JOURNAL OF MARINE SCIENCES & ENVIRONMENTAL TECHNOLOGIES
Vol. 9, Issue No. 1 (June-2023)
DOI: https://doi.org/10.59743/jmset.v9i1.147

ISSN (Print): 2413-5267
ISSN (Online): 2706-9966

Assessment of Air pollution in Benghazi City during February and March periods using Airvisual Outdoor Monitor

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تقييم تلوث الهواء في مدينة بنغازي خلال فترتي فبراير ومارس باستخدام محطة قياس جودة الهواء الثابتة

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Received: 28 March 2023; Revised: 30 May 2023; Accepted: 14 June 2023.

Abstract

Particulate matter is a major indicator of the level of air pollution. The ratio of fine and coarse particles and particle type determine the ability of atmospheric processes and affect human health. The aim of this work is to assess the spatiotemporal variation of particulates (PM_1, $PM_{2.5}$, and PM_{10}) during the monitoring period from February 2023 to March 2023 and to assess the correlations between pollutants and the impact of meteorological factors. The results showed the main average air quality index (AQI) in the February period was about 138 $\mu g/m^3$, which reflected the air quality is unhealthy for sensitive groups, while the main average AQI in the March period was about 89 $\mu g/m^3$, which reflected the air quality is moderate. Based on $PM_{2.5}/PM_{10}$ ratios in February the mixed particles and anthropogenic source are more common in the atmosphere and $PM_{2.5}/ PM_{10}$ ratios in March period the mixed particles and natural sources are more common in the atmosphere in Benghazi city. The February period has more pollutants than the March period due to more than type of pollution. The bivariate polar plots of temperature AQI, $PM_1/PM_{2.5}$, and $PM_{2.5}/PM_{10}$ were negatively correlated with temperature while positively correlated with wind speed. SE directions of wind have a major impact on increasing PM and natural pollution type concentrations in Benghazi city.

Keywords: *Air quality index; Particulates matters (PMs); Meteorological parameters; Benghazi city; NE Libya.*

ISSN (Print): 2413-5267
ISSN (Online): 2706-9966

الملخص

الجسيمات هي مؤشر رئيسي على مستوى تلوث الهواء. تحدد نسبة الجسيمات الدقيقة والخشنة ونوع الجسيمات قدرة العمليات الجوية وتؤثر على صحة الإنســـان. الهدف من هذا العمل هو تقييم التباين الزماني المكاني للجســـيمات (PM_1 و$PM_{2.5}$ و PM_{10}) خلال فترة المراقبة من فبراير 2023 إلى مارس 2023 وتقييم الارتباطات بين الملوثات وتأثير عوامل الأرصـاد الجوية. أظهرت النتائج أن المتوســط الرئيســي لمؤشــر جودة الهواء (AQI) في فترة فبراير حوالي 138 ميكروجرام/م^3، مما يعكس أن جودة الهواء غير صحية للمجموعات الحساسة، في حين بلغ المتوسط الرئيسي لــ AQI في فترة مارس حوالي 89 ميكروجرام/م^3، مما يعكس جودة الهواء بشـكل معتدل. اسـتنادًا إلى نسـب $PM_{2.5}/PM_{10}$ في فبراير، تكون الجسـيمات المختلطة والمصـدر البشـري أكثر شـيوعًا في الغلاف الجوي ونسـب $PM_{2.5}/PM_{10}$ في فترة مارس، تكون الجسـيمات المختلطة والمصـادر الطبيعية أكثر شـيوعًا في الغلاف الجوي في مدينة بنغازي. تحتوي فترة فبراير على ملوثات أكثر من فترة مارس بســـبب تأثرها بأكثر من نوع من التلوث. كانت المخططات القطبية ثنائية المتغير لدرجات الحرارة AQI و$PM_1/PM_{2.5}$ و$PM_{2.5}/PM_{10}$ مرتبطة سـلبًا بدرجة الحرارة بينما كانت مرتبطة بشـكل إيجابي بسـرعة الرياح. اتجاهات الرياح الجنوبية الشرقية لها تأثير كبير على زيادة تركيزات الجسيمات الدقيقة والتلوث الطبيعي في مدينة بنغازي.

الكلمات الدالة: مؤشر جودة الهواء، العوامل الجسيمية (PMs)، بارامترات الأرصاد الجوية، مدينة بنغازي، شمال شرق ليبيا.

1. Introduction

Air pollutants are substances that are suspended in the atmosphere and are caused by a variety of human activities such as manufacturing, building, transportation, or the exploitation of natural resources. These contaminants have negative effects on people, animals, and plants (Shaddick, 2020). In the world, air pollution is one of the major sources of pollution. Most nations view this issue as a danger to their citizens' health and, among other measures, impose rigorous rules in an attempt to reduce it (Alias *et al*., 2007). Windblown dust from deserts is a common primary source of particulate matters (particulate pollution) in Libya, in additional, the secondary sources usual originated from fossil fuel combustion, waste, agricultural burning and industrialization (Busheina *et al*., 2017). Benghazi is the second populous city in Libya after Tripoli city, located on the Gulf of Sidra in the Mediterranean, Benghazi is also a major seaport shown in Figure (1). During recent years, and Benghazi city is experiencing unprecedented economy growth rate and rapid urbanization. This resulted in expansion of this city, increase in urban population, vehicular population, a backlog of vehicles and construction activity. There are two main pollution sources in Benghazi city: **1)** natural source includes sandstorms and dust that come from desert; **2)** Human activity includes combustion of garbage, fuel oil combustion, car exhaust and oil refining companies. The objectives of this work which are; **1)** To assess the spatiotemporal variation of particulates (PM_1, $PM_{2.5}$ and PM_{10}) during the monitoring period from February 2023 to March 2023. **2)** To assess the correlations between pollutants and the impact of meteorological factors, and **3)** To aware, the local people risk of air pollution in Benghazi city.

1.1. Previous studies

Based on the publications, the authors believe that this work is considered the first survey of particulate pollution (particulate matters) in the center of Benghazi city, NE Libya. The following is a brief survey on the published data especially that dealing with aerosol metals pollutants in Benghazi city and other cities.

