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Pollutant Analysis and Forecasting Report for three regions of Jammu-India against the period 2014-2016

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Abstract: The air pollution and its resulting relationship with public health have gained increasing attention in the past decade. Many air pollution analyses have been conducted across the world. The study involves the air pollution analysis of pollutants involving Nitrogen oxide (NO_x), Sulphur oxide (SO_x), Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM) against three major regions Narwal, Bari Brahmana and M.A Stadium of the Indian city of Jammu. The analysis involves the study of trend over a period of three years from January 2014 to December 2016. The analysis was done using statistical and machine learning tools. While time-series analysis was carried out for statistical cause, the regression model was developed for calculating the pollution concentration over the regions.

Keywords: Concentration Analysis; Trend Analysis; KSVM; Time series prediction; Linear regression model

I. INTRODUCTION

Air pollution has a direct impact on human health. Critical air pollution event frequently occur where the geographical and meteorological conditions do not permit an easy circulation of air and a large part of the population moves frequently between distant places of the city [1]. The economic development of a region is directly associated with the level of industrialization and urbanization. Unfortunately, along with its positive aspects, there are various hazards to the environment and human health associated with it. Researches in recent decade have indicated that urban air pollution has been a growing problem in both developed and developing world. Outdoor air pollution is responsible for a range of cardiovascular and respiratory diseases.

The present trend towards increasing industries and transport volume, and the associated risk of harm to air quality and health, threaten the lives on the planet. Size, shape and chemical properties of particles govern their lifetime in atmosphere and also their deposition site within the respiratory system. Air pollution is caused due to a heterogeneous mixture of gaseous and particulate components. The main gaseous pollutants are sulphur oxides, nitrogen oxides, carbon monoxide, ozone, and particulate matter (PM). Recently, emissions of particulate matter have gained attention, owing mainly to epidemiological findings that indicate its adverse effect on human health [2].

The amounts of pollutants released in the atmosphere on a global scale, are resulting in damage to human health and the environment. It is also resulting in the damage of resources needed for the long-term development of world. Hence, all we need is to develop echo friendly systems by controlling the exhausts that cause harm to environment.

II. LITERATURE SURVEY

An important task providing the proper quality of our life is the protection of environment in which we live. Deterioration of air quality is the main concern in many urban centers. As per the Census of India 2011, the urban population of India is 31.16% of total population. This proportion of urban pollution has grown from 27.81% in 2001 to 31% in 2011[3]. This increase in the statistics for the urban population has resulted in the expansion of cities in density as well as area.

In India, the atmospheric conditions have progressively deteriorated due to urbanization, industrial development, poor maintenance of motor vehicles and poor road conditions [4] as it has been taken as the most obvious sink for various pollutants.

Rise in the number of vehicles along with lack of smooth traffic flow due to congested and narrow roads results in frequent jams. Road traffic can be considered as the major contributor for some of the pollutants, such as nitrogen oxides, carbon monoxide and particulate matter.

Studies reveal that air pollution causes about 1.2 million deaths in India annually which is only a “fraction less” than number of deaths caused by tobacco usage and almost three percent of the GDP is lost due to it [5].The World Health Organization (WHO) in its latest study has indicated that the winter capital of the state Jammu and Kashmir is among the twenty cities in the world having dirtiest air [6]. The movement of around 5-6 lakhs vehicles in the radius of 4-5 square kilometers in Jammu city is one such factor while execution of mega constructions in different parts of the city also add on to the air pollution. The city appears to have been paying a heavy ecological price for ongoing development activities and is emerging as one of the polluted cities in the country.

There are a number of significant works devoted to this problem. For instance, Yin Zhao et.al. [7] proposed the use of data mining methods to forecast fine particles (PM2.5) concentration level in Hong Kong Central. Ioannis N.Athanasiadis et.al. [8] presented the application of a novel classifier namely σ-FLNMAP for estimating the ozone concentration level in the atmosphere. Giovanni Raimondo et.al. [9] presented a view on the application of Machine learning for forecasting PM10 level. Arnaud Jutzeler et.al.[10] proposed a Region-based model for estimating Urban Air pollution in the city of Zurich. A study on monitoring the outdoor ambient air quality of Jammu city with respect to two pollutants SO_2 and NO_2 was conducted for time period 2004-2005 [11]. Another study focused on air quality of Katra town(J&K) with reference to SO_2 and NO_2 contents for time period July2010-June 2012 [12].Status of pollutant SPM in Jammu city for 2004-2005 was also estimated [13].

