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Assessment of Air Status Pre-Lockdown, Lockdown and Post-Lockdown in Dewas, M.P. (India)

Pragya Jha[1]; Jay Singh Rajput[2]; Aditya Kumar Agarwal[3]
[1]PG Scholar; [2]Research Scholar; [3]Assistant Professor
Department of Civil Engineering, MITS, Gwalior, (M.P.) India

Abstract:- This study aims to assess and analyze the effect on air pollutants (PM10, PM2.5, SO2, NO2, NH3, Ozone) during different lockdown phases in Dewas, M.P. India. These different lockdown phases are classified as pre-lockdown (01 Jan – 24 Mar), lockdown (25 Mar – 31 May) and post lockdown (1 Jun – 31 Dec). The air pollutants dataset was acquired from the CPCB website from the duration of 2018 to 2022. A comparative analysis was employed to evaluate the distribution of air pollutants throughout the year including the lockdown phase. Furthermore, hypothesis testing was conducted using a z-test to ascertain the facts obtained through comparative analysis. Consequently, the outcomes revealed that the concentration level of particulate matter along with gaseous pollutants significantly reduced except for ozone during the lockdown phase.

Keywords:- *Air Pollutants, Lockdown, Air Quality, Statistical Analysis, Hypothesis Testing.*

I. INTRODUCTION

Today air pollution is the, one of the burning issues globally it is also notice air pollution is not only limited to environmental issue. But now it also related to health issue and it is estimated in 2015 due to ambient air pollution contribute 4.2 million death and premature mortality across the global [1]. The typical rhythm of people's livelihood has been tremendously upset because of the deadly new coronavirus (COVID-19) [2]. COVID-19, a disease caused by – Coronavirus was first diagnosed in December 2019 in Wuhan, China. As a consequence, it has caused widespread tension and anxiety. It has had an influence on health care as well as social ties and the economy [3]. The first incidence of COVID-19 in India was reported in Kerala in January 2020. To stem the spread of the illness, India implemented a statewide public curfew on March 22nd, After that, on March 25th, 2020, there will be a lockdown (lockdown 1.0, 21 days). Lockdown 2.0 (19 days), lockdown 3.0 (14 days), and lockdown 4.0 (14 days) were then implemented.). Due to lockdown limits are imposed on public transit and service sectors, large gatherings in various locations, and so on, as well as self-quarantine measures. Similarly ,construction activities, the industrial and retail malls, recreational facilities, gymnasiums, and theatres, among other things, were shut down across the country [4]. Consequently, the atmosphere gets time to heal again in the absence of major emission-producing activities. Numerous publications have reported similar inherence and claimed a significant improvement in the ambient air quality with this course of action. Also, the same outcomes were found in global megacities and countries**,** Ontario, Canada [5], New York City, USA [6], Japan [7], Korea [8], Spain [9], Jaipur India [10] Gujarat India [11], etc. Pollution has no national restrictions and is beyond control unless authorities all around the world may work together. the globe take decisive action and strictly implement pollution-reduction measures. Technology progress has surpassed environmental goals. [12].

II. STUDY AREA

Dewas air quality data was observed in this study, as it is untouched in the existing study, and air pollutant data from 2018 to 2022 was available. Dewas is a district of Madhya Pradesh State, which has a land area of 3,08,000 km2 and is physically located in the central region of India at coordinates (23°47'33"N, 77°94'79"E) Fig. 1. As of 2011, the state has 72.6 million inhabitants with a population density of 236/km2, making it the second most populated state in the country. The Central Pollution Control Board (CPCB) monitors the ambient air quality through the Continuous Ambient Air Quality Monitoring Station (CAAQMS) in Dewas regularly located at Bhopal Chauraha, Dewas at coordinates 22°58'05.7"N 76°03'50.8"E. The primary cause of air pollution in Dewas is automobile emissions. Cities are designated as non-attainment, as their air quality routinely falls below the National Ambient Air Quality Standards.

