

RESEARCH ARTICLE

SPATIAL AND TEMPORAL VARIABILITY ANALYSIS OF PM_{2.5} CONCENTRATION IN LAHORE CITYSana Basheer^{1*}, Haroon Rashid¹, Abdul Nasir¹, Rana Ali Nawaz²¹Department of Structures and Environmental Engineering, University of Agriculture, Faisalabad, Pakistan.² Department of Irrigation and Drainage University of Agriculture, Faisalabad, Pakistan.*Corresponding Author Email: sana_basheer96@yahoo.com

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ARTICLE DETAILS

ABSTRACT

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In order to understand the air quality of Lahore city we analyzed the PM_{2.5} concentration at three sampling station Gulberg, Ravi road and Jail road from November 2017 to October 2018. Variations in concentration of PM_{2.5} was observed on monthly basis and also on seasonal basis. Air quality data was collected and then analyzed with the help of GIS. Concentration of PM_{2.5} varies 23 to 70 µg/m³ at Gulberg station. At Jail road station values were observed between 34 and 170 µg/m³ while Ravi road had concentration level of PM_{2.5} between 70 and 188 µg/m³. Highest concentration was observed at Ravi road while lowest concentration was observed at Gulberg sampling station. GIS maps tells us about the spatial variations of PM_{2.5} in the study area. Then compare the observation with NEQS, NAAQS-USEPA and WHO standards. Results shows that PM_{2.5} concentration was above the standards at Ravi road and Jail road stations while Gulberg had also concentration level above the standards but concentration level was below the NEQS AND NAAQS-USEPA standards during March 2018 and August 2018. Reasons of high concentration level may include industrial emissions, vehicular emissions and crop residue burning. Metrological factors also effects air quality. High level of PM_{2.5} concentration is an alarming situation for air quality and have direct impact on the human health as well as on other environmental factors.

KEYWORDS

PM_{2.5} concentration, GIS, NEQS, NAAQS-USEPA, Metrological, environmental.

1. INTRODUCTION

According to the World Health Organization (WHO), air pollution is defined as presence of such elements which are harmful to all living organisms above the specified limit. Air pollution occurs when excessive amount of harmful elements are present in atmosphere. These excessive amount of harmful elements are harmful for outdoor as well as indoor. These harmful elements may be Ozone (O₃), Particulate Matter (PM), Oxides of carbon (CO, CO₂), Aerosols, Nitrogen oxides (NO, NO₂) etc. Due to rapid urbanization and industrialization Pakistan is also facing the issues regarding air quality (Colbeck et al., 2010). The estimated decrease of 6% in annual GDP of the country was noticed by World Health Organization (WHO) because of environmental degradation.

The presence of particles in the air in the form of liquid droplets and solids referred as Particulate Matter. Presence of particulate matter in air has a significant effect of the quality of air and also has adverse effect on human health. Sources of particulate matter includes both natural and anthropogenic sources. Sources of the emissions of particulate matter includes industrial emissions, vehicular emissions, burning of fossil fuels for domestic purposes, crop residue burning etc. PM_{2.5} means the mass per cubic meter of air of particles with a size (diameter) generally less than 2.5 micrometers (µm). PM_{2.5} is also known as fine particulate matter (2.5 micrometers is one 400th of a millimeter). Presence of particulate matter can causes an increase in number of patients of certain diseases like asthma, lungs cancer, skin issues and acute respiratory symptoms. PM_{2.5} has become one of the major issue regarding environmental degradation. Air born particulate matter is one of major environmental issue in urban areas of Asia [1]. PM_{2.5} exposure is dangerous to human health [2].

Lahore is the second largest city of Pakistan and also the capital of Punjab having coordinates 31°15'-31°45' N and 74°01'-74°39' E. "This city's atmosphere is overwhelmed with many harmful air pollutants including Particulate Matter, ozone (O₃), zinc, carbon monoxide (CO), lead, carbon dioxide, and as well as some others" [3]. During last few years, Lahore is

engulfed by a disturbing of air quality due to rapid industrial development and urbanization. Increase in number of industries and automobiles, deforestation and crop burnings contributed to this alarming situation in Lahore [4]. Increase in population leads towards the decrease in the natural sources [5].

