ASSESSMENT OF AIR QUALITY OF LUCKNOW CITY AND PROPOSING A MODEL USING MATLAB

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Abstract :

The present study deals with ambient air quality during (Jan2019 - March 2019) in three areas viz. Aliganj (Residential area), Qaisarbagh (Commercial area), IITR Gheru Campus (Industrial area, Sarojani Nagar) of Lucknow city. The air quality depended on estimating four air parameters to be specified as Particulate Matter ($PM_{2.5}$ and PM_{10}), SO_2 and NO_2. The PM_{10} levels at all the observing areas were higher than the NAAQS furthest reaches of 100µg/m^3. The $PM_{2.5}$ level at the observing areas were higher than the NAAQS furthest reaches of 60µg/m^3. The SO_2 and NO_2 level at the checking areas were lower than the NAAQS level i.e. 80µg/m^3. The grouping of PM_{10} and $PM_{2.5}$ in industrial area is higher than residential and commercial. The grouping of SO_2 is higher in residential area than commercial and industrial area. The grouping of NO_2 is higher in industrial area than residential and commercial area. MATLAB Toolbox (Fuzzy Logic) is used for proposing the model in which input parameters are $PM_{2.5}$, PM_{10}, SO_2 and NO_2 are utilized for making the air quality model in which the parameters are classified as Good (G), Satisfactory (S), Moderately polluted (MP), Poor (P), Very Poor (VP) and Severe (SE).The proposed model is designed to predict Air Quality Index (AQI). There were 214 fuzzy rules defined. The output parameter is delegated Good (G), Satisfactory (S), Moderately polluted (MP), Poor (P), Very Poor (VP) and Severe (SE).

Key Words: MATLAB Toolbox, Fuzzy Logic, Lucknow, NAAQS.

Introduction :

Lucknow (26°52′N latitude, 80°56′E longitude, 128 m above sea level) is the capital of India's largest state, Uttar Pradesh, spread over an area of 310 km2 and located at the bank of the river Gomati. It is famous for its historical, splendid buildings and monuments. Population is about 28,15,033 as per 2011 censes (34,70,400 estimated population 2018). The main causes of air pollution in Lucknow are vehicular emissions and day by day increasing private vehicles on road. Rapid urbanization on the expenditure of greenery, industries surrounding the city, unconsciousness of government and public toward this problem, Burning of woods for fuel purposes, burning of the garbages. The year is divided into three distinct seasons i.e. summer (March–June), monsoon (July–October) and winter (November–Feburary). The temperature ranges from 5°C in winter to 45°C in summer. The mean average relative humidity is 60% and rainfall 1,006.8 mm (Barman et al. 2008). The respirable particles are responsible for the cardiovascular as well as respiratory diseases (Sagai et al., 1996) of human being because these particles can penetrate deep into the respiratory system, and studies indicates that the smaller the particle, more severe the health impacts (Dockery et al., 1993; Pope et al., 1995; Schwartz et al., 1996). Ambient particulate matter may be carriers of acidic or toxic species (e.g., heavy metals, acids and carcinogenic organic compounds) and may have detrimental effects on human health and ecosystems. Besides the effect of particulate matter, literature also suggests that there is a strong relationship between higher concentration of SO2 and NOx and several health effects (Curtis et al., 2006), like cardiovascular diseases (Zanobetti and Schwartz, 2002; Peters et al., 2004; Chen et al., 2005; Dockery et al., 2005) respiratory health effects such as asthma and bronchitis (Ye et al., 2001; Barnett et al., 2005) and reproductive and developmental effects such as increased risk of preterm birth (Liu et al., 2003). The modeling formalism has embraced two valued logic-based probability theory wherein random variable is used as the basis of probability computations. The standard probability theory is not designed to deal with imprecise probabilities or Z-probabilities which pervade real-world uncertainties. Fuzzy set theory is the way of modeling uncertainty due to imprecision, fuzziness, and ambiguity wherein human perception plays a pivotal role. The limitations of conventional AQI