Fig 1 Map of Study Area

III. DATASET PREPARATION

The 24-hour concentration data of six air pollutants (PM2.5, PM10, NO2, NH3, SO2, O3) were collected from collected form CPCB web portal from 2018 to 2022 for a whole year. Subsequently, datasets were arranged in MS Excel as per the study requirements. In this process, datasets were segregated based on different phases like pre-lockdown, lockdown, post lockdown **Table 1**. Correspondingly, the missing value in the datasets remains blank so that it will not get involved in the calculation. In this manner, whole datasets were arranged including date, phase, and concentration of air pollutants for each year.

Table 1 Phase of Lockdown

Phases	Duration (2020)	Restriction
Pre-Lockdown	Before Mar 24	Normal circumstances
Lockdown 1.0	Mar 24 - Apr 14, **(21 days)**	Except for essential services, there is a complete closure.
Lockdown 2.0	Apr 15 - May 3, **(18 days)**	Except for essential services, there is a complete closure.
Lockdown 3.0	May 4 - May 17, **(14 days)**	Except for essential services, there is a complete closure.
Lockdown 4.0	May 18 - May 31, **(13 days)**	The city was separated into zones. 1.Red zone - total lockdown 2.Orange zone - No public transport available 3.Green zone - Public transport buses with a capacity of 50%
Post-Lockdown	After May 31	The unlocking stage

Source: Home ministry of Madhya Pradesh

IV. METHODOLOGY

➢ *Statistics for Analytics*

We utilized a two-sample z-test analysis to evaluate the statistically significant reduction in pollutant concentrations since the z-test allows us to compare the average values of the two data sets and estimate the p-value. The p-value is the difference between the acceptance and rejection zone.

- *One-sample Z-test*

The One-Sample Z test is used to compare the mean of a sample to the mean of the population.

$$Z=(x-\mu)/(\sigma/\sqrt{n})$$

If x denotes the sample mean, is the mean,μ is the standard deviation, and n denotes the sample size.

- *Two sample Z-test*

We utilize the Two Sample Z test to assess the means of two samples.

$$Z = \frac{x_1 - x_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

The sample means are x1 and x2, the standard deviations are σ_1 and σ_2, while n1 and n2 are sample sizes.

By presenting heat maps for each location, we performed Pearson's correlation analysis to discover the most significant pollutant statistically. Pearson's correlation, also known as the "product-moment correlation coefficient" (PMCC), is a statistical technique for calculating the value of a linear relationship that exists between two quantitative variables. Pearson's correlation is a number between 1 and +1 that represents an optimistic linear to antagonistic correlation. Given a couple of random variables (X1, X2), the Pearson's correlation formula is given by.

$$\rho x1, x2 = \frac{Cov(X1, X2)}{\sigma x1 \sigma x2}$$

In descriptive statistics, a boxplot is used to graphically represent the adaptation, variation, and skewing groups of data points through their quartiles. It provides a five-number summary for a certain collection of data, such as lowest value, second quartile, median, third quartile, and greatest value.

