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Fuzzy based Air Quality Indices at Iron Ore Mine Area

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Abstract*—Nowadays, artificial intelligence methods are using for the solution of environmental problems. The study is to determine the pollution level at iron ore mine by developing air quality indices using fuzzy technique. The AQI is based on the concentration of 4 atmospheric pollutants, namely Sulfur-Dioxide (SO_2), Nitrogen Dioxide (NO_2), Suspended Particulates (PM_{10}) and Respirable Suspended Particulate Matter ($PM_{2.5}$) was measured at the mine region in a season wise. The concentration of pollutants are expressed in terms of micrograms per cubic meter (µg/m^3). The activities of Subbarayanahalli iron ore mine contribute to air pollution in and around the mine areas. The monitoring was conducted at 8 locations considering various activities in the core zone and haul roads of villages in the buffer zone. The results showed that SPM varied from 23 µg/m^3 to 113 µg/m^3 and RSPM varied from 13 µg/m^3 to 56 µg/m^3. In summer the values are very high and low in the rainy season due to the variations in rainfall, humidity, temperature, wind velocity and direction. The concentrations of SO_2 and NO_X found within the limits of National Ambient Air Quality Standards in all the locations. The average concentrations of Core Zone and Buffer Zone was analyzed in fuzzy logic to develop air quality index to get better understanding of the pollution level. The results shows that in core zone FAQI is 217 during summer, 187 and 191 in winter and 82.4 during rainy season. In buffer zone FAQI in summer and winter is varied from 144- 174 and during rainy season it is varied from 42.4-59.6.

***Keywords*—Fugitive Dust, Core Zone, Buffer Zone, Air Quality Index, Fuzzy Inference System.**

I. INTRODUCTION

The dust arising from machineries, iron ore benches, screening, crushing, transport equipment and unpaved haul roads are the main sources in the working of mines. Running vehicles on an unpaved haul road has been identified as the main source for the emission of fugitive dust. The content of Silica and trace element in airborne dust are important parameters governing the dispersion and health effects among mine workers and residents of the surrounding villages [14]. The parameters are monitored on 16 hourly average basis for determining the pollutant level. The obtained concentration (in µg/m^3) of the pollutants is analyzed in fuzzy logic using Mamdani fuzzy inference system to develop air quality index to get better understanding of the pollution level. The health effects of mine workers due to long exposure to dust also estimated using fuzzy inference system.

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II. METHODOLOGY

A. Study Area

Subbarayanahalli iron ore mine is one of the leading iron ore mines of M/s Mysore Minerals Limited in the Hospet-Bellary sector. The mine has an area of 80.93 hectares. The area falls in the survey of India toposheet No.57A/12 and lies inside the Kumaraswamy Betta Forest. It is approachable by good road from Sandur town to Devagiri at a distance of about 12 km towards Subbarayanahalli village. The total area lies between $76^0 32'45''$ and $76^0 33'48''$ in longitude and between $15^0 00'58''$ and $15^0 01'55''$ in latitude. Toranagallu is the nearest railway station at a distance of 40 km in the NNE direction. Figure 1 shows the map of study area with sampling Locations.

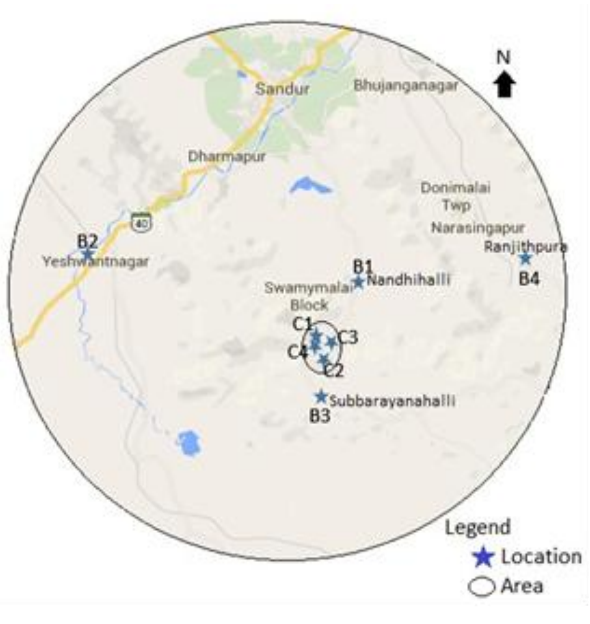

Fig 1 Map showing the location of Subbarayanahalli Iron Ore Mine and the sampling stations.

