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Analysis of the Impact of Saharan Dust in the Rural Areas of Brezovica and the Concentration of PM10, PM2.5, NO2, O3, SO2, and CO

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ABSTRACT

Brezovica, a well-known winter tourist destination in Kosovo, is the subject of this study. The skiing area is located on the slopes of the Sharri National Park, encompassing a territory of 39,000 hectares with alpine mountainous terrain and forests rich in flora and fauna. Although known for its clean air, warm African air masses occasionally bring Saharan dust, particularly during the spring and summer seasons.

This study analyzes standard monitoring data to assess pollution levels in an area devoid of anthropogenic factors that could degrade air quality. Parameters measured during the study include SO2, CO, NO2, O3, PM10, and PM2.5, expressed in μg/m³, and CO in mg/m³, based on the 2008/50/EC directive for ambient air quality and Law No. 08/L-025 for air pollution protection.

The results indicate an increase in PM10 and PM2.5 levels during periods when warm air masses originating from Africa or the Sahara are present.

Keywords: Air quality, measurement, Brezovica, winter tourism, pollution analysis, Saharan dust, air pollution, monitoring data, anthropogenic factors, PM10, PM2.5

INTRODUCTION

Brezovica, a renowned winter tourism destination located within the slopes of the Sharri National Park in Kosovo, is increasingly recognized for its environmental significance. Spanning over 39,000 hectares, the region's alpine terrain, lush forests, and diverse flora and fauna make it a vital natural habitat. Despite its reputation for clean mountain air, the area is occasionally affected by external meteorological phenomena, such as the arrival of warm air masses from Africa, carrying Saharan dust, particularly during the spring and summer seasons. This study aims to assess the air quality in Brezovica, with a particular focus on analyzing pollution levels in a region that lacks significant anthropogenic factors typically associated with air quality degradation. The investigation was based on data collected from standard monitoring systems, measuring pollutants such as sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM10 and PM2.5), following the guidelines set by the European Directive 2008/50/EC on ambient air quality, as well as Kosovo's Law No. 08/L-025 on air pollution protection. Although Brezovica does not have significant industrial or urban pollution sources, the findings show sporadic increases in particulate matter (PM10 and PM2.5), particularly during periods when Saharan dust is transported to the region by warm air currents. This raises important considerations about the impact of natural transboundary pollution in otherwise clean and remote areas. By monitoring and analyzing air quality in Brezovica, the study contributes to a deeper understanding of environmental conditions in Kosovo's protected natural zones and highlights the importance of continuous air quality monitoring in mitigating potential health and environmental risks.

MATERIAL AND METHODS

Airquality monitoring in Brezovica is conducted through an automatic monitoring station, which is fully equipped and compliant with both European Union directives and local laws, including Kosovo's Law on Air Pollution Protection (AMMK, 2019). This station measures key pollutants such as PM10, PM2.5, SO2, NO2, O3, and CO, along with meteorological parameters. The monitoring system collects data continuously, recording readings every second, and aggregates the results into hourly averages for each parameter.

The station operates under the Hydrometeorological Institute of Kosovo (IHMK) and is part of the national air quality monitoring network. Data from this station are also integrated into the European Air Quality Index (EEA, 2022), allowing for real-time tracking and comparison of air quality across Europe.

To measure pollutant concentrations, the station uses standard methods approved by European regulations. These methods include:

- **SO_2: EN 14212 - ultraviolet fluorescence**
- **NO_2 and NOx: EN 14211 - chemiluminescence**
- **CO: EN 14626 - non-dispersive infrared spectroscopy**
- **O_3: EN 14625 - ultraviolet photometry**
- **PM10: EN 12341 - beta attenuation (Sharp) and optical methods (Grimm M180)**
- **PM2.5: EN 12341 - gravimetric method**

This monitoring ensures that Brezovica's air quality is assessed using reliable, standardized methods, contributing to accurate data collection for pollution control and environmental protection.