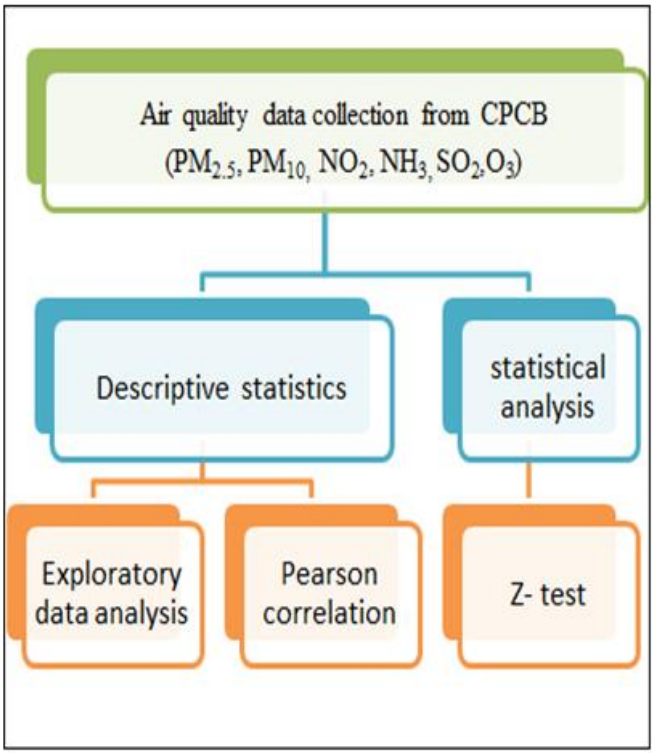

Fig 2 Flow Diagram of Methodology

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V. RESULTS AND DISCUSSIONS

A. Exploratory Data Analysis

The box whisker plot is the graphical representation of the distribution of the dataset. in which we evaluated the concentration of $PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, and O_3, in Dewas. Which lies below and above the permissible limit during observation. The observation duration of data is (2018-2022) yearly and data is further divided into three stages (pre-lockdown, lockdown, and post-lockdown), The red line indicates 24 hourly permissible limits of pollutants. 24-hour concentration of $PM_{2.5}$ in the lower atmosphere greater than 60 µg/m3 is harmful to human health as show in fig 3(a)In 2019 the concentration of PM2.5 was observed highest permissible level. In the box plot shows that in the year 2020 in all phases their concentration is the lowest and also lies below the permissible limit. 24-hour concentration of PM_{10} in the lower atmosphere greater than 100 µg/m3 is hazardous to human health in industrial, residential, and commercial areas show in figure3(b). In 2018 the concentration of PM10 was observed highest permissible level. In the box plot, it is shown that in the year 2020 in all phases their concentration is the lowest and also lies below the permissible limit. 24-hour concentration of NO_2 in the lower atmosphere greater than 80 µg/m3 is harmful to human health in industrial, residential, and commercial areas. In 2019 the concentration of NO_2 observed the highest permissible level. The inbox plot, it is shows that in the year 2020 in all phase their concentration is the lowest and also lies below the permissible limit show in figure3 (c). 24-hour concentration of NH_3 in the lower atmosphere greater than 400 µg/m3 is harmful to human health in industrial, residential, and commercial areas. In 2019 the concentration of NH_3 observed the highest permissible level. In the box plot, it is shown that in the year 2018 in all phases their concentration is the lowest and also lies below the permissible limit show in figure 3(d). 24-hour concentration of SO2 in the lower atmosphere greater than 80µ g/m3 is harmful to human health in industrial, residential, and commercial areas. In 2021 the concentration of SO2 observed the highest permissible level. In the box plot, it is shown that in the year 2019 in all phases their concentration is the lowest and also lies below the permissible limit show in figure 3(e). 24-hour concentration of O3 in the lower atmosphere greater than 100 µg/m3 is hazardous to human health in industrial, residential, and commercial areas. In 2018 the concentration of O_3 was observed highest permissible level. Inbox plot it is shown that in the year 2022 in all phases their concentration is least and also lies below the permissible limit as shown in figure 3(f) given below:

