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Feasibility Analysis of Air Quality Indices using Fuzzy Logic

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Abstract **- The Air Quality Index is a simple and generalized way to describe the air quality in in India. Indian Air Quality Index (IND-AQI) is mainly a health related index with the descriptor words: Good (0- 100), Moderate (101-200), Poor (201-300), Very Poor (301-400), and Severe (401-500). Central Pollution Control Board (CPCB) is responsible for measuring the level of air pollution in India. An individual score is assigned to the level of each pollutant and the final AQI is the Highest of those scores. The present investigation was carried out to significant of air pollutant concentrations at Residential, Industrial &Sensitive Areas Bangalore. Sulphur dioxide (SO_2), oxides of nitrogen (NO_2) and R.S.P.M were collected over six sites in Bangalore. First station location at Victoria Hospital, second station location at Graphite Industrial Area, and third station location at Amco Apartments, fourth station location at Peenya Industrial Area, fifth station location at Yeshwantapur Residential Area and sixth station location at K.H.B Industrial Area. All the sampling stations selected are located in Residential, Industrial and Sensitive areas.**

The Conventional method used Linear Interpolation for calculating AQI. We applied a real time Fuzzy Logic System with Simulink to calculate AQI. This method gives satisfactory result and it is efficient to work under continuous working mode.

Keywords: Air Quality Index, Fuzzy Logic System, Pollutants, Membership functions

1. INTRODUCTION

Air pollution is a serious worldwide public health problem. The short-term health impacts of air pollution have been studied extensively since the London fog in the mid-20th century and the subsequent series of dramatic episodes in industrialized countries. However, the magnitude of effect estimates varies across cities and countries, hindering interpretation and generalization of the causal association between air pollution and health. Some investigators have attempted to explain the heterogeneity of effects estimates among regions in terms of different levels of air pollutant, specific city characteristics and potential confounders including temperature and humidity.

About 60 per cent of air pollution in Indian cities is due to automobile exhaust emission. The vehicular emission contains more than 450 different organic chemical compounds either in gaseous or in particulate or in the combined forms. The emission loads in Indian urban cities are in the range of thousands of tons per day. The gains achieved through reduced standalone vehicle emissions are offset by the rapid rise in volume of vehicles.

Defining “air pollution” is not simple. One could claim that air pollution started when humans began burning fuels. In other words, all man-made (anthropogenic) emissions into the air can be called air pollution.

An environmental index is a tool, which is used to report the overall environmental status and trends based on specific standard. It was developed on the lines of health index and measured by the degree of human suffering. Each AQI category makes it easier for the general public to understand how clean or polluted the air is. To evaluate overall air pollution measures can be used to give meaningful assessment of air pollution control to the common man.

Fuzzy logic is very useful for addressing real-world problems, which usually involve a degree of uncertainty. Fuzzy logic uses variables like low, medium and high in place, of true/false or yes/no variables. Fuzzy sets are determined by membership functions. The membership function of a fuzzy set is expressed as SO_2 and membership degree of its fuzzy set is determined as a number between 0 and 1.

The structure of a fuzzy rule based system is the fuzzy algorithm the fundamental concepts of which are derived is the fuzzy algorithm the fundamental concepts of which are derived from fuzzy logic (Zadeh*et al*. 2010).

We can simply say that fuzzy logic is the new view of science towards the universe. In fact, processes are analysed as they truly are, not the way we want them to be, but how can we use them? Everything should be formulized in technical and engineering sciences; otherwise, its application will be limited and does not have a scientific basis.

The rules represent the relationship between the inputs and the output of the system. The generalized structure of a fuzzy system is presented.Two commonly used inference system are, i.e. Mamdani fuzzy model and Sugeno fuzzy model.

Comprises the process of transforming the crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. The fuzzification is the first step in fuzzy logic processing involves a domain transformation where the crisp inputs are transformed into fuzzy inputs (Nilesh*et al*. 2009).

