# Air pollution Monitoring in Urban Areas due to Heavy Transportation and Industries: a Case Study of Rawalpindi and Islamabad

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**Summary:** The present study deals with the air pollution caused by Industry and transportation in urban areas of Pakistan. Rawalpindi and Islamabad, the twin cities of Pakistan were considered for this purpose. The concentrations of major air pollutants were taken from different location according their standard time period using Air Quality Monitoring Station. Five major air pollutants were considered i.e., $NO_2$, $SO_2$, CO, $O_3$ and $PM_{2.5}$. The average mean values for all pollutants were taken on monthly and four monthly bases. The concentrations of $NO_2$ and $PM_{2.5}$ were exceeding the permissible limits as define by Environmental Protection Agency of Pakistan. Other pollutants concentrations were within the standard limits. Geographic Information System was used as a tool for the representation and analysis of Environmental Impacts of air pollution. Passquill and Smith dispersion model was used to calculate the buffer zones. Some mitigation measures were also recommended to assess the environmental and health Impacts because of $PM_{2.5}$ and $NO_2$.

Keywords; Air Quality Monitoring Network; Multi-pollutant; Industrial area; Road transportation.

## Introduction

Air pollution is an emerging environmental issue in major cities of Asia. Societies /Government agencies from developing countries have failed to recognize the limitations of the cleansing capabilities of the atmosphere. Rapid growth of infrastructure in cities, together with associated growth in road transport systems, has made the region increasingly concerned for pollution emissions. Direct and indirect cost-benefit analyses of environmental problems are difficult to evaluate and needs prioritization and judgment. The seriousness of the atmospheric pollution for urban communities had led to the introduction of National Pollution Control (NPC) Policies in the developed countries in 70's and implementation of National Ambient Air Quality Standards (NAAQS) / Indoor Air Quality Standards (IAQS) for domestic and industrial application. These NPC, NAAQS and IAQS were basically aimed at tackling local pollution problems without considering trans-national transport of pollutants. Given that pollution control is itself costly and long-term gains cannot be achieved, since developing countries lack the technical & financial resources to address this issue. It is necessary for the individual country to decide how much of their limited resources should be allocated for pollution control [1].

The industrial, energy and transport sectors are generally considered as major contributors to urban air pollution and associated problems. Suspended particulate matter (SPM), CO, $SO_2$, NOx and $O_3$ are widespread urban air pollutants [2, 3]. The public health is significantly important in regard of the release of some major air pollutants like carbon monoxide, ozone and particulate matter. Pollutant of air may cause irritation to the eyes, snout and gullet, high respiratory disease like cancer of bronchitis lungs. Several heart diseases are also a result of air pollution. Brain, nerves system and liver or kidneys also damage harshly because of air pollution contaminants. The organs and central nervous system of wild life also affected strongly at high concentration of CO which reduces the supply of oxygen to these systems. Atmospheric stability and wind speed are key factor in transportation, dilution and dispersion of air contaminants. Air pollutants spread widely because of wind speed and direction from one place to another. Air pollutant concentrations within the urban boundary layer are controlled by a combination of industrial and vehicular sources and meteorological factors [4-7]. Atmospheric stability and wind speed are the two important parameters that decide the concentration of contaminant at particular place.

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The air pollution is mostly because of road transportation and industry in developing countries; however, air over major developed cities throughout the world is also over burdened with gases produced by automobiles and industry. Most of the cities in Pakistan are growing at a faster rate than the national average, as subsistence workers migrate from rural areas to cities in search of lucrative income [8, 9]. Environmental pollution in large urban areas is regarded as a growing problem for communities, and it has been documented by toxicological studies involving both short and long exposure of times. Some compounds like ozone, nitrogen compounds, sulfur dioxide and atmospheric particulates are considered typical indicators of air quality. $NO_2$ monitoring was conducted in 2006 in Pakistan and was executed by Japan International Cooperation Agency and Pakistan Environmental Protection Agency in five major cities of Pakistan [10]. In another study in 2008 [3], average concentrations of $NO_2$ from 42 sampling sites were found to be 27.46±0.32 ppb in Rawalpindi. Moreover, the study showed that the values obtained for $NO_2$ for all sampling points exceeded the annual limit value set by World Health Organization [3].

