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A Study of Ambient Air Quality Status in Karachi, By Applying Air Quality Index (AQI)

Durdana Rais Hashmi*, Akhtar Shareef and Razia Begum
Centre for Environmental Studies, PCSIR Laboratories Complex, Karachi-75280, Pakistan

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Abstract. Present study was carried out to determine the concentration of ambient air quality in terms of atmospheric trace gases and air born particulate matter (PM_{10}) at 20 different locations on the busy roads in the commercial, residential and industrial areas of Karachi city. Concentrations of trace gases and particulate matter were used to calculate the results in terms of air quality index (AQI). At each selected location the assessment was carried out to estimate the concentrations of trace gases and particulate matter for a period of 8 h during January - November, 2015. Samples were collected at twenty selected locations i.e., Jail Road (R-1), Gulberg chowrangi (R-2), Gulshan-e-Iqbal (R-3), PECHS Society (R-4) and Model Colony (R-5) in residential areas, paramount ground, Landhi (I-1W), Abbott, Landhi (I-2W), Lucky Textile, Landhi (I-3W), Naurus G belt, SITE (I-4E), Siemens G. belt, SITE (I-5E), Manghopir, SITE (I-6E), Singer chowrangi, KIA (I-7W), Chamra chowrangi, KIA (I-8W) and Korangi #2 (I-9W) Port Qasim (1-10) in industrial areas, Hasan Square (C-1), Liaquatabad (C-2), Garden (C-3), Gulistan-e-Johar (C-4) and NIPA chowrangi (C-5) in commercial areas of the city. Results were used to analyse the concentrations of the pollutants for air quality index (AQI). Air quality index is a single number to measure the quality of air with respect to its effects on the human being. Results received from different air quality categories were calculated according to national ambient air quality standard at selected locations, as residential areas Gulshan-e-Iqbal (R-3) and PECHS Society (R-4) found the AQI under good category with respect to the trace gases and moderate for the PM_{10} pollution, having low traffic density, Gulberg chowrangi (R-2) and Model Colony (R-5) presents moderate AQI category for trace gases and PM_{10} with moderate traffic density, whereas Jail Road (R-1) found under moderate pollution category for trace gases and unhealthy level for PM_{10} due to high traffic flow. In industrial areas Singer chowrangi (I-7W), Chamrah chowrangi (I-8W) and Korangi #2 (I-9W) found under moderate pollution AQI values with moderate traffic density, Paramount ground (I-1W), Abbott (I-2W) and Lucky Textile (I-3W) found unhealthy AQI category pollution due to high traffic congestion whereas, Naurus G. belt (I-4E), Siemens G. belt (I-5E) and Manghopir (I-6E) locations are represented by moderate pollution AQI values for trace gases and found under poor pollution level for PM_{10} pollution, may be due to industrial emissions and heavy vehicular emission. In commercial areas as Hasan Square (C-1), Gulistan-e-Johar (C-4) and NIPA (C-5) having moderate AQI pollution level for trace gases and unhealthy PM_{10} level of pollution, may be due to high traffic density, whereas Liaquatabad (C-2) and Garden (C-3) locations found under poor and unhealthy pollution AQI category. These locations are situated in extremely overcrowded commercial areas having very high traffic density and commercial activities.

Keywords: ambient air quality, trace gases, particulate matter, air quality index

Introduction

Air pollution is a global hazards and has immense effects on human health, metrology, climatic changes and ecosystem. In developing countries modernization and industrialization increases the use of fossil fuel in many ways and producing environmental damages especially in rapidly growing megacities. These days air pollution is well-known to be significantly aggravated by infectious atmospheric trace gases, liquid droplets and suspended solid particles (Kaldellis *et al*., 2012). In Pakistan ambient air quality has increasingly deteriorated due to anthropogenic sources like industrialization, unplanned urbanization, rapid growth of population, open burning of waste and vehicular emission due to poor transportation system. Many decade scientist and researchers have provided undeniable data that the emission and deposition of air pollutants damage the life and quality of plants and animals, quality of water, degraded the soil, productivity of forest and hazards for human health. It becomes an important environmental risk factor for cardiopulmonary and cardiovascular diseases. High particulate matter pollution is one of the most important issue in urban cities, not only affects the status of cultural heritages but produce severe health hazards particularly pulmonary disorders because it can

*Author for correspondence: E-mail: drhpak@yahoo.com

penetrate deep into the lungs and cause pulmonary disorder (Pal *et al*., 2014). Besides particulate matter, literature also suggests that there is a strong relationship between higher concentrations of SO_2, NO_2 and CO that may exaggerate several health effects (Faustini *et al*., 2014).