B. Sampling Locations

In this study, eight sampling stations have been selected based on the emission of particulate matter considering the (i) traffic density in unpaved road, (ii) wind direction and (iii) site activities. Sampling selection criteria plays an important role in the developmental activity as it provides an outlook on the type of environmental compliance and management to be adopted by the project proponent [11,14]. Locations detailed report is tabulated in Table 1.

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Table1: Location Report of Monitoring Stations

Code	Longitude E	Latitude N	Surface above mean sea Level (m)	Direction from Core Zone
C1	76º 33’ 15.1”	15º 01’ 23.4”	966	---
C2	76º 33’ 20.7”	15º 01’ 01.9”	987	---
C3	76º 33’ 29.3”	15º 01’ 17.9”	915	---
C4	76º 33’ 18.2”	15º 01’ 09.2”	1001	---
B1	76º 34’ 05.1”	15º 02’ 11.9”	633	NNE
B2	76º 29’ 57.9”	15º 02’ 37.1”	601	W
B3	76º 33’ 16.2”	15º 00’ 38.1”	1015	S
B4	76º 36’ 33.5”	15º 02’ 44.3”	638	NEE

C. Sampling Procedure

Fine particulate samplers of model APM 550 of envirotech Instruments were used for monitoring Suspended Particulate Matter and Respirable Particulate Matter fraction. Sampling and analysis of Particulate Matter in ambient air were implemented by the Gravimetric method. Air was sucked through a size selective inlet and a filter at a flow rate of 1132 L/min. Particles with aerodynamic diameter less than 10 µm and 2.5 µm were collected by the respective filter paper. The mass of these particles was determined by the difference in filter paper weights before and after sampling. The concentration of PM_{10} and $PM_{2.5}$ was calculated by dividing the weight gain of the filter paper by the volume of air sampled [2,3]. Sampling was conducted on 16 hourly basis at each station during the study period. The concentrations of SPM and RSPM were measured in $\mu g/m^3$. Guidelines of Central Pollution Control Board, New Delhi on National Ambient Air Quality Standards-2009 were followed for undertaking the monitoring [2].

D. Application of Fuzzy Logic

The concentrations of four air pollutants namely SO_2, NO_X, PM_{10} and $PM_{2.5}$ was analyzed using Mamdani fuzzy model with more accurate results. Application of Mamdani fuzzy inference systems leads to estimation of precise outputs and helps to better understanding between inter-relationship of human and the environment[9]. Air Quality Index (AQI) is an index giving more clarity of atmospheric air for that environmental conditions and that associated with health effects of mine workers and local residents. AQI focuses on health effects on the mine workers and local residents of the region, people who exposed to polluted air may get certain type of diseases. AQI varies from 0 to 500. Higher AQI value, greater level of air pollution which leads to more health effects. An AQI value of 0 to 200 generally corresponds to within national ambient air quality standards for pollutants, has set to protect public health in India. AQI less than 200 are normally thought of as satisfactory. When AQI more than 200, then quality of air is considered to be unhealthy for the peoples working exposed to that condition. AQI and category with respect to pollutants is detailed in Table 2.

Table 2: Air Quality Index and Category With Respect to Concentration of Pollutants

FAQI	Category	PM_{10}	$PM_{2.5}$	SO_2	NO_X
0-100	Good	0-50	0-30	0-40	0-40
101-200	Moderate	51-100	31-60	41-80	41-80
201-300	Poor	101-200	61-120	81-120	81-120
301-400	Very Poor	201-300	121-200	120-160	120-160
401-500	Severe	>301	>201	>160	>160

Fuzzy model was developed to calculate the AQI of particular locations based on the concentrations of particulate matter. Sulphur dioxide and oxides of nitrogen was not considered to calculate AQI since the concentrations at all locations are within in national ambient air quality standards. The structures of a fuzzy inference system to calculate AQI is shown in Figure 2.

