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Analysing the Ambient Quality of Air Using Fuzzy Inference System during Intervention Events

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ABSTRACT

The developing countries around the world have increase in population, industrialization without any plan and commercialization of residences facing the air pollution problem. The major pollutants such as CO, SO_2, RSPM, TSPM, NO_2 emission affects the human health as well as animals and growth of crops. In this paper, a model is proposed to assess the quality of air using fuzzy inference system which is one of the upcoming computational techniques in data mining. For this purpose the air pollution data of Chennai city is taken during January month which is an intervention event for Chennai pollution data from 2007 to 2017. The model which has been proposed gives good results in assessing the air quality of the city. The model is based on fuzzy inference system which is the latest tool used to assess air quality throughout the world.

Keywords— fuzzy inference system, data mining techniques, air quality index, intervention event, computational methods.

Introduction:

Air pollution is one of the very important issues in all the cities. The air is getting polluted by some of the pollutants like CO, NO_2, O_3, SO_2 and particulate matter ($PM_{2.5}$, PM_{10}). These pollutants are called primary pollutants which affect human health, damage other living things like animals, food crops and even tend to death. Chennai city is having the base of 30% of production in four wheeler vehicles and 35% of its component production in India. Chennai is the fourth largest metropolitan city of the country and the capital of the state Tamilnadu. In the year 2008, Tamil Nadu had over 16 million 2 and 4-wheeled vehicle registrations. The six of the top cities based on the vehicle population are Delhi, Chennai, Hyderabad, Pune, Mumbai and Kolkata. Out of these six cities Chennai has taken the first place with 2093 in the vehicle density. The industries and motor vehicles emit pollutant NO_2 and which results in pulmonary oedema (accumulation of excessive fluid in the lungs). The fossil fuel emits SO_2 and disturbs eyes, nose and throat and injures the lungs when breathed in. Motor vehicles and industries are among the largest fictitious sources of carbon monoxide emissions. Carbon monoxide is the most usual type of fatal poisoning in many countries everywhere in the world. It disturbs the central nervous system and heart and severe effects on the foetus of pregnant woman and also causes headache and dizziness. To reduce all these effects in humans as well as other living things we monitor the quality of air which we inhale to get oxygen to live. Many of the researchers worked to predict the air quality in the cities using the data mining techniques as well as the fuzzy logic technique which is one of the computational method applied nowadays. Gopal Upadhyaya et al, proposed a Fuzzy logic based model for monitoring air quality index in the year 2011[2]. In the same year, Daniel Dunea, et al proposed a paper in Fuzzy inference systems for estimating air quality index [3]. In 2012, R. Kumaravel et al presented a work in Fuzzy Inference System for Air Quality in Using MATLAB for Chennai [5]. In the same year, P. Balashanmugan, et al, proposed a work in assessing ambient air quality of Chidambaram in Tamilnadu using fuzzy logic [8]. In 2014 Abhishek Upadhyay, et al, developed a fuzzy recognition model to assess the air quality of Howrah city in their work[1]. In the same year, Bouharati Saddek et al, proposed a model based on fuzzy inference system to analyse the air quality index and public health [7]. In 2016, B. Lokeshappa et al , proposed a work in analyzing air quality indices using fuzzy logic[9]. In this paper we present the model using fuzzy inference system which is going to monitor the four major places in Chennai namely Anna Nagar, Adayar, T.Nagar, Kilpauk and Vallalar Nagar.

Fuzzy inference system is used for analysing the real-time problems, which generally describes the degree of uncertainty and is one of the upcoming data mining [14] techniques. Fuzzy logic apply the variables like low, moderate and high in place, true/false or yes/no variables. Fuzzy sets are decided by membership functions. The membership function of a fuzzy set is represented as RSPM and membership degree as a number between 0 and 1. Here to analyse the air quality of Chennai during Bhogi festival we use fuzzy inference system. Now the system variables are selected. The system variables are namely the input and output variables in fuzzy system. The input variables are the pollutants namely SO_2, NO_2, RSPM, TSPM. If the selection of number of variables are more than the rules will be more which increases the complexity. The input and output are taken in linguistic form. For example, SO_2 (very low, low, moderate, high, very high), NO_2 (very low, low, moderate, high), RSPM (very low, low, moderate, high), TSPM (very low, low, moderate, high). The output variable in the same way divided into Air Quality Index (good, moderate, poor, very poor, severe).

