Air Quality Scenario And Its Analysis Using Fuzzy Rule Base Approach: A Case Study Pune, India

Bedmutha P.J[1]
Undrgraduate student of bachelor in
Civil engineering department
Zeal College Of Engineering & Research,
Pune,Maharashtra,India
Corresponding Author

Anaokar G.S[2]
Assistant Professor
Civil engineering department
Zeal College Of Engineering & Research,
Pune,Maharashtra,India

Abstract — Air quality of metro cities is a severe challenge considering health risk analysis studied in last few decades. The major air quality parameters like Sulphur dioxide, nitrogen oxide, respirable suspended particulate matter (RSPM) were studied for Pune city (MS) India. Due to uncertainty and larger variation in observed values it is difficult to judge the scenario of air quality. An air quality model was developed for a decade 2005 to 2015 and 2007 to 2017 using fuzzy rule base approach. Sensitivity study of two models for each decade was carried out. The comparison between air qualities was analyzed in order to check status of air quality changed. The concerned parameters and factors influencing the same were studied.

With reference to the model developed for the span 2005 to 2007 the parametric values were considerably low. Naturally the same model failed to operate for the decade 2015 – 2017. A revised model was developed considering a present air quality scenario and validated. For the parameter like oxides of sulfur and nitrogen the concentration was found lowered down with to minimum scale whereas about 150% increase was observed towards maximum level. The -present suggested model was found validated for the purpose of forthcoming years when the considerable attempts has been proposed towards green environment.

Keywords— air quality index; fuzzy rule base; decade; forecasting.

I. INTRODUCTION

In environmental engineering different issues need to analyzed on the basis of human interface, determination of pollution level is one of them. As the pollution intensity measurement involves multiple complex processes and can be interpreted by different ways. A common index or number which could be able to give whole sum idea about pollution intensity to layman will be helpful to forecast air quality and perform health risk analysis.

Air quality in cities from India gets diminished due to flooded populations, day by day increasing vehicles, rapid and haphazard industrialization and unawareness regarding pollution measures. The World Health Organization (WHO) report in 2014 had endorsed that 14 Indian cities among the top 20 most polluted cities of the world. Those 14 were Delhi, Patna, Gwalior, Raipur, Ahmedabad, Lucknow, Firozabad, Kanpur,

Amritsar, Ludhiana, Allahabad, Agra, Khanna and Pune. (Source: The Hindu; 16th July 2015). This would be a threatening message for the country like India where average 20% deaths are due to polluted air. The major cause of increased air pollution in Indian megacities includes unprecedented surge in the number of vehicles, the expansion of road network and increase in built-up area. The Indian Institute of Tropical Meteorology (IITM) has revealed that Pune's pollution level is over twice that of the prescribed national air quality standards.

Air quality index (AQI) is a number used by government agencies to communicate to the public; how polluted the air currently is or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. As this will be an indicative number, will be easily interpretable by layman.

Air Quality Index is being calculated on the basis of the concentration of air pollutants like SO_2, NO_2, CO, $PM_{2.5}$, PM_{10}, Temperature, etc. It is necessary to bring all these parameters under single indicative number which can give an idea about air quality. The Fuzzy logic system helps to identify this unique number by considering these parameters as membership functions and applying necessary rule base.

Fuzzy set theory allows partial membership by generalizing the classical set theory to some extent. The fuzzy sets could be defined by redefining and expanding the usual characteristics of classical sets. A classical set might be expressed as

$$A = \{x \mid x > 6\}; \qquad \text{……. (Equation 1)}$$

Where as Fuzzy Set A in X is defined as a set of ordered pairs.

$$A = \{x, \mu A(x) \mid x\ X\} \qquad \text{……. (Equation 2)}$$

where μA(x) is the membership function of x in A. The membership function converts each element of X to a membership value between 0 and 1. Fuzzy logic consists of membership function (MF) which is a graphical representation of the magnitude of participation of input. MF deals with weight of input, their functional overlap and expected response in the form of output.Here weighing factors which influence fuzzy output sets are being used as rules. Fuzzy mechanism replaces the decisions by fuzzy sets and rules by fuzzy rules. Most of the decisions are logical decisions, based on situation. Fuzzy rules also operate using a series of if - then statements; usually designated as rules. Defuzzification which converts fuzzified input into an output is obtained after the functions will be inferred, scaled and combined. Depending on the fuzzy set the shape of the membership function is decided.The membership function choice is the subjective aspect of fuzzy logic; it allows the desired values to be interpreted appropriately. Rather than using numbers lingusitc variables are being used in fuzzy systems using linguistic words. In the present study minimum, average and maximum are the variables used to define input. The actual process of mapping is fuzzy inference. This process starts from a given input and finishes to an output using fuzzy logic. A Mamdani type fuzzy inference system was preferred so as to get a simplified and interpretable output.

