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ENVIRONMENTAL CLEANSING: AN EFFECT OF LOCKDOWN FOCUSING ON KOLKATA TO DETERMINE AIR POLLUTION BASELINE

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ABSTRACT

Environmental pollution is one of the major problems facing the human civilization. The world this year has been facing a unique situation due to a very contagious disease with a high mortality rate called SARS-Cov 2. It is a viral disease caused by the virus COVID-19. One of the ways to battle the disease, generally called CORONA has been imposing total lockdown. The unprecedented lockdown had many implications. On economy, health, education the effect has been mostly negative. However, the effect on the environment has been hopeful. Due to total closure of human activity, the pollution level has come down to a minimum. It has become imperative to critically analyse the environmental conditions arising due to this unique situation. This opportunity was used to calculate the baseline pollution level of a busy city like Kolkata, i.e the minimum pollution that the city has to produce to survive. This was done by statistically analyzing the pre and post lockdown data of various pollutants from the automated machines at different sites in Kolkata installed by the Central Pollution Control Board. The analysis revealed by how much the air pollution of a polluted city like Kolkata has decreased. Time analysis study revealed that the cleansing effect has continued after lockdown and the positive effect on the environment may be sustained by taking effective measures.

KEY WORDS : Baseline, CORONA, Environment, Kolkata, Lockdown, Pollution.

INTRODUCTION

The world is facing an unprecedented struggle today with the advent of the disease Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which is due to the CORONA virus commonly referred to as COVID-19. The disease was first detected in the city of Wuhan in China and soon spread to different parts of the world due to its highly contagious nature. After it was detected in almost all the countries in the world, World Health Organisation (WHO) declared it a Public Health Emergency of International Concern (PHEIC) on 30th January, 2020 and characterized it as a pandemic on 11th March, 2020 (Paital *et al.,* 2020). The first case in India was detected on 30th of January, 2020 from a person coming from China. The WHO guideline to combat COVID-19, stressed on testing of population for the virus, contact tracing of people coming in contact with infected individual, quarantine of the patient and finally treatment, but all in the ambit of lockdown, either full or partial (Salathé *et.al*., 2020). China and New Zealand was very successful in implementing social distancing by ensuring strict lockdown (Lin *et al.,* 2019, Lau *et al.,* 2020). Great Britain initially had gone for the concept of herd immunity but due to high mortality rate had to adopt the system of lockdown (Kwok *et al.,* 2020). India also adopted lockdown and social distancing as part of the strategy to combat COVID-19. The Indian population has gone through 5 phases of lockdown

from 25th March to 31st of May, 2020 for 68 days (Rana, 2020). India being a very diverse country with different demographic, social and climatic conditions, the lockdown and its effects were also diverse (Kundu *et al.,* 2020). Beyond 31st of May, 2020, India has gradually started the process of lifting the lockdown.

The implication of the lockdown on people's livelihood, education, health has been of concern (Lin, 2020). The loss of human interaction, being indoors always has taken its toll on the psychology of people. Depression, domestic violence is on the rise (Sinha and Manna, 2020). However, the effect of the lockdown on the environment has been that of cleansing it (Muhammad *et al.,* 2020). After the lockdown, the human activities had ceased to a bare minimum. The two main sources of atmospheric pollutants: the vehicular traffic and industrial activities consequently decreased. The measurement of air quality is based on eight pollutants PM10 (Particulate matters of size less that 10 micron), PM2.5, Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3), Ammonia (NH_3), and Lead (Pb). Air Quality Index (AQI) transforms complex air quality data of eight pollutants into a single number (index value). AQI was introduced on 17 October 2014 to make it easier for general population to understand extent of pollutants in air (Prakash and Bassin, 2010). An AQI of 0 to 50 is desirable and values more than 100 can cause breathing discomfort. WHO (2005) as well as Central Pollution Control Board, Government of India (CPCB) (2009) has a guideline about the permissible levels of the pollutants in the air, which is given in Table 1.

This article will concentrate on the city of Kolkata, the capital of West Bengal, India. According to a study published by CNN (CNN, 2020) Kolkata is the 23rd most polluted city in terms of air pollution. Kolkata suffers from severe air pollution due to high population density, relatively less greenery, unplanned urbanization, very high road to car ratio, construction work etc (Sahu, 2019). The main pollutants in the city of Kolkata, are PM 2.5, PM 10, NO_2, SO_2, CO, Ozone etc (Gurjar *et al.* 2016). Due to pollution respiratory distress and allergic disorders have become prevalent in Kolkata. Children and elderly are especially vulnerable to it (Spiroska *et al.,* 2011). Gurjar and Nagpure (2015) observed that PM 2.5 are specially dangerous for the respiratory distress as due to their smaller size they can penetrate deep into the pulmonary muscles. In Kolkata the AQI has always been much higher than the WHO/National standard.