calls for devising fuzzy logic-based formalism, known as Zadeh– Deshpande (ZD) approach (Yadav et al. 2011, 2013, 2014). Li et al. (2008) proposed an integrated fuzzy-stochastic modelling approach for quantifying uncertainties associated with both source/medium conditions and evaluation criteria and thus assessing air pollution risks. Hajek and Olej (2009) presented an approach for design of AQIs based on tree/cascade hierarchical fuzzy inference systems. Mandal et al. (2012), Sowlat et al. (2011) used rule-based fuzzy techniques for air quality assessment. Fisher (2003) illustrated that the use of fuzzy sets formalizes the underlying uncertainty and therefore leads to better decision-making.

Materials and Methods :

Monitoring of PM_{10}, $PM_{2.5}$, SO_2, and NOx were done in the ambient air of Lucknow city at three locations (residential area namely Aliganj, commercial area namely Qaisarbagh and industrial area IITR Gheru Campus (Sarojani Nagar)). Monitoring was conducted during the month of January, February and March , 24 hr for PM_{10}, $PM_{2.5}$,SO_2 and NOx.

Sampling of respirable particulates was conducted continuously on 24 hourly. Fine particles $PM_{2.5}$ were sampled which runs at a constant flow rate of 16.7 L/min. It has a portable Wins-Anderson impactor for the sampling of $PM_{2.5}$. Respirable Dust Sampler was used for PM_{10} sampling. The samplers were installed at a height of 4 feet at each sampling site. Glass fiber filter were used for sampling of PM_{10} and $PM_{2.5}$, respectively. The filters were equilibrated in desiccators containing silica gel for 24 h before and after sample collection and weighed on pre-calibrated electronic balance before and after the sampling to know the weight of collected dust. The ambient air mass concentration was calculated by dividing the weight of collected dust by volume of air sampled.The analysis of SO_2 and NOx was done by a known quantity of air was passed through the impinger containing known volume of absorbing solution; SO_2 was absorbed in absorbing solution, sodium tetrachloromecurate. A dichlorosulphitomercurate complex was formed which was made to react with para-rosaniline and methysulphonic acid. The absorbance of the solution was measured at a wavelength of 560 nm on spectrophotometer. Whereas, Nitrogen oxides (NOx) as nitrogen dioxide (NO_2) was absorbed in absorbing solution, sodium hydroxide which formed a stable solution of sodium nitrite. The nitrite ion so produced, was determined spectrophotometer at wavelength 540 nm by reacting the exposed absorbing reagent with phosphoric acid, sulphanilamide and N (1-naphthyl) ethylenediamine dihydrochloride.

Matlab toolbox fuzzy logic is used for proposing the model for estimating the air quality index. In making a fuzzy logic model uses four air quality parameters such as PM_{10}, $PM_{2.5}$,SO_2 and NO_X and the membership functions of each parameters are classified as Good, Satisfactory, Moderately polluted, Poor, Very poor, Severe and coded as G, S, MP, P, VP and SE. The output of this model is classified as Good, Satisfactory, Moderately polluted, Poor, Very poor, Severe and coded as G, S, MP, P, VP and SE. This is fuzzy logic based model which gives the result according to AQI levels such as Good (0-50), Satisfactory (51-100), Moderately polluted (101-150), Poor (151-200), Very poor (201-300), Severe (300-500). Fuzzy logic model is divided into three parts first is input, second is fuzzification, third is de-fuzzification, in first part is to input the data in the membership function of each parameters. The process of fuzzification involves no. of steps including designing and applying rule base, defining membership functions, defining classes as an output etc. De-Fuzzification as an input the variables were Air quality parameters that is $S0_2$, NOx, PM_{10} and $PM_{2.5}$. The membership function for all was decided as trapezoidal The output obtained is in the area form. Fuzzy logic system has the advantages as being a more prominent way for advanced software based models. FLC is a basic tool for decision making though few limitations. In environmental modelling system Fuzzy Rule base approach can be utilized in significant way as it provides a comfortable approach while making decisions through multiple criterions.

