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Research Article

Analysis of Air Pollution in Bayburt Province with Statistical Methods

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ABSTRACT

In this study, the temporal changes of air pollutants belonging to the city center of Bayburt, their interactions with local meteorological parameters, and trends were analyzed using statistical methods. In this context, hourly measured PM_{10}, SO_2, NO, NO_2, NO_X, O_3 and hourly temperature (t), wind speed (ws), humidity (rh), pressure (p) data for the 2017-2019 period were analyzed. The average value of PM_{10} concentrations from primary pollutants was 40.5 µg/m^3, and the average value of SO_2 concentrations was 6.85 µg/m^3. According to the results of the Mann-Whitney U test, it was found that the averages concentrations of the cold season pollutants significantly differed statistically from the averages concentrations of the hot season ($p=0.000<0.05$). According to the Kruskal Wallis test, a statistically significant difference was found between the averages of the pollutant concentrations by years ($p=0.000<0.05$). It was determined by Post-Hoc/Tamhane's T2 analysis which years there was a differentiation between. Spearman's rho correlation analysis results reveal a statistically significant relationship between air pollutants and meteorological parameters ($p=0.000<0.05$). Accordingly, it was determined that the relationship between PM_{10}, and relative humidity is negative, the relationship between SO_2 and air pressure is positive, the relationship between NO, NO_2, and NOx, wind speed and temperature is negative, the relationship between O_3 and temperature with wind speed is positive. According to the innovative trend analysis method (ITA) results, PM_{10} levels tend to decrease and other pollutants tend to increase. Considering the time interval of the data used, although it is not observed that the pollutant averages exceed the limit values, the increasing trend of pollutants reveals that more efforts should be made to maintain positive air quality. Statistical data analysis in the study was carried out with SPSS 22 software.

Keywords: *Bayburt, Air pollution, Meteorological parameters, Spearman's rho, Trend analysis.*

Bayburt İli Hava Kirliliğinin İstatistiksel Yöntemlerle Analizi

ÖZ

Bu çalışmada Bayburt şehir merkezine ait hava kirleticilerinin zamansal değişimleri, yerel meteorolojik parametreler ile olan etkileşimleri ve trendleri istatistiki yöntemlerle analiz edilmiştir. Bu kapsamda, 2017-2019 dönemi saatlik ölçülen PM_{10}, SO_2, NO, NO_2, NO_X ve O_3 ile saatlik sıcaklık (t), rüzgâr hızı (ws), nem (rh) ve basınç (p) verileri analiz edilmiştir. Birincil kirleticilerden PM_{10} konsantrasyonlarının ortalama değeri 40.5 µg/m^3 ve SO_2 konsantrasyonlarının ortalama değeri ise 6.85 µg/m^3 olarak tespit edilmiştir. Mann-Whitney U testi sonuçlarına göre, kirletici konsantrasyonlarının soğuk mevsim ortalamaları sıcak mevsim ortalamalarından istatistiki manada anlamlı şekilde farklılaştığı tespit edilmiştir ($p=0.000<0.05$). Kruskal Wallis testine göre kirletici konsantrasyonlarının yıllara göre ortalamaları arasında da istatistiksel açıdan anlamlı bir farklılaşma olduğu saptanmıştır ($p=0.000<0.05$). Hangi yıllar arasında farklılaşmanın olduğu Post-Hoc/Tamhane's T2 analizi ile

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belirlenmiştir. Spearman's rho korelasyon analizi sonuçları hava kirleticiler ile meteorolojik parametreler arasında istatistiki manada anlamlı bir ilişki ortaya koymaktadır ($p=0.000<0.05$). Buna göre, PM_{10} ile bağıl nem arasındaki ilişkinin negatif yönlü, SO_2 ile hava basıncı arasındaki ilişkinin pozitif yönlü, NO, NO_2 ve NO_X ile rüzgâr hızı ve sıcaklık arasındaki ilişkinin negatif yönlü, O_3 ile sıcaklık ve rüzgâr hızı arasındaki ilişkinin pozitif yönlü olduğu tespit edilmiştir. Yenilikçi trend analiz yöntemi (ITA) sonuçlarına göre, PM_{10} seviyeleri azalış, diğer kirleticiler ise artış eğilimi göstermektedir. Kullanılan verilerin zaman aralığı göz önüne alındığında kirletici ortalamalarının her ne kadar sınır değerleri aştığı gözlenmese de kirleticilerin artış eğiliminde olması, pozitif hava kalitesinin korunması için daha fazla çaba gösterilmesi gerektiğini ortaya koymaktadır. Çalışmadaki istatistiksel veri analizleri SPSS 22 programı ile gerçekleştirilmiştir.

Anahtar Kelimeler: *Bayburt, Hava kirliliği, Meteorolojik parametreler, Spearman's rho, Trend analizi.*

I. INTRODUCTION

The rapid increase in the world population, irregular urbanization, and increasing energy needs as a result of agriculture and industrial development have caused the deterioration of the balanced relationship between humans and the natural environment [1]. The uncontrolled release of waste materials generated by the rapid consumption of natural resources to nature also brings some ecological concerns. Nowadays, air pollution is at the top of the increasing environmental problems, threatening the ecological structure of the future and exposing it to ecological and biological hazards [2]. The adverse effects of pollutants that cause air pollution on human health is an undeniable fact [3]. In this context, the EPA (Environmental Protection Agency) defines air pollution as "the presence of pollutants in the air in a way that will harm human health or welfare or create other harmful environmental effects" [4,5]. In clinical studies on humans, pollutants such as O_3, SO_2, PM_{10}, NO_X, and biogenic antigens such as pollen have been reported to increase respiratory diseases [6-8]. It has been found that there is a relationship between air pollution and admission to hospitals or emergency services for adults and children due to respiratory complaints or exacerbation of asthma [9-11].

