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Evaluation of air pollution by PM_{10} and SO_2 levels in Erzurum province, Turkey: Descriptive study

Türkiye Erzurum ilinde havadaki PM_{10} ve SO_2 düzeyleri ile hava kirliliğinin değerlendirilmesi: Gözlemsel çalışma

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Abstract

Aim: Air pollution is an important, global, health-threatening environmental risk factor. Air pollution can cause potentially fatal respiratory tract and other diseases. Erzurum is the largest and most developed city in northeast Turkey. The purpose of this study was to determine levels of air pollution in the center of Erzurum province in 2012 and 2017.

Methods: Data for the Erzurum station for July 2012-July 2017 in this cross-sectional descriptive study were obtained from the Turkish Ministry of the Environment and Urban Planning Air Quality Monitoring Stations web site. The data obtained were compared with European Union (EU) Countries, World Health Organization (WHO) and Turkish national threshold values. Descriptive statistics were expressed as median, minimum-maximum value and percentage, Kruskal Wallis and Mann Whitney U tests were used in the analysis.

Results: At the Erzurum station, the PM_{10} (particles less than 10 microns) median value for the years 2012-2017 was 27 (min: 2; max: 443), the SO_2 median value was 6 (min: 0; max: 443).

PM_{10} exceeded the Turkish national limit on 22 days in 2012; 37 in 2013; 23 in 2014; 40 in 2015; 74 in 2016; and 27 in 2017. SO2 did not exceed the Turkish national limit on any days in 5 years. SO_2 (sulfur dioxide) exceeded the WHO limits on 3 days in 2012, 30 in 2013, 42 in 2014, 56 in 2015, 37 in 2016 and none in 2017.

Statistical analysis revealed that PM_{10} and SO_2 values varied significantly by year ($p<0.001$), season ($p<0.001$) and month ($p<0.001$). The values for both parameters were higher in winter, and the highest median values occurred in January.

Conclusion: The problem of air pollution in Erzurum has decreased compared to previous years, but it still not at recommended levels.

Keywords: Air pollution, Particulate matter, Sulfur dioxide

Öz

Amaç: Hava kirliliği, küresel sağlığı tehdit eden önemli bir çevresel risk faktörüdür. Hava kirliliği, ölümcül olabilen solunum yolu hastalıkları ve diğer hastalıklara neden olur. Erzurum, Türkiye'nin kuzeydoğusundaki en büyük ve en gelişmiş şehridir. Bu çalışmada 2012-2017 yılları arasında Erzurum şehir merkezinde havadaki PM_{10} (10 mikrondan küçük partiküller) ve SO_2 (sülfür dioksit) düzeylerinin değerlendirilmesi amaçlanmıştır.

Yöntemler: Kesitsel tanımlayıcı tipte yapılan bu çalışmada T.C. Çevre ve Şehircilik Bakanlığı Hava Kalitesi İzleme İstasyonları Web Sitesinden Temmuz 2012-Temmuz 2017 Erzurum istasyonu verileri edinilmiştir. PM_{10} ve SO_2 ölçümlerinin 24 saatlik ortalamaları belirtilen tarihler için indirilmiş ve Dünya Sağlık Örgütü (DSÖ), Avrupa Birliği (AB) Ülkeleri ve Türkiye ulusal sınır değerleri ile karşılaştırılmıştır. Tanımlayıcı istatistikler ortanca, en küçük-en büyük değer ve yüzde olarak sunulmuş, analizlerde Kruskal Wallis ve Mann Whitney U testleri kullanılmıştır. İstatistiksel anlamlılık düzeyi $p<0,05$ kabul edilmiştir.