ISSN (Print): 2413-5267
ISSN (Online): 2706-9966

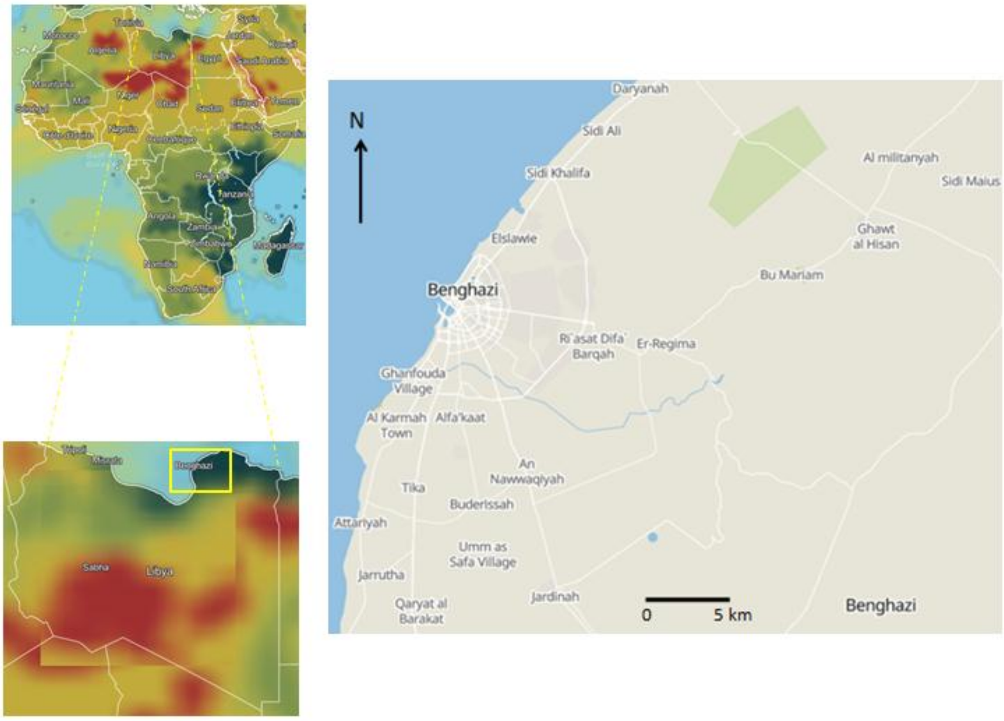

Figure 1. Location map of the study area shows Benghazi and its surrounding areas. It also shows the location of Benghazi in Libya and the location of Libya in the north of the African continent (Modified after: IQAir, 2023).

Yasser *et al*. (2017) studied the sources of air pollution in Libya. They found that the largest pollutants were carbon dioxide CO_2 (96.76%) followed by carbon monoxide CO (2.13%), then particulate matters PM (0.55%), then sulfur dioxide SO_2 (0.21%), nitrogen oxides NOx (0.18%), then methane gas (0.089%), voltaic organism component VOC (0.061%), and in the last position was nitrous oxide N_2O with (0.028%). Shalthami *et al*. (2017) studied carbonaceous particles in the air of two urban environments (Tobruk and Emsaed) in Libya. They reported that the probable sources of the carbonate particles in Emsaed are combustion of garbage and car exhaust, while fuel oil combustion and car exhaust are the possible sources of these particles in Tobruk. Busheina *et al*. (2017) studied the assessment and measurement of atmospheric pollution (particulate matter) around Zawiya City, NW Libya. They reported the maximum of total suspended particulates were observed in May 2008, which is characterized by high wind speed (7.8 knots) compared to other months of the year. Alhadi *et al*. (2017) studied ozone concentrations in Tripoli city atmosphere, Libya. They reported observed high concentration of ozone gas with increased strength the solar radiation decreased during the night, the peak of its activity was at three o'clock in the afternoon and the reason for increasing the concentration of averages due to high temperature and increase the number of hours of solar brightness. Almabrok *et al*. (2020) studied the level concentration of heave metals of aerosol metals contamination in falling dust at different roadsides in Benghazi city. They found the concentrations of aerosols metals were increased with increased the movement of traffic in that particular areas, density of population and industrial activities.

ISSN (Print): 2413-5267
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2. Materials and Methods

The concentrations of AQI, PM_1, $PM_{2.5}$, PM_{10} and Temperature (T °C) were monitored at the center of Benghazi city using Air visual outdoors (AVO) under serial number (W1QS). The monitoring station measure every five minutes for each parameter. We collected daily reads from this station for couple of months (February 2023 and March 2023). The speeds and directions of wind were taken from the local weather station. The Airvisual outdoors is characterized by high quality sensing elements to provide reliable and accurate readouts. Table (1) showed the specification monitoring station of air visual outdoor while, Tables (2 and 3) showed the daily average values of PM_1, PM_2, PM_{10}, temperature, wind speed and wind directions during period from February 2023 to March 2023.

Table 1. Description of Air visual outdoor (monitoring station).

Paramters	Functions
PM_1	0-1,000 µg/m^3 ±10 µg/m^3 / or ±10%
$PM_{2.5}$	0-1,000 µg/m^3 ±10 µg/m^3 / or ±10%
PM_{10}	0-1,000 µg/m^3
CO_2	requires optional module
T	-40 to 90 °C / -40 °F to 194 °F ±2 degrees C or F
Humidity	0 - 100% RH ±1%
Data Display	AirVisual app (iOS and Android)
Usage	Web dashboard

3. Results and Discussion

The AQI is divided into six classes, each class corresponds to a different level of health concern is shown in Table (4). The study revealed the most of AQI records in February period were above the permissible health limit of US AQI (2104, Figure 2), where the main average of AQI was found to be (138 µg/m^3) is considered as unhealthy for sensitive groups. Members of sensitive groups may experience health effects, but the public is unlikely to be affected. The proportions of the six AQI pollution levels in the atmosphere conformed that the unhealthy for sensitive groups is highest level in February period in Benghazi city shown in Figure (3).

In the March period, the results showed the most AQI records were in the safe health limit of US AQI (2104, Figure 4). The main average of AQI was found to be (89 µg/m^3) is considered moderate, however, a very small number of individuals may find this level of pollution to be moderately unhealthy. Respiratory symptoms can occur in people who are highly sensitive to ozone or particulate pollution (US AQI., 2104).

