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Breathing Through Time: 9 Years Apart - Assessing and Comparing Air Quality in Khulna, Bangladesh: 2013 to 2021

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ABSTRACT

This study investigates the dynamics of air quality and pollutant concentrations in Khulna Division over a nine-year period, from 2013 to 2021. Focusing on particulate matter (PM), sulfur dioxide (SO_2), carbon monoxide (CO), and ground-level ozone (O_3). Through an assessment conducted over these nine years, it was observed that during the dry season, air quality consistently exceeded standard limits, while during the wet season, it remained within acceptable levels. Despite governmental policies aimed at curbing air pollution, minimal improvement was noted over the years. Analysis of trends for sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO) revealed that these pollutants consistently remained within standard limits. However, PM2.5 emerged as a major contributor to poor air quality, as indicated by the calculated Air Quality Index (AQI). The air quality throughout the years was "Moderate" to Very unhealthy" in category. The findings underscore the persistent challenges in mitigating air pollution in Khulna, despite efforts to address it. This study highlights the urgent need for more effective measures to control PM2.5 emissions and improve overall air quality, emphasizing the importance of sustained policy interventions and public awareness campaigns.

KeyWords: **Air quality index, Long-term trends, Gaseous Pollutants, PM2.5**

1. INTRODUCTION

Urban areas in Bangladesh grapple with heightened levels of particulate matter in the air, particularly during the dry season spanning November to April. This period observed scarce rainfall, northwesterly winds, and low relative humidity, exacerbating air pollution. In response, the Government of Bangladesh introduced limit values for key air pollutants (such as PM, Pb, SO_2, CO, NOx, and O_3) in 2005 [1]. Among the primary pollutants, fine Particulate Matter (PM), such as PM2.5 and PM10, with aerodynamic diameters less than 2.5 µm and 10 µm respectively, exhibit notably higher concentrations in the atmosphere. These particles are major contributors to mortality stemming from respiratory, cardiovascular, and various other diseases [2]. The purity of the air is greatly compromised by emissions from industrial sectors. Among these emissions, power plants make a significant contribution to air pollution [3]. Various measures have been implemented over time to ameliorate air quality in urban regions. Khulna, a vital industrial and urban hub in Bangladesh, grapples with significant air pollution challenges stemming from various sources. One prominent contributor to air pollution in Khulna is industrial emissions. The city hosts numerous industrial facilities, including factories, power plants, and manufacturing units, which release a cocktail of pollutants into the atmosphere. These emissions typically comprise particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs) [4, 5]. Another significant source of air pollution in Khulna is vehicular emissions. With rapid urbanization and motorization, the number of vehicles on Khulna's roads has surged, leading to heightened levels of exhaust emissions. These emissions contain pollutants such as nitrogen dioxide (NO_2), carbon dioxide (CO_2), and particulate matter, contributing to the city's overall air quality deterioration [6]. Furthermore, biomass burning, including the combustion of crop residues, wood, and other biomass fuels for cooking and heating purposes, also adds to Khulna's air pollution burden [7]. These activities release fine particulate matter and other pollutants into the air, further compromising air quality. The combination of these pollution sources has led to a degradation of air quality in Khulna, with elevated levels of pollutants posing significant health risks to the city's residents. Particulate matter, in particular, has been a major concern, as exposure to fine particles can cause respiratory issues, cardiovascular diseases, and other health problems [8]. As for the present air quality in Khulna, it likely reflects a complex interplay of these pollution sources along with meteorological factors. Depending on the season, weather patterns, and local emissions, the air quality in Khulna may

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vary. Regular monitoring and assessment are essential to gauge the current state of air quality and implement effective measures to mitigate pollution levels and safeguard public health. Many studies were conducted in recent years [9-13] that asses the variation of air quality in Khulna for different particular reasons. But there are limited studies about the scenario of previous year air pollution and recent year in Khulna Division. So, this study aims to observe concentration levels variation of 4 air pollutants i.e., PM2.5, SO_2, CO, O_3 and the temperature was also observed of the year 2013 to 2021, to find out the air quality by determining air quality index (AQI) and finally to make a comparative study in order to observe how the air quality changes over these 9 years.

