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Geochemical Assessment of the Air Quality Index for Urban Areas (Case Study of Benghazi, Al Byada, Zliten and Tripoli Cities).

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Highlights

- **Air quality was assessed in four Libyan cities—Benghazi, Al Bayda, Zliten, and Tripoli—using AirVisual Outdoor monitors during 2024.**
- **Al Bayda recorded moderate AQI levels (Level 2), while Zliten showed the highest pollution levels among the studied cities.**
- **The $PM_{2.5}/PM_{10}$ ratio suggests that natural sources and coarse particles are the dominant contributors to air pollution in the study areas.**
- **The CO_2 concentration in Libya (~441 ppm) is close to the global average (~444 ppm), indicating the nearly uniform distribution of atmospheric CO_2 worldwide.**

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ABSTRACT

One of the biggest environmental issues in cities is air pollution. Over 80% of urban dwellers are thought to be exposed to air pollution levels above the World Health Organization's (WHO) recommended limits. This work aims to compare the air quality index (AQI) with the WHO 2014 guideline during 2024 and to determine the sources of air pollution in the study areas, as well as to compare carbon dioxide (CO_2) emissions in Libya with global emissions. The AirVisual Outdoor monitors were used in this work to measure AQI, $PM_{2.5}$ PM_{10} and CO_2, The finding revealed the AQI in Benghazi city during the February period was unhealthy for sensitive groups (level 3) and in April period was unhealthy (level 4), in Al Byada city was moderate throughout all periods (level 2), the air quality in Zliten city from January to May period was unhealthy for sensitive groups (level 3) and in the air quality in Tripoli city during February period was unhealthy for sensitive groups (level 3). Zliten city is considered the most polluted city due to the lack of infrastructure and afforestation in the city. Based on $PM_{2.5}/PM_{10}$ ratios, the natural source and coarse particles of pollution were more prevalent in the studied areas. The concentration of CO_2 in Libya was approximately 441 ppm, while the global average reached about 444 ppm, indicating that the distribution of CO_2 in the atmosphere is nearly uniform worldwide.

1. Introduction

The Air Quality Index (AQI) is a tool used to measure and communicate how clean or polluted the air is and what associated health effects might be a concern for the public. It helps raise awareness about air pollution levels simply and understandably. The main polluted measured in this work Particulate matter ($PM_{2.5}$ and PM_{10}). Particulate matter is a complex mixture of liquid and solid airborne particles, particulate matter is one of the main air contaminants of public health concern. Particulate matter can be further divided into $PM_{2.5}$, which are fine particles with diameters less than 2.5 µm, and PM_{10}, which are coarse particles with sizes less than 10 µm, based on the aerodynamic diameter (Dominici, et al., 2001; Marcazzan, et al., 2006). According to the (IQA) annual report on global air quality for 2023, which is based on the average annual concentration of $PM_{2.5}$, the most polluted countries were identified as Bangladesh, Pakistan and India, in Libya, the annual mean $PM_{2.5}$ concentration for 2023 was 30.4 mg/m^3 ranking the country 20th globally and seventh in Africa among the most polluted nations (IQAir,2024). This marks Libya first recorded ranking. In 2024, the pollution level decreased compared to 2023, and the country ranked 36th globally(IQAir.2025). This improvement is attributed to change in weather condition. The aim of this work is the aim of this work; 1) To compare air quality index (AQI), $PM_{2.5}$ amd PM $_{10}$ with WHO 2014 guideline during 2024. 2)to determine the source of air pollution in the study areas. 3)To determine the concentration of CO_2 in atmosphere and compare with global emissions and to aware, the local people risk of air pollution in the study areas. There are several previous works dealing with air pollution, such as Abogrean *et al.* (2015), who studied the seasonal behavior of gaseous, PM_{10}, and VOC pollutants in Tripoli ambient air, Libya. They recorded the highest level of PM_{10} in the winter season. (Nassar *et al.*, 2018) studied the sources of air pollution in Libya. They found that the largest pollutants were CO_2 (96.76%) with lesser values of CO (2.13%), PM (0.55%), SO_2 (0.21%), NO_x (0.18%), CH_4 (0.089%), VOC (0.061%) and N_2O (0.028%). Busheina *et al.* (2017) evaluated the atmospheric pollution around Zawiya city, NW Libya. They reported that the maximum of total suspended particulates was observed in May 2008, which is characterized by high wind

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speed (7.8 knots) compared to other months of the year. Almabrok et al. (2020) studied the levels of aerosol metals contamination in falling dust at different roadsides in Benghazi city. They found that the concentrations of aerosols metals were increased with increased the movement of traffic in those particular areas, density of population and industrial activities. Najar *et al.* (2023) measured VOCs in twelve refuelling stations from different regions of Benghazi City. They reported that the pollutant concentrations were within the range of the FEPA air quality standard in most stations. A study conducted by Fares *et al.* (2023) assessed air pollution levels in Benghazi during February and March using an AirVisual Outdoor Monitor. The results showed that pollutant concentrations were higher in February than in March. The average Air Quality Index (AQI) in February was about 138 μg/m^3, indicating air quality that was unhealthy for sensitive groups, whereas the average AQI in March was about 89 μg/m^3, indicating moderate air quality. A study conducted by Fares et al. (2024) assessed air quality and meteorological conditions in Tripoli and Zliten in north-western Libya. The results indicated that particulate matter concentrations were higher in Zliten than in Tripoli. The study also found that air pollution in Tripoli was mainly associated with human activities, whereas pollution in Zliten was largely influenced by desert dust transported from surrounding arid regions.