In previous contributions, urban air pollution was mainly analyzed for developed nations and major improvements in air quality have occurred over the last 50 years. But ironically no major stride has been made in the developing countries to control the incidence of air pollution. In a small region like Jammu, air pollution remains the main cause of many cardiovascular and respiratory diseases. In this work, the prediction of concentration of various pollutants along with the trend analysis is carried out. The forecasting for the time period 2017-2018 is also done based on 2014-2016 data obtained.

In this research, kernel based support vector machine (KSVM) is used to predict the pollutant levels. Also, linear regression model is used to forecast the pollution levels in the coming years as well.

III. DESCRIPTION OF THE STUDY AREA

Jammu, winter capital of Jammu and Kashmir State, is the largest city of Jammu Division. Situated at the banks of river Tawi, city is located at 32.73°N 74.87°E and has an average elevation of 327m (1,073 ft). Jammu, with 12.55 million population lies at uneven ridges of low heights at the Shivalik hills and is surrounded by Shivalik range to the north, east and south-east while Trikuta Range surrounds it in north-west. Tourism is the largest industry and has number of woodgrain mills to cater its large population. Jammu, popularly known as city of temples is now being recognized as city of traffic congestion and polluted air. Absence of major industries in and around city, vehicular emissions contributes to be the main pollution sources and is attaining alarming proportion.

IV. NEED FOR STUDY

Evaluation of air quality levels is very important for the better management practices. Like other parts of country, air pollution in Jammu and Kashmir State is also increasing with the increase in the number of motor vehicles. Vehicular traffic is the main source of air pollution in Jammu city as every year number of vehicles goes on increasing [11]. At least 9 lakh vehicles are plying on the roads in J&K, making it one of the most vehicle populated state in the country [12]. Adulteration of diesel and petrol with kerosene oil increases vehicular pollution, which is the major arbiter to the increasing pollution levels in the city [14]. Air pollution continues to remain the biggest cause of many respiratory diseases among city residents. The major concern in the city like Jammu is traffic-derived pollution. Environment management has not found a proper place in the planning of state as it has always remained short fall of equipments and man power. This study is an attempt to evaluate the status of four pollutants, nitrogen oxide (NO_x), sulphur oxide (SO_x), suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM) in the city of Jammu for time period 2014-2016. To quantify pollutants emissions and to study the ambient air pollution in the city, three major regions two industrial and one residential are identified namely Bari Brahmana(A), the industrial estate of Jammu district and has a large presence of industrial units manufacturing a variety of products; Narwal (B), includes small industries and is commercial hub of the city; and M.A Stadium(C), Residential area is located near bus stand Jammu and features high traffic volume due to presence of various educational institutions and government offices. The identified regions are more prone to pollution and maximum ground level concentrations are expected especially in the context of pollutants selected for study.

V. EFFECTS OF AIR POLLUTION

According to WHO, air pollution is defined as the presence of materials in the air that are harmful to humans and their environment [15]. Thus, if the concentration of any material or element in air exceeds the permissible limit, it may affect humans and various resources, either directly or indirectly and may be titled as air pollution. Variety of pollutants are emitted which have an increasing impact on air quality.

A. Sulphur oxide

The most important oxide emitted by pollution sources is Sulphur oxide (SO_x) and is a colorless, reactive gas, produced by chemical interaction between sulphur and oxygen and is emitted when sulphur containing fuels such as coal and oil are burned. Major sources of emissions include petroleum refineries, paper mills, power plants, and industrial boilers.

Health Effects: At low concentrations, very brief exposure causes bronchoconstriction in asthma patients accompanied by wheezing, chest tightness, and shortness of breath. At high levels, even healthy individuals will experience similar effects. Long-term exposure to sulphur dioxide may lead to respiratory symptoms and illness, and aggravate asthma.

B. Nitrogen oxide

Nitrogen oxide (NO_x) is a generic term for Nitric oxide (NO) and Nitrogen dioxide (NO_2) [16]. NO_x gases react with moisture, ammonia and other atmospheric substances to form nitric acid vapor and other related particles. Motor vehicles are a major source of nitrogen dioxide in India and other source of nitrogen oxides is the combustion of fossil fuels from stationary sources including power plants, industrial boilers.

Health Effects: Small particles resulting from reaction of NO_x gases with atmospheric substances can penetrate deeply into lung tissue and damage it, which can cause premature death in extreme cases. Inhalation of such particles may cause respiratory diseases such as emphysema, or even needle the existing heart diseases.

C. *Suspended Particulate Matter*

Suspended Particulate Matter (SPM) is a generic name for fine solid or liquid particles of up to 100 micron in size, added to atmosphere. Particulate matter includes smoke, dust, pollen and soil particles [17]. Some of the main sources of SPM include natural dust, vehicles, and industries such as sugar, thermal, cement.