Table 1. Ranges of the concentrations in the Kosovo Air Quality Index (AQI) for selected pollutants (EEA n.d., QRK 2011) (Hapësinor, 2011)

Table 1. The table is taken from the European Directives of 21 May 2008 and 15 December 2004, other in part with Directive 2015/1480, articles for monitoring, information and action. (IHMK, 2022)

Pollutant	Index level (based on pollutant concentrations in μg/m³)					
	Good	Fair	Moderate	Poor	Very poor	Extremely poor
Particles less than 2.5 μm (PM2.5)	0-10	10-20	20-25	25-50	50-75	75-800
Particles less than 10 μm (PM10)	0-20	20-40	40-50	50-100	100-150	150-1200
Nitrogen dioxide (NO_2)	0-40	40-90	90-120	120-230	230-340	340-1000
Ozone (O_3)	0-50	50-100	100-130	130-240	240-380	380-800
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-750	750-1250

RESULTS AND DISCUSSION

The results of pollutant substances for the parameters SO2, NO2, O3, CO, PM10, and PM2.5 in the air are presented in terms of annual average concentration, 24-hour exceedances, 8-hour exceedances, and 1-hour exceedances from Table 2 to Table 7. Meanwhile, from Table 8 to Table 18, the concentrations of PM10 and several meteorological parameters such as temperature, humidity, wind speed, and precipitation are presented.

Table 2: Values Recorded During the Year 2019 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average Table 2: Values Recorded During the Year 2019 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average; Table 3: Values Recorded During the Year 2020 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average; Table 4: Values Recorded During the Year 2021 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average.; Table 5: Values Recorded During the Year 2022 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average; Table 6: Values Recorded During the Year 2023 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average.; Table 7: Values Recorded During the Year 2024 These values represent the annual average, 24-hour average, 8-hour average, and 1-hour average;

Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	2.4 μg/m3	0		
$PM_{2.5}$	2.1 μg/m3			
NO_2	1.7 μg/m3			0
SO_2	1.1 μg/m3	0		0
O_3	64.1 μg/m3		0	
CO	0.5 mg/m3		0	

Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	7.6 μg/m3	1		
$PM_{2.5}$	5.7 μg/m3			
NO_2	1.5 μg/m3			0
SO_2	3.8 μg/m3	0		0
O_3	92.4 μg/m3		18	
CO	0.3 mg/m3		0	

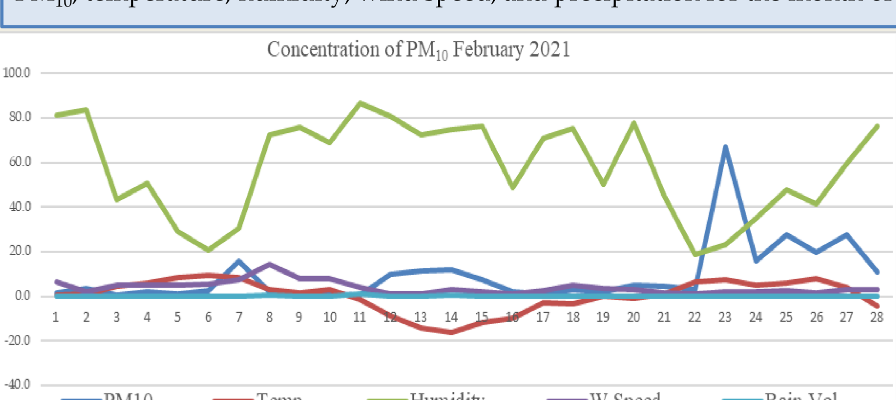
Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	11.7 μg/m3	0		
$PM_{2.5}$	7.9 μg/m3			
NO_2	3.5 μg/m3			0
SO_2	2.3 μg/m3	0		0
O_3	81.2 μg/m3		6	
CO	0.7 mg/m3		0	