2024 AQI* country ranking Which country had the worst air quality in 2024?		**Worldwide PM2.5 ranking**
# Country	Population	AQI* US
1 Chad	17,179,740	176
2 Bangladesh	169,356,251	167
3 Pakistan	231,402,117	164
4 Democratic Republic of the Congo	95,894,118	153
5 India	1,407,563,842	138
6 Tajikstan	9,750,064	128
7 Nepal	30,034,989	119
8 Uganda	45,853,778	115
9 Rwanda	13,461,888	114
10 Burundi	14,047,800	113
36 Libya	6,735,277	76

Fig.1. Libya's ranking in 36th place among the most polluted countries in the world in 2024 (IQ*Air*,2025).

2. Methodology

AirVisual Outdoor (AVO) is featured on a worldwide platform known as the AirVisual Platform for monitoring air quality. The AirVisual Outdoor, which was designed in Switzerland and produced in Germany, is a top-notch air quality-monitoring device that needs a constant power supply and can synchronize data via WiFi. The description of AirVisual Outdoor, (Table 1). The stations that were used in this work were named Benghazi and Al Byada. Zliten and Tripoli stations (Fig. 2). These stations are high-quality sensing elements that produce reliable and reliable readouts. The following parameters were measured at these stations: AQI, $PM_{2.5}$, PM_{10}, temperature (T), pressure (P), humidity (H), and carbon dioxide (CO_2) (refer to Tables 2–6). The monitoring stations collected data every five minutes and transmitted it to a global platform known as the AirVisual platform. In this study, the primary average for each month from January to November 2024.

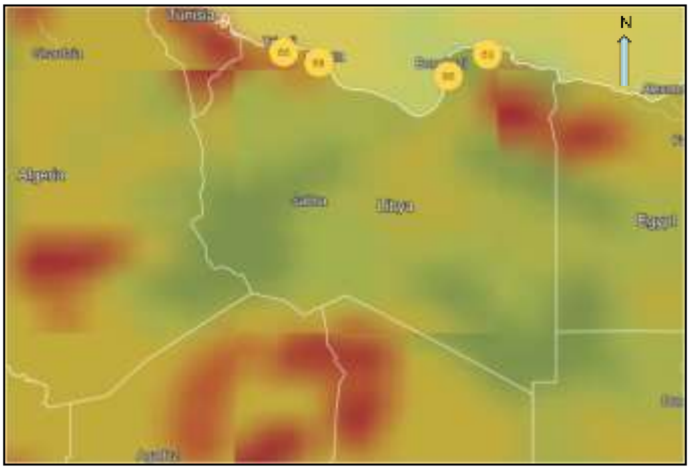


Fig. 2. Location map of the studied areas and stations in Libya (IQAir,2025).

Table 1

AirVisual Outdoor (AVO) monitoring station description**.**

Parameters	Functions
PM_1	0-1,000 μm/m³ =**10** μm/m³ / or =10%
$PM_{2.5}$	0-1,000 μm/m³ =10 μm/m³ / or =10%
PM_{10}	0-1,000 μm/m³
CO_2	Requires optional module
T	-40 to 90°C
Humidity	0-100 %
Data display	Airvisual app
Usage	Web dashboard

Table 2

Monthly average concentration of $PM_{2.5}$, PM_{10}, AQI (concentrations in μg/m³), temperature (C°), and humidity (%) in Benghazi city**.**

Parameters	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov
AQI	83	115	81	145	87	85	72	74	76	83	90
$PM_{2.5}$	26	31	25	34	28	27	21	21	23	26	30
PM_{10}	113	183	113	243	98	84	53	56	55	72	75.6
$PM_{2.5}/PM_{10}$	0.23	0.17	0.22	0.14	0.29	0.32	0.4	0.38	0.42	0.36	0.4

Table 3

Monthly average concentration of $PM_{2.5}$, PM_{10}, AQI (concentrations in µg/m^3), temperature (C°) and humidity (%) in Al Byada city.

Parameters	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov
AQI	57	76	0	63	62	65	58	60	59	60	67
$PM_{2.5}$	13	22	0	15	15.2	16.6	13	14	13.5	14	17
PM_{10}	28	53	0	36	52	60	40	56	55	34	80
$PM_{2.5}/PM_{10}$	0.46	0.42	0	0.42	0.29	0.28	0.33	0.25	0.25	0.41	0.21

Table 4

Monthly average concentration of $PM_{2.5}$, PM_{10}, AQI (concentrations in µg/m^3), temperature (C°), and humidity (%) in Zliten city.

Parameters	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov
AQI	111	102	140	102	103	88	72	66	73	76	76
$PM_{2.5}$	39	34	46	36	36.6	29	21	17	21	22.6	22.3
PM_{10}	176	122	233	141	151	110	45	39	63	61	48
$PM_{2.5}/PM_{10}$	0.22	0.28	0.2	0.26	0.24	0.26	0.47	0.44	0.33	0.37	0.46

Table 5

Monthly average concentration of $PM_{2.5}$, PM_{10}, AQI (concentrations in µg/m^3), temperature (C°), and humidity (%) in Tripoli city.

Parameters	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov
AQI	83	111	67	70	81	80	69	69	67	66	71
$PM_{2.5}$	26	22	18	19	22	21	19	18.7	17.6	17	19
PM_{10}	81	175	60.6	62	61	64	40	32	38	40	48
$PM_{2.5}/PM_{10}$	0.32	0.13	0.3	0.31	0.36	0.33	0.48	0.58	0.46	0.43	0.56

3.1. The ratio of mass concentration of particulate matter (PM)

The ratio of $PM_{2.5}$ to PM_{10} was calculated to identify the main contributors to mass concentration across different months and seasons. When the ratio is greater than 0.4, fine particles dominate the atmosphere, whereas a ratio lower than 0.4 indicates the predominance of coarse particles in the atmosphere. (Pratap et al., 2020). Based on the $PM_{2.5}$/ PM_{10}, coarse particles dominated in all periods in Benghazi city except during September when the fine particles were more prevalent (Fig. 3). In Al Bayda city, the ratio indicated a dominance of fine particles during January, February and October, while reaming months were characterized by coarse particles (Fig. 4). In Zliten city, the coarse particles were more dominate throughout the year except November (Fig. 5). In Tripoli city, the fine particles prevailed January to June while from July to November the coarse particles increased in atmosphere(Fig. 6).

