



Periodical and regional change of particulate matter and CO₂ concentration in Misurata

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Abstract Today, environmental pollution, air pollution in particular, is among the most important problems in the world. Air pollution, which has become a global issue, is estimated to cause the death of around 1 in 8 people worldwide. Due to the significance of air pollution, all components of air pollution are of great importance for human health, and thus the studies on air pollution are highly important, especially in areas with high population density. In this study, it was aimed to determine the regional and periodic

change of CO₂ and particulate matter pollution in the city of Misurata, one of the important cities of Libya. The study was conducted in the city centre of Misurata, and the measurements were made once in every three days between November and February at 7 different locations selected in the city centre. As a result of the measurements made, the changes in the pollution parameters were evaluated on the basis of zones and months. As a result of the study, the cleanest areas were found to be the industrial area (B3) located in the east of the city and the zone (B4), where the Al-Swehli farm was located, while the dirtiest areas were found to be the main street (B1 and B2) in the city centre and the city centre, in general. In terms of months, the lowest CO₂ values were obtained in January, and the highest value was in February, whereas the lowest particulate matter values were obtained in January and the highest values in December.

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Introduction

Nowadays, worldwide population growth and migration from rural to urban areas are shown as the cause of the most critical problems around the world. While the world population was only around 717 million in the 1750s, it exceeded 7.7 billion by 2020 (Batir, 2019; Worldometers, 2020). World population growth

is estimated to continue to rise and to reach 8.5 billion by 2030 (Gultekin, 2020).

Both world population growth and migration from rural to urban areas cause many social, economic and ecological problems in urban centres (Gultekin, 2020; Kilicoglu et al., 2020). Environmental pollution is one of the most important of these problems. This process causes soil (Bayraktar et al., 2019a, b), water (Mutlu, 2019; Ozel et al., 2020; Emin et al., 2020) and air (Adiguzel et al., 2020; Aricak et al., 2020; Cetin, 2019, 2020; Cetin et al., 2020) to get polluted; and this pollution is felt at a higher level in urban centres, where the population is dense, since it is human-induced (Adiguzel et al., 2020; Cetin, 2019, 2020; Ozel et al., 2019; Turkyilmaz et al., 2018a, b).

Air pollution in urban areas is among the main environmental problems which have a direct impact on public health on a global scale (Bozdogan Sert et al., 2021; Gungor et al., 2021; Sevik et al., 2020a, b; Turkyilmaz et al., 2019). The studies conducted point out to a significant relationship between air pollution and diseases such as lung cancer, cardiovascular diseases and asthma attack. On the other hand, epidemiological studies show that there is a link between air pollution in cities and the increase in early death rates (Adiguzel et al., 2020; Cetin, 2019, 2020; Cetin et al., 2019; Grzędzicka, 2019; Hvidtfeldt et al., 2019).

Even though there are several components of air pollution, the best known ones are CO₂ and particulate matter. Particularly, the increase in CO₂ concentration in the indoors causes fatigue, drowsiness and absence of perception. When the CO₂ concentration in the ambient air rises above 1000 ppm, anomalies such as fatigue, dizziness, headache, malodour problems and impairment of concentration occur; and when it rises above 1500 ppm, anomalies such as nasal draining, throat and nose irritation, watery eye and cough occur (Cetin, 2016; Cetin & Sevik, 2016). The increase in CO₂ concentration in the atmosphere is associated with greater problems. When the terms such as greenhouse effect and global climate change are used, CO₂ gas, which is considered the main actor of these changes, is the first thing that comes to mind (Elsunousi, 2020).

Whereas particulate matter can be shortly defined as solid and liquid substances suspended in the air (Demirarslan & Kaya, 2017). Particulate matter is one of the pollutants that is most studied and cared

about in recent years. One of the most important reasons for this is the fact that particulate matter is very small in dimension so that it can penetrate deep into the lung and can even be breathed into the bloodstream. Particulate matter, which can enter the lungs and bloodstream in this way, may cause serious health issues. The studies conducted indicate that exposure to particulate matter, particularly those contaminated with heavy metals, can lead to a significant increase in disease and mortality rates (Bozdogan Sert et al., 2019; Cesur et al., 2021; Mossi, 2018; Sevik et al., 2019a, b; Shahid et al., 2017).

Due to the significance of air pollution, the components of air pollution are of great importance for human health, and thus it is vital to monitor regional and periodic changes, especially in areas with high population density. In this study, it was aimed to determine the regional and periodic changes of CO₂ and particulate matter pollution in Misurata, one of the important cities of Libya, during the winter season when pollution level increased.