The causes of air pollution observed in Turkey can be largely based on fuels consumed for household fuel and motor vehicles. The poor quality of the fuels used in heating and the insufficiency of the appropriate combustion techniques cause an increase in the number of pollutants sent to the atmosphere [12]. In addition, meteorological parameters also affect the distribution of air pollutants in the atmosphere. Air pollutants move horizontally and vertically in the atmosphere. As a result of these movements, the larger the volume of pollutants mix with the air, the more they dilute, and their concentration decreases. The reduction of pollutant concentrations has a reducing effect on the adverse effects of pollutants [12,13]. Many studies in the literature have found a relationship between pollutant concentrations and meteorological parameters. [14-18].

Air pollutants can be of natural origin or human origin. Although naturally sourced pollutants are not permanent (acute effect), they are released into the air in greater concentrations than anthropogenic pollutants. Human source pollutants, on the other hand, are in high or low concentrations but are continuous (chronic effect). In this case, considering the pollutant loads in the atmosphere, it is seen that the atmosphere can control naturally originated pollutants over time but cannot adequately control anthropogenic pollutant concentrations [19]. For this reason, it is essential to examine the changes in air pollutants over time. In recent studies, changes in pollutant concentrations over time have been examined using trend analysis methods [20-22].

In this study, the temporal changes of air pollutants in the city center of Bayburt, their interactions with local meteorological parameters, and their trends were examined by statistical methods. In this context, hourly measured PM_{10}, SO_2, NO, NO_2, NO_X, and O_3 and hourly temperature (t), wind speed (ws), humidity (rh), and pressure (p) data for the 2017-2019 period were used in the analysis.

II. MATERIALS AND METHODS

A. STUDY AREA AND GEOGRAPHICAL FEATURES

Bayburt is located between 40°37' north latitude and 40°45' east longitude, 39°52' south latitude, and 39° 37' west longitude. It is a province with a surface area of 3652 km², established in the northeast of Anatolia, on the banks of the Çoruh River, and at an altitude of 1550 m from the sea. Bayburt and its surroundings generally consist of three parts in terms of landforms. The first is the Bayburt plain, which forms the western half of the field, the second is the valleys formed by streams, and the third is the mountainous areas surrounding the region and located in the eastern half. In the province of Bayburt, a transition climate with predominant terrestrial features prevails between the Eastern Black Sea climate and the Eastern Anatolian climate [23,24].

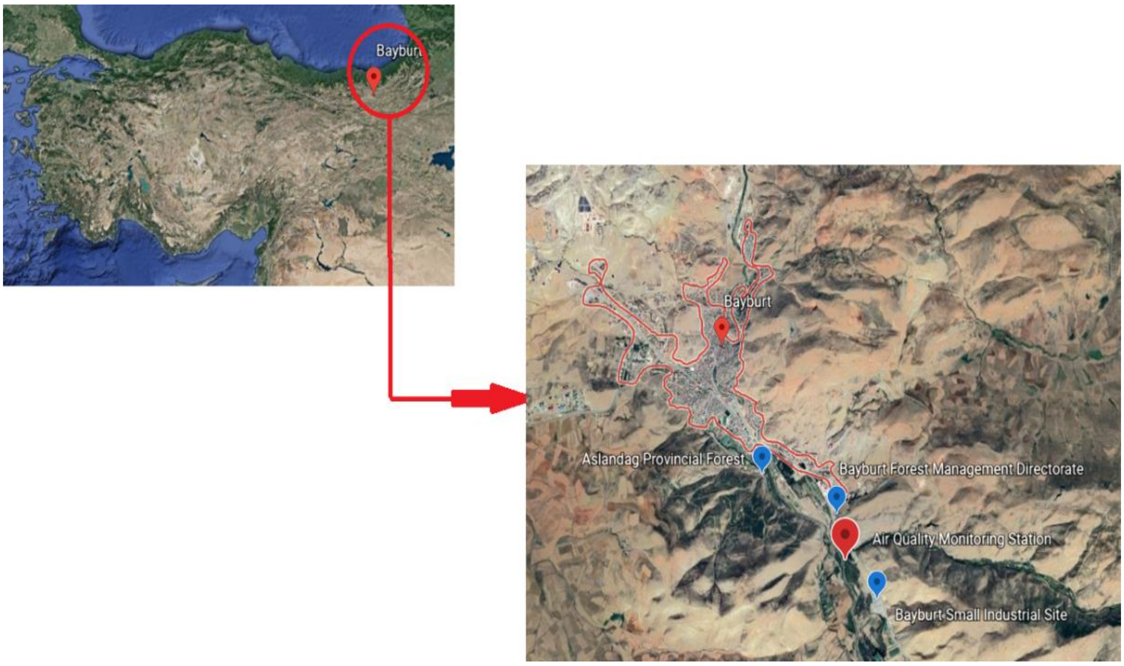

Figure 1. *Bayburt city center and air quality observation station (Google Earth Image © 2021).*

B. THE DATA FOR THIS STUDY

Two types of databases were used in the study: air pollutants and local meteorological parameters. These different databases are the "hourly" measured and recorded data, which are the same period time, and cover the 2017-2019 period. Hours with missing any parameters or incorrect measurements are completely ignored. In this way, included 18434 data for each variable in the study were used in the statistical analyses. Hourly air pollution parameters (PM_{10}, SO_2, NO, NO_2, NO_X, and O_3) for the 2017-2019 period were obtained from the air quality monitoring station in the city center. Hourly meteorological parameters (temperature (t), wind speed (ws), humidity (rh), and pressure (p)) were also obtained from the same station [25]. The location of the air quality measurement station is presented in Figure 1.