Increase in the concentration PM_{2.5} has become one of the core issues in the study area and has adverse effect on environment. This alarming situation needs proper monitoring, analysis and mitigation measures to overcome this alarming situation. Therefore, we found a dire need to monitor and analyzed the PM_{2.5} concentration in the study area. The proper mitigation measures must be needed to overcome an environmental issue [6]. The main purpose of this research to monitor PM_{2.5} concentration in the study area at selected three sampling stations. Data was collected from November 2017 to October 2018 on these sampling stations then this data was analyzed using GIS spatially and temporally.

The Geographic Information System has been found as one of the most common and efficient way in order to know as well as forecast the different environmental quality parameters for a particular location. In this research, it helps in order to understand the trends and the variation of PM_{2.5}. This helps to describe the present scenario and situation about the parameter for air quality under consideration. The GIS system involves a process which captures, collects, investigates, manages and characterizes the information with respect to location statistics. PM_{2.5} concentration was also compared with the National Environmental Quality Standards (NEQS), USEPA-NAAQS and World Health Organization (WHO) standards. Monthly variations and seasonal variations in PM_{2.5} were also observed during the study period.

Table 1: Ambient Air Quality Standards

Standards	Time Weighted Annual Avg.	PM _{2.5} (µg/m ³)
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NEQS-PAK	24-hr*	35
USEPA-NAAQS	24-hr**	35
WHO	24-hr	75

*24 hourly /8 hourly values should be met 98% of the in a year.2% of the time. It may exceed but not on two consecutive days.

** PM_{2.5} 98% average over 3 year not to be exceeded

2. MATERIALS AND METHODS

2.1 Study area and Sampling Stations

The study was conducted within the Lahore city. Lahore is the second largest most populated city of Pakistan that ranked at 32nd position in world. Lahore is among the wealthiest city in Pakistan and having estimated GDP of \$58.14 billion (PPP) as of 2014. But also at the same time it is 20th most populated city in the world. Its geographical coordinates are 31°15'-31°45' N and 74°01'-74°39' E. Population of Lahore city is almost 9.44 million. Lahore have 2700 registered industries out of which 2025 industries are concerned as large scale industries 3.9 million motor vehicles [7,8]. The major industries in Lahore city comprise the manufacturing of pharmaceuticals, motor cars, motorcycles, chemicals, construction materials, engineering products and steel. The reasons for the major air pollution are the construction activities, increase in number of vehicles, uncontrolled industrial emissions, crop residue burnings and its contributing factor of transboundary emissions from India. Lahore has a climate having variations in temperature made it distinct. During the last decade June was the hottest month in the year and on the other hand January was the coldest month in the year [9].

For this study three sampling stations were selected

1. Gulberg
2. Jail Road
3. Ravi Road

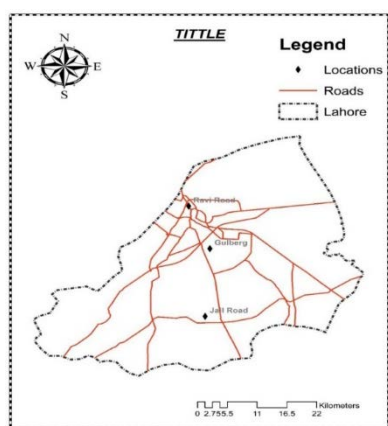


Figure 1: Map Showing the Sampling Stations in Study Area

Gulberg is one of the famous administrative town in Lahore. It is also known as the land of flowers. Gulberg is a developed residential and commercial area. Jail road Lahore has three lanes and total length of jail road is about five kilometers. This area is one of busiest commercial area in Lahore. This area includes educational institutes, hospitals, residential colonies and also parks. Ravi Road is a street has an elevation of 545 meters. It is also a residential and commercial area. Figure 1 shows the all three sampling stations in the study area.

