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Spatial Fluctuation of Sulphur Dioxide (SO_2) and Particulate Matter (PM) Levels Measured in Bursa

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ABSTRACT

Sulphur dioxide (SO_2) and particulate matter (PM) constitutes of the classical air pollutants have important environmental effects. In the scope of this study, the results of SO_2 and PM concentrations measured from 7 districts of Bursa, their spatial fluctuations and the reasons of variations among districts are discussed. Samples were collected with a Bulab 201/8 model semi-automatic sampling device. Monthly average concentrations were calculated for the evaluation of pollutant concentrations. When average concentrations of the districts were assessed, it was observed that the concentrations are dependent on meteorological and topographical conditions, fuel usage and population characteristics.

Key Words: Bursa, Air Pollution, SO_2, PM

1. INTRODUCTION

Air pollution can be described as the existence of one or more pollutants which can cause hazard on public health and the ecosystem in the atmosphere depending on its amount and duration [1]. Knowledge of the pollutant types and emission rates form the foundations of air pollution studies and control [2].

SO_2 emissions are generally caused from combustion of sulphur containing fuel and melting of some mines [3]. When the SOx emission inventories were investigated in European countries, it was indicated that the most responsible sector was fossil fuel used for the thermal electric production sector [1]. Other important sources are melting plants (used for copper, lead and zinc mines), refineries, solid wastes and their destruction [4, 5, 6, 7].

Particle matter (PM), solid or liquid was dispersed in air and their dimensions changed between 0,002 and 500 μm [6]. Particles are recognized depending on their shapes, sizes, densities and chemical structures as aerosol, smoke, fog and dust [3, 6]. Sources of particle matter were separated into two types; man-made and natural sources. An important part of particles in the atmosphere originate from anthropogenic (human sources) sources and they are released from burning process, mining, construction activities and vehicles [4, 7, 8, 9].

Bursa became one of the cities that have air pollution depending on industrial development, as well as increases in population and vehicle numbers [7, 10, 11, 12]. Concentration increases are observed due to residential heating in winter months. Air pollution began to be felt seriously in 1988 and air pollution has continued until 1992 when natural gas began to be used.

The main aims of this study are to present the measured SO_2 and PM concentrations and their fluctuations at different districts of Bursa, to explain their statistical relationships.

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2. MATERIAL AND METHODS

2.1. Sample Collection

Sample collections were achieved with a Bulab 201/8 model semi automatic equipment belonging to the Bursa Local Health Authority. The semi automatic SO_2 and PM measurement devices have 8 filter papers and 8 Dreschel bottles. The devices are generally used for daily measurements. The measurement range of equipment used in this study is between 0,003 and 0,3 ppm for SO_2. Without any user interference, the system works for 8 days (Model 201/8). About 3 m^3/day air firstly passes through filter paper and Dreschel bottle then leaves the system [9].

Dust concentration collected by the filter paper is determined from a standard calibration curve as mg/m^3 after the measurement done with a reflactometer. Hydrogen peroxide in Dreschel bottles is aimed to react with SO_2 in the air during the sampling period. Sulphuric acid (H_2SO_4) formed after the reaction is titrated with a standard alkali solution (0.01 N sodium carbonate (Na_2CO_3)). BDH indicator is used in the titration process [9]. The methods used to determine PM and SO_2 concentrations are the advised methods in the AQPR (Air Quality Protection Regulation) [13].

2.2. Sampling Districts

SO_2 and PM concentration measurements have been done routinely from 7 districts of Bursa (Tophane, Sanatral Garaj, Eğitim, Arabayatağı, Küçükbalıklı, Karaman, Çekirge) by the Bursa Local Health Authority. In this study, concentrations measured between May-2001 and December-2003 months were used. Monthly and annual averages were calculated by using the daily data. Locations of sampling areas were shown on the map in Figure 1.

2.3. Meteorological Data

Monthly average meteorological data between May 2001 and April 2003 in Bursa were summarized in Table 1.