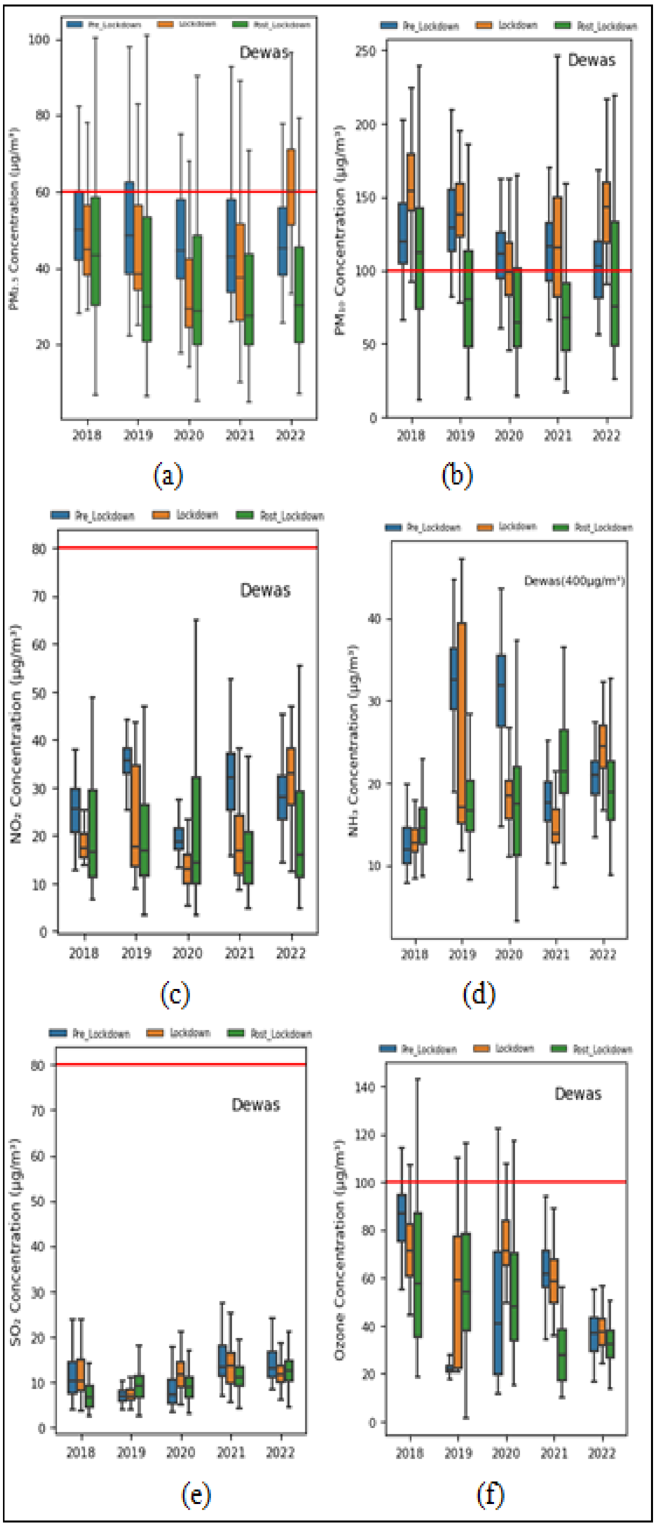

Fig 3 The Changing Trend of (a) $PM_{2.5}$, (b) PM10, (c) NO2, (d) NH_3, (e) SO2, and (f) O3, within the Sampling Period Pre-Lockdown, Lockdown and Post- Lockdown Phase (2018–2022)

B. Pearson Correlation Analysis

The Pearson correlation coefficient is computed by constructing a heatmap of pollutants concentration in Dewas before, during, and after the lockdown.