II. MATERIALS AND METHODS

A. Background

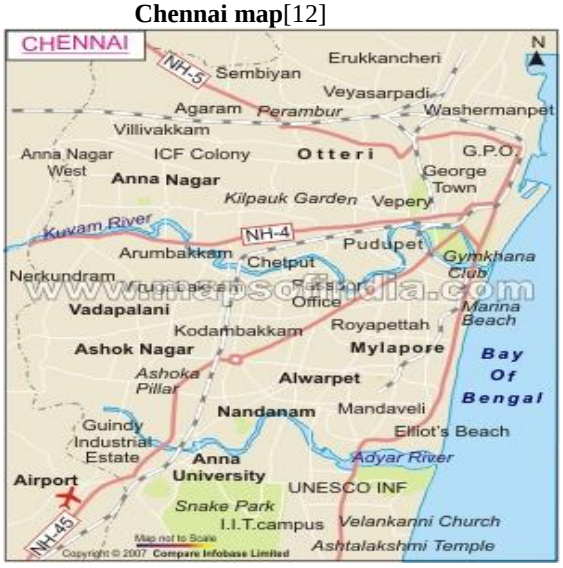
To calculate the Air Quality Index of urban Area for the present study, Chennai city which is the capital of Tamilnadu was selected. Chennai is the 4th Metropolis in India and is considered as one of the major Industrial, commercial and educational centre in southern India and also as Information Technology and Bio Technology centre. It is a very centre place with good network of surface, air and sea transportation facilities and also connected with rest of India. The population of Chennai city in 2015 is 4.28 million. It gets the average rainfall of 110 cm during the north eastern monsoon and has the humidity level ranges from 50% to 90%. Because of its dense population and increase in economic activity the pollution also raises. The outer area of the city is mostly covered with industries which is also one of the reasons for the increase in pollution. India is getting fastly urbanised not only in the capital but also in the city which is taken for study mainly the Bhogi festival period which is taken as the intervention event. Bhogi is taken as the intervention event because during this time the air quality will reach above the standard limit due to the smokes from burning the waste goods. The sampling stations selected for the analysis are Adyar, T. Nagar, Kilpauk and Vallalar Nagar. Out of these stations Adyar is considered as residential area, T. Nagar and Kilpauk are considered as commercial areas and Vallalar nagar is considered as industrial area.

Intervention event:

Bhogi festival is the preceding day of Pongal and is celebrated to thank Lord Indra, "the God of Clouds and Rains". Lord Indra is worshipped for the fortune of harvest, thereby bringing plenty and prosperity to the land. On Bhogi all people clean their homes from top to bottom, and remove all unwanted goods. This day is meant for domestic activities and of being together with the family members. All the houses from the richest to the humblest are thoroughly scrubbed and whitewashed. Homes are cleaned and decorated with "Kolam" - floor designs drawn in the white paste of newly harvested rice with outlines of red mud. Another ritual observed on this day is Bhogi Mantalu, when unwanted household articles are thrown into a fire made of wood and cow-dung cakes. Girls dance around the bonfire, singing songs in praise of the gods, the spring and the harvest. The significance of the bonfire, in which is burnt the agricultural wastes and firewood is to keep warm during the last lap of winter.[13]

Thiyagaraya nagar map

Chennai map[12]



B. Parameters Considered and Duration:

The parameters which are affecting the air quality differ from place to place. However, by considering in mind the industrial activities and vehicle usage in the study area, four air quality parameters are taken into account namely, SO_2, NO_2, TSPM & RSPM were selected to establish AQI. AQI data of the selected sampling stations were collected for ten years period for the month January from 2007 to 2017 where this month is the intervention event for Chennai pollution data. The data was collected from Tamilnadu State Pollution Control Board (TNPCB) Chennai.