2.2 Data Collection

Data of concentration of PM_{2.5} was collected regularly on the selected sampling stations on the daily basis from November 2017 to October 2018. Then we calculate the average of the concentration of PM_{2.5} on the monthly basis. Method of measurement was Beta ray adsorption method. Table 2 shows the concentration of PM_{2.5} on monthly basis from November 2017 to October 2018.

Table 2: Concentration of PM_{2.5} on Monthly Basis at Three Sampling Stations

Concentration of PM _{2.5} at Three Sampling Stations in (µg/m ³)			
Month	Gulberg	Jail Road	Ravi Road
November	70	65	156
December	64	76	170
January	44	170	188

February	35	124	172
March	25	69	133
April	44	35	140
May	38	34	86
June	53	86	100
July	40	38	70
August	23	45	80
September	36	41	80
October	45	44	90

2.3 Analysis and Characterization of PM_{2.5}

Better analysis of the concentration of PM_{2.5} concentration at three sampling station GIS maps was used. The mapping of air quality was the major technique which provides information of actual air quality scenario of specific area.

3. RESULTS AND DISCUSSIONS

Collected data at three different locations of the study area was analyzed. These three locations are Gulberg, Jail Road and Ravi Road. PM_{2.5} concentration was analyzed at these three location between November 2017 and October 2018. PM_{2.5} concentration was observed on daily basis then we calculate the average on monthly basis for all three sampling stations. Then maps were made on monthly basis for better analysis of PM_{2.5} concentration with the help of GIS. Concentration of PM_{2.5} varies 23 to 70 µg/m³ at Gulberg station [10]. At Jail road station values were observed between 34 and 170 µg/m³ while Ravi road had concentration level of PM_{2.5} between 70 and 188 µg/m³. Highest concentration was observed at Ravi road while lowest concentration was observed at Gulberg sampling station [11]. Detailed analysis of concentration of PM_{2.5} on monthly basis discussed below:

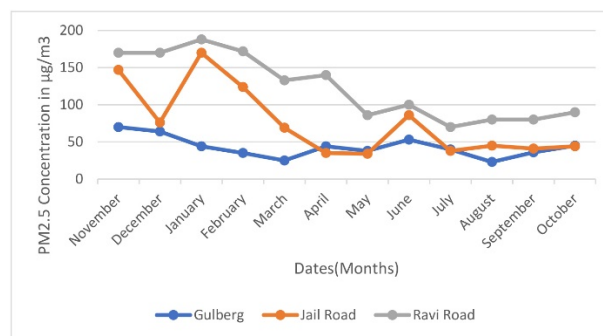


Figure 2: Monthly Wise Comparison of PM_{2.5} at Three Sampling Stations

3.1 November 2017

During the month of November 2017 70 PM_{2.5} concentration was observed at Gulberg station which was lowest concentration level of PM_{2.5} in study area during the month of November 2017. Gulberg is a residential cum commercial area. This area had the less average value of PM_{2.5} because of less vehicular emission. On the other hand Ravi road and Jail road have more values of PM_{2.5} and these are 147 and 170 µg/m³ respectively due to high vehicular emissions and combustion of fuels. These areas are commercial and have more traffic. Figure 3 shows the concentration of PM_{2.5} in the study area during the month of November.