The $PM_{2.5}/PM_{10}$ ratio is a crucial indicator for identifying the dominance of air pollution (Fares *et al.*, 2023). The air pollution sources can generally be categorized into three types: natural sources, mixed sources, and anthropogenic sources (Huang et al., 2014). In Benghazi city, air pollution was primarily influenced by natural sources (sand and dust storms and dust road) except September, when mixed sources were dominant (Fig. 7). In Al Bayda city, the air pollution was mainly influenced by mixed sources (natural and anthropogenic sources) during January, February, April and October, while the natural sources prevailed during the reset of months. (Fig. 8). In Zliten city, natural sources dominated air pollution throughout most of the year, except July, August, and November when they contributed significantly (Fig. 9). In Tripoli city, air pollution was largely attributed to natural sources, except during November, when mixed sources were more evident. In general, pollutants originating from natural sources influenced the studied areas (Fig. 10). This is primarily due to the Libyan desert climate, which plays a significant role in the transport and dispersion of pollutants. Additionally, the scarcity of vegetation across the country exacerbates this impact, as the limited plant cover reduces the natural ability of the environment to capture and mitigate dust and particulate matter in the atmosphere (NASA, 2012; Elalam *et al.*, 2017) (Figs. 11-12).

The correlation coefficient between $PM_{2.5}$ and PM_{10} in the studied area showed a strong positive correlation (r=0.88,0.9 and 0.80) in Benghazi, Al Byada and Zliten cities whereas a moderate positive correlation was observed in Tripoli city, this suggests that the $PM_{2.5}$ and PM_{10} were came from similar sources (Fig.13). The presence of coarse particles related to natural pollution in the atmosphere is confirmed by a low $PM_{2.5}/PPM_{10}$ ratio, whereas the presence of fine particles linked to anthropogenic pollution is confirmed by a high $PM_{2.5}/PM_{10}$ ratio (Gulnur et al., 2018; Kwanma et al., 2019).

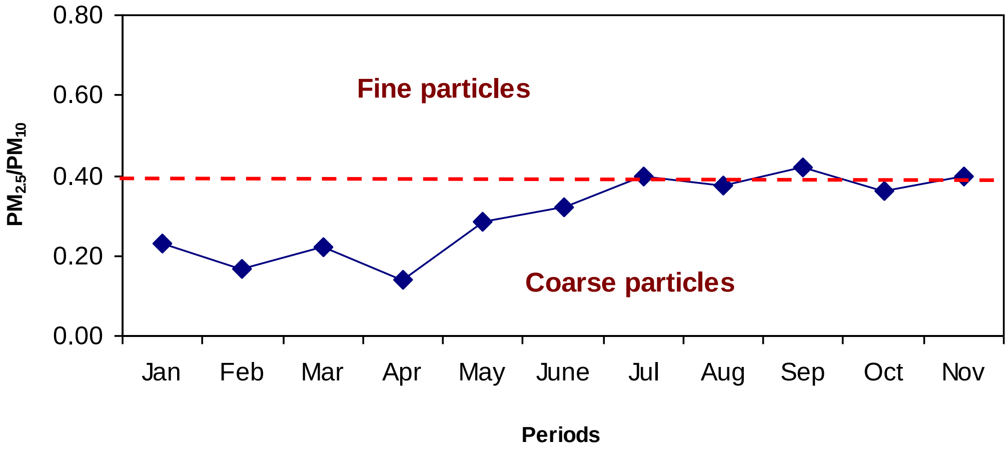


Fig.3. Particle classification based on the $PM_{2.5}/PM_{10}$ ratio in Benghazi city (fields after Pratap *et al.*,2020)**.**

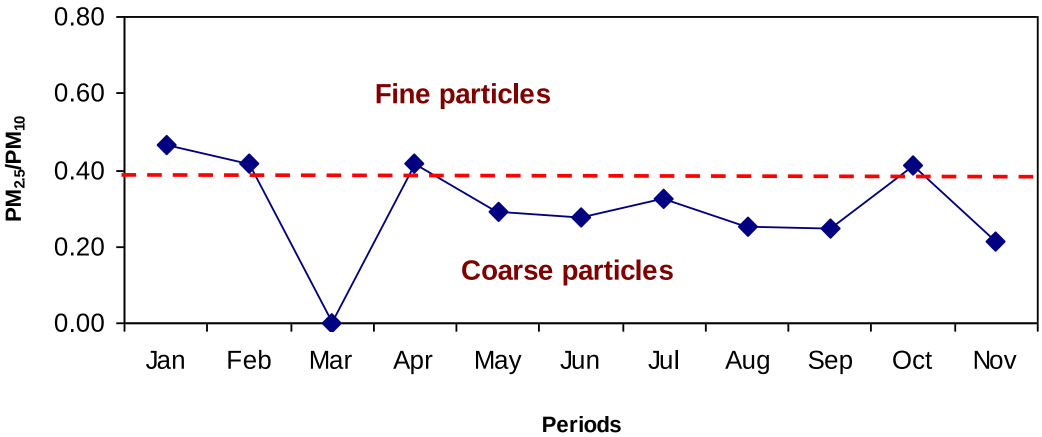


Fig.4. Particles classification based on the $PM_{2.5}/PM_{10}$ ratio in Al Byada city (fields after Pratap *et al.*,2020).