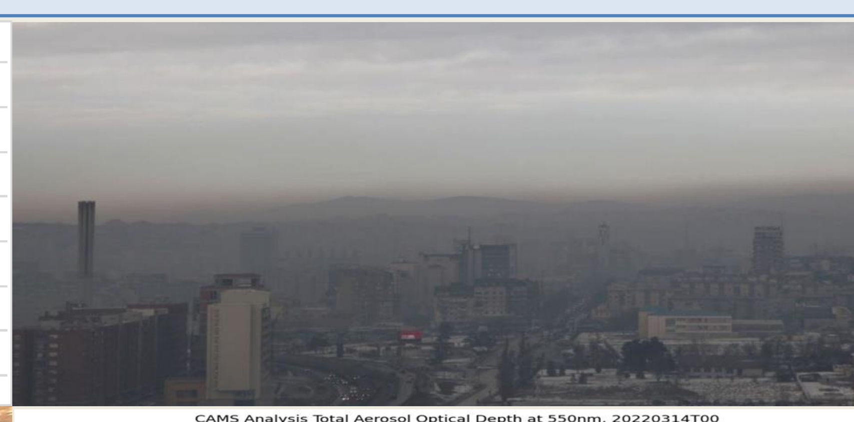
Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	10.4 μg/m3	2		
$PM_{2.5}$	7.3 μg/m3			
NO_2	1.5 μg/m3			0
SO_2	5.2 μg/m3	0		0
O_3	81.7 μg/m3		12	
CO	0.6 mg/m3		0	

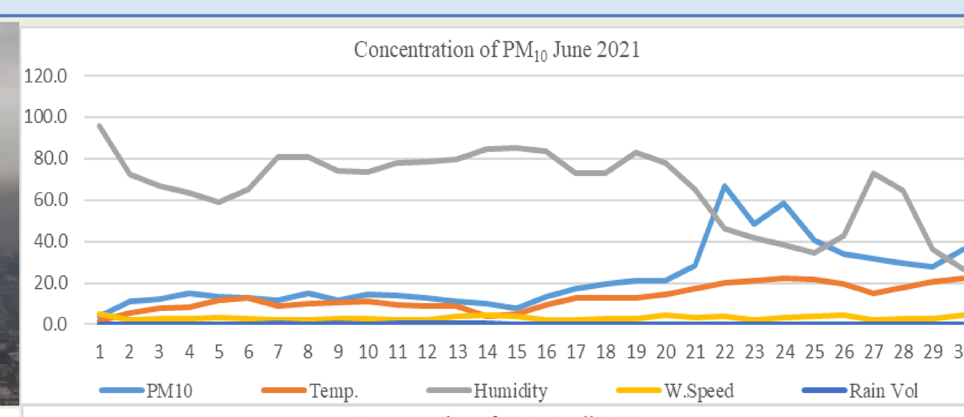
Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	10.5 μg/m3	1		
$PM_{2.5}$	8.0 μg/m3			
NO_2	1.3 μg/m3			0
SO_2	4.5 μg/m3	0		0
O_3	85.1 μg/m3		6	
CO	0.8 mg/m3		0	

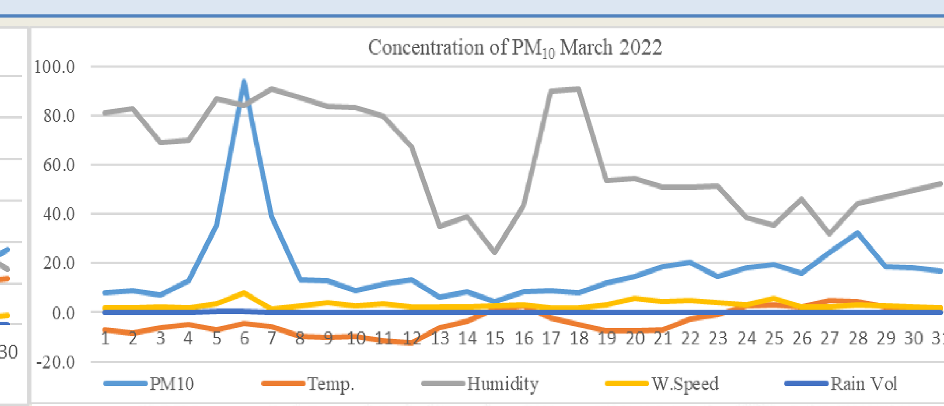
Parameter	Annual Average Concentration	24-Hour Exceedances	8-Hour Exceedances	1-Hour Exceedances
PM_{10}	10.7 μg/m3	2		
$PM_{2.5}$	7.8 μg/m3			
NO_2	0.8 μg/m3			0
SO_2	1.9 μg/m3	0		0
O_3	92.2 μg/m3		16	
CO	0.3 mg/m3		0	