Bulgular: Erzurum istasyonunda 2012-2017 yıllarının PM_{10} ortanca değeri 27 (min:2; max:443), SO_2 ortanca değeri 6 (min:0; max: 137)'dır. Yıllara göre PM_{10} Türkiye sınır değerini aşan gün sayısı 2012'de 22; 2013'te 37; 2014'te 23; 2015'te 40; 2016'da 74; 2017'de 27'dir. SO_2 değerleri için Türkiye sınır değeri aşan gün 5 yıl için bulunmamaktadır. SO_2 DSÖ sınır değerini aşan gün sayısı 2012'de 3, 2013'te 30; 2014'te 42; 2015'te 56; 2016'da 37'dir ve 2017'de bulunmamaktadır. Verilerin analizleri sonucunda PM_{10} ve SO_2 değerlerinin yıllara göre ($p<0,001$), mevsimlere göre ($p<0,001$) ve aylara göre ($p<0,001$) aralarındaki farkın istatistiksel olarak anlamlı olduğu bulunmuştur. Kış mevsiminde her iki parametre ortancaları daha yüksek olup, en yüksek ortancalar Ocak ayına aittir.

Sonuç: Erzurum'daki hava kirliliği sorunu önceki yıllara göre azalmıştır, ancak hala hedeflenen edilen seviyelerde değildir.

Anahtar kelimeler: Hava kirliliği, Partiküler madde, Kükürt dioksit

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Introduction

Air pollution is an important, global, health-threatening environmental risk factor. Air pollution refers to contamination by any chemical, physical or biological agent that alters the natural atmospheric characteristics of an internal or external space. Important sources of air pollution include fuels used for heating, motorized vehicles, industrial facilities, and forest fires [1]. In 2014, 92% of the world population were living in regions with poor air quality according to World Health Organization (WHO) guidelines [2].

Air pollution can cause potentially fatal respiratory tract and other diseases. Air pollution of the external environment is estimated to have caused 3 million cases of premature death worldwide in 2012. Approximately 72% of these deaths were due to ischemic heart disease and stroke, 14% to chronic obstructive pulmonary disease or acute lower respiratory tract infections, and 14% to lung cancer. Significant inequality exists in exposure to air pollution, with 88% of these deaths occurring in low and moderate income countries [2].

Investigation of air pollution commenced with episodes that occurred in the Meuse Valley in Belgium in 1934, in Donora in the USA in 1947, and in London in 1952 [3]. The London smog of 1952 is regarded as the catalyst for air pollution epidemiology research, with a mortality rate three time higher than normal during this period [4]. Legal measures aimed at controlling air pollution were first implemented in the USA and the UK, and reducing urban air pollution was found to contribute significantly to the elimination of winter fogs [5]. The "Directive on Achieving Savings in Fuel Consumption and Reducing Air Pollution Caused by Heating Facilities in Cities," published by the Turkish Ministry of Energy and Natural Resources in 1972, was the first to directly address the question of air pollution [6]. This directive was subsequently updated over the years, and the Directive on Air Quality Evaluation and Management (DAQEM) entered into effect on 06.06.2008 as a result of harmonization with European Union (EU) regulations. Under the scope of that directive, pollutants such as ozone (O3), carbon monoxide (CO) and nitrogen oxide (NO), and particularly sulfur dioxide (SO2) and particulate matter (PM), are measured at fully automated measurement stations established in all 81 provinces in Turkey. Measurement data collected from these stations are forwarded to the Turkish Ministry of the Environment and Urban Planning Data Processing Center and are simultaneously published on the www.havaizleme.gov.tr web site [7].

Erzurum is the largest and most developed city in northeast Turkey. The city is not an industrial one. It is one of Turkey's highest-altitude cities, and winter temperatures can be as low as -40 C. Air pollution in Erzurum is to a large extent caused by the heating and traffic [8]. In addition, air pollution on windless days represents a serious threat to public health in Erzurum, which is surrounded by mountains 2-3000 m in height to both north and south.

Previous scientific research into air pollution in Erzurum has involved data for 1990-2008, 2003-2004, 2003-2006, and 2009-2012 [8-11]. The purpose of this study was to determine levels of air pollution in the center of Erzurum province in 2012 and 2017, and to assess the current situation compared to that in previous years.

