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Outdoor air quality sulphur dioxide in Istanbul

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Oxidation of sulfur dioxide (SO_2) may form various atmospheric air pollutants, which is caused by natural processes or human activity. Chemical composition of the atmosphere and biosphere can change depending on the efficiency of the oxidation processes. Atmospheric gases like H_2SO_4 released by the oxidation of SO_2 is naturally removed from the atmosphere through oxidizing chemical reactions. Human activity can increase the amount of gases in the atmosphere, therefore it can affect the oxidation capacity. As a result of OH reaction, these gases are destroyed and removed from the atmosphere. OH reaction converts SO_2 to sulfuric acid H_2SO_4. Rain carries the sulfuric acid to biosphere or hydrosphere.

Free radicals are found in the atmosphere in small amounts, however, they rapidly react with other substances and thus spread through the atmosphere. SO_2 is one of the reactive radicals which has an effect on the oxidation processes. It plays an important role in the balance of atmospheric composition.

This study evaluates the SO_2 values in Kandilli, Sultanbeyli and Umraniye districts in Istanbul that was measured by Istanbul Marmara Clean Air Centre between March 1, 2013 and April 30, 2016. According to the measurements, the level of SO_2 was below the minimum level recommended by Turkish Government. Accordingly, it has been determined that the air quality was satisfactory; and the air pollution poses little or no risk to human health. In addition, temperature was found to have a significant impact on SO_2 compared to wind velocity and humidity. It was observed that SO_2 concentrations increased in winters compared to other seasons. SO_2 mean concentrations were lower in Istanbul compared to other countries.

Key words: outdoor air quality; SO_2; oxidation; Istanbul

1. INTRODUCTION

SO_2 is a colorless, pungent gas emitted by the combustion of sulfur-bearing fuels like coal or fuel-oil, metal smelting and other industrial facilities. The main sources of SO_2 in the atmosphere are domestic heating, thermal power plants and industrial boilers. Highest concentrations of SO_2 are generally measured in the settlements where low-quality coke is burned for heating or where there are large industrial facilities.

Children, elderly and the people suffering from asthma are the most vulnerable group to the effects of SO_2. SO_2 exposure harms the respiratory system by narrowing the respiratory tract, which can be detected with the symptoms such as wheezing, chest compression and cutaneous breathing. These symptoms may emerge as a result of high concentrations of SO_2 and increased breathing rate. After the exposure stops, lung returns to its normal functioning within one hour. Moreover, high concentrations of SO_2 may cause wheezing, chest compression, cut-off breathing.

Long-term exposures to SO_2 can lead to respiratory illnesses and changes in defense mechanisms of the lungs, and worsen the existing cardiac diseases. Children, elderly and the people who have chronic lung or heart diseases are the most sensitive group to this effect of SO_2.

Meteorological parameters may also be effective in dispersion or chemical transformation of air pollutants. For example, when the temperature decreases, the amount of combustion pollutants increases in the atmosphere, which in the end leads to the emission of SO_2 [1].

There are various studies which investigated the level of atmospheric SO_2 in different urban region areas [2-7].

2. EXPERIMENTAL

Figure 1(a) shows the areas of investigation, which are certain locations selected from crowded districts of İstanbul (Figure 1b). The residents in these districts use heating systems in winter and the main sources for heating systems are coal, and natural gas. Only the Kandilli district (Uskudar) is located on the Marmara Sea coast among the three locations. SO_2 values of these 3 areas are shown in Figure 1(c), which were measured by staff of Marmara Clean Air Center. Ambient air quality was measured through TS EN 14212 method by determining the level of sulfur dioxide using ultraviolet fluorescence [8].

SO_2 limit values determined and implemented by Turkish authorities, EU and WHO in order to protect human health are shown in Table 1. The limit value of SO_2 determined by EU for 1 hour is 350 μg/m³ and permitted number of exceedence is 24 times per year [9].