Keeping in view of limited studies on air pollution from the region, our goal was to monitor the air pollution level in twin cities caused by vehicular and industrial emissions. Geographic Information System (GIS) was used as a tool for the representation and analysis of Environmental Impacts of air pollution. The role of GIS for advanced transportation planning and management is quite obvious [11, 12].

## Results and Discussion

The concentration of all the pollutants was taken in microgram per meter cube. According to the EPA-PAK Ambient Air Quality Standards the permissible limit of $NO_2$ and $PM_{2.5}$ is 80 µg/m³ and 35 µg/m³ respectively (Table-1). The average mean values on monthly basis for all other pollutant were taken according to their standard time period.

Table-1: The ambient air quality standards for PAK-EPA and US-EPA

| Parameter | Draft PAK-EPA (µg/m³) | US-EPA (µg/m³) | Average Time |
|---|---|---|---|
| $O_3$ | 130 | 235 | 1 Hour |
| CO | 5000 | 10,000 | 8 Hour |
| $SO_2$ | 120 | 365 | 24 Hour |
| $NO_2$ | 80 | 100 (annually) | 24 Hour |
| $PM_{2.5}$ | 35 | 35 | 24 Hour |

*Monitoring of $NO_2$ and $PM_{2.5}$*

It was found that the concentration of $NO_2$ and $PM_{2.5}$ was only exceeding the standard limits at almost all location (Fig. 1 and 2). However the concentration of $NO_2$ was lower than the permissible limit in month of September at station IEI, I-10. The highest value (90 µg/m³) of $NO_2$ was found in October at station service road north (IE-5), I-10/3 and in December at CDA colony (IE-4), I-10/1 Islamabad. The highest concentration (75 µg/m³) of $PM_{2.5}$ was recorded in December at service road north (IE-5), I-10/3 Islamabad. Lowest concentration of $NO_2$ (70 µg/m³) in October and $PM_{2.5}$ (40 µg/m³) in December was observed at Karachi steel (IE-6), I-10 Markaz Islamabad.
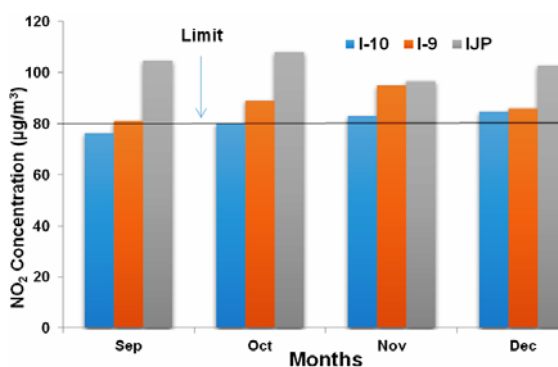


Fig. 1: Monthly Mean values for $NO_2$ at station IEI-Sector I-10, I-9 and IJP.

The concentration of $NO_2$ was found to be highest (100.7 µg/m³) in the month of November at Industrial area (IE-3), Sector I-9/2 Islamabad. On the other hand the concentration of $PM_{2.5}$ was found to be the highest (55 µg/m³) in the month of October at Industrial area (IE-3), Sector I-9/2 Islamabad. The concentration of $PM_{2.5}$ in the month of September as well as in November was below the permissible limit at locations Police line station (IE-1) and near Fazal Industry (IE-2), I-9/4 Islamabad. $PM_{2.5}$ concentration at Police line station (IE-1) I-9/4 was also below the standard limit in the month of December. The concentration of $NO_2$ remains high above the standard value at all location and in all months. Lowest concentration of $NO_2$ (80µg/m³) was found to be in the month of September at Police line station (IE-1), I-9/4 Islamabad.