C. METHODS APPLIED IN DATA ANALYSIS

To increase the air quality, an emission inventory of the region should be created. In this context, in the design of projects to be carried out to improve air quality, regular and continuous measurement of the pollutant parameters of the region, their interpretation under local meteorological parameters, and the changes in air pollution parameters over time should be examined [19]. As in all other environmental data, data on air pollutants are generally asymmetrical, seasonal, sequentially dependent, and nonnormal distribution, containing contradictory and missing observations [22]. Because of all these features should do a normality test to decide whether parametric or nonparametric tests should be used in analyzes from statistical methods. In cases where the sample size is 30 and above ($n \geq 30$), the fitness of the quantitative variable to the normal distribution is tested with the Kolmogorov Smirnov test [26]. Both histogram graphs and Kolmogorov Smirnov test results ($p < 0.05$) revealed that the meteorological and air pollutant parameters were not normally distributed. Therefore, nonparametric tests were used in statistical methods. Within the scope of this study, first of all, general descriptive statistical parameters (means, confidence intervals for the average at 95% significance level, min/max values) belonging to the air pollution parameters and meteorological parameters of the city center were calculated.

Whether the seasonal averages of the air pollution parameters have a statistically significant difference or not was investigated by the Mann-Whitney U test. Similarly, investigated the significance of the difference between the annual averages of the air pollution parameters with the Kruskal Wallis test. The years between which there was a significant difference in parameters with significant differences were determined by Post-Hoc/Tamhane's T2 test. The statistical relationships of each hourly data with each other were examined with Spearman's rho analysis. Especially in recent years, the change of data in climatological and hydrological large data sets over time is often investigated with trend analyses. [19,27,28].

In this study, since it is considered that the data sets of air pollutants may have seasonal changes, may contain incomplete or abnormal values, the changes of air pollutants over time have been examined by nonparametric trend analysis method. Because parametric tests are possible under a series of restrictive assumptions such as normal distribution, specific data length, and independent structure of time series, for this reason, in the study, the changes in air pollutants in a certain period were examined using the innovative trend analysis method (ITA) proposed by Şen (2012) [29]. In the innovative trend analysis method, the time series is first divided into two equal parts, and the separated series are ordered from the smallest to the largest. Then, as shown in Figure 2, the first half of the time series (x_i) is placed on the X-axis of the cartesian coordinate system and the second half of the time series (x_j) on the Y-axis. These series set in the coordinate system are mutually punctuated. If the points stay above the 1:1 (45^o) line as in Figure 2, it is concluded that there is an increasing trend in the time series, a decreasing trend if it falls below the line, and if it remains in the 1:1 line, it is concluded that there is no trend.

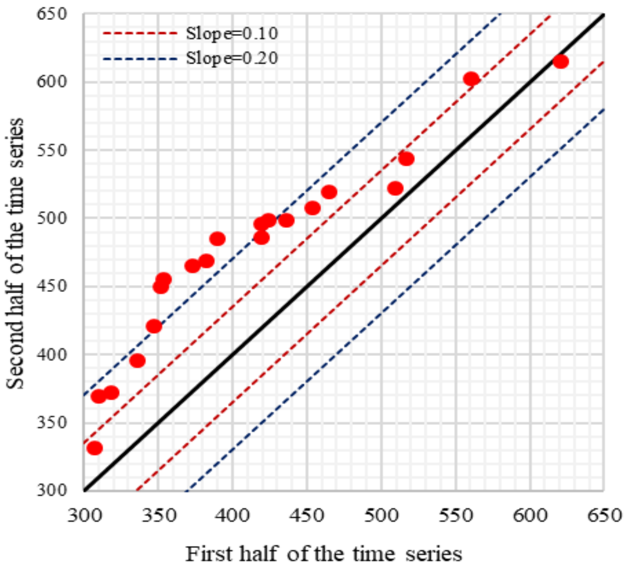

Figure 2. *Graph showing innovative trend analysis.*

The examination of air pollution and meteorological parameters with statistical methods was carried out with SPSS 22 software. The results obtained from these analyses are explained in detail in the next section.

III. RESULTS AND DISCUSSION

A. GENERAL STATISTICAL INFORMATION ON AIR POLLUTION AND METEOROLOGICAL PARAMETERS

General descriptive statistical parameters (averages, confidence intervals for the average at 95% significance level, min/max values) of air pollutants (PM_{10}, SO_2, NO, NO_X, NO_2 ve O_3), and of meteorological parameters (temperature (t), wind speed (ws), relative humidity (rh) and air pressure (p)) that make up the wide data set in the study are presented in Table 1.