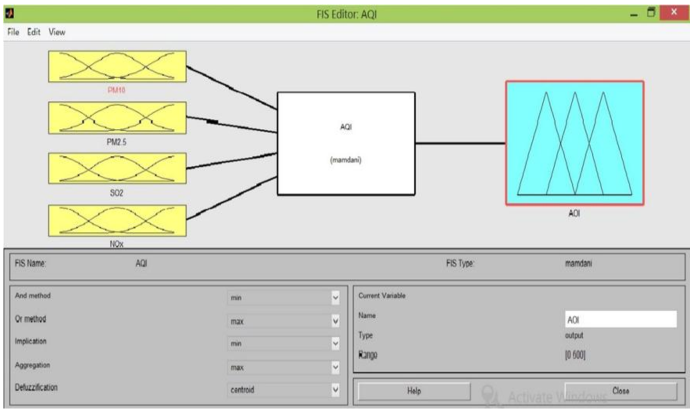

Fig 2 Structure of Fuzzy Inference System for AQI.

The membership function is plotted for PM_{10} as shown in Figure 3.

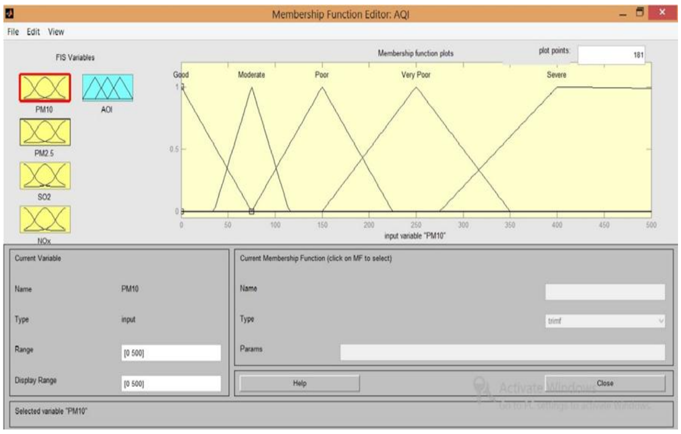

Fig 3 Membership Function for PM_{10}.

The membership function is plotted for $PM_{2.5}$ as shown in Figure 4.

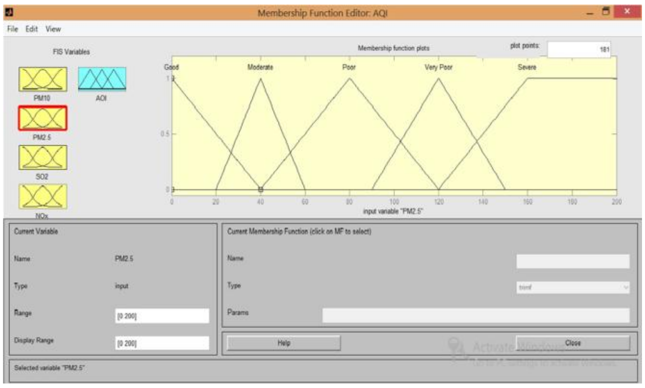

Fig 4 Membership Function for $PM_{2.5}$.

The Value of AQI assigned from 0-500 by dividing into 5 sub divisions. Each Sub division is related to the effects on human health as follows,

- If the value of FAQI is between 0-100, then the quality of the air in the atmosphere is good. No need to modify any outdoor activity.
- If the value of FAQI is vary from 101-200, then the quality of air in the atmosphere is moderate and long term exposure to this outdoor condition causes symptoms for sensitive group of peoples such as cough and throat irritation. Safety equipment's should be used when exposed to this atmosphere.
- If the value of FAQI is vary from 201-300, then quality of air in the atmosphere is poor condition and it is necessary to modify the outdoor activity. In case if peoples exposed to this condition may get symptoms such as cough, throat irritation, asthma.
- If value of FAQI is vary from 301-400, then atmosphere is very poor and need to avoid direct inhaling the polluted air. Mask or air filter should be use when exposed to this condition otherwise people may experience respiratory symptoms and leads to premature death.
- If the value of FAQI is vary from 400-500, then atmosphere is severe and outdoor activities should be stopped since it is very harmful to the environment.

Output membership function of AQI is shown in Figure 5.

