

FUZZY EVALUATION OF IMPACT OF LOCKDOWN AMID CORONA VIRUS ON DELHI'S POLLUTION

SUMITA GULATI¹, ASHOK PAL, AND ANSHUL BANSAL

ABSTRACT. The outbreak of novel Corona virus has been stated as a pandemic by World Health Organisation. The World Health Organisation enunciates to all of the countries in the world to continue efforts that have been effective in limiting the number of cases and slow down the spread of the virus. Social distancing has been addressed as the most effective measure of mitigation. In this direction to suppress social contact, India is under a three week lockdown with around 130 crore people urged to stay in their homes. With rigorous travel restrictions along with shutting down of almost all of the non-essential activities there has been observed a drastic reduction in air pollution in all of the major cities. The present study aimed to interpret the dip in air pollution of Delhi. For this analysis, Fuzzy Inference System of MATLAB has been employed. The simulation results shows a drastic fall in air pollutants $PM_{2.5}$, PM_{10} and NO_2 levels at all of the sampling sites. This study highlights the impact of lockdown on pollution level along with a suggestion to the government to implement a one day lockdown in 3-4 months to put a check on pollution. Mother Nature is expecting from us through present crisis to reciprocate perfectly and positively.

1. INTRODUCTION

The Corona virus (Covid 19) outbreak has transformed the world in such a short span. This new virus first appeared in the Wuhan city of China in December 2019 and has spread to almost every country of the world. Till now

¹*corresponding author*

2010 *Mathematics Subject Classification.* 90C70, 62A86.

Key words and phrases. Corona virus, Delhi, Air pollution, Lockdown, Fuzzy Inference System, MATLAB .

thousands of people have died and hundreds of thousands are struggling to survive. On March 11, World Health Organization (WHO) has declared it a pandemic. In the absence of specific vaccination for this pandemic, social distancing is being used to lessen and interrupt community transmittal of this novel corona virus. Social distancing seeks to decrease the speed with which cases are appearing and to diminish the level of virus activity. The abolition of social contact in schools, colleges, workplaces and other public zones have been targeted for mitigation and control of this virus. The government pushed public to stay in their homes, avoid needless travelling and work from home. Worldwide, all flights are being cancelled along with all but indispensable trades sealed just to control the spread of corona virus and expectantly reducing the death count.

With the continuous spread of this deadly pandemic, most of the countries are implementing different types of lockdowns (not a technical term used by public health officials) on their citizens. The world's biggest and most confining mass quarantines have been enforced by China, Italy, New Zealand, Poland, UK, France and India. The Wuhan city of China from where this virus outburst has been under lockdown for more than 1.5 months and still many of the China's cities are under travel constraints. In India, a nationwide lockdown of 21 days was declared by Prime Minister as a measure to fight against this disaster and to mitigate its effects. With fewer vehicles on the road and even fewer industries running there is a drastic dip observed in pollution. The lockdown results in flattening of air pollution curve in most of the metro cities is shown in Figure 1 [1-2].

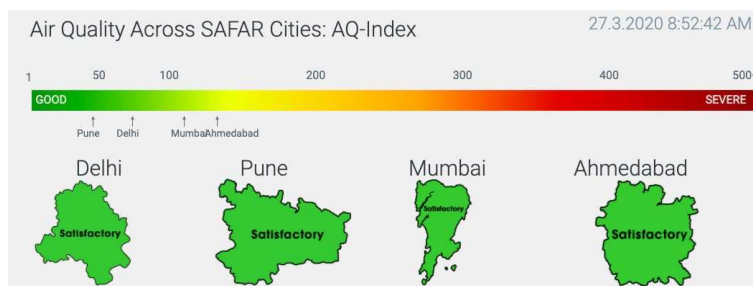


Figure 1. Air quality index of metro cities

(Source: <https://www.indiatoday.in/india/story/coronavirus-india-lockdown-metros-aqi-air-quality-1660209-2020-03-27>)