Table 1. Air quality guidelines (microgram/m^3)

Pollutant	WHO	CPCB (India)
PM 2.5	25	60
PM 10	50	100
NO_2	40*	80
SO_2	20	80
O_3**	100	100
CO**	-	2

*Permissible annual value; **Permissible values over 8 hours

The objective of this article is to measure by how much the pollution has decreased due to lockdown, to deduce whether the effect is short or long term and to determine the baseline pollution of Kolkata by statistically analyzing the data of six major atmospheric pollutants in the pre and post lockdown period. The strategy to utilize the lockdown to determine the baseline pollution of a city have been carried out in Delhi (Dhaka *et al.* 2020). The data were collected from the automated air quality measurement machines maintained by the Central Pollution Control Board, India (CPCB).

METHODOLOGY

Location of the study area

This article will concentrate on the city of Kolkata, the capital of West Bengal, India situated in 22°58 °N and 88°36 °E.

Data collection method

The air quality data was collected from the automatic air quality measurement machines installed and maintained by the CPCB. The real time data is uploaded regularly in their data base available to all (https://app.cpcbccr.com/AQI_India). The automatic machines measure PM 2.5, PM 10, NO_2, SO_2, CO, NH_3, O_3. The data were collected for all the pollutants listed except for ammonia as its values remained the same throughout the time period (7 microgm/m^3 before lockdown and 1 microgm/m^3 after lockdown). The data was collected at every hour to record the daily variation, for all other purpose data for 7 pm was used (as it recorded maximum pollution level). For prelockdown and post lockdown data 13th March,

2020 (in the state of West Bengal lockdown started from 16th March, 2020) and 29th May, 2020 was chosen respectively. The data from the automatic station situated in Fort Williams, Kolkata was used for the major findings.

Data Analysis Procedure

Inferential Statistics was used to statistically test the hypothesis and analyze the data from various angles. A two way fixed effects Analysis of Variance (ANOVA) was performed on the data set to study the significant difference of the variation between each of the pollutant groups and pre and post lockdown pollutant level. A p-value of less than 0.05 (5% level of significance) was considered as statistically significant. Time series analysis was done by simple exponential smoothening, which is of the following form:

$$S_t = \alpha Y_{t-1} + (1-\alpha) S_{t-1}.$$

where, S_t is the smoothed and forecasted value, whereas Y_t is the observed value at time t. Here, α is the smoothing constant and (1-α) is the damping factor, the values of which ranges from 0 to 1. The time interval is taken as 7 days starting from 29th January to 3rd June and is forecasted upto 24th June. Mathematical extrapolation has been done for substituting the Y_t values required for forecasting after 3rd June. The damping factor is chosen as such to appropriately smooth the data and forecast pollutant levels at the further time period. According to the different patterns of the pollutant levels, the damping factors has been chosen accordingly for each pollutant in the following manner- 0.85 (PM 2.5), 0.9 (PM 10), 0.8 (NO_2) and 0.7 (SO_2, CO, O_3). The data analysis was performed using MS-Excel.

RESULTS AND DISCUSSION

Hourly analysis (Daily)

When the data for the air pollutants of Kolkata before and after the lockdown was studied, on a weekday (Wednesday) and weekend (Sunday), given as supplementary Table 1 and 2 respectively the following were observed

(a) Before the lockdown, pollution levels were above the permissible guidelines. On Sunday the pollution level was much less than that on a weekday, due to lesser vehicular traffic. After the lockdown, the level of pollution decreased and the values were within the limits set by the CPCB and WHO.

(b) Before the lockdown, pollution was maximum between 11am to 8pm on weekdays as PM 2.5, PM 10, NO_2, SO_2 had the highest values then. On Sunday, the pollution was highest around 11am and continuously decreased beyond that. However, after the lockdown, the difference in the pollution pattern on a weekday and Sunday is eliminated.