We select the system variables i.e. the fuzzy system modelling is the identification of input and output variables. The most important input variables are

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SO_2,NO_2,RSPM,PM. Suppose select of more number of inputs to the system inputs to the system requires more number of rules and hence the complexity increases. The input and output are taken in the form of linguistic format. For example, SO_2= (Good, Moderate,Poor), NO2=(Good,Moderate,poor),RSPM=(Good, Moderate, Poor), PM=(Good, Moderate, Poor). The output variable similarly divided into Indian AQI=(A-Good, B-Moderate, C-Unhealthy).

2. MATERIALS AND METHODS

2.1 Background

To establish AQI of urban Area, for present study, Bangalore city, capital of Karnataka was selected. Bangalore, the 5th Metro and situated at a height of over 3000 feet above sea level.It is considered as one of the major Industrial, commercial and educational centre in southern India and also as Information Technology and Bio Technology centre. Urbanization in India is more rapid around national capital but also on the city itself. Fig 2.1 shows the sampling stations of study areasconsidered.and state headquarters. The city has taken dubious distinction of being the fastest growing metropolis in the country. The polarized development has significant impact on culture, economy and growth of not only surrounding areas of India, occupies important position not only in the state but also in the country. The Bangalore City Corporation limits are enclosed within 12º58' north and 77º35' east longitude at an average elevation of about 900 meters

2.2 Selection of Sampling Stations

Six sampling stations were selected for establishing AQI. Out of these six sampling stations- two were residential, one was sensitive area (hospital) and three were industrial Areas. The Table 2.1 shows the details of sampling stations selected for study.

Table 2:1Details of Sampling Stations.

Sl. No.	Stations Selected	Zone Type	Geographical Area
1	AMCO Apartments	Residential	12º,57', 84" N 77,32',25.7" E
2	Yeshwanthpura Residential Area	Residential	13º,01', 4.8" N 77º,33', 35" E
3	Victoria Hospital	Sensitive	12º,57', 47.2" N 77º,34', 30.0" E
4	Peenya Industries	Industrial	13º,00' 37.9" N 77º,30', 10.2" E
5	Graphite Industries	Industrial	12º,58', 31.2" N 77º,42', 36.1" E
6	K H B Industries	Industrial	13º,6', 26.6" N 77º,34', 10.2" E

2.3 Parameters Considered and Duration

The parameters affecting air quality varies widely. However, by keeping in mind the industrial activities in the study area and vehicular movement, four air quality parameters viz., SO_2, NO_2& RSPM were selected for establishing AQI. AQI data of selected sampling stations were collected for 5 years period viz., 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13. The data was collected from Karnataka State Pollution Control Board (KSPCB) Bangalore.

2.4Random Ambient Air Quality Monitoring

The development of AQI should be based on air quality data on longer duration which category seasonal, diurnal and
monthlymeteorological parameters. Thus, air quality data o f five years was selected.

2.4.1Instrument Used

Ambient air quality was measured by using high volume air sampler. The working principle of high volume air sampler is documented in brief as below.

High Volume Air Sampler (HVAS) is a filtering device commonly employed in atmospheric monitoring. It. is widely used for particulate collection for determining the concentration of RSPM in urban areas. HVAS is also used to monitor air for analysing gases like NO_2 and SO_2. RSPM iscollected on the filter paper, while NO_2 and SO_2 gases are absorbed in their absorbing solutions respectively in the impinger tubes. The functions of this impinger are to provide sufficient contact between the sampled air and liquid surface, to provide complete absorption of the gas. The impinger is usually made of glass with an inlet tube connected to as stopper fitted into a graduated vial such that the inlet tube rests slightly above the vial bottom. A measured volume of the absorber liquid is placed into the vial, the stopper inlet is put into place and the unit is then connected to the pump by flexible tubing. When the pump is turned on, the air sample is channelled down through the liquid at right angle to the bottom of the vial. The air stream then impinges against the vial bottom, mixing the air with the absorber liquid, the necessary air to liquid contact is achieved by the agitation.