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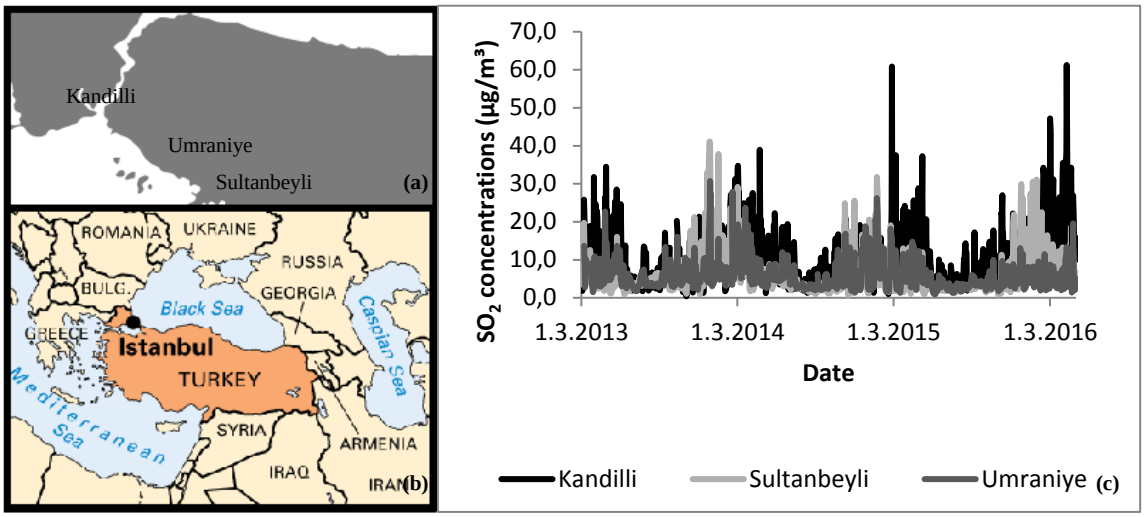

Fig. 1. (a) Investigation sites: Kandilli, Sultanbeyli, and Umraniye; (b) Istanbul, Turkey; (c) SO_2 concentrations

Table 1. Daily limit values for SO_2 (µg/m³) [9,10,11]

Year	Turkey	EU (Permitted exceedences each year)	WHO
2013	280	125 (3)	20
2014	250	125 (3)	20
2015	225	125 (3)	20
2016	200	125 (3)	20

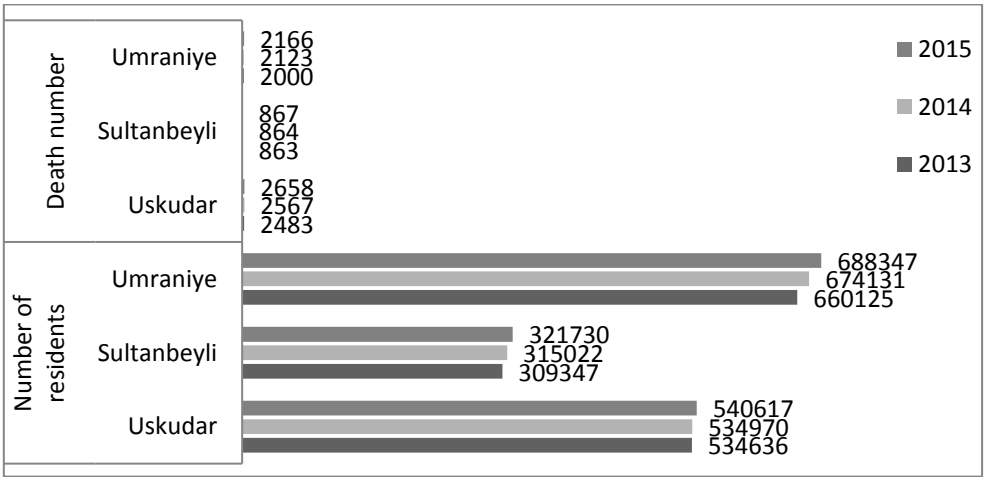

Fig. 2. Mortality rate and resident numbers for Umraniye, Sultanbeyli, and Uskudar [12].

3. RESULTS AND DISCUSSION

According to the measurements, the levels of SO_2 in three locations did not exceed the limit value during the 2013-2016 period. According to Turkish health index, air quality was assessed through SO_2 concentration and determined as good with 100 µg/m³. Therefore, it was determined that the health risk of SO_2 emissions was low in Kandilli, Sultanbeyli and Umraniye in the years between 2013-2016, the air quality was suitable for outdoor activities.

There was a correlation between the number of residents and mortality, which was determined as 0.99 for Umraniye and 0.85 for Sultanbeyli. The mean SO_2 concentration value between Umraniye and Sultanbeyli was 0.98. As indicated in Fig. 2, as the mortality and resident numbers increased, the mean SO_2 concentration did not increase.

Monthly mean SO_2 values for all areas were higher in winter than in summer during 2013-2016 period (Figure 3).

There was an incident occurred in this period which has appeared in the newspaper. After a fuel tank explosion in Sultanbeyli on 22 April, 2014 [13], SO_2 level in the environment was measured. Accordingly, SO_2 concentrations were found to be high, which were 38.9 µg/m³ in Kandilli, 6.1 µg/m³ in Sultanbeyli, and 8.7 µg/m³ in Umraniye. Highest concentration was observed in Kandilli due to westward direction of the wind blowing from Kartal (265°). For this reason, substances emitted after the explosion were carried to Kandilli from Sultanbeyli through the wind.