Table 2. Particulate matters and metrological parameters
(concentrations in μg/m^3, except for WD in m/n) in ambient air during February period (2023).

Date	AQI	$PM_{2.5}$	PM_{10}	PM_1	T	WD	WS	$PM_1/PM_{2.5}$	$PM_{2.5}/PM_{10}$
3	46	18.5	27	14.5	17	_	8.1	0.78	0.69
4	49	11.8	17.4	9.1	12.1	_	13.5	0.77	0.68
5	59	15.8	24	12.6	12.2	_	8.1	0.80	0.66
6	37	8.9	13.6	7.1	9.8	_	6.48	0.80	0.65
7	58	15.3	32.1	12.2	10.8	SE	4.86	0.80	0.48
8	98	34.3	51.8	27.5	11.8	SE	3.51	0.80	0.66
9	475	463	695	370	10.6	SE	5.67	0.80	0.67
10	123	44.6	67.1	35.7	9.6	SE	6.21	0.80	0.66
11	59	15.8	24	17.2	10.9	ESE	5.13	1.09	0.66
12	116	41	62.9	33.4	11.5	NE	4.59	0.81	0.65
13	108	38.5	58	30.9	11.3	NE	3.24	0.80	0.66
14	80	26	39.3	20.8	10.7	NE	3.24	0.80	0.66
15	79	25.4	38.3	20.3	12.6	NE	3.78	0.80	0.66
16	133	48.4	72.9	38.7	12.5	NE	4.32	0.80	0.66
17	145	53.5	80.5	42.9	12.2	NE	4.86	0.80	0.66
18	149	55.1	82.8	44	13.9	ESE	4.32	0.80	0.67
19	153	58.4	87.8	46.7	14.2	ESE	3.24	0.80	0.67
20	75	23.5	54.8	10	14.9	SSE	3.24	0.43	0.43
21	158	68.3	255	18.7	14.5	SSE	3.78	0.27	0.27
22	85	28.3	64.1	12.7	15.7	S	4.32	0.45	0.44
23	139	51.7	137	22	15.3	SSW	4.86	0.43	0.38
24	119	42	120	17	15.9	SE	4.32	0.40	0.35
25	123	44.3	173	9.8	17	SE	6.75	0.22	0.26
26	286	236.5	1155	35	17.7	SE	10.8	0.15	0.20
27	299	249.4	1233	37.3	17.5	SE	11.07	0.15	0.20
28	170	100	335.8	25	19.8	SE	8.64	0.25	0.30
Average	138	50.4	198.2	39.1	13.3	-	5.8	0.64	0.54

Table 3. Particulate matters and metrological parameters
(concentrations in μg/m^3, except for WD in m/n) in ambient air during February period (2023).

Date	AQI	$PM_{2.5}$	PM_{10}	PM_1	T	WD	WS	$PM_1/PM_{2.5}$	$PM_{2.5}/PM_{10}$
1	170	91.9	184	18.7	18.5	NE	4.86	0.20	0.50
2	158	69.5	197.5	24.1	17.1	NE	4.86	0.35	0.35
3	152	56.8	169.5	12.5	19.3	SE	9.3	0.22	0.34
4	114	40.9	120.9	10.2	17.5	NE	10.8	0.25	0.34
5	54	13.6	32.4	4.7	15	NW	5.94	0.35	0.42
6	50	12	44.3	7.6	15.5	W	6.75	0.63	0.27
7	99	34.9	108	14.8	16.8	W	5.94	0.42	0.32
8	71	21.8	57.9	6.5	16.2	NW	5.4	0.30	0.38
9	66	19.2	104.5	10.5	16.9	NW	5.94	0.55	0.18
10	82	26.7	99.7	12.3	19.4	SE	6.75	0.46	0.27
11	77	24	59	8.2	18.1	SE	6.75	0.34	0.41
12				No data recorded					
13	70	21.1	72.1	9.5	15.7	NW	5.94	0.45	0.29
14	62	17.3	57	8.5	15.3	NE	8.91	0.49	0.30
15	72	22.2	58.3	8.4	15.6	S	8.64	0.38	0.38
16	77	24.3	61.2	7.6	15.5	NW	8.64	0.31	0.40
17	62	17.5	39.7	6.3	13.9	N	8.64	0.36	0.44
18	77	24.5	68.2	9.7	15.1	N	5.94	0.40	0.36
19	80	25.9	71.2	9.9	15.2	E	13.5	0.38	0.36
20	139	50.9	160.6	16.5	15.1	E	13.5	0.32	0.32
21	126	45.5	173.8	8	19.6	SE	8.64	0.18	0.26
22	152	57.4	220	11.9	19.9	E	10.8	0.21	0.26
23	64	18.4	66.8	12.5	16.4	N	9.72	0.68	0.28
24	62	17.5	42.7	12.2	15	N	7.83	0.70	0.41
25	74	23.2	46.5	15.6	16.5	NW	7.02	0.67	0.50
26	83	27.4	61.5	12.5	16.4	NW	7.83	0.46	0.45
27	77	24.5	61.6	12.5	16.8	SW	8.64	0.51	0.40
28	98	34.4	79.8	12.9	19	NW	4.86	0.38	0.43
29	87	29.2	97.5	6.7	15.1	NW	5.94	0.23	0.30
30	93	32.2	99.8	7.3	14.4	N	5.9	0.23	0.32
31	70	20.6	64.9	5.7	15.7	N	5.5	0.28	0.32
Average	89	30	94.7	10.7	16.5	-	8.23	0.36	0.32

ISSN (Print): 2413-5267
ISSN (Online): 2706-9966

The proportions of the six AQI pollution levels in the atmosphere conformed that the moderate air quality is highest level in March period in Benghazi city shown in Figure (5).

Table 4. Scheme for assessment of Air Quality Index.