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Figure **Error! No text of specified style in document.**.2 Pictorial View of High Volume Air Sample

2.5 Methods Adopted for AQI Calculation

AQI can represent the overall air quality status in a better way since the cumulative effect of all the pollutants and the related standard can be taken into account. As a result an equation, which transforms the parameter, values by means of numerical manipulation into a more simple and precise form can be obtained. The index of specific pollutant is derived mainly from the physical measurement of pollutants like RSPM, SO_2 and NO_2. There are several methods and equations used for determining the AQI. In the present study AQI for each location in the study area has been estimated with the help of a mathematical equation given below.

2.5.1 Calculating the Air Quality Index (AQI)

AQI Equation:

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where: I_P = the index for pollutant P

C_P = the rounded concentration of pollutant P

BP_{Hi}= the breakpoint that is greater than or equal to CP

BP_{Lo} = the breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

2.6 Indexing Based on Air Quality

The Air Quality Index (AQI) is an index for reporting daily air quality. It tells how clean or polluted the air is and what associated health effects might be a concern for community. The AQI focuses on health effects community may experience within a few hours or days after breathing polluted air. The AQI varies from 0 to 500.The higher the AQI value, the greater the level of air pollution and the greater are the health concerns. When AQI values are above 100, air quality is considered to be unhealthy at first for certain sensitive groups of people, then for everyone as the AQI values get higher as detailed in Table 2.2

Table 2.2 Break Point Concentrations and AQI Values for India (Source: Gopal*et al.* 2010).

Index	Category	SO_2 24 hr. avg (µgm/m3)	NO_2 24 hr. avg (µgm/m3)	CO 8 hr. avg (µgm/m3)	O_3 1 hr. avg (µgm/m3)	PM_{10} 24 hr. avg (µgm/m3)
0-100	Good	0-80	0-80	0-2	0-180	0-100
101-200	Moderate	81-367	81-180	2.1-12	180-225	101-150
201-300	Poor	368-786	181-564	12.1-17	225-300	151-350
301-400	Very poor	787-1572	565-1272	17.1-35	301-800	351-420
401-500	Severe	>1572	>1272	>35	>800	>420

3.0 RESULTS AND DISCUSSIONS

3.1 Back Ground

Data collected to meet the objectives of the study and the results obtained with regard to the random/sample air quality monitoring of the selected pocket are documented in this chapter. The data and results are presented in Tables and are also presented by graphs for convenient of analysis. Based on the data and results documented discussions were made, inferences were drawn. Further, the AQI for different areas, for different study pockets established and comments there-of are also presented in this chapter.

3.2Air Quality Status of Study Areas

Data depicting air quality status of six study areas collected for five consecutive years with reference to the parameters viz., SO_2, NO_2 and RSPM are taken into account to proceed with discussions and to draw inference. Area wise discussions are documented in further sub sections.

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3.2.1 Air Quality Status of Victoria Hospital

The study pocket is the hospital area is categorized as sensitive area. The concentration of all the parameters in this area was found to be alarming. Indexing clearly speaks – off unhealthy ambient air quality. During the entire study period the concentration of parameters were found to be more than permissible limits. However, because of meteorological condition which might results on dispersion/diffusion/dilution.Table 3.1 and Figure 3.1 shows the air quality status at victoria hospital.

Table 3.2Air Quality Status At Victoria Hospital

Study Period	Concentration of Stated Parameters µg/m^3		
	SO_2	NO_2	R.S.P.M
2009	11	22	73.72
2010	12	24	77
2011	13	27	82
2012	22.66	38.4	86
2013	12.6	28.4	70
Standard	15	15	50