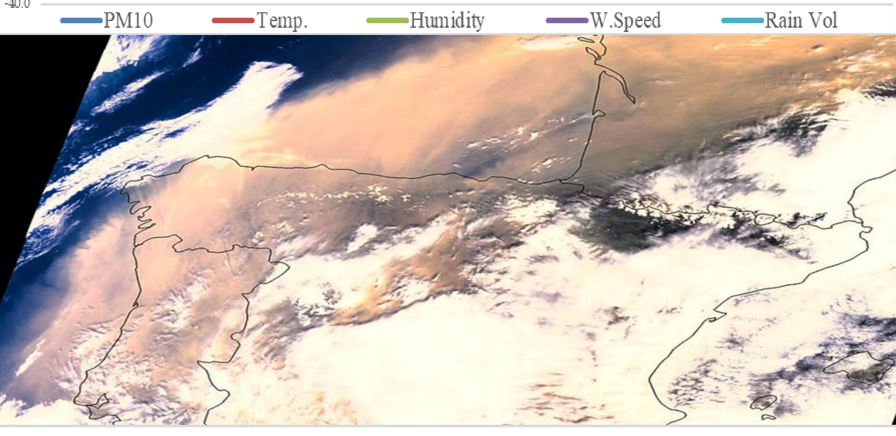
Table 8**:** Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation in February 2021; Figure 9. Prishtina under the influence of Saharan dust, February 2021 (Photo from the internet) **Figure 10:** Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation in June 2021 **Figure 11**: Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation for the month of March 2022; **Figure 12.** Record Saharan dust transport over Iberia and France on March 2022. European Union, Copernicus Sentinel 3. Iban Ameztoy (Photo Atmosphere Monitoring Service) **Figure 13:** CAMS aerosol optical depth analyses between 14-18 March 2022. Source: ECMWF/CAMS; **Figure 14**: Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation for the month of April 2022 **Figure 15:** CAMS monitors reoccurring Saharan dust transport across southern and central Europe; **Figure 16**: Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation for the month of January 2023;. **Figure 17**: Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation for the month of March 2024; **Figure 18**: Presents the concentration of PM_{10}, temperature, humidity, wind speed, and precipitation for the month of April 2024;.