Air Quality Index AQI Values	Levels of Health Concern
0 - 50	Good
51 - 100	Moderate
101 - 150	Unhealthy for sensitive groups
151 - 200	Unhealthy
201 - 300	Very unhealthy
301 - 500	Hazardous

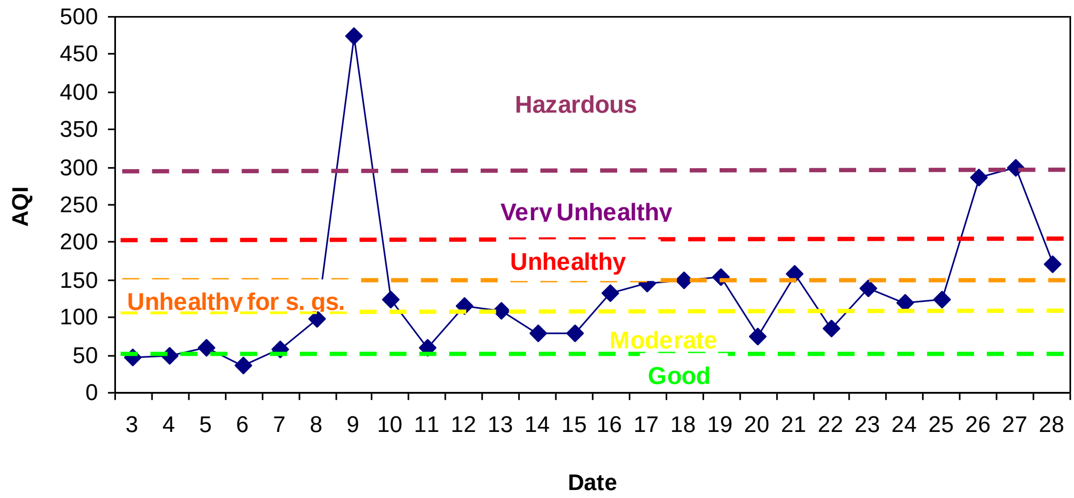

Figure 2. levels of pollution in Benghazi city during the February period.

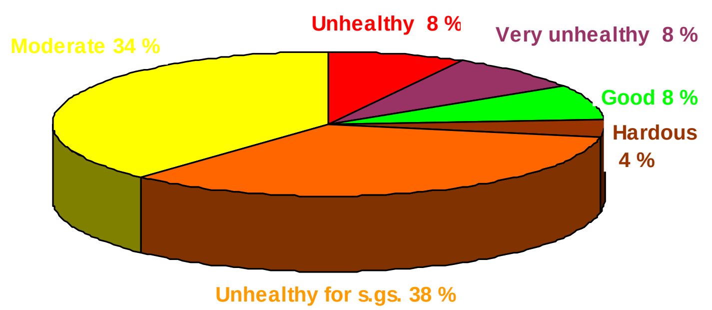

Figure 3. The proportions of the six AQI classes for Benghazi city during February period.

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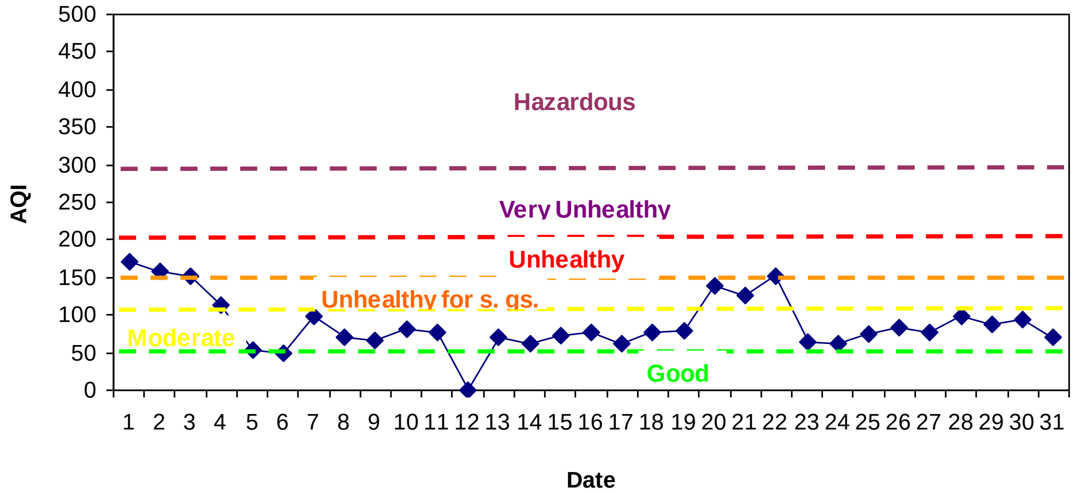

Figure 4. levels of pollution in Benghazi city during the March period.

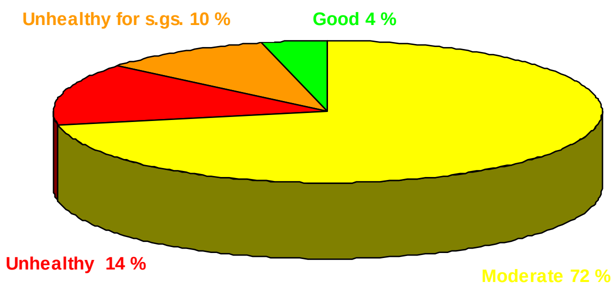

Figure 5. The proportions of the six AQI classes for Benghazi city during March period.

3.1. Classification and sources of air pollution

Wu (2015), Kong (2016), and Tian *et al*. (2018) classified the ratio of $PM_{2.5}/PM_{10}$ into three categories namely:

1) Coarse particulates, are originating from natural sandstorms over deserts and traffic induced dust re-suspension ($PM_{2.5}/PM_{10} < 0.2$).
2) Mixed particulates are characterizing the fair distribution of fine and coarse particles ($PM_{2.5}/PM_{10}$ ranges from 0.2–0.8).
3) Fine particulates are either primary particles that are directly released by combustion processes or secondary particles that are formed in the atmosphere from reactions of inorganics ($PM_{2.5}$ / PM_{10},> 0.8).