Air pollution has been a subject of substantial and health issues especially in metro cities. To put up information regarding Air Quality (AQ) in public domain is thus an essential task. Air Quality Index is one of the effective means of information diffusion regarding AQ in simple linguistic manner. Various environmental and health organizations adopt this tool to convey public about the status of AQ. Under Swach Bharat Abhiyan in India, National Air Quality Index (AQI) was launched in Delhi on 17 September, 2019 [3]. In this program Central Pollution Control Board (CPCB) along with State Pollution Control Boards with around 342 monitoring stations covers 240 cities. This AQI considers eight air pollutants namely Particulate Matter $PM_{2.5}$ and PM_{10} , Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Carbon mono oxide (CO), Ozone (O_3), Ammonia (NH_3) and Lead (Pb). AQI index chart is shown below:

AQI Category (Range)	PM_{10} 24-h	$PM_{2.5}$ 24-h	NO_2 24-h	O_3 8-h	CO 8-h mg/m^3	SO_2 24-h	NH_3 24-h	Pb 24-h
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	350-430	121-250	281-400	209-748	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

(Units: $\mu g/m^3$ unless mentioned otherwise) (source: National Air Quality Index Report by CPCB)

Uncertainties and vagueness experienced within AQ management could be dealt with Fuzzy logic. Zadeh established Fuzzy logic in 1965 [4-5] and came up with the concept of linguistic reasoning which is better understood by human beings. In this study, a fuzzy analysis has been conducted to interpret the impact of lockdown on pollution level of the national capital Delhi.

2. MATERIALS AND METHOD

The present study is an attempt to evaluate the dip in Delhi's pollution after implementation of lockdown. For this evaluation an effective and well known

Fuzzy Inference (FI) rule based mechanism known as ‘Mamdani Method’ has been employed which broadly comprises of three essential steps (Figure 2) described below:

Step 1: Fuzzification of the crisp inputs: The crisp inputs are fuzzified via linguistic variables and membership functions (MF’s). MATLAB FI System tool box is equipped with various MF’s viz. trapezoidal, triangular, Gaussian, logistic, sigmoidal etc. In this study we adopted triangular and trapezoidal MF’s.

Step 2: Inferencing: FI rules are being constructed in the form of if-then statements. These rules are constituted by subject experts or decision makers according to characteristics of the input variables and expected outcomes. The inputs from step 1 along with their corresponding MF’s are then exposed to these rules to produce fuzzified output for each of the rule.

Step 3: Defuzzification of the fuzzy output: The fuzzy output gathered from step 2 is defuzzified into a non-fuzzy (crisp) output. The defuzzification is done by ‘centroid of gravity’ method

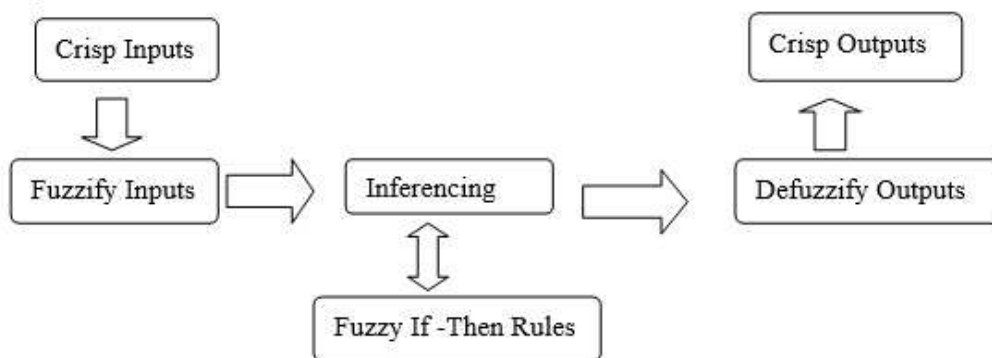


Figure 2. Steps of Fuzzy Inference System

2.1. Study Area. In this analysis Delhi which is shameful for its frightful pollution levels has been chosen. Delhi has received the embarrassment in November 2019, of becoming the most polluted major city in the world by the Air Visual [6]. But in March 2020, the effect of lockdown has been impressive. There has been a great dip observed in Delhi’s pollution. We have considered four sites to calculate the impact of lockdown Ashok Vihar, Bawana, Rohini and Wazirpur.