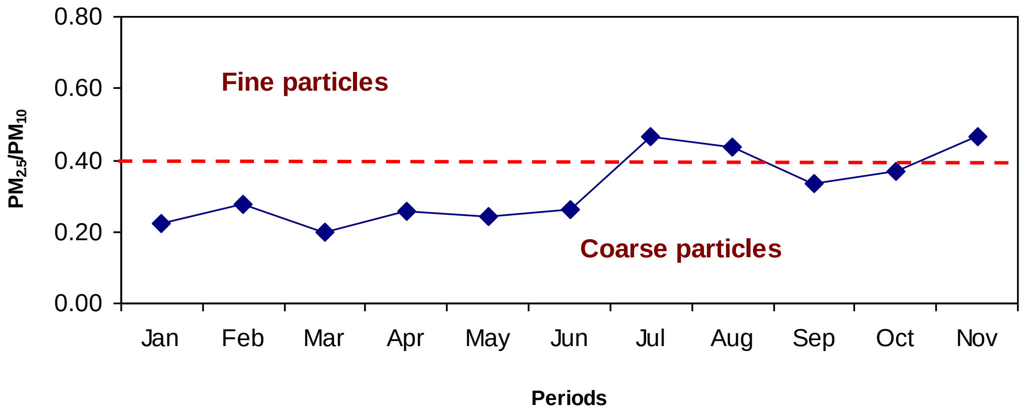


Fig.5. Particles classification based on the $PM_{2.5}/PM_{10}$ ratio in Al Byada city (fields after Pratap *et al.*,2020).

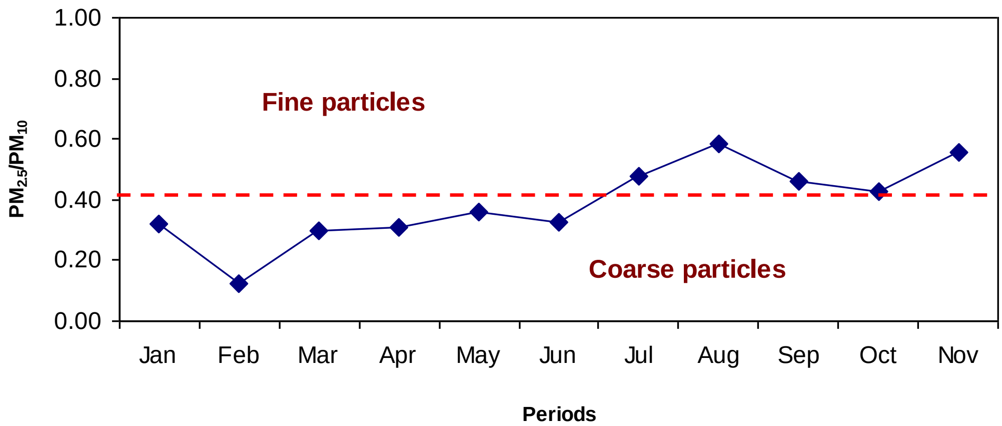


Fig.6. Particles classification based on the $PM_{2.5}/PM_{10}$ ratio in Al Byada city (fields after Pratap *et al.*,2020).

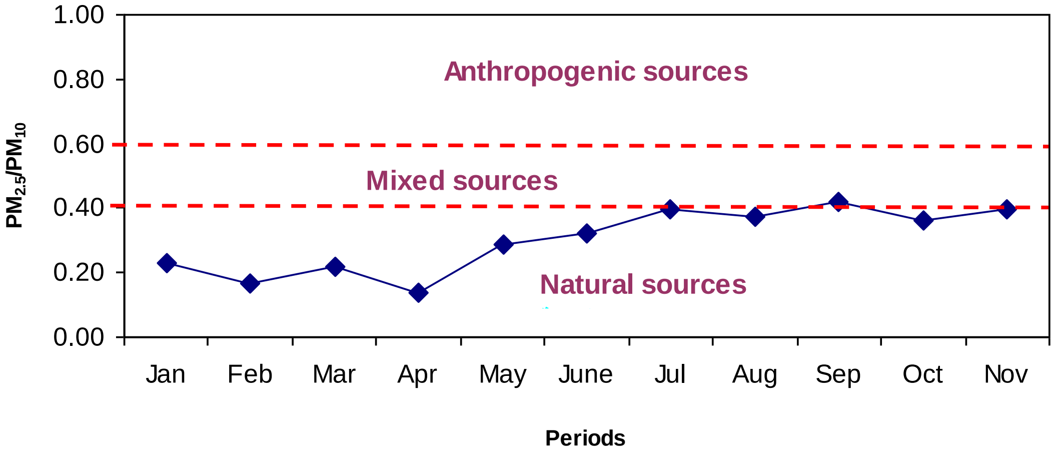


Fig.7. Air pollution sources based on the $PM_{2.5}/PM_{10}$ ratio in Benghazi city (fields after Huang *et al.*, 2014)

