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Asymmetric nexus between air quality index and nationwide lockdown for COVID-19 pandemic in a part of Kolkata metropolitan, India

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\begin{abstract}
The diffusion of COVID-19 or Coronavirus since last few months is the prime matter of concern for the entire world. The government of India had declared the complete lockdown from 24th March. After the second step lockdown, now third step lockdown was declared. So, India in Lockdown 3.0 situation. Although the economy of our country has severely been affected by the impact of lockdown, this situation is good for natural healing. Major metropolitan cities of India are trying to recover from various pollution. This study, therefore, attempts to analyze the trend of air pollution before and during the lockdown situation in Kolkata metropolitan and surrounding areas. To identify air pollution trends before and during the lockdown, the non-parametric Maan-Kendall test and Sen’s slope estimator have been applied in this study. This research has been done based on air quality index data of the Kolkata metropolitan region’s observatory stations. The time range of the data set is from mid of February to 2nd May. The study results show that air pollution has been reduced up to 80\% in almost all the stations due to strict lockdown.
\end{abstract}

\section{Introduction}
Air is an utmost important element for the survival of all animals. So, there is a profound influence of air quality deterioration on all biotic elements. With rapid urbanization and industrialization level of pollution is increasing at a high rate. To meet the basic needs of the second-largest populous country of the world, the emission of harmful gases is contaminating the quality of the air drastically. Urban centres occupy nearly 5\% of the earth’s land surface. The air quality of these urban centres is very vulnerable due to excessive traffic contamination and industrial smog (Haque and Singh, 2017). About 1.1 billion people in the world are breathing unhealthy air (UNEP et al., 2003). The World Health Organization (WHO) estimated that urban air pollution is liable for 5\% of the trachea, lung cancer, bronchus and, 1\% of respiratory infections mortality and about 2\% of cardiorespiratory mortality globally (WHO, 2002). Significant contributors to urban air pollution in India are vehicular emission and emission from red and orange industries (CPCB, 1998; Mukherjee et al., 2012). West Bengal Department of Environment, Chittaranjan National Cancer Institute, and the Central Pollution Control Board observed in a study that approximately 70\% of the patients of the Kolkata who experience respiratory infections are caused by air pollution (Haque and Singh, 2017). Chicago University made an observation that air pollution in Kolkata is reducing the life expectancy of its residents by 3.5 years on average (Bandyopadhyay, 2020). Particulate Matters like PM\textsubscript{2.5} and PM\textsubscript{10},

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NH₃, NO₂, CO, SO₂, and Ozone are the main contributors to urban air pollution (Mukherjee et al., 2012).

COVID-19 virus was initially spread out from Wuhan of China. This novel virus causes respiratory infections in the human body like simple cold to Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS). As this virus can spread from person to person through physical contact, the Government of India declared a nationwide lockdown on 24th March 2020, which is continuing till now for safety measures. Due to lockdown, all industrial activities and mass transportation for which mass gathering occurs have been strictly prohibited (Mahato et al., 2020). Within this lockdown period, the environment has started to heal herself.

Parliament of India has passed and enacted the AIR (Prevention and Control of Pollution) Act in 1981, latter in 1986, passed the Environment (Protection) Act. National Air Quality Index (NAQI) was launched to monitor the air quality index of the major urban centres of India based on eight pollutants by the Central Pollution Control Board Under the Ministry of Environment, Forests and Climate Change of Government of India. In India, a total of 223 stations under the Central Pollution Control Board (CPCB) of the Ministry of Environment, Forests and Climate Change are continuously monitoring the air quality with Air Quality Index (AQI). In this study, the National Air Quality Index has been used. With the help of NAQI, health impacts of the pollutants can be understood. This index has been simplified and made easy for the people to understand using different colours for the five different classes.

Trend analysis of the air quality has been assessed to detect how anthropogenic causes deeply deteriorate the air quality of an urban centre. One of the finest robust techniques to analyze the levels of significance of the trend is the Mann-Kendall non-parametric test. This technique can easily quantify the trend of temporal data sets. Contrary to this, the Sen’s slope can estimate the magnitude of the trend (Gibrilla et al., 2018). This non-parametric test is widely applied by various researchers in the different fields of study like groundwater level change, rainfall variability, temperature change, etc. (Mondal et al., 2012; Yadav et al., 2014, Ahmad et al., 2015; Hussain and Ghulam Nabi, 2015; Hussain et al., 2015; Karmeshu Supervisor Frederick Scatena, 2015; Anie John and Brema, 2018; Gedefaw et al., 2018; Panda and Sahu, 2019). In this study, the Mann-Kendall test has been carried out to understand the trend of air quality index statistically.