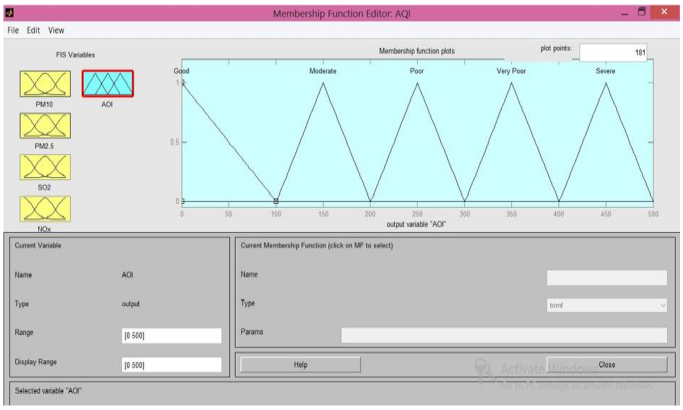

Fig 5 Output Membership Function for AQI.

The developed fuzzy rules (3*3=9) to calculate AQI is given in the form of an algorithm as follows.

1. If (PM10 is Good) and (PM2.5 is Good) then (AQI is Good)
2. If (PM10 is Good) and (PM2.5 is Moderate) then (AQI is Moderate)
3. If (PM10 is Good) and (PM2.5 is Poor) then (AQI is Poor)
4. If (PM10 is Moderate) and (PM2.5 is Good) then (AQI is Moderate)
5. If (PM10 is Moderate) and (PM2.5 is Moderate) then (AQI is Moderate)
6. If (PM10 is Moderate) and (PM2.5 is Poor) then (AQI is Poor)
7. If (PM10 is Poor) and (PM2.5 is Good) then (AQI is Poor)
8. If (PM10 is Poor) and (PM2.5 is Moderate) then (AQI is Poor)
9. If (PM10 is Poor) and (PM2.5 is Poor) then (AQI is Poor)

III. RESULTS

Fuzzy model was developed to calculate air quality index for better understanding the pollution level in the atmosphere. The parameters such as SO_X and NO_X are suppressed for fuzzy based AQI analysis because in all the locations these pollutant levels are with in National Ambient Air Quality Standards. Hence the net analysis are based on PM_{10} and $PM_{2.5}$ only.

FAQI was calculated on season wise and mentioned the category of pollution for core zone and it is tabulated in Table 3. The obtained results for each season are shown in Figure 6 to Figure 9.

Table 3: Fuzzy Air Quality Index for the Core Zone

Parameters	Core Zone (C1,C2,C3,C4)				Fuzzy Air Quality Index	Category
Months	PM_{10}	$PM_{2.5}$	SO_2	NO_X		
Jan-14	101	50	12	14	191	Moderate
May-14	110	54	13.8	15.5	217	Poor
Sept-14	41	23	9.7	9.3	82.8	Good
Jan-15	99	52	12.3	14.3	187	Moderate

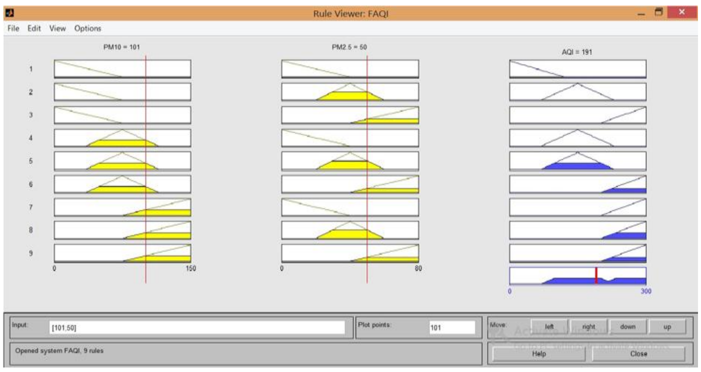

Fig 6 Output AQI of Core Zone for the Month of January 2014.