Material and method

Material

Misurata, where the study was conducted, was the third largest city of Libya with a population of around 517 000 people before the civil war. The location of Misurata is 32°22'39.12"N and 15°05'31.26"E. It is a port city around 187 kms east of Tripoli and around 825 kms west of Benghazi. The location of Misurata is given on Fig. 1.

The study was conducted in 7 zones located in the city centre of Misurata. The general characteristics of the zones, where the study is conducted, are as follows:

B1: City centre—In the city centre of Misurata, which is the heart of the city and where the shopping centres and commercial and educational activities are carried out intensely, there are restaurants, cafes, many commercial shops as well as state and administrative buildings. In this zone, there is heavy traffic every day of the week.

B2: City centre street—This zone is one of the main streets of the city, and there are commer-

Fig. 1 Location of Misurata



cial buildings such as bank buildings, commercial stores and residential buildings. This street can be regarded as the zone with the highest vehicle and pedestrian traffic following the city centre.

B3: Industrial zone—In the east of the city, it is the industrial zone where many factories are located including the largest steel and iron factory. The zone is adjacent to the main fuel stations of the port and the city. The movement to and from the port is quite intense for those working at the factory and the container transporter trucks.

B4: Farm—The zone is the area where Al-Swehli farm is located. Al-Swehli is a large farm owned by the Libyan state, located at the edge of Misurata province. There are a great number of olive and almond trees. Traffic is very low in the zone that serves as a green belt for the city.

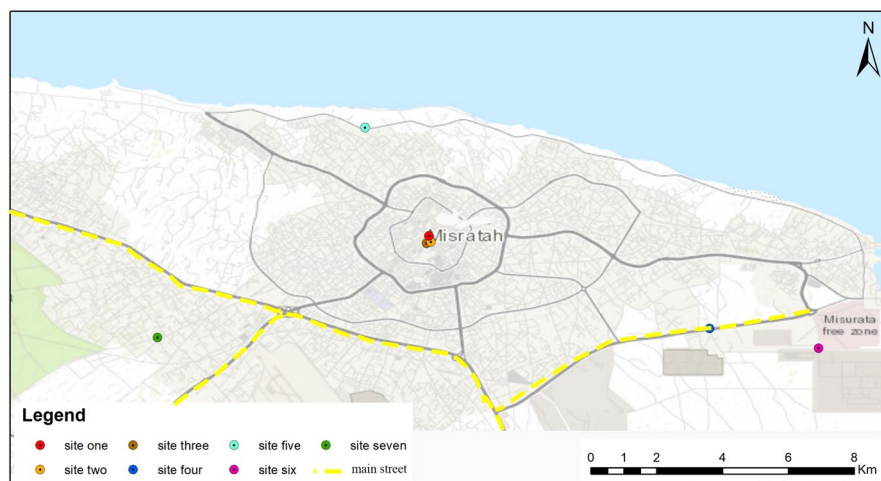
B5: Near the factory—This zone is where the Al-Naseem Dairy Factory, Misurata Paint, Paste and Iron Melting Factories and a heavy transportation route are located. Dense traffic is experienced throughout the day. The most important reason for this traffic is the movement of the trucks to the port and the iron and steel factory.

B6: Beach road—This zone is an open area, and there is a gas station located in this area. Traffic on the road can be considered irregular and sometimes heavy. However, traffic density is mostly low.

B7: Park located in the city centre—In the park located in the city centre, a bus and taxi station is set up in order to transport passengers to the cities on Friday and Saturday mornings, which are the non-business days in Libya. From time to time, automobile shows, festivals, shows and cultural events are held in the public park. Vehicle and pedestrian traffic is extremely intense between the zones subject to the study on holidays. Figure 2 shows the points where measurements are taken within the scope of the study.

Method

The study was carried out in the areas selected in the city centre of Misurata between the months of November and February. The measurements were made every three days during the specified period and in 5 different time zones throughout the day. The pollution factors subject to the study were measured with

Fig. 2 Points of measurement

portable measuring devices. The measurements were performed in 5 replicates.

The data were evaluated with the help of SPSS package program. In order to determine the changes of the data on the basis of months and zones, variance analysis was applied, and homogenous groups were formed by applying Duncan test to the data, which were found to have statistically significant differences at minimum of 95% confidence level ($p < 0.05$). Variance analysis and Duncan test results were simplified and tabulated, and the results obtained were interpreted. Within the scope of the study, correlation analysis was applied to the data with the help of the SPSS package program in order to find the relationship levels of the parameters

subject to the study, and the results obtained were tabulated and interpreted.