After the breaking of the COVID-19 pandemic throughout the entire world, almost all the countries were compelled to enforce

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**Fig. 1.** Location map of the test area showing Air Quality Monitoring stations. (Source: Central Pollution Control Board, October 2014).
lockdown. With the enforcement of the lockdown air quality index of all the metro cities drastically improved. Several research works have also been done in this regard (Mahato et al., 2020; Tobías et al., 2020; Yagbasan and Demir, 2020). Being a metropolitan city and the capital of West Bengal, Kolkata was suffering from continuous deterioration of air quality, but now the entire nation is under lockdown due to the spread out of the novel Coronavirus, which is healing the environment. Although different research work has already been done on air quality status of Kolkata (Ghose et al., 2005; Haque and Singh, 2017; Mukherjee et al., 2012) but this study reveals how human activity hampers the air quality and how air quality index has improved with the advent of lockdown.

Lockdown has a significant role in the restoration of air quality. In this study, an attempt has been made to represent the temporal variation of the air quality index. This study will help us to rethink the probable ways to improve the air quality of our environment keeping parity with continuous sustainable development. The article aims to discover the impact of lockdown on air quality in a part of the Kolkata metropolitan city. In this present situation, this kind of research has practical implementation because through this study one can easily understand that before the diffusion of this virus we had created enormous pressure on our mother earth. So, it is a good time for the mother earth to recover herself. In this perspective, after recovering from the COVID-19 situation or post-lockdown situation we should take care of mother earth so that she does not get into under pressure again. This study also reveals that though lockdown may negatively affect the country’s economy but it positively may affect on nature’s revival. Therefore, this kind of study gives a message to the greedy human world to stop harassing our nature.

2. The test area

The trend of air quality has been tested in a part of the Kolkata metropolitan area (Fig. 1). Kolkata is the administrative capital of West Bengal of India and the only metro city of eastern India. As per the Census of India 2011, Kolkata metropolitan is one of the densest populated metropolitan of India and the home of 4.5 million population. Although there are several anthropogenic sources of air pollution among them, transport plays a crucial role.

Traffic in Kolkata metropolitan is dangerous and uncontrollable because of high vehicular density, narrow roads, and insufficient parking facilities. This vast traffic produces poisonous gases and deteriorates air quality (Ghose et al., 2005). To analyze the trend of air quality, seven stations of Kolkata metropolitan has been taken into consideration viz. Ballygunge, Fort William, Bidhannagar, Jadavpur, Rabindra Bharati University, Rabindra Sarobar, and Victoria. The maps of India and West Bengal have been prepared with the help of digitization process after georeferencing of raster data of India and West Bengal. Kolkata metropolitan city map has been shown with the help of Landsat OLI satellite imagery (collected from the official website of USGS EarthExplorer, https://earthexplorer.usgs.gov/) with 5,4,3 band combination underlaid by Kolkata municipal corporation shapefile, which prepared from Kolkata municipal corporation raster data (Fig. 1).

Only five observation station has been taken into consideration for the study, because this region is very much high traffic zone. So, in this particular congested zone effect of lockdown can be best observed. For this reason, only a small congested area has been selected instead of greater Kolkata.

3. Materials and methods

3.1. Materials

To analyze the trend of air quality index in the course of nationwide lockdown due to diffusion of the COVID-19 virus, air quality index data has been collected from the portal of the Central Pollution Control Board of the Ministry of Environment, Forests and Climate Change (https://app.cpcbccr.com/AQI_India/). Seven stations of Kolkata have been taken into consideration to proceed with the study. Air quality index data of the concerned stations have been collected from 15th of February 2020 to 2nd May of 2020 at 6 pm for trend analysis and spatial mapping.

3.2. Methodology

3.2.1. Method to calculate air quality index

Air quality index (AQI) has been prepared with the help of individual suspended pollutants in the air and converted all pollutants in a single platform as the index (Ott, 1978). At the initial phase, AQI has been calculated as a maximum sub-index approach based on five parameters viz. PM10, PM2.5, NO2, SO2, and CO. After that, Indian Institute of Tropical Meteorology (IITM) of Pune has prepared a new AQI which is known as IITM-AQI and it incorporates O3 as an additional parameter of sub-index. In this AQI, the five-points scale has been introduced to explain the vulnerability of air pollution viz. very unhealthy, poor, very poor, moderate and good. After consulting numbers of literature, Indian National Air Quality Standards (INAQS) formulated a modified AQI (CPCB, 2016). This method involves 12 parameters to calculate AQI viz. Particulate Matter of >10 μm size (PM10), Particulate Matter of >2.5 μm size (PM2.5), Nitrogen dioxide (NO2), Sulphur dioxide (SO2), carbon monoxide (CO), ozone (O3), lead (Pb), Ammonia (NH3), Benzo pyrene (BaP), Benzene (C6H6), Arsenic (As) and Nickel (Ni). But practically CPCB has taken seven parameters to calculate AQI as the data of seven parameters which are regularly available. There are two steps to calculate AQI, INAQS.