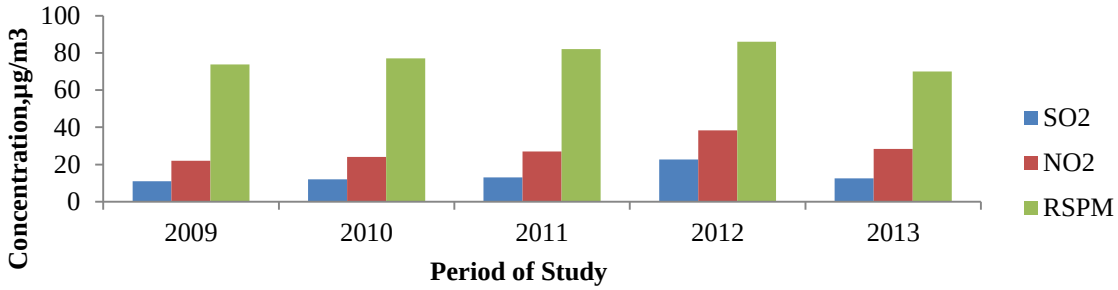

Figure 3.1 Variation of Air Quality during the Study Period at Victoria Hospital

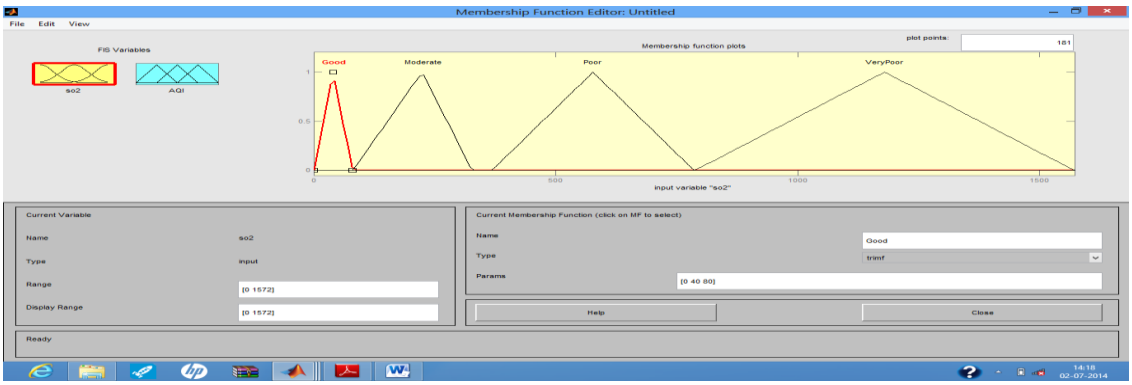

Figure 3.2 Membership function for SO_2

Figure 3.2 shows the membership function. For a fuzzy set A on the universe of discourse X is defined as μ_A:X → [0,1], where each element of X is mapped to a value between 0 and 1. This value, called membership value or degree of membership, quantifies grade of membership of element in X to fuzzy set A.

Membership functions allow us to graphically represent a fuzzy set. *X* axis represents universe of discourse, whereas the *y* axis represents degrees of membership in [0,1] interval. Membership function is used to associate a grade to each linguistic term.

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Table 3.3 Pollutent Concentration for SO_2 in Sensitive Area During Summer Season

Sl.No	Zonal Area	Name of Pollutant	Permissible Limit	Year	Name of station	lutant Concentration
1	Sensitive area	SO_2	15	2009	Victoria Hospital	13.75
2	Sensitive area	SO_2	15	2010	Victoria Hospital	16.25
3	Sensitive area	SO_2	15	2011	Victoria Hospital	17.5
4	Sensitive area	SO_2	15	2012	Victoria Hospital	28.75
5	Sensitive area	SO_2	15	2013	Victoria Hospital	16.25