The monthly mean value of $PM_{2.5}$ was highest at Faizabad (IJP-9) during the month of December and lowest in November at Double road signal (IJP-7), (Fig. 2) On the other hand the four monthly mean concentration of $PM_{2.5}$ was varied from 32.9 µg/m3 at Police line station I-9/4 (IE-1) to 73.2µg/m³ at Karachi steel I-10 Markaz (IE-6) with overall mean concentration of 51.8 µg/ m³.
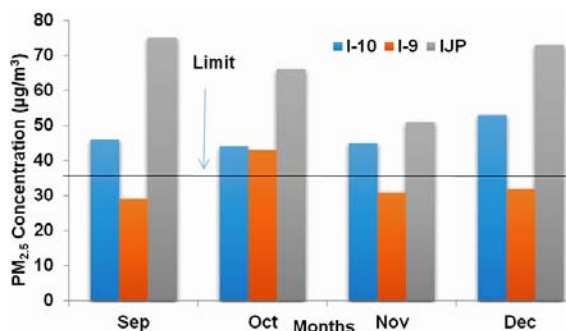
Fig. 2:  Monthly Mean values for $PM_{2.5}$ at station IEI- Sector I-10, I-9 and IJP.

The monthly mean concentrations of $NO_2$ were also above the air standard limit throughout the observational time period at station IJP intersection. The values of $NO_2$ were varied from 82.5μg/m$^3$ at double road ninth avenue signal (IJP-7) to 110.6 μg/m$^3$ at Karachi steel I-10 Markaz (IE-6).

In a same way the four monthly average concentrations were also observed for $NO_2$ and $PM_{2.5}$ at various locations of IJP Intersection by using Ambient Air Quality Monitoring Station (Fig. 3). The mean concentration of $NO_2$ was lowest at IJP-8 (96.62 μg/m$^3$) but above the NAAQS limits (80 μg/m$^3$) and was recorded highest at station IJP-9 (110.6 μg/m$^3$). Four monthly averages concentration of $PM_{2.5}$ was also highest at IJP-8 (73.2 μg/m$^3$) and recorded lowest (64.7 μg/m$^3$ at IJP-7.
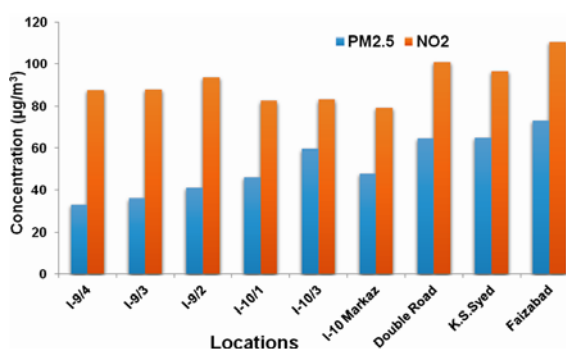


Fig. 3:  Four Monthly Maximum Concentration of $NO_2$ and $PM_{2.5}$ at three locations of I-9, I-10 and IJP.

*Sulfur dioxide (SO$_2$), Ozone (O$_3$) and carbon monoxide (CO) monitoring at different Stations*

The concentrations of $SO_2$, $O_3$ and CO were within permissible limit. The concentration of $SO_2$ (8 μg/m$^3$) was lowest in the month of Oct 2010 at location Fazal Industry I-9 and recorded highest (82.5