2. METHODOLOGY

2.1 Study Area

Khulna, positioned in the southwestern region of Bangladesh, stands as a vital urban center, situated along the banks of the Rupsha and Bhairab rivers. Its geographical coordinates are approximately 22°49′N latitude and 89°33′E longitude. The city is enveloped by neighboring districts like Jessore, Narail, Bagerhat, and Satkhira. Hosting a population of roughly 1.5 million inhabitants by 2022, Khulna serves as a pivotal nexus for commerce, industry, and transportation within the area. Much like its counterparts across Bangladesh, Khulna undergoes rapid urbanization and population surge. Its proximity to the Sundarbans, the world's largest mangrove forest, further enhances its stature as a hub for commercial and industrial activities. Despite its economic prominence, Khulna grapples with various environmental hurdles, prominently air and water pollution. The degradation of air quality poses a significant concern, propelled by emissions from industrial operations, vehicular traffic, and diverse sources. Air pollution, notably the presence of particulate matter like PM2.5, elevates health risks for Khulna's residents, mirroring challenges experienced in other urban locales across the nation. The surge in urbanization, alongside unchecked emissions from industries and automobiles, exacerbates the city's air pollution woes. The rapid expansion of Khulna's industrial sector, coupled with urban development, further strains its environment and infrastructure. Initiatives are underway to confront these environmental issues, including endeavors to enhance air quality monitoring and curb pollution sources. However, tackling pollution in Khulna remains a formidable task, necessitating collaborative endeavors from governmental bodies, industries, and the local populace.

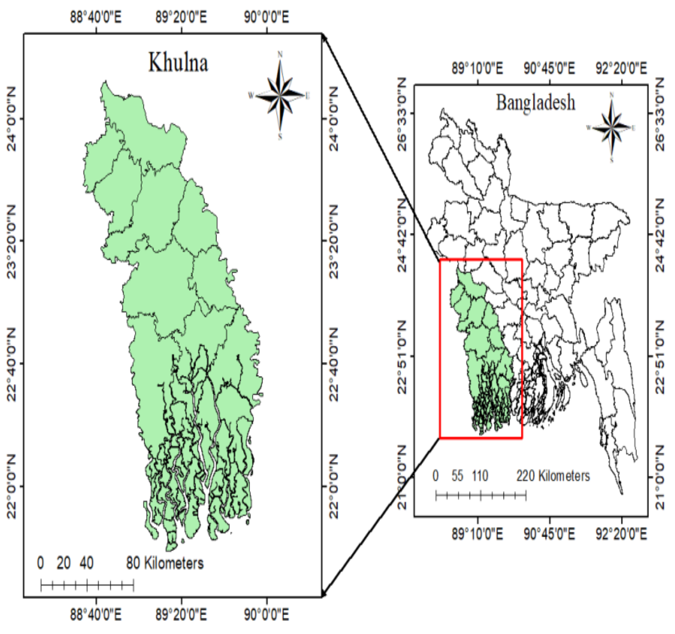

Figure 1: Study Area Map

2.2 Data Collection

The Ministry of Environment, Forest, and Climate Change [14] is the primary source for air quality parameters in Bangladesh. Through initiatives such as the Clean Air and Sustainable Environment (CASE) project, they actively monitor air quality to gauge adherence to national ambient air quality standards and track pollution trends. This monitoring involves the collection of data on various pollutants to assess their levels in the atmosphere. Additionally, MoEF provides meteorological data, including information on solar radiation, relative humidity, ambient temperature, rainfall, and other relevant factors. These comprehensive datasets aid in understanding the dynamics of

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air quality and its correlation with meteorological conditions, facilitating informed decision-making for environmental management and policy formulation. The air quality hourly data for PM2.5, SO_2, O_3, CO and temperature for the year of 2013 and 2021 was collected and analyzed using Microsoft Excel Software.