In first step sub-indices (I1, I2, I3, I4) have developed for each pollutant (X1, X2, X3, Xn). This index has been prepared based on the standard of air quality and impact on health. Mathematically, it has been expressed in Eq. (1).

\[ I_i = f(X_i) \]  \hspace{1cm} (1)
where, \( i = 1, 2, \ldots, n \).

In the later stage, all sub-indices are aggregated to get the single value of AQI and mathematically it has been expressed in Eq. (2).

\[
\mathbf{I} = F(I_1, I_2, I_3, \ldots I_n)
\]  (2)

Agglomeration of all sub-indices is a summation or multiplication function or it can be referred to as the maximum operator.

### 3.2.1.1. Steps-I: Development of Sub-indices

Sub-indices depict the relation among pollutants concentration \( (X_i) \) and corresponding sub-indices \( (I_i) \). This index aims to identify the impact of pollutants on the environment when the amount the pollutants has been changed. It may be taken as linear, non-linear and segmented linear form. The \( 1-X \) is presented in Eq. (3):

\[
I = \alpha X + \beta
\]  (3)

where, \( \alpha = \) slope of the line, \( \beta = \) intercept at \( X = 0 \).

The mathematical equation for the sub-indices \( (I_i) \) for a pollutant \( (C_p) \) is as follows. The Eq. (4) is based on ‘linear fragmented principle’.

\[
I_i = \left[ \frac{(I_{HI} - I_{LO})}{(B_{HI} - B_{LO})} \right] \cdot (C_p - B_{LO}) + I_{LO}
\]  (4)

where
- \( B_{HI} = \) Breakpoint concentration \( \geq \) given concentration.
- \( B_{LO} = \) Breakpoint concentration \( \leq \) given concentration.
- \( I_{HI} = \) AQI value similar to \( B_{HI} \).
- \( I_{LO} = \) AQI value similar to \( B_{LO} \).
- \( C_p = \) Concentration of pollutants.

### 3.2.1.2. Steps-II: Agglomeration of sub-indices

After calculating sub-index of each pollutant, a composite index has been developed. This single form of index is called a weighted additive form and mathematically it has been expressed in Eq. (5).

#### 3.2.1.2.1. Weighted additive form

\[
I = \text{Aggregates Index} = \sum W_i I_i \quad \text{(For} \quad i = 1, 2, 3 \ldots n) \]  (5)

where
- \( \sum W_i = 1 \)
- \( I_i = \) sub-index for pollutant \( i \)
- \( n = \) number of pollutant variables
- \( W_i = \) Weight of the pollutant
- \( I = \) Aggregated index

Besides, there is another form of calculation which is known as non-linear as Root-sum-power form. Mathematically, it has been expressed in Eq. (6).
expressed in Eqs. (6, 7, 8).

\[
I = \text{Aggregated index} = \left( \sum_{i,j} \right) 0.5
\]  
(6)

where \( P = \text{Positive real number of } >1. \)

3.2.1.2.2. Root-mean-square form

\[
I = \text{Aggregated index} = \left\{ 1/K (l_1^2 + l_2^2 + \ldots + l_K^2) \right\} 0.5
\]  
(7)

**Min or Max operator (Ott, 1978)**

\[
I = \text{Min or Max} \left( I_1, I_2, I_3, \ldots, I_n \right)
\]  
(8)

Fig. 3. a–g Distribution of air quality index data.

3.2.2. Mann-Kendall test and Sen’s slope estimator to detect the trend of air pollution

Mann-Kendall test is a kind of non-parametric statistical analysis to detect the trend of a data series (Yadav et al., 2014). The main benefit of this test is that this test is not affected by any outlier characteristics of data and non-normality of the data series (Lanzante, 1996). Mann-Kendall test most frequently used to understand the trends of hydrological, meteorological data. But in this study, this test has been uniquely applied to identify the trend of air quality index. This study uses this method to detect the monotone trend of air quality of time series data.