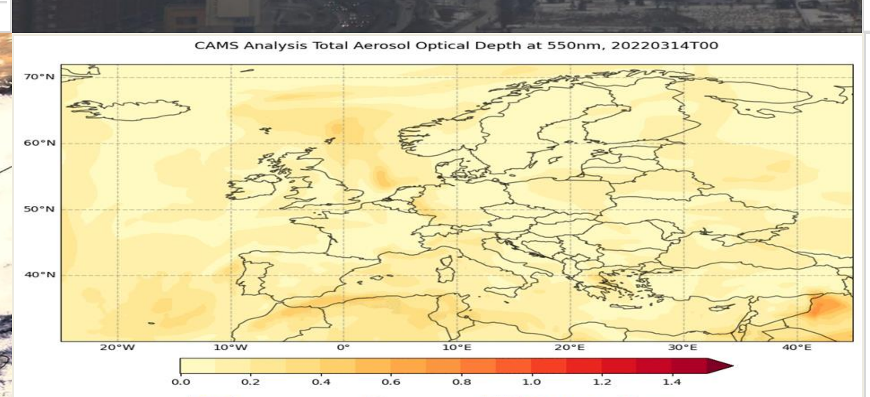


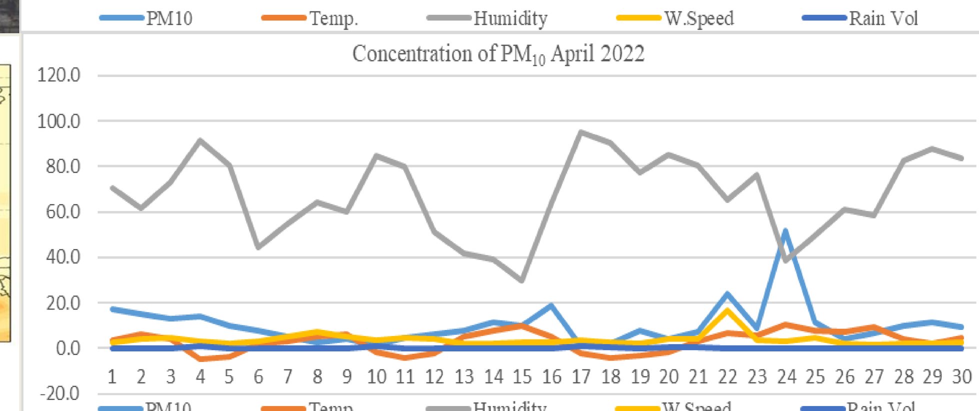


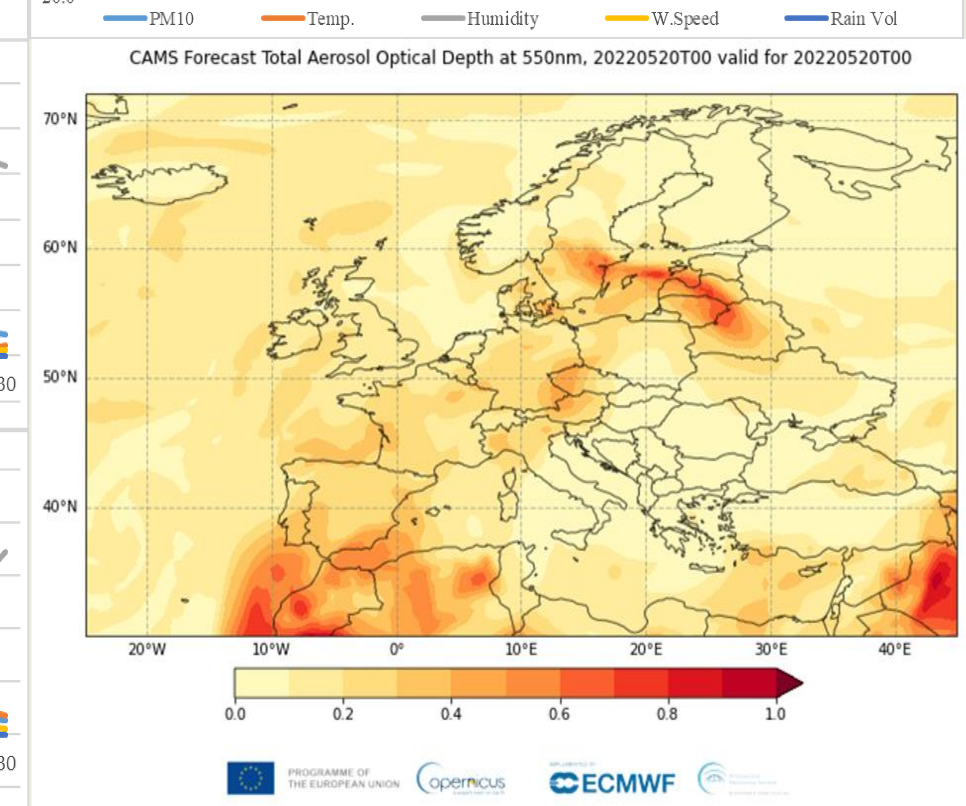


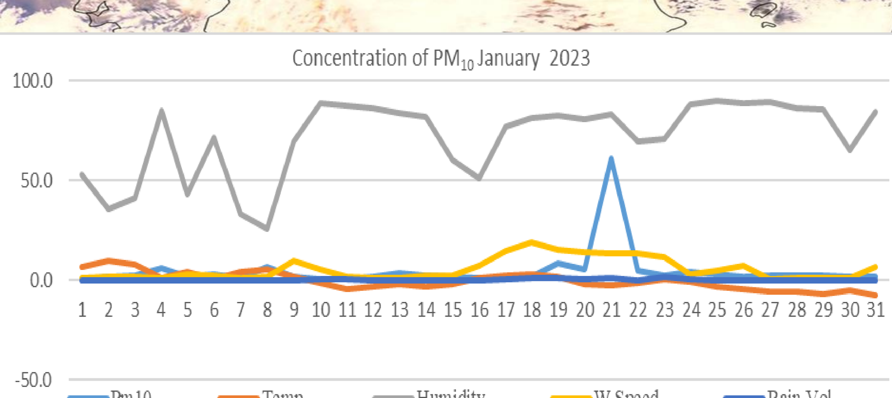


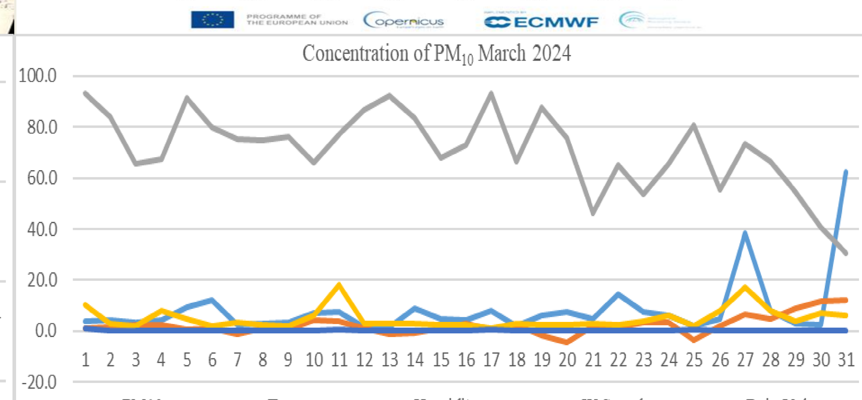


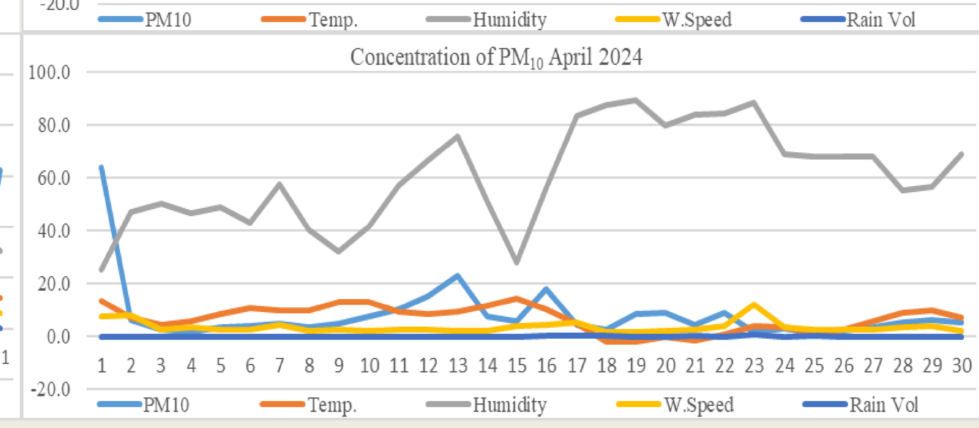












3.2.Discussion of Results

The data presented in Tables 2-7 and the corresponding figures show a significant variation in pollutant concentrations during the period from 2019 to 2024. The transport of Saharan dust has a substantial impact on air quality in Brezovica, causing increases in PM10 and PM2.5 concentrations during specific periods. PM10 and PM2.5: The concentrations of PM10have shown a slight increase from 2019 to 2024, reaching a maximum value of 10.7 μg/m³ in 2024. Meanwhile, daily PM10 concentrations have exceeded the permissible standards in several instances, particularly during the winter and spring months. This suggests the influence of seasonal factors and meteorological conditions, such as low temperatures and a lack of precipitation, which favor the concentration of particles in the air. This is especially evident in March and April 2024, where daily concentrations reached up to 62.6μg/m³ and 63.9μg/m³, respectively. Other influencing factors may include industrial activities and transportation. For PM2.5, a similar trend is observed, with an increase from 2.1 μg/m³ in 2019 to 8.0μg/m³ in 2023. This rise in fine particle pollution is a concerning indicator for air quality and public health, as PM2.5 particles penetrate deeper into the respiratory system and have a greater impact on health. Seasonal Variations: The results show significant seasonal variations in PM10 and PM2.5 concentrations, with noticeable increases during periods of