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Research Paper

Air quality monitoring and its relation to potential health impacts in green spaces / parks and playgrounds in Karachi with the view of air quality index (AQI)

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ABSTRACT

Monitoring of ambient air quality parameters such as PM_{10}, SO_2, CO and NO_2 were carried out at nineteen selected green spaces / parks and playgrounds in residential, industrial and commercial areas of Karachi city during the year, 2016. Concentrations of trace gases and particulate matter were found to be higher in commercial and industrial areas than the residential areas green spaces / parks and playgrounds. Further, the Air Quality Index (AQI) was also calculated for these sampling locations. AQI values showed poor and unhealthy pollution level for commercial and industrial areas, and for residential areas moderate and good level of AQI values were shown. Similarly, with respect to the health effect due to ambient air pollution in these areas, it was observed that, the commercial and industrial areas are comparatively more affected then the residential areas.

Key words: Green spaces, parks and playgrounds, trace gases, particulate matter, AQI.

INTRODUCTION

Air pollution is the introduction of harmful gases, particulates, dust, smoke, biological molecules or other injurious materials in the atmosphere causing mortality and morbidity in plants, animals and human being. A pollutant can be of natural origin or man-made. Primary pollutants are usually emitted directly from any process, such as CO emitted from the vehicular exhaust and SO_2 emitted from factories. Whereas, Secondary pollutants are not emitted directly rather they are formed in the air when primary pollutants react or interact to form O_3, PAN, acid rain etc (Panda et al., 2010). Ambient air quality in the atmosphere of Karachi city deteriorated due to rapid urbanization, unplanned industrialization, waste incineration, uncontrolled increase of vehicles etc. It has become an important environmental risk factor for lung cancer and cardiopulmonary disturbances (Ghose and Majee, 2001). According to the World Health Organization (WHO), urban air pollution is responsible for approximately 800,000 deaths annually around the globe (Maji et al., 2010). The most common air pollutants in the urban environment are 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 and trace metals.

At present, particulate matter pollution is one of the most important issue in urban cities, not only produces adverse health effects, but reduces the atmospheric visibility and also affect the status of cultural heritages (Van Grieken and Delalieux, 2004). Several epidemiological studies (Dockery and Pope III , 2006; Anderson et al., 2005; Analitis, 2006) have shown a strong association between elevated concentrations of inhalable particulate (PM_{10}) and increased mortality and morbidity. As it can be absorbed into the lung tissues during breathing, even at low concentrations create serious short-term and long-term effects on Human health. Short-term health effects link with airborne particulate matter (PM) concentrations cause lung function disorder, hospital admissions and mortality, whereas long-term health effects shows the incidence of mortality due to respiratory diseases such as asthma, bronchitis and other cardio pulmonary disorders

(Sicard et al., 2011).

Gaseous pollutants have main harmful effects on health. These pollutants are responsible for changing the atmospheric chemistry and cause environmental damage. Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) form acids through different chemical reactions in the atmosphere, and subsequently these acids deposited on land and ocean surfaces due to formation of acid rain. It is predicted that the increasing concentration of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) in the atmosphere will contribute to global climate change. Besides particulate matter, literature also suggests that there is a strong relationship between higher concentration of SO_2 and NO_2 and several health effects (Curtis, 2006), such as cardiovascular diseases (Peters et al., 2004; Dockery, 2006), respiratory health effects such as asthma and bronchitis (Burnett, 2005), and reproductive and developmental effects such as increased risk of preterm birth (Liu et al., 2003). Trace metals present in suspended PM are considered to be a health hazard since they are readily absorbed by the lung tissues. Toxicological *in vitro* and *in vivo* studies have shown that metals are harmful components of PM as they can cause different cardiovascular and lung diseases (Dominici 2006).