The results showed that $PM_{2.5}/PM_{10}$ ratio ranged from 0.27 to 0.69 and 0.29 to 0.50 respectively, which reflected the air pollution in Benghazi city is affected by mixed particulates pollution in the atmosphere for two periods shown in Figures (6 & 7). Hao *et al*. (2021) reported three types of air pollutions, which are: 1) dust type (type I); with the ratio of $PM_{2.5}/PM_{10} < 0.4$, 2) mixed type (type II) with the ratio of $PM_{2.5}/PM_{10}$ ranges from 0.4 to 0.6, 3) anthropogenic

ISSN (Print): 2413-5267
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type (type III) with the ratio of $PM_{2.5}/PM_{10} > 0.6$. Based on this classification the average ratio of $PM_{2.5}/PM_{10}$ in February period is about 0.59, which suggests the Benghazi city is implying the dominance of anthropogenic pollution type in the emission sources shown in Figure (8), while the average ratio of $PM_{2.5}/PM_{10}$ in March period is about 0.34, which suggests the Benghazi city is implying the dominance of dust type shown in Figure (9).

In the February period, the anthropogenic source represented about 61% from the total pollution sources such as fuel oil combustion, car exhaust, combustion of garbage, unpaved roads, industrial factories, and thermal power generating plants, dust type (natural type) is represented about 27% from total pollution sources such as dust and sand storms and the mixed type is represented about 11% from total pollutions shown in Figure (10). In March period, the dust type (natural type) represented about 77% from the total pollution sources such as dust and sand storms and the mixed type is represented about 23% from total pollutions shown in Figure (11). The authors concluded that, the higher the ratio of $PM_{2.5}/PM_{10}$, the pollution resulting from human activity becomes more common and associated with fine particles, whereas the lower the ratio $PM_{2.5}/PM_{10}$, the pollution resulting from nature becomes more common and associated with coarse particles.

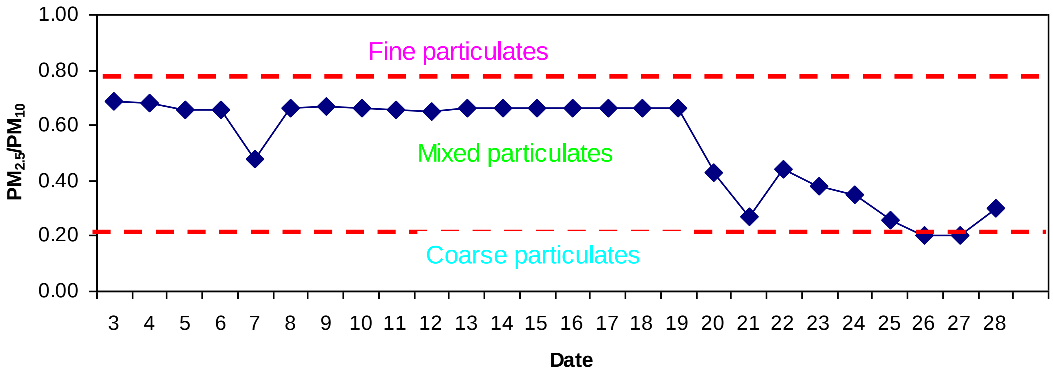

Figure 6. Classification of particles based on $PM_{2.5}/PM_{10}$ ratios during February period.

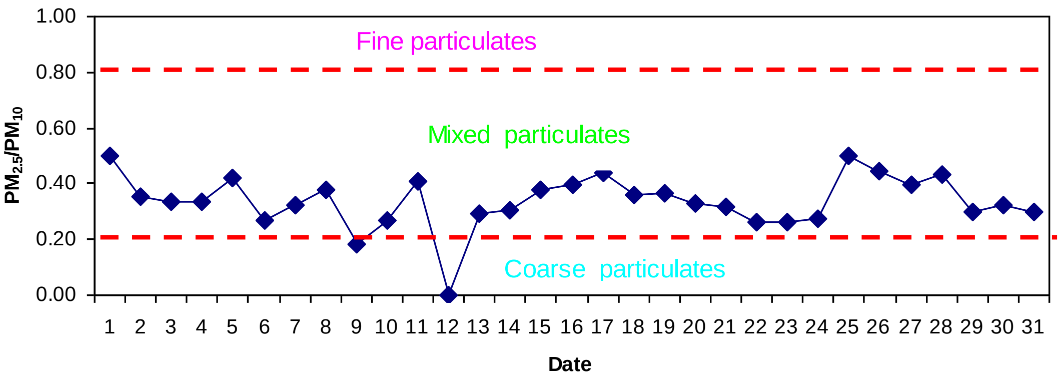

Figure 7. Classification of particles based on $PM_{2.5}/PM_{10}$ ratios during March period.

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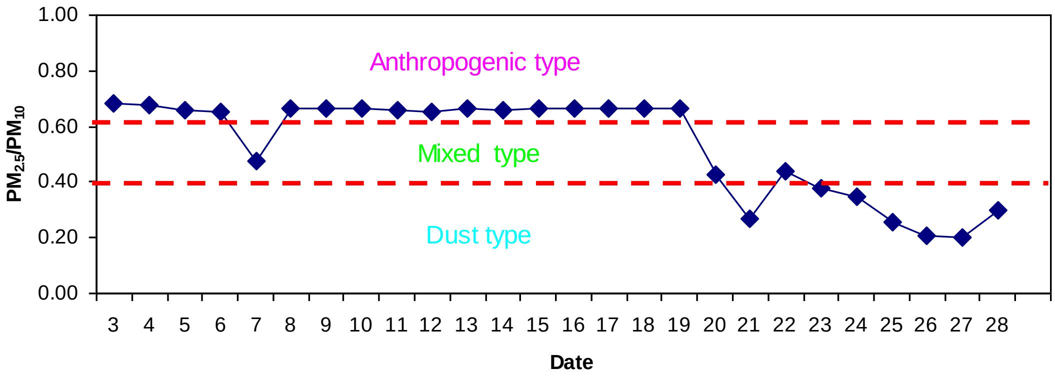

Figure 8. Source of particles based on $PM_{2.5}/PM_{10}$ ratios during February period.