μg/m$^3$) in the month of Sep 2010 at location Faizabad of IJP Rawalpindi (Fig. 4). Lowest concentration (67 μg/m$^3$) for $O_3$ was recorded in the month of Oct 2010 at location I-10 Markaz. CO concentration was 1200 μg/m$^3$ in the month of Nov 2010 0 at location Industrial Estate I-9 Islamabad. Highest concentrations for $O_3$ were found to be 177 μg/m$^3$ in the month of Dec-2010 at Faizabad IJP Rawalpindi. Similarly Highest concentration (2600 μg/m$^3$) for CO was found in the month of Dec 2010 at location Police line Station, Industrial Estate I-9 Islamabad (Fig. 5 and 6).
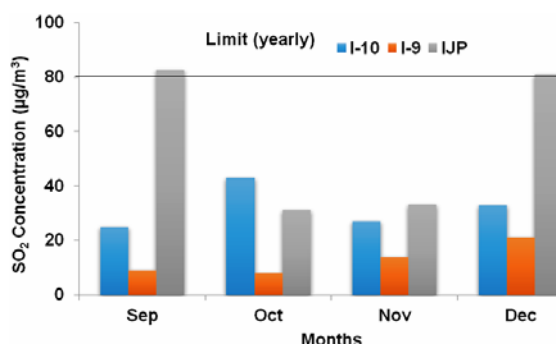


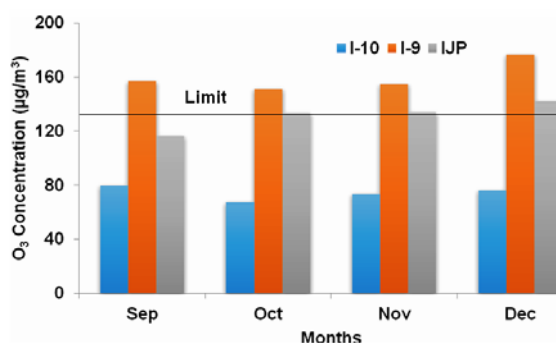Fig. 4:  Monthly Mean values for $SO_2$ at station IEI- Sector I-10, I-9 and IJP.



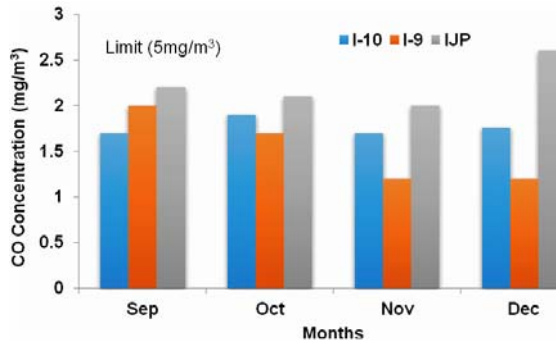Fig. 5:  Monthly Mean values for $O_3$ at station IEI- Sector I-10, I-9 and IJP.



Fig. 6:  Monthly Mean values for CO at station IEI- Sector I-10, I-9 and IJP.

*Dispersion Modeling for Buffer Zone Calculations*

Air pollution linked with local weather condition was made by using automatic ambient air quality monitoring station. The temperature of the monitoring stations was varied from $10^{o}C$ to $27^{o}C$ with an average humidity of 62%. The average wind speed was found to be 4 $ms^{-1}$. No rain fall was observed during the study period except last week of December 2010. Visibility remains low during some observational days, because of light fog at early in the morning and dust particles in the evening. Variation in the solar radiation was observed from minimum value of 75 $wm^{-2}$ in month of December to 169 $Wm^{-2}$ in the month of September with average value of 113 $Wm^{-2}$.

On the basis of these Metrological parameters the atmospheric conditions were remain slightly unstable to neutral throughout the study period. By using micrometeorological parameters and traffic data, buffer zones were calculated for $PM_{2.5}$ and $NO_2$. Buffer zones were calculated on the basis of Passquill Smith dispersion model and using data sets [13]. Mathematical formulation of passquill and smith dispersion model is given in equation 1.

$$C\,(x,z) = [(2Q/L)/\,((2p)^{1/2}\,us_z)]\,exp\,(-z^2/2s^2_z) \quad (Eq.1)$$

Q/L=Emission per unit length of road (mg/second metre)

$s_z$=Gaussian coefficient for vertical dispersion (metre)

u = Mean wind speed (metre/second)

C = concentration of pollutant $(mg/metre^3)$

Using the all required parameters in equation 1, three buffer zones for $NO_2$ and three buffer zones for $PM_{2.5}$ were calculated along IJP Intersection. The concentrations along with the length of buffer zones for $PM_{2.5}$ and $NO_2$ are given in Table-2.