2.2. Critical Air Quality Parameters considered in this analysis. In this study we proposed a Fuzzy Air Quality Index (FAQI) and the AQ parameters considered here are PM2.5, PM10 and NO2. PM stands for Particulate Matter and

is microscopic particles which are mixture of solid particles and liquid droplets dangling in air. PM_{2.5} specifies to that particulate matter with a diameter less than 2.5 micrometers (which is around three percent of diameter of human hair) and PM₁₀ refers to those which have diameter less than 10 micrometers. Few of the PM occurs naturally from dust storms, forest fires, volcanoes, vegetation etc. while some other are results of anthropogenic activities like burning of fossil fuel in vehicles, wet cooling towers, power plants and many other industrial processes. Since they have the ability to penetrate deep into the lungs and bloodstreams they are considered as the most harmful type of air pollutant [7]. NO₂ i.e. Nitrogen dioxide is another major air pollutant as it contributes to the formation of photochemical smog and thus causes serious health problems especially respiratory problems [8].

3. IMPACT EVALUATION USING MATLAB FI SYSTEM

In this analysis, Fuzzy logic is used to calculate the impact of lockdown on air pollution of Delhi in terms of most critical air quality parameters PM_{2.5}, PM₁₀ and NO₂. The steps of FI System in MATLAB are carried out by considering PM_{2.5}, PM₁₀ and NO₂ as input variables and FAQI as output variable. The trapezoidal and triangular MF's are used to represent linguistic variables. We have used linguistic variables Low (L), Medium (M), High (H) for inputs PM_{2.5}, PM₁₀ and NO₂ shown in Figure 3 and Table 1 and Good (G), Satisfactory (S), Average (A), Unhealthy (U), Hazardous (H) for the depiction of FAQI shown in Figure 4 and Table 2. Generally, the number of rules is given by (linguistic variables)^{number of parameters}. As here we have three linguistic variables and three parameters so we have $3^3=27$ rules. Rules are formulated by expert's advice. Few of them are listed in Table 3.

Table 1. Membership Functions of Input variables

Linguistic Representation	PM _{2.5}	PM ₁₀	NO ₂
L	[0 30 60 80]	[0 40 60]	[0 40 60 80]
M	[60 120 180]	[80 140 200]	[60 90 120]
H	[160 300 400 500]	[180 300 400 500]	[100 135 170 200]

Table 2. Membership Functions of Output variable

Linguistic Representation	FAQI
G	[0 15 35 50]
S	[50 75 100]
A	[100 150 200]
U	[200 300 400]
H	400 430 470 500]

Table 3. Few of the rules formed in this analysis

Rule No.	PM _{2.5} If	PM ₁₀ And	NO ₂ And	FAQI Then
1	L	L	M	S
2	L	M	M	A
3	L	M	H	U
4	L	H	H	H
5	M	M	H	U
6	H	L	L	U
7	H	M	H	H