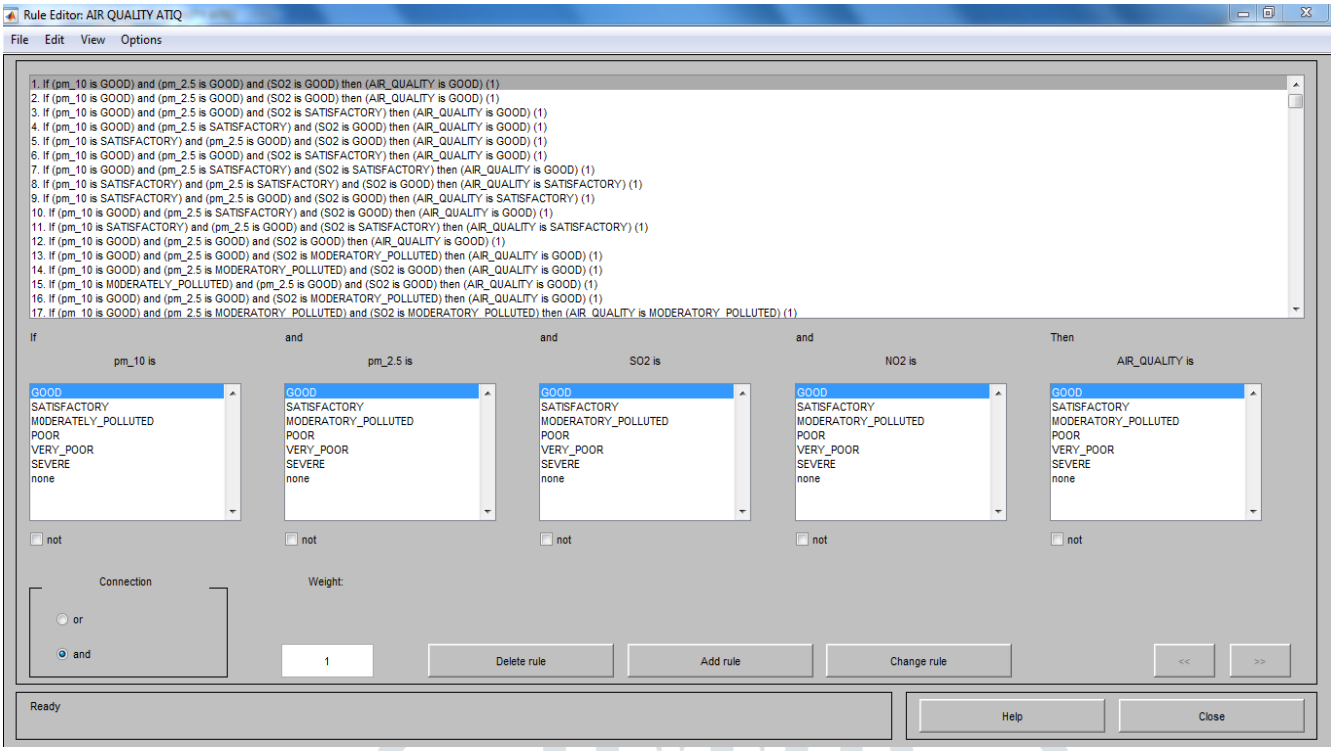
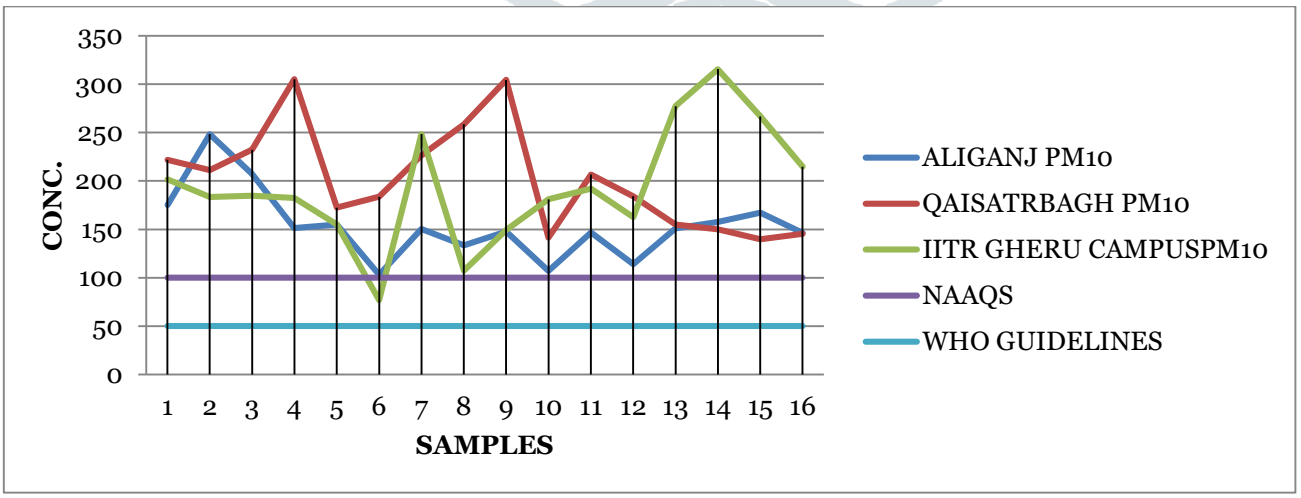