II. METHODOLOGY

Present work is carried out to know the difference in air quality from 2005-2015 & 2007-2017. In this work the air quality model for city Pune, was developed. The necessary data was fetched through Maharashtra Pollution Control Board (MPCB) and processed through the software FisPro3.5®. Air quality for the city Pune, India was monitored by Maharashtra Pollution Control Board (MPCB).

Table 1 Air Quality Monitoring Database at Swargate

MONTH	YEAR	MIN	MAX	AVG
JUNE-SEP	2005-2007	10	14	19.18
		14	58	38.27
		27	168	84.92
OCT-JAN	2005-2007	12	38	21.81
		22	61	43.17
		47	222	118.96
FEB-MAY	2005-2007	17	37	26.30
		29	73	44.95
		73	229	134.91
JUNE-SEP	2015-2017	8	47	11.96
		12	331	26.92
		6	378	44.08
OCT-JAN	2015-2017	6	102	30.70
		20	167	74.53
		27	378	131.97
FEB-MAY	2015-2017	12	79	26.83
		9	177	57.48
		26	271	105.26

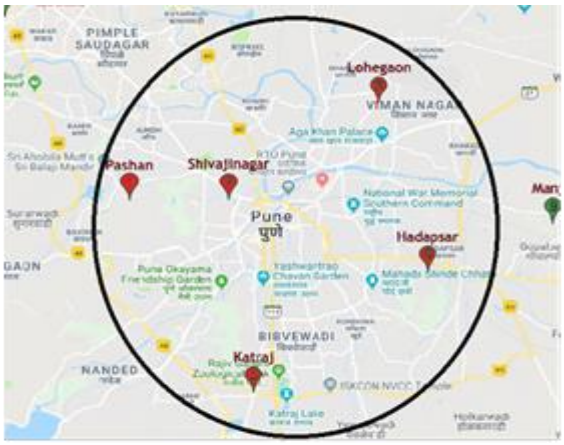

Fig.1 Study area map

The monitoring is being carried out through Indian Institute of Tropical Meteorology (IITM), Pune, a constituent under the Ministry of Earth Sciences, Government of India, is spearheading country's first major initiative named as "System of Air Quality Forecasting and Research (SAFAR)". The SAFAR provides location specific information on Air Quality in near real time and its forecast 24 hours in advance. It has capability to forecast 3 days (72hrs) in advance but 3 day's advance forecast will be issued only when there is some specific extreme event. It is complemented by the weather forecasting system designed by Indian Meteorological Department, Pune. Air quality index has been calculated for the data obtained through MPCB. The ambient air quality monitoring was carried out at Swargate – a most crowded location Pune city throughout the day - at location terrace of Swargate police Chowky. The frequency of monitoring was maintained as twice a week from January 2005 to December 2007 and from January 2015 to December 2017. Parameters monitored were $S0_x$, NO_x, and RSPM in $\mu g/m^3$.

Fuzzification is the process of normalizing the crisp data, applying weights considering relative importance, abiding membership functions, constructing and applying rules and finally obtaining optimized output etc. Rule base can be defined on the basis of the available database above. Total 27 rules were applied considering opinions of expert from various industries, filed observations and literature. Accordingly the Air quality ranges are identified as follows;

Table 2 Indicative Ranges of Air Quality

CHARACTERISTICS	SO_x	NO_x	RSPM
Poor	0 to 35	10 to 130	5 to 120
Acceptable	30 to 65	125 to 245	115 to 230
Excellent	60 to 95	240 to 360	225 to 340
CPCB LIMITS			
Residential	60	60	60
Industrial	80	80	120
Sensitive	15	15	50