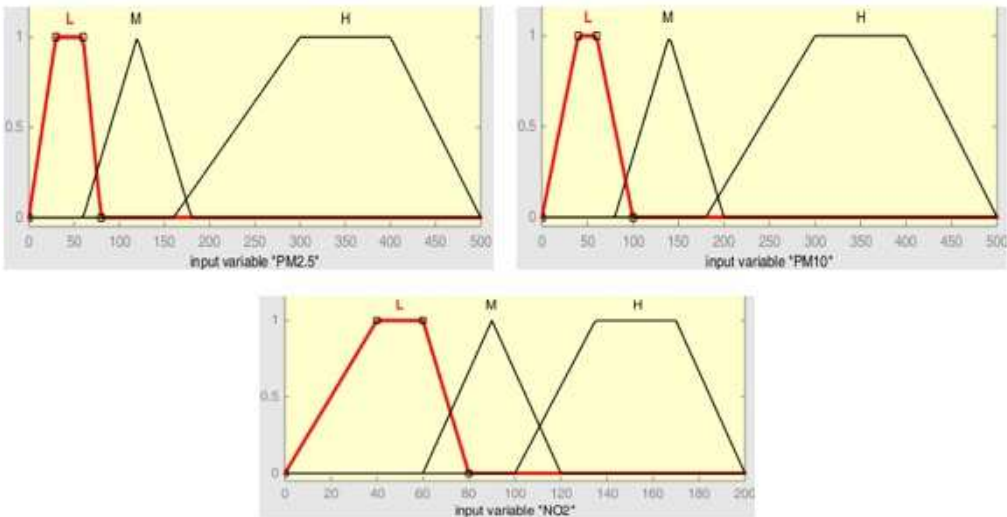


Figure 3. Membership Functions of Input variables

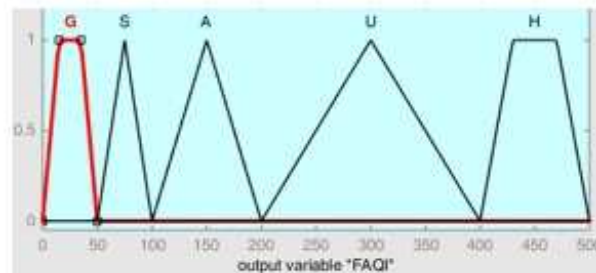


Figure 4. Membership Functions of Output variable

The rules are then gathered to get the final output through defuzzification.

4. SIMULATION RESULTS AND INTERPRETATION

The proposed technique to assess the reduction in air pollution was justified by using MATLAB simulation investigation. To calculate the FAQI, the Fuzzy logic designer has been employed. Table 4 and 5 represents FAQI at each of the sampling sites on 01 January, 2020 and 31 March, 2020 at 3:00 p.m., respectively. The values attained using FI System affirms a drastic dip in air pollution. Significant deductions of the model are:

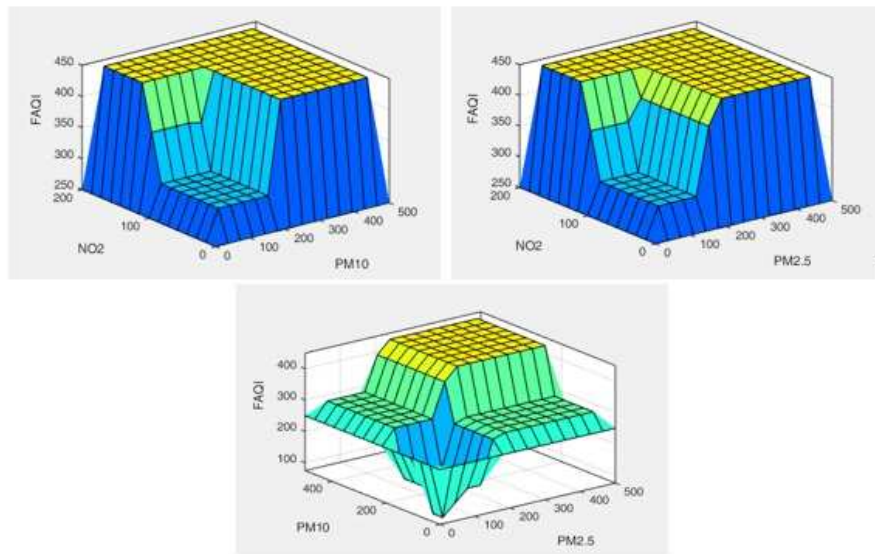
1. There is a huge reduction observed in values of all of the three pollutants PM_{2.5}, PM₁₀ and NO₂ after one week of lockdown.
2. Values of FAQI are fairly close to AQI validating the proposed model.
3. The pollution levels which are in severe and hazardous range transverses to moderately polluted and satisfactory range. The surface graphs representing the interactions between the parameters are shown in Figure 5.

