

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 human health particularly some sensitive groups such as children, pregnant, elderly people, asthmatics etc. in many ways, including reduced lung function, increased morbidity, increased use of health care services, and infant mortality. The aim of this study was to assessment of health effects due to particulate matter (PM), sulfur dioxide (SO₂), pollen, and meteorological variables in children in Zonguldak city which is the main mining centre of Turkey. Daily counts of children admission for respiratory diseases to Karaelmas University Hospital were obtained for the period January-December 2002. Some statistical analyses like regression analysis, MSE values and p-values were used to assess the associations between the occurrence of respiratory symptoms and diseases (ORSD) and those parameters: PM, SO₂, pollen and meteorological variables.

Monthly average of ORSD increased significantly with increasing ambient level of PM, SO₂ and pollen. The R-squared statistic of multiple regression models indicates that the model as fitted explains 99.97 % of the variability in total report. In the second case, ORSD episode, higher values than annual mean value, were analyzed to understand the relationship between air pollution, pollen counts. The model indicates that there is a good correlation between ORSD episode and monthly average concentrations of air pollution and pollen in Zonguldak. Current study is the first study of children admissions for respiratory diseases and air pollution in Zonguldak showing that SO₂, PM, pollen and some meteorological parameters are associated with ORSD in children

Key Words: respiratory disease, children, air pollution, Zonguldak.

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 (Moshhammer 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 helath 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).

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, SO₂), 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 (ORS) and diseases.

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 108.000. The city is characterized 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. The adverse consequence for the population and industrialization 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 SO₂ emission, the hard coal mines emits particulate matter which contains hazard heavy metals, into the city's atmosphere. Measured monthly average concentrations of SO₂ and PM ($\mu\text{g}/\text{m}^3$) are shown in Figure 2.

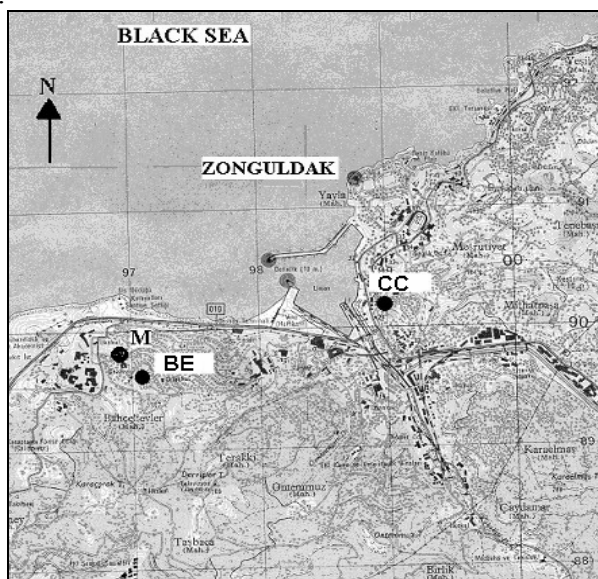


Figure 1. Map of Zonguldak City showing the locations of monitoring stations (M: Meteorological station, BE: Bahçelievler Station and CC: City Center Station)

2.2 The data

The data are provided from the two air quality measurement stations established by Ministry of Health. SO₂ 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. 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 meters.

The computerized daily number of hospital admission for respiratory diseases in children was collected by researchers from Department of Pediatric Diseases, Faculty of Medicine (University of Karaelmas).

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 optimizing 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 percent. 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 $C_p = n$. 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

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 cities. 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 cities of Turkey.

Air pollution criteria pollutants, SO₂ and PM have been monitoring in two stations since 1999 in Zonguldak city. Measured monthly average concentrations of SO₂ and PM ($\mu\text{g}/\text{m}^3$) are shown in Figure 2. Yearly average concentrations of SO₂ and PM have not significant differences, 65,55 $\mu\text{g}/\text{m}^3$, and 72,21 $\mu\text{g}/\text{m}^3$, 70,65 $\mu\text{g}/\text{m}^3$ for SO₂ and 84,35 $\mu\text{g}/\text{m}^3$, 79,68 $\mu\text{g}/\text{m}^3$, 73,09 $\mu\text{g}/\text{m}^3$ for PM from 1999 to 2001. The Turkish Health Ministry, air pollution control regulations annual mean concentration criteria is 60 $\mu\text{g}/\text{m}^3$ for SO₂ and PM and all this records are higher than 60 $\mu\text{g}/\text{m}^3$. In order to understand the relationships between ORSD and this air pollution situation in Zonguldak City, some case studies were carried out.