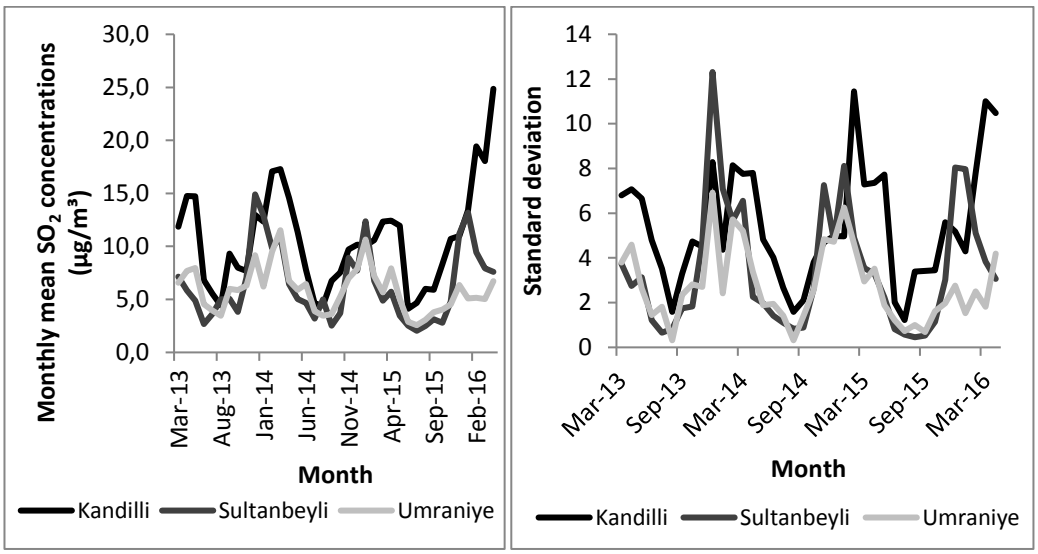

Fig. 3. (a) Monthly mean of SO_2 concentrations; (b) monthly standard deviation

In January, SO_2 values were higher in Sultanbeyli than the other areas. Rest of the months, SO_2 values were higher in Kandilli compared to other regions. In August, SO_2 decreased in all the locations. Highest SO_2 values were observed in February and March. It was determined that high SO_2 concentrations in Kandilli are caused by the ship activities.

Table 2. Annual maximum, minimum, and mean values for SO_2 (µg/m³)

	Year	Kandilli	Sultanbeyli	Umraniye
Maximum	2013	34.50	41.12	30.73
	2014	38.94	37.84	27.92
	2015	60.89	31.76	26.19
Minimum	2013	0.39	0.89	1.46
	2014	1.23	0.70	1.40
	2015	0.99	0.77	0.96
Mean	2013	10	6	6
	2014	10	6	6
	2015	9	5	5

Annual maximum, minimum and mean SO_2 concentrations were calculated for each district. Maximum values were below 61µg.m^{-3} (Table 2). Annual maximum values for Kandilli, Sultanbey li, and Umraniye were determined 34.50, 41.12, and 30.73 µg/m³, respectively, which are below the limit values determined by Turkey, EU, and WHO. The annual mean SO_2 concentrations were observed below the limit value (20 µg/m³ for annual and winter) that is specified in the Air Quality Assessment and Management Regulation for Turkey.