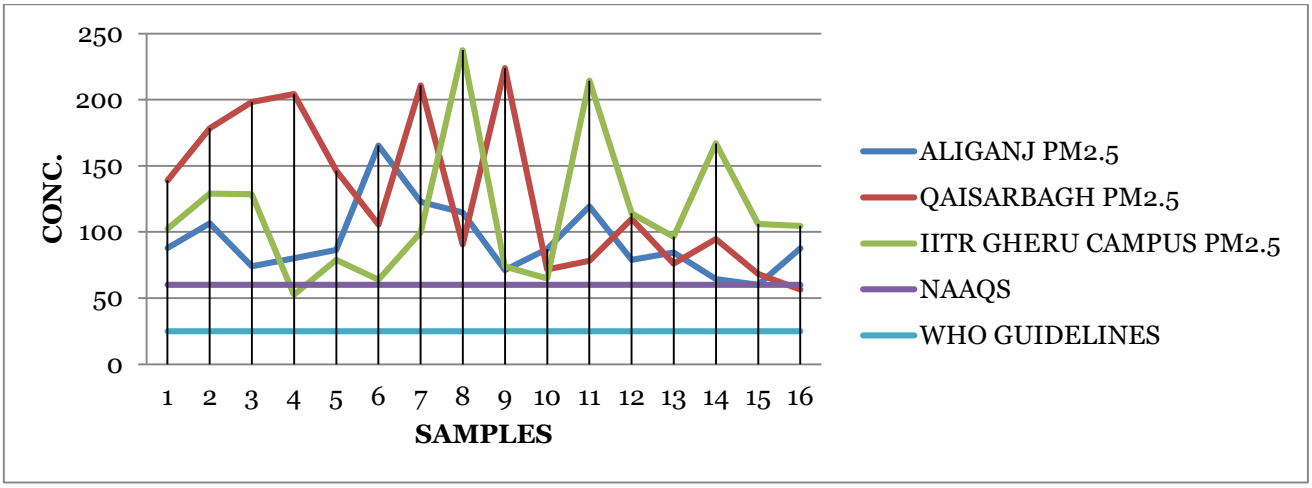
Fig 1. Determination of air quality index using Fuzzy logic