Materials and methods

Our research was designed as a descriptive, cross-sectional study, and was performed between August and December, 2017. PM_{10} (particles less than 10 microns) and SO_2 values constituted the dependent study variables, while winter, summer, month and year represented the independent variables. Winter was defined as the period between 1 October and 31 March, and summer as the period between 1 April and 30 September. Air pollution measurements in Erzurum are performed by fully automated devices installed by the Turkish Ministry of the Environment and Urban Planning, and data are published on the ministry website. Mean 24-h PM_{10} and SO_2 measurements for the Erzurum, Aziziye, Palandöken and Taşhan stations (in the central part of the province) between July 2012 and July 2017 were collected from the Turkish Ministry of the Environment and Urban Planning web site. These data were compared with Turkish national threshold values, and threshold values recommended by EU countries and the World Health Organization (WHO) (Table 1).

Table 1: EU, Turkish and WHO limits for SO_2 and PM_{10}

	EU countries [12]	Turkey (2017) [13]	WHO [14]
SO_2 (sulfur dioxide)	125 μg/m^3 *	175 μg/m^3	20 μg/m^3
PM_{10} (particulate material)	50 μg/m^3**	70 μg/m^3	50 μg/m^3

* not to be exceeded more than 3 times in one year, ** not to be exceeded more than 35 times in one year, EU: European Union, WHO: World Health Organisation

Statistical analysis

Data recording and analysis was performed using SPSS 22.00 software. Normal distribution of variables was examined using the Kolmogorov-Smirnov test. Non-normally distributed data were expressed as median, minimum, maximum, and percentage values. The Kruskal Wallis and Mann Whitney U tests were used for statistical analysis. P values <0.05 were regarded as statistically significant.

Results

PM_{10} was measured on 1707 days (93.4%) and SO_2 on 1507 days (82.5%) in the Erzurum station in 2012-2017. The median PM_{10} value in this five-year period was 27 μg/m^3 (min: 2; max: 443), and the mean SO_2 value was 6 μg/m^3 (min: 0; max: 137). PM_{10} exceeded Turkish national, EU and WHO threshold values on 395 days, representing 21.6% of the days on which measurement was carried out. SO_2 exceeded national and EU threshold limits on 1 day (0.1%) and WHO limits on 168 days (9.2%). Annual SO_2 and PM_{10} levels are shown in Table 2.

Table 2: SO_2 and PM_{10} levels in Erzurum by years

	PM_{10} (μg/m^3)			SO_2 (μg/m^3)		
	Median	Minimum	Maximum	Median	Minimum	Maximum
2012	41	9	336	7	2	36
2013	20	2	305	5	1	82
2014	21	5	249	6	1	116
2015	29	4	237	7	1	137
2016	34	7	443	7	1	118
2017	29,5	5	182	11,5	4	19

PM_{10} values exceeded Turkish threshold limits on 22 days in 2012 (11.9%), 237 in 2013 (10.1%), 23 in 2014 (6.3%), 40 in 2015 (11.0%), 74 in 2016 (20.2%), and 27 in 2017 (14.9%). PM_{10} values exceeded EU country and WHO threshold limits on 53 days in 2012 (28.8%), 56 in 2013 (15.3%), 43 in

2014 (11.8%), 80 in 2015 (21.9%), 116 in 2016 (31.7%), and 47 in 2017 (26.0%) (Figure 1, 2).

SO_2 values did not exceed Turkish threshold limits on any days during the five-year study period, and exceeded EU country limits on only one day, in 2015. However, SO_2 values exceeded WHO limits on 3 days in 2012 (1.6%), 30 in 2013 (8.2%), 42 in 2014 (11.5%), 56 in 2015 (15.3%), 37 in 2016 (10.1%) and none in 2017.