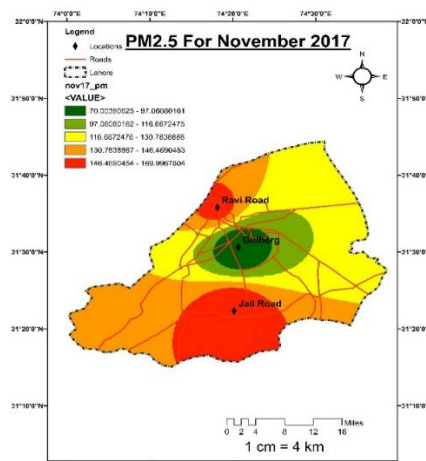


Figure 3: PM_{2.5} for November 2017

3.2 December 2017

During the month of December $PM_{2.5}$ having different values ranges $64 \mu g/m^3$ to $170 \mu g/m^3$. The highest values are observed at Ravi Road which is $170 \mu g/m^3$. Gulberg area have the average value of $PM_{2.5}$ is $64 \mu g/m^3$ because of less vehicular emission. On the other hand Ravi road and Jail road have more values of $PM_{2.5}$ and these are $170 \mu g/m^3$ and $76 \mu g/m^3$ respectively due to high vehicular emissions and combustion of fuels and at all three station concentration was above the permissible limits. These areas are commercial and have more traffic. Figure 4 shows the concentration of $PM_{2.5}$ in the study area during the month of December.

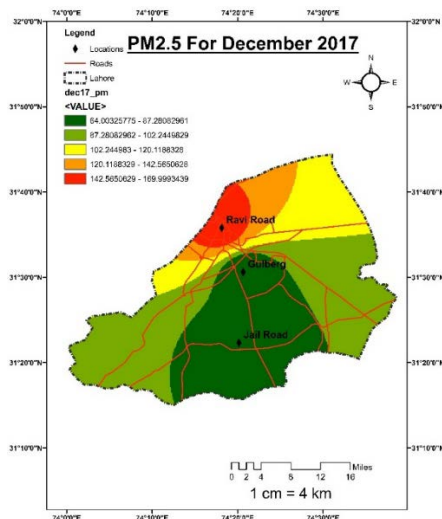


Figure 4: $PM_{2.5}$ for December 2017

3.3 January 2018

During the month of January 2018 concentration of $PM_{2.5}$ was 5 to 6 times higher than the permissible limits at Ravi road and Jail road. The concentration value of $PM_{2.5}$ at Ravi Road was $188 \mu g/m^3$ while the concentration value at Gulberg and Jail Road were 44 and $170 \mu g/m^3$ respectively. Gulberg also had concentration above the permissible limit as per EPD standards. Figure 5 shows the concentration of $PM_{2.5}$ in the study area. Concentration level above the permissible limit were due to the fuel burning and vehicular emissions.

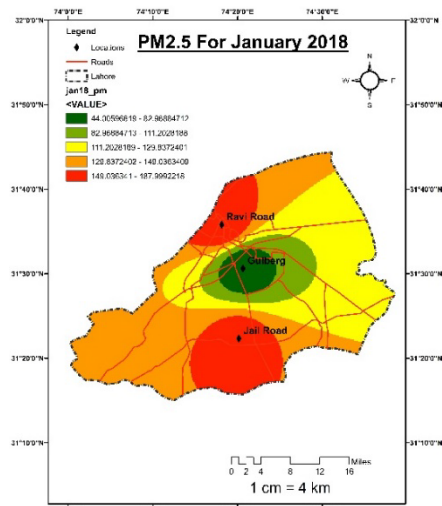


Figure 5: $PM_{2.5}$ for January 2018

3.4 February 2018

During the month of February 2018, concentration of all studied parameters were above the permissible limits. Figure 4.16 shows the concentration of $PM_{2.5}$ in the study area. Gulberg had monthly average of $35 \mu g/m^3$. While Jail road and Ravi road had $PM_{2.5}$ concentrations $124 \mu g/m^3$ and $172 \mu g/m^3$ respectively. Gulberg had the lowest concentration level as compare to the other two sampling stations. Ravi road and Jail road had very high concentration of $PM_{2.5}$ as compare to Gulberg sampling station and also above the standards of NAAQS-USEPA, NEQS and also WHO. The reason for higher concentration of $PM_{2.5}$ at Ravi road station was due to the industrial activities and burning of fuels.