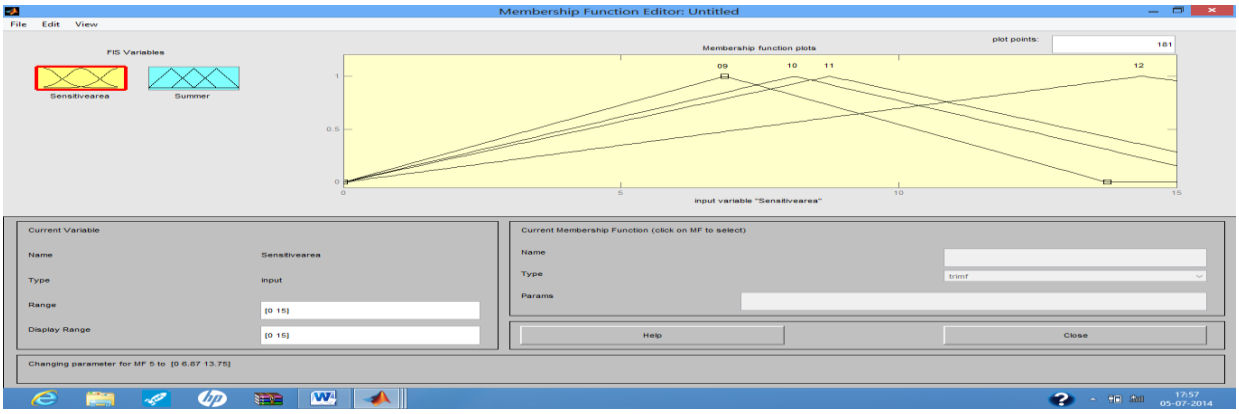

Figure3.3Membership function for SO_2 in Sensitive area during Summer Season

Table 3.2 and Figure 3.3 represent membership function for SO_2. During entire study period concentration of parameters exceeds permissible limit except in year 2009 lies with in permissible limit. Increasing trends indicated that air quality is deteriorating at the faster rate. It is a clam area so as to avoid traffic near hospital premises.

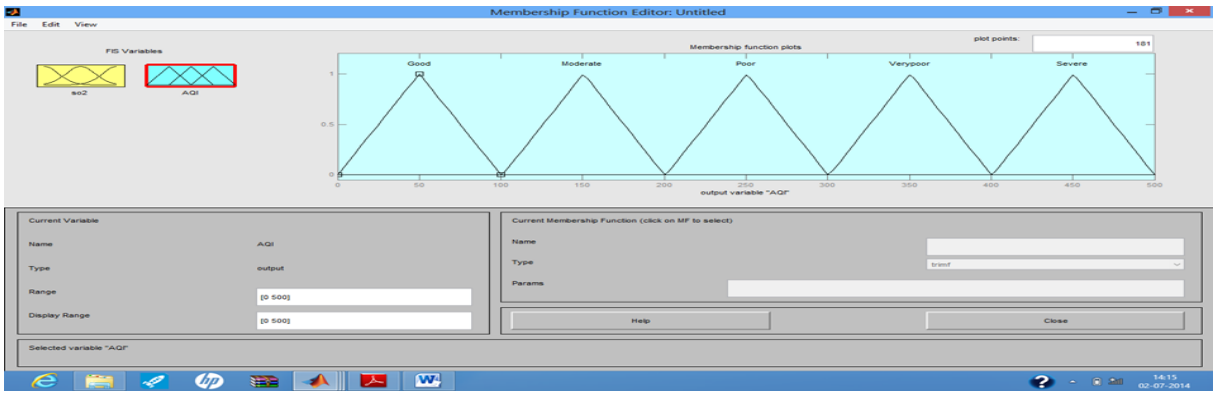

Figure 3.4 Output functions of the fuzzy inference system for SO_2

Figure 3.4 shows the output function for SO_2.Now that the variables have been named and the membership functions have appropriate shapes and names. It shows the ranges of air quality index. It shows the index levels if AQI varies from 0-100 named as good,101-200 named as moderate,201-300 named as poor,301-400 named as very poor,401-500 named as severe. According to this we find out the index.

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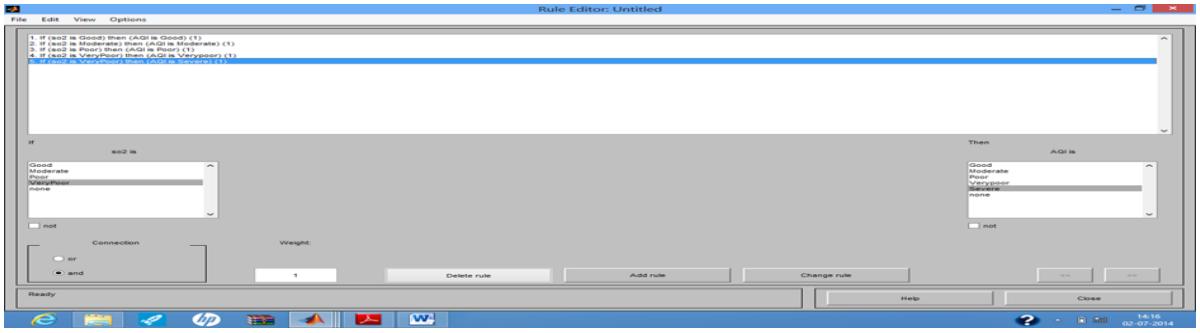