Table 1. *General descriptive statistics on air pollution and meteorological parameters.*

Descriptive Statistical Parameters		Air Pollution Parameters						Meteorological Parameters			
		PM_{10}	**SO_2**	**NO**	**NO_2**	**NO_X**	**O_3**	**t** (^oC)	**ws** *(m/sn)*	**rh** *(%)*	**p** *(mbar)*
Mean		40.5	6.85	7.74	27.2	34.9	39.2	10.1	1.58	56.1	837.58
CI*	**Lower**	39.9	6.76	7.48	26.9	34.5	38.9	9.90	1.57	55.9	837.04
	Upper	41.1	6.93	7.99	27.5	35.5	39.5	10.2	1.59	56.3	838.11
Change Range	**Min.**	0.00	0.96	0.09	2.80	3.05	0.40	-20.9	0.00	2.81	808.40
	Max.	449	99.5	435	134	493	159	39.7	6.17	89.5	1046.9
N	18434										

*Confidence interval of the mean at the 95% significance level
N: Number of data

As stated in the previous section, the study covers the 2017-2019 period, and the hourly measurement value was taken for each parameter. Hours with missing any parameters or incorrect measurements are completely ignored. Thus, 18434 data were included in the analysis. Considering the long-hour averages of the most important air pollutants (PM_{10}, SO_2 and, NO_2) in this context, the following conclusions can be reached.

The average value of PM_{10} concentrations measured in the city center is determined to be 40.5 $\mu g/m^3$, and it is estimated that the value of PM_{10} at the statistical significance level of 95% is between 39.9 and 41.1 $\mu g/m^3$. The highest hourly PM_{10} level was measured at 449 $\mu g/m^3$ on 25 October 2017 at 1 pm. This maximum value measured is approximately nine times higher than the air quality legal limit. (Air Quality Assessment and Management Regulation, ANNEX 1-B 24-hour limit value for PM_{10}, 50 $\mu g/m^3$) [30]. The average of long-hour SO_2 concentrations measured in the city center was calculated as 6.85 $\mu g/m^3$. It is estimated that the average value of SO_2 at the statistical significance level of 95% is between 6.76 and 6.93 $\mu g/m^3$. During the study period, the highest SO_2 concentration was measured as 99.5 $\mu g/m^3$ at around 6 pm on 24 November 2019. It was determined that the maximum hourly measured SO_2 value was below the legally allowable limits. (Air Quality Assessment and Management Regulation, ANNEX1-B for SO_2 hourly limit value, 350 $\mu g/m^3$) [30]. The average of long-hour NO_2 concentrations measured in the city center is calculated as 27.2 $\mu g/m^3$ and it is estimated that the average value of NO_2 at the statistical significance level of 95% is estimated to be between 26.9 and 27.5 $\mu g/m^3$. Within the scope of the study period, the highest NO_2 concentration was measured as 134 $\mu g/m^3$ at around 5 pm on 24 November 2019. It was determined that the maximum hourly measured NO_2 value was below the allowed legal limits. (Air Quality Assessment and Management Regulation, ANNEX1-B, hourly limit value for NO_2, 200 $\mu g/m^3$) [30].

The highest levels of pollutant parameters PM_{10}, SO_2, and NO_2 were observed during the cold season (October 1st-March 31st) as expected, and at noon and end of the shift (1 pm, 6 pm, and 5 pm). It is thought that reasons such as heavy traffic activities in the city center during these hours, coal used for heating due to the cold season, fuel-oil emissions and use of poor quality fuel are the main causes of air pollution in the city center.

B. STATISTICAL ANALYSIS OF SEASONAL AND ANNUAL DISTRIBUTIONS OF AIR POLLUTANTS

It is also essential to examine the seasonal changes in air pollutants formed in city centers. Especially during the mild season transitions when sudden temperature and pressure differences are observed, the increase in air pollutant levels and adverse meteorological conditions create adverse health effects on people living in city centers [19]. The cold (winter) season has been specified as "October 1-March 31" within the scope of the "Air Quality Assessment and Management Regulation" [30]. In this context, under this heading, the Mann-Whitney U test was applied to nonnormal distribution data (PM_{10}, SO_2, NO, NO_2, NO_X, and O_3) to analyze the significance of the differences in the mean of air pollutants measured in the city center in the cold and hot seasons.

PM_{10} levels in cold seasons (average: 46.58 µg/m^3) are mathematically higher than PM_{10} levels in hot seasons (33.34 µg/m^3). It has been determined that SO_2 levels (average: 8.98 µg/m^3) in cold seasons are higher than SO_2 levels in hot seasons (average:4.32 µg/m^3). In the Air Quality Assessment and Management Regulation Annex 1-B Limit values, evaluation, and warning thresholds table, the cold season limit value for SO_2 is given as 20 µg/m^3, and it has been determined that the SO_2 levels occurring in the city center are below the allowable limit values for the cold seasons [30]. It has been determined that NO levels in cold seasons (average: 10.75 µg /m^3) are higher than NO levels in hot seasons (average: 4.16 µg /m^3). Similarly, NO_2 levels in cold seasons (average: 31.81 µg/m^3) were determined to be higher than NO_2 levels in hot seasons (average: 21.83 µg/m^3). It was determined that NO_X levels in cold seasons (average: 42.54 µg/m^3) are higher than NO_X levels in hot seasons (average: 25.99 µg /m^3). Finally, the changes in O_3 levels in cold and hot seasons were investigated. O_3 levels in cold seasons (average: 33.82 µg/m^3) were determined to be less than O_3 levels in hot seasons (average: 45.57 µg/m^3). According to the Mann-Whitney U test results, this difference between the seasons is statistically significant at 95% significance level in all parameters (p_{value} = 0.000). Although natural gas-fired heating systems have been switched to in recent years, PM_{10}, SO_2, NO, NO_2 and NO_X levels increase in cold months since part of the city center still has coal-fired heating systems. Ozone is the only parameter where the hot season level is higher than the cold season level. At this point, it should not be forgotten that air temperature is essential in ozone formation and that ozone formation may reach higher values in hot seasons between May-September. Statistical descriptive information on pollution changes over the years is presented in Table 2.