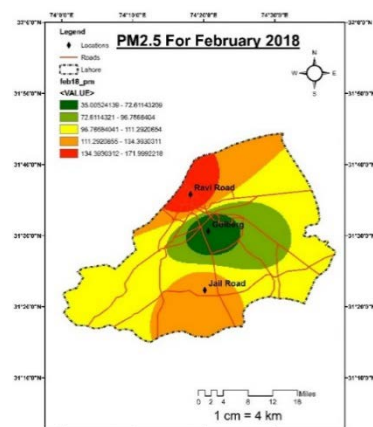


Figure 6: $PM_{2.5}$ for February 2018

3.5 March 2018

During the month of March 2018 there was a change observed in the concentration of $PM_{2.5}$. This was because of change in weather and metrological parameters. Highest concentration of $PM_{2.5}$ was observed at Ravi road which was $133 \mu g/m^3$ as red color shows in Figure 7. While less concentration was observed at Gulberg which is $25 \mu g/m^3$. Gulberg station had concentration level below the all the three standards. While Ravi road and Jail road had concentration level above the NEQS, NAAQS-USEPA and also WHO standards. This was due to emissions from anthropogenic sources.

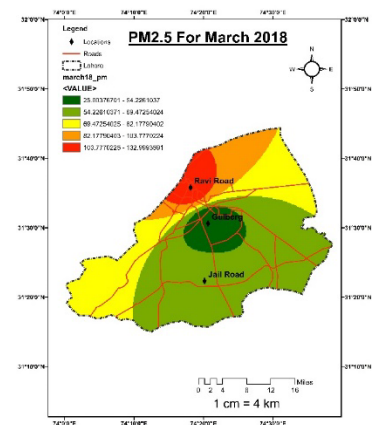


Figure 7: $PM_{2.5}$ for March 2018

3.6 April 2018

During the month of April 2018 the value of $PM_{2.5}$ lies $35 \mu g/m^3$ to $140 \mu g/m^3$ in the study area. Maximum value was observed at Ravi road station which $140 \mu g/m^3$. Which was almost four to five times above the permissible limit according to the NEQS, NAAQS-USEPA and WHO standards. Lowest concentration was observed at Jail road. Reasons behind this was the emissions from the industries and also vehicular emissions. Figure 8 shows the concentration level of $PM_{2.5}$ in the study area.

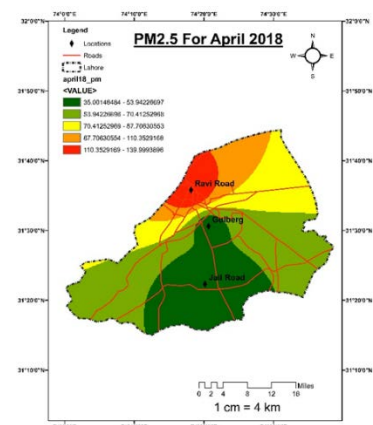


Figure 8: $PM_{2.5}$ for April 2018

3.7 May 2018

Figure 9 describes the concentration of PM_{2.5} during May 2018. All three stations had concentration level above the EPD standards. Maximum concentration was observed at Ravi road which was 86 µg/m³. Which was almost 4 times above the permissible limit. Jail road had the lowest value 34 µg/m³. During the month of May 2018 Gulberg and Jail road had the concentration near to the NEQS and NAAQS-USEPA standards. Although this was occurred only in this month during the whole study period but this situation was also alarming.