Figure 3.5 Fuzzy inference rules for SO2

Figure 3.5 shows the Rules for SO_2.Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows you to construct the rule statements automatically.
Rule:

- If AQI at particular time and place is observed. Then Value of AQI is (0-100) OR(101-200) OR(201-300)OR(301-400)OR(401-500).
- If value of AQI is between (0-100).Then atmosphere is Good and ideal air quality for outdoor activity.
- If value of AQI is between (101-200).Then atmosphere is Moderate and no need to modify any outdoor activity unless you experience symptoms such as cough and throat irritation.If value of AQI is in between (201-300). Then atmosphere is Poor and considering reducing or rescheduling strenuous outdoor activities if you experience symptoms such as cough and throat irritation.
- If value of AQI is between (301-400).Then atmosphere is very poor and avoid or rescheduling strenuous outdoor activities if you experience symptoms such as cough and throat irritation.
- If value of AQI is between (400-500).Then atmosphere is severe and strenuous outdoor activities because it is very harmful for human body.

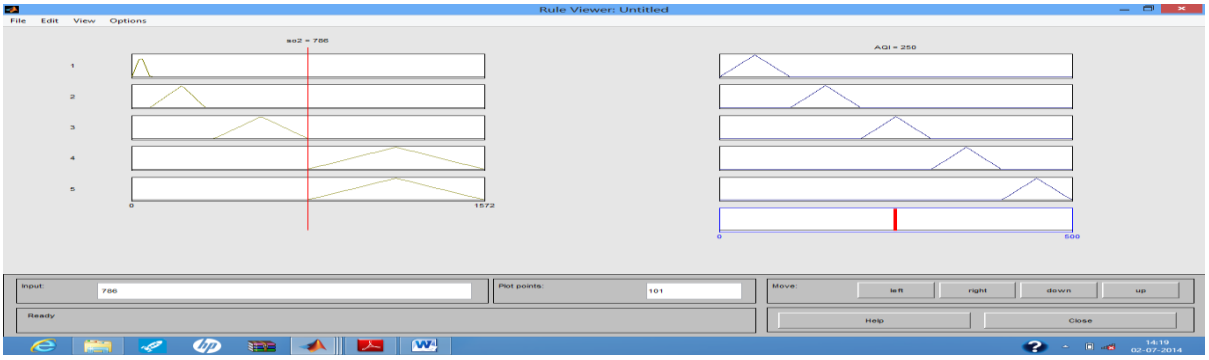

Figure 3.6Rule Viewer for SO_2

Figure 3.6 shows the Rule Viewer. It displays a roadmap of the whole fuzzy inference process. It is based on the fuzzy inference diagram. You see a single figure window with 10 plots nested in it. The three plots across the top of the figure represent the antecedent and consequent of the first rule. Each rule is a row of plots, and each column is a variable. Rule numbers are displayed on the left of each row.

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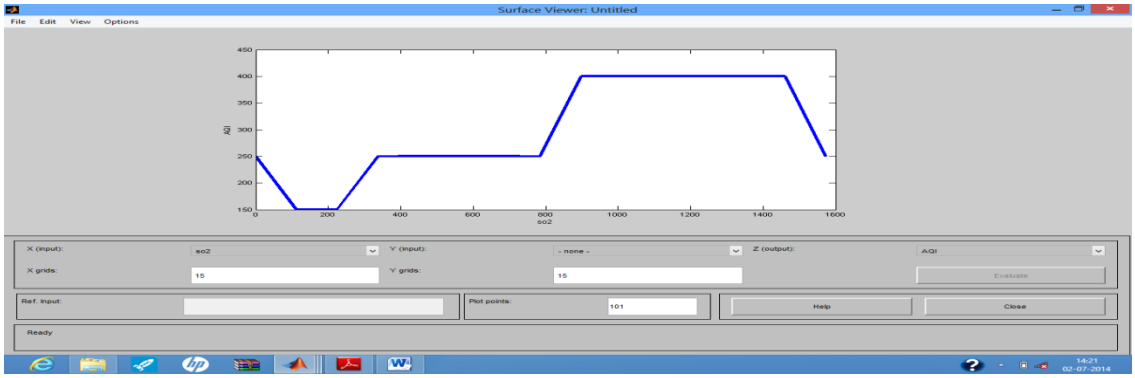