III. RESULTS AND DISCUSSIONS

Air quality index is the index which is used to know the quality of the air which we are breathing daily. It tells us the amount of pollutants in the air which we are inhaling and what are the health effects for the humans and animals and also the effects in plants. The air quality index particularly contemplates on the health issues which may get experienced within a few hours or days after inhaling polluted air. The AQI varies from 0 to 500. The greater value of AQI reports how much the air got polluted and effect on health. When the AQI values are extreme, the air quality is referred as unhealthy mainly for sensitive people, then for other persons. The air quality index has been given as follows [3]

TABLE I **Sub- Index and breakpoint pollutant concentration for Indian Air Quality Index**

		IND-AQI		
Sub–index	***Category***	***Pollutants (µg/m3)***		
		SO2	***NO2***	***RSPM***
0 – 100	Excellent	0 - 80	0 - 80	0 - 100
101 – 200	Good	81-367	81- 180	100 - 150
201 - 300	Moderate	368- 786	181-564	151 - 350
301 - 400	Poor	787- 1572	565-1272	351 - 420
401 - 500	Very poor	> 1572	> 1272	>420

The air quality data of four study areas are collected for eleven consecutive years with reference to the parameters namely SO_2, NO_2 and RSPM are taken into account to analyze and discuss and to write the inference rules.

A. Air Quality Status of T.Nagar

The case study is the shopping area which is specified as commercial area. The ambient concentration level of all pollutants are found to be above the limited level in this area. During the period of study all the pollutants in this area recorded above the standard limit. Table II shows the air quality at T.Nagar.

Table II Air Quality at T. Nagar during Bhogi festival

Study period	**Concentration of stated parameters**		
	SO_2	**NO**	**RSPM**
2007	10	28	94
2008	8.3	24	103
2009	8.3	23.9	103
2010	12.8	29.3	127
2011	8	22	127
2012	11	14	112
2013	16	51	97
2014	21	27	103