2.3 Air Quality Index (AQI)

The Air Quality Index (AQI) serves as a vital tool in gauging the overall health of the air we breathe. It consolidates multiple air pollutants into a single numerical value, providing a clear and concise assessment of air quality levels. Ranging from good to hazardous, the AQI communicates the potential health risks associated with varying levels of air pollution, empowering individuals and communities to make informed decisions about outdoor activities and protective measures. The air quality index value for the year 2013 and 2021 were determined to observe the air quality variation. For the calculation of air quality index, the concentrations of the selected parameters were used. The Air quality index of the air pollutants was then calculated using the following equation:

$$I = \frac{I_{High} - I_{Low}}{C_{High} - C_{Low}} (C - C_{Low}) + I_{Low} \quad (1)$$

Where, I represents the (air quality) index, C is the pollutant concentration, C_{Low} is the concentration breakpoint that is ≤ C, C_{High} is the concentration breakpoint that is ≥ C, I_{Low} is the index breakpoint corresponding to C_{Low} and I_{High} is the index breakpoint corresponding to C_{High}. The ambient air pollutants will be then classified into categories as presented in Table 1 and 2.

Table 1: Rating of air quality index

AQI Values	Health concern	Health Effects
0-50	Good	None
51-100	Moderate	Usually, sensitive people should consider reducing prolonged or heavy exertion.
101-150	Unhealthy for sensitive groups	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly
151-200	Unhealthy	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population
201-300	Very Unhealthy	Significant increase in respiratory symptoms and aggravation of lung disease, such as asthma; increasing likelihood of respiratory effects in general population.
301-500	Hazardous	Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population

Table 2: Air quality parameter breakpoints

AQI Category range	PM2.5 24-hr ($\mu g/m^3$)	SO_2 24-hr (ppb)	CO 8-hr (ppm)	O_3 8-hr (ppm)
0-50	0-12	0-35	0-4.4	0-54
51-100	12-35.4	35-75	4.4-9.4	54-70
101-150	35.5-55.4	75-185	9.4-12.4	70-85
151-200	55.5-150.4	185-304	12.4-15.4	85-105
201-300	150.5-250.4	304-604	15.4-30.4	105-200
301-500	250.5+	604+	30.4+	200+

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3.0 RESULTS AND DISCUSSION

3.1 Particulate Matter

These fine particles originate from various sources such as vehicle emissions, industrial processes, construction activities, and natural sources like wildfires and dust storms. Numerous research investigations have consistently demonstrated a robust correlation between exposure to elevated levels of particulate matter (PM) and the development of cardiopulmonary disease (CPD) as well as mortality from ischemic heart disease (IHD) [15]. Monitoring PM2.5 levels is crucial for assessing air quality and implementing measures to protect public health and mitigate the impacts of air pollution. Fig. 02 shows the variation of PM2.5 over 9 years. It shows that throughout the year 2013-2021, the concentration of PM2.5 is higher and cross the BNAAQS limit in the dry season (November-April). The concentration during wet season (May-October) was within the standard limit [16]. The trendline shows that the air quality in 2021 is slightly good compared to year 2013. In 2016, the concentration of PM2.5 was highest 222.81 µg/m^3 and it was above the standard limit throughout the year. Considering 2013 baseline, we have found out that there is increase of PM2.5 of 17.03%, 4.97%, 9.13%, -12.45%, 9.01%, -7.38%, -23.36% and, -19.44% from the year 2014 to 2021 respectively. Where, the positive sign indicates an increase and negative sign signifies a decrease in concentration. So, there is a gradual improvement in air quality towards 2021. Although, government has taken many actions but the improvement in air quality is very low. So, after 9 years the scenario has slightly improved but the seasonal air pollution variation is still in the same position.