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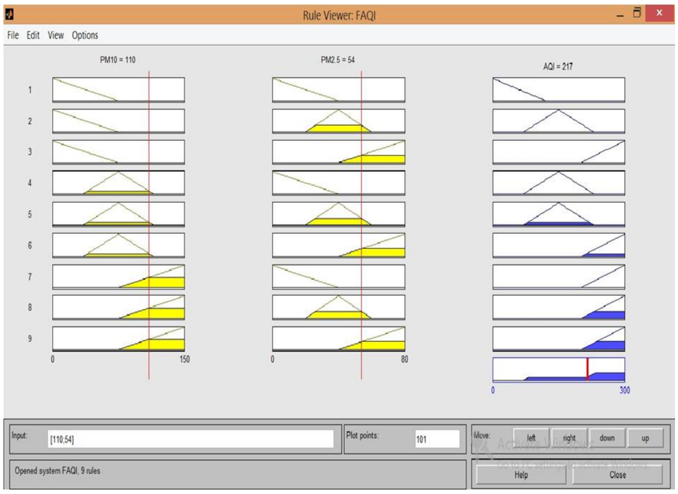

Fig 7 Output AQI of Core Zone for the Month of May 2014.

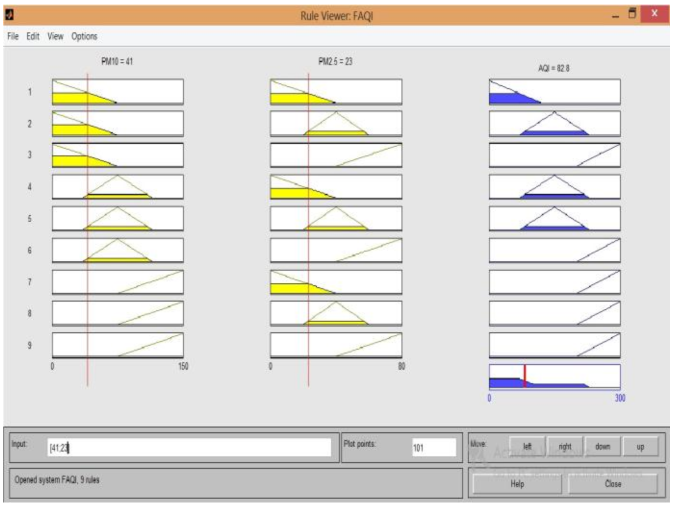

Fig 8 Output AQI of Core Zone for the Month of September 2014.

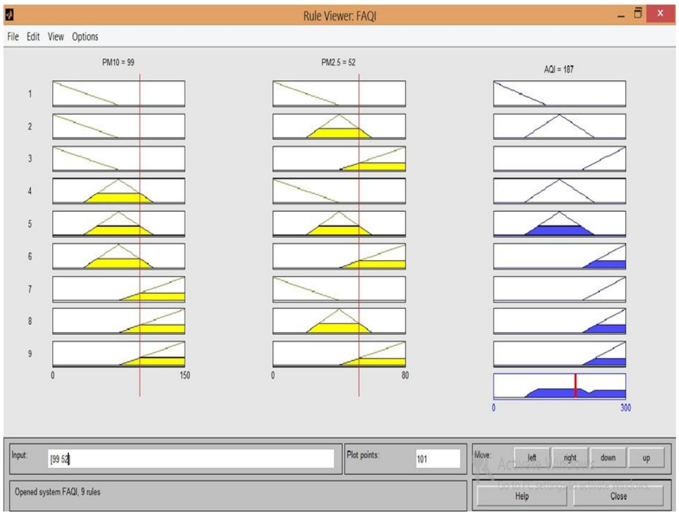

Fig 9 Output AQI of Core Zone for the Month of January 2015.

FAQI was calculated on season wise and mentioned the category of pollution for Buffer zone which is tabulated in Table 4. The obtained results for every season are shown in Figure 10 to Figure 13.

Table 4: Fuzzy Air Quality Index for the Buffer Zone

Parameters	Buffer Zone (B1,B2,B3,B4)				Fuzzy Air Quality Index	Category
Months	PM_{10}	$PM_{2.5}$	SO_2	NO_X		
Jan-2014	83	35	10.5	11.9	161	Moderate
May-2014	92	39	11	12.5	174	Moderate
Sept-2014	37	20	8.5	8.1	59.6	Good
Jan-2015	88	34	10.8	12	168	Moderate