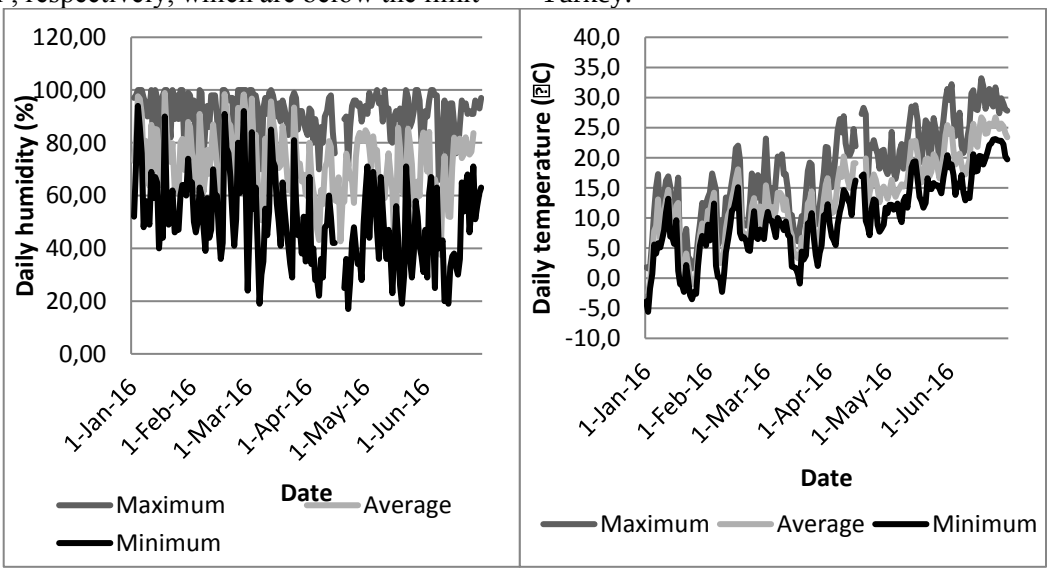

Fig. 4. (a) Daily humidiy for Kandilli; (b) daily temperature for Kandilli.

Table 3. Descriptive statistics of the data: SO_2 (µg/m³) in Umraniye, Sultanbeyli, Kandilli, January-April 2016

Variable	Mean	±SD	Minimum	Maximum	Station
Daily humidity (%)	73.52	12.58	17.00	100.00	Kandilli
	74.32	16.39	14.00	100.00	Umraniye
	74.41	13.03	12.00	100.00	Sultanbeyli
Daily temperature (°C)	10.14	5.15	-5.60	28.30	Kandilli
	9.39	5.54	-6.00	27.80	Umraniye
	9.72	5.23	-10.70	29.10	Sultanbeyli
Daily wind speed (m/sec.)	3.21	1.47	1.30	23.20	Kandilli
	3.24	1.23	1.30	21.90	Umraniye
	2.61	1.34	0.60	21.90	Sultanbeyli
Daily SO_2(µg/m³)	19.31	9.75	4.42	61.25	Kandilli
	5.50	2.75	1.40	19.58	Umraniye
	9.52	5.68	2.80	31.10	Sultanbeyli
Daily wind direction	192.53	109.58	5.00	359.00	Kandilli
	191.66	105.01	5.00	360.00	Umraniye
	204.02	107.62	3.00	359.00	Sultanbeyli

Daily mean values for humidity, temperature, wind speed, and wind direction in all stations were %74; 10°C; 3m/sec.; and SSW, respectively (Table 3). Daily mean SO_2 concentrations in Kandilli were higher than in other districts due to wind direction and the ship activities (Figure 4 and 5).

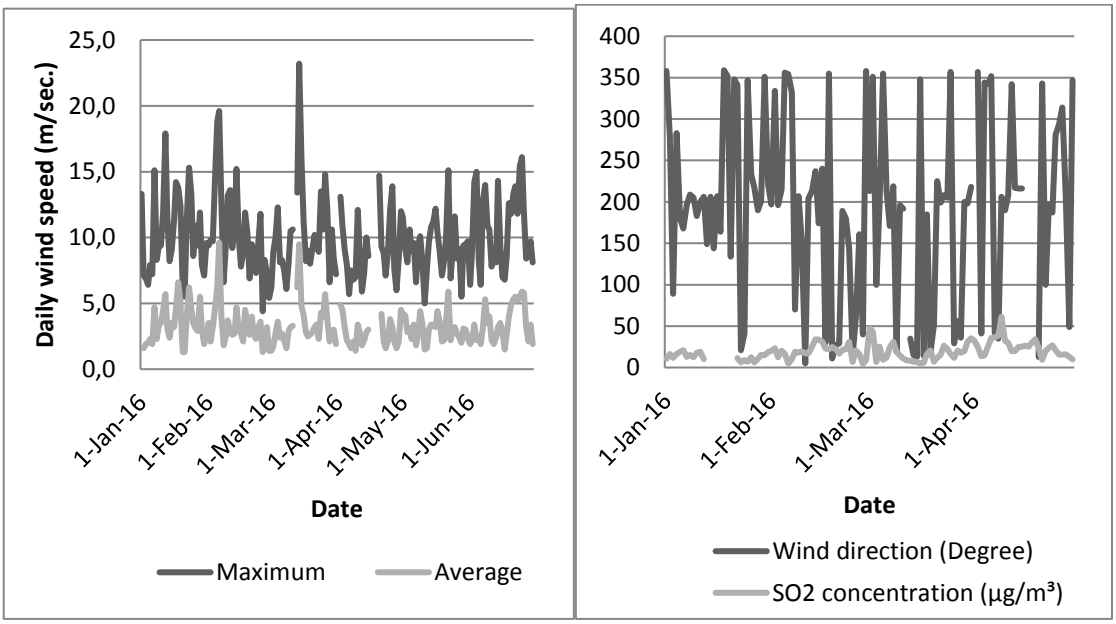

Fig. 5. (a) Daily wind speed for Kandilli; (b) daily wind direction and SO_2 concentration for Kandilli.