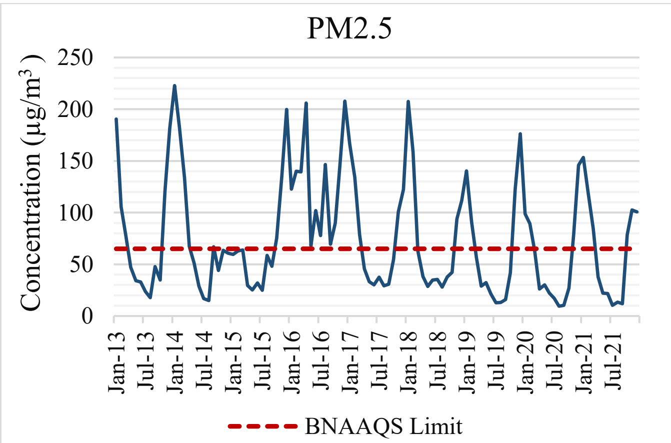

Figure 02: Variation of PM2.5 and BNAAQS limit

3.2 Gases

Sulfur dioxide (SO_2) is a byproduct of burning fossil fuels containing sulfur, such as coal and oil, in power plants and industrial facilities. contributing to respiratory issues and exacerbating conditions such as asthma and bronchitis. High levels of SO_2 can reduce visibility and contribute to the formation of haze and smog, further degrading air quality and posing risks to public health. Fig. 03 shows the variation of SO_2 from the year 2013 to 2021. The highest concentration (30.72 ppb) was found in 2013 and lowest (5.94 ppb) was in 2020. The concentrations decreased by 21.86%, 37.63%, 59.89%, 44.78%, 21.89%, 79.75%, 80.66%, and 65.69% from 2014 to 2021 compared to the concentration levels in 2013. From the figure we can also observe that the concentrations of SO_2 gas in each year was within the standards limit set by BNAAQS for air pollution.

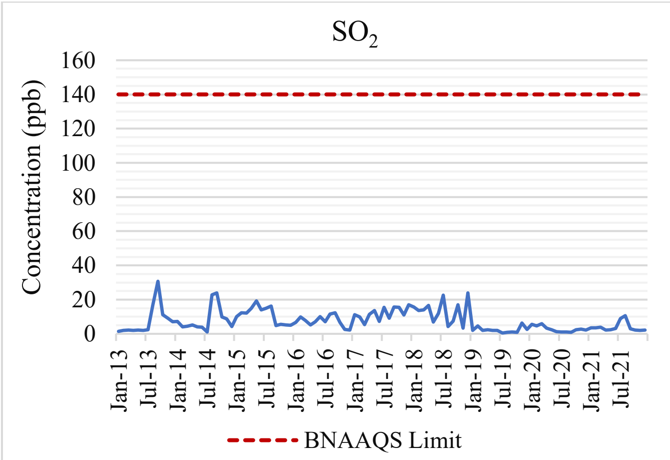

Figure 03: Variation of SO_2 and BNAAQS limit

Carbon monoxide (CO) is a colorless, odorless gas primarily produced by the incomplete combustion of fossil fuels in vehicles, industrial processes, and residential heating systems. Its presence interferes with the body's ability to transport oxygen in the bloodstream, resulting in symptoms ranging from headaches and dizziness to more severe effects such as impaired cognitive function and cardiovascular problems.

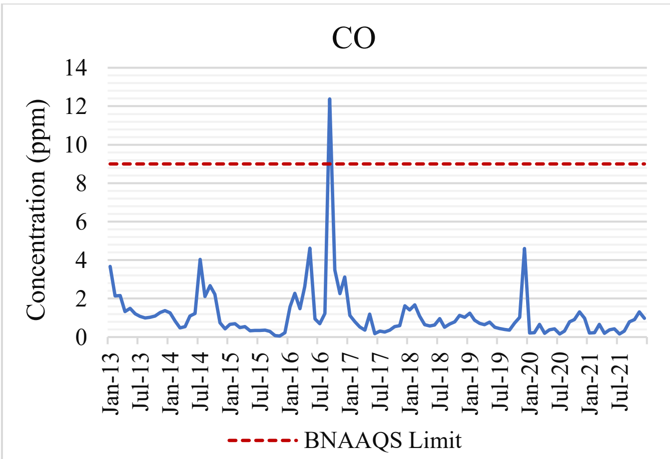

Figure 04: Variation of CO concentration from 2013-2021 and BNAAQS limit

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Fig. 04 depicts the monthly variations of CO levels from 2013 to 2021. The highest concentration was recorded in 2016 (12.38 ppm), exceeding standard limits. However, concentrations in other years remained within acceptable limits. In 2021, there was a 16.44% decrease compared to 2013. Notably, there was an 81.26% decrease in concentration observed in 2015. Additionally, there was a 57.2% increase in 2021 compared to 2020.

Ground-level ozone, resulting from the interaction of pollutants such as nitrogen oxides and volatile organic compounds with sunlight, stands as a significant element of urban air pollution. Its presence can worsen respiratory ailments, damage vegetation, and necessitate actions to curb emissions for the sake of public health and environmental preservation. Fig. 05 illustrates the monthly fluctuations of O_3 levels from 2013 to 2021, the concentration of O_3 remained within the standard limit set by BNAAQS. However, there has been a notable increase in concentration towards recent years, with 2021 registering approximately 4.5 times higher levels than those of 2013. Although the measured gaseous pollutants from 2013-2021 did not surpass the limit values of the BNAAQS, it's essential to note that their increasing trend poses potential risks despite compliance with the set standards.

