VEHICULAR EMISSIONS AND AMBIENT AIR QUALITY ALONG ROAD SIDE IN RAHIM YAR KHAN, PAKISTAN

N. Naz, F. H. Nasim and M. Ashraf

Chemistry Department, TheIslamia University of Bahawalpur, Bahawalpur – 63000, Pakistan.
Corresponding author's e-mail: faiz.nasim@hotmail.com

ABSTRACT: The present study aimed to monitor the ambient air quality along the main road to assess risk factors to which various living and non-living things are exposed in Rahim Yar Khan, an industrial town of Southern Punjab, Pakistan.LaMotte air sampling pump was used to monitor SO_2, NO_2 and total oxidants concentration. GasAlert™Extreme Single-Gas Detectors were used to monitorpersonal exposure of CO, O_2 and Cl_2, whereas, Mini-Vol SPM sampler was used to sample PM_{10}. Monitoring was done three times a day to assess the short-term exposure and five times a year to analyze the effect of seasonal shifts. Highest concentration of CO, SO_2, NO_2, total oxidants and PM_{10} was observed in summer season. Lowest pollution level was observed in winter season. Bus station and residential areas were the most polluted sites, whereas vegetative area was found to be the least polluted.The results indicated that vehicular movement played an important role in a gradual increase of air pollutants from morning to evening.

Keywords: Ambient air quality, vehicular emissions, Rahim Yar Khan, Air pollution .

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INTRODUCTION

The term air pollution refers to the presence of damaging substances in the air beyond the permissible limit. These life damaging substances or air pollutants cause a serious threat to human and plants life, man-made structures and environment. In urban areas the effect of these pollutants are more threatening due to large emissions by increased economic activities and poor dispersion characteristicsowing to large buildings and dense population(Kanyoke, 2004).The ambient air concentration of vehicular pollutants varies from region to region. It largely depends upon the number of vehicles, distance covered by each category of vehicles and technologies used to control emissions of in-use vehicles. Vehicular emissions are more harmful than industrial emission due tothe release at lower height along the road sides and surrounding buildings poorly support their dispersion(Safai *et.al.,* 2004). The shopkeepers, drivers, conductors, pedestrians, passengers, local residents and traffic policeman are therefore posed to increased health risk by vehicular emissions(Glovsky *et. al.,* 1997).

Vehicle age, speed and fuel type has prominent effect on vehicle emission. Therefore, old vehicles need proper maintenance and technical control to reduce vehicular emissions(Alkama *et. al.,* 2006).

Vehicular emissions may cause numerous health problems in human beings. The particulate matter (PM) consists of solid materials like dirt, soot, dust, smoke and liquid droplets. PM with other pollutants cause respiratory problems, carcinogenesis and premature deaths. The effects are more severe in persons suffering from cardiovascular diseases. Nitrogen oxide irritates lungs and impairs immune system. Oxides of nitrogen are precursors of acid rain that causes damage to aquatic and terrestrial life(Walsh, 2000). The airborne Fluorides act as bio-indicator by visible changes of plant foliage and as bio-monitor for some grasses in the form of biochemical, physiological or genetic changes(Weinstein and Davison, 2003).

Monitoring of air quality in relation to direct or indirect sources of emissions is an emerging issue all over the world. In Pakistan few studies have been conducted on vehicular emissions and air pollution in big cities including Lahore, Karachi, Peshawar and Quetta. The present study was conducted to investigate air pollution levels along the roadside in Rahim Yar Khan(RYK), a relatively small industrial town in the southern part of the Punjab province of Pakistan.

MATERIALS AND METHODS

Selection of sampling sites: Seven sampling sites covering an area of about 20 km, were selected along the main road of RYK city (Fig. 1) to monitor air quality. The sites included were:

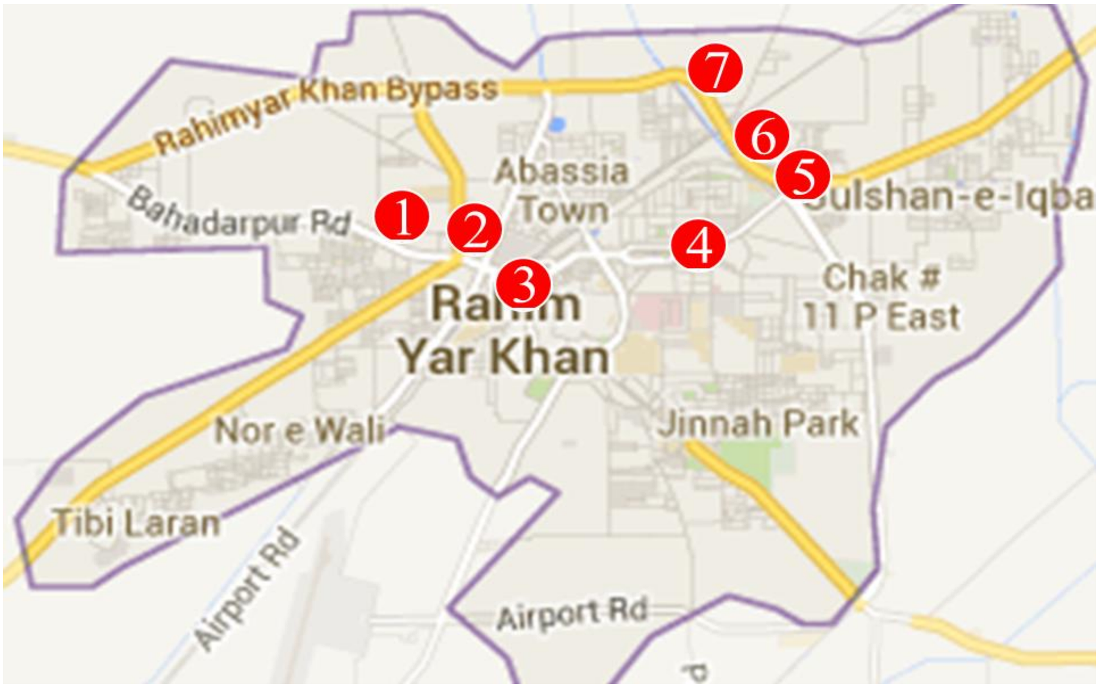

Fig 1.Road Map of Rahim YarKhan City.

1. **Industrial Area (IA):** Having heavy industries and small industries along a busy road crossing with all sorts of traffic.
2. **Railway Station (RS):** Selection was based upon the areacrowded by motorcycles, cars, LPG / CNG Rickshaws, Suzuki vans, pickups and carts. The sampling was done at the central point of road and railway station.
3. **The Market Area (MA):** Overcrowded area with large number of cars, rickshaws and motorcycles. The main market crossing with buildings all around was selected as the sampling point.
4. **Residential Area (RA):** The road at residential area having thick plantation on both sides overcrowded by auto-rickshaws and personnel vehicles was selected.
5. **Bus Station (BS):** The busiest spot of the city with large number of heavy buses and mini coaches all the time, open area around the canal filled with solid waste, garbage, spoiled fruits and food trashed by hawker'svendors and shop keepers was selected as sampling point.
6. **CNG Stations (CN):** The road with two CNG Stations side by side having shops on both sides and all type of traffic was selected.
7. **Vegetative Area (VA):** Vegetative area selected was approximately 10 km away from the main city with cultivated crops along the roadside. No houses were built at about 1km along the road at sampling point, where all types of vehicles were moving on the road.

Monitoring Schedule and Experimental Frequency: Ambient air quality was monitored for five times in a year starting from April 2011 to March 2012, to observe seasonal variations including Summer (April, May), Rainy/monsoon (August), Autumn (October), Winter (January) and Spring (March). At each site ambient air parameters were analysed three times in a day for three consecutive days, i.e. morning (M) 07:00 to 08:00 AM, afternoon (N), 01:00 to 02:00 PM and evening (E), 06:00 to 07:00 PM.

Scope of study and data limitations: The scope of the present research was collection of the baseline air pollution data for comparison with National Environmental Quality Standards (NEQS) to assess the air pollution level along the road side at various sampling sites.The ambient air quality of each site was monitored for seven parameters including PM_{10},O_2, CO, Cl_2, NO_2, SO_2 and total oxidants.The meteorological parameters included temperature, Relative Humidity and wind speed. Guidelines of US-EPA method 40 CFR part 58 were utilized for the selection of siting criteria and surrounding environment at each sampling site(US-EPA 1998).

1. **SO_2, NO_2 and Total oxidants**: The SO_2, NO_2 and total oxidantswere monitored at each site by LaMotte air sampling pump (Model BD-Code 1949, USA) utilizing impingent method, where, the sampling manual was followed for sampling time and analysis. The SO_2, NO_2 and total oxidants concentration was reported as µg/m^{3}by (Akama*et. al.*, 2009).

2. **CO, O_2, Cl_2:** The CO, O_2 and Cl_2 were measured using GasAlert™ Extreme Single-Gas Detector (GAXT-M-DL, Canada). For each parameter the measurements were recorded for 1 hr. at 5 minutes interval and the average values were recorded to check the air quality.

3. **Particulate Matter:** A portable Mini-Vol SPM sampler (Sr. # 4126, Mini-Vol, USA) was used to measure respirable Particulate Matter of aerodynamic size 10 µm (PM_{10}). At each spot PM_{10} sampling was done for 8 hrs.in the day time.

   All equipments used for ambient air analysis in the current study was properly calibrated before use.

4. **Motor vehicular load:** The **m**otor vehicles were counted physically for 15 minutes for three consecutive days. The average value wasobserved as vehicular load/15 min, at a given sampling site.

5. **Meteorological data:** During air pollution monitoring in the present study meteorological data was obtained from local Meteorological office at RYK City.

Statistical Analysis: The observed data was analysed statistically using SPSS 20 software. One-way ANOVA followed by LSD test was applied for comparison to calculate significance of variance ($p \leq 0.05$)among sampling time, sampling sites and seasons. The bivariate Pearson correlation r was highly significant at 0.01 and significant at 0.05 (2-tailed)used for various parameters.

RESULTS AND DISCUSSION

Significant variation in monitored air pollutants was observed at various sampling sites along the road. One-way ANOVA comparison showed that the mean difference of vehicular load, CO and total oxidants was highly significant (p 0.000) at different sampling sites. The ambient air O_2 and PM_{10} level varied significantly (p 0.011, 0.004, respectively) at different sampling sites(Table 2). However, the mean difference of SO_2 and NO_2 was non-significant at different sampling sites. It was noted that bus stop and residential area with wide-ranging human activities were most polluted sites whereas, VA was the least polluted site. Cl_2 gas was not detected at any site. In a similar study at Dar-es-Salaam City, Tanzania, elevated level of NO_2, CO and suspended particulate matter were reported at residential areas in the morning and evening time due to increased traffic flow and substantial domestic heating, where activities pattern and emission from mobile sources confirmed the elevated level of air pollutants at residential area(Jackson, 2009).

Table 1.Comparison of monitored data with National Ambient Air Quality Standards (NAAQS).

Pollutants	Time-weighted Average	Ambient air NAAQS	Monitored Air Pollutants Level	Sites with Highest Pollutants level	Sites with Lowest Pollutants level
Sulphur dioxide(SO_2)	24 hours	120 µg/m^3	0 – 78.52 µg/m^3	BS, RS, RA, MA	VA
Oxides of Nitrogen(NO_2)	24 hours	80 µg/m^3	0 – 263.4 µg/m^3	BS	VA
Respirable Particulate matter (PM_{10})	24 hours	150 µg/m^3	148 – 439 µg/m^3	BS, RA	VA
Carbon monoxide(CO)	1 hour	10 mg/m^3	0 – 18.15 mg/m^3	BS, RA	VA

Note:BS: Bus Station, RS: Railway Station, RA: Residential Area, MA: Market Area, VA: Vegetative Area

Table 2: One-way analysis of variance (ANOVA) comparison of air pollutants.

Dependent variable	Comparison by Sampling sites Sig. ($p \leq 0.05$)	Comparison by Sampling time Sig. ($p \leq 0.05$)	Comparison by Seasons Sig. ($p \leq 0.05$)
Vehicular load	0.000*	0.183	0.003*
CO mg/m^3	0.000*	0.093	0.130
O_2 %	0.011*	0.018*	0.041*
SO_2 µg/m^3	0.089	0.000*	0.226
NO_2 µg/m^3	0.089	0.235	0.181
Total oxidants ppm	0.000*	0.108	0.038*
PM_{10} µg/m^3	0.004*	NA*	0.000*

Note: NA*: Not Applicable

Anthropogenic factors and ambient air quality: Anthropogenic factors like vehicular exhausts, gaseous emissions, construction of buildings, industrial development, urbanization, and development in science and technology have immensely affected the natural environment(Kan *et. al.,* 2012). In a study at Jahra city, Kuwait where,multivariate statistical analysis was carried out for eight yearsdata of ambient air quality variables, i.eSO_2, non-methane hydrocarbon, NM-HC, CH_4, NO_x; (as nitric oxide, NO and nitrogen dioxide, NO_2), CO, O_3, PM_{10}, CO_2 and four meteorological parameters; wind speed, wind direction, ambient temperature and solar intensity. Box plots revealed that O_3, PM_{10}, NO, SO_2 and CO had significant seasonal pattern and contribution of anthropogenic sources i.etraffic, power plants and water desalination plants prevailed, particularly during winter were reported by (Al-Anzi*et. al.,*2016) showing similarity with the results of the present study. Monitoring of air pollutant's concentration, exposure time and frequency of exposure helped to estimate the health effects and in turn formulation of policies to reduce or control the air pollution. In present study results indicated modest ambient air quality at sampling sites with acute human activities indicatingthe contribution of human activities, vehicular emissions, topographic and anthropogenic factors towards air pollution at different sampling sites of RYK city. The air quality was comparatively acceptable at VA with least intrusion of anthropogenic factors.

A similar study carried out along the National Highway N-5 in Pakistan, revealed the alarming situation of PM_{10}, CO, SO_2 and NO_2 at sites with increased vehicular load(Ali and Athar, 2008). In nine selected sites of Caliber, Nigeria, five parameters CO, NO_2, PM_{10}, SO_2, and noise level were analyzed for vehicular emissions. A high PM_{10} concentration was observed at all sites depending on vehicular load and meteorological conditions especially wind speed and wind direction. The study revealed a frightening situation of air pollutants at traffic intersection, pointing towards vehicular emissions as dominant source of air pollution reported by(Abam, 2009). In another study from Pakistan air quality was estimated at ten busy road crossings of Peshawar city, the monitored air pollutants included CO, NO_x, SO_2 and HCs. The results indicated that automobile exhaust from cars, buses, trucks and auto rickshaw were declining the ambient air to survive. At most of the studied sites in Peshawar the ambient air pollutants level was exceeding the National Ambient Air Quality Standards(NAAQS). The ambient CO concentration was in the range of 9 – 24 ppm at the ten sampling sites. The NO_x level was in the range of 1.70 – 3.50 ppm whereas SO_2 was detected at general bus stand only. It was observed that ambient air pollutants level was high at the sampling sites with dense traffic and narrow roads surrounded by multi-story buildings. The engine age, fuel quality and combustion of solid waste were found to be minor contributors of ambient air pollution (Khan *et. al.,* 2008). The study of ambient air pollution in China indicated adverse respiratory effects including cough and phlegm in school going children due to long term exposure to PM_{10} and NO_2 concentration. The adverse health effects of PM_{10} also included asthma showing respiratory symptoms and lungs cancer(Gao*et. al.*, 2014).

Temporal variation of ambient air pollutants: During the present study a large temporal variation of CO, SO_2, NO_2 and total oxidants was observed in all sampling seasons. Statistical analysis of M, N and E data revealed that the mean difference of vehicular load, CO, NO_2 and total oxidants was non-significant (p 0.183, 0.093, 0.235 & 0.108, respectively) during different sampling times (Table 2), showing no detectable difference in vehicular load, CO, NO_2 and total oxidants during M, N and E sampling times. The mean difference of O_2 and SO_2 was highly significant (p 0.018, 0.000, respectively) in different sampling times. In comparing M and N sampling times, the mean difference of O_2, SO_2 and total oxidants was highly significant (p 0.006, 0.000, 0.042, respectively) due to the change in concentration of analyzed parameters. Analysis of variance (ANOVA) indicated the accretion of CO level in air from morning to evening by various anthropogenic factors with significant value of p 0.034.

Results of present study revealed that short-term exposure of CO and NO_2 was sometimes exceeding the NAAQS permissible limits (Table 1). This indicated the progressive addition of tested pollutants to the environment, which resulted in adverse effects through long-term exposure. Although the SO_2 level was within the upper boundary of permissible limit, its incidence frequency was greater than any other tested parameter. Major sources of SO_2 emissions were burning of fuels, industrial emissions and vehicular exhaust.

In a study ambient air pollution level of air borne dust, CO, SO_2 and NO_2 was monitored in Lahore city, Pakistan at 23 road crossings. An increased level of these pollutants at various sampling sites indicated an alarming situation which needed decisive measures to control the vehicular emissions(Jafary and Faridi, 2006) showing similarity with the present study.

Seasonal change and variation of air pollutants: The seasonal variations not only marked the human activities but also inflicted some change in transport and deposition of air pollutants. The ambient air analysis data of the present study revealed that the vehicular load, O_2, total oxidants and PM_{10} concentration varied significantly (p 0.003, 0.041, 0.038, 0.000, respectively) with season. The mean difference of CO, SO_2 and NO_2 was non-significant (p 0.130, 0.226, 0.181, respectively) (Table 2). Increased level of ambient air CO, SO_2, NO_2 and total oxidants was noted in summer and autumn seasons whereasambient air CO level washigh in spring season. Moderate concentration of NO_2 and total oxidants was detected in rainy season. Highest vehicular load was counted in rainy season followed by summer and autumn seasons. The lowest monitored ambient air pollutants level was observed in winter season followed by the spring season. PM_{10} concentration was highest in summer season with total average of 300±79.72 μg/m^3. The lowest average (206.7 ± 41.01 μg/m^3) of PM_{10} suspension was noted in winter season. In present study the higher level of ambient air pollutants in summer may be due to increased temperature and reduced humidity, which may upturn vehicular exhaust emissions. The dry atmosphere in summer also promoted dust suspension from vehicular movement leading to increased level of PM_{10} concentration. These results are supported by another study carried out in Lahore, Pakistan, where the suspended particulate matter was monitored by free fall method at 50, 100 and 200 m distance away from the road. It was reported that dust concentration decreased as the distance from road increased indicating contribution of vehicular exhaust as the major source of suspended particulate matter(Ahmad and Usman, 2006). Yet in another study in USA, emission factors of PM_{10} and $PM_{2.5}$ from in use vehicles were examined. The results indicated that re-suspended road dust and vehicles tail pipe emissions were dominating factors for PM_{10} and $PM_{2.5}$ emission(Abu-Allaban *et. al.*, 2003). Regarding seasonal variability, results of present study were contradictory to a similar study at Basra city, Iraq, where the maximum level of CO, CO_2, SO_2, NO_2 and HCs was observed in winter season then in summer season(Douabul*et. al.*, 2013). The seasonal fluctuation of ambient air pollution indicated a significant contribution of meteorological conditions in dispersion and dilution of ambient air pollutants. In Tirupati city, India, maximum level of NO_x, SO_2, and CO was observed in summer than in winter. The warm and dry wind contributed to the loss of moisture and increased in pollutant's level. It was also reported that there exists a significant correlation between pollutants and meteorological parameters like wind velocity, rain fall, temperature and relative humidity(Vanadeep and Krishnaiah, 2011). However, Bridgman had reported that there may be no correlation between pollutants and meteorological parameters suggesting that these correlations values were site specific(Bridgman *et. al.*, 2002).

The Fig. 2 and Fig. 3 depicted variations in CO and SO_2 concentrations at different sampling sites in summer and winter seasons.

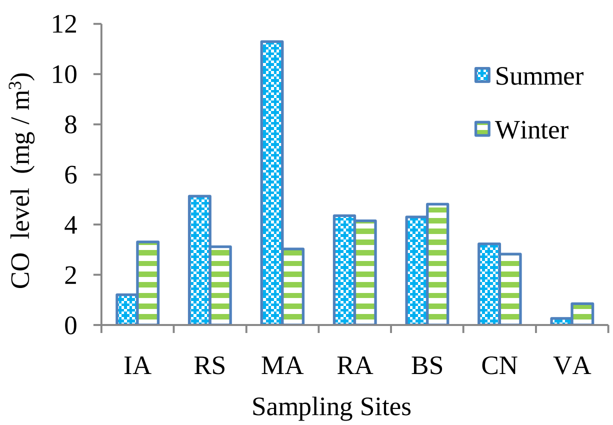

Figure 2: CO level of Sampling sites in summer and winter season

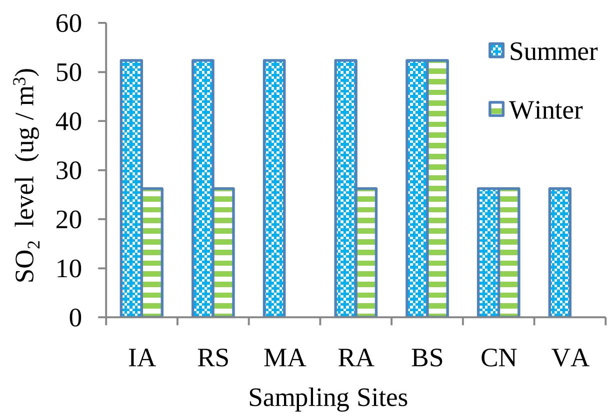

Figure 3: SO_2 level of Sampling sites in summer and winter season

Correlation of Vehicular load, meteorological parameters and ambient air pollutants: In the present study the ambient air pollutantsi.e CO, SO_2, NO_2, total oxidants and PM_{10} showed highly significant (P 0.000) positive correlation (r 0.460, 0.429, 0.478, 0.417 & 0.423, respectively) with vehicular load and insignificant at (p 0.121) with negative correlation (r, -0.152) with ambient air O_2 level (Table 3).

In meteorological parameters RH showed a negative correlation with air pollutants level whereas temperature showed positive correlation with tested parameters. The ambient air SO_2, NO_2 and PM_{10}concentration showed insignificant positive correlation (r 0.159, 0.040, 0.177, respectively) with wind speed. In the present study positive correlation of temperature with ambient air pollutants indicated the influence of temperature to increase vehicular exhaust. It was reported that absence of rainfall promoted a surge in temperature, thereby lacking cleaning action of atmosphere. This facilitated the agglomeration of air pollutant in summer season (Vanadeep and Krishnaiah, 2011). The negative correlation of RH with tested parameters supported the fact that RH suppressed the dispersion and dilution of ambient air pollutants (Jayamurugan *et. al.*, 2013).

Table 3:Correlation of Ambient air pollutants with vehicular load and Meteorological Data.

Parameter	Analysis	CO mg/m^3	O_2 %	SO_2 $\mu g/m^3$	NO_2 $\mu g/m^3$	Total Oxidants (ppm)	PM_{10} $\mu g/m^3$
Vehicular load	Pearson Correlation	0.460**	-0.152	0.429**	0.478**	0.417**	0.423**
	Sig. levelp ≤ 0.01	0.000	0.121	0.000	0.000	0.000	0.000
Wind Speed (KTS)	Pearson Correlation	-0.030	0.061	0.159	0.040	-0.012	0.177
	Sig. levelp ≤ 0.01	0.759	0.536	0.105	0.687	0.906	0.070
Temp. (^oC)	Pearson Correlation	0.255**	-0.044	0.348**	0.221*	0.212*	0.455**
	Sig. levelp ≤ 0.01	0.009	0.657	0.000	0.023	0.030	0.000
RH (%)	Pearson Correlation	-0.318**	0.198*	-0.379**	-0.217*	-0.240*	-0.165
	Sig. levelp ≤ 0.01	0.001	0.043	0.000	0.026	0.014	0.093

** Correlation is significant at 0.01 level (2-tailed)

* Correlation is significant at 0.05 level (2-tailed).

Permissible NAAQS and AQI: In present study the increased level of air pollution was noted at sampling sites with intense human socio-economic activities and comparatively high vehicular load. To relate monitored data with public health impacts the complex air pollution monitoring data was compared with UK limits of Air Quality Index (AQI). The CO concentration level of present study ranged from “Low to High” category, NO_2, SO_2 levels ranged in “Low” category and PM_{10} fell in “Very High” category of air quality indices (Table 4).

Table 4.Concentration break points of air pollutants and categories of AQI.

Categories	AQI Indices*	CO (mg/m^3)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
		8-hour avg.	1-hr avg.	15-min. avg.	24-hr avg.
Low	1 - 3	0 - 11.5	0 - 286	0 – 265	0 - 64
Moderate	4 - 6	11.6 - 17.3	287 - 572	266 – 531	65 - 96
High	7 - 9	17.4 - 23.1	573 - 763	532 – 1063	97 - 129
Very High	10	≥ 23.2	≥ 764	≥ 1064	≥ 130

**Source;*(Ayres 2011)

Table 5.Description of health risk for sensitive individuals by UK AQI Indices.

Categories	AQI Indices	Health Description
Low	1 - 3	The air pollutants effects are hardly noticed even by sensitive person.
Moderate	4 - 6	Only sensitive people may feel mild health effects.
High	7 - 9	The sensitive people are imperilled to severe health effects. For asthmatic persons the reliever inhalant will have adverse effects in such air. Precautionary measures are necessary and outdoor activities should be restricted.
Very High	10	The adverse health effects of ambient air pollution are more serious for sensitive as well as general public.

Source; (Ayres, 2011)

The AQI comparison suggested that PM_{10} concentration was touching the hazardous limit and it was a major challenge to public health. The AQI “Low” category indicated safe side of pollution level and any health effect was hardly observed, whereas the “Moderate level” of AQI indicated a diminutive effect for sensitive individuals (Table 5). The significant and worst health effects were determinant for “High” and “Very High” AQI levels, respectively where such situation required proper attention and policies to control the exposure duration of sensitive individuals in outdoor polluted areas(Ayres, 2011).Different techniques for monitoring and reporting of time series air quality data for public awareness are in progress. Recently in Chennai, India, geographical information system (GIS) and global positioning system (GPS) having solid state pollution monitoring sensors were utilized to report real-time monitoring data with the help of internet facility. The availability of real-time air quality monitoring data will help the public, government and private organizations to control alarming situation of air pollution by taking in-time decisive measures(Raju *et. al.,* 2012). In the present study as the short term exposure of CO and NO_2 was sometimes exceeding the NAAQS permissible limits, in such a situation if real-time air quality data is available in the locality then health sensitive people may take in-time precautionary measures by staying inside and having less exposure to polluted air. However there is a need for proper interpretation and display of air quality data in the form of maps and AQI colors, so that common persons could easily understand it.

Besides human beings plants and vegetation also encounter adverse effects of increased ambient air pollution. Although the adverse consequences of ambient air pollution on plants life work slowly, the chronic effects may be noticeable after long-term exposure or on seasonal shifts. The ambient air SO_2 and NO_2 monitoring also helped to predict the possibility of soil acidification arising from dry and wet deposition of SO_2, sulfuric acid, NO_2, nitric acid, ammonium ions and acid aerosols(Stevenson *et. al.,* 2000). The research for identification of plants as environmental bio monitors is also going on in Pakistan. In Karachi University, Karachi along the busy road sites the plant *Alastoniascholaris* was found to bea good bio monitor for quantification of aerial Pb and Cd metal than *Cassia siamea* (Shafiq*et. al.,* 2010).

For the validity of monitored data and to present a true picture of ambient air quality at any site, it was necessary to report its spatial and temporal variation pattern. The pollutants emission level also varied in different times of the year not only because of temporal variation of human socio-economic activities but also due to changes in meteorological parameters and weather conditions(WHO, 1999). The present study encounters all themes of said criteria for the validity of results to depict air quality of RYK city.

Conclusion: Various anthropogenic factors are contributing air pollutants; the residential area and sites like bus stand being the most affected.Meteorological parameters such as temperature, wind and rain are involved in transport and dilution of the pollutants affecting their presence in the air. Vehicular emissions are the dominant source of air pollution. The policy makers need to devise mechanisms to control ever increasing air pollution to save humanity and the natural environment.

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