Pearson correlation coefficient (r) between temperature and SO_2 in Umraniye is found to range between 0.3 and 0.5, which represents a positive medium strength association between these variables (Table 4). Pearson's r between temperature and SO_2 levels in Kandilli ranges between 0.5 and 1, which means there is a strong positive association between these variables. Pearson's r between humidity and SO_2 levels in Kandilli and Umraniye ranged between -0.3 and -0.5, which indicates a medium negative association between these variables. Pearson's r values between SO_2 and meteorological parameters in Sultanbeyli take a range from -0.1 to -0.3, which indicates a weak negative association between two variables.

Table 4. Daily values of Pearson correlation coefficient between SO2 (μg/m³) and meteorological data in Umraniye, Sultanbeyli, and Kandilli, 2013-2016

Pearson correlation between daily SO_2 and	Kandilli	Umraniye	Sultanbeyli
Daily maximum humidity (%)	-0.34	-0.40	-0.05
Daily Mean humidity (%)	-0.47	-0.55	-0.12
Daily minimum humidity (%)	-0.41	-0.42	-0.15
Daily maximum temperature (°C)	0.65	0.47	-0.06
Daily Mean temperature (°C)	0.62	0.48	-0.14
Daily minimum temperature (°C)	0.58	0.43	-0.24
Daily maximum wind speed (m/sec.)	-0.32	0.01	-0.17
Daily Mean wind speed (m/sec.)	-0.42	-0.09	-0.23
Wind direction (Degree)	0.05	0.25	0.17

High mean values were generally observed in winter (Table 5).

Table 5. Seasonal SO_2 (μg/m³) in Umraniye, Sultanbeyli, Kandilli, 2013-2016

Year	Period (season)	Kandilli	Sultanbeyli	Umraniye
2013	Spring	13.8	5.9	7.6
	Summer	5.6	3.8	4.0
	Autumn	8.3	5.3	6.0
	Winter	14.0	12.6	8.1
2014	Spring	14.4	7.4	8.1
	Summer	5.3	3.4	4.3
	Autumn	8.0	4.9	5.2
	Winter	10.3	9.0	8.6
2015	Spring	12.2	4.7	6.2
	Summer	4.9	2.3	2.8
	Autumn	8.31	3.56	4.11
	Winter	14.62	11.29	5.55
2016	Spring	21.40	7.77	5.87

In 1989, mean and maximum SO2 concentrations were calculated as 102 and 630 μg/m³, respectively in Beijing, China [14]. In the Esino Valley, Italy, hourly mean(±SD) values were calculated as 20.02 μg/m³ (±17.18) in summer and 36.22 μg/m³ (±14.92) in winter [1]. In the seven cities of Korea, mean SO2 level was calculated as 23.3 μg/m³ from 1991 to 1997 [14]. Second highest daily mean value was measured in Philadelphia as 299 μg/m³ from 1973 to 1980 [15]. In this study, SO2 concentrations in Istanbul were lower than the previous data in the literature.

4. CONCLUSIONS

The aim of this study was to investigate the correlation between meteorological parameters and SO_2 concentration levels, and monthly and seasonal variations of SO_2 in the atmosphere. Mean seasonal values for Kandilli took a range from 4.9 to 21.4 μg/m³, for Umraniye from 2.8 to 8.6 μg/m³, for Sultanbeyli from 2.3 to 12.6 μg/m³.

The amount of air pollution in İstanbul has considerably declined in 2015 thanks to the advancements in heating system of the city like widespread use of natural gas. Nowadays, air pollutants pose a significant threat to human health by harming respiratory system. Intense and long-term exposure to SO_2 is especially dangerous for people with asthma, chronic lung patients and children. In addition, high concentrations of SO_2 can cause asthma attacks. There are some precautions which can be taken to reduce the adverse effects of SO_2 on human health such as moving the industrial and business centers out of the settlement areas, promotion of public transport instead of using

personal vehicles, developing and using electric transport vehicles, using air filters in industrial areas and using natural gas as fuel, increasing the forestation especially in areas where the air pollution is intense.

Compared to China, Italy, Korea, Philadelphia, SO_2 values in Istanbul were low.

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