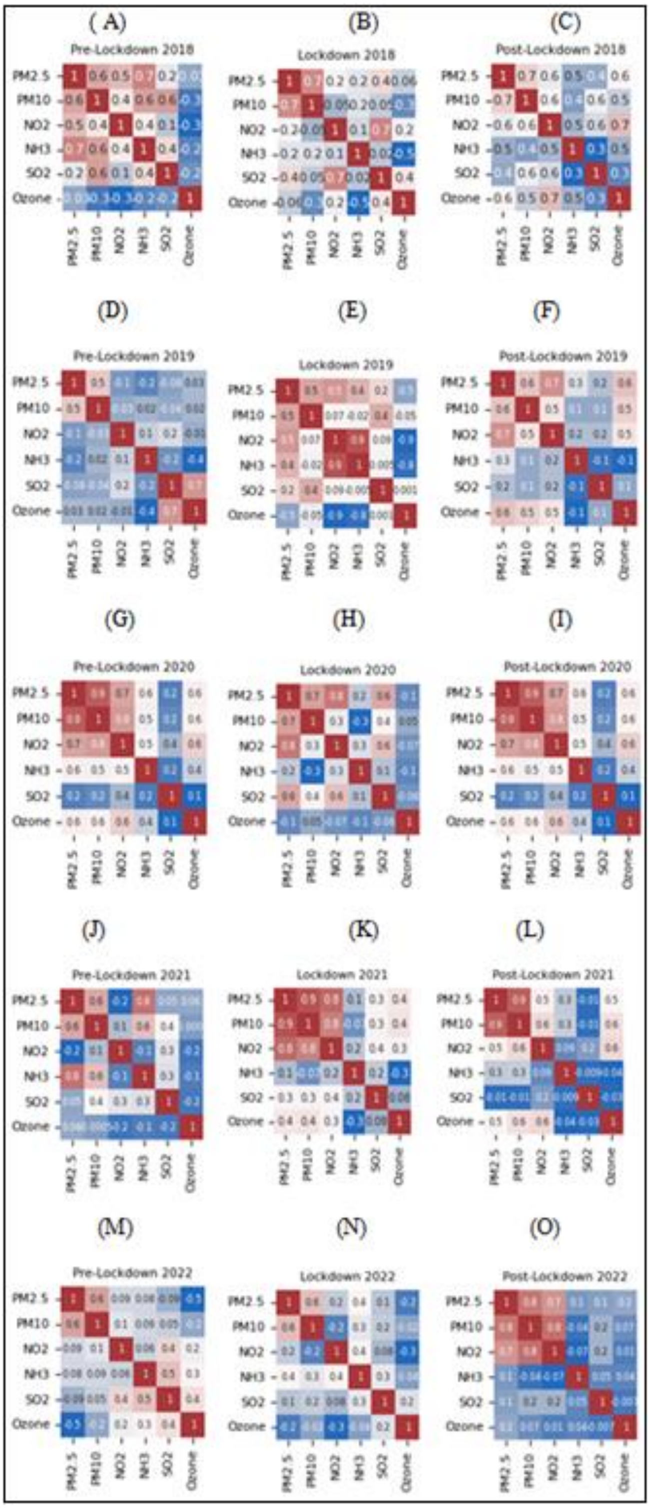

Fig 4 Pearson's Correlation Heatmap for Air Pollutants Pre-Lockdown, Lockdown and Post-Lockdown (2018-2022)

➢ *Pre-Lockdown (2018-2022)*

During the pre-lockdown phase, a perfect positive correlation was observed between PM2.5 and PM10 for all five years. The correlation coefficient between PM2.5-PM10 was found to be 0.6, 0.5, 0.9, 0.6, and 0.6, respectively, indicating a much more favorable association between the two pollutants. On the other hand, an antagonistic correlation was observed for ozone and other pollutants. In 2018, the correlation coefficients for Ozone-NO2, Ozone-NH3, and Ozone-SO2 were -0.3, -0.2, and -0.2, respectively. In 2019, these correlations were -0.01, -0.4, and 0.7, indicating low negatively correlated variables. In 2020, the correlation coefficients for Ozone-NO2, Ozone-NH3, and Ozone-SO2 were 0.6, 0.4, and 0.1, respectively show weak correlation with each other. In 2021, they were -0.2, -0.1, and -0.2. In 2022, the correlation coefficients for Ozone-NO2, Ozone-NH3, and Ozone-SO2 were 0.2, 0.3, and 0.4, respectively, except for 2020 and 2022, which followed a negative correlation. These correlations are shown in the figures 4(A), 4(D), 4(G), 4(J) and 4(M).

➢ *Lockdown (2018-2022)*

During the five-year lockdown phase, there was a perfect positive association between $PM_{2.5}$ and PM_{10}The correlation coefficient between $PM_{2.5}$ and PM_{10} was (0.7, 0.5, 0.7, 0.9, 0.5. On the other hand, a negative association was found between ozone and NH3 (-0.5, -0.8, -0.1, -0.3, and -0.04), showing that greater NH_3 concentrations reduce ozone concentrations. Here, a modest association between NO2 and SO2 is also found. Which are show in figures.4(B), 4(E), 4(H),4(K) and 4(N).