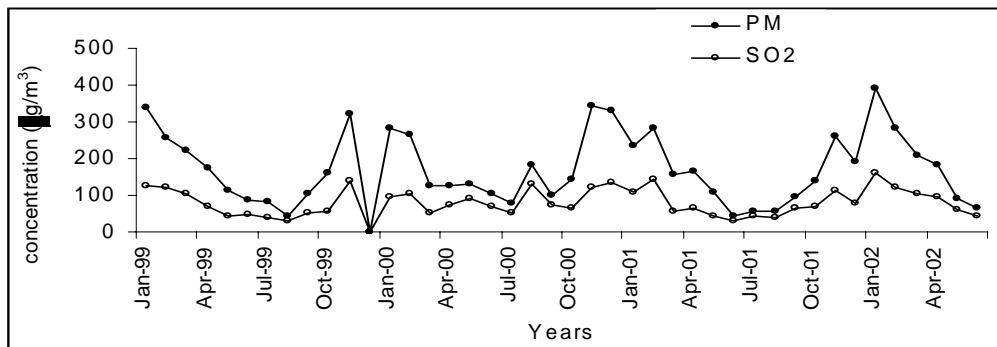


Figure 2. Monthly average concentrations of SO₂ and PM during 1999-2002

3.1 Case 1

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

Firstly we used some functions to define the best curve to fit the relationships between ORSD-SO₂ and ORSD-PM. Best fittings were achieved with cubic functions of both pollutants (Figure 3 and Figure 4).

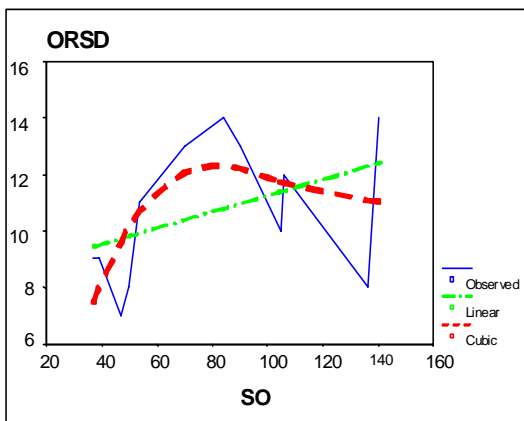


Figure 3. Curve fitting for ORSD-SO₂. ORSD: Monthly average, Person; SO₂: $\mu\text{g}/\text{m}^3$

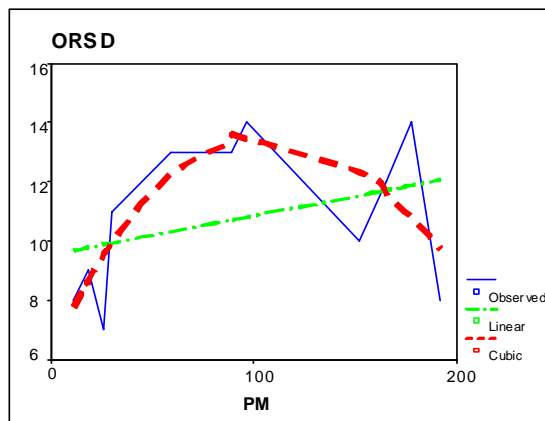


Figure 4. Curve fitting for ORSD-PM. ORSD: Monthly average, Person; PM: $\mu\text{g}/\text{m}^3$

We were used multiple regression models to describe the relationship between ORSD and 10 predictor variables. These are $1/(\text{SO}_2^3)$, $1/(\text{PM}^3)$, pressure, cloudiness, solar intensity, solar radiation, humidity, temperature, precipitation, and pollen. Models have been fit containing all combinations of from 0 to 10 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 mean squared error (MSE). Finally, it was decided that the best model has 9 variables; cubicSO₂, cubicPM, pressure, cloudiness, solar radiation, humidity, temperature, and precipitation. 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 summarized in Table 1.