Non-parametric hypothesis test has few underlying assumptions and can be easily used in the data which is not normally distributed. Non-parametric test also ignores the magnitude of observation in favour of relative values of data (Blain, 2013). So, from the Mann-Kendall non-parametric trend test we can understand whether there is the trend of data or not, that means it does not give the magnitude of the data but generalize the presence or absence of trend of data of the study. Moreover, the data regarding the quality of air pollution is not normally distributed. Fig. 3 (a to g) depicts that data are positively skewed that means air pollution has been reduced with the extension of a lockdown situation. Based on the above explanation, Mann-Kendall non-parametric test has been taken as one of the best methods to analyze the trend of air pollution.

This test used to prove the hypothesis. The null hypothesis (H0) reveals there is no trend of air quality index over time. But alternative hypothesis (H1) confirms there is a definite trend (increasing or decreasing) of air quality index over time. This test is calculated with the help of a rank-based non-parametric procedure and eligible for the application of skewed variables (Hamed, 2008). The mathematical procedure to calculate the Mann-Kendall test has been shown in Eq. (9).

\[
\text{sgn}(x_j - x_i) = \begin{cases} 
1 & \text{if } x_j > x_i \\
0 & \text{if } x_j = x_i \\
-1 & \text{if } x_j < x_i 
\end{cases}
\]  
(9)

where, \( x_i \) and \( x_j \) are the data value in the time series i and j and \( \text{sgn}(x_j - x_i) \) is the sign function which is shown in Eq. (10)

\[
S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i)
\]  
(10)

Now, the identically distributed random variable with no tied value considers as \( E(S) = 0 \). Therefore, to calculate the variance the Kendall statistics following mathematical expression has been applied (Eq. 11)

\[
\text{Var}(S) = \frac{n(n-1)(2n+5)}{18} - \sum_{t=1}^P t(t-1)(2t+5)
\]  
(11)

wheren = number of data; \( P = \text{number of tied groups} \); \( t_i = \text{number of ties of } i^{\text{th}} \text{ extent} \) (tied group represents a set of data of equal value). To identify the increasing and decreasing trend of data series, \( Z \) statistic has to be calculated with the help of the following formula (Eq. 12).

\[
Z = \begin{cases} 
\frac{s-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\
0 & \text{if } S = 0 \\
\frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 
\end{cases}
\]  
(12)
A positive $Z$ value of the Mann-Kendall test reveals an increasing trend of data series, and a negative value represents a decreasing trend of data series. Therefore, the pollution criteria of the concern study area have been evaluated based on the $Z$ value. The calculated $Z$ value has been compared to the tabulated value to prove the hypothesis. The probability value has been compared at 1% significance level of two-tailed. Here the null hypothesis ($H_0$) is rejected if the calculated $Z$ value is greater than $|Z| \geq |Z_{1-\alpha/2}|$.

One of the significant advantages of this non-parametric test is that this test is not affected by any missing value. In case of any missing value, VSP help to calculate the MK test, usually for smaller data range.

### 3.2.3. Sen’s slope estimator

The magnitude of the trend has been presented with the help of Sen’s slope (Sen, 1968; Sharma et al., 2018). It is also a non-parametric method where the median is used to present this (Sen, 1968). In this method, the data has been sorted into ascending manner. Then, the first sub-series are plotted in X-axis, and another half of the sub-series are plotted on Y-axis in the Cartesian co-ordinate system (Fig. 4). The straight line of 45° represents the no trend of data, but the data below the no trend represents decreasing trend and above no trend represents increasing trend (Yagbasan and Demir, 2020).

Mathematically, the magnitude of Sen’s slope has been presented with the help of following formula (Eq. 13)

$$Q_i = \frac{X_j - X_k}{j - k}$$

(13)

where $Q$ indicates the magnitude of the slope, $X_j$ and $X_k$ are data values at times $j$ and $k$ ($j > k$), respectively.

Sen’s slope estimator ($Q$) is the median of the number of observations (N). Now if the number of observations (N) is odd, Sen’s estimator is calculated using the following formula (14)

$$Q_{\text{med}} = Q \left( \frac{N + 1}{2} \right)$$

(14)

If the number of observations (N) is even, then the following formula is used (15)

$$Q_{\text{med}} = \frac{1}{2} \left[ Q \left\{ \frac{N}{2} \right\} + Q \left\{ \frac{N}{2} + 1 \right\} \right]$$

(15)

The positive value of the $Q_{\text{med}}$ represents increasing trend of the data set and vice-versa. The confidence interval of the $Q_{\text{med}}$ at specific probability is used to identify whether the median slope is statistically different from zero or not. It is calculated in Eq. (16)-

$$Ca = Z_{1-\alpha/2} \sqrt{\text{Var}(s)}$$

(16)

Where $\text{Var}(s)$ is obtained from Equation no. 3, $Z_{1-\alpha/2}$ is usually obtained from the standard normal distribution table. The confidence levels in this study were computed at $\alpha = 0.05$ significant level.