Table-2: Buffer zones for $NO_2$ and $PM_{2.5}$.

| Buffer zone length (m) | $NO_2$ Concentration $(mg/m^3)$ | $PM_{2.5}$ Concentration $(mg/m^3)$ |
|---|---|---|
| 0-300 | 90 | - |
| 0-500 | 76 | 75 |
| 0-1000 | 35 | 36 |
| 0-1500 | - | 10 |

It was found that significant numbers of population were affected by air pollution because of road transportation and industry. From the calculation of dispersion model, it was found that the population lying within 0-300m buffer zone along the either side of the IJP road were affected by highest concentration (90 $\mu g/m^3$) of $NO_2$ (Fig. 7). This concentration was reduced to 76 $\mu g/m^3$ from 300-500 meters along the either sides of IJP Intersection. In this buffer zone the concentration is slightly less than the National Air Quality Standard (NAQS) limits but still creating major threats for surrounding populations. However $NO_2$ concentration signify-cantly reduces (36 $\mu g/m^3$) from 500-1000 meters length of the buffer zone. On the other hand the first buffer zone for $PM_{2.5}$ was considered from 0-500m along the either sides of IJP Intersection. The concentration in this buffer zone was calculated as 75 $\mu g/m^3$ which is above the NAAQS permissible limit (Fig. 8). In the range of 500-1000m, $PM_{2.5}$ concentration was reduced to 36$\mu g/m^3$. Significant amount of $PM_{2.5}$ was reduced from 1000-1500 meters buffer zone. The maximum intensity of air pollution was recorded at IJP intersection signal that linked with double road and $9^{th}$ avenue Islamabad. This was because of peak rush hours, i.e. 12 pm to 3 pm. The high intensity pollution was also recorded across the I-9 industrial estate Islamabad. Main reason of high intensity pollution across these locations is the industrial area and it's surrounded highly congested traffic roads. Two roads were remains a major concern in this study, first one is the service road north (IE-5) that linked with the commercial and populated areas of I-9 and I-10. The second one is the IJP Intersection of Rawalpindi that linked with $9^{th}$ avenue of Islamabad. Consequently, industry and heavy traffic congestion contribute high level of air pollution across the industrial estate and its surrounding areas.