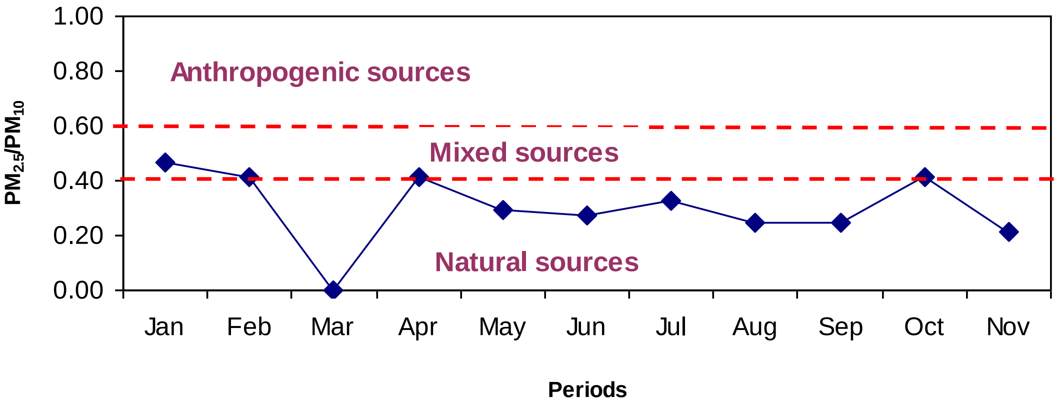
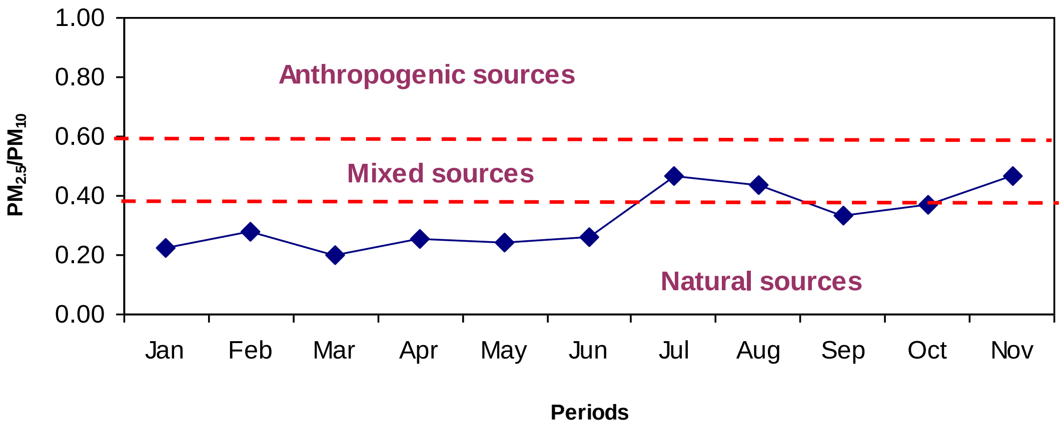


Fig.8. Air pollution sources based on the $PM_{2.5}/PM_{10}$ ratio in Al Byada city (fields after Huang *et al.*, 2014).



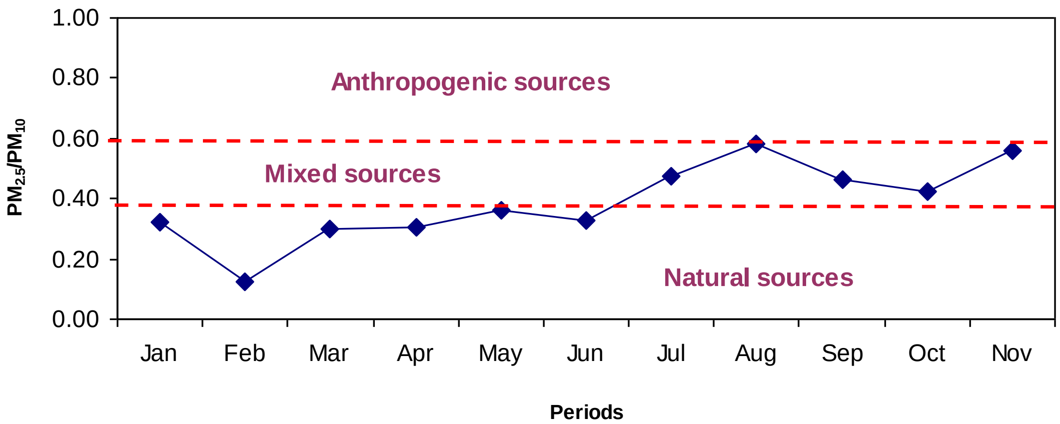


Fig.10. Air pollution sources based on the $PM_{2.5}/PM_{10}$ ratio in Tripoli city (fields after Huang *et al.*, 2014).