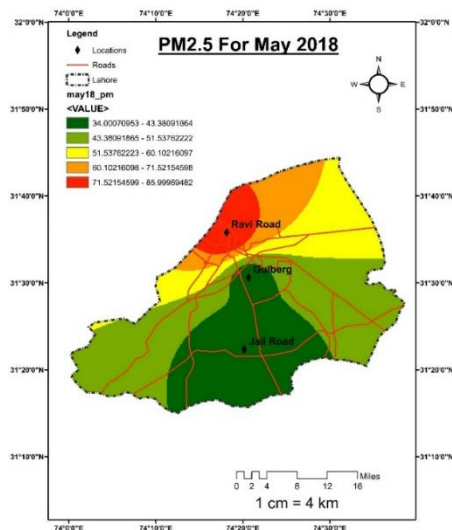


Figure 9: PM_{2.5} for May 2018

3.8 June 2018

During the month of June all three sampling stations had PM_{2.5} concentration above the standards. Highest values was observed at Ravi road which was 100 µg/m³. Reasons of high concentration level at Ravi road were vehicular emissions as shown in Figure 10. Also, the value of concentration of PM_{2.5} in Gulberg was 53 µg/m³ which was above the standard value. Observing the value of PM_{2.5} at Jail Road, it was noticed that the value was 86 µg/m³ which was more than the Gulberg but less than the value at Ravi Road.

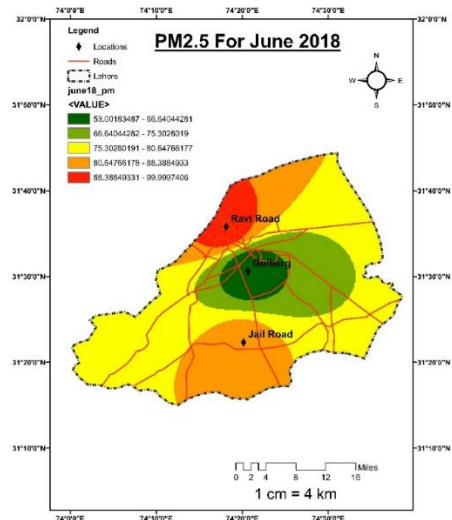


Figure 10: PM_{2.5} for June 2018

3.9 July 2018

July was the month when monsoon season starts. Although average Temperature remains high during this month but this month also hits with rains. PM_{2.5} concentration decreases during this month at all sampling stations as compare to previous one. Maximum concentration was observed at Ravi road due to its industrial and vehicular emissions. In July, the values of PM_{2.5} at all three sampling stations were again higher than the standard value. The concentration value of PM_{2.5} at Ravi Road was higher than the other two stations. The value of PM_{2.5} at Gulberg was 40 µg/m³ while Jail Road and Ravi Road showed 38 µg/m³ and 70 µg/m³ respectively Figure 11 shows the PM_{2.5} concentration in study area.

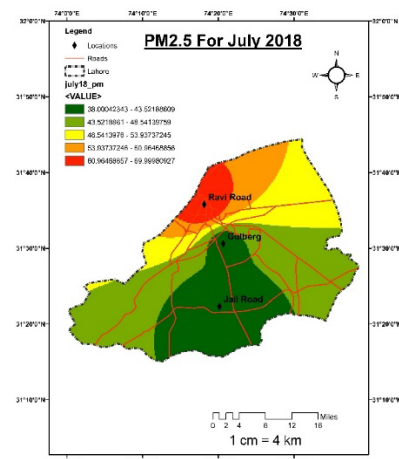


Figure 11: PM_{2.5} for July 2018

3.10 August 2018

Figure 12 shows the concentration of PM_{2.5} during August 2018. During this month Gulberg station had concentration level below the permissible limits. The concentration value of PM_{2.5} in Gulberg is 23 µg/m³ while the values at Jail Road and Ravi Road are 45 µg/m³ and 80 µg/m³ respectively. This residential area have less vehicular emissions and burning of fossil fuels.

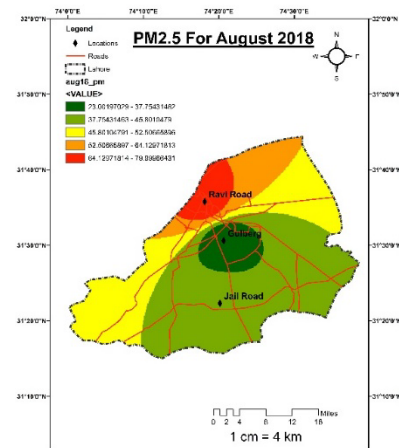


Figure 13: PM_{2.5} for August 2018

3.11 September 2018

Figure 14 describes the PM_{2.5} the month of September 2018. During this month Gulberg had concentration below the permissible limit while other two stations had concentration of PM_{2.5} above the permissible limits. The concentration value of PM_{2.5} at Gulberg was 36 µg/m³ while Jail and Ravi Road showed 41 and 80 µg/m³ respectively. Ravi road and Jail road had more burning of fuels for the industrial activity and transportation purposes.