**Experimental**

The Horiba Automatic Ambient Air Quality Mobile Station (HA3QMS) was used in this study. HA3QMS has advanced technology, field proven reliability with excellent sensitivity and precise measurement in units of part per billion (ppb). HA3QMS consist of different air quality monitors each of which differs in its operation, principle, measured single and multiple components in ambient air or diluted stack gases. Sampling systems are designed and built to meet precisely the high demands of International ambient air quality standards. All parts in contact with the sampled air are made out of boro-silicate glass. Meteorological sensors are fitted above the HA3QMS that measure continuously the temperature, relative humidity, wind direction and wind speed.
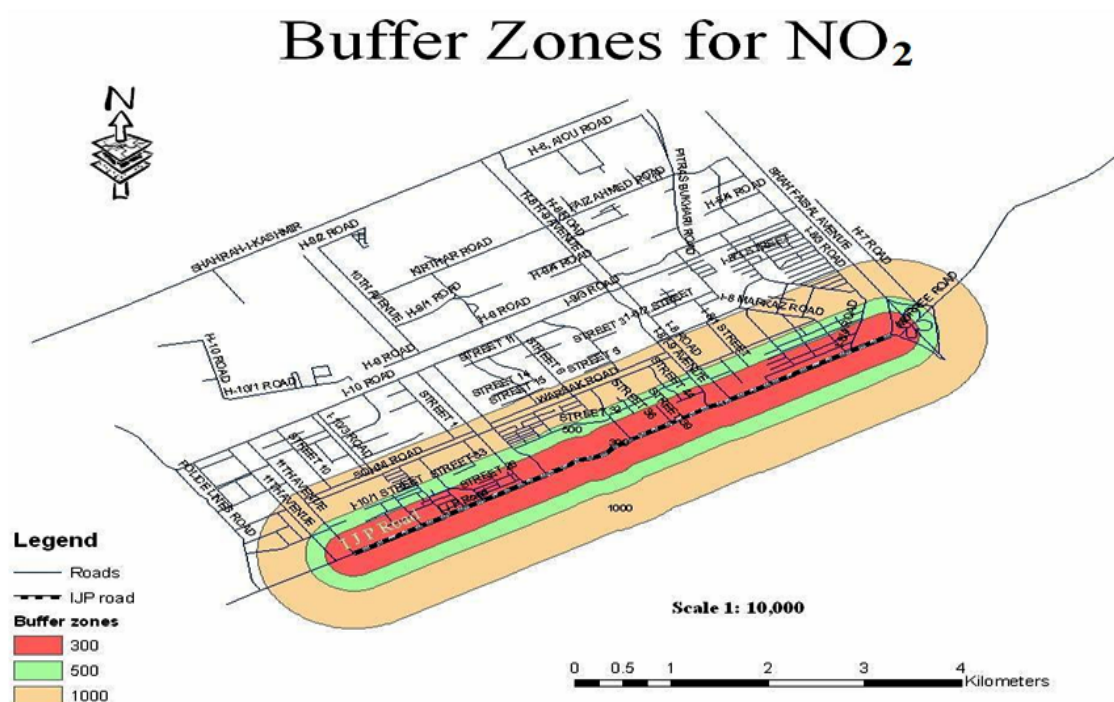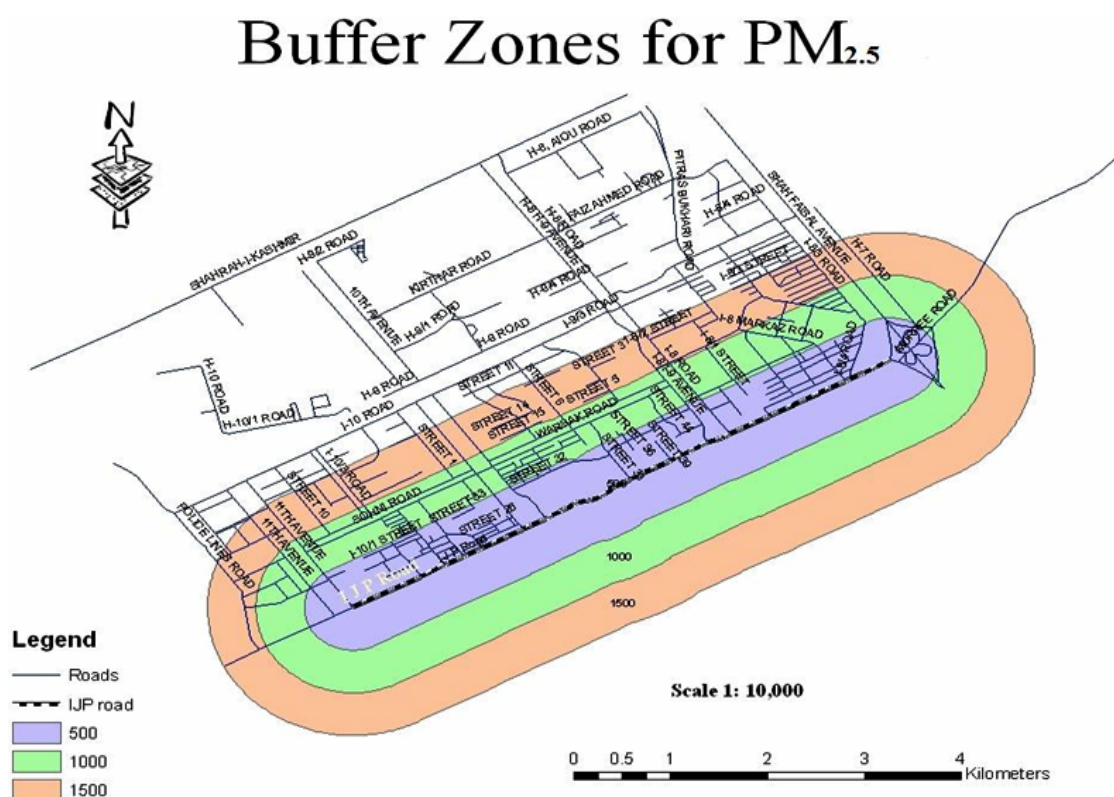
Figure 7 Buffer Zone of $NO_2$.