Health Effects: Fine particles easily get trapped in respiratory airways of human lungs causing inflammation and worsening the condition of people with heart diseases and lung diseases.

D. *Respirable Particulate Matter*

Respirable Particulate Matter (RSPM) are particles with aerodynamic diameter particularly 0.5 to 10 micron and is a causative agent of mortality and morbidity. The vehicle pollution is increasing exponentially in many cities and is the single major factor for high RSPM levels. Some other sources may include engine gunsets, small scale industries, resuspension of traffic dust, commercial and domestic use of fuels.

Health Effects: These particles of smaller size can cause several health hazards and are more likely to enter the respiratory tract and get infix in the air spaces of lungs and therefore increase the susceptibility of respiratory infections.

VI. EXPERIMENTAL MODEL

Three year data come from J&K State Pollution Control Board (SPCB) for the time period January 2014 - December2016. Four air pollutants viz., Sulphur oxide (SO_x), Nitrogen oxide(NO_x), Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM/PM10) have been identified for regular monitoring along with two additional parameters wind speed(ws) and wind direction(wd). The monitoring of pollutants is carried out for 24 hours involving 4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter with a frequency of twice a week, to have 104 observations in a year. Measurement of Sulphur oxide and Nitrogen oxide is carried out by wet chemical method and high volume sampler is being widely used for particulate matter measurement. The database consists of records for regions Bari Brahmana (A), M.A Stadium (B), and Narwal (C) as shown in Table I.

To quantify pollutants emissions and to study the ambient air pollution in the city, these regions have been analyzed using time-series analysis. The linear regression model was developed with an aim to associate time- varying pollution exposure with time-varying event counts during the study period 2014-2016. In addition, Kernel based SVM (KSVM) was used to calculate density of pollutants over these regions for generated values against each pollutant.

Table I. Showing name of the regions under study along with the parameters used in the analysis

S.no.	Region	Code	Type	Parameters
1.	Bari Brahmana	A	Industrial area	ws, wd, NO_x, SO_x, SPM, RSPM
2.	M.A Stadium	B	Residential area	ws, wd, NO_x, SO_x, SPM, RSPM
3.	Narwal	C	Industrial area	ws, wd, NO_x, SO_x, SPM, RSPM

VII. RESULTS AND DISCUSSION

The analyses were done using Time series, OpenAir and forecast package available in R. The trend analysis involves estimating the trend in the concentration of a pollutant or other variable. Monthly mean values are calculated from an hourly time series. Trend analysis uses a Generalized Additive Model to find the most appropriate level of smoothening. The function is particularly suited to situations where trends are not monotonic. The smoothTrend function is useful as an exploratory technique so as to check how linear or non-linear trends are between specified period. And forecast is a function used while forecasting from time series or time series models. The forecasting function used here is “tslm” that fit linear models to time series including trend and seasonality components.

A. *Pollutant Concentration Analysis*

1) Pollutant NO_x: The average concentration of NO_x was observed to be maximum in October 2014 for region B with a value of 41.6 followed by region C and A having values 33.2 and 30.6 respectively. The range of NO_x was observed to be >0.1 and <42 over the period 2014 and 2016 for all the regions as shown in Table II.

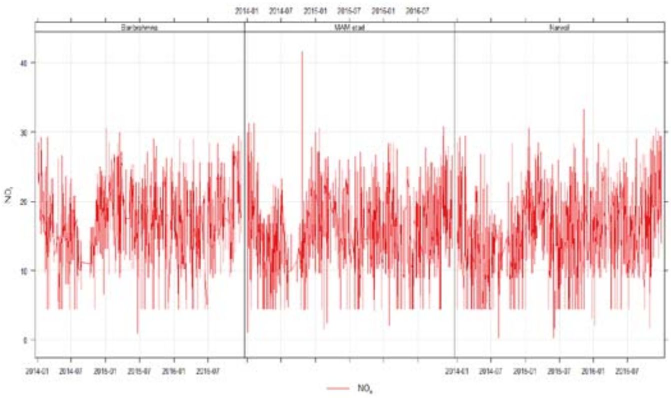

Figure 1. Showing Region plot for average concentration of Pollutant NO_x for years 2014-2016

2) Pollutant SO_x: The average concentration of SO_x was observed to be maximum in October 2014 for region A with a very high value of 52 followed by region B and C with values 32 and 14.9 respectively. The range of SO_x was observed to be >0.1 and <53 during the period 2014 and 2016 over all the regions as shown in Table II.