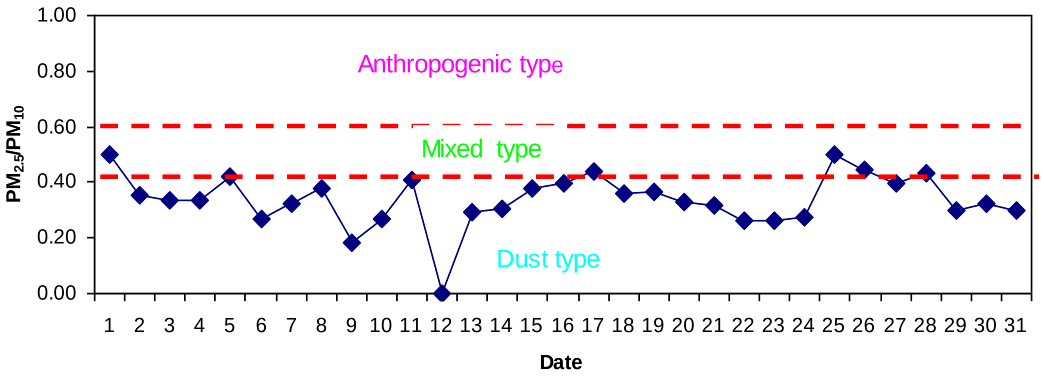

Figure 9. Source of particles based on $PM_{2.5}/PM_{10}$ ratios during March period.

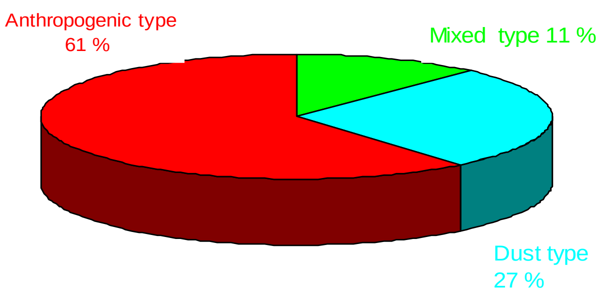

Figure 10. The proportions of pollution types in February period.

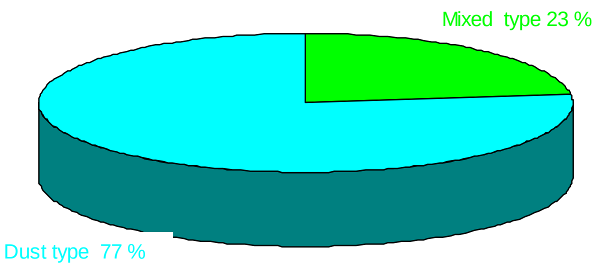

Figure 11. The proportions of pollution types in March period.

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3.2. Effects of meteorological parameters on AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios

Meteorological parameters are mainly responsible for atmospheric pollution whenever PM emission in an area is constant Li *et al*. (2015), such as removal (dry and wet deposition) and transport dispersion of PM from the atmosphere is influenced by meteorological factors, such as wind speed, wind direction and temperature. The variations of meteorological parameters with AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios were investigated using correlation analysis. The correlation coefficient of temperature (T, C°) and wind speed (WS) with AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios. In the present work, the relationship between temperature and AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios were negatively correlations in two periods (r= -0.1, -0.6, and -0.5, - 0.1respectively) except $PM_1/PM_{2.5}$ in March period was a weakly positive correlation (r= 0.27) which suggests the particulate matters may increase with low temperature in the study area (Lin *et al*., 2009; and Munir *et al*., 2103) shown in Figures (12 & 13).

The correlation coefficient of wind speed with AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios in two periods. In February period, the ratios were weakly to strong passivity correlations (r= 0.16, 1, and 0.3), which indicated that the wind speed play a major importance in the distribution of pollutants in the atmosphere shown in Figure (14), as the pollutants move towards the prevailing winds, so the areas located in the winds, there are pollutant reception areas, which are more polluted (Milad, 2018). Wind direction changed from NE to SE on the 20th and continued to the end of the February with the increased in wind speed, the dust storm moved over Benghazi city, which caused dust load and greatly affected visibility of air quality shown in Figure (15). This result confirmed SE wind direction is a statistically significant factor for natural sources of particulates pollution. Figure (16) revealed the percentage of the wind directions in Benghazi city, NE and SE directions are the major trend of wind in February period. In the March period, the ratios recorded a weakly negative correlation (r= -0.01 and -0.01) because the wind disperses and transports the particulates pollution (PM) somewhere else Figure (17), (Farooq *et al*., 2022). The direction to the southeast became discontinuous from the February period, with an increase in temperature, which led to a decrease in human activities shown in Figure (18), where the particles caused by natural factors became more prevalent in the March period. Figure (19) revealed the percentage of NW and SE are the major trend wind directions in March period.

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ISSN (Online): 2706-9966

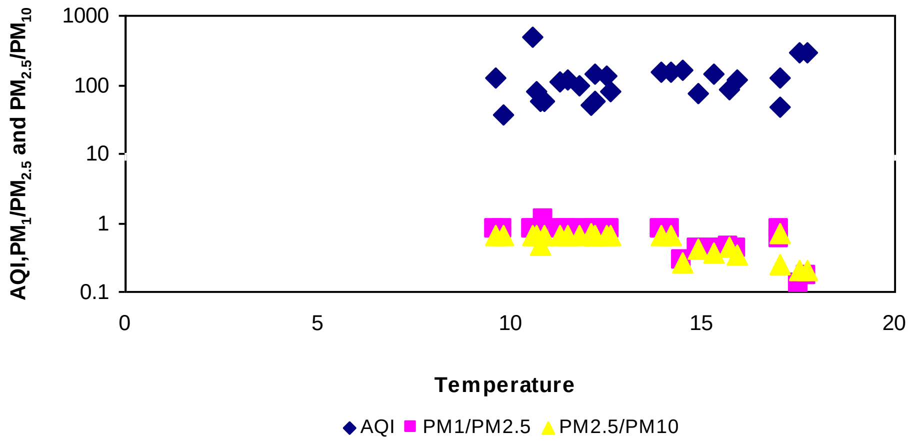

Figure 12. Relationship between temperature vs. AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios during February period.