Results

Changes of pollution parameters on the basis of zones, months and days

The changes of the pollution parameters considered within the scope of the study on basis of zones and months were evaluated separately, and the changes on the basis of zones are given in Table 1.

The change of CO_2 , which was one of the pollution factors considered within the scope of the study, was

Table 1 Changes of the pollution parameters on the basis of zones

Letters: Shows the group they are in as a result of the Duncan test

Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)

Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Zones	CO_2	PM0.3	PM0.5	PM1.0	PM2.5	PM5.0	PM10
B1	609bc	36817bc	13849b	3573b	1095b	241c	90d
B2	615c	32275ab	10965a	3301ab	970ab	209abc	79bcd
B3	574a	29536a	10025a	2962a	848a	169ab	59a
B4	580a	26080a	9815a	2967a	841a	159a	61ab
B5	588ab	42367c	15271b	5404c	2034c	470d	179e
B6	563a	28257a	10493a	3303ab	942ab	199abc	69abc
B7	613bc	38203bc	13826b	3739b	1035ab	220bc	81 cd
F value	5,638***	7,984***	9,985***	20.637***	32,608***	38,669***	40.493***

found to be statistically significant ($p < 0.001$). When the groupings formed as a result of mean values and Duncan test are examined, values are seen to be varying between 563 and 615 ppm. The lowest values were obtained in the B6 (563 ppm), B3 (574 ppm) and B4 (580 ppm) zones, whereas the highest values were obtained in the B2 (615 ppm), B7 (613 ppm) and B1 (609 ppm) zones.

Also, it was found that the change of PM numbers on the basis of zones was statistically significant ($p < 0.001$). While the lowest values were obtained in the B4 (26,080 pcs) and B6 (28,257 pcs) zones in terms of PM0.3, the highest values were obtained in the B5 (42,367 pcs) and B7 (38,203 pcs) zones. The PM0.5 numbers can be seen to be ranging from 9815 (B4) to 15,271 (B5). As a result of the Duncan test performed, the data were collected in two homogeneous groups, and while the B2, B3, B4 and B6 zones formed the first homogeneous group, the B1, B5 and B7 zones formed the second homogeneous group.

As a result of Duncan test made, PM1.0 numbers were collected in three homogeneous groups. While the B3 (2962 pcs) and B4 (2967 pcs) zones, where the lowest values were obtained as a result of Duncan test, were only in the first homogenous group, only the B5 zone, where the highest value (5404 pcs) was obtained, was in the last homogeneous group,. In terms of the PM2.5 numbers, it is seen that the lowest values were obtained in the B4 zone with 841 pcs and the B3 zone with 848 pcs. The highest PM2.5 values were obtained in the B5 zone with 2034 pcs and the B1 zone with 1095 pcs.

According to mean values, the lowest values in terms of PM5.0 were obtained in the B5 zone with 159 pcs and B5 zone with 169 pcs, while the lowest values in terms of PM10 were obtained in the B3 zone with 59 pcs and the B4 zone with 61 pcs. In terms of PM5.0, the highest values were obtained in the B5 zone with 470 pcs and the B1 zone with 241 pcs, while the highest values in terms of PM10 were obtained in the B5 zone with 179 pcs and the B1 with 90 pcs.

When evaluated in general, it can be said that the B3 and B4 zones in the first homogeneous groups in terms of all dimensions of CO₂ and particulate matter according to Duncan test results are the zones with the lowest pollution level. The zone with the highest pollution level was found to be the B5, followed by the B1 zone. The changes of the pollution factors

Table 2 The changes of the pollution factors on a monthly basis

	November	December	January	February	F value
CO2	531b	549c	495a	767d	684.401***
PM0.3	36407bc	40314c	25392a	32554b	17.393***
PM0.5	12465b	15427c	8385a	12034b	33.421***
PM1.0	3261b	5171c	2310a	3547b	83.015***
PM2.5	880b	1604d	702a	1160c	53.121***
PM5.0	165a	327c	167a	264b	35.976***
PM10	64a	124c	59a	97b	36.830***

Letters: Shows the group they are in as a result of the Duncan test

Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)

Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

subject to the study were determined on a monthly basis, and the mean values, variance analysis and Duncan test results obtained are given in Table 2.