Table 4. Simulation results of sampling sites 01 January, 2020

Sampling sites	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO ₂ ($\mu\text{g}/\text{m}^3$)	AQI	FAQI
Ashok vihar	444	385	58	444	450
Bawana	468	419	76	468	450
Rohini	463	399	43	463	450
Wazirpur	460	432	49	460	450

Table 5. Simulation results of sampling sites 31 March, 2020

Sampling sites	PM _{2.5} ($\mu\text{g}/\text{m}^3$)	PM ₁₀ ($\mu\text{g}/\text{m}^3$)	NO ₂ ($\mu\text{g}/\text{m}^3$)	AQI	FAQI
Ashok vihar	78	64	16	78	62
Bawana	145	105	17	145	150
Rohini	122	92	12	122	125
Wazirpur	81	69	48	81	75

**Figure 5. Surface Graph Representations**

5. CONCLUSION AND SUGGESTION

The proposed model in this study ratifies a great depletion in pollution level at all of the sampling sites in Delhi. The reduction in values of pollutants confirms an unintended outcome of Corona lockdown. Moreover, the pandemic is spreading and what so ever is being done to control it, seems inadequate. Actually it is Mother Nature which is admonishing us of its pre-eminence and is warning us to step back. It's time to assess what we have done to our environment and surroundings. Nature does not depend upon us in fact we rely on nature for its resources. The present crisis is teaching us a lesson to introspect and to get compassionate and positive towards our Mother Nature. In this time of crisis the lockdown has come with this unexpected aspect and we suggest our ministry that even in normal time lockdown must be implemented after every 3-4 months for a day so that we can pay gratitude and protect our Mother Nature.

REFERENCES

- [1] <https://www.hindustantimes.com/india-news/air-pollution-curve-flattens-in-delhi-ncr-due-to-lockdown-impact/story-4HABR2AowrywwtoGVcUh7O.html>
- [2] <https://www.indiatoday.in/india/story/coronavirus-india-lockdown-metros-aqi-air-quality-1660209-2020-03-27>
- [3] https://en.wikipedia.org/wiki/Air_quality_index
- [4] L.A. ZADEH: *Fuzzy sets*, Information and Control, **8**(3) (1965), 338-353.
[https://doi.org/10.1016/S0019-9958\(65\)90241-X](https://doi.org/10.1016/S0019-9958(65)90241-X)
- [5] L.A. ZADEH: *A fuzzy-algorithm approach to the definition of complex or imprecise concepts*, International Journal of Man-Machine Studies, **8**(3) (1976), 249-291.
[https://doi.org/10.1016/S0020-7373\(76\)80001-6](https://doi.org/10.1016/S0020-7373(76)80001-6)
- [6] <https://www.news18.com/photogallery/india/delhi-pollution-photos-delhi-tops-the-list-of-most-polluted-city-in-the-world-2369829.html>
- [7] <https://en.wikipedia.org/wiki/Particulates>
- [8] <https://www.environment.gov.au/protection/publications/factsheet-nitrogen-dioxide-no2>

RESEARCH SCHOLAR,
CHANDIGARH UNIVERSITY
PUNJAB
PRESENTLY WORKING AT
AMBALA CITY

DEPARTMENT OF MATHEMATICS
CHANDIGARH UNIVERSITY
PUNJAB

DEPARTMENT OF CHEMISTRY
AMBALA CITY