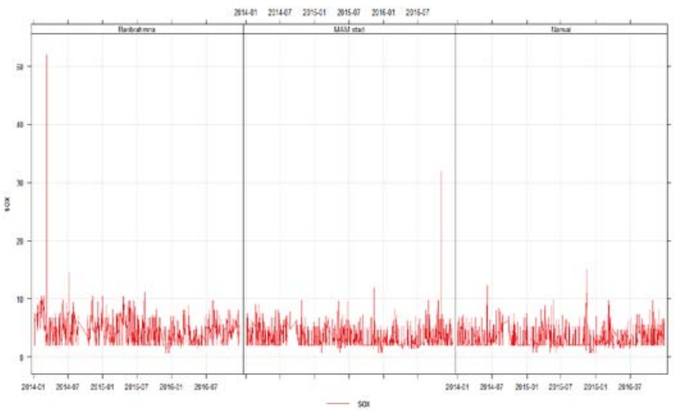

Figure 2. Showing Region plot for average concentration of Pollutant SO_x for years 2014-2016

3) Pollutant SPM : The average concentration of SPM was maximum in August 2014 for region A with a value of 397 followed by region B and C with values 374 and 360 respectively. The range of SPM was observed to be >25 and <398 during the period 2014 and 2016 over all the regions as shown in Table II.

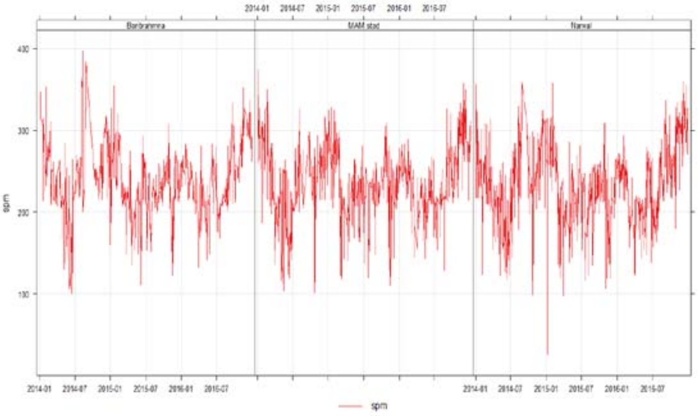

Figure 3. Showing Region plot for average concentration of Pollutant SPM for years 2014-2016

4) Pollutant RSPM : The maximum value of average concentration of RSPM was in January 2014 for the region B with a value of 278 followed by region A and C with values 229 and 218 respectively. The range of RSPM was observed to be greater than 4 and less than 279 during the period 2014 and 2016 over all the regions as shown in Table II.

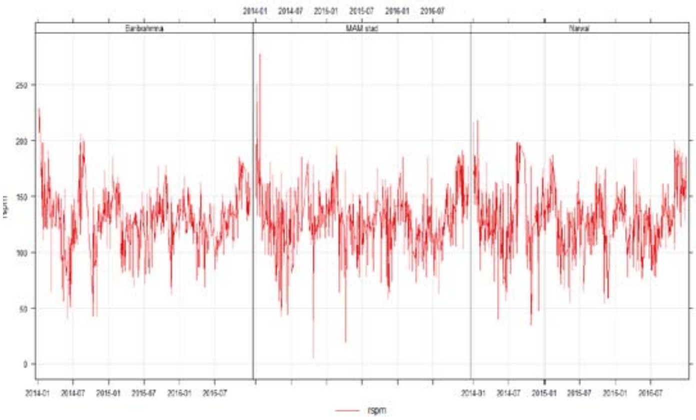

Figure 4. Showing Region plot for average concentration of Pollutant RSPM for years 2014-2016

Table II. Showing Concentration of Pollutants

Sno.	Pollutant	Region	Month/Year	Max	Min
1	NO_x	B	October 2014	41.6	-
2	NO_x	C	August2014, June2015	-	0.3
3	SO_x	A	March2014	52	-
4	SO_x	A,B,C	February2015, December2015	-	0.7
5	SPM	A	August2014	397	-
6	SPM	C	January2015	-	26
7	RSPM	B	January2014	278	-
8	RSPM	B	October2014	-	5

B. Pollutant Trend Analysis

1) Pollutant NO_x: Three upward trends for pollutant NOx during period August2014-February2015, October2015-December2015, August2016-December2016 and three downward trends during January2014-July 2014, March 2015-September 2015, January2016-July2016 were observed against region A. While in case of region B, three upward trends during August2014-March2015, August2015-November2015, August2016-December2016 and three downward trends during period January2014-July2014, March2015-August 2015, January2016-June2016 were observed. For region C three upward trend July2014-March2015, September2015-February2016, July2016-December2016 and three downward trends between period January2014-June2014, April2015-August2015, March2016-June2016.