### 3.2.4. Methodology regarding trend analysis and calendar chart preparation

The trend of daily air quality index has been presented with the help of simple scatter diagram using Microsoft excel, and the colour ramp has been used as per government guidelines. The Scatter diagram shows the positive and negative trend of air quality. Another important chart has been shown in this article, i.e., quality calendar, and this calendar has been prepared with the help of Microsoft
excel, where air quality has been demonstrated daily basis with the help of colour codes, where red colour indicates highly polluted and green colour shows poorly polluted. The methodology of the entire study has been shown in Fig. 5.

4. Result analysis

4.1. Spatial improvement of air quality index

Spatial maps have been prepared based on the availability of the air quality index data (Fig. 7). The spatial maps have been generated using IDW tool of spatial analysis tool in the ArcGIS 10.5 (evaluation version) software. Where it can be observed that 30 days before lockdown the quality of the air is under severe pollution and Ballaygaunge area is badly affected by air pollution. But in the next Fig. (Fig. 7b) of 10 days before lockdown, the quality of the air pollution is to some extent improve but the improvement rate is not so much higher. But now when the official lockdown was started, a distinct change of improvement is noticeable. Fig. 7c and d are proof of this. Both the Figs. 6 and 7 show that the quality of the air is improved highly. All seven stations progressively improve the health of the air. Fig. 6 explain the qualitative improvement of air quality. Among all stations, Ballygaunge and Jadavpur show a very sharp decrease in the rate of air pollution. But the rest of the stations also depict the decreasing trend of air pollution rate.

4.2. The trend of air quality index during COVID-19 pandemic

Fig. 9 explains that there is a sharp reduction of air quality index has been recorded in all monitoring stations. In Ballyguange air quality monitoring station experienced a sharp reduction of air quality index during the lockdown period i.e., about 88.78%, in Bidhannagar maximum 85.17% reduction has been noticed, Fort William station experienced maximum 87.11% reduction, Jadavpur has maximum 89.69% reduction, Rabindra Bharati University observed maximum 86% decrease, Rabindra Sarobar station experienced maximum 82.29% reduction, and in Victoria maximum, 87.1% reduction in air quality index has been noticed.

To understand the nature of the air quality index box plot has been prepared for each station (Fig. 8). It depicts that Ballygaunge and Bidhannagar have the same median value, which means the average pollution decreasing pattern of both the station is the same. On the other hand, four outliers are found for the station Fort William, Jadavpur, Rabindra Bharati University and Rabindra Sarobar. The outlier indicates exceptional data or abnormality in the data. So, here outlier means there is an exceptional or dramatic decrease in the pollution rate of these four places.

The Central Pollution Control Board has classified the air quality index into six categories (Table 1). As per the colour code, the air quality of the maximum number of the monitoring stations was either under moderate or poor groups before the lockdown announced, but after the announcement, air quality status has come under good or satisfactory classes. From Fig. 9 it is clear that all the stations were suffering from unhealthy breathing of air almost every day before the lockdown phase, but during the lockdown phase, it has reduced drastically.

Fig. 10 represents the status of air quality in daily basis for individual seven-station. It can be easily understood from the Fig. that all harmful elements of air began to decrease on and from 15th February. But acute decreasing rate can be detectable on and from the 25th of March.

4.3. Mann Kendall’s and Sen’s slope trend test

As we know Mann Kendall’s trend test is a kind of non-parametric test, so, it doesn’t have any data related difficulties. It’s used to
identify the trend of air quality during lockdown and Sen’s slope estimation that has been done for every station to understand whether the trend of air pollution increases or decreases. All mathematical procedures of this test have been described in the methodology section (Vide 3.2.1 & 3.2.2). The result of Kendall’s trend test and Sen’s slope estimation has been presented in Table 2.