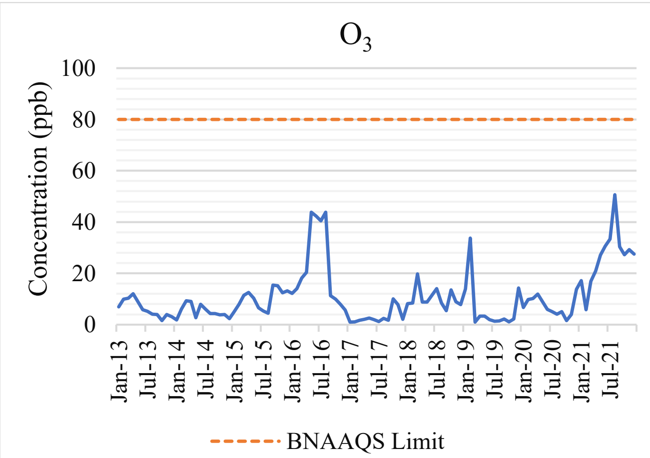

Figure 05: Variation of O_3 and BNAAQS limit

3.3 Air Quality Index (AQI)

The air quality index (AQI) of Khulna Division spanning from 2013 to 2021 has been thoroughly examined. The primary pollutant contributing to air pollution was PM2.5. Fig. 06 illustrates the fluctuation in AQI values for the respective years. During the dry season, the air quality for each year indicated an "Unhealthy" status, with the exception of 2016, which reached a "Very Unhealthy" level. Conversely, in the wet season, air quality deteriorated from 2013 to 2016, with 2016 registering as "Unhealthy." Even in the most recent year, 2021, the air quality ranged from moderate to unhealthy. This suggests a consistent pattern throughout the years. Despite various governmental initiatives to mitigate air pollution, the air quality has remained largely stagnant.

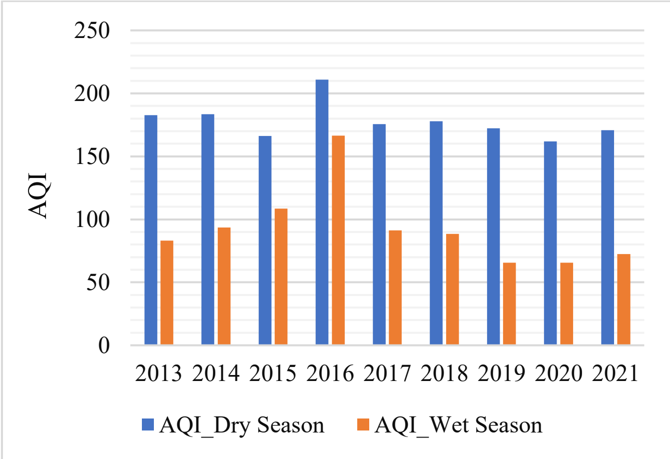

Figure 06: Air Quality Index

3.4 Relation of PM2.5 Concentration and Temperature

The relation between PM2.5 and temperature during dry season and wet season is shown in Fig. 07 and Fig. 08. In the dry season of 2013, the PM2.5 concentration measured 120.47 µg/m³ with a temperature of 23.21°C. The following year, in 2014, the concentration slightly increased to 121.83 µg/m³ while the temperature rose to 23.57°C. By 2016, both the PM2.5 concentration and temperature further escalated to 160.55 µg/m³ and 24.85°C respectively. This trend initially indicated a positive correlation between PM2.5 concentration and temperature. However, intriguingly, a contrasting pattern emerged in the subsequent years. In 2020 and 2021, during the same dry season, the PM2.5 concentration exhibited a decline despite an increase in temperature.