3. RESULT AND DISCUSSION

When the data is evaluated in Table 1, it can be understood that Bursa has a mild climate (Mediterranean – Blacksea climate features). The temperature in the winter months is lower than the ones in the summer months and combustion originated air pollution is high in the winter months (7, 14). Industrial production level is high in Bursa. These plants are densely located in the north (NNE-NNW) side of the city centre. When the wind directions are taken into consideration, generally south winds are dominant. As a result of this it is expected that the city centre should be affected from industrial originated emissions at lower levels.

SO_2 and PM concentrations have been measured routinely from 7 districts of Bursa (Tophane, Sanatral Garaj, Eğitim, Arabayatağı, Küçükbalıklı, Karaman, Çekirge) by the Bursa Local Health Authority. Measurements done simultaneously at all districts were considered in Table 2. Months not included in the Table indicated that samples were not taken simultaneously at least at one district. In order to evaluate the pollutant concentrations at all districts, the monthly average concentrations were calculated. When the standard deviation values were considered, relatively high values were observed. Higher concentration differences among months could be the probable reason for the high standard deviation. Depending on the emission sources, these values were up to 4 times for SO_2 and 18 times for PM. The maximum average SO_2 concentration was measured at Arabayatağı district (102.16 µg/m^3**)** while minimum average SO_2 concentration was measured at Karaman district (61.15 µg/m^3) during the sampling period. The Arabayatağı sampling point where high SO_2 concentrations were observed due to vehicles using diesel was close to the Bursa-Ankara highway. Furthermore, increases in SO_2 concentrations were possibly due to widely usage of coal for residential heating. On the other hand, the Karaman sampling point was only 1-2 km away from the Bursa-İzmir highway where traffic was heavy. Even this distance was not big, Karaman was away from the main artery compared to the Arabayatağı. Furthermore usage of natural gas in Karaman could cause lower SO_2 discharges to the atmosphere. Moreover, Karaman was located on a flat land and it was exposed to relatively high wind levels. This situation caused increase in dispersion while decrease in concentration.

Average concentrations of PM and SO_2 were determined for the sampling period. Temporal variations of PM and SO_2 were shown in Figure 2. Due to emissions of combustion, increases in PM and SO_2 concentrations were observed. Both pollutant concentrations decreased dramatically during the non-heating period.

In order to present the relationships among SO_2 levels measured at different districts, T values were calculated and the results were summarized in Table 3.

While the T values were calculated, 16 monthly average SO_2 concentrations measured at each district between 2002 and 2003 were considered. The measured SO_2 concentrations at Karaman, Küçükbalıklı, Eğitim, Tophane, Santral Garaj and Çekirge districts were not statistically different from each other because this value was under the critical value read from t-table ($t_{30;0.975}$ =2.042). The most important result reached from Table 3 was that the SO_2 concentration measured in the Arabayatağı district was different from SO_2 concentrations measured at other districts. As understood from the data presented in Table 2, the measured average value in the Arabayatağı district was higher than the other districts. Average SO_2 concentrations increased among other districts sequentially Tophane, Çekirge, Santral Garaj, Eğitim, Küçükbalıklı. Data used in the calculation of average concentration mostly represent the spring, fall and winter months. Therefore, the residential heating effect was important on the averages. Natural gas was used in some parts of Karaman, Tophane, Çekirge and Santral

Garaj and solid fuel (coal) was likely used in other districts. For this reason, SO_2 levels were relatively high at Arabayatağı, Eğitim and Küçükbalıklı districts. In spite of Arabayatağı's geographic height (z=140m) being higher than Karaman and Küçük Balıklı, greater SO_2 concentration values were expected due to usage of low calorific fuel and heavy traffic.

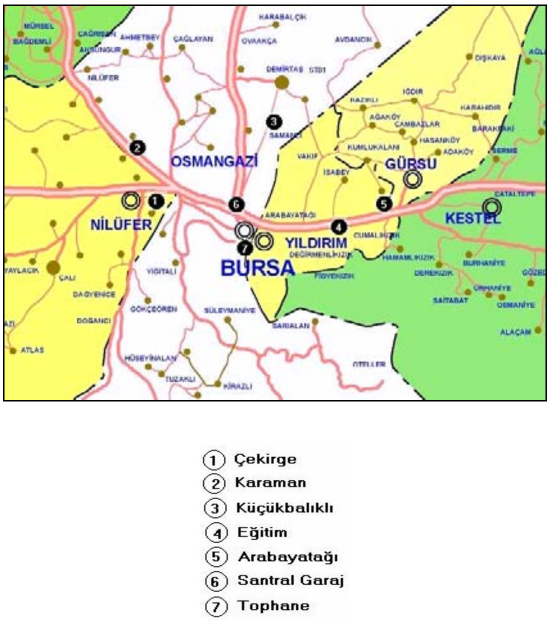

Figure 1. Air quality sampling points in Bursa.