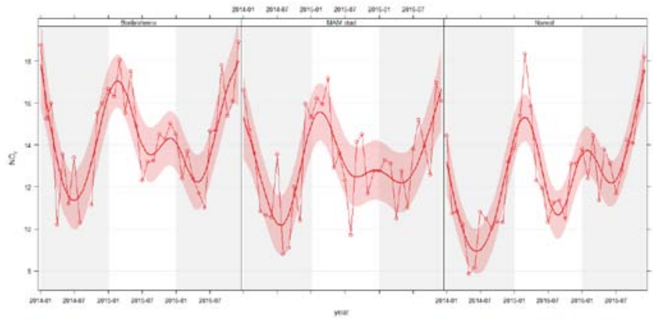

Figure 5. Showing trend analysis for Pollutant NO_x against regions Bari Brahmana(A), M.A Stadium(B), Narwal(C)

2) Pollutant SO_x: An upward trend was observed for pollutant SOx against region A between April2014–September2014, January2015-April2015, October2015-February2016, April2016-October2016 and during January2014- March2014, October2014-December2014, May2015-September2015, November2016-December2016 downward trend was observed for the same pollutant. And for region B it was observed that between period April2014-September2014, January 2015-May2015, December2015-October2016 there was an upward trend whereas a downward trend was observed between periods October2014-December2014, June2015-November2015. While for region C between period April2014-September2014, October2015-December2016, there was a upward trend and downward trend was observed between October2014–December2014, July2015-September2015.

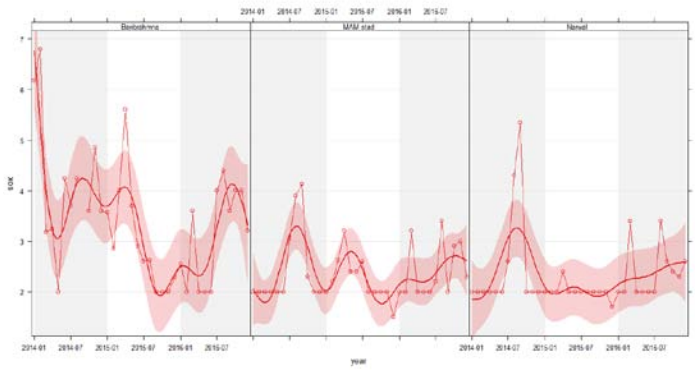

Figure 6. Showing trend analysis for Pollutant SO_x against regions Bari Brahmana(A), M.A Stadium(B), Narwal(C)

3) Pollutant SPM: An upward trend for pollutant SPM, between July2014-October 2014, June 2015-August 2015 and August2016- December2016 and downward during January2014–May2014, November2014-May2015, January 2016-July2016 were observed against region A. For region B it was observed that between period July2014-September2014, June2015-November2015, July2016-December2016 there was an upward trend whereas a downward trend was observed between periods January 2014-June 2014, October2014-May2015, November2015-June2016. In case of region C between period June 2014–October2014, May2015-November2015 and May2016-December2016, there was an upward trend and downward trend was observed between January2014–May2014, November2014-April2015 and December2016-April2016.

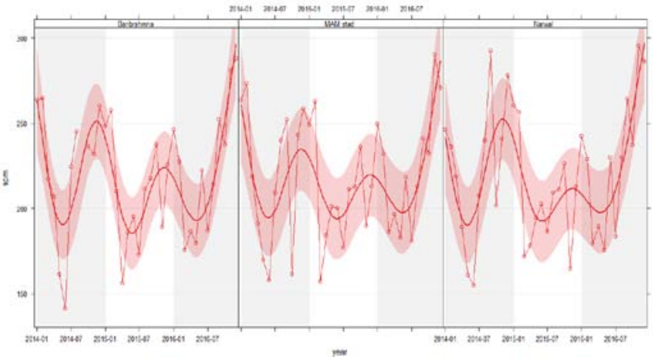

Figure 7. Showing trend analysis for Pollutant SPM against regions Bari Brahmana(A), M.A Stadium(B), Narwal(C)

4) Pollutant RSPM: An upward trend for pollutant RSPM between July2014-September2014, May2015-November2015, August2016-December2016 was observed and downward trend was observed between January2014–June2014, October2014-April2015, December2015-July2016. For region B it was observed that between period July2014-October2014, May2015-October2015, July2016-December2016 there was a upward trend whereas a downward trend was observed between periods January 2014-June2014, November2014-April2015, November2015-June2016. In case region C, there was upward trend between July2014-October2014, July2015-November2015, June2016-December2016 and downward trend between January2014-June2014, November2014-June2015, December2015-May2016.