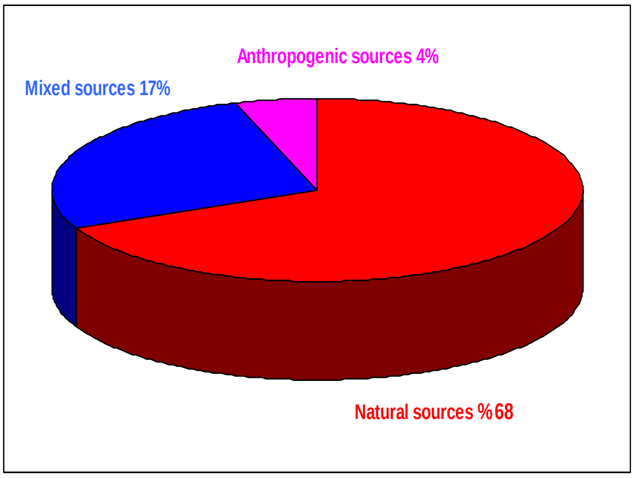


Fig.11. Shows the studied area was mainly affected by natural pollution**.**

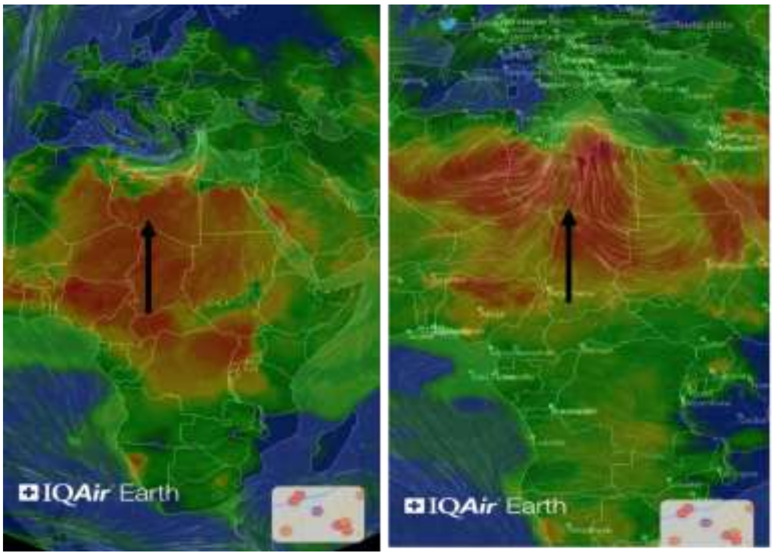


Fig.12. IQAir map for air pollution showing Libya affected by dust events during February and May periods in 2024 (IQAir,2024).

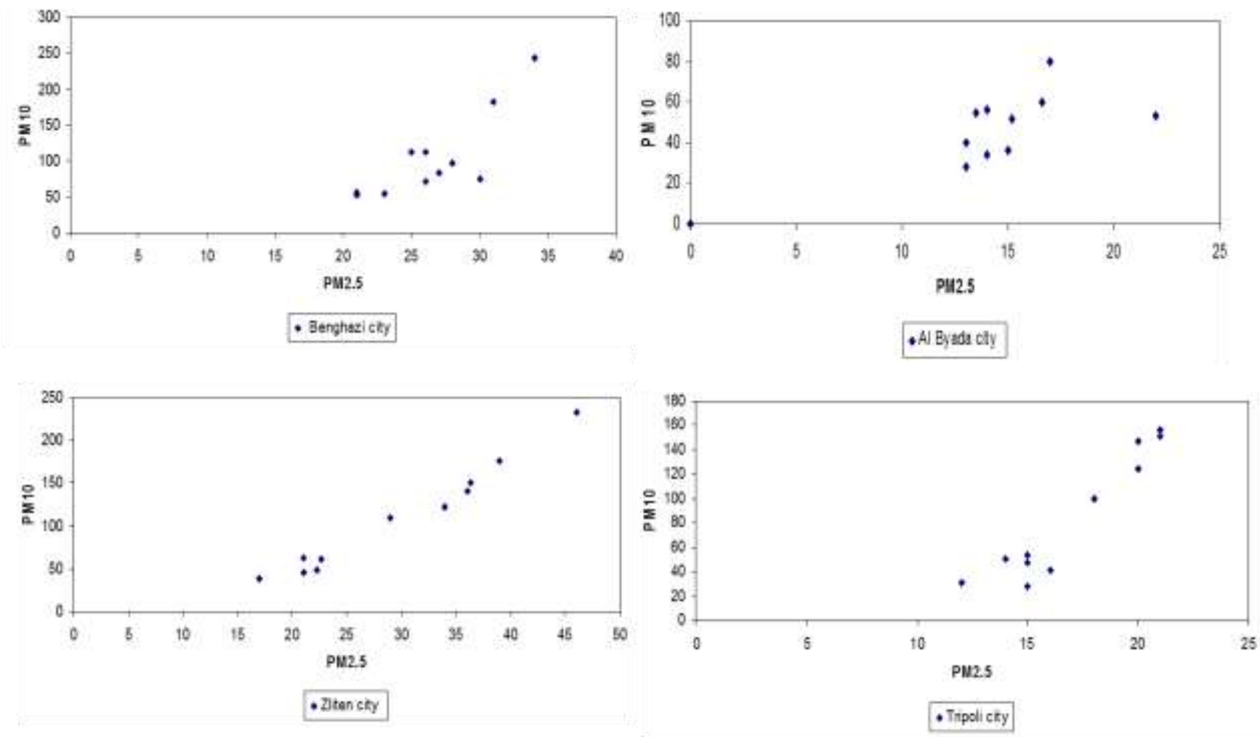


Fig.13. Relationship between $PM_{2.5}$ and PM_{10} in the studied areas

3.2. Air Quality Index (AQI)

The AQI is divided into ranges, these ranges are numbered and then marked with color codes, and each color determines the level of health concern and its meaning. The ranges are from a healthy standard level of zero to a hazardous level of above 300, which indicates the level of health risk associated with air quality. Table 6 below shows six major classifications, which are designated by a color code, levels of health concern, and also levels of air pollution (US EPA, 2014). According to the results, The AQI in Benghazi city during March and May periods reached level 3 (unhealthy for sensitive groups) whereas the rest periods were classified as level 2 (moderate) (Fig.14). In Al Byada city, the AQI remained at level 2 (moderate) throughout all period of the study (Fig.15). In Zliten city, the AQI was from January to May in level 3 (unhealthy for sensitive groups) while the reset periods were in level 2 (moderate) (Fig.16). In Tripoli city, the AQI June was recorded at level 3 (unhealthy for sensitive groups) while other period was in level 2(moderate) (Fig.17). Based on the findings, Zliten was identified as the most polluted city among the studied areas due to the lack of infrastructure and afforestation in the city.

Table 6. AQI values, concentration color codes, and air pollutant level of health concern (US EPA, 2014).