Fig. 8:   Buffer Zone of $PM_{2.5}$.

*Study Area*

Islamabad is located at latitudes 33° 49' north and longitudes 72° 24' east with altitudes ranging from 457 to 610 meters. The population of the Islamabad city is around 950,000 people with an area of about 910 square kilometers. Islamabad has sub-humid and sub-tropical climatic conditions. The summer is hot with monsoon rains occurring during August. In the coldest month, January, the average daily maximum temperature is 16°C. Three man-made lakes Rawal, Simli and Khanpur regulate the micro climate of Islamabad. The average humidity level of Islamabad is 55% with an average rainfall of 1150 millimeters each year. Rawalpindi is the twin city of Islamabad, located 16 km south of Federal Capital and situated at 33 37' in the north latitude and 73 6' in the east longitude with a height of 500 meters above mean sea level. Just like Islamabad, the climate of Rawalpindi is also sub-tropical and sub-humid. It receives rainfall from both monsoon and winds from the western direction. The maximum rainfall occurs in monsoon season from July to September.

The major concern of Islamabad city is the Industrial estate that includes sector I-9 and I-10. Industrial estate Islamabad is spread over 625 acres of land on the border of cities of Rawalpindi and Islamabad. There are 487 total plots and 260 industrial units in sector I-9. On the other sector I-10 has total plots 269 and 215 total industrial units. These industrial units include flour mills, pharmaceuticals, steel furnace, steel re-rolling, marble industries, automobile workshops, steel fabrications, dall mills, soap industries, leather garments, food packing industries and woolen mills. Ambient air over the industrial estate Islamabad is overburdened due to air pollution which is a major threat to the residents of industrial estate. On the other hand Rawalpindi is also in the grip of serious air pollution problems because of heavy transportation load across the major arterial roads. Unbalanced and rapid urbanization has enhanced the potential negative impacts of transportation. The alarming situation is the vehicle growth rate in Rawalpindi city, i.e. 3.4% per year [14]. This increase in vehicle population in turn results in traffic congestion which leads to highest emission rates per vehicle. Despite the introduction of more severe emission policy, national inventories show that emissions of traffic-related pollutants persist to increase. Inter Junction Principle (IJP) is adjoining road between Rawalpindi and Islamabad was considered in this study because of heavily traffic flow. The net traffic flow across the IJP road is 356,416 vehicles per day [15].