Table 2. *Statistics of pollutants by years.*

	Years	N	Mean	Lower Bound	Upper Bound	Minimum	Maximum
PM_{10}	2017	5953	42.29	41.16	43.43	0.00	449
	2018	7428	43.71	42.88	44.55	1.01	373.89
	2019	5053	33.77	33.04	34.51	1.22	272
SO_2	2017	5953	6.84	6.72	6.96	1.32	38.96
	2018	7428	5.04	4.95	5.13	0.96	63.52
	2019	5053	9.53	9.31	9.75	2.51	99.5
NO	2017	5953	9.16	8.71	9.61	0.09	259.51
	2018	7428	5.51	5.28	5.74	0.11	152.86
	2019	5053	9.34	8.64	10.03	0.13	435
NO_2	2017	5953	29.47	28.91	30.02	3.27	116.33
	2018	7428	25.11	24.75	25.46	2.80	109.07
	2019	5053	27.79	27.21	28.38	3.90	134
NO_X	2017	5953	38.59	37.67	39.50	3.40	362.89
	2018	7428	30.61	30.08	31.14	3.05	201.49
	2019	5053	37.13	35.97	38.29	4.08	493
O_3	2017	5953	33.03	32.53	33.52	0.40	83.80
	2018	7428	40.46	39.98	40.94	0.52	114.33
	2019	5053	44.60	43.93	45.27	0.97	159

Variance analyzes were applied to analyze the changes of the pollutant parameters of the previous years, how the pollutant changes were between 2017 and 2019, in which years these pollutants reached their highest pollutant levels in this period time or in which years they had the lowest pollutant levels. In this context, the Kruskal Wallis Test, which is applied for nonnormal distribution parameters, was used in this part of the study. According to the results of these tests, the annual averages of all parameters are not equal, the differences between the year averages are statistically significant (p_{value} =0.000, X^2=381.117 for PM_{10}; p_{value} =0.000, X^2=2894.454 for SO_2; pvalue =0.000, X^2=196.262 for NO; p_{value} = 0.000, X^2=27.816 for NO_2; p_{value} = 0.000, X^2=45.220 for NO_X and p_{value} =0.000, X^2=623.209 for O_3). Tamhane's T2, which is one of the methods used in cases where variances are not homogeneously distributed, was chosen to determine which years there was a significant difference (Table 3).

Table 3. *Post-Hoc/Tamhane's T2 test results, including yearly comparisons of parameters.*

Parameter	(I) Years	(J) Years	Average Difference (I-J)	p_{values}
PM_{10}	2017	2018	-1.42	0.138
		2019	8.52	0.000*
	2018	2017	1.42	0.138
		2019	9.94	0.000*
	2019	2017	-8.52	0.000*
		2018	-9.94	0.000*
SO_2	2017	2018	1.80	0.000*
		2019	-2.69	0.000*
	2018	2017	-1.80	0.000*
		2019	-4.49	0.000*
	2019	2017	2.69	0.000*
		2018	4.49	0.000*
NO	2017	2018	3.65	0.000*
		2019	-0.18	0.964
	2018	2017	-3.65	0.000*
		2019	-3.83	0.000*
	2019	2017	0.18	0.964
		2018	3.83	0.000*
NO_2	**2017**	2018	4.36	0.000*
		2019	1.67	0.000*
	2018	2017	-4.36	0.000*
		2019	-2.69	0.000*
	2019	2017	-1.67	0.000*
		2018	2.69	0.000*
NO_X	**2017**	2018	7.98	0.000*
		2019	1.46	0.151
	2018	2017	-7.98	0.000*
		2019	-6.52	0.000*
	2019	2017	-1.46	0.151
		2018	6.52	0.000*
O_3	**2017**	2018	-7.43	0.000*
		2019	-11.57	0.000*
	2018	2017	7.43	0.000*
		2019	-4.14	0.000*
	2019	2017	11.57	0.000*
		2018	4.14	0.000*

* The mean difference is significant at the 0.05 level.

The highest annual average of PM_{10} levels was measured in 2018, while measured the lowest annual average of PM_{10} in 2019. The highest annual SO_2 average was measured in 2019, measured the lowest annual SO_2 average in 2018. Likewise, measured the highest annual NO average in 2019 and the lowest annual NO average in 2018. The highest annual average of NO_2 levels was measured in 2017, while the lowest annual average of NO_2 was measured in 2018. The highest annual average of NO_X levels was measured in 2017, while the lowest annual average NO_X was measured in 2018. The highest annual average at O_3 levels was measured in 2019, while the lowest annual average of O_3 was measured in 2017. The years when air pollutants peak or the years when they reach their lowest level are different from each other.

C. INTERACTIONS BETWEEN AIR POLLUTANTS AND METEOROLOGICAL PARAMETERS

Regional meteorological conditions play an important role in the primary and secondary formation, transport, and accumulation of air pollutants [31]. Many studies have revealed an important relationship between air pollution and meteorological parameters [12, 32-34]. Therefore, in this section, the strength and direction of the relationship between the pollutant parameters causing air pollution and meteorological parameters were calculated with Spearman's rho correlation coefficient, and the SPSS 22 analysis output is presented in Table 4.