Analysis of Variance (ANOVA)

A two factor fixed effect ANOVA (with replication) was performed on the data of pre and post lockdown for weekdays and Sunday. The results of the ANOVA are presented in Table 2 and 3. If F is greater than F critical for sample, column and interaction, with a p value of 0.000 (<0.05), we reject

Table 2. Result of ANOVA (For weekday)

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	558096.1	1	558096.1	2516.335	0.000	3.875
Columns	516860.5	5	103372.1	466.0826	0.000	2.247
Interaction	271639.5	5	54327.89	244.9528	0.000	2.247
Within	61213.83	276	221.7893			
Total	**1407810**	**287**				

Table 3. Result of ANOVA (For Sunday)

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	230237.7	1	230237.67	2683.41423	0.000	3.875
Columns	263671.6	5	52734.3229	614.617202	0.000	2.247
Interaction	115990.1	5	23198.0118	270.372242	0.000	2.247
Within	23680.9	276	85.8002717			
Total	**633580.2**	**287**				

the null hypothesis. This result indicates that there is indeed a significant difference between the pollution level at pre and post lockdown period, all the pollutants show different levels of pollution, pre and post lockdown. Most importantly, there is significant interaction between the pollutants.

The average values of the pollutant, pre and post lockdown for a weekday and Sunday was plotted in Fig. 1. It is observed from the figure that each of the pollutant has decreased post lockdown (column 1 and 2 relative to column 3 and 4 for each pollutant). The relative decrease can be defined as, the ratio between the difference between the highest and lowest value and the highest value. Relative decrease of PM 2.5, PM 10, NO_2, SO_2, CO, O_3 were calculated as 0.89, 0.78, 0.93, 0.85, 0.83 and 0.91 respectively. Ozone shows the highest decrease of 91% and PM 10 shows the lowest decrease at 78%. Figure 1 also corroborates our finding that the difference in pollution of a weekday and a holiday has been neutralized by the lockdown (the height difference between column 3 and 4 is much less than that between 1 and 2 for each pollutant). Similar observation of decreases level of CO_2 during the lockdown has also been reported by other groups (Mitra *et al.*, 2020; Singh *et al.*, 2020). The reduction of particulate matter has also been seen in other cities in India and around the world (Kumar *et al.* 2020).

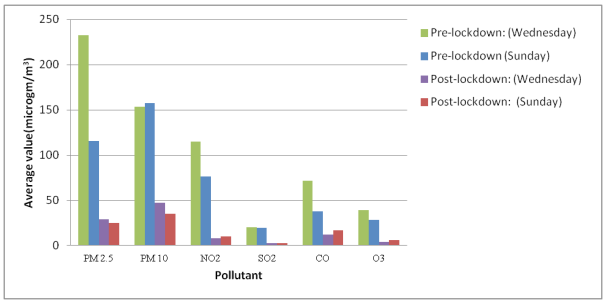

Fig. 1. Comparison of average value of Pollutant obtained from ANOVA

Time Series Analysis

It was observed that the pollution level of Kolkata has decreased to a very low level during the lockdown. Hence, this situation was utilized to find the pollution baseline for Kolkata, i.e the minimum level of pollution the city of Kolkata has to produce to maintain its function. The pollutant level of the six pollutants (Wednesday, 7pm) was plotted from the last week of January through June, every week. The variation has been shown in Fig. 2. It is observed that after the lockdown the pollutant level slowly decreased and reached a plateau and stayed constant, which signifies that the basic activities of an urban place like Kolkata demands this minimum amount of pollutant. Hence these values signify the baseline of the pollutants in Kolkata.

For proper evaluation of the baseline values, an

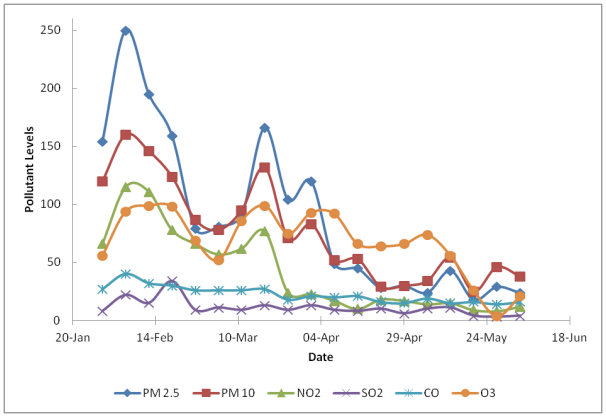

Fig. 2. Level of Pollution against time plot. (29th June to 3rd June, 7pm data)

exponential smoothing of the data was performed to smoothen the fluctuating pattern of the graph in Fig. 2 and forecasting is carried out (with damping factors 0.85 (PM 2.5), 0.9 (PM 10), 0.8 (NO_2) and 0.7 (SO_2, CO, O_3) and is shown in Fig. 3.