Saharan dust transport. Pollution from Natural Sources: The increases in PM10 and PM2.5 concentrations during Saharan dust transport periods indicate the impact of pollution from natural sources in an area that typically has clean air. O3 and CO: Ozone (O3) concentrations are higher compared to other pollutants and have shown a significant increase from 2019 to 2020. High ozone concentrations are evident throughout the studied years, suggesting a possible impact from meteorological factors and the transport of pollutants from other regions. The highest value of 92.4 μg/m³ in 2020 suggests that atmospheric conditions favored the formation of tropospheric ozone, which is created as a result of photochemical reactions. High ozone concentrations can negatively affect both public health and local ecosystems. NO2 and SO2: NO2 concentrations have remained relatively low throughout the period, with a maximum value of 3.5μg/m³ in 2021. These results are below permissible limits and suggest that the main sources of NO2, such as road traffic and industrial activities, have not caused high pollution levels in the monitored area during this period. However, SO2 pollution has shown some fluctuations, with an increase in 2022, reaching a value of 5.2μg/m³. This may be related to increased industrial activity or the burning of sulfur-containing fuels. On the other hand, CO concentrations have consistently remained low, reaching a maximum of 0.8 mg/m³ in 2023. These low levels indicate minimal impact from sources of this pollutant, such as road traffic and the burning of fossil fuels. The concentrations of NO2, SO2, and CO have been relatively low, reflecting the absence of significant anthropogenic pollution sources in the studied area.