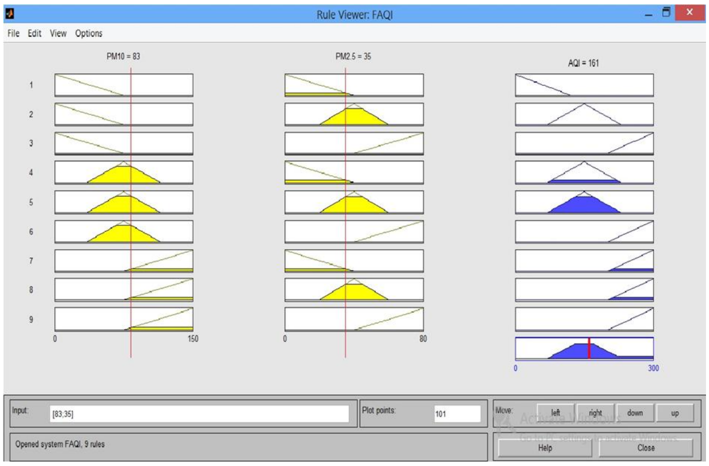

Fig 10 Output AQI of Buffer Zone for the Month of January 2014.

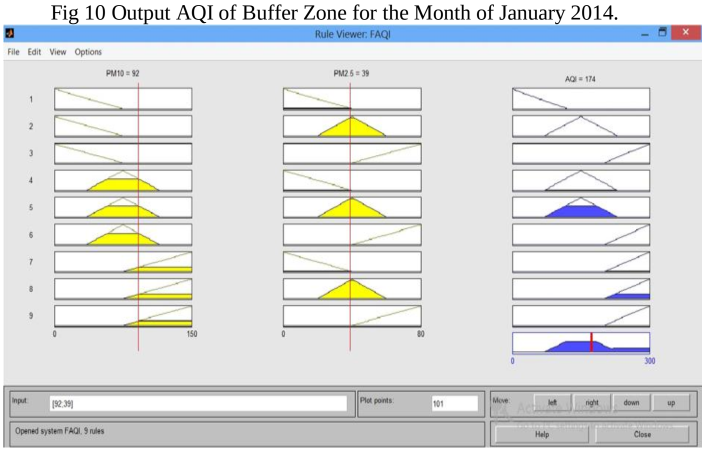

Fig 11 Output AQI of Buffer Zone for the Month of May 2014.

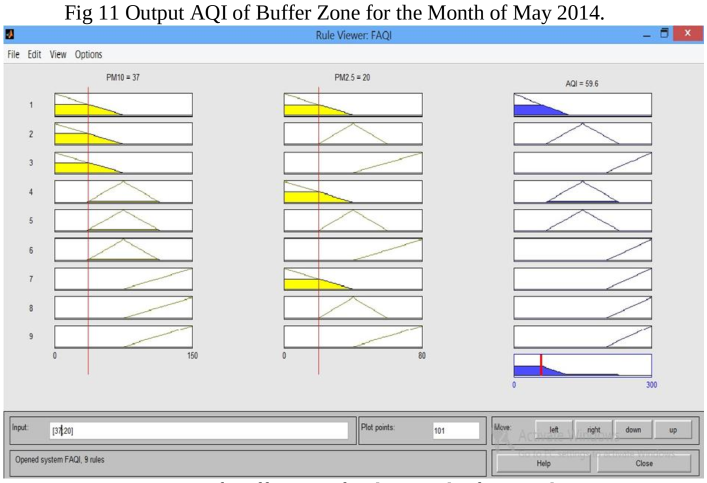

Fig 12 Output AQI of Buffer Zone for the Month of September 2014.

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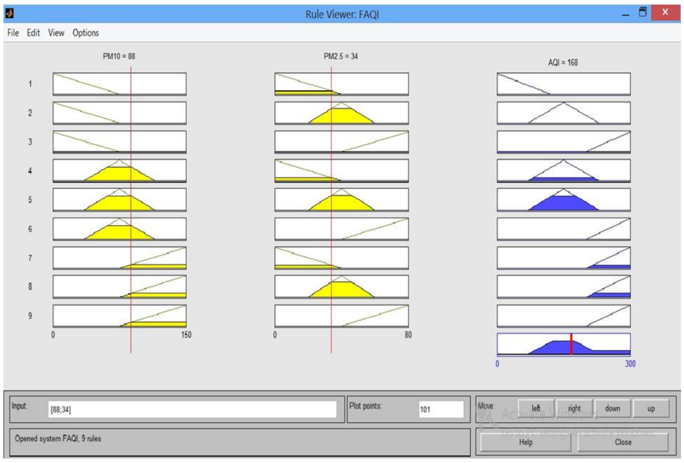

Fig 13 Output AQI of Buffer Zone for the Month of January 2015.