The most common air pollutants in the urban environment are gaseous pollutants as sulphur dioxide (SO_2), nitrogen oxides (NO and NO_2 collectively represented as NOx), carbon monoxide (CO), Ozone (O_3), suspended particulate matter (SPM), methane and non methane hydrocarbons.

Gaseous pollutants mainly effects on human health. These pollutants are responsible for changing the atmospheric chemistry and cause environmental damage. SO_2 and NO_2 produce acids by diverse type of chemical reactions in the environment and deposited on the surface of sea and earth. Increasing concentration of SO_2, NO_2 and CO in the atmosphere are also responsible for global climate change. Several researches pay attention on particulate matter (PM) pollution due to their perilous health hazards, particularly fine particulate matter. A number of epidemiological studies found strong association of inhalable particulate (PM_{10}) and increased risk in mortality and morbidity (Sicard *et al*., 2011; Brook *et al*., 2010).

In the atmospheric air particulate matter pollution it mainly depends on the size of particle as micron and sub-micron particles emitted by anthropogenic activities (industrialization, unplanned urbanization, rapid growth of population, open burning of waste and vehicular emission) and natural sources (plants' photosynthesis, forest fires, volcanic eruptions etc.) (Park and Kim, 2005). Increasing concentration of fine particulate pollution in the atmosphere has become one of the most important issues in urban cities paying attention to the researchers due to its health hazards and cultural heritage (IPCC, 2001). Severe health hazards of particulate pollution include cardiopulmonary diseases.

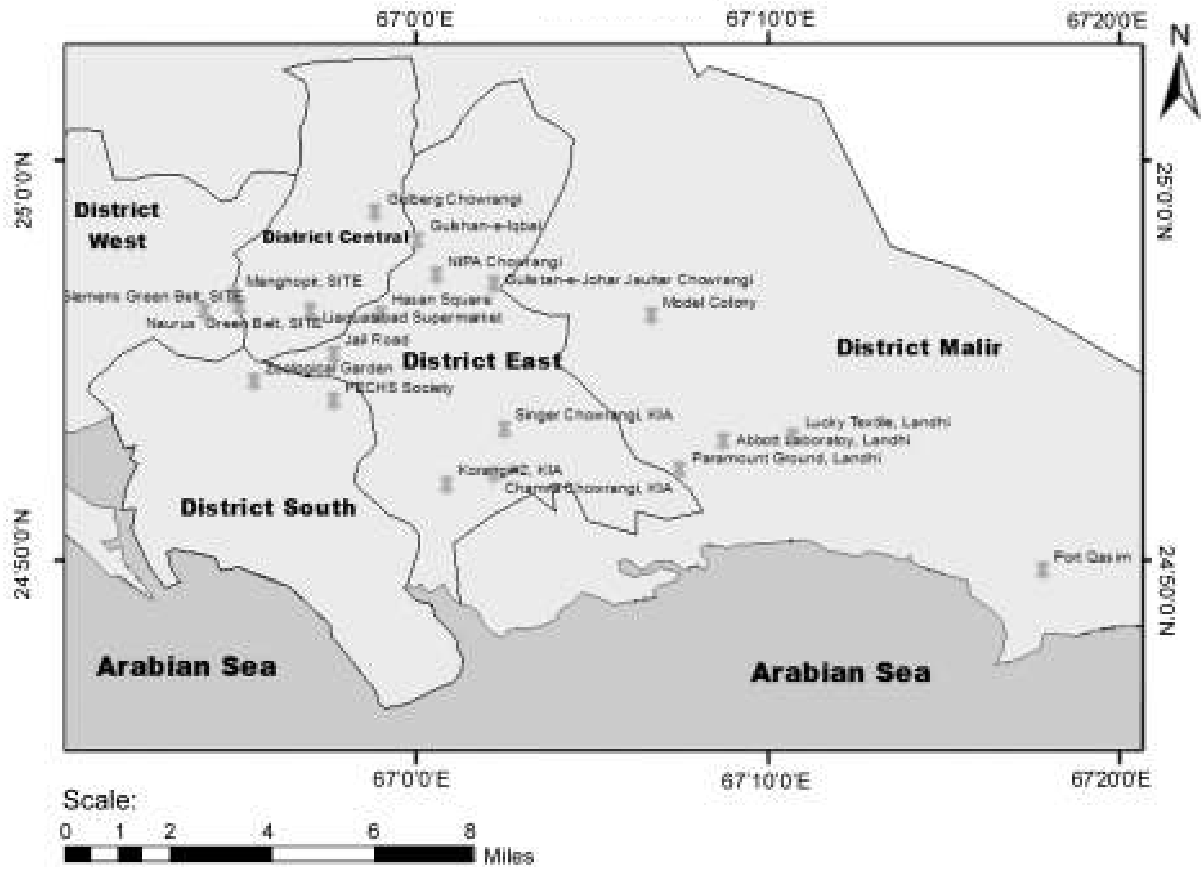
As air pollution is one of the major problems of modern day societies, especially in urban areas. In order to control the intensity of air pollution and to avoid hazardous effects on human being and environment, scientist use mathematical models in order to define the overall status of the air quality in the area under investigation. Air quality index (AQI), a scale to show or characterize the degree of ambient air pollution at a particular monitoring location during a certain moni-toring period (e.g., 1, 8 or 24 h) due to the concentration of human activities that occur in cities. The main aim of AQI calculation is to aware the public about the risk of pollution level day to day and to prepare for precautionary measurement and to regulate the safety measures for health hazards. Generally it is related with the pollutants range and category described as good, moderate, poor or hazardous in order to understand the meaning of AQI easily. In a simple way AQI shows that ambient air is how much polluted and what are the health hazards for the citizens (Kanchan *et al*., 2015). Air quality Index is the number used by the agencies to communicate to the public that how polluted the air is or how polluted it will become ((USEPA, 2014), for an effective ambient air quality monitoring, meteorological data of an area should also be recorded. Some of the similar studies in the field of ambient air quality monitoring and AQI study are reported by Sahoo *et al*. (2017) and Dash and Dash (2015a; 2015b).