According to the results of Spearman's rho correlation analysis, changes in PM_{10} levels in the city center of Bayburt can be negatively and weakly correlated with the relative humidity (rh) and then wind speed (ws) parameters. The highest correlation coefficients were determined by relative humidity ($r = -0.161$, $p<0.01$) and wind speed ($r = -0.153$, $p<0.01$), and there is a trend toward a decrease in PM_{10} levels when relative humidity and wind speed increase.

When examined SO_2 levels, determined that the highest correlation coefficient was in the air pressure (p) parameter ($r=0.428$, $p<0.01$), and this relationship were linear/positive. After the air pressure parameter, in the temperature (t) ($r = -0.416$, $p<0.01$) parameter, moderate correlation but negative relationship can be mentioned. Namely, SO_2 levels tend to decrease with an increase in temperature and tend to increase with increasing air pressure.

The relationship of NO levels with air pressure (p) ($r = 0.221$, $p<0.01$) is weakly correlated with a linear/positive directional. In addition, it was determined that there is a negative directional and weak correlation with the parameters of temperature (t) ($r = -0.188$, $p<0.01$) and wind speed (ws) ($r = -0.181$), $p < 0.01$). In other words, NO levels tend to decrease with the increase in temperature and wind speed and tend to increase with the increase of air pressure.

The relationship of NO_2 levels with the parameters of temperature (t) ($r = -0.273$, $p<0.01$) and wind speed (ws) ($r = -0.298$, $p < 0.01$) is negative directional and weak correlation. However, its relationship with relative humidity (rh) ($r = 0.156$, $p < 0.01$) and air pressure (p) ($r = 0.128$, $p<0.01$) is linear/positive directional and weak correlation. That is, NO_2 levels tend to decrease with increasing temperature and wind speed, and tend to increase with increasing air pressure and relative humidity.

The relationship between NO_X levels and the parameters of temperature (t) ($r = -0.274$, $p<0.01$) and wind speed (ws) ($r = -0.287$, $p < 0.01$) is negative directional and weak correlation. However, its relationship with relative humidity (rh) ($r = 0.143$, $p < 0.01$) and air pressure (p) ($r = 0.158$, $p < 0.01$) is linear/positive directional and weak correlation. That is, NO_X levels tend to decrease with increasing temperature and wind speed and tend to increase with increasing air pressure and relative humidity.

The relationship of O_3 levels with the parameters of temperature (t) ($r = 0.339$, $p < 0.01$) and wind speed (ws) ($r = 0.533$, $p < 0.01$) is positive and moderate correlation. However, its relationship with relative humidity (rh) ($r = -0.384$ $p < 0.01$) and air pressure (p) ($r = -0.317$, $p < 0.01$) is negative and moderate correlation. In other words, O_3 levels tend to decrease with increasing air pressure and relative humidity and tend to increase with increasing temperature and wind speed.

Table 4. *The matrix of Spearman's rho correlations.*

		PM_{10}	**SO_2**	**NO**	**NO_2**	**NO_X**	**O_3**	**t**	**ws**	**rh**	**p**
PM_{10}	Correlation Coefficient	1,000	,296**	,423**	,482**	,487**	-,296**	,098**	-,153**	-,161**	,078**
	Sig. (2-tailed)	.	,000	,000	,000	,000	,000	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
SO_2	Correlation Coefficient	,296**	1,000	,470**	,459**	,483**	-,112**	-,416**	,038**	-,040**	,428**
	Sig. (2-tailed)	,000	.	,000	,000	,000	,000	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
NO	Correlation Coefficient	,423**	,470**	1,000	,736**	,817**	-,434**	-,188**	-,181**	,039**	,221**
	Sig. (2-tailed)	,000	,000	.	,000	,000	,000	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
NO_2	Correlation Coefficient	,482**	,459**	,736**	1,000	,989**	-,483**	-,273**	-,298**	,156**	,128**
	Sig. (2-tailed)	,000	,000	,000	.	,000	,000	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
NO_X	Correlation Coefficient	,487**	,483**	,817**	,989**	1,000	-,492**	-,274**	-,287**	,143**	,158**
	Sig. (2-tailed)	,000	,000	,000	,000	.	,000	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
O_3	Correlation Coefficient	-,296**	-,112**	-,434**	-,483**	-,492**	1,000	,339**	,533**	-,384**	-,317**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	.	,000	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
t	Correlation Coefficient	,098**	-,416**	-,188**	-,273**	-,274**	,339**	1,000	,233**	-,566**	-,328**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	.	,000	,000	,000
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
ws	Correlation Coefficient	-,153**	,038**	-,181**	-,298**	-,287**	,533**	,233**	1,000	-,499**	-,006
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	,000	.	,000	,400
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
rh	Correlation Coefficient	-,161**	-,040**	,039**	,156**	,143**	-,384**	-,566**	-,499**	1,000	,013
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	,000	,000	.	,072
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434
p	Correlation Coefficient	,078**	,428**	,221**	,128**	,158**	-,317**	-,328**	-,006	,013	1,000
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	,000	,400	,072	.
	N	18434	18434	18434	18434	18434	18434	18434	18434	18434	18434

**. Correlation is significant at the 0.01 level (2-tailed).

D. TREND ANALYSIS OF AIR POLLUTANTS

It is common to examine the changes of environmental data over time with nonparametric analysis. In this study, the innovative trend analysis method proposed by Sen (2012) was used to examine the changes in air pollutants over time (Figure 3). In addition, in this study, on the innovative trend analysis method (ITA), parallel to the 1:1 (45°) line trend bands of ± 10% and ± 20% are drawn. Thanks to the trend bands, inferences can be made about the percentage of the trend change.