The air quality index (AQI) is a scale to show or characterize the degree of ambient air pollution at a particular monitoring location during a certain monitoring period (e.g., one, 8 or 24 h) due to the concentration of human activities that occur in cities. The main aim of AQI calculation is to inform the public about the risk of pollution level day to day and to prepare for precautionary measurement and regulate the safety measures for health hazards. Generally, it is related with the pollutants range and category describe 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 (Gurjar et al., 2008).

The present study was carried out to estimate the level of atmospheric trace gases such as carbon monoxide, sulphur dioxide, nitrogen dioxide and particulate matter in the environment of Karachi city with reference to air quality index (AQI) in the year of 2016. This AQI study describes the range of air quality and its associated health hazards to provide public awareness.

MATERIALS AND METHODS

Study area

Karachi lies between 24°45'N in longitude and 66°37'E in latitude. It has an area of 3,640 km^2 and is located along the cost of the Arabian Sea. It is the largest metropolitan city of Pakistan. With respect to the population Karachi is the2nd-largest city in the world. Karachi has a moderately temperate climate with a generally high relative humidity that varies from 58% in December (the driest month) to 85% in August (the wettest month). In winter, the average temperature of the city is about 21°C, while in summer it reaches up to 35°C. Karachi receives about 256 mm of average annual rainfall (Sajjad et al., 2010).

Karachi is 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 define industrial base, such as Sindh Industrial Trading Estate, Korangi Industrial Area, 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 ninteen different green spaces / parks and playground, consisting of main roads, side road, round about, and open places along the busy roads of Karachi during 2016 for gaseous pollutants and PM_{10}. Selected spaces / parks and playgrounds were differentiated 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 fiber filters (203×254 mm) using high volume air sampler with an average flow rate of 1.0 m^3/min. Eight hour sampling was done in duplicate at each location during the year 2016. The high volume is considered a reliable instrument for measuring the weight of PM_{10} in ambient air (USEPA—Method 40 CFR).

These locations were chosen to reflect the influences from residential, commercial, industrial areas regarding the low, moderate and heavy traffic sources. This was done with an intention to get better representation of the city. Eight hour sampling / monitoring was done in duplicate at each location during the year 2016. The features of air quality around selected green spaces / parks and playground are presented in Table 1.

Table 1: Description of the sampling locations (green spaces / parks and playground) during the study period in Karachi.

S/N	Locations	Cod #	Activities
	Residential areas		
1	KMC Park	P-1(R)	Moderate Traffic Density, exposed dump/exposed pit surface, domestic waste burning and residential activities.
2	Jheel Park	P-2(R)	Low Traffic Density with transport on paved road and unpaved road, haul road and exposed dump/exposed pit surface, domestic waste burning and residential activities.
3	PIB colony playground	P-3 (R)	Moderate Traffic Density, exposed dump/exposed pit surface, domestic waste burning and residential activities.
4	TaleemiBagh	P-4 (R)	Moderate Traffic density, surrounded by residential area.
5	Model colony playground	P-5 (R)	Average Traffic Density with residential activities
6	Tipu Sultan playground	P-6 (R)	Average Traffic Density with residential activities
7	Fath-e-Park	P-7 (R)	Moderate Traffic Density, low emission due to wide roundabout with residential activities
	Industrial areas		
8	H.M playground	P-8 (I)	Moderate Vehicular emission due to average traffic density and other industrial activities.
9	Sunday Market ground	P-9 (I)	Moderate Vehicular emission due to average traffic density and other industrial activities.
10	Young's Shaheen Playground	P-10 (I)	Low Vehicular emission due to average traffic density and industrial activities.
11	Paramount Cricket Ground	P-11 (I)	Vehicular emission due to average traffic density, waste incineration, Stack emissions and other industrial activities.
12	Green Belt near Habib Bank Chorangi	P-12 (I)	Vehicular emission due to heavy traffic density, waste incineration, Stack emissions and other industrial activities.
13	Green Belt near Siemens Chorangi	P-13 (I)	
	Commercial areas		
14	F.C. Area Cricket Ground	P-14 (C)	Heavy Traffic density with transport on paved road and unpaved road, haul road and exposed dump/exposed pit surface, domestic waste burning and commercial activities.
15	AnnuBhai Park	P-15 (C)	Vehicular emission due to Average traffic density,
16	Safari Park	P-16 (C)	
17	UBL Sport ground	P-17 (C)	
18	Aram Bagh	P-18 (C)	Heavy Traffic Density on paved road and unpaved road, haul road and exposed dump/exposed pit surface, domestic waste burning and heavy commercial activities.
19	Zoological garden	P-19 (C)	