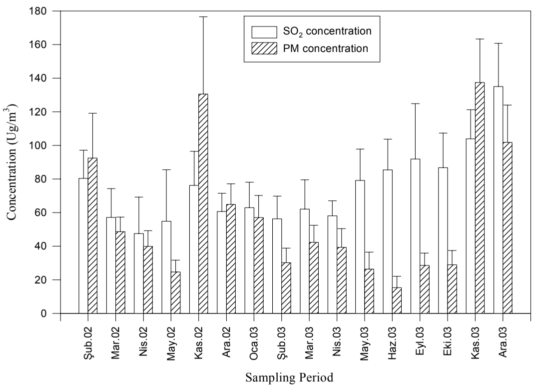

Figure 2. Fluctuations of PM ve SO_2 Concentrations During the Sampling Period

Santral Garaj district had small enterprises rather than residential settlement. The location of the district was in the city centre and at a low level. In addition, the dense in this area caused SO_2 concentrations at higher levels than at the Çekirge Karaman and Tophane districts. Lower dispersion values in Santral Garaj had influence on the concentration increase.

As seen from the data in Table 2, the highest average PM value obtained in the Eğitim district (67.78 µg/m^3) and the lowest average PM value similar to SO_2 obtained at the Karaman district (39.8 µg/m^3) during the sampling period. Concentrations measured from Küçük Balıklı, Santral Garaj and Arabayatağı districts were close to the Eğitim district (Sequentially, 66.71, 64.23 and 61.21 µg/m^3). The Arabayatağı and Eğitim districts, which have higher PM concentrations, were close to the Bursa-Ankara highway. Küçük Balıklı and Santral Garaj districts had dense vehicle traffic. Dense PM was released from exhaust gases, vehicle brake systems and abrasive vehicle tyres at these districts. Furthermore these districts were residential settlement areas and solid fuels were used for residential heating. The Karaman sampling point was near the main road and it was 1-2 km away from the Bursa-İzmir highway where a dense traffic existed. In addition, lower PM values discharged to the atmosphere were expected due to extensive natural gas usage. Topographical characteristics of Karaman was another reason for the increase in dispersion.

In order to show the relationship among the PM concentrations measured by the Bursa Local Health Authority at 7 districts, T values were calculated and presented in Table 4.

While T values were calculated, 16 monthly average PM concentrations measured between 2002 and 2003 were considered.

As seen in Table 4, calculated t test value indicated that pollution levels at Karaman and Eğitim districts were statistically different from each other. The minimum PM value was obtained in the Karaman district (39.80±29.41 µg/m^3) and the maximum value was obtained in the Eğitim district (67.78±39.15 µg/m^3). Natural gas has been used for heating at Tophane and Çekirge districts and PM concentrations were lower than other districts (47,76±24,91 and 49,62±41,17 µg/m^3). Other districts had comparatively higher PM concentrations possibly due to geographical location, population and traffic density.

The LLTV (Long Term Limit Value) value was 150 µg/m^3 for SO_2 and PM in Air Quality Protection Regulation (AQPR). When the standard values were taken into consideration, PM and SO_2 concentration were found to be under the limits of AQPR after rehabilitation in fuel in districts where sampling points were located (13).

Monthly PM concentration variations at Karaman and Eğitim districts were shown in Figure 2.

Table 1. Monthly meteorological data averages between May 2001 and April 2003.