The forecasted and actual pollutant values for 24th June, 2020 (3rd week after the last data used for analysis) were plotted in Figure 4. The correspondence between the observed and forecasted value shows that the time series modeling performed in the study has shown significant predictions and depicts validity around the true scenario. Hence the observed value on 24th June, 2020 is considered as the baseline value of the pollutants for Kolkata. The baseline values are, 33

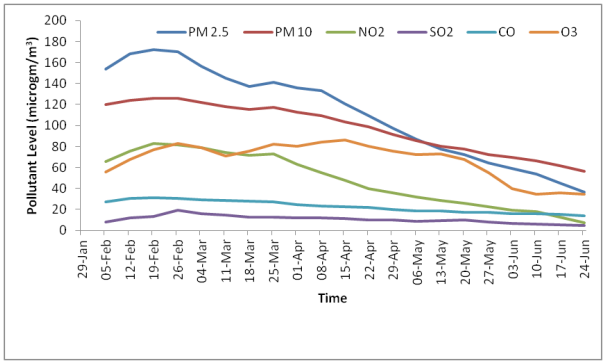

Fig. 3. Simple exponentially smoothed and forecasted levels of pollutants over time

and 57 microgm/m^3 for PM 2.5 and PM 10.0 respectively, which are within the prescribed limits of CPCB. For NO_2, SO_2, CO and O_3 the values are 9, 3, 14 and 16 microgm/m^3 respectively. These values are also within the limits prescribed by CPCB. Therefore it can be concluded that, Kolkata which was a polluted city in the beginning of the lockdown has gone though a cleansing process to have decreased air pollutants level within the safe limits prescribes by the CPCB. However, it must be kept in mind that it is a consequence of an unfortunate epidemic situation that the world is facing.

From 31st of May till the present date India has gone through gradual unlocking in 5 phases (Order of Ministry of Home Affairs). In Fig. 5, we plot the pollutant level for one representative day (Wednesday of 2nd week, 7pm) from each unlocking phase to analyze whether the cleansing effect is lasting even after the lockdown has been lifted. In July no reliable data was available for the 2nd and 3rd week, hence the data for 4th Wednesday was used. For comparison purpose the data for the pre lockdown period has also been inserted. It shows that the cleansing effect of the lockdown is operative even after the lockdown has been lifted.

On a longer time scale the time series forecast

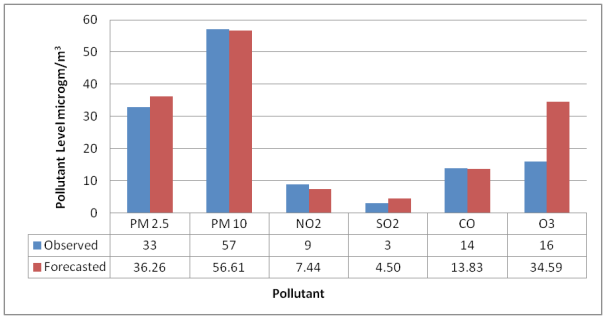

Fig. 4. Observed (Automated Machines) and forecasted (Time series analysis) for 24.6.2020

Table 1. The level of pollutants in the city of Kolkata (Automated machine, Fort Williams) on 5th February, 2020 (*) and 9th February, 2020 (**) [All units in microgram/meter^3 or mg/m^3]

Time (24H)	PM 2.5*	PM 2.5**	PM 10*	PM 10**	NO_2*	NO_2**	SO_2*	SO_2**	CO*	CO**	O_3*	O_3**
1	194	117	138	169	110	91	18	23	78	49	11	21
3	206	121	141	169	112	86	19	22	91	47	4	12
5	218	122	146	168	114	83	20	22	94	46	4	6
7	230	124	152	167	115	80	20	21	97	44	4	4
9	239	127	157	166	114	81	17	20	94	44	4	4
11	243	130	158	167	118	79	20	21	87	41	8	9
13	245	125	158	164	118	76	22	21	74	38	27	23
15	247	118	159	156	118	70	22	18	61	32	52	39
17	248	109	159	148	118	66	22	18	49	25	76	58
19	250	101	160	142	115	65	22	18	40	22	94	68
21	247	96	159	137	114	68	21	17	42	25	87	58
23	238	90	157	132	111	71	21	17	47	33	64	44

Table 2. The level of pollutants in the city of Kolkata (Automated machine, Fort Williams) on 27th May, 2020 (*) and 31th May, 2020 (**) [All units in microgram/meter^3 or mg/m^3]