Table 1. 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	412942	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

$$Y_{\text{MonthlyORSD}} = 1394 + 412942 * x_1 + 6460 * x_2 - 1,34 * x_3 + 2,94 * x_4 + 2,13 * x_6 - 0,84 * x_7 - 1,73 * x_8 + 1,44 * x_9 + 0,005 * x_{10}$$

3.2 Case 2

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

Of one year PM data 52 days records are over than 24 hour average standards of 150µg/m³. Annual mean of ORSD is 9 person/day/hospital. 91 episodes of ORSD values were recorded during the period of January 2002 - December 2002 in Zonguldak (Table 2).

Table 2. ORSD episode occurrence numbers and corresponding monthly average concentrations of SO₂ and PM

Month	ORSD episode occurrence	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			
Average		73,69	79,54	91,92

The Table 3 shows the results of fitting various multiple regression models to describe the relationship between ORSD episode occurrence and 3 predictor variables. Models have been fit containing all combinations of from 0 to 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 3. Model Results of the Selection of Best Regression Model

Number	MSE	R-Squared	Adjusted R-Squared	Cp	Included Variables n=3
1	8,44697	0	0	30,0716	No Variables
2	1,93197	79,2075	77,1283	0,331886	SO ₂
3	2,1793	76,5457	74,2002	1,39854	PM
4	8,44697	9,09091	0	29,1985	Pollen
5	2,13454	79,3247	74,7301	2,28495	SO ₂ , PM
6	2,0617	80,0302	75,5925	2,00223	SO ₂ , Pollen
7	2,42041	76,5557	71,3458	3,39453	PM, Pollen
8	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 (cf. Figure 5).

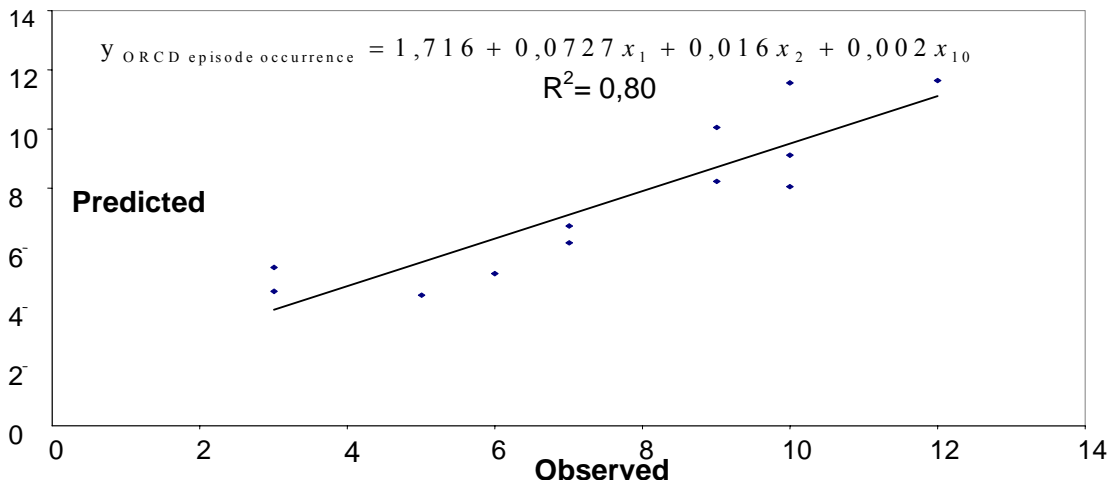


Figure 5. Occurrence of Respiratory Symptoms and Diseases (ORSD), X_1 = Observed SO_2 , X_2 = Observed PM, and X_{10} = Pollen counts.

4 CONCLUSION

Most published studies of health effects of air pollution on respiratory morbidity have been performed in different parts of the world. Turkey has 83 cities. 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 percentages of ORSD values among all the cities 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 questionnaire 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 criteria is $60\mu\text{g}/\text{m}^3$ for SO_2 and PM and Zonguldak city's air pollution records are higher than $60\mu\text{g}/\text{m}^3$ during 1999 to 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 occurrence of respiratory symptoms and diseases (ORSD) statistically analyzed. With the purpose of identifying 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 analyzed to explain the relationship. A regression model was developed by means of parameters; SO₂, 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 analyzed the data according to higher values than annual mean value (episodes) of ORSD and corresponding air pollution data. Annual mean of ORSD is 9 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; SO₂, 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 SO₂, 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.

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