature} + \beta_9 \text{ precipitation} + \beta_{10} \text{ pollen} + \beta_{11} \text{ windspeed.}$$

Models have been fit containing all combinations of from 0–11 variables. To determine which models are best we compared the Mean Squared Error (MSE), the adjusted and unadjusted *R*-Squared values, and Mallows' *Cp* statistic. The adjusted *R*-Squared statistic measures the proportion of the variability in total report which is explained by the model. Larger values of adjusted *R*-Squared correspond to smaller values of the MSE. In this study, stepwise selection method was used for the individual variables The individual coefficients' statistics imply that the hypothesis, where all individual coefficients are zero, is rejected for nine variables in the model. As a guide to find out useful predictors, look for statistic values estimated for the individual coefficients well below –2 or above +2. Finally, it was decided that the best model has nine variables; cubicSO_2, cubicPM, pressure, cloudiness, solar radiation, humidity, temperature, and precipitation. The individual coefficients of solar intensity and wind speed are not statistically significant. Therefore, these variables do not contribute in explaining the magnitudes of the dependent variable observed. These parameters automatically were eliminated by stepwise procedure in this analysis. The *R*-Squared statistic indicates that the model as fitted explains 99.97% of the variability in total report. The standard error of the estimate shows the standard deviation of the residuals to be 0.132. This value can be used to construct prediction limits. Since the *P*-value is greater or equal to 0.10, that term is not statistically significant at the 90% or higher confidence level. All these nine parameters are significant at the 90% confidence level. Obtained statistics for best regression model are summarised in Table 2.

Table 2 Obtained statistics for best regression model

Parameter	*Estimate*	*Standard error*	*T-Statistic*	*P-value*
CONSTANT	1394	121.9	11.4	0.05
x_1 = cubicSO_2	4,12,942	47560.9	8.6	0.07
x_2 = cubicPM	6460	464.2	13.9	0.04
x_3 = pressure	–1.34	0.117	–11.3	0.05
x_4 = cloudiness	2.94	0.492	5.9	0.09
x_6 = solar radiation	2.13	0.132	16.0	0.03
x_7 = humidity	–0.84	0.026	–31.6	0.02
x_8 = temperature	–1.73	0.133	–12.9	0.04
x_9 = precipitation	1.44	0.079	18.1	0.03
x_{10} = pollen	0.005	0.000	8.7	0.07

The equation of the fitted model is

$$\begin{aligned} Y_{\text{Monthly ORSD}} &= 1394 + 412942{*}x_1 + 6460{*}x_2 - 1.34{*}x_3 + 2.94{*}x_4 \\ &+2.13{*}x_6 - 0.84{*}x_7 - 1.73{*}x_8 + 1.44{*}x_9 + 0.005{*}x_{10}. \end{aligned}$$

3.2 Case 2

In the second case, in order to understand the relationship between air pollution data, pollen counts and ORSD episodes, we analysed the episode occurrence day counts according to higher values than annual mean value (episodes) of ORSD.

52 days of one year PM data records are over than 24 hour average standards of 150 μg/m^3. Annual mean of ORSD is nine person/day/hospital. 91 episodes of ORSD values were recorded during the period of January 2002 – December 2002 in Zonguldak.

Table 3 ORSD episode occurrence numbers and corresponding monthly average concentrations of SO_2 and PM

Month	*ORSD episode occurrence day counts*	*SO_2 average concentration* (μg/m^3)	*PM average concentration* (μg/m^3)	*Pollen count*
January	10	136	192	129
February	9	106	165	448
March	9	90	89	62
April	10	84	96	191
May	7	54	30	290
June	5	37	18	18
July	3	50	11	6
August	6	47	26	16
September	3	39	18	8
October	7	70	59	15
November	10	105	152	7
December	12	140	178	5
Total	*91*			

Table 4 shows the results of fitting various multiple regression models to describe the relationship between ORSD episode occurrence and three predictor variables. Models have been fit containing all combinations of from 0–3 variables. The statistics include MSE, the adjusted and unadjusted *R*-Squared values, and Mallows' *Cp* statistic. First four model's MSE values are very close to each other, but 4th model's *Cp* value is the closest one to number of included variables, $n = 3$. 8th model results have optimum *R*-squared, adjusted *R*-squared and *Cp* values. Based on these statistics we selected 8th model as the best model.