2015	22	28	89
2016	13	22	125
2017	9	14.5	87

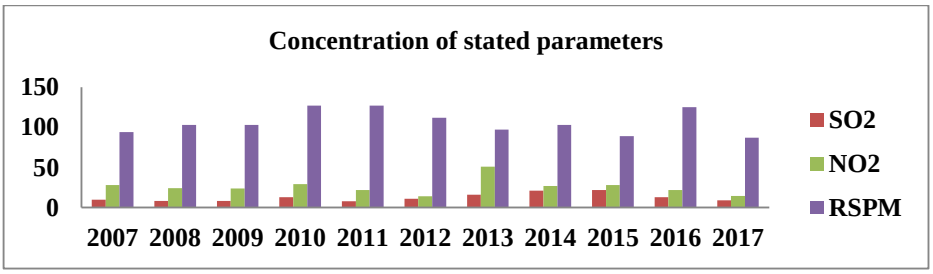


Fig 1 Variation of pollutants concentration during Bhogi festival at T. Nagar

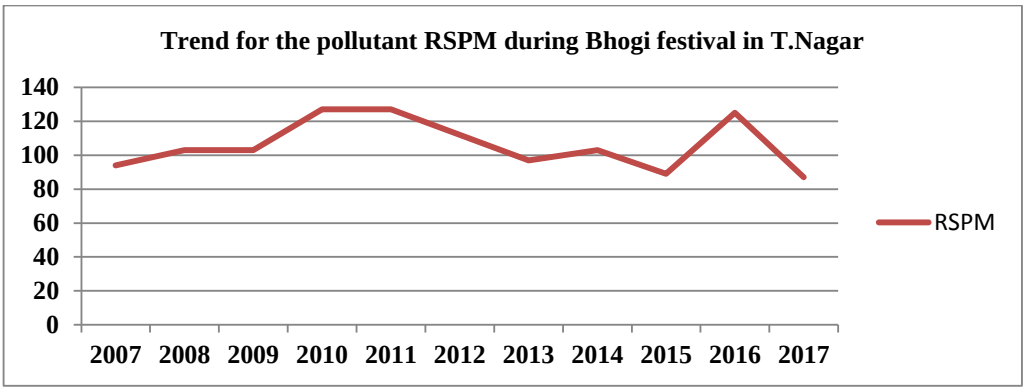


Fig 2 Trend for the pollutant RSPM during Bhogi festival at T. Nagar

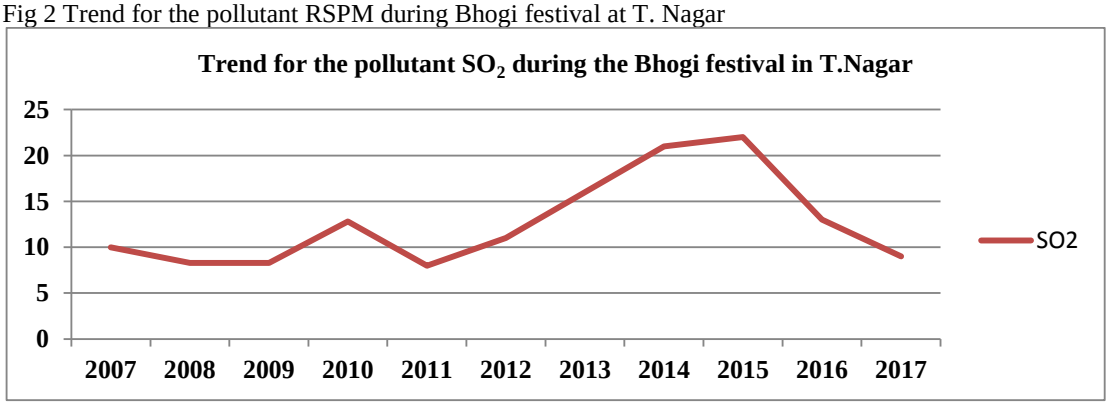


Fig 3 Trend for the pollutant SO_2 during Bhogi festival at T. Nagar

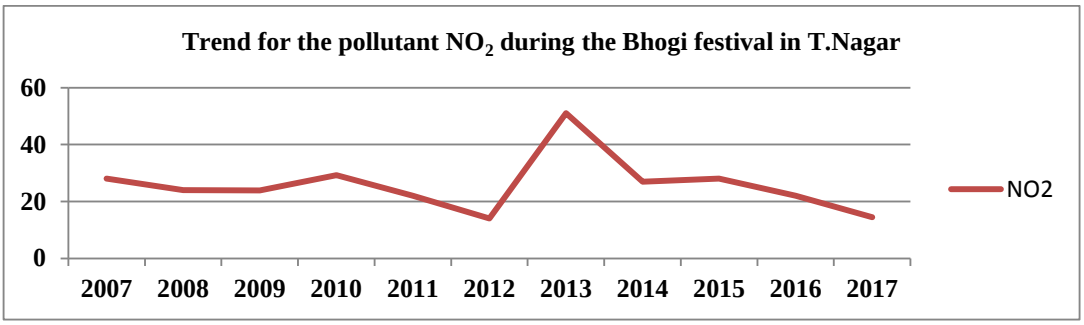


Fig 4 Trend for the pollutant NO_2 during Bhogi festival at T.Nagar

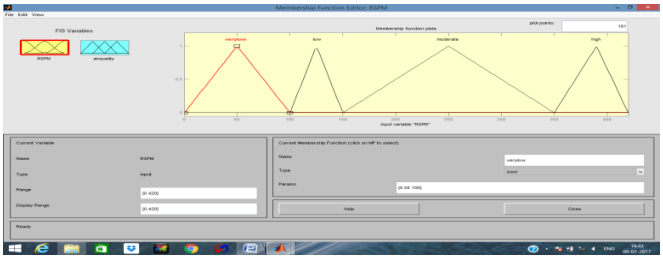


Fig 5 Membership function of RSPM

Figure 5 represents the membership function of RSPM. For a fuzzy set A on the universe of discourse X is defined as μ_A:X→[0,1], where every element of X is mapped to a value between 0 and 1. This value is called the membership value or degree of membership which measures grade of membership of element in X to fuzzy set A[10]. The membership function allow us to denote the fuzzy set as a graph. The x-axis denotes the universe of discourse, while the y-axis denotes the membership in [0,1] interval. The membership function is used to allot a grade to each linguistic term.

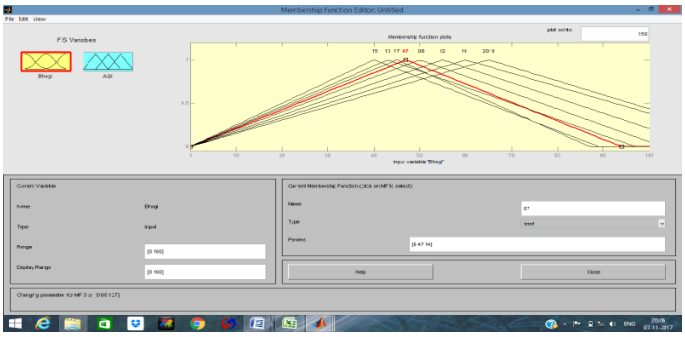