United State Environmental Protection Agency (US-EPA) concerning the calculation of AQI for five "criteria pollutants" (CO, SO_2, NO_2, MP and O_3) and set National Ambient Air Quality Standards (NAAQS) in writer for these pollutants against the risk of pollution on human health and environment (USEPA, 2012).

The aim of this study was to determine the level of atmospheric trace gases such as sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and particulate matter (PM) in the environment of Karachi city with reference to air quality index (AQI) for the year of 2015. This AQI study explained the range of air quality and its relation to health hazards to provide awareness in the nation.

Materials and Methods

Study area. Karachi lies between 24°45′N in longitude and 66°37′E in latitude covered 3,640 km² area along the coast of the Arabian Sea. Estimated population of the largest metropolitan city of Pakistan, Karachi was counted over 23.5 million people, reported in 2013 and stand as the 2nd largest city in the world. The climate of Karachi is moderately temperate with a high relative humidity 58% in December (the driest month) to 85% in August (the wettest month). Whereas, the average temperature is about 21 °C in winter and reaches up to 35 °C in summer. The average rain fall amounts to about 256 mm in Karachi (Sajjad *et al*., 2010).



Location Map for study area

Karachi is a sea shore and a busy port encountering both the sea and land breeze periodically. It is congested with a large number of motor vehicles, including both public and private transportation. It has also a well defined industrial base, such as Sindh Industrial Trading Estate (SITE), Korangi industrial area (KIA), Landhi Industrial Trading Estate, Northern by-pass industrial area, Karachi Export Processing Zone, Bin Qasim and North Karachi industrial estate, located in the boundary of the city (Sajjad *et al*., 2010), there are about 20,000 small and large industrial units working in these industrial areas of Karachi city. Main industries are textiles, pharmaceuticals, steel, and auto-mobiles. People migrate from the outlying region due to the abundant employment and business opportunities in the city. Vehicular emission, biomass, burning for cooking and brick kilns and industrial emissions around the Karachi city are the main contributors of atmospheric pollution in Karachi.

Ambient air monitoring. *Sampling*. Sampling was carried out at twenty different locations consisting of main roads, side roads, round abouts, and open places along the busy roads of Karachi from January to November 2015 for gaseous pollutants and PM_{10}. Selected locations were categorized as residential, commercial and industrial areas of the Karachi's environment.