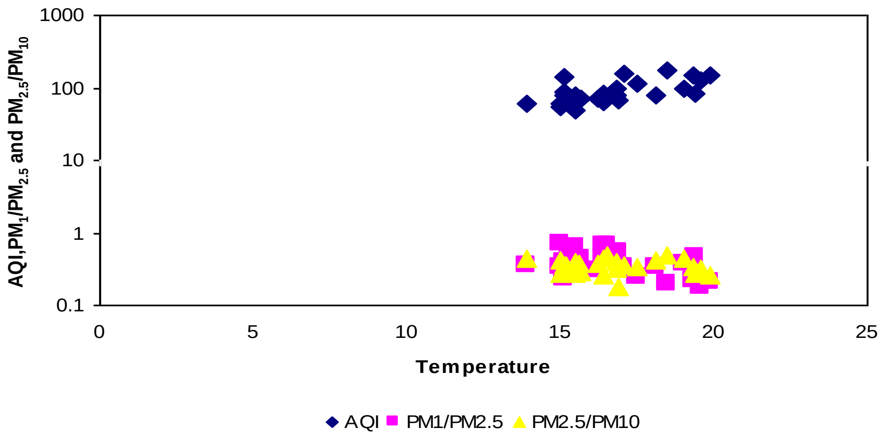

Figure 13. Relationship between temperature vs. AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios during March period.

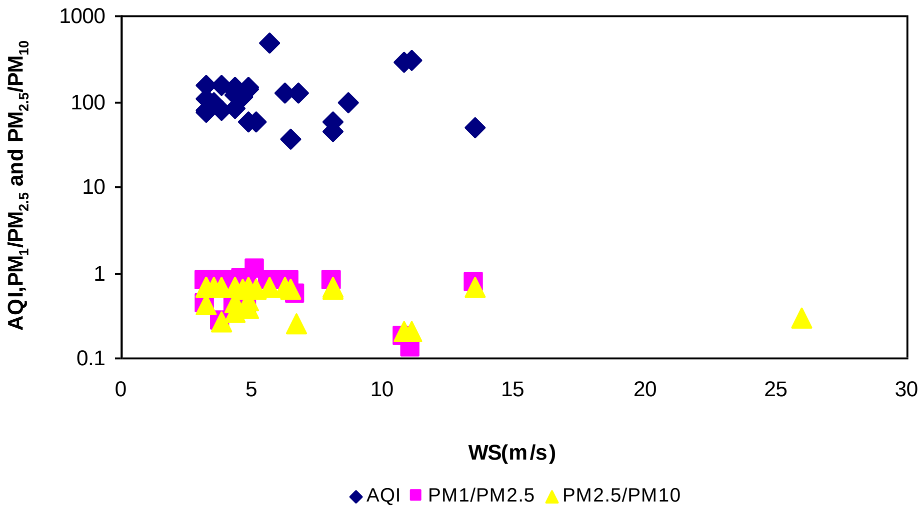

Figure 14. Relationship between wind speeds vs. AQI, $PM_1/PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios during February period.

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ISSN (Online): 2706-9966

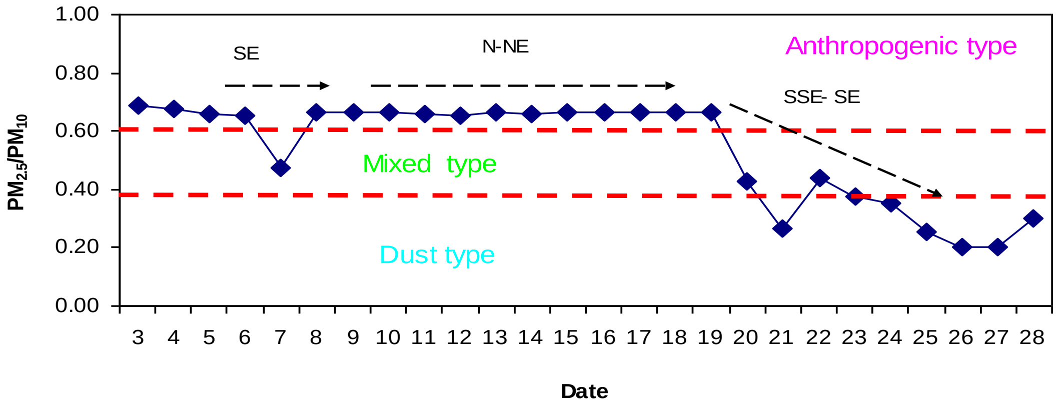

Figure 15. Relationship between $PM_{2.5}/PM_{10}$ ratios and wind direction (WD) during February period.

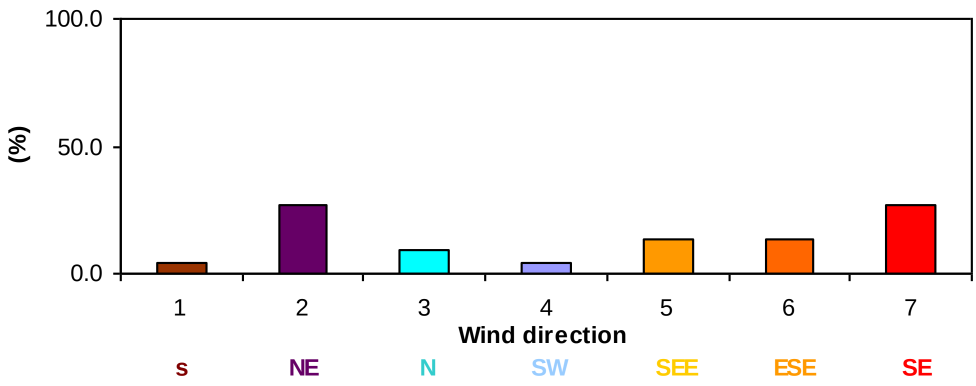

Figure 16. Shows the percentage of wind direction during February period.