Fig 6 Membership Function of RSPM in T. Nagar during Bhogi festival

Figure 6 represents the membership function for RSPM during Bhogi festival inT. Nagar.

During the study period the pollutant concentration crosses the standard limit except in the years 2007, 2015 and 2017 within the standard limit. Increasing trends indicates the poor air quality in this area which can be avoided by not burning waste goods like rubber tyresa nd plastics in this area.

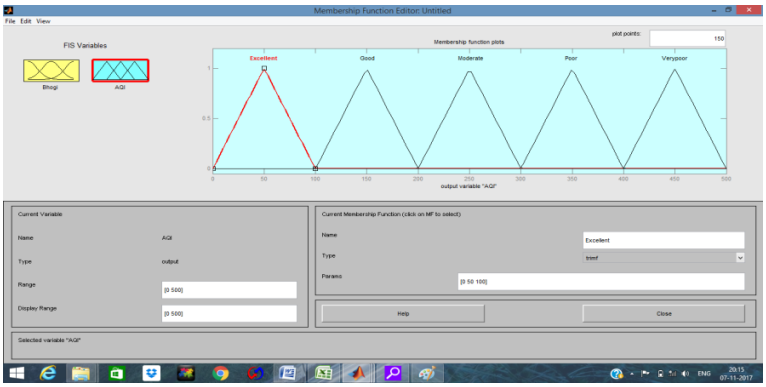


Fig 7 Output function of the fuzzy inference system for RSPM

Fig 7 shows the output function for RSPM. Now the variables have been named and the membership functions got the correct shapes and names. It shows the range of air quality index. It shows the level of the index if air quality varies from 0 -100 as excellent, 100- 200 as good, 200 – 300 as moderate, 300- 400 as poor and 400 – 500 as very poor. According to this categorization we find the index.

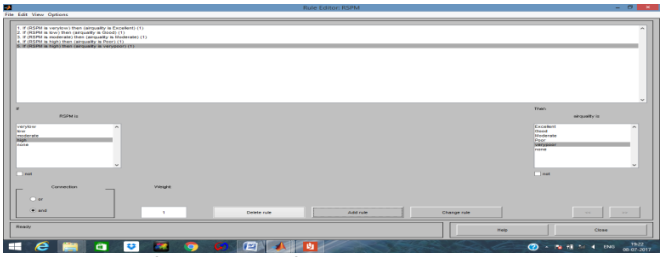


Fig 8 Fuzzy inference rules for RSPM

Fig 8 represents the fuzzy inference rules for RSPM which can be formed based on the input and output variables automatically in the Rule editor.