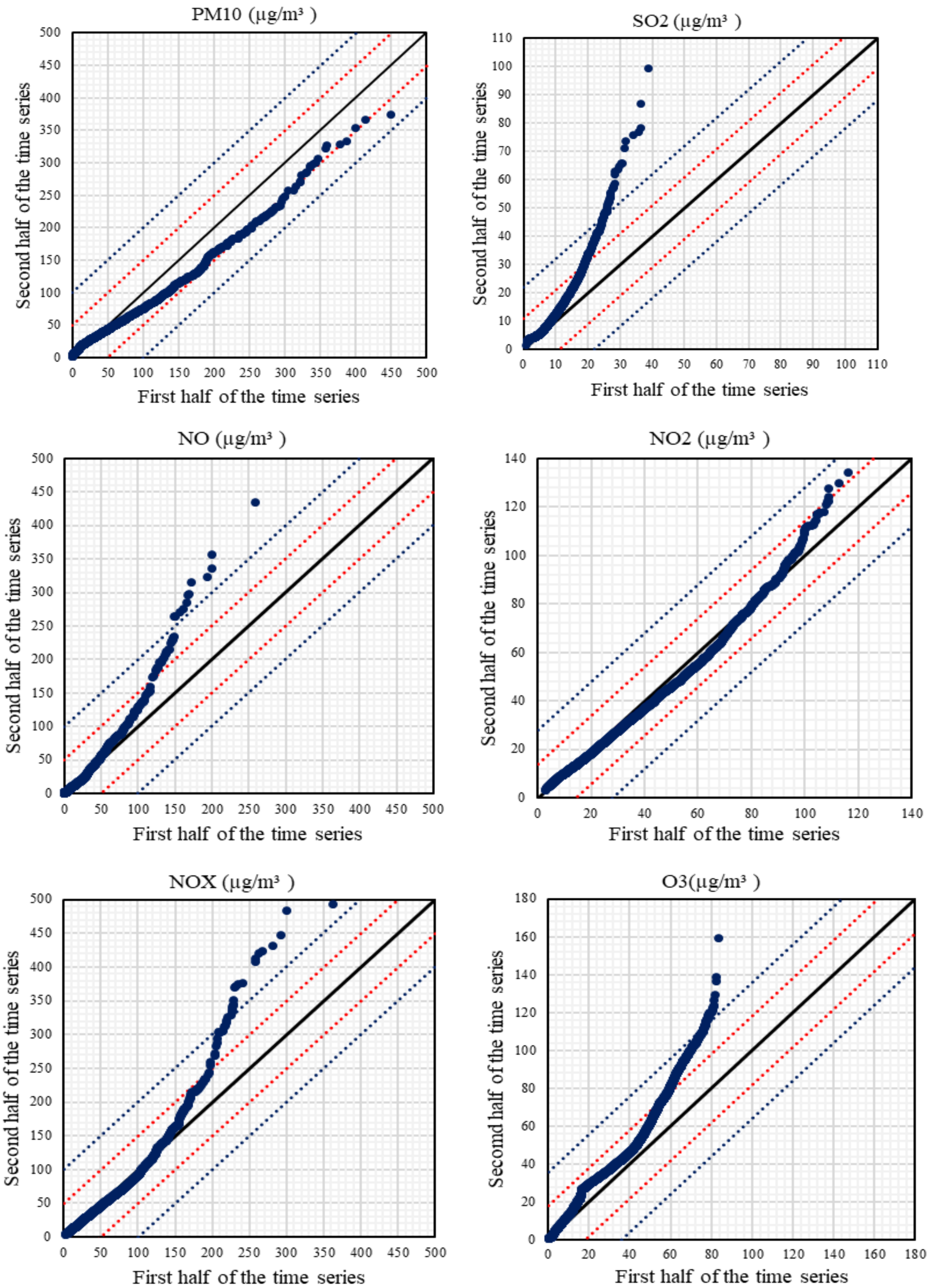

Figure 3. *ITA results of Bayburt city center air pollutants.*

While there is no trend between 0-50μg/m^3 in PM_{10} levels, a decreasing trend is observed as this value increases. At levels exceeding the limit value of PM_{10} (50 μg/m^3), a reduction trend of up to-10% was determined. When the changes in SO_2 concentrations are examined, a trend between 0-10 can not be found. However, as this value increases, an increasing trend is seen with a trend that exceeds the + 20% trend band. In addition, the hourly average limit value (Air Quality Assessment and Management Regulation, ANNEX1-B for SO_2 hourly limit value is relevant, 350 μg/m^3). It seems that it has not been exceeded at all for the working period. Similarly, it is valid for NO, and there is no trend between 0-60 μg/m^3, but as this value increases, the trend exceeding the + 20% band also increases. When the NO_2 graph is considered, there is no trend between 0-100 μg/m^3, while there is a trend up to + 10% in values after this interval. However, the hourly average limit value for the working period has never been exceeded (Air Quality Assessment and Management Regulation, ANNEX1-B, the hourly limit value for NO_2 are 200 μg/m^3). From the NO_X graph, it can be seen that there is no trend between 0-150 μg /m^3; as this value increases, the trend exceeding the + 20% band also increases. NO and NO_2, together form NO_X. NO_X is generally (in 90% cases) exhausted as NO. Therefore, an increase in one of the NO_X-forming pollutants will increase NO_X. Finally, the ITA method was applied in the study area for the changes in O_3 levels, and no trends between 0-20 μg /m^3 were found. As with other pollutants, there is an increasing trend as this value increases. O_3 pollution occurs mainly in summer, sunny weather, and high temperature (NO_2+sunlight =NO+O $\longrightarrow$ O+O_2 =O_3). Therefore, the growth of the pollutants that form it, similar to NO_X, causes an increase in O_3.