As can be seen in Table 2, the changes of all pollution factors on a monthly basis are statistically significant at 99.9% ($p < 0.001$) confidence level. When the mean values and Duncan test results are examined, it is noteworthy that the values obtained in all pollution parameters in January are included in the first homogeneous group according to the Duncan test results. The highest values were obtained in February in terms of CO₂, and in December in terms of particulate matter. Based on the results given in Table 2, it can be said that the particulate matter pollution is generally the highest in December, then in February and then in November, whereas it is the lowest in January. In terms of CO₂, while the lowest value was obtained in January, the highest value was obtained in February.

Within the scope of the study, the changes of pollution factors in different zones were evaluated on a monthly basis, and the mean values, variance analysis and Duncan test results in relation to the changes of CO₂ concentration on the basis of zones and months are given in Table 3.

When the changes of CO₂ concentration on the basis of zones and months are examined, it is seen that the changes on the basis of zones are not statistically significant ($p < 0.05$) only in February, while they are statistically significant (at least $p < 0.01$) during the other months. When the changes of CO₂ concentrations in the zones are examined, it is seen

Table 3 The changes of CO₂ concentration on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	570Bc	562Bbc	512Ab	775C	89.225***
	B2	540Abc	580Bc	520Ab	788C	90.337***
	B3	502ABa	530Bab	485Aa	751C	118.154***
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	505Aa	538Bab	481Aa	764C	137.391***
	B5	524ABab	555Bbc	487Aa	762C	84.114***
	B6	518Bab	500ABa	472Aa	746C	133.427***
	B7	557Bc	579Bc	511Ab	782C	76.398***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	5.350***	3.603**	9.833***	1.140 ns	

that the values obtained in the B3, B4 and B6 zones are in the first homogeneous groups in all months according to the Duncan test results. The values measured in the B1, B2 and B7 zones, where the highest values are obtained, are observed to be in the last homogeneous groups in all months according to the Duncan test results.

When the changes of CO₂ concentration in the zones on the basis of months are examined, it is seen that the changes in all zones are statistically significant ($p < 0.001$). When the mean values are examined, it is seen that the CO₂ concentration is generally sorted from low to high as January, November, December and February. While the CO₂ concentration varied between 472 and 520 ppm on the basis of zones in January, when the lowest values were obtained, the CO₂ concentrations in February, where the highest values were measured, varied between 746 and 788 ppm.

The changes in the number of 0.3 µm sized particulate matter (PM0.3), one of the pollution factors subject to the study, on the basis of zones and months are given in Table 4.

When the above-given values in Table 4 are examined, it is seen that the changes of the PM0.3 number on a regional basis are statistically significant (at least $p < 0.05$) in all months. When the mean values and groupings formed as a result of Duncan test are examined, it is noteworthy that the values obtained in the B3, B4 and B6 zones are in the first homogeneous groups in all months.

In terms of PM0.3, the B1 and B5 zones, where the highest values were obtained in general, were in the last homogeneous groups according to the results of Duncan test made every three months. According to these results, it can be said that the zones with the highest level of PM0.3 pollution are the B1 and B5 zones, whereas those with the lowest level are the B3, B4 and B6 zones.

As a result of the variance analysis regarding the changes of PM0.3 number in the zones on the basis of months, the changes of PM0.3 number in all zones except for the B3 were found to be statistically significant (at least $p < 0.05$). When the mean values and groupings formed as a result of Duncan test are examined, it is noteworthy that the values obtained

Table 4 The changes in the PM0.3 number on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	48627Bbc	43820ABbc	28809Abc	30738Aa	3.337***
	B2	33462ABab	43820Bbc	24471Aabc	26785Aa	3.646*
	B3	23705a	33514ab	24164abc	34429a	2.548 ns
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	29210Bab	30133Ba	18880Aa	27349Ba	5.637**
	B5	27749Aab	53986Bc	30649Ac	51236Bb	8.196***
	B6	27869Aab	35883Bab	21377Aab	27744Aa	7.303***
	B7	64231Bc	10007Aab	29390Abc	29596Aa	9.161***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	4.548***	3.435**	2.261*	7.038***	

Table 5 The changes of PM0.5 number on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	17325bc	14821ab	10,693	13947b	1.611 ns
	B2	11247Bab	13812Ca	8123A	10792Bab	9.222***
	B3	8395Aa	13095Ba	8179A	9777.9Aa	6,108***
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	10391Bab	12108Ba	6093A	10898Bab	10.186***
	B5	9951Aab	21517Bc	8837A	18650Bc	17.668***
	B6	10079Bab	14598Cab	7410A	9721.0ABa	13.776***
	B7	19867Bc	18097Bb	9361A	10456Aab	7.376***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	3.072**	7.701***	1.961 ns	7.743***	

in January are in the first homogeneous group in all zones. Except for B7, the values obtained in December were in the last homogeneous groups in all zones. Based on these results, it can be said that the month with the highest pollution in terms of PM0.3 is December and the month with the lowest pollution is January. The changes in the number of 0.5 µm sized particulate matter (PM0.5) on the basis of zones and months are given in Table 5.