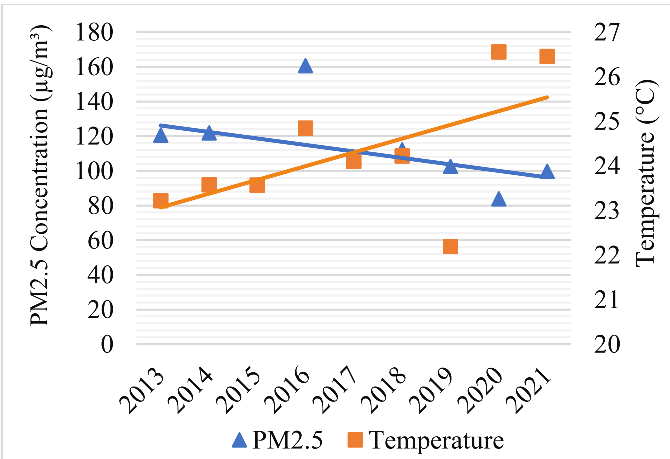

Figure 07: Variation of PM2.5 concentration and temperature in dry season

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This anomaly prompts consideration of exceptional environmental factors that could influence this relationship. Upon comprehensive analysis of the data, it becomes evident that while there exists a general trend of PM2.5 concentration increasing with temperature in the dry season, there are instances where this correlation is disrupted, likely due to unique environmental conditions.

During the wet season, notable variations in PM2.5 concentration and temperature were observed across different years. In 2013, the PM2.5 concentration stood at 31.82 µg/m³ with a corresponding temperature of 28.34°C. The subsequent year, 2014, saw a slight increase in concentration to 37.17 µg/m³ alongside a temperature rise to 28.76°C. However, the most significant spike in concentration occurred in 2016, peaking at 92.29 µg/m³ with a temperature of 28.65°C. Conversely, in the more recent year of 2020, a lower concentration of 22.90 µg/m³ was recorded when the temperature decreased to 27.52°C. Upon examination of the wet season data, a clear trend emerges: as temperature increases, so does PM2.5 concentration, and conversely, as temperature decreases, PM2.5 concentration tends to decrease as well.

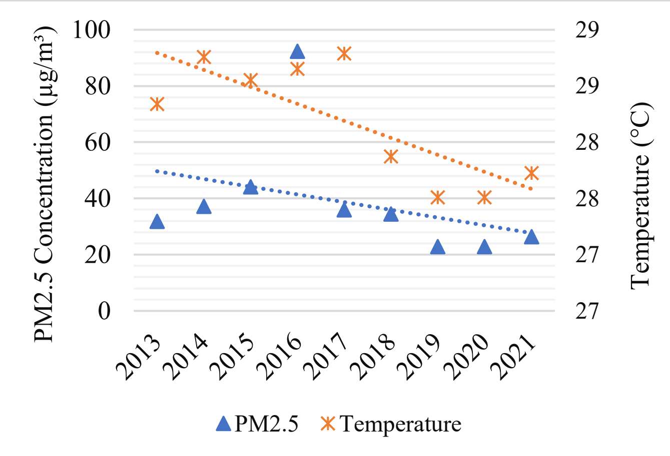

Figure 08: Variation of PM2.5 concentration and temperature in wet season

4. CONCLUSIONS

The study confirms the persistence of elevated PM2.5 levels, especially during the dry season, surpassing the air quality standards set by BNAAQS. While there has been a gradual improvement in PM2.5 levels from 2013 to 2021, the reduction is insufficient, indicating limited effectiveness of government interventions. Despite slight improvements over the 9-year period, seasonal variations in air pollution remain consistent, particularly with higher concentrations observed during the dry season. Concentrations of sulfur dioxide (SO2) and carbon monoxide (CO) generally decreased from 2013 to 2021, staying within acceptable limits set by BNAAQS. Although ground-level ozone (O3) concentrations remained within standards, there was a notable increase over the years, indicating a concerning trend. The fluctuations in these gases highlight the need for continuous monitoring and regulatory measures to prevent potential risks associated with their increasing trend. PM2.5 emerged as the primary pollutant affecting air quality, with consistently unhealthy levels during the dry season. Despite governmental initiatives, air quality in Khulna Division has stagnated, with minimal improvement observed over the years. Analysis of PM2.5 concentrations in relation to temperature reveals complex interactions, with both positive and negative correlations observed, suggesting the influence of diverse environmental factors. the study underscores the persistent challenges posed by air pollution in Khulna Division, emphasizing the need for more effective measures to mitigate particulate matter and gas emissions and improve overall air quality. Additionally, the complex relationship between pollutants and environmental variables necessitates further research to better understand and address the underlying causes of air pollution in the region.

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