AQI value of index	Level 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

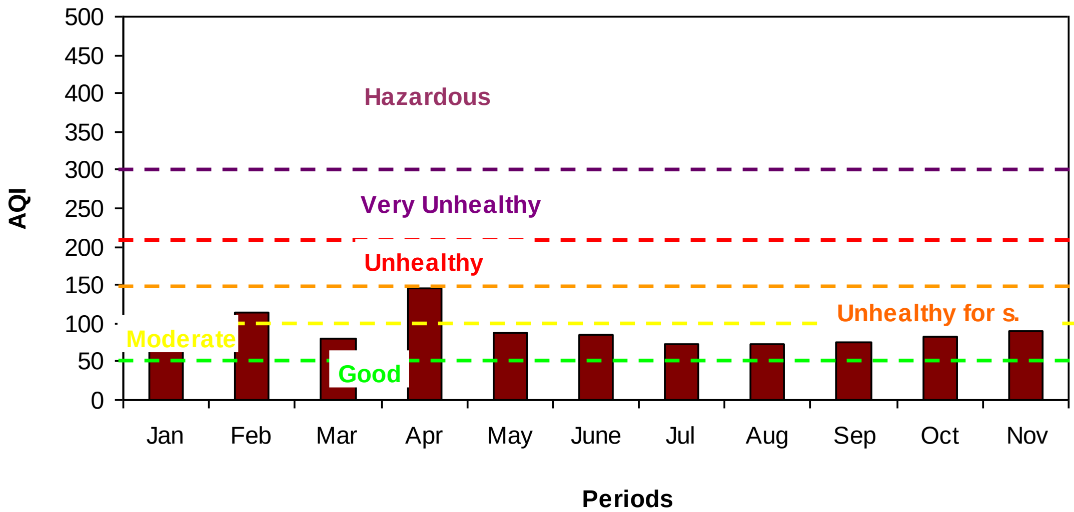


Fig.14.Monthly average concentrations of AQI in Benghazi city (US EPA, 2014).

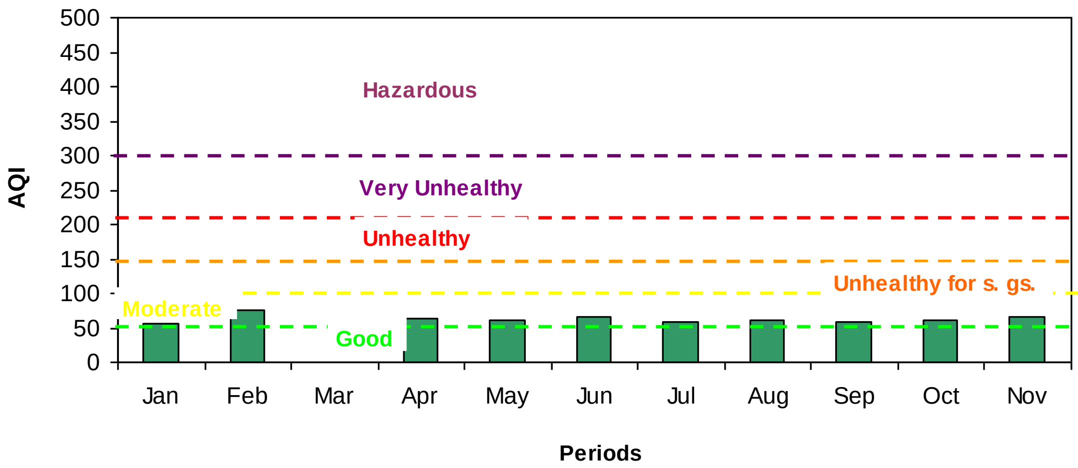


Fig.15. Monthly average concentrations of AQI in Al Byada city (US EPA, 2014).

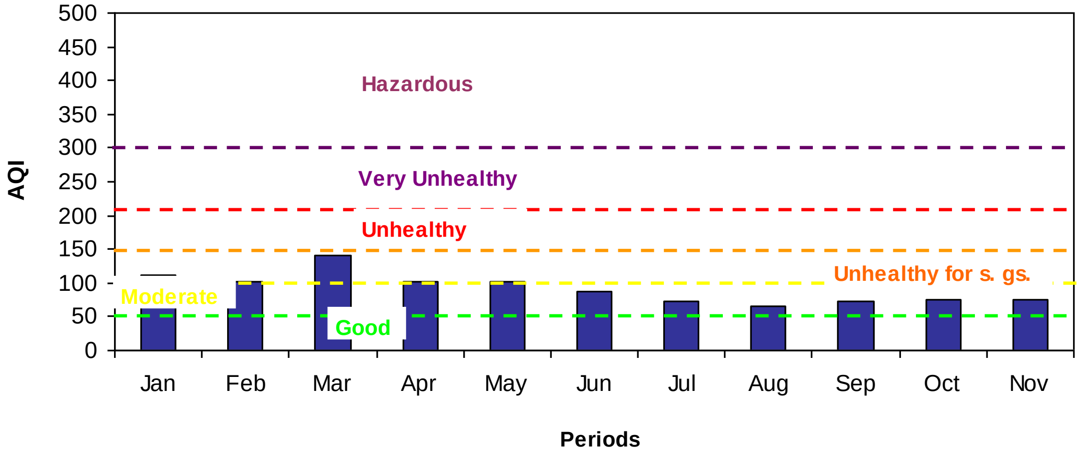


Fig.16. Monthly average concentrations of AQI in Zliten city (US EPA, 2014).