When the values in Table 5 indicating the changes of PM0.5 number on the basis of zones and months are examined, it is seen that the changes on the basis of zones are not statistically significant ($p < 0.05$) only in January, while the changes on the basis of zones in other months are statistically significant (at least $p < 0.01$).

When the changes of PM0.5 numbers in the zones are examined, it is seen that, according to Duncan test results, the values obtained in the B2, B3, B4 and B6 zones are in the first homogeneous groups in all months. The highest values were obtained in the B1 and B7 zones in November and in the B5 zone in December and February.

When the change of CO₂ concentration in the zones are examined on the basis of months, it is seen that the changes of PM0.5 number in all zones except for the B1 are at a statistically significant level ($p < 0.001$). When the mean values are examined, it can be said that the lowest values are obtained in January while the highest in December. When generally assessed, the lowest PM0.5 value was obtained in the B4 zone in January with 6093 pcs, and the highest value was obtained in the B5 zone in December with 21,517 pcs. The changes in the number of 0.1 µm sized particulate matter (PM1.0), one of the pollution factors subject to the study, on the basis of zones and months are given in Table 6.

When the changes of PM1.0 number on the basis of zones depending on the months are examined, it is seen that the changes on the basis of zone in all months are statistically significant (at least $p < 0.05$). When the values in Table 6 are examined, it can be said that the B2, B4 and B6 zones included in the first homogeneous group in all months are those with the lowest values. The highest values were obtained in the B5 zone included in the last homogeneous groups in all months.

Table 6 The changes of PM1.0 number on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	3573Bb	4944Ca	2335Ab	3607Ba	15.625***
	B2	3301Aab	4712Ba	2378Ab	2967Aa	21.017***
	B3	2434Aa	4236Ba	2360Ab	2607Aa	11.411***
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	2967Ba	4105Ca	1719Aa	3036Ba	18.087***
	B5	5404ABc	8069Bb	2955Ac	6470Bb	17.261***
	B6	3303Aab	5022Ba	2178Aab	2909Aa	21.134***
	B7	3739Bb	5112Ca	2247Aab	3230Aa	12.940***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	2.574*	11.957***	3.332**	13.343***	

Table 7 The changes of the PM2.5 number on the basis of months and zones

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	971AB	1437Ca	745Ab	1179BCa	7,625***
	B2	827A	1396Ba	721Aab	878Aa	18,699***
	B3	635A	1149Ba	709Aab	814Aa	4,560**
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	873B	1165Ca	449Aa	890Ba	12,997***
	B5	1002A	3174Bb	1103Ac	2444Bb	13,533***
	B6	809A	1421Ba	603Aab	882Aa	11,378***
	B7	1041B	1486Ca	583Aab	1033Ba	20.216***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	1,711 ns	19,183***	5.050***	13,449***	

When the changes of PM1.0 number in the zones on the basis of months were examined, it was found that the change in all zones was statistically significant at 99.9% confidence level ($p < 0.001$). When Duncan test results are examined, it is noteworthy that all values obtained in January are in the first homogeneous group and all values obtained in December are in the last homogeneous group. While the PM1.0 values in January range between 1719 and 2955 pcs, the PM1.0 values in December range between 4105 and 8069 pcs. The changes in the number of 2.5 μm sized particulate matter (PM2.5), which is another pollutants evaluated within the scope of the study, on the basis of months and zones are given in Table 7.

When the values in Table 7 indicating the changes of PM2.5 number on the basis of zones and months are examined, it is seen that the changes on the basis of zones are not statistically significant ($p < 0.05$) only in November and the changes on the basis of zones are statistically significant ($p < 0.001$) in other months.

When the changes of PM2.5 numbers in the zones are examined on the basis of months, it is seen that the values obtained in the B2, B3, B4, B6 and B7 zones

are in the first homogeneous groups in all months according to the Duncan test results. When the values and the groupings formed as a result of Duncan test are examined, it can be said that the data are gathered in two homogeneous groups in December and February, B5 zone forms one homogeneous group and all other zones form the other homogeneous groups. In the light of these data, the most polluted zone in terms of PM2.5 is the B5 zone, and there is no statistically significant difference ($p < 0.05$) between other zones except for the months of January.