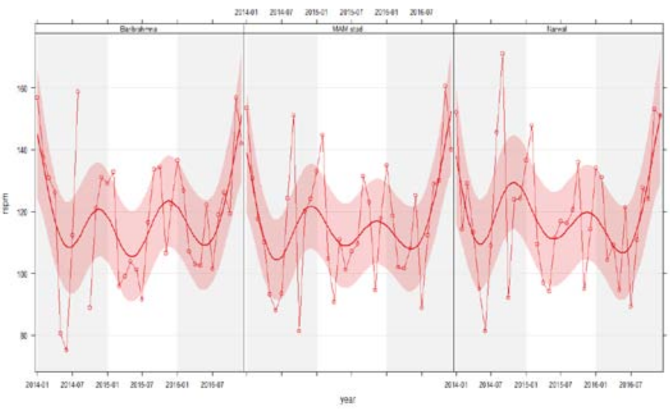

Figure 8. Showing trend analysis for Pollutant RSPM against regions Bari Brahmana(A), M.A Stadium(B), Narwal(C)

Table III. Showing Trend Analysis of Pollutants

S no.	Pollutant	Region	Month/Year	Max	Min
1	NO_x	A	December2016	18.9	-
2	NO_x	C	May2014	-	7.85
3	SO_x	A	February2014	6.8	-
4	SO_x	B	December2015	-	1.5
5	SPM	C	November2016	295.4	-
6	SPM	A	June2014	-	141
7	RSPM	C	September2014	171	-
8	RSPM	A	June2014	-	75

C. Pollutant prediction and forecasting

In the region-wise probability prediction of pollutant NO_x, region C was observed to have maximum probability with value 0.393 while region A was having minimum value 0.229. The probability was calculated for the pollutant concentration values recorded over specific period against the mentioned regions.

The similar results were observed for pollutant SO_x and SPM with maximum values 0.387 and 0.389 respectively for regions C. While lowest values 0.234 and 0.238 were recorded against mentioned pollutants for region A.

The predicted probability score was almost similar for regions B and C with highest values 0.378 and 0.391 compared to region A being least affected with value 0.231 for pollutant RSPM.

Table IV. Showing predicted probability score of three regions against four pollutants

S.no.	Pollutant	Region		
		A	B	C
1	NO_x	0.229	0.378	0.393
2	SO_x	0.234	0.379	0.387
3	SPM	0.238	0.372	0.389
4	RSPM	0.231	0.378	0.391

1) Pollutant NO_x: In the density plot against pollutant NOx region A and B were observed to have density value >60 while region C was observed to have value >50. None of the regions were observed to have values between 0.28 and 0.34. In the linear regression analysis, the year 2017-2018 were forecasted to follow the similar trend observed in the previous years for pollutant NOx.

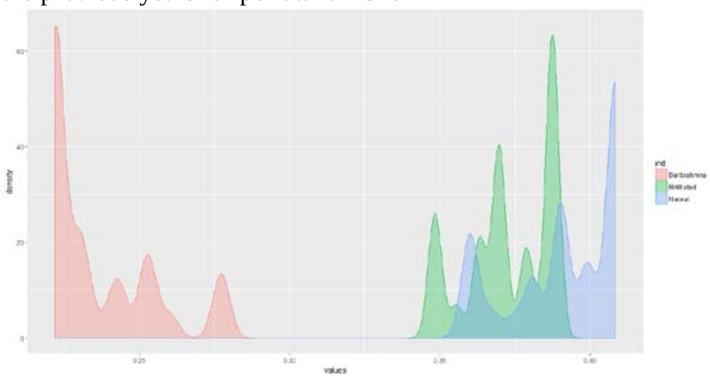

Figure 9. Density Plot for NOx concentration against KSVM predicted values for three regions

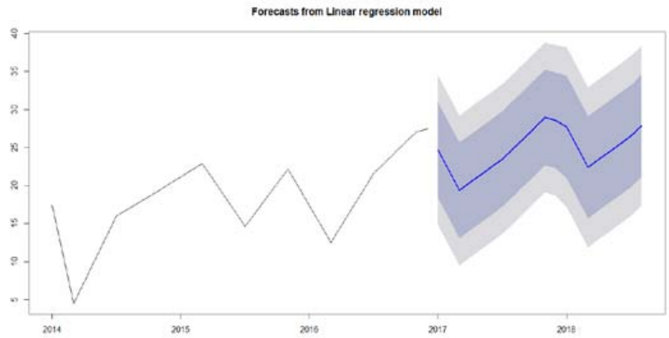

Figure 10. Showing forecasted trend for pollutant NO_x against time period 2017-18

2) Pollutant SO_x : In the density plot against pollutant SO_x region A was observed to have density value between 40 and 50 while region B was having density value equal to 60 and region C >50. Pollutant SO_x was forecasted a decline for the year 2017-2018.