Result :

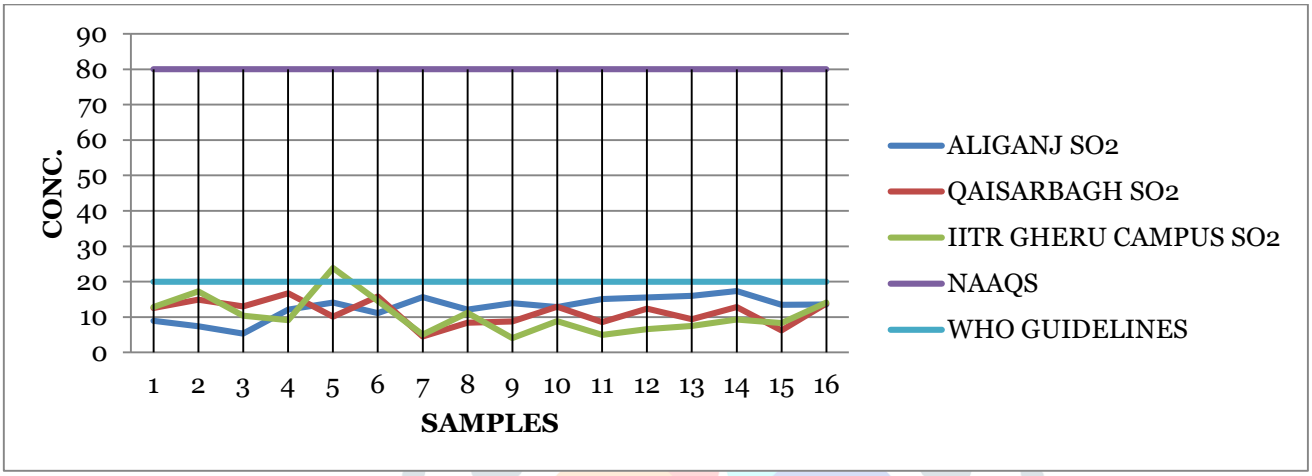
Results of PM_{10}, $PM_{2.5}$, SO_2, and NOx during study period. The minimum and maximum concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NOx at Aliganj area is found to be 102.9 - 248.3, 60.14415 - 165.4289, 5.299 - 17.38 and 23.47 - 49.19, Qaisarbagh area is found to be 139.869 - 305.152, 56.5065 - 198.293, 4.504665 - 16.73373, 26.65545 - 107.8667 and in IITR Gheru campus (Sarojani Nagar) area is found to be 76.7116 - 315.52, 63.8204 - 237.532, 4.006265 - 23.89175, 31.85723 -80.98075 and the average concentration of PM_{10}, $PM_{2.5}$, SO_2, and NOx at Aliganj area is found to be 153.784, 93.21217, 12.7754 and 32.1435, average concentration of PM_{10}, $PM_{2.5}$, SO_2, and NOx at Qaisarbagh area is found to be 202.4, 128.29, 11.2902 and 45.5354 and the average concentration of PM_{10}, $PM_{2.5}$, SO_2, and NOx at IITR Gheru campus (Sarojani Nagar) area is found to be 193.703, 100.602, 10.4901 and 49.3666. The concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NOx at monitoring locations as compared to NAAQS and WHO guidelines as shown in graph.