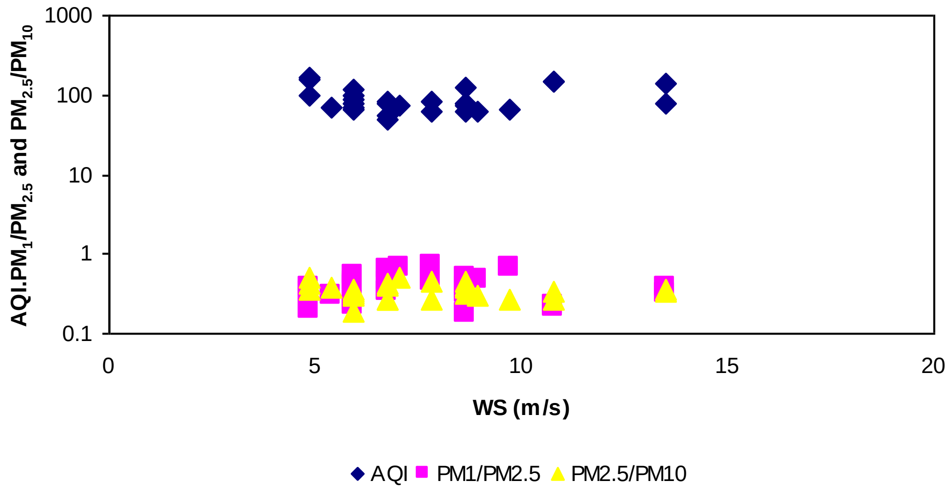

Figure 17. Relationship between wind speeds . vs. AQI, PM_1 /$PM_{2.5}$ and $PM_{2.5}/PM_{10}$ ratios during March period.

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ISSN (Online): 2706-9966

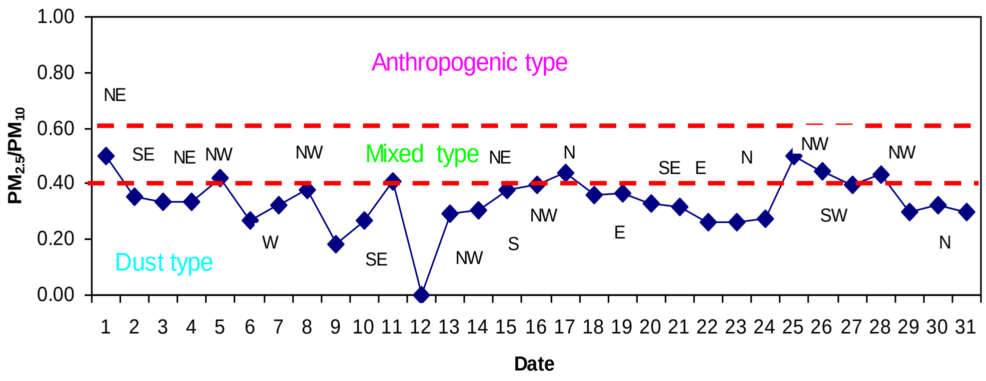

Figure 18. Relationship between $PM_{2.5}/PM_{10}$ ratios and wind direction (WD) during March period.

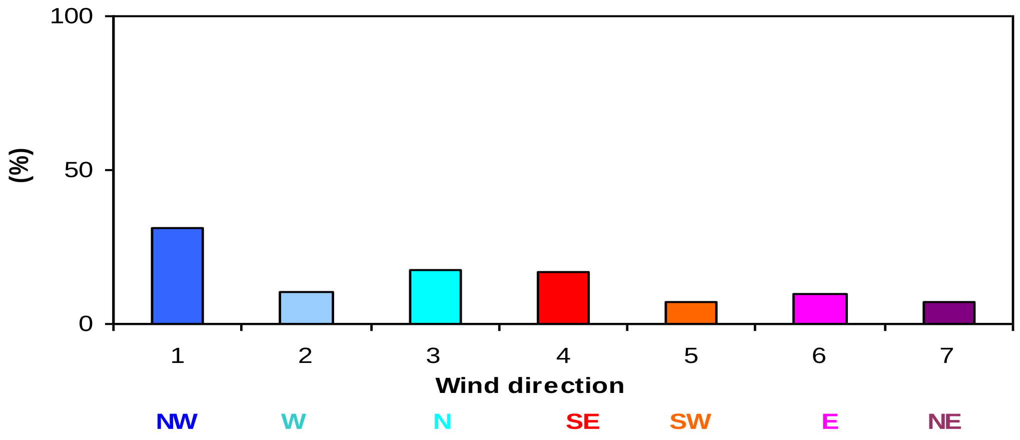

Figure 19. Shows the percentage of wind direction during March period.

4. Conclusion

- This work looked at PMs Pollution in Benghazi City, and its link to metrological parameters, which is important for improving local air quality.
- The main average concentration of air quality index (AQI)in February period is 138 µg/m^3 is considered as unhealthy for sensitive groups and affected by anthropogenic (61%), natural (27%) and mixed sources (11%).
- The main average concentration of air quality index (AQI)in March period is 89 µg/m^3 is considered moderate and affected by natural (77%) and mixed sources (23%).
- The February period has more pollutants than the March period due to affected more than type of pollutions.
- The correlation coefficient of AQI with PM_1, $PM_{2.5}$ and PM_{10} in two periods were strongly positive correlative, which reflects the pollution, originates from similar sources.
- The February and March periods are characterized by the fair distribution of fine and course particles pollution in the atmosphere.

ISSN (Print): 2413-5267
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- The temperature has a negative correlation with PMs, which reflects the PMs increased with low temperature, the opposite is true.
- The wind speed recorded passivity correlation with PMs in February period, which indicated that the wind speed, play a major importance in the distribution of pollutants in the atmosphere while wind speed recorded negative correlation in March period due dispersion in directions and speed of wind.

5. Recommendation

- Expanding the cultivation of gardens, parks, trees, shrubs, and green spaces inside and outside cities because of their important role in purifying the air from pollutants suspended in it, and in improving and beautifying the environment and the surrounding community.
- Proper disposal of solid and liquid waste, ambient reduction of harmful gases that may result from landfill or waste incinerated or processed and recycled.
- Monitoring industrial and agricultural establishments and any other sources of pollution, and obliging these establishments and sources to follow production methods and systems.
- Spreading environmental awareness among community members and urging them to cooperate with municipalities and other relevant governmental and non-governmental agencies in order to preserve air safety and purity.

Acknowledgment

This study was carried out in a cooperation agreement with IQAir, North America. Inc. as a collaboration strategy that allows the establishment of measures that guarantee the continuous improvement of air quality in Libya.

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