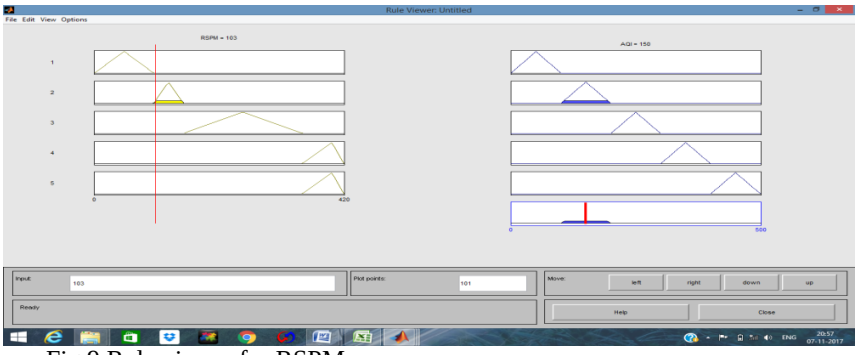


Fig 9 Rule viewer for RSPM

Fig 9 shows the rule viewer.This displays a map of the entire fuzzy inference system. The area shown in the first three plots of the diagram denotes the antecedent and consequent of the rules. Each rule is represented as a row of graph and each column is a variable. Rule integers are mentioned in the left of each row.

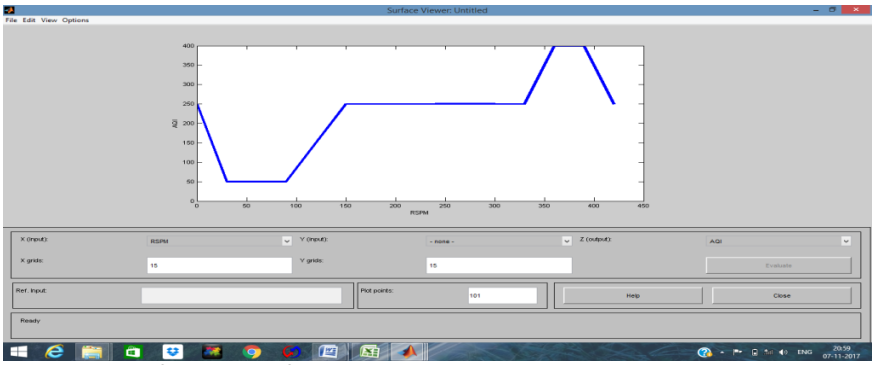


Fig 10 Surface viewer for RSPM

Fig 10 explains the surface viewer which is a Mamdani tool that checks the output surface of a fuzzy inference system. It is just a read only editor.

Rule:

- If air quality index(AQI) at a particular time and place is recorded. Then value of the AQI is 0 – 100 or 100- 200 or 200 – 300 or 300 – 400 or 400 – 500.
- If the value of AQI falls in 0 – 100 then the surrounding is excellent.
- If the value of AQI falls in 100 – 200 then the surrounding is good.
- If the value of the AQI falls in 200 – 300 then the surrounding is moderate.
- If the value of the AQI falls in 300 – 400 then the surrounding is poor.
- If the value of the AQI falls in 400 – 500 then the surrounding is very poor.

Bhogi festival in chennai makes a draustic change in the air quality of chennai than usual time period, since people used to burn waste and old household things in this intervention period.

CONCLUSION

Air pollution is very important issue in the urban areas nowadays and which is also affecting the health of the public. Fuzzy rule based system for AQI, is the useful model to give suggestions to human outdoor actions on some areas. Result of this work of fuzzy inference system has a better result than other computational methods. Our work will help to develop a better quality environment in good area as well as polluted area.

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