Table 4 Model results of the selection of best regression model

MSE	*R-Squared*	*Adjusted R-Squared*	*Cp*	*Included variables* ($n = 3$)
8.44697	0	0	30.0716	No Variables
1.93197	79.2075	77.1283	0.331886	SO_2
2.1793	76.5457	74.2002	1.39854	PM
8.44697	9.09091	0	29.1985	Pollen
2.13454	79.3247	74.7301	2.28495	SO_2, PM
2.0617	80.0302	75.5925	2.00223	SO_2, Pollen
2.42041	76.5557	71.3458	3.39453	PM, Pollen
2.31876	80.0357	72.5492	4	SO_2, PM, Pollen

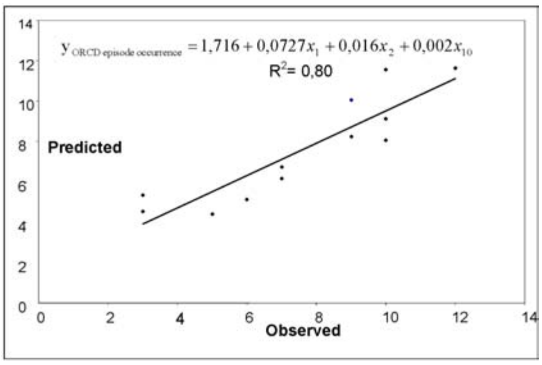
The best equation of the fitted model is

$$y_{\text{ORCD episode occurrence}} = 1.716 + 0.0727x_1 + 0.016x_2 + 0.002x_{10}.$$

ANOVA analysis was performed to check this statistical relationship and *P*-value was found 0.00002. Since the *P*-value in the ANOVA analysis is less than 0.01, there is a statistically significant relationship between the variables at the 99% confidence level.

The *R*-Squared statistic indicates that the model as fitted explains 72.54% of the variability in ORSD episode occurrence. According to this second case study, it is suggested that there is a good correlation between ORSD episodes and monthly average concentrations of air pollution in Zonguldak city (Figure 5).

Figure 5 Occurrence of Respiratory Symptoms and Diseases (ORSD), x_1 = Observed SO_2, x_2 = Observed PM, and x_{10} = Pollen counts (see online version for colours)



4 Conclusion

Most published studies of health effects of air pollution on respiratory morbidity have been performed in different parts of the word. Turkey has 83 cites. The average value of the percentages of the ORSD values among all the total reported symptoms for Turkey is 6.16%. This value for Zonguldak is 8.1% one of the highest percentage of ORSD values among the all cites of Turkey (Republic of Turkey, Prime Ministry State Institute of Statistics (SIS)). In Zonguldak, chronic respiratory asthma, chronic bronchitis diseases are prevalent conditions. One recent study has been carried out in Zonguldak by Tomaç et al. (2002) related with asthma prevalence, other respiratory symptoms and diseases on children which are 6–17 years old based on questioner method. According to the results of this study the cumulative asthma prevalence, during last year asthma prevalence, wheezing prevalence, bronchitis prevalence were 14.5%, 2.1%, 27.1% 57%, 29.3%, respectively. The Turkish Health Ministry, air pollution control regulations, annual mean concentration standard is 150 μg/m^3 for SO_2 and PM, but criteria are 60 μg/m^3. Zonguldak city's air pollution records are higher than 60 μg/m^3 during 1999–2002.

This study is the first to investigate the relationship between hospital admissions of children due to respiratory symptoms and diseases and air pollutants. Herein, the effect of air pollution on the health status of Zonguldak city population was evaluated and the relation between exposure to air pollution (PM and SO_2) and the ORSD statistically analysed. With the purpose of identify with the relationships between ORSD and this air pollution situation in Zonguldak some case studies were carried out.

Statistically in 90% confidence level, no relationships were found among whole year data, so it was necessary to make some detailed analyses. Firstly, monthly averages of whole year data were analysed to explain the relationship. A regression model was developed by means of parameters; SO_2, PM, pressure, cloudiness, solar radiation, humidity, temperature, precipitation, pollen and Monthly ORSD. There was a positive and significant association between ORSD and two pollutants. In addition, pollen counts were found to be significant associations. The model explains 99.97% of the variability in total report.

In the second case we analysed the data according to higher values than annual mean value (episodes) of ORSD and corresponding air pollution data. Annual mean of ORSD is nine person/day/hospital. 91 episodes of ORSD values were recorded during the period of January 2002-December 2002 in Zonguldak. Another regression model was developed with the parameters; SO_2, PM, Pollen and ORSD episodes. According to this second case study, it is suggested that there is a good correlation between ORSD episodes and monthly average concentrations of air pollution in Zonguldak city. The model explains 72.54% of the variability in ORSD episode occurrence.

Several studies have confirmed the significant associations of the level of air pollutants and visits to emergency department or hospital admissions due to respiratory symptoms (Sunyer et al., 1997; Atkinson et al., 1999; Hajat et al., 2001; Anderson et al., 1998). Given that the majority of studies have demonstrated a positive association, ambient air pollutants probably have a contributory role to respiratory morbidity. In conclusion, current study is the first study of children admissions for respiratory diseases and air pollution in Zonguldak showing that SO_2, PM, pollen and some meteorological parameters are associated with ORSD in children. The results of this study support that the current level of air pollution contributes to respiratory morbidity in children in Zonguldak.

5 Further developments

In the future, it will be concluded the relationship of ORSD, air pollution and local meteorology of the city. In order to achieve this idea, the living locations of the people who visit to the hospital due to Respiratory Symptoms had been started to record in the city hospitals. Emission inventory of the city is necessary to figure out the local and regional effect of the air pollution. This study will be link to another study which focuses on the health effects of the air pollution of the city.

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