The null hypothesis (H₀) has been tested for each station at 1% significant level. The null hypothesis indicates that there is no trend in the pollution of the concerned stations. The test result shows that the Z value of the Mann Kendall non-parametric test is higher than the critical value of \( Z_\alpha \) (Vide formula 4), therefore, the null hypothesis has been rejected for each station which means there is a definite trend of changing the pollution rate. Moreover, the \( Q_i \) value of Sen’s slope (Formula 6) is the negative value of each station (Table 2), therefore, the trend of pollution shows the decreasing trend. Another value in Table 2 is the \( p \)-value. The \( p \)-value indicates the probability value. Based on the probability value, the significance of the test depends. If we look at all \( p \)-values, it can be observed that all \( p \)-values are less than 0.01. It means here we must reject the null hypothesis (H₀) and retain the alternative hypothesis (H₁).

5. Discussion

All the above of the study reveals the fact that there is a direct visible impact of official lockdown on the improvement of air pollution rate or air quality index. Longer the duration of lockdown, higher the improvement of the health of the air. To maintain lockdown, social contacts among people were strictly restricted. To make lockdown successful, all kinds of vehicle movements have been restricted along with the closing of industrial activities. This decision has become a blessing for the rejuvenation of nature. Within 10 days after lockdown, air quality started to improve dramatically, and after 30 days of lockdown, the air quality of the city become much healthier. So, this study usually focuses on how the reduction of anthropogenic activities will accelerate the reduction of air pollution. A huge concentration of both legal and illegal tanneries are present in Kolkata which damages the environment as well as it generates odour pollution in the air. Not only the tanneries but also the different other industries like chemical industries, cast iron industries also pollution air through the emission of SPM, SO₂, NO, CO₂, air discharge etc.

Traffic is one of the biggest problems in Kolkata metropolitan. Every day several thousand vehicles are moving in and around Kolkata metropolitan. This creates immense pressure on traffic. Kolkata metropolitan fails to meet the guidelines of WHO about the emission of PM from vehicles. In Kolkata metropolitan, the average emission of PM is 85.4 microgram per cubic meter (\( \mu g/m^3 \)) which is more than 8 times higher than WHO guidelines (Chowdhury 2016). Ballygunge area shows higher improvement in reducing air pollution. It used to experience massive congestion of traffic in this area in normal time since this area is one of the vital campuses of Calcutta university. However, this situation has been able to get come under little control due to lockdown. The university campus has remained closed due to lockdown and this help bringing control on the congestion of traffic.

Moreover, the Jadavpur area is another major traffic-congested area and is famous for its renowned university of India. So, usually, pollution from traffic congestion is very high in the above-said areas. Rabindra Bharati University is also a traffic pollutant area. Motor vehicles emit carbon monoxide, Sulphur dioxide, hydrocarbon etc. Kolkata and its surrounding area is the busiest traffic-congested area of this country. Around 879 thousand registered two-wheelers are present only in Kolkata metropolitan in 2018. The density of vehicles is not under control in this region, moreover, roads are poorly maintained and parking facilities are not
It has also been observed that so many drivers are not disciplined and they have not the capability to manage traffic (Mukherjee and Mukherjee, 1998). So, from this discussion, it is obvious that traffic congestion deteriorates the health of the air in the study area.

Fig. 7. a–d Spatial improvement of air quality index in the before and after lockdown.
Fig. 8. Box Plot to understand the nature of air quality data.

Table 1
National air quality index classes and impacts on health.

| AQI   | Class            | Colour code | Impacts on human health                                           |
|-------|------------------|-------------|-------------------------------------------------------------------|
| 0–50  | Good             |             | Minimum health impact                                             |
| 51–100| Satisfactory     |             | Minimum breathing trouble to sensitive people                    |
| 101–200| Moderate       |             | Breathing discomfort to the people with lungs, asthma and heart diseases |
| 201–300| Poor            |             | Breathing discomfort to most people on prolonged exposure         |
| 301–400| Very Poor      |             | Respiratory illness on prolonged exposure                         |
| 401–500| Severe          |             | Affects healthy people and seriously impacts those with existing diseases |

Source: https://app.cpcbccr.com/AQI_India/

Fig. 9. Trend of air quality index of before and during lockdown period.
Fig. 9. (continued).
Fig. 10. Status of air quality in a daily manner from 15th February 2020 to 2nd May 2020 of seven stations (a) Ballyguange, (b) Bidhannagar, (c) Fort William, (d) Jadavpur, (e) Rabindra Bharati University, (f) Rabindra Sarobar, (g) Victoria.
### Table (d)