When the changes of PM2.5 number in the zones are examined on the basis of months, it was found that the changes in the number of PM2.5 in all zones were statistically significant (minimum $p < 0.01$). When the mean values are examined, it can be said that the lowest values are obtained in January, while the highest are obtained in December. While PM2.5 values range between 449 and 1103 pcs in January, they range between 1149 and 3174 pcs in December. The changes in the number of 5.0 μm sized particulate matter (PM5.0), which is another pollution factor subject to the study, on the basis of zones and months are given in Table 8.

Table 8 The changes of PM5.0 number on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	170A	300Ca	205ABcd	260BCa	4.530**
	B2	158A	278Ba	175Abc	204Aa	8.873***
	B3	115	209a	171bc	161a	1.764 ns
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	175B	215Ba	81Aa	170Ba	11.963***
	B5	200A	672Bb	278Ad	621Bb	11.484***
	B6	158A	304Ba	138Aab	178Aa	11.503***
	B7	176A	312Ca	122Aab	254Ba	19.644***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	1.485 ns	19,799***	5.637***	19.384***	

When the values in Table 8 are examined, it is seen that, as in PM2.5 number, the changes of PM5.0 number on the basis of zones are not statistically significant ($p < 0.05$) only in November, whereas its changes on the basis of zones are statistically significant ($p < 0.001$) in other months.

When the changes in the number of PM5.0 in the zones on the basis of months are examined, it is seen that the values obtained in the zones B4, B6 and B7 are in the first homogeneous groups in all months according to the Duncan test results. When the values and the groupings formed as a result of Duncan test are examined, as in the PM2.5 numbers, it is found that the data are gathered in two homogeneous groups in December and February, and that the B5 zone form one homogeneous group and all other zones form the other homogeneous group. In the light of these data, as in terms of PM2.5, the most polluted area in terms of PM5.0 number is also the B5 zone, and there is no statistically significant difference ($p < 0.05$) among other zones except in January. It is also observed that the value obtained in the B5 zone was 278 in January is 278 pcs, while the values obtained in the other zones varied between 81 and 205 pcs.

On the basis of months, it was found that the changes in the number of PM5.0 were statistically significant (at least $p < 0.01$) in all zones except for B3. When the mean values are examined, it is noteworthy that all the values obtained in January and the values obtained in November except for B4 are included in the first homogeneous group. All the values obtained in December are in the last homogeneous groups according to the results of Duncan test. According to these results, the amount of pollution can be sorted as December > February > November > January, in general. The changes in the number of the largest particulate matter (PM10)

subjected to the study with a size of 10.0 μm on the basis of zones and months are given in Table 9.

According to the above-given values in Table 9, it is seen that the changes in the number of PM10 on the basis of zones by months are not statistically significant only in November, as in the other large-sized particulate matters of PM2.5 and PM5.0, and that the changes in other months on the basis of zones are statistically significant ($p < 0.001$).

When the changes in the numbers of PM10 in the zones based on months are examined, it is seen that the values obtained in the zones of B4, B6 and B7 are in the first homogeneous groups in all months according to the Duncan test results. When the values and the groupings formed as a result of Duncan test were examined, it was found that the data were collected in two homogeneous groups in December and February, as in the numbers of PM2.5 and PM5.0; the B5 formed one homogeneous group; and all other zones formed the other homogeneous group. In the light of these data, as for PM2.5 and PM5.0, the most polluted zone in terms of PM10 number is the B5 zone, and that there is no statistically significant difference ($p < 0.05$) between other zones except for January. Also, in January, while the value obtained in the B5 zone was 103, it was found that the values obtained in the other zones were maximum of 80.

On the basis of months, it was found that the changes in the number of PM10 were statistically significant (at least $p < 0.05$) in all zones except for B3, as in the number of PM5.0. When the mean values are examined, it is noteworthy that all the values obtained in January, as in the number of PM5.0, and the values obtained in November except for B4 are in the first homogeneous group. According to Duncan test results, all of the values obtained in December are

Table 9 The changes in the number of PM10 on the basis of zones and months

	Zones	Months				F value
		November	December	January	February	
Letters: Shows the group they are in as a result of the Duncan test	B1	971AB	1437Ca	745Ab	1179BCa	7,625***
	B2	827A	1396Ba	721Aab	878Aa	18,699***
	B3	635A	1149Ba	709Aab	814Aa	4,560**
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	B4	873B	1165Ca	449Aa	890Ba	12,997***
	B5	1002A	3174Bb	1103Ac	2444Bb	13,533***
	B6	809A	1421Ba	603Aab	882Aa	11,378***
	B7	1041B	1486Ca	583Aab	1033Ba	20.216***
Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	F value	1,711 ns	19,183***	5.050***	13,449***	