3.3.The Impact of Meteorological Parameters on the Transport of Saharan Dust

Meteorological parameters play a crucial role in the transport and dispersion of Saharan dust. Some of the key factors include:

Wind Speed and Direction: Strong and sustained winds are essential for lifting and transporting dust from the Sahara over long distances. High-altitude winds can carry dust to other continents. This has also been recorded in measurements taken in Brezovica, as has occurred in many countries in the Balkans and Europe. Atmospheric Pressure: Low and high-pressure systems influence the direction and intensity of winds that transport dust. For example, low pressure over the eastern Mediterranean can aid in transporting dust towards Europe. Temperature: High temperatures in the desert assist in lifting dust into the atmosphere. Temperature variations also affect atmospheric stability and the vertical distribution of dust. Humidity: Low humidity in the desert helps keep dust suspended in the air for longer periods. However, high humidity can facilitate dust deposition through precipitation. Conclusion: Meteorological parameters such as wind speed, atmospheric pressure, temperature, and humidity significantly impact the transport and dispersion of Saharan dust. These parameters also affect the concentrations of PM10 and PM2.5 during dust episodes, creating a strong connection between weather conditions and air quality.

3.4.Comparison with Air Quality Standards

When comparing the results with the standards set by the European Union and the World Health Organization for air quality, it is observed that concentrations of pollutants such as PM10 and O3 exceed permissible limits during certain periods, posing a risk to public health. This is particularly concerning during the winter and spring months, when meteorological conditions may favour the accumulation of pollutants.

CONCLUSIONS

Continuous Air Monitoring: It is essential to collect accurate and detailed data on key pollutants such as PM10, PM2.5, NO2, SO2, O3, and CO. This helps identify pollution sources and enables prompt action when pollution levels rise. Forecasting and Warning: Meteorological models are important for predicting episodes of Saharan dust transport and alerting the public to take precautionary measures. Public Education and Awareness: Awareness campaigns are necessary to educate the public about the impacts of air pollution and ways to reduce exposure to pollutants. Policies and Regulations: The implementation of strict regulations on pollutant emissions and the establishment of stringent air quality standards are essential for improving air quality.

Recommendations:

Expansion of the Monitoring Network: Improving and expanding the network of monitoring stations to cover more areas and provide more detailed and accurate data. Use of Advanced Sensors: Implementing advanced sensors to monitor and control pollution in real-time. Precautionary Measures during Dust Episodes: Limiting outdoor activities and using protective masks during periods of Saharan dust transport. Awareness Campaigns: Organizing awareness campaigns to educate the public about the impacts of air pollution and ways to reduce exposure to pollutants. Strict Emission Regulations: Enforcing strict regulations on pollutant emissions and establishing rigorous air quality standards.

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•Meteorological effects on particulate matter PM10, PM2.5 concentrations with diurnal and seasonal variations in cities neighboring desert lands.

•Analysing PM2.5 and its Association with PM10 and Meteorology in the Arid Climate of Makkah, Saudi Arabia.