Figure 3.7Surface Viewer for SO_2

Figure 3.7 shows the Surface Viewer. Surface viewer invoked using surf view ('a') is a Mamadani tool that lets you examine output surface of a FIS, for any one or two inputs. Since it does not alter fuzzy system or its associated FIS matrix in any way, it is a read-only editor.

3.2.2 Air Quality Status of Graphite Industrial Area

Graphite India Ltd is considered as industrial area. Concentration of SO_2 and NO_2 varying from 8 to 38µg/m^3 was observed during study period of five successive years. These stated gaseous parameter concentrations were found to be below the prescribed limits for industrial area.RSPM concentrations of the study period were recorded as 128 to 134µg/m^3.All other year concentration were found exceeding the permissible limit of 120 µg/m^3.

3.2.3 Air Quality Status of AMCO Residential Area

Amco Apartments is considered as residential area.SO_2 and NO_2 concentrations were found to be within the permissible limits fixed for residential area (60 µg\$m^3$). SO_2 and NO_2 concentrations ranging from 11to24 µg\m3 and 17 to 37 µg\$m^3$ were recorded during the study period considered. RSPM should be exceeding the permissible limits due to change in meteorological conditions.

3.2.4 Air Quality Status of Peenya Industrial Area

Peenya is considered as industrial area. The graphical variation of the selected parameters for study period.

The concentration of sulphur dioxide recorded at this station was below the permissible limits for all the years. NO_2 concentrations were ranging from 17 to 37µg/m^3respectively. These concentrations were found to be within the permissible limits fixed for industrial area.Except in the year 2009-10, RSPM concentrations in the ambient air at the study pocket was found less than the permissible limit of 120µg/m^3. The concentration of RSPM was 120µg/m^3.

3.2.5 Air Quality Status of Yeshwanthpura Residential Area

Yeshwanthpura is considered as residential area. Trends of SO_2 and NO_2 with passage at time were found to be similar to that of AMCO Residential area. These concentrations in ambient air at Yeshwanthpura Residential Area were found to be within permissible concentration 60µg/m3.In general the concentration of RSPM was found to be increasing between year to year from 2009 to 2012.

3.2.6 Air Quality Status of KHB: Industrial Area

KHB selected is considered as the industrial area.The data includes year wise details of KHB from 2009-13.These concentrations of SO_2 were found within the permissible limit. (80 µg/m^3).Another gaseous pollutant NO_2 was observed during the study period and minimum concentration of 14µg/m3 during 2009 and the maximum concentration of 33µg/m3 during 2012 were observed against permissible concentration of 80 µg/m^3.RSPM concentration during 2009 was less than two times the prescribed limit. This might be because of dilution of the pollutants with favourable metrological condition.

4.0 CONCLUSIONS

Urban air pollution in many cities is currently an issue of great concern to the general public. Fuzzy rule based system of AQI based model, is the powerful model to give the suggestions to human outdoor activities on particular area. Result of this research work of fuzzy approach has better performance than linear Interpolation Approach used in past working. Our work will help to develop healthy environment in good atmospheric area as well as in polluted area.

Fuzzy rule based system of AQI based model, is powerful model to give the suggestions to human outdoor activities on particular area.

Result of this research work of fuzzy approach has better performance than linear Interpolation Approach used in past working. Our work will help to develop healthy environment in good atmospheric area as well as in polluted area.

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