| Data Set | Sample |
|----------|--------|
| From     | 2/15/2020 |
| To       | 5/2/2020 |
| Avg:     |          |
| Feb      |          |
| Sun      | 196      |
| Mon      | 175      |
| Tue      | 166      |
| Wed      | 142      |
| Thu      | 92       |
| Fri      | 109      |
| Sat      | 217      |
| Mar      |          |
| Sun      | 253      |
| Mon      | 274      |
| Tue      | 250      |
| Wed      | 115      |
| Thu      | 93       |
| Fri      | 216      |
| Sat      | 170      |
| Apr      |          |
| Sun      | 60       |
| Mon      | 70       |
| Tue      | 84       |
| Wed      | 74       |
| Thu      | 74       |
| Fri      | 75       |
| Sat      | 60       |
| May      |          |
| Sun      | 44       |
| Mon      | 23       |
| Tue      | 22       |
| Wed      | 34       |
| Thu      | 33       |
| Fri      | 57       |

### Table (e)

| Data Set | Sample |
|----------|--------|
| From     | 2/15/2020 |
| To       | 5/2/2020 |
| Avg:     |          |
| Feb      |          |
| Sun      | 281      |
| Mon      | 298      |
| Tue      | 300      |
| Wed      | 292      |
| Thu      | 181      |
| Fri      | 231      |
| Sat      | 270      |
| Mar      |          |
| Sun      | 248      |
| Mon      | 276      |
| Tue      | 262      |
| Wed      | 139      |
| Thu      | 90       |
| Fri      | 125      |
| Sat      | 82       |
| Apr      |          |
| Sun      | 73       |
| Mon      | 163      |
| Tue      | 164      |
| Wed      | 121      |
| Thu      | 132      |
| Fri      | 119      |
| Sat      | 168      |
| May      |          |
| Sun      | 53       |
| Mon      | 97       |
| Tue      | 129      |
| Wed      | 214      |
| Thu      | 210      |
| Fri      | 112      |
| Sat      | 125      |

### Table (f)

| Data Set | Sample |
|----------|--------|
| From     | 2/15/2020 |
| To       | 5/2/2020 |
| Avg:     |          |
| Feb      |          |
| Sun      | 267      |
| Mon      | 259      |
| Tue      | 278      |
| Wed      | 137      |
| Thu      | 68       |
| Fri      | 113      |
| Sat      | 192      |
| Mar      |          |
| Sun      | 132      |
| Mon      | 157      |
| Tue      | 131      |
| Wed      | 78       |
| Thu      | 55       |
| Fri      | 49       |
| Sat      | 47       |
| Apr      |          |
| Sun      | 65       |
| Mon      | 102      |
| Tue      | 113      |
| Wed      | 106      |
| Thu      | 92       |
| Fri      | 107      |
| Sat      | 109      |
| May      |          |
| Sun      | 57       |
| Mon      | 61       |
| Tue      | 51       |
| Wed      | 62       |
| Thu      | 49       |
| Fri      | 35       |
| Sat      | 52       |
| Sun      | 60       |
| Mon      | 37       |
| Tue      | 45       |
| Wed      | 53       |
| Thu      | 34       |
| Fri      | 37       |
| Sat      | 55       |
| Sun      | 61       |
| Mon      | 40       |
| Tue      | 43       |
| Wed      | 53       |
| Thu      | 53       |
| Fri      | 51       |
| Sat      | 55       |
6. Conclusion

Air pollution sometimes referred to as “diseases of civil society”. Based on the study it is observed that this region is predominantly always experienced the increasing rate of air pollution. Corona’s paw has brought silence to the whole city as govt. declared complete lockdown. Now let us explain about the innovative aspect of the study. Here the study tries to make a quantitative comparison between before and after lockdown situations about air pollution. Null hypothesis (H₀) of the work means there is no difference in air pollution between the before and during the lockdown. But minute analysis of data and Maan-Kendall non-parametric test proves that the null hypothesis (H₀) has been rejected here. That means there is a difference in air pollution before and during the lockdown. Any common people can easily perceive the fact that lockdown can prevent air pollution. But they cannot prove it until statistics applied. So, the novelty of this work is that here the voice of common people has been proved statistically and this work giving 100% assurance of the fact that such kind of lockdown can easily increase the quality of health of the air. From this work, an environmentalist can easily judge the impact of lockdown on air pollution and a planner can formulate the ways to decrease the rate of air pollution.

During the last 100 years, we were not facing any epidemic or pandemic situation. So, how the situation like pandemic can bring blessing to the mother earth has been shown in this research. Also, in a normal situation of so-called development, we cannot expect the drastic reduction of air pollution. Therefore, pandemic and lockdown have a very high positive impact on the drastic reduction of air pollution. So, this study brings a lesson to all human being that if we want to survive and keep mother earth healthy, we should maintain some guidelines. Moreover, with the future development man will further create immense pressure over mother earth and at that time there will be no alternative than lockdown. All of them represent the uniqueness of this research.