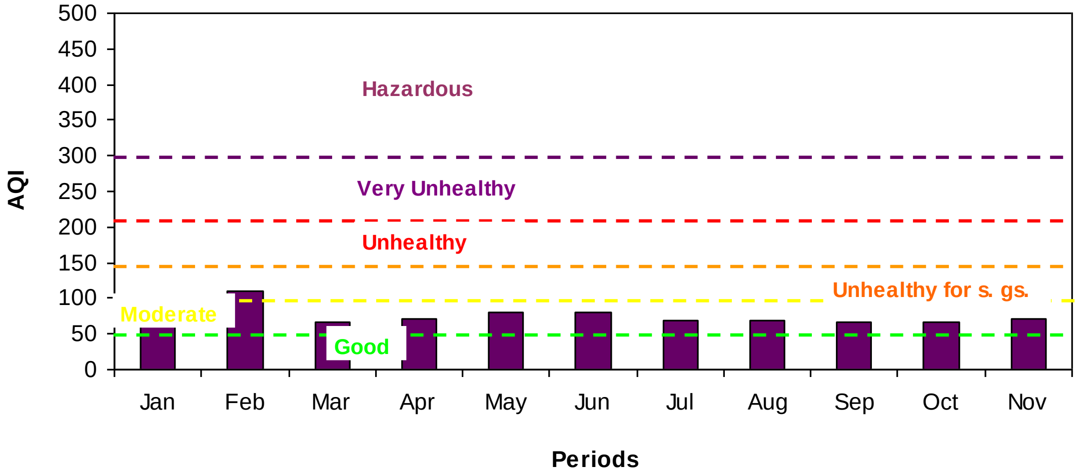


Fig.17. Monthly average concentrations of AQI in Tripoli city(US EPA, 2014).

3.3. Concentration of Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is the most significant long-lived greenhouse gas produced by human activities, exceeding other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) in its contribution to long-term climate change. Approximately half of the CO_2 emitted by human activities remains in the atmosphere, while the rest is absorbed by natural carbon sinks, including oceans and terrestrial ecosystems such as forests (CSIRO, 2023; Ballantyne et al., 2012). These sinks collectively absorb around half of anthropogenic emissions, but the remaining portion accumulates in the atmosphere and contributes to rising global temperatures (Planète É., 2024). Because CO_2 persists in the atmosphere for long periods, its climatic effects can last for centuries, meaning that current emissions will continue to influence global temperatures far into the future.

The concentration of atmospheric carbon dioxide (CO_2) has increased significantly in recent decades. The global average CO_2 concentration was about 417 parts per million (ppm) in 2019, and it increased to approximately 441 ppm in 2024 (Fig. 18). This rapid rise is considered unprecedented in modern climate records and is a major driver of global climate change. The increase in greenhouse gas concentrations has contributed to extreme climate events, including severe heat waves and large wildfires in several regions of the world.

This rise in CO_2 levels is primarily caused by human activities such as the burning of fossil fuels, deforestation, and insufficient implementation of sustainable development practices, all of which contribute to global warming.

Monitoring stations in Libya recorded an average CO_2 concentration of approximately 441 ppm in 2024, while the global average concentration reported by IQAir was about 444 ppm (Fig. 19). The close similarity between these values indicates that the CO_2 concentration in Libya is nearly equivalent to the global average. Furthermore, Libya, like many developing countries, is affected by greenhouse gas emissions largely originating from industrialized nations, highlighting the global nature of climate change and atmospheric pollution (NASA., 2023).

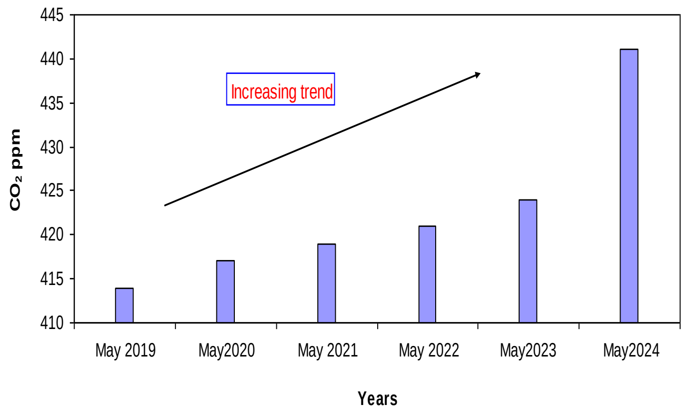


Fig. 18. Average global annual carbon dioxide concentration from 2019 to 2024.

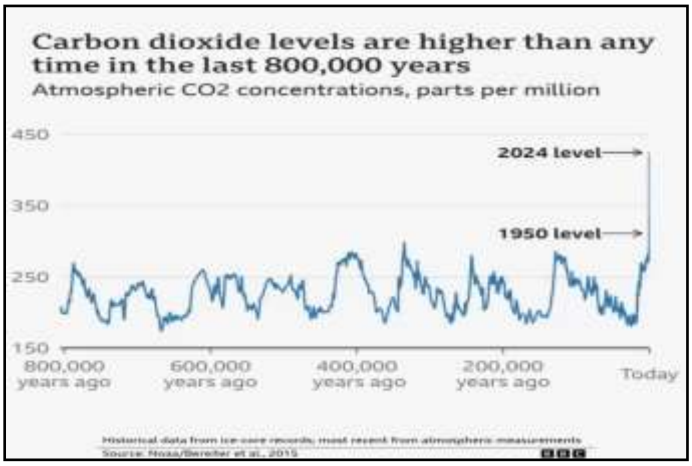


Fig. 19. Global emission of CO_2 in the atmosphere (IQAir, 2025 b).

4. Conclusions:

- AirVisual Outdoor monitors were used in this study to measure air quality parameters, including AQI, $PM_{2.5}$, PM_{10}, and CO_2 in the selected study areas.
- Zliten city was identified as the most polluted area among the studied locations. This may be attributed to inadequate infrastructure and the lack of afforestation, whereas Byada city was found to be the least polluted.
- The $PM_{2.5}/PM_{10}$ ratio indicated that **coarse** particulate matter had a higher distribution in the atmosphere.
- Based on the $PM_{2.5}/PM_{10}$ ratio, natural pollution sources appear to be more dominant in the studied cities.
- According to the correlation coefficient analysis**,** $PM_{2.5}$ and PM_{10} showed a strong positive correlation**,** suggesting that both pollutants likely originate from similar emission sources**.**
- Afforestation within and around urban areas is recommended as an effective strategy to improve and maintain better air quality**.**

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