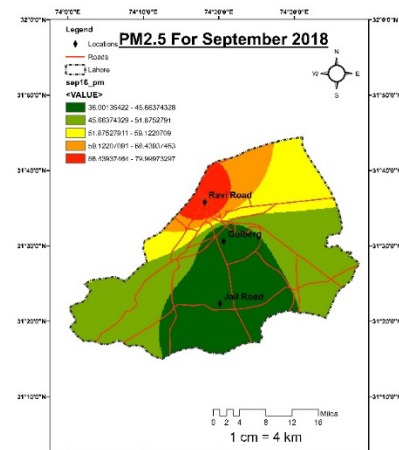


Figure 14: PM_{2.5} for September 2018

3.12 October 2018

During the month of October 2018 PM_{2.5} concentration was highest at the Ravi road station. Concentration level was 90 µg/m³ which was 3 µg/m³ times above the permissible limit. While the Gulberg and Jail road had concentration 45 µg/m³ and 44 µg/m³ respectively. All three sampling stations had concentration level above the three standards.

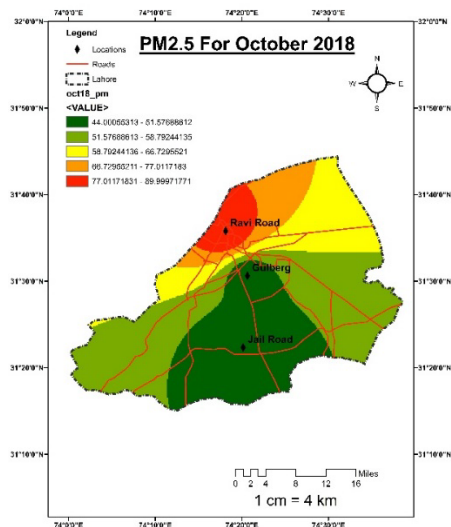


Figure 15: PM_{2.5} for October 2018

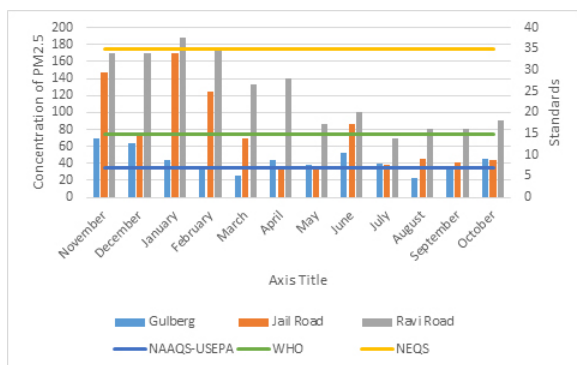


Figure 16: Comparison of concentration of PM_{2.5} with Standards

4. CONCLUSION

Ambient air particulate matter (PM_{2.5}) was analyzed within the Lahore city from November 2017 to October 2018. Concentration of PM_{2.5} varies 23 to 70 µg/m³ at Gulberg station. At Jail road station values were observed

between 34 and 170 µg/m³ while Ravi road had concentration level of PM_{2.5} between 70 and 188 µg/m³. Highest concentration was observed at Ravi road while lowest concentration was observed at Gulberg. During the summer season the concentration level lies above the NEQS and NAAQS-USEPA standards while below the WHO standards at all three sampling stations. On the other hand during winter season concentration level lies above the all three standards. This spatial and temporal analysis shows that the main sources of increase of PM_{2.5} concentration in study area were vehicular emissions and industrial emissions.

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