The lockdown due to COVID-19 has been imposed throughout the globe, has made us rethink how nature is so precious for human beings as well as for the entire biological elements. Within a few days of lockdown, various changes have been noticed throughout the world that made us believe homeostatic resilience of nature.

This study focuses on how nature can be rejuvenated when there is no regular human intervention. Restriction on the mode of transports, social contacts, and the closing of industries are the main principles of lockdown and this event helps to drop down the levels of air pollution. It is expected that the air quality index will still improve in forthcoming two weeks as lockdown has been extended up to 17th May 2020.

There is no gainsaying that currently, the entire world is facing one of the most difficult challenges, but the COVID-19 virus

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Table 2

Mann Kendall’s trend test and Sen’s slope estimation of the air quality monitoring stations.

| Sl. No. | Station                          | MK Z value | Sen’s slope | p-Value     | Significant at 99% confidence level | Trend   |
|--------|---------------------------------|------------|-------------|-------------|-------------------------------------|---------|
| 1      | Ballygunge                      | -8.53180   | -2.71429    | 2.200E-16   | ✓                                   | Decreasing |
| 2      | Bidhannagar                     | -7.08590   | -1.67692    | 1.382E-12   | ✓                                   | Decreasing |
| 3      | Fort William                    | -6.84000   | -1.33803    | 7.917E-12   | ✓                                   | Decreasing |
| 4      | Jadavpur                        | -7.47430   | -1.47626    | 7.762E-14   | ✓                                   | Decreasing |
| 5      | Rabindra Bharati University     | -7.92290   | -2.10714    | 2.315E-15   | ✓                                   | Decreasing |
| 6      | Rabindra Sarobar                | -7.17740   | -1.24000    | 7.107E-13   | ✓                                   | Decreasing |
| 7      | Victoria                        | -7.16790   | -2.20408    | 7.614E-13   | ✓                                   | Decreasing |

Fig. 10. (continued).

Table 2

Mann Kendall’s trend test and Sen’s slope estimation of the air quality monitoring stations.

| Sl. No. | Station                          | MK Z value | Sen’s slope | p-Value     | Significant at 99% confidence level | Trend   |
|--------|---------------------------------|------------|-------------|-------------|-------------------------------------|---------|
| 1      | Ballygunge                      | -8.53180   | -2.71429    | 2.200E-16   | ✓                                   | Decreasing |
| 2      | Bidhannagar                     | -7.08590   | -1.67692    | 1.382E-12   | ✓                                   | Decreasing |
| 3      | Fort William                    | -6.84000   | -1.33803    | 7.917E-12   | ✓                                   | Decreasing |
| 4      | Jadavpur                        | -7.47430   | -1.47626    | 7.762E-14   | ✓                                   | Decreasing |
| 5      | Rabindra Bharati University     | -7.92290   | -2.10714    | 2.315E-15   | ✓                                   | Decreasing |
| 6      | Rabindra Sarobar                | -7.17740   | -1.24000    | 7.107E-13   | ✓                                   | Decreasing |
| 7      | Victoria                        | -7.16790   | -2.20408    | 7.614E-13   | ✓                                   | Decreasing |
convinces us that we can breathe pure air if we want.

This study will help us to rethink environmental issues and how we can improve the air quality for our benefit if we want. Cities like Kolkata, New Delhi are suffering from extreme of air pollution on regular basis and it was impossible to reduce air pollution in all of our megacities because of large scale industrial polluted emission and heavy traffic congestion which are an integral part of city life. But the outbreak of COVID-19 teaches us nothing is impossible. Strict lockdown since the middle of the March accelerates the reduction rate of air pollution in Kolkata and surroundings. As it is a matter of health, we all should be more careful about it. Therefore, the implementation of short-term lockdown will reduce the level of air pollution. There is no doubt that the lockdown will hamper the economy of the nation, but it will heal the entire environment. Therefore, for the welfare of future generations, policymakers may have to focus on short-term lockdown to keep the environment pure.

Credit author statement

Niladri Das: Writing - original draft, Methodology, Writing - review & editing, Visualization, Formal analysis. Subhashish Sutradhar: Conceptualization, Writing - original draft, Visualization, Formal analysis. Ranajit Ghosh: Data curation, Software, Formal analysis. Prolay Mondal: Supervision, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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