➢ *Post-Lockdown (2018-2022)*

During the five-year post-lockdown period, there was a noticeable positive correlation between PM2.5 and PM10. The correlation coefficient between PM2.5 and PM10 was found to be (0.7, 0.6, 0.9, 0.9, and 0.8) respectively, indicating a considerably more beneficial relationship. Additionally, PM2.5, PM10, and NO2 showed a positive correlation with each other, while NH3, SO2, and Ozone had a weaker correlation between them, as shown in Figures.4(C),4(F),4(I),4(L) and 4(O).

C. Inferential Statistics (Two Tail Z-Test)

A statistical analysis was conducted to assess determine whether there was a significant variation in the mean concentration of pollutants evaluated from January 1, 2018 to December 31, 2022, a period of five years. The analysis was conducted using a Z-test. The datasets were divided into pre-lockdown, lockdown, and post-lockdown in such a manner which is shown in (table 1). The study sought to ascertain the significance of pre-lockdown, lockdown, and post-lockdown confinement on Dewas air quality. A two-sample Z-test, an inferential statistic, used to evaluate the hypothesis, was utilized in the investigation.

- H0: There is no statistically significant difference between the means.
- HA: There is a significant discrepancy in the means.

As a result, because the p-value is substantially smaller than the significance level of 0.05, we reject the null hypothesis that the initial assumption is correct.

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➢ *Pre-Lockdown*

The study's findings show there is a significant discrepancy in the concentration of particulate matter ($PM_{2.5}$) in 2019 but not in the 2018, 2020, 2021, and 2022. PM10 levels differed considerably in 2018 and 2019, but not in 2021 and 2022. NO2 levels varied dramatically in 2018, 2019, 2021, and 2022. NH3 levels differed dramatically in 2018, 2019, 2021, and 2022. In 2018, 2020, and 2022, SO2 exhibited a considerable change, but not in 2019. Ozone levels decreased significantly in 2018, 2019, 2021, and 2022. These data confirm the notion that there was a substantial change in air pollution concentrations when compared to the period COVID-19 pandemic in 2020 to same duration with different year. The results show that the concentrations of the examined pollutants were much lower throughout the lockdown period compared to the pre-lockdown period, but in some observation, it is indicating that diverse activities and sources continued to operate even when the limitations were in place. (Table 2)

Table 2 Pre-Lockdown

Pollutant	Compare with 2020	P-value	Remark
PM2.5	2018	**0.168499**	**NHA**
	2019	0.040224	AHA
	2021	**0.593972**	**NHA**
	2022	**0.789239**	**NHA**
PM10	2018	0.001608	AHA
	2019	1.76E-08	AHA
	2021	**0.230099**	**NHA**
	2022	**0.64635**	**NHA**
NO2	2018	2.78E-08	AHA
	2019	0	AHA
	2021	0	AHA
	2022	4.44E-16	AHA
NH3	2018	0	AHA
	2019	0.016	AHA
	2021	0	AHA
	2022	0	AHA
SO2	2018	1.03E-05	AHA
	2019	**0.092541**	**NHA**
	2021	2.22E-16	AHA
	2022	0	AHA
Ozone	2018	0	AHA
	2019	1.34E-10	AHA
	2021	9.38E-05	AHA
	2022	0.002427	AHA

➢ *Lockdown (2018-2022)*

The study's results ($p < 0.05$) showed that significant discrepancy in the concentration of particulate matter ($PM_{2.5}$, PM_{10}) and gaseous pollutant (NO_2, NH_3, and O_3) in the years 2018, 2019, 2021, and 2022. However, SO2 showed a significant difference only in 2019, and not in 2018, 2020, or 2022. The statistical analysis supported the hypothesis demonstrated the amount of air pollutants fluctuated dramatically as compared to the 2020 lockdown period due to COVID-19. The levels of pollutants were considerably lower during the lockdown period compared to the non-lockdown phases of the same duration in different years. These findings are presented in Table 3.