IV. CONCLUSION

As a result of the rapid increase in industry and population in the study area, increasing use of fossil fuels for energy and heating purposes and increasing vehicle exhaust gases cause air pollution. In other words, the main reason for air pollution is (artificial) anthropogenic reasons. Due to these reasons, large amounts of pollutants are mixed into the air. However, most of the time, different factors also affect air pollution. In this study, the effect of meteorological parameters, one of these factors, was examined.

The presence of the study area in the bowl, surrounded by high mountains, causes air circulation in the plain to be complicated. Since there is a transitional climate between the Eastern Black Sea climate and the Eastern Anatolia climate, with its terrestrial characteristics, the need for heating is high, causing an increase in air pollution.

In this study, investigated seasonal and annual changes of air pollutants belonging to the research area by using hourly data for the 2017-2019 period. Then, correlation analyzes were conducted to reveal the relationship between climatic/meteorological parameters and air pollutants of the same period. Finally, investigated the change of air pollutants over time with the ITA trend analysis method. Thanks to this study, detailed information about the air pollution situation at Bayburt city center has been revealed. These results obtained from the study can be summarized as follows;

- Mann-Whitney U test was used to analyze the changes in air pollutant levels in cold and hot seasons. According to the test results, found the difference between the averages of all pollutants in cold and hot seasons statistically significant at the 95% significance level (p_{value} =0.000). Only O_3 levels averages in hot seasons are higher than averages in cold seasons. It is thought that the reason for this situation is that the air temperature is essential in the formation of O_3 and that the ozone formation reaches higher values in the hot seasons between May and September. The average cold season is higher than the average hot season in all other air pollutant parameters. As a reason for this situation, the increase in household fuel consumption during the cold season and the condensation of the cooling air during this season can be considered an increase in pressure by collapsing towards the earth under the influence of weight and gravity. High-pressure conditions and inversion, especially in the cold season, are meteorological parameters that prevent the removal of pollutants added to the air.

- Kruskal Wallis Test was applied to test the significance of the difference between the previous years' averages. As a result of the test, the difference between the annual averages of all pollutants was found to be statistically significant. Post-Hoc/Tamhane's T2 test examined the years in which there was a significant difference. The test results revealed that the years of peak pollutants or the years of their lowest level differ from each other. Although the study period covers a short period of time on an annual basis (2017-2019), hourly data were used in the analyzes (18434 data). Therefore, it is thought that the main reason for the variation between years is the instantaneous change in pollutants (anthropogenic origin) arising from traffic, transportation, industry, and heating in this time period.

- The strength and direction of the relationship between pollutant parameters causing air pollution and meteorological parameters were calculated with Spearman's rho correlation coefficient. As a result of this analysis, it was seen that there is a statistically significant (pvalue = 0.000) relationship between city center air pollution and meteorological parameters. It has been determined that there is a negative relationship between other pollutants except for O_3 and SO_2 and wind speed. It is expected that the concentration will decrease when the wind speed increases because, with the increasing wind speed, the transport and dilution of the pollutants become more. But the reason for the positive relationship between wind speed and O_3 may be that the wind brings O_3 from other regions. One of the biggest factors causing air pollution is household fuel and the properties of these fuels. Therefore, air temperature is a factor that closely affects the burning times and degrees of household fuel. If there is no inversion, an increase in temperature will cause less emission of air pollution parameters caused by household fuel use. Air temperature affects air movement, and thus the movement of air pollution. Because the Earth's surface absorbs energy from the Sun, air near the ground is warmer than air that is further up in the troposphere. The warmer, lighter air at the surface rises, and the cooler, heavier air in the upper troposphere sinks. This is known as convection and it moves pollutants from the ground to higher altitudes. The issues mentioned above may be the reasons for the negative relationship between temperature and air pollution parameters. O_3 is a secondary pollutant, which means it is not directly emitted by traffic, or industry. But it is formed on warm summer days by the influence of solar radiation on a cocktail of airborne pollutants. Therefore, this situation may explain the positive relationship between O_3 and temperature. High air pressure conditions and heat inversion are meteorological events that prevent the pollutants entering the air from going away. Fort this reason air pressure is positively correlated with all parameters (except O_3). Low-pressure systems bring wet and windy conditions. A passing storm front can wash pollutants out of the atmosphere or transport them to a new area, producing clear skies. It is important to note, however, that the pollutants are not gone; rather they have been moved to a new location.

- ITA analyzed trend changes in pollutant parameters. Although there is a tendency to decrease PM_{10} levels, an increasing trend has been observed in other pollutants.

- It has been determined that pollutants tend to increase in Bayburt due to traffic, industry, and household fuel (caused by the need for heating). It has been determined that the average of pollutants does not exceed their limit values. This is due to the location of the sampling point or meteorologically to the high dispersion.

It is seen from the study that there is a close relationship between air pollution and the climatic and topographic characteristics of the region. Considering the time interval of the data used, although it is not observed that the pollutant averages exceed the limit values, the increasing trend of pollutants reveals that should make more efforts to maintain positive air quality. In this context, it is clear that providing the necessary incentives for industries and combustion processes used for heating to turn to alternative energy sources will help reduce pollution.

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