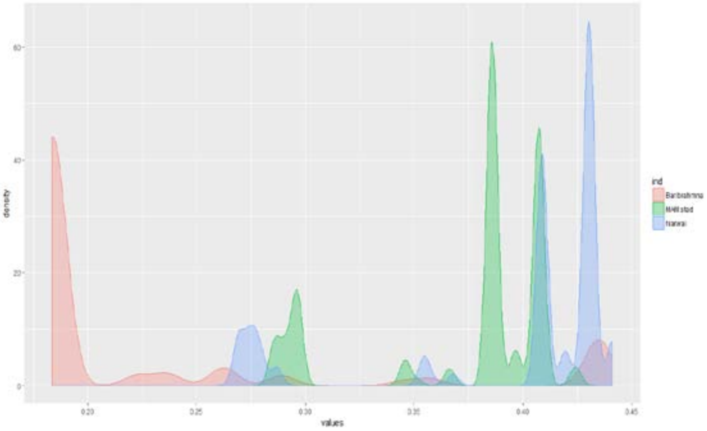

Figure 11. Density Plot for SOx concentration against KSVM predicted values for three regions

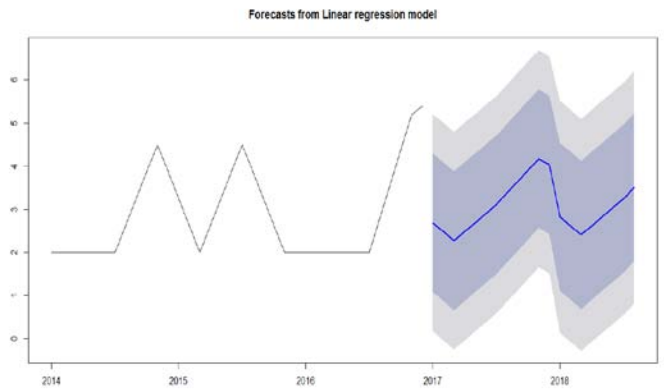

Figure 12. Showing forecasted trend for pollutant SOx against time period 2017-18

3) Pollutant SPM: In the density plot against pollutant SPM region A was observed to have density value <60 while region C was observed to have value >60 and region B had lowest density value <50. None of the region were observed to have values between 0.28 and 0.33. The linear regression model for pollutant SPM forecasts a rise in trend for year 2017-2018.

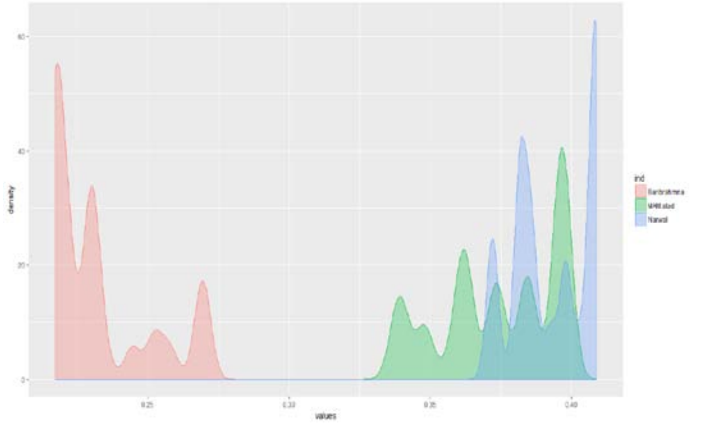

Figure 13. Density Plot for SPM concentration against KSVM predicted values for three regions

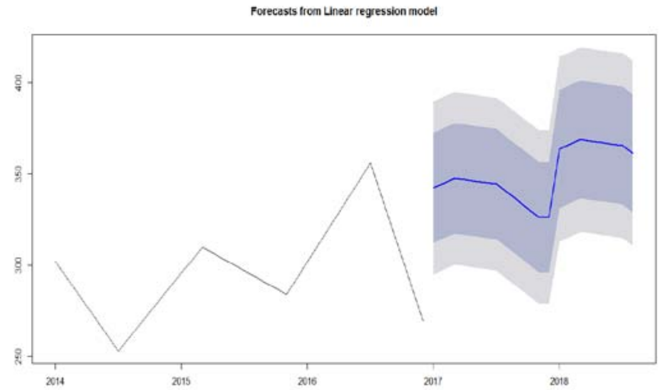

Figure 14. Showing forecasted trend for pollutant SPM against time period 2017-18

4) Pollutant RSPM: In the density plot against pollutant RSPM region A was observed to have density value >60 while region C and B were observed to have value <30. None of the regions were observed to have values between 0.28 and 0.32.The regression model forecasts the similar pattern against time period 2017-2018 as observed in previous years for pollutant RSPM.