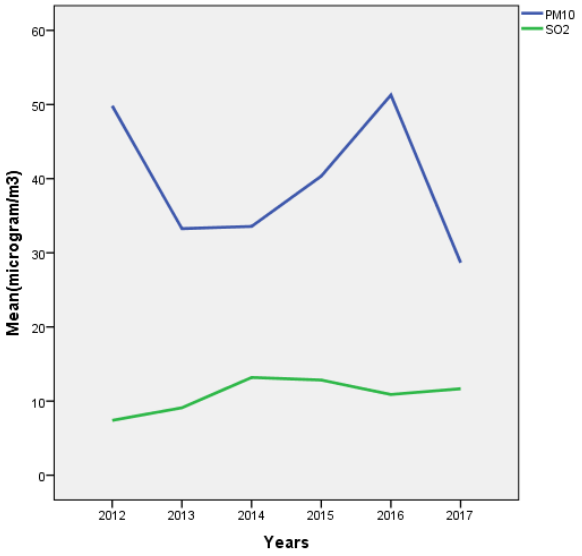

Figure 1: SO_2 and PM_{10} levels in Erzurum by years

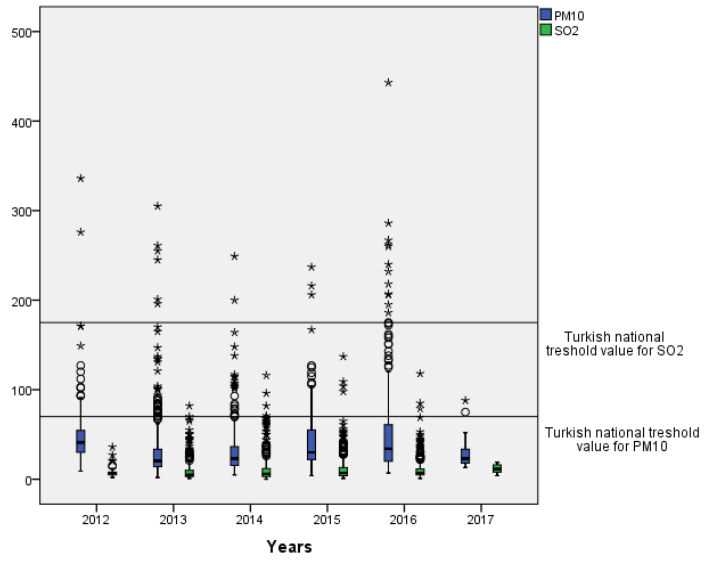

Figure 1: Distribution of SO_2 and PM_{10} parameters by national threshold values

Variation in PM_{10} and SO_2 values by years was statistically significant ($p<0.001$ for both). There was no statistically significant difference in terms of PM_{10} levels between 2013 and 2014, or between 2016 and 2017, but significant decreases were observed in the following years. A significant decrease occurred in SO_2 levels between 2012 and 2013, while a significant increase occurred between 2016 and 2017. SO_2 increased significantly at the end of five years ($p<0.001$).

No statistically significant difference was determined in PM_{10} and SO_2 levels in terms of seasons or months ($p<0.001$ for both). The median PM_{10} winter value was 55.4 (minimum: 2, maximum: 443), and the median SO_2 value was 14.9 (minimum: 1, maximum: 137). Median summer values were 24.1 (minimum: 2, maximum: 106) for PM_{10} and 6.2 (minimum: 1, maximum: 96) for SO2. SO_2 and PM_{10} levels by months are shown in Table 3.

Table 3: SO_2 and PM_{10} levels by months

	PM_{10} ($\mu g/m^3$)			SO_2 ($\mu g/m^3$)		
	Median	Minimum	Maximum	Median	Minimum	Maximum
January	81.09	5	305	22.56	1	116
February	80.63	13	443	20.03	4	118
March	37.13	7	174	8.10	2	31
April	22.60	4	76	7.47	1	19
May	18.26	6	48	4.15	1	18
June	22.10	4	58	3.82	1	13
July	23.52	8	70	8.23	1	96
August	32.23	7	78	4.45	1	9
September	25.87	2	106	8.78	1	69
October	31.14	2	118	7.06	2	29
November	41.54	8	98	14.06	2	137
December	63.37	8	336	18.63	1	82

The highest monthly median values for both air pollution parameters were determined in January, while the highest mean values were recorded in February.