Months	Wind Direction	Wind Speed (m/s)	Temperature (^{0}C)	Humidity (%)
May 2001	S	1,14	21,90	51,58
June 2001	SSW	1,24	24,53	45,37
July 2001	SSE	1,28	28,08	49,31
August 2001	SE	1,28	26,76	54,34
September 2001	SSW	1,02	23,02	54,73
October 2001	SSE	1,08	17,54	59,17
November 2001	S	1,19	11,76	68,12
December 2001	SE	1,76	5,67	79,22
January 2002	SE	1,25	4,29	70,04
February 2002	S	1,09	11,21	57,65
March 2002	S	1,14	11,80	64,74
April 2002	S	0,97	12,35	72,57
May 2002	S	1,08	19,35	56,30
June2002	S	1,19	24,68	52,26
July 2002	SSW	1,02	28,13	54,49
August 2002	SSW	1,06	26,06	55,89
September 2002	S	0,87	22,15	61,42
October 2002	SSW	0,88	17,71	66,97
November 2002	S	0,92	13,76	62,52
December 2002	SE	1,32	5,96	66,86
January 2003	S	1,62	9,92	70,86
February 2003	SE	2,07	6,04	69,86
March 2003	SSE	0,69	5,99	68,55
April 2003	SSW	0,80	11,35	65,63

Table 2. Measured SO_2 and PM concentrations at Bursa Local Health Authority sampling points (µg/m^3).

	Çekirge		Karaman		Küçük Balıklı		Eğitim		Arabayatağı		Santral Garaj		Tophane	
Term	SO_2	PM	SO_2	PM	SO_2	PM	SO_2	PM	SO_2	PM	SO_2	PM	SO_2	PM
February 2002	66,96	86,36	59,75	62,04	82,36	65,50	70,82	120,54	103,96	123,21	100,89	115,07	77,79	74,32
March 2002	44,35	44,55	39,39	31,61	54,19	52,65	59,48	56,19	92,68	50,32	53,63	56,73	55,97	48,55
April 2002	30,93	29,40	33,20	29,20	41,17	45,67	57,83	54,00	92,67	38,80	39,55	46,66	37,38	35,34
May 2002	31,16	21,45	37,45	16,48	49,65	28,40	68,29	37,13	118,81	18,78	40,74	27,42	37,87	23,06
November 2002	65,33	156,78	60,37	88,07	108,61	209,06	67,57	124,67	99,13	144,31	77,37	121,67	54,60	68,90
December 2002	65,23	59,23	52,58	42,61	79,19	83,90	45,84	65,42	59,13	68,90	66,55	67,32	56,03	66,26
January 2003	47,27	48,17	49,47	37,83	83,37	80,67	52,80	58,47	79,50	59,27	72,77	61,33	55,00	53,23
February 2003	45,96	21,93	38,64	17,21	73,29	44,71	49,00	31,68	71,00	32,80	65,82	31,86	49,71	30,46
March 2003	46,90	31,23	39,90	24,45	81,13	48,90	46,68	46,03	64,87	48,13	81,52	51,00	73,26	45,87
April 2003	45,43	32,10	47,73	22,23	58,63	40,63	60,47	58,20	71,63	39,90	62,97	45,40	59,30	36,77
May 2003	99,42	18,81	82,13	12,26	69,29	27,00	90,71	42,71	99,35	20,74	55,65	33,84	57,23	28,97
June 2003	88,83	8,43	93,57	8,93	71,83	11,33	94,77	26,90	113,33	12,67	79,00	20,67	56,57	17,67
September 2003	126,23	20,20	66,00	32,20	73,56	25,48	105,97	42,57	142,33	23,89	71,26	29,56	57,33	25,50
October 2003	85,23	21,19	83,71	21,90	73,94	34,94	107,26	45,26	121,19	25,55	72,55	27,74	63,26	25,68
November 2003	80,60	119,80	85,03	105,07	108,33	155,40	98,83	155,07	127,00	151,73	121,87	167,53	105,6	107,13
December 2003	111,53	74,35	109,47	84,65	161,29	113,06	121,65	119,65	177,94	120,41	135,59	123,82	127,47	76,47
Average	67,59	49,62	61,15	39,80	79,36	66,71	74,87	67,78	102,16	61,21	74,86	64,23	64,02	47,76
Std.Deviation	28,68	41,17	23,23	29,41	28,40	52,73	24,59	39,15	31,20	46,92	26,06	43,80	23,23	24,91

Table 3. Calculated T values of SO_2 at the sampling points.