Table 3 Rules Applied To Ranges of Air Quality

Rule	If_SO	And_NO	And_RSPM	Than_AQI
1.	Objectionable	Objectionable	Objectionable	Objectionable
2.	Objectionable	Objectionable	Acceptable	Poor
3.	Objectionable	Poor	Significant	Significant
4.	Objectionable	Significant	Acceptable	Acceptable
5.	Excellent	Significant	Acceptable	Excellent

An expert opinion is taken before applying these rules and then the Air quality index in the range from 1 to 5 has been defined. Accordingly these quality index are as follows:

Table 4 AQI Classes

Air Quality	Air Quality Index
Objectionable	1
Poor	2
Significant	3
Acceptable	4
Excellent	5

The process of defuzzification is carried out by using a freeware soft tool FisPro3.5®. As an input the variables were SO_2, NO, and RSPM the membership function for all was decided as triangular as it is a most convenient being a linear functions. The output obtained is in the area form. The desired value can be obtained by Centroidal Method.

Figure 1 AQI for the duration 2005 to 2007

Figure 2 AQI for the duration 2015 to 2017

The output obtained is as shown in figure 1 whereas figure 3 shows the desired value of air quality index which can be calculated by Centroid Method.

III. CONCLUSION

Decision making under uncertainty can be carried out using fuzzy logic. Environmental monitoring systems largely affected by surrounding parameters like season. temperature, approach, etc. In present work, the air quality index has been calculated using Fuzzy logic system. After fuzzy analysis of data obtained by 92 stations air quality index of value 3 has been obtained. The output is as shown in figure 3. This figure indicates overlaid membership functions and corresponding result.

REFERENCES

[1] Anonymous; Fuzzy Logic Fundamentals; March 26, 2001

[2] Ashok Deshpande, D. V. Raje; Fuzzy logic applications to Environmental Management studies: Case studies

[3] Babaei Semiromi, F.1, Hassani, A.H., Torabian, A., Karbassi, A.R. and Hosseinzadeh Lotfi; Water quality index development using fuzzy logic: A case study of the Karoon River of Iran; African Journal of Biotechnology Vol. 10(50), pp. 10125-10133, 5 September, 2011.

[4] Bai. V, Reinier Bouwmeester and Mohan. S, Fuzzy Logic Water Quality Index and Importance of Water Quality Parameters, Raman, Air, Soil and Water Research 2009:2 51–59

[5] Bezdek, J. C., 1993. Fuzzy models—what are they and why — editorial. IEEE Transactions on Fuzzy Sys- tems, vol .1, pp. 1–5.

[6] Cox, E., 1994. The Fuzzy Systems Handbook. Cambridge, MA: Academic Press.

[7] Dubois, D. and Prade, H., 1980. Fuzzy Sets and Systems: Theory and Applications. New York: Academic Press.

[8] Franck Dernoncourt ; Introduction to fuzzy logic; Masssachusets Institute of Technology; MIT, January 2013

[9] Klir G.J, Clair, Yuan B; Fuzzy sets and Fuzzy Logic – theory and Application; PHIL publisher, ISBN 978-81-203-1136-7

[10] G.Vijayaraghavan, M.Jayalakshmi; A Quick Review on Applications of Fuzzy Logic in Waste Water Treatment; International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume 3 Issue V, May 2015;ISSN: 2321-9653; pp 421-425

[11] H.J. Zimmermann; Fuzzy set theory ; WIREs Computational Statistics; John Willey & Sons; Volume 2, May/June 2010 PP 317-331

[12] Robert Fuller; Fuzzy Reasoning and Fuzzy Optimization; Turku Centre for Computer Science; 1998.

[13] Shah Abhishek and Khambete A. K. ; Statistical Analysis To Identify The Main Parameters To The Wastewater Quality Index Of CETP : A Case Study At Vapi, Gujarat, India; Journal of Environmental Research And Development; Vol. 7 No. 3, January-March 2013; pp 1294-1304.

[14] Steven D. Kaehler, An Introduction to Fuzzy Logic - Six Toipcs, Annoted

[15] Vinayak K. Patkia, S. Shriharia, B. Manua and Paresh Chandra Deka; Fuzzy system modeling for forecasting water quality index in municipal distribution system; Urban Water Journal, 2015 Vol. 12, No. 2, 89–110,

[16] Zadeh, L. A., 1965. Fuzzy sets. Information and Control, vol, 8, pp, 338–353.

[17] http://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/sbaa/report.html