Discussion

Levels of PM_{10} and SO_2, two parameters assessing air pollution in measurements performed in the center of Erzurum province in 2012-2017 significantly exceeded both EU and WHO limits and also Turkish national threshold values. PM_{10} values exceeded the recommended limits for EU countries on more than 35 days a year in this research. SO_2 levels did not exceed EU country limits more than three days in any of the five years. However, SO_2 levels were considerably above the limit recommended by the WHO for a healthy ecosystem.

Turalıoğlu et al. [12] showed that air pollution levels in Erzurum increased significantly in 2003-2004. Beyhun et al. [11] reported that pollution continued to rise in 2003–2006, after which a statistically significant decrease was observed in pollution parameters (particularly SO_2). In particular, the short-term and winter limits determined by the 2006 Directive on the Protection of Air Quality were not exceeded. One study of air pollution in Erzurum between 1990 and 2008 determined a decrease in SO_2 and PM_{10} in the city center [10]. In our own research, while we observed a decrease in PM_{10} levels between 2012 and 2017, SO2 levels increased. Our findings and those of other studies performed in our province indicate that there has been a marked decrease in both parameters compared to previous years. All studies conducted in Erzurum, which is not affected by industrial air pollution, have reported, in agreement with our findings, that air pollution peaks in January, in parallel to increased fuel consumption in winter [10,11].

The Erzurum Air Quality Assessment Report, which evaluated data for the province in 2009-2012, reported that the peak PM_{10} and SO_2 emissions occurred at times of high fuel consumption, that significant increases occurred when ambient temperatures were very low, and that motorized transport emissions occurring at the same times as heating system-based emissions contributed significantly to peaks in air pollution parameters and to intense air pollution lasting many hours [8]. The use of natural gas is a major factor in the gradual decrease observed since 2015 in our province, in which fuels and traffic are the most important pollutants [11]. SO2 levels increased at the end of our five-year study period, an increase that may be attributed to a move away from high-quality fuels, increased traffic, and problems with motorized vehicle exhaust emissions. The results of studies conducted in different provinces of Turkey

have shown that decreases in air pollution parameters can be achieved through actions taken by local administrations [13,14]. Studies conducted at the international level have also shown that air pollution prevention measures and amendments to legislation can overcome various problems, but that air pollution agents continue to represent a threat to health by changing forms over the years [15]. For all these reasons, the adoption of appropriate measures by local administrations will be effective in reducing air pollution. The results of scientific research into air pollution and its causes at the national level must be closely monitored to permit the updating of legislation aimed at air pollution agents.

In its reports into air pollution, the Union of Chambers of Turkish Engineers and Architects regards the province of Iğdır as a region under particular threat from air pollution, and has reported that air pollution has persisted in the province due to a failure to take precautionary measures. PM_{10} limits in the province of Iğdır were exceeded 265 times in 2015 and 242 times in 2016. Inversion deriving from natural geographic conditions prevents the dispersion of pollution [16]. This shows the importance of establishing air corridors through urban areas in order to avoid long-term persistence of the threat caused by air pollution episodes.

The present study also evaluated SO_2 and PM_{10} levels in Erzurum in 2012-2017 in terms of months and seasons. The fact that this descriptive, cross-sectional study was unable to reveal the causes of air pollution represents a limitation. However, the findings are important in terms of assessing the existing position for local administrators and for future research on the subject, and in showing the dimensions of the preventable problem of air pollution with its impacts on public health.

Conclusion

The problem of air pollution in Erzurum has decreased compared to previous years, but it still not at recommended levels. It continues to represent a threat to public health. Local administrations must adopt the requisite precautionary measures to prevent air pollution, particularly in winter; our province has especially harsh winters. Inspections are essential, and the public must be incentivized on the subject of using high-quality fuels.

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