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; result 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, level of CO in the ambient air was collected at an interval of 2 min and a set of various readings was noted to analyze the results.

UV fluorescent SO_2 analyzer model AF22 M

AF22M, Sulfur dioxide analyzer, capable of measuring sulfur 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 $NO\text{-}NO_2\text{-}NO_X$ analyzer, model AC32M, is capable of measuring nitrogen oxides at ppb levels. Applied to 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 using 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 mass. Weights for the blank filters were also recorded. Before weighing, all filter papers (glass fiber 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 was calculated with reference to the concentration of pollution proposed by US-EPA (US-EPA, 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. The following equation was used to calculate the AQI values using the pollutant concentration data.

$$I_p = \frac{IHi - Ilo}{BPHi - BPLo}(C_p - BPLo) + ILo$$

Where
Ip = Index for pollutant p
Cp = Rounded concentration of pollutant p
BPHi = Breakpoint that is greater than or equal to Cp
BPLo = Breakpoint that is less than or equal to Cp
IHi = AQI value corresponding to BPHi
ILo = AQI value corresponding to BPLo

After compiling the data, the concentration of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM_{10}) pollutant was converted into an AQI value for each location (the higher the AQI value, the higher the level of air pollution) and describe the associated health hazards, providing full information to the citizens.

Table 2 shows the air quality index with the category of health risk. The air quality index of zero to fifty is good for human health and indicates clean air, 50 to 100 indicates moderate air quality, 101 to 150 points toward unhealthy for sensitive group, 151 to 200 express unhealthy for all people, 200 to 300 very unhealthy, 301 to 500 hazardous and > 500 indicates sever hazardous (Table 2).

RESULTS AND DISCUSSION

Evaluation of the concentrations of ambient PM_{10} and trace gases, that is, SO_2, NO_2 and CO, were determined on the basis of PM_{10} size fractions at the selected spaces / parks and playgrounds of Karachi during the year 2016. The sampling green spaces / parks and playgrounds were KMC park (P-1), Jheel park (P-2), PIB colony playground (P-3), Taleemibagh (P-4), Model colony playground (P-5), Tipu sultan ground (P-6), Fathe park (P-7), H.M. playground (P-8), Sunday market ground (P-9), Young's shaheen playground (P-10), Paramount playground (P-11), Green belt Siemens Chowrangi (P-12), Green belt Nauruschowrangi (P-13), F.C. Area cricket ground (P-14), AnnuBhai park (P-15), Safari park (P-16), UBL sports ground (P-17), Aram bagh (P-18) and Zoological garden (P-19) in Karachi city. The descriptions of the sampling sites are shown in Table 1.

The recorded results varied between residential, industrial and commercial areas green spaces / parks and playgrounds of Karachi. Ambient AQI values 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 and graphically represented in Figures 1, 2, 3 and 4, respectively.

In general, the average trace gases and PM_{10} concentrations were higher in commercial and industrial areas green space / parks and playgrounds with high traffic density and industrial emissions than the residential areas green spaces / parks and playgrounds. Most of the green

Table 2: AQI criteria and quality category.

AQI	AQI Category	Colour show the category
0 - 50	Good	Green
51 - 100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive	Orange
151 - 200	Poor / Unhealthy	Red
201 - 300	Very poor / very unhealthy	Purple
301 - 500	Hazardous	Mahroon

Source: US-EPA (2012) and Gurjaret al. (2008).