IV. CONCLUSION

Particulate Matter concentrations for all the eight locations have been interpreted. It is inferred that the values in the core zone are higher while in buffer zone the concentrations are within the National Ambient Air Quality Standards. In the summer the values are very high, they are low in the rainy season due to the variations in the rainfall, humidity, temperature, wind velocity and direction. Compared with meteorological conditions it is observed that humidity higher than 65% in mining region maintain safe air quality conditions. The fuzzy results shows that at the core zone the AQI for summer season is high up to 217 and hence it is identified as a poor category. During winter season at core zone the FAQI is 187 and 191 and hence it is identified as a moderate category. At rainy season all pollutants are controlled which is indicated in air quality analysis with value 82.8 which falls under good ambient condition. The observation made on the fuzzy results shows that at Buffer Zone the AQI in the summer and winter season is varied from 161-174 and hence it is identified as moderate category. During rainy season AQI is 59.6 which falls under good ambient condition.

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REFERENCES

[1] Banerjee G K, Srivastava K K, Chakraborty M K and Sundararajan, “An approach towards the estimation of emission rate from various activities of noamundi iron ore mine – A Case Study,” Journal of Scientific and Industrial Research, Volume 62, 339-343, 2003.

[2] Central Pollution Control Board. (2011), “Guidelines for the Measurement of Ambient Air Pollutants,” Volume-I, available from: http://www.cpcb.nic.in

[3] Chakraborty M K, Ahmad M, Singh R S, Pal D, Bandopadhyay C and Chaulya S K, “Determination of the emission rate from various opencast mining operations,” Environmental Modelling & Software 17, 467–480, 2002.

[4] Daniel D., Alexandra A. and Emil L, (2011),” Fuzzy Inference Systems for estimation of Air Quality Index”, Romania international journal,7(2): pp. 63–70.

[5] Fisher B, (2003), “Fuzzy environmental decision-making: applications to air pollution”. Atmospheric Environment 37, pp.1865-1877.

[6] Gopal Upadhyaya and Nilesh Dashore, (2010), “Monitoring of Air Pollution by Using Fuzzy Logic”, International Journal on Computer Science and Engineering, Vol. 02, No. 07, pp. 2282-2286.

[7] Huertas J I, Huertas M E, Cervantes G and Díaz J, “Assessment of the natural sources of particulate matter on the opencast mines air quality,” Science of the Total Environment 493, 1047–1055, 2014.

[8] Indian Meteorological Department, available from: http://www.imd.gov.in

[9] Khan F I and Sadiq R, (2005), “Risk-based prioritization of air pollution monitoring using fuzzy synthetic evaluation technique. Environmental Monitoring and Assessment 105, pp.261-283.

[10] Kiran Kanti Panda, Akhila Kumar Swar, Rahas Bihari Panda and Meikap B.C, “Distribution of Respirable suspended particulate matter in ambient air and its impact on human health and remedial measures in Joda-Barbil region in Odisha,” South African Journal of Chemical Engineering,vol.18, no. 1, 18-29, 2011.

[11] Panda S.R and Anil Barik, “ Impact of iron ore mines generated pollutants on peripheral environment and its effective management—A case study of Koira Region, Odisha,” Proceedings of the XI international seminar on mineral processing technology, 1147-1156, 2010.

[12] Seyed Ebrahim Vahdat and Foroogh Mofid Nakhaee, (2011), “Air Pollution Monitoring Using Fuzzy Logic in Industries”, Advanced Air Pollution. Dr. Farhad Nejadkoorki (Ed.), ISBN: 978-953-307-511-2, InTech, Available from: http://www.intechopen.com/books/advanced-air-pollution/air-pollution-monitoring-using-fuzzy-logic-inindustries.

[13] State of Environment Report and Action Plan, (2003), Published by Government of Karnataka.

[14] Subrato Sinha and Banerjee S P, “Characterization of haul road dust in an Indian opencast iron ore mine”, Atmospheric Environment vol. 31, no. 17, 2809-2814, 1997.

[15] Zadeh L A, (1965), “Fuzzy sets, Information and Control”, Vol. 8, Issue 3, pp. 338-353.