*Sampling Sites and Data Collection*

For sampling and analysis nine ambient air quality monitoring stations were selected in the area I-9, I-10 Industrial Estate (IE) Islamabad and IJP road of Rawalpindi. These areas include, Police station I-9/4, Fazal Industry I-9/3, Industrial area I-9/2, CDA Colony I-10/1, Service Road North I-10/3, Near Karachi Steel I-10 Markaz, Double Road at 9th Avenue Signal, Khayaban-e-Sir Syed and Faizabad. The details of monitoring stations are given in Table-3. The samples were collected with collaboration of Central Laboratory for Environmental Analysis and Networking (CLEAN) Islamabad, which is a part of Environmental Protection Agency Pakistan (EPA-PAK). The total duration of sampling time was four month from September 2010 to December 2010.The sampling time was 24 hours per day. The concentration of different air pollutants were collected on the basis of their standard time period as prescribed by EPA-PAK. Monthly and four monthly mean values for each pollutant was determined and then compared with permissible limits draft of EPA-PAK. The average standard time for SPM, $NO_2$ and $SO_2$ is 24 hours. The average standard time for CO and $O_3$ is 8 and 1 hour respectively (Table-1).

Table-3: Locations of Ambient air monitoring stations.

| Ambient air quality monitoring station | Location | Monitoring station no. | Height from ground level (m) |
|---|---|---|---|
| Industrial area Police station I-9/4 | Industrial estate I-9 | IE-1 | 10 |
| Fazal Industry I-9/3 | Industrial estate I-9 | IE-2 | 10 |
| Industrial area I-9/2 | Industrial estate I-9 | IE-3 | 10 |
| CDA Colony I-10/1 | Industrial estate I-10 | IE-4 | 10 |
| Service Road NorthI-10/3 | Industrial estate I-10 | IE-5 | 10 |
| Near Karachi Steel I-10 Markaz | Industrial estate I-10 | IE-6 | 10 |
| Double Road at 9th Avenue Signal | Main Inter Junction Principle Road | IJP-7 | 10 |
| Khayaban-e-Sir Syed | Main Inter Junction Principle Road | IJP-8 | 10 |
| Faizabad | Main Inter Junction Principle Road | IJP-9 | 10 |

The guide map of Rawalpindi/Islamabad city on 1: 10,000 scale surveyed in 2002 was used for preparing the base maps. The maps were then digitized and incorporated within GIS domain for creating thematic layers like land use, road network and to calculate the automobile pollution load. Data was collected with the help of Automatic Ambient Air Quality Monitoring Station for five major pollutants. These pollutants includes Sulfur Dioxide ($SO_2$), Nitrogen Dioxide ($NO_2$), Carbon Monoxide (CO), Ozone ($O_3$) and Particulate Matter ($PM_{2.5}$). Data collection times for all pollutants were taken according to EPA-PAK standards as give in Table 1 [16]. Total duration for data collection was four month. At least four days continuously data was collected at different locations once in a month. Average mean values on monthly and four monthly bases were taken by considering the standard time period for each pollutant.

**Conclusion**

This study shows that the pollution level due to $NO_2$ and $PM_{2.5}$ across IJP road Rawalpindi and Industrial Estate Islamabad was found to be highest. According to the study traffic report 2009, by transportation department CDA Islamabad, the net traffic flow across Inters Junction Principle road is 247447 vehicles per day. This flow contributes to high level of air pollution and has been reflected in the present study. There is dire need for an alternative route for public transport, specifically for heavy transport like buses, and trucks. Results concluded from this study indicate that the air pollution because of the Industrial Estate Islamabad was also reaching at alarming level. Population of industrial estate is at most risk, which surrounded by 475 total industrial units. The observations shows that the $PM_{2.5}$ level at Industrial Estate I-10 and IJP road has reached the critical level (>35 $\mu g/m^3$) whereas at Industrial Estate I-9 it was moderate to high level (31.9$\mu g/m^3$ to 41.1$\mu g/m^3$). The concentration of $NO_2$ at location I-9 Industrial Estate was normal value 87.5 $\mu g/m^3$ to a critical value of 93.5 $\mu g/m^3$. On the basis of observational data it was also concluded that the concentrations of $NO_2$ at sampling sites IJP road and Industrial Estate I-10 were also reached the threatening level. The buffer zones calculation indicates that population in the surroundings of these locations are at most risk in regard of health aspects.

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