Table 10 Results of correlation analysis

	PM0.3	PM0.5	PM1.0	PM2.5	PM5.0	PM10	
Letters: Shows the group they are in as a result of the Duncan test	CO ₂	0.053**	0.065**	0.062**	0.048*	0.061**	0.060**
Lowercase letters are vertical values; capital letters are horizontal values; (Duncan test shows the group it is in as a result)	PM0.3		0.704**	0.643**	0.541**	0.477**	0.471**
	PM0.5			0.774**	0.674**	0.612**	0.601**
	PM1.0				0.929**	0.867**	0.844**
	PM2.5					0.942**	0.929**
	PM5.0						0.972**

Ns: $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

in the last homogeneous groups. According to these results, it can be said that the amount of pollution can be sorted as December > February > November > January, in general, as in the number of PM5.0.

In order to determine the relation levels of the pollutants evaluated within the scope of the study, correlation analysis was applied to the data, and the results are given in Table 10.

When the correlation analysis results indicating the relations between the pollutants within the scope of the study are examined, it is seen that the relations between all the pollution parameters are statistically significant (at least $p < 0.05$). When the values in Table 10 are examined, it is seen that all relations are positive, which means that when the value of one increases, the value of the other one also increases. The pollutants with the strongest relations with each other are determined as PM 5.0 and PM10 (0.972); PM5.0 and PM2.5 (0.942); PM2.5 and PM10 (0.929); and PM2.5 and PM1.0 (0.929). According to these results, it can be said that the pollutants with the strongest relations with each other are the large-sized particulate matter. Apart from this, it is observed that the relations of particulate matter with each other are generally strong, whereas the relations of CO₂ concentration with other pollutants are very weak.

Discussions

Within the scope of the study, the CO₂ concentration (ppm) and the changes of 6 different-sized particulate matter (pieces) on the basis of zones and months between November and February were evaluated in the city centre of Misurata in Libya. As a result of the study, the cleanest zones were found to be the B3, B4 and B6 zones, and the most polluted zone is the B2 zone in terms of CO₂ concentration. In studies carried out on the changes of CO₂ concentration, it is found

that the CO₂ concentration is higher in city centres and the zones with high human activity (Cetin et al., 2017a; Sevik et al., 2017). In terms of CO₂, while the lowest value was obtained in January, the highest was obtained in February.

CO₂ concentration mostly changes due to human activities and air circulation in urban centres (Cetin et al., 2017b; Sevik et al., 2017). In a study conducted in the city centre of Kastamonu province, it was found that the CO₂ concentration in the forest area was 148 ppm, while it was 230 ppm in the suburbs, and 398 ppm in the city centre in summer, and that the CO₂ concentration, which was around 473 ppm in the suburbs in winter, was around 758 ppm and could go up to 918 ppm in the city centre (Sevik et al., 2015).

In studies conducted on the subject, the CO₂ concentration was measured as 384 ppm in Chicago (Grimmond et al., 2002); 478 ppm in Korea (Yoon et al., 2011); 435–550 ppm in Shanghai (Kim & Choi, 2019); 411 ppm in Kraków, Poland (Chmura et al., 2008); 418 ppm in Erbil, Iraq (Abbas et al., 2019); 384 ppm in Spanish Plateau (Garcia et al., 2008); 477 ppm in Rome (Gratani & Varona, 2006); 475 ppm in Dallas (Clark-Thorne & Yapp, 2003); 373 ppm in Hawaii (Keeling & Whorf, 2005); 397 ppm in California (Newman et al., 2008); 425 ppm in Vilathur, India (Palanivelraja & Manirathinam, 2009); and 384 ppm in Brazil (Sikar & Scala, 2004). In the studies conducted, the CO₂ concentration was found to be significantly changing at different times during the day, depending on the weather conditions and on the basis of different zones within the same city (Abbas et al., 2019; Cetin et al., 2017b; Dai et al., 2018; Sevik et al., 2015; Takahashi et al., 2019).