Sampling Point	Karaman	Küçük Balıklı	Eğitim	Tophane	S. Garaj	Arabayatağı
Çekirge	0,698	1,167	0,772	0,386	0,750	3,264
Karaman	-	1,986	1,623	0,350	1,570	4,217
K.Balıklı	-	-	0,478	1,672	0,468	2,161
Eğitim	-	-	-	1,283	0,002	2,748
Tophane	-	-	-	-	1,241	3,922
Santral Garaj	-	-	-	-	-	2,687

Table 4. Calculated T values of PM at the sampling points.

Sampling Points	Karaman	Küçük Balıklı	Eğitim	Arabayatağı	S.Garaj	Tophane
Çekirge	0,777	1,021	1,278	0,743	0,972	0,155
Karaman	-	1,783	2,286	1,547	1,852	0,827
Küçük Balıklı	-	-	0,065	0,311	0,145	1,299
Eğitim	-	-	-	0,430	0,242	1,726
Arabayatağı	-	-	-	-	0,188	1,013
Santral Garaj	-	-	-	-	-	1,307

PM concentrations measured in Eğitim and Karaman districts showed similar trends with each other as shown in Figure 2. However, monthly average PM values in the Eğitim district were higher than the ones measured in the Karaman district. Eğitim district was nearby the Uludağ side. The Uludağ was located to the south side of the district so the pollutants could be dispersed at a limited rate. Main differences between concentrations measured from two districts could be the closeness to the highway and usage of solid fuel. In all months the PM concentration measured in the Eğitim district was 1.5 or 2 times higher than the PM concentration of Karaman. The highest PM concentration values were measured in the winter months and the lowest concentrations were measured in the summer months in the Eğitim district.

4. CONCLUSION

Usage of natural gas, if natural gas is not available, fuel-oil and coal having higher calorific value, lower PM and sulphur content should be used in order to decrease air pollution [14, 15]. Besides negative effects of combustion events on classical air pollution concentration, the geographical layout of Bursa prevents the dispersion of pollutants in the atmosphere [16]. A study conducted by Payan and Ertürk (2002) indicated that air pollution levels in the districts of Bursa namely Heykel, Yıldırım and Altıparmak had been influenced by dense population and traffic as well as the topographical structure. Moreover, meteorological characteristics, traffic load of the district, income level and type of fuel used influence the air quality.

The most important source of the high level of air pollutant concentrations reached in the winter months was the fossil fuels used for residential heating. Fossil fuels (i.e. coal) causes most of the part of the PM and SO_2 emissions [17]. Table 2 indicates that air pollution caused by SO_2 and PM originated mainly from fuels used for residential heating purposes in the winter months. The amount of PM and SO_2 emissions originated by natural gas are small. Therefore, extensive usage of natural gas can be effective on the solution of air pollution. Similar results were reported in the previous studies [18, 19].

The results showed that measurements should be taken from a representative sampling points in order to reach a conclusion about the air pollution level for a city. Results from randomly chosen sampling points are open to debate. While sampling point locations and numbers are determined, some parameters such as population density, population structure, topography of district, meteorological conditions, fuel type and amount, and traffic density etc. should be considered. The SO_2 and PM measurements are achieved in the sampling points at Çekirge, Karaman, Küçük Balıklı, Eğitim, Arabayatağı, Santral Garaj, Tophane, Heykel and Duaçınarı in Bursa. The sampling points, in general, may represent Bursa when traffic density, location areas and fuel types are considered. Sampling points are located in two big towns of Bursa called Osmangazi and Yıldırım. In these towns natural gas has been used while coal and wood were used widely and traffic was dense in some districts. The Nilüfer town, one of the towns of Bursa centre, should have at least one sampling station for monitoring the air pollution level of Bursa.

Obtained average values illustrate the influence of topography on SO_2 and PM concentrations. Concentration values are higher at Eğitim, Arabayatağı, Küçük Balıklı, Santral Garaj where less air circulation exist during winter when residential heating continues.

The pollution cannot be dispersed due to their location and irregular district settlement.

Used fuels effective on concentration levels mainly depend on income level. For example, natural gas has been used for heating at Çekirge, Karaman and Tophane districs and the pollution level is smaller compared to other districts.

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