Table 3 Lockdown

Pollutant	Compare with 2020	P-value	Remark
PM2.5	2018	0.000117	AHA
	2019	0.020575	AHA
	2021	0.045165	AHA
	2022	6.66E-16	AHA
PM10	2018	0	AHA
	2019	1.78E-15	AHA
	2021	0.001521	AHA
	2022	0	AHA
NO2	2018	0.000333	AHA
	2019	3.45E-13	AHA
	2021	0.001649	AHA
	2022	0	AHA

NH3	2018	0	AHA
	2019	1E-06	AHA
	2021	0.001787	AHA
	2022	0	AHA
SO2	2018	**0.652976**	**NHA**
	2019	6.97E-14	AHA
	2021	**0.090491**	**NHA**
	2022	**0.394619**	**NHA**
Ozone	2018	**0.119618**	**NHA**
	2019	6.04E-08	AHA
	2021	4.24E-11	AHA
	2022	0	AHA

- *Post-Lockdown (2018-2022)*

The results of this investigation show a statistically significant discrepancy in particulate matter ($PM_{2.5}$, PM10), NO2, NH3, SO2, and ozone concentrations across years. Specifically, PM2.5 shows a significant difference in all years except for 2018, 2021, and 2022. PM10 shows a significant difference in 2018 and 2020, but not in 2019 and 2021. NO2 shows a significant difference in 2021, except for 2018, 2019, and 2022. NH3 shows a significant difference in 2018, 2021, and 2022, but not in 2019. SO2 shows a significant difference in 2018, 2020, and 2022, but not in 2019. Ozone shows a significant difference in 2018, 2019, 2021, and 2022, as shown in Table 4. The statistics confirm the premise that there is a substantial difference in air pollution concentrations compared to the length of the COVID-19 pandemic in 2020. The study also discovered that the levels of the contaminants investigated was much lower during the lockdown period comparison to the pre-lockdown phase.

Table 4 Post-Lockdown

Pollutant	Compare with 2020	P-value	Remark
PM2.5	2018	1.16E-05	AHA
	2019	**0.67631**	**NHA**
	2021	**0.133857**	**NHA**
	2022	**0.640622**	**NHA**
PM10	2018	5.8E-13	AHA
	2019	**0.131595**	**NHA**
	2021	**0.074342**	**NHA**
	2022	0.000777	AHA
NO2	2018	**0.576374**	**NHA**
	2019	**0.498368**	**NHA**
	2021	2.81E-05	AHA
	2022	**0.476955**	**NHA**
NH3	2018	2.93E-06	AHA
	2019	**0.781844**	**NHA**
	2021	4.04E-14	AHA
	2022	0.002077	AHA
SO2	2018	0.024964	AHA
	2019	**0.333435**	**NHA**
	2021	2.91E-08	AHA
	2022	0	AHA
Ozone	2018	0.001056	AHA
	2019	0.006709	AHA
	2021	0	AHA
	2022	0	AHA

VI. CONCLUSIONS

The goal of this investigation was to look at the effects of pre-lockdown, lockdown, and post-lockdown on air quality in Dewas. In order to conduct this analysis, the Central Pollution Control Board (CPCB) provided a dataset containing measurements of PM2.5, PM10, NO2, NH3, SO2, and ozone from January 1, 2018 to December 31, 2022. The study used Z-test and Pearson correlation analysis to assess whether or not there was a significant increase in air quality throughout this time period. The study's findings indicate that air quality in Dewas has improved dramatically over time. The fact that the test's p-values were quite near to the significance level of 0.05 reinforced this conclusion. Furthermore, Pearson's correlation analysis demonstrated that important pollutants such as $PM_{2.5}$ and PM_{10}, as well as NH_3 and ozone, were highly related to one another.

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