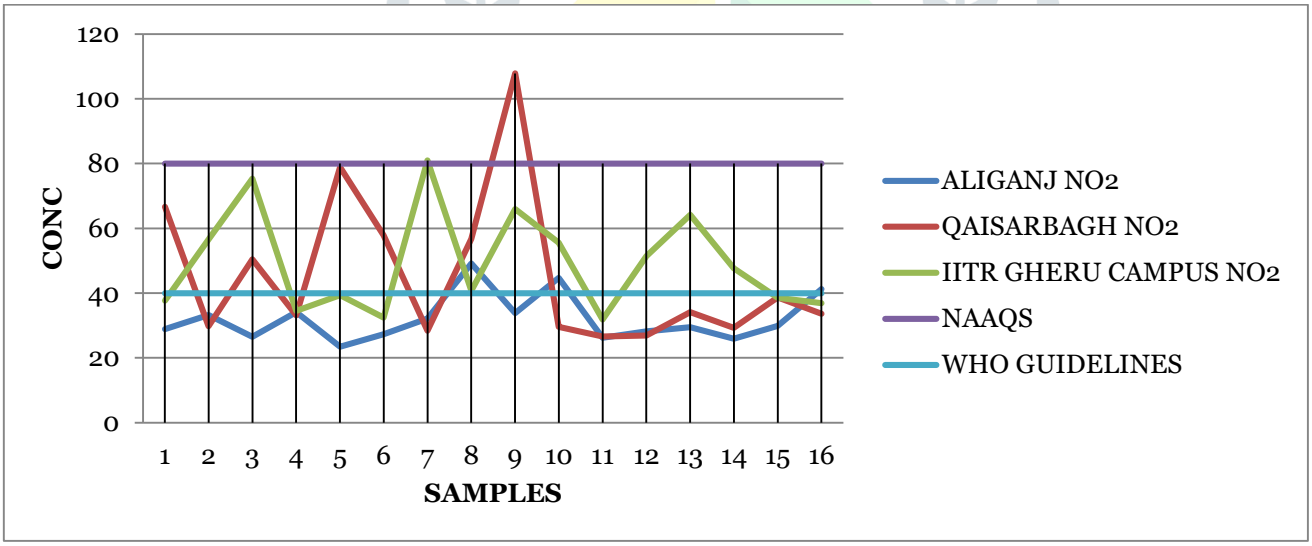
GRAPH 1: CONCENTRATION OF PM_{10} AT MONITORING LOCATIONS



GRAPH 2: CONCENTRATION OF $PM_{2.5}$ AT MONITORING LOCATIONS



GRAPH 3: CONCENTRATION OF SO_2 AT MONITORING LOCATIONS



GRAPH 4: CONCENTRATION OF NO_2 AT MONITORING LOCATIONS

Conclusion :

The observing at three areas viz: Aliganj, Qaisarbagh, and IITR Gheru Campus (Sarojani Nagar) were embraced amid (Jan 2019 - March 2019) at Lucknow. The Assessment of ambient air quality was attempted based on following air parameters which were Particulate Matter ($PM_{2.5}$ & PM_{10}), SO_2 and NO_2.

The PM_{10} levels at all the observing areas were higher than the NAAQS furthest reaches of 100µg/m^3. The $PM_{2.5}$ level at the observing areas were higher than the NAAQS furthest reaches of 60µg/m^3.The SO_2 level at the checking areas were lower than the NAAQS level i.e. 80µg/m^3. The NO_2 level at the observing areas were lower than the NAAQS level i.e. 80µg/m^3.

The grouping of PM_{10} in industrial area is higher than residential and commercial area The grouping of $PM_{2.5}$ in commercial area is higher than residential and industrial area The grouping of SO_2 is higher in residential area than commercial and industrial area. The grouping of NO_2 is higher in industrial area than residential and commercial area.

MATLAB Toolbox (Fuzzy Logic) is used for making the air quality model in which air quality parameters such as Particulate Matter ($PM_{2.5}$ & PM_{10}), SO_2 and NO_2 are to be classified as Good (G), Satisfactory (S), Moderately polluted (MP), Poor (P), Very Poor (VP) and Severe (SE) . There were 214 fuzzy rules formulated. The output parameter is classified as Good (G), Satisfactory (S), Moderately polluted (MP), Poor (P), Very Poor (VP) and Severe (SE).

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