Monitoring of gaseous pollutants were carried out by UV fluorescent SO_2 analyzer model AF22 M, NO-NOx analyzer model, AC 32M and Snifit CO analyzer (Model 50). These analyzers are considered as reliable for monitoring the pollution level.

PM_{10} samples were collected on glass fibre filters (203×254 mm) by using high volume air sampler with an average flow rate of 1.0 m^3/min. Eight hour average sampling was done in duplicate at each location during the year 2015. This instrument is reliable to measure the mass concentration of particulate matter in the atmospheric air (USEPA—Method 40 CFR).

The sampling locations were chosen to reflect the influences from residential, commercial, industrial areas regarding the low, moderate and heavy traffic sources. Eight hour average sampling was done in duplicate at each location during the year 2015. Features of air quality stations are presented in Table 1.

Monitoring of trace gases. ***CO Gas analyzer (Model 50).*** Snifit CO analyzer (Model 50) was used to measure the concentration of carbon monoxide. This is an ideal analyzer for measuring the carbon monoxide in ambient air and the results are shown in ppm. For measuring the CO in surrounding air, meter was kept at about 1.2 m height above the ground level. At each selected locations, CO in the ambient air was collected at an interval of 02 min and a set of various readings was noted to analyze the results.

UV fluorescent SO_2 analyzer model AF22 M. AF22M, sulphur dioxide analyzer capable of measuring sulphur dioxide at ppb level. Applied to SO_2 measurement, the universally known UV fluorescent principle consists in detecting the characteristic fluorescence radiation emitted by SO_2 molecules. In the presence of a specific wavelength of UV light (214 nm) the SO_2 molecules reach temporary excited electronic state. The subsequent relaxation produces a florescence radiation which is measured by a non-cooled photomultiplier tube (PM).

NO-NOx analyzer model AC 32M. The Chemiluminescent NO-NO_2-NO_X analyzer, model AC32M, capable of measuring nitrogen oxides at ppb levels was applied for nitrogen oxides measurement. Chemiluminescence corresponds to an oxidation of NO molecules by O_3 molecules. The return to a fundamental electronic state of the excited NO_2 molecules is made by luminous radiation, detected by the PM tube. The model AC32M is a state-of-the-art single chamber – single photomultiplier tube design which automatically cycles between the NO and NO_X modes.

PM_{10} mass concentration. In addition to the determination of elemental concentrations, airborne particle masses of PM_{10} samples were calculated by using

Table 1. Descriptive features of the sampling locations during the study period in Karachi

Locations	Code #	Status of the sites
Jail Road	R-1	Residential area with high traffic
Gulberg chowrangi	R-2	Residential area with moderate traffic
Gulshan-e-Iqbal	R-3	Residential area with low traffic
PECHS Society	R-4	Residential area with low traffic
Model Colony	R-5	Residential area with moderate traffic
Paramount ground, Landhi	I-1W	Industrial / residential area with high traffic
Abbott Laboratories, Landhi	I-2W	Industrial / residential area with high traffic
Lucky Textile, Landhi	I-3W	Industrial / residential area with high traffic
Naurus G. belt, SITE	I-4E	Industrial / commercial area with high traffic
Siemens G. belt, SITE	I-5E	Industrial / residential area with high traffic
Manghopir Road, SITE	I-6E	Industrial area with high traffic
Singer chowrangi, KIA	I-7W	Industrial area with moderate traffic
Chamra chowrangi , KIA	I-8W	Industrial area with moderate traffic
Korangi # 2	I-9W	Industrial area with moderate traffic
Port Qasim	I-10	Industrial area with low traffic
Hasan Square	C-1	Commercial / residential area with moderate traffic
Liaquatabad	C-2	Commercial / residential area with high traffic
Garden	C-3	Commercial / residential area with high traffic
Gulistan-e-Johar	C-4	Commercial / residential area with moderate traffic
NIPA chowrangi	C-5	Commercial / residential area with moderate traffic

analytical balance (KERN, ALS 220-4). The filter papers were weighed under controlled conditions of meteorological parameters (humidity and temperature) before and after collection of particulate matter. Weights for the blank filters were also recorded. Before weighing, all filter papers (glass fibre filter paper) were left for 24 h in desiccators to equilibrate their humidity and temperature conditions. The collected particulate mass was calculated by weighing the pre and post–weight difference of the filters.