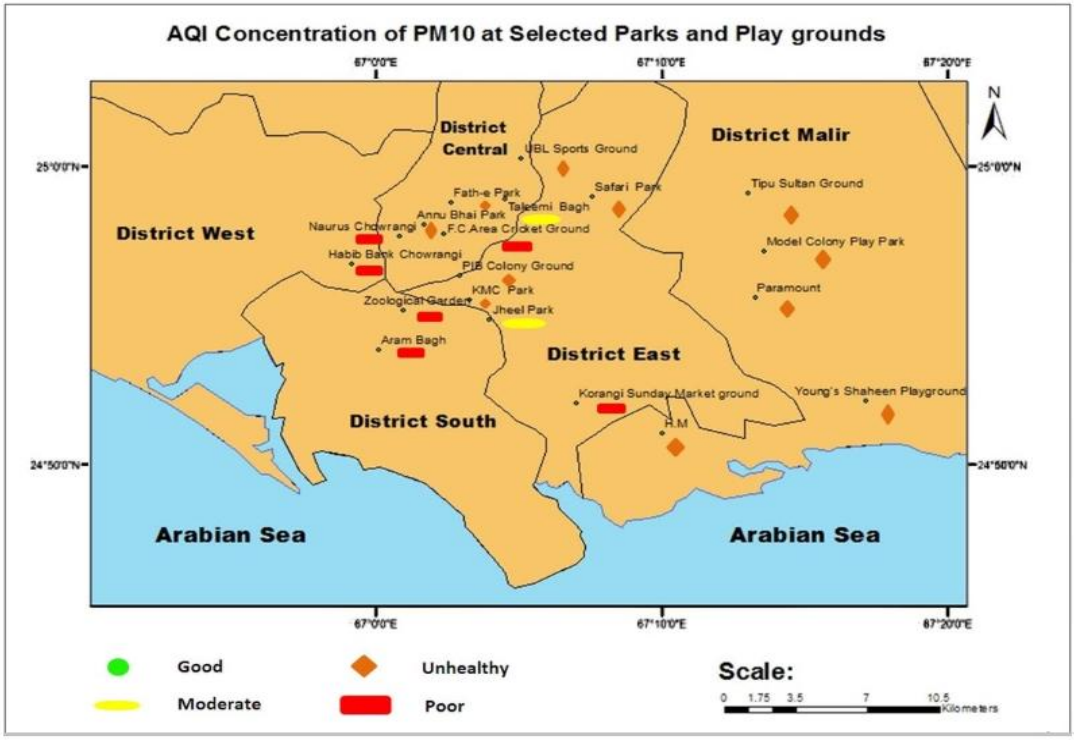

Figure 1: Air quality index values of PM_{10}.

spaces / parks and playgrounds in commercial and industrial areas have PM_{10} concentrations exceeded the specified permissible limits by US-EPA (US-EPA, 2012).

The calculated Air Quality Index values of PM_{10} and trace gases at the selected green spaces / parks and grounds vary between a maximum of 200.0 and a minimum of 88.0, respectively. Results of the calculation of AQI values for PM_{10} at the sampling green space / parks and grounds show moderate pollution in residential areas and poor or unhealthy pollution in commercial and industrial areas (Figure 1). Whereas, calculated Air Quality Index values for SO_2 vary between a maximum of 81.0 and a minimum of 22.0 (Figure 2), respectively, while for CO vary between a maximum of 57.0 and a minimum of 14.0 (Figure 3), for NO_2 vary between a maximum of 107.0 and a minimum of 49.0 (Figure 4), respectively.