Time(24 H)	PM2.5*	PM2.5**	PM10*	PM 10**	NO_2*	NO_2**	SO_2*	SO_2**	CO*	CO**	O_3*	O_3**
1	30	26	52	39	8	9	3	3	12	17	4	6
3	30	25	51	38	8	10	3	3	11	16	3	4
5	29	25	50	36	8	10	3	3	11	16	3	4
7	28	25	48	36	8	10	3	3	10	16	3	4
9	28	27	48	36	8	10	3	3	11	16	3	4
11	28	26	47	35	8	10	3	3	12	17	3	4
13	28	25	47	33	8	10	3	3	12	18	4	6
15	28	24	46	33	8	11	3	3	13	17	4	8
17	29	24	46	33	8	11	3	3	14	17	4	9
19	29	24	46	33	8	11	3	3	14	17	4	10
21	29	25	45	33	8	11	3	3	14	18	5	8
23	29	26	43	34	8	11	3	3	14	18	5	7

Table 3. The level of pollutants at 7 pm in different parts of the state of West Bengal (Automated machines) on 13th March(*) and 29th May(**), 2020 for pre and post lockdown data respectively. [All units in microgram/meter^3 or mg/m^3]

Site of Automated Machine	PM 2.5*	PM 2.5**	PM 10*	PM 10**	NO_2*	NO_2**	SO_2*	SO_2**	CO*	CO**	O_3*	O_3**
Asansol Court Area/Asansol	107	47	121	57	57	10	13	5	20	23	41	45
Ward, 32 Bapupara, Siliguri	187	36	135	42	74	37	8	5	29	21	36	21
Belur Math Howrah	57	18	84	30	66	30	27	11	27	18	25	54
Bidhan Nagar, Kolkata	73	31	94	24	31	7	11	18	21	17	83	69
Ballugunge, Kolkata	122	33	124	40	29	8	10	3	28	11	100	55
Fort Williams, Kolkata	94	30	98	42	60	14	9	3	30	16	80	7
Jadavpur, Kolkata	70	26	81	38	30	11	11	9	32	20	63	62
Rabindra Sarobar, Kolkata	77	24	90	51	20	9	13	6	23	11	93	44

may not be sustainable as the world will get back to normal activities unless, policies with strong environmental outlook is enforced (Forster *et al.* 2020). The current high pollution level in New Delhi is a testimonial to that (theprint.in). Many nations in the world after observing the positive effect of lockdown on environment has been discussing voluntary lockdown even after situation become normal. Indian Government or the State governments may consider such a policy as reported in the online newspaper Financial Express (financialexpress.com).

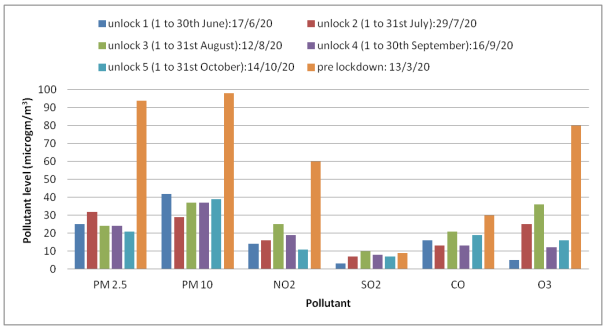

Fig. 5. Levels of pollutant during phases of unlocking in India

To check that the results are not influenced by the site of the automated machines, the data from other automated machines in Kolkata was tabulated pre and post lockdown (13th March and 29th May, 7pm). The data is shown as table 3 and all of them show the same trend of environment cleansing as an effect of lockdown.

CONCLUSION

The lockdown to restrict CORONA has resulted in mostly negative impacts in various fields. However, it has made a positive impact on the environment, reducing pollutants in the air. This article has quantitatively and statistically analyzed the air quality data of Kolkata pre and post lockdown. It has been observed after a two way ANOVA with replication that average values of each pollutants has decreased after lockdown was implemented. The difference in the pollution pattern for a weekday and a Sunday was neutralized. The ANOVA concluded that the difference in the total pollution level pre and post lockdown is statistically significant, with proof of interaction within the pollutants. The decrease in the level of pollution ranged from 78% to 91%. A time series analysis was performed with many data points. It was observed that after continuously decreasing, the pollutants reach a plateau and this denoted the baseline pollution level of Kolkata. The values of the pollutants in this stage signify the amount of pollutants that Kolkata has to produce to function. It also showed a short term lasting effect of decreased pollution even after the lockdown was withdrawn. Less pollution leads to less health hazards, better agricultural products. The maintenance of the less polluted state will be effective in the long run only if there are stringent, green policies of the government. There have been suggestions of voluntary lockdown every year. However, it has to be done keeping in mind social and economic implications. Findings of this and similar studies will help to understand the impact of lockdown on the air quality over India and may help in policy formation.

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