In a lot of studies conducted, it is found that the level of pollution in the city centres is a lot higher than the suburbs or rural areas (Alaqouri et al., 2020a, b). The most significant reason for this is the human activities and traffic density in the city centres. CO₂ is

mainly caused by anthropogenic emissions from road traffic and the burning of natural gas, oil and coal for heating purposes (Grzędzicka, 2019; Kordowski & Kuttler, 2010; Perez-Martínez et al., 2014). Plants can significantly reduce the CO₂ concentration in the ambient through photosynthesis, when the temperature and light are sufficient during the vegetation season (Cetin et al., 2017a). In addition to this, weather conditions, especially wind, have a great impact on CO₂ concentration (Cetin et al., 2017b).

As a result of the study, it was found that the B3 and B4 zones in the first homogeneous groups were the zones with the lowest pollution level according to Duncan test results and that the zones with the highest level of pollution were the B5 and B1 zones, respectively. It is noteworthy that the zones with the lowest pollution level are industrial zones and fields and the zone with the highest pollution level is next to the factory and the city centre.

Even though there are many sources of particulate matter pollution, power plants, vehicle exhaust, factories and industrial activities are the most important sources of PM (Bell et al., 2011; Grzędzicka, 2019; Shahid et al., 2017). Traffic emissions are the main global source of air and soil pollution in cities (Adelasoye & Alamu, 2016; Kimbrough et al., 2013; Kumar et al., 2016). Road emissions contribute to around 66% of PM_{2.5} (Grzędzicka, 2019).

Particulate matter (PM) is the air pollution that represents one of the main health risks for people living in European cities. The powder of PM may contain toxic components such as heavy metals, polychlorinated biphenyls, polycyclic aromatic hydrocarbons and other carcinogens (Arıcak et al., 2019; Bozdogan Sert et al., 2019; Grzędzicka, 2019; Sevik et al., 2020c; Turkyilmaz et al., 2020). In the studies conducted, it is found that every 10 µg/m³ increase in PM₁₀ concentration causes 6% increase in daily death rate, 1% in asthma complaints and 0.5% in cardiovascular complaints. In addition to this, it is determined that it causes lung diseases in people over 65 years old (Elfantazi et al., 2018).

The World Health Organization (WHO) recommends that PM_{2.5} concentration should not exceed an average of 10 µg/m³ per year and an average of 25 µg/m³ per day (WHO, 2006). The limitation of the World Health Organization for PM₁₀ is average of 20 µg/m³ annually and average of 50 µg/m³ daily (EEAP, 2014). Despite this, approximately 85% of

the European population lives in zones above the recommended PM levels (Guerreiro, 2013; Guerreiro et al., 2014).

According to the results of the study, it was found that the highest level of particulate matter pollution in general was in December, February and November, respectively, and the lowest in January. Similar results were obtained in the studies conducted on this subject. In a study conducted by Adin et al. (2017) and in which the changes of PM amount in winter period (between November and March) between 2006 and 2011 were evaluated, it was found that the highest values were obtained in 2010 and the highest values in 2010 were obtained in November and December.

Weather and spatial conditions are the factors that identify air quality significantly. Temperature and humidity affect pollutant concentrations (Fuller et al., 2017; Saha et al., 2018). Cetin et al. (2017b) found that the number of PM_{0.5} was around 109 in calm weather, 30 on calm and rainy weather and 112 on breezy weather. Direction of wind is another factor affecting PM concentration (Tong et al., 2015).

Conclusions

As a result of the study, all of the pollution parameters were found to be significantly changing on the basis of the factors subjected to the study. In the study, it is recommended to take necessary measures and to decrease the level of pollution in the areas with high level of pollution. Planting can be recommended as one of the most effective factors in reducing the level of pollution. It is known that trees with large crown diameter and leaf surface are quite effective in reducing air pollution. Therefore, planting can contribute to reducing the level of pollution, significantly.

Industrial, traffic and human activities are the main sources of the level of pollution. The high level of pollution can considerably affect human health. For this reason, it is recommended to take necessary measures in urban planning by taking this situation into consideration. In order to achieve this, it may be recommended to establish industrial areas away from settlement areas; to plan shopping centres, entertainment and recreational areas in places with no intense industrial activities and traffic; and to plan human activities in such a way to prevent crowd.

Air pollution is a factor that not only affects human life, but also the life of all living things, and even non-living things. For this reason, studies on air pollution should never be deemed sufficient. This is because air pollution is a concept that changes over time, and thus the data obtained in areas, where many studies have been conducted, will expire in time. For this reason, it is recommended to continue conducting studies on the subject by being diversified and increased, even to determine how the components of air pollution change over time, and to repeat the studies at certain intervals in areas, where the change in the process cannot be monitored.

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