The results of air quality monitoring showed that the pollution concentrations were highly variable at different sampling locations. This is expected as the extent of air pollutants in a site depends on the active mobile and stationary pollutant emitting sources and is influenced by meteorological factors. It was also observed that the concentration of particulate PM_{10} pollutants exceeded the allowable standard limit at all the location except TaleemiBagh (P-4), a purely residential area park with controlled emission from transport vehicles. The concentrations of gaseous pollutants were observed to be within permissible limits in all the selected green spaces / parks and playground. The results of the calculation of AQI values for trace gases (SO_2, CO and NO_2) at the sampling areas showed moderate pollution level in the green spaces / parks and ground situated in residential areas, whereas

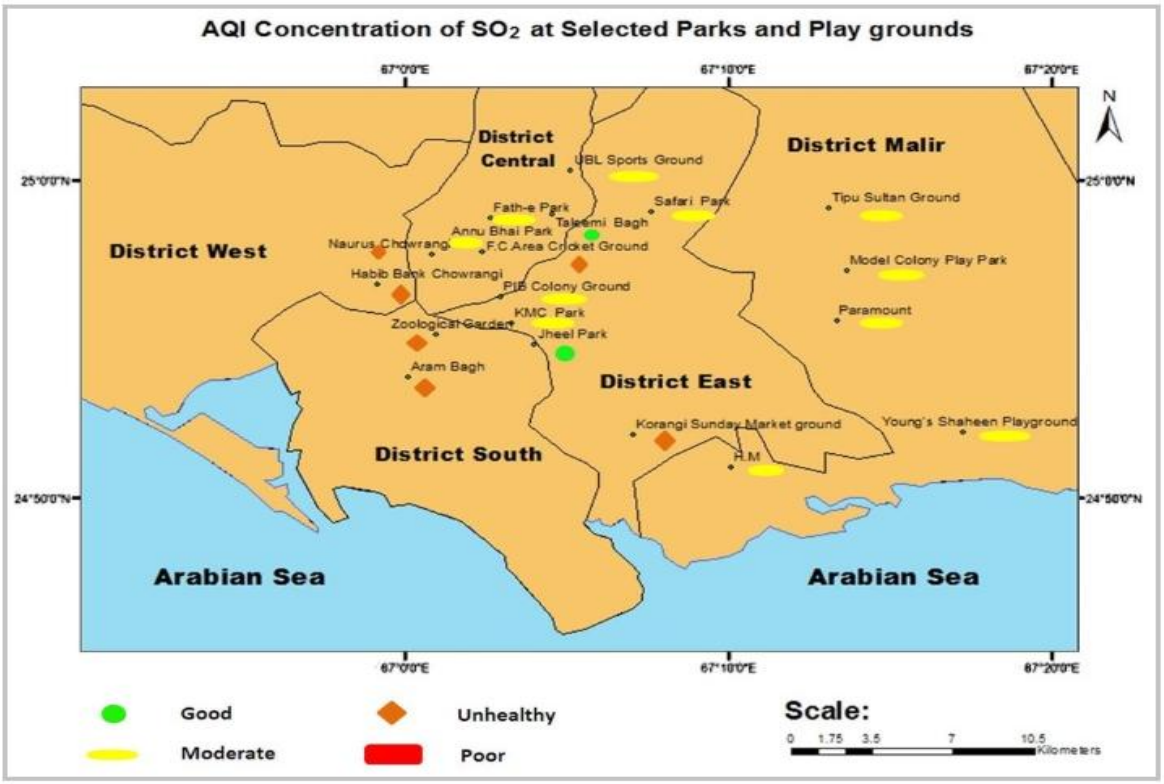

Figure 2: Air quality index values of SO_2.

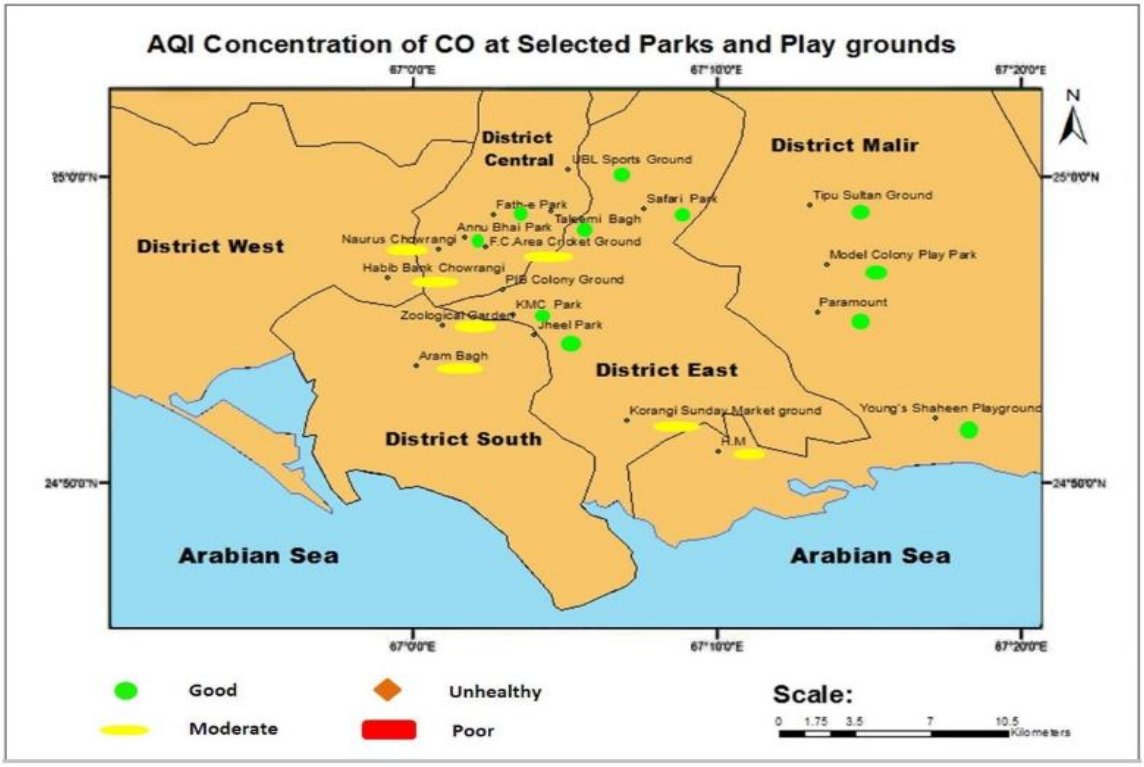

Figure 3: Air quality index values of CO.

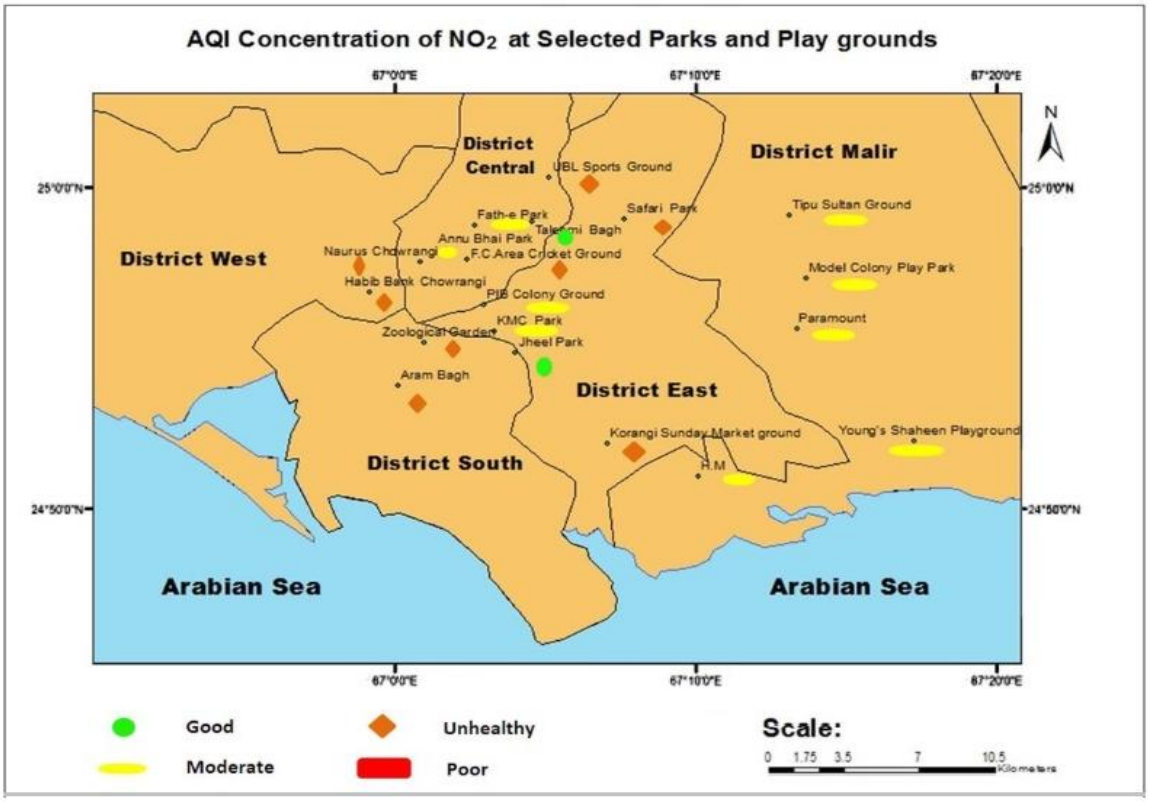

Figure 4: Air quality index values of NO_2.

poor or unhealthy pollution in the green spaces / parks and playgrounds of commercial and industrial areas of Karachi city.

Health hazards

As regards health effect due to ambient air pollution, a study was undertaken using a survey method (face to face interview). The main reasons for using this method were that it allows the collection of data within a limited time framework, it is relatively cost-effective and provides a minimal imposition on respondents' time as compared with other methods. Primary data were collected using the semi-structured questionnaire interviews. A research team consisting of two principal investigator and two research assistants was formed. Initially, a draft questionnaire was developed on issues such as socio-economic background of the respondents and the perception about the health hazards of air pollution. The questionnaire used in this study had three parts. The first part contained some general questions, such as age, level of education and awareness about air pollution related diseases. Several discussions were held among the researchers who found certain anomalies regarding ordering the questions and then felt the necessity of adding few more questions with changes and adjustments in the questionnaire. With some addition and correction, the questionnaire was finalized for testing. Both open and close-ended questions were also incorporated in the questionnaire.

Field investigation was carried out during the year 2016. Since Karachi is one of the largest cities of Pakistan, the population is increasing rapidly (with annual growth rate of 3.49 %) because of its industrial and intensive commercial activities and also for lesser jobs opportunities in the up country. The sites selected for the study based on different social backgrounds were interviewed. It is worthwhile to mention here that they all gave responses voluntarily. The underlying reason for doing this was to examine variation from diverse socio-economic backgrounds in terms of the perception of the health hazards of air pollution related diseases. Frequency distribution figures with percentage are provided to describe responses.

Regarding the health effect due to ambient air pollution in the area, it was observed that, resident of commercial and industrial areas were most effected due to air pollution related diseases as a result of heavy vehicular emission and industrial emission. Further, in these areas, most of the residents belong to low income category and illiterate having no awareness about air pollution health hazards. Whereas in residential areas, most of the residents belong to middle and high income group with higher education level up to HSC to master level education, and they are aware about air pollution and air pollution hazards and

how to protect themselves from these diseases.

The particulate and gaseous pollutants affect the peoples' lives in the study area causing asthma, chronic obstructive pulmonary diseases (COPD) and Bronchitis. Asthma has been observed mostly in children.

Conclusion

The present study shows that the concentration of suspended particulate matter exceeded the permissible standards in highly commercial areas, densely populated residential areas, industrial areas and in