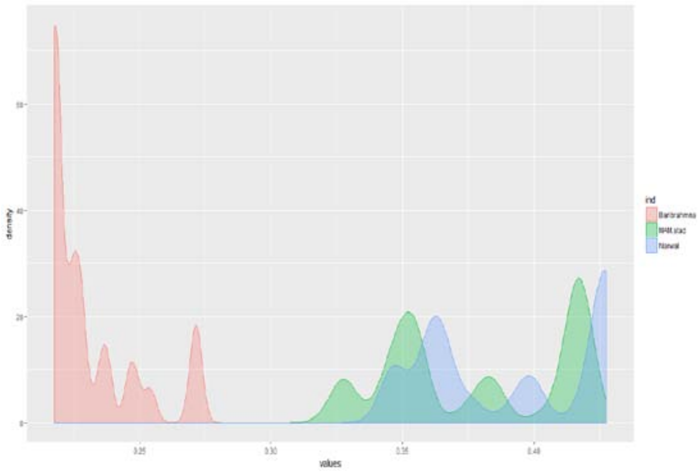

Figure 15. Density Plot for RSPM concentration against KSVM predicted values for three regions

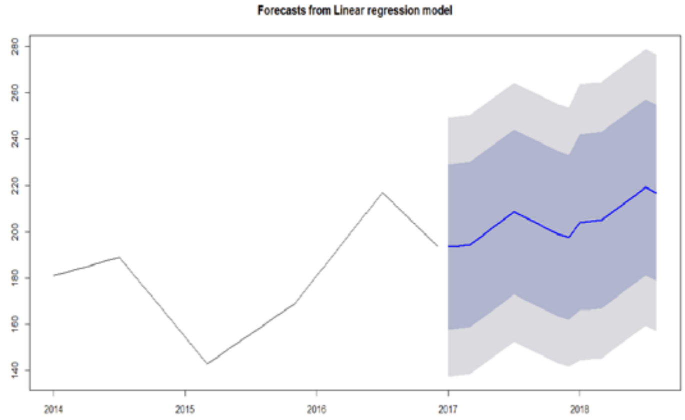

Figure 16. Showing forecasted trend for pollutant RSPM against time period 2017-18

Table V. Showing mean forecasted values for the pollutants

Sno	Pollutant	Mean	Lower1	Lower2	Upper1	Upper2
1	NO_x	24.65	18.19	14.52	31.11	34.78
2	SO_x	3.04	1.39	0.45	4.69	5.63
3	SPM	350.28	319.22	301.59	381.33	398.97
4	RSPM	204.46	167.82	147.01	241.10	261.91

VIII. CONCLUSION

Air pollution is becoming a major problem. Air pollution cause adverse health effects if they present in the air in excess concentrations and for a long duration of time.

In the region wise pollutant analysis region B was observed to have maximum concentration of NO_x with value 41.6. In case of pollutant SO_x region A was observed to have the maximum concentration with value 52. The lowest concentrations were observed for region A against NO_x and region B against SO_x with values 30.6 and 11.9 respectively.

The SPM pollutant concentrations were observed maximum in case of region A with value 397 while RSPM concentration was high in region B with value 278. The lowest concentrations for SPM and RSPM were seen for region C with values 356 and 218 respectively.

Maximum upward trend was observed during year 2014 and 2016 compared to 2015 indicating rise in the pollutant concentration in 2016 compared to 2015.

While the pollutant concentrations of NO_x and SO_x were found to be within permissible limits. The pollutant concentrations of SPM and RSPM were found to be at alarming high during the study period.

In the linear regression model it was predicted that the pollutant concentrations for NO_x and RSPM were to follow the similar trend in 2017-18 compared to previous years. The decline in pollutant SO_x concentration is predicted for the year 2017-18, while a rise is indicated for SPM in the coming years.

The forecasting model output clearly indicated regions A and C are likely to be most polluted followed by region B. The predicted density plot as in Figure10, Figure12, Figure14, and Figure16 justifies the forecasting argument against regions.

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