Air quality index (AQI). In this study AQI has been calculated with reference to the concentration of particulate pollution proposed by USEPA (2012). These AQI values predict, evaluate and explained the air quality status and health concerns at the selected sites. As the air pollution increases, adverse health effect also increases.

Following equation was used to calculate the AQI values by using the pollutant concentration data.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi}\ BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo}$$

where:

I_p = Index for pollutant p; C_p = Rounded concentration of pollutant p; BP_{Hi} = Breakpoint that is greater than or equal to Cp; BP_{Lo} = Breakpoint that is less than or equal to Cp; I_{Hi} = AQI value corresponding to BP_{Hi}; I_{Lo} = AQI value corresponding to BP_{Lo}.

After compiling the data, the concentrations of SO_2, NO_2, CO and PM_{10} pollutant were converted into an AQI value for each location, higher the AQI value, higher the level of air pollution that describe the associated health hazards to the citizens.

Table 2. AQI criteria and quality category

AQI	AQI category	Colour show the category
0 - 50	Good	
51 - 100	Moderate	
101 - 150	Unhealthy for sensitive	
151 - 200	Poor/Unhealthy	
201 - 300	Very poor/very unhealthy	
301 - 400	Hazardous	
401 - 500	Very hazardous	
>500	Very critical	
USEPA standard	150	

Source: USEPA 2012; Gurjar *et al*. (2008).

Table 2 shows the air quality index with the category of health risk. The air quality index zero to fifty is good for human health and indicate clean air, 50 to 100 indicate moderate air quality, 101 to 150 point toward unhealthy for sensitive group, 151 to 200 express unhealthy for all people, 201 to 300 very unhealthy, 301 to 500 hazardous and > 500 indicates severe hazardous and very critical (Table 2) (USEPA, 2012; Gurjar *et al*., 2008).

Results and Discussion

Evaluation of particulate matter and trace gases concentrations, were carried out on the basis of PM_{10} size fractions at the selected twenty locations in Karachi, from January to November 2015. The sites were Jail Road (R-1), Gulberg chowrangi (R-2), Gulshan-e-Iqbal (R-3), PECHS Society (R-4) and Model Colony (R-5) in residential areas, Paramount ground (I-1W), Abbott (I-2W), Lucky Textile (I-3W), Naurus G. belt (I-4E), Siemens G. belt (I-5E), Manghopir (I-6E), Singer chowrangi (I-7W), Chamra chowrangi (I-8W) and Korangi #2 (I-9W) Port Qasim (1-10) in industrial areas, Hasan Square (C-1), Liaquatabad (C-2), Garden (C-3), Gulistan-e-Johar (C-4) and NIPA (C-5) in commercial areas of Karachi.

Table 1 shows the descriptions of the sampling sites. The recorded results varied between residential, industrial and commercial areas of Karachi.

Table 3 depicted the statistics (mean, median, st.dev, maximum and minimum values) of measured trace gases and PM_{10} concentration in different air monitoring areas during the study period. The highest mean concentrations of particulate matter and trace infectious gases were recorded in commercial and industrial areas and graphically represented in Fig. 1-4, respectively.

Table 4 shows the ambient AQI values that has been calculated with the recorded pollutant concentration data of the selected sampling locations, showing the degree/intensity of ambient air pollution category at monitoring locations during a certain monitoring period (e.g., 1, 8 or 24 h) due to its surrounding metrology and human activities and its relation to health hazards.

Trace gases. Atmospheric trace gases (SO_2, NO_2 and CO) were measured at twenty selected locations in Karachi during the period of January to November 2015. Samples were collected twice in a month at each location. The sampling time was 8 h for SO_2, NO_2 and 1 h for CO. The samples were collected by analyzers designed and fabricated by environmental S.A., France.

The total average concentrations of SO_2 at twenty selected locations in Karachi was found 46.0 µg/m^3 and under the limit of annual World Health Organization

Table 3. Statistical values of the pollutants during the study period in Karachi

Pollutants	PM_{10}	SO_2	CO	NO_2
	µg/m^3			
Residential areas				
Mean	141.4	32.0	2.7	73.6
Median	130.0	30.0	3.0	68.0
St. Dev	5.9	1.3	0.3	0.8
Max	192.0	40.0	0.5	106.0
Min	117.0	25.0	0.1	54.0
Industrial areas				
Mean	161.4	39.4	3.2	79.8
Median	210.0	46.0	3.6	89.0
St. Dev	4.7	2.0	0.3	1.1
Max	298.0	76.0	5.1	141.0
Min	81.0	29.0	2.3	59.0
Commercial areas				
Mean	256.8	56.8	4.6	106.0
Median	278.0	58.0	4.3	100
St. Dev	4.1	2.2	0.4	1.3
Max	319.0	72.0	4.1	136.0
Min	151.0	50.0	3.7	82.0

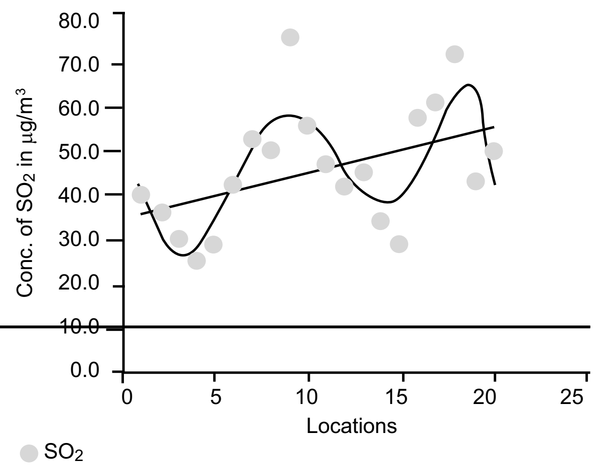


Fig. 1. Concentration of SO_2 at selected locations in Karachi.

Table 4. Air quality index (AQI) and air quality category at selected locations in Karachi city

Locations	Code #	PM_{10} Values	PM_{10} Category	SO_2 Values	SO_2 Category	CO Values	CO Category	NO_2 Values	NO_2 Category
Jail Road	R-1	119.0	Unhealthy	56.0	Moderate	43.0	Good	102.0	Unhealthy
Gulberg chowrangi	R-2	98.0	Moderate	54.0	Moderate	40.0	Good	78.0	Moderate
Gulshan-e-Iqbal	R-3	78.0	Moderate	43.0	Good	25.0	Good	66.0	Moderate
PECHS Society	R-4	88.0	Moderate	36.0	Good	17.0	Good	58.0	Moderate
Model Colony	R-5	82.0	Moderate	41.0	Good	34.0	Good	51.0	Moderate
Paramount ground, Landhi	I-1W	126.0	Unhealthy	59.0	Moderate	51.0	Moderate	81.0	Moderate
Abbott Laboratoy, Landhi	I-2W	130.0	Unhealthy	72.0	Moderate	39.0	Good	101.0	Unhealthy
Lucky Textile, Landhi	I-3W	148.0	Unhealthy	69.0	Moderate	41.0	Good	102.0	Unhealthy
Naurus G. belt, SITE	I-4E	169.0	Poor	101.0	Unhealthy	53.0	Moderate	103.0	Unhealthy
Siemens G. belt, SITE	I-5E	172.0	Poor	76.0	Moderate	57.0	Moderate	109.0	Unhealthy
Manghopir, SITE	I-6E	167.0	Poor	65.0	Moderate	43.0	Good	90.0	Moderate
Singer chowrangi, KIA	I-7W	100.0	Moderate	59.0	Moderate	39.0	Good	81.0	Moderate
Chamra chowrangi, KIA	I-8W	98.0	Moderate	62.0	Moderate	41.0	Good	86.0	Moderate
Korangi #2, KIA	I-9W	91.0	Moderate	49.0	Good	34.0	Good	79.0	Moderate
Port Qasim	I-10	64.0	Moderate	41.0	Good	26.0	Good	56.0	Moderate
Hasan Square	C-1	162.0	Poor	79.0	Moderate	49.0	Good	100.0	Moderate
Liaquatabad	C-2	168.0	Poor	82.0	Moderate	59.0	Moderate	105.0	Unhealthy
Garden	C-3	183.0	Poor	96.0	Moderate	64.0	Moderate	108.0	Unhealthy
Gulistan-e-Johar	C-4	147.0	Unhealthy	60.0	Moderate	47.0	Good	88.0	Moderate
NIPA	C-5	98.2	Moderate	69.0	Moderate	42.0	Good	81.0	Moderate

(WHO) guideline values for the European Union (WHO 2000: 50 μg/m^3). Total duration of sampling in this study was 11 months (twice a month, 8 h for SO_2 and NO_2, 1 h for CO). The highest concentration (76.0 and 72.0 μg/m^3) of SO_2 found in the industrial and commercial areas at location I-4E and C-3, whereas the lowest concentration (25.0 μg/m^3) in residential area at location R-4, respectively (Fig. 1). The main source of SO_2 emission in the city center is the combustion of fossil fuel in automobile and industrial sectors.

The total average concentration of NO_2 at the selected locations in Karachi was found 92.0 μg/m^3, which is more than double of the annual guideline value of WHO, 2005(40 μg/m^3). The NO_2 concentration in the atmospheric environment enters from both natural and anthropogenic sources. The major anthropogenic source of NO_2 emission is fossil fuel combustion in vehicles and industries. The highest concentration of NO_2 (141.0 μg/m^3) was found in industrial area, at location I-5E with high traffic density and industrial emission, whereas, the lowest concentration (54.0 μg/m^3) found at location R-5 in purely residential area (Fig. 2).

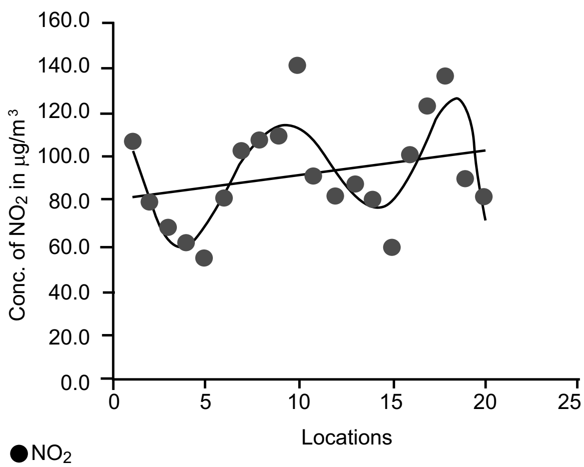


Fig. 2. Concentration of NO_2 at selected locations in Karachi.

The measured CO values varied between 1.5 to 5.8 μg/m^3 in residential, industrial and commercial areas. The maximum concentration (5.8, 5.3 and 5.1 μg/m^3) of CO was measured at the commercial and industrial locations C-2, C-3 and I-5, whereas the lowest concentration (1.5 μg/m^3) was found at location R-4 in residential area. The high concentration of CO in commercial and industrial areas probably due to the incomplete combustion of fossil fuel in faulty vehicles and due to different mechanical and industrial combustion. However, the total average value of CO (11 months at these twenty sampling locations) in Karachi was 3.7 μg/m^3 (1-h sampling time) (Fig. 3) which is under the WHO guidelins.

PM_{10} concentrations. The distribution parameters for PM_{10} for residential, industrial and commercial areas varied from 117.0 to 319.0 μg/m^3, for residential areas 117.0 to 192.0 μg/m^3, for industrial areas 136.0 to 298.0 μg/m^3 and for commercial areas 151.0 to 319.0 μg/m^3,

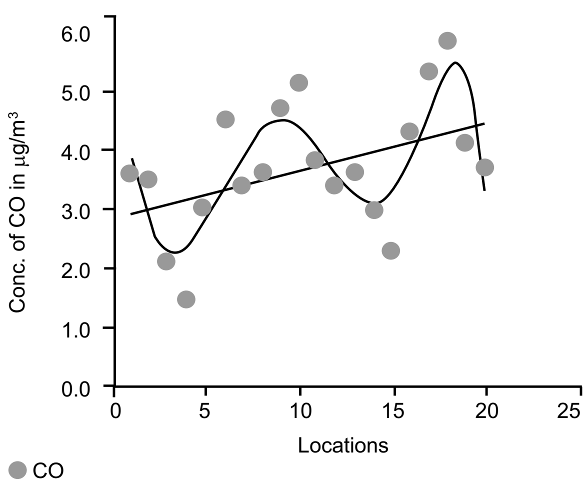


Fig. 3. Concentration of CO at selected locations in Karachi.

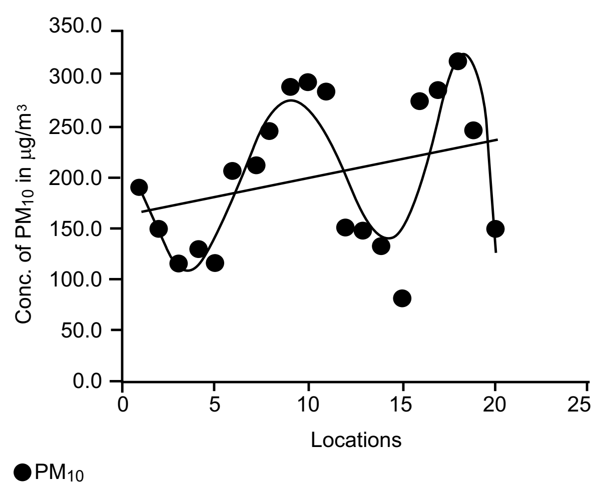


Fig. 4. Concentration of PM_{10} at selected locations in Karachi.

respectively. In residential areas PM_{10} concentrations were higher at locations R-1 (192.0 $\mu g/m^3$) having high traffic density and producing emission due to vehicular emission and different commercial activities, In Industrial areas PM_{10} concentrations were higher at locations I-5E (298.0 $\mu g/m^3$) and receiving higher emissions due to industrial and vehicular emission, whereas in commercial areas PM_{10} concentrations were higher at location C-3(319.0 $\mu g/m^3$). This location was surrounded by roundabouts having automobile repairing shops, unplanned rickshaws stand, and traffic jams due to narrow and congested roads and they are receiving higher emissions due to vehicles and commercial activities. Overall mean concentration of PM_{10} at various locations of residential, industrial and commercial areas was 202.4 $\mu g/m^3$ for Karachi region (Fig. 4). The PM_{10} in Karachi mostly emitted from vehicular and industrial combustion producing fine fraction, which produces severe health hazards particularly pulmonary disorder. It can penetrate deep into the lungs and cause pulmonary disorder.

In general, the average trace gases and PM_{10} concentrations were higher in commercial and industrial areas with high traffic density than the residential areas. Most of the commercial and industrial areas having trace gases and PM_{10} concentrations exceeded the specified permissible limits by USEPA (2012).

The ambient AQI values have been calculated with the recorded pollutant concentration data of the selected sampling locations presented in Table 4.

The calculated AQI values of PM_{10} at the selected locations vary between a maximum of 183.0 and a minimum of 64, respectively. Results of the calculation of AQI values for PM_{10} at the selected locations show moderate pollution in residential areas and poor or unhealthy pollution in commercial and industrial areas. Whereas, calculated AQI values for SO_2 vary between a maximum of 101.0 and a minimum of 36, for CO vary between a maximum of 64.0 and a minimum of 17.0, for NO_2 vary between a maximum of 109.0 and a minimum of 51.0, respectively.

The results of air quality monitoring show that the pollution concentrations were highly variable at different locations. This is expected as the extent of air pollutants depend on the active mobile and stationary pollutant emitting sources and is influenced by meteorological factors. It can also be seen that the concentration of particulate PM_{10} pollutants exceeded the allowable standard limit at all the locations with un-controlled emission from transport vehicles. The concentration of gaseous pollutants was observed to be within permissible limits at all the selected locations. Results of the calculation of AQI values for trace gases (SO_2, CO and NO_2) at the sampling locations show good and moderate pollution in residential areas whereas moderate or unhealthy pollution found at commercial and industrial locations.

Conclusion

Atmospheric pollution at twenty selected locations in Karachi, Pakistan, was characterized in terms of trace gases and PM. The average concentration of SO_2 and NO_2 at the selected sampling locations in Karachi are higher than the annual average of WHO guidelines, may be due to the high content of sulphur in fossil fuel and heavy traffic density whereas concentration of CO is lower than WHO guideline values. Overall mean concentration of PM_{10} at various locations of residential, industrial and commercial areas was 202.4 $\mu g/m^3$ for Karachi region. Elevated concentrations of PM were observed in Karachi city, but these were still lower than most of the southeast Asian cities.

It can be concluded from this study that the concentration of atmospheric pollutant in the environment shows deterioration of air quality in the city. Observed values exceeding the permissible limits in commercial and industrial areas and in that residential areas having both commercial and residential status of the city. The main source of the pollution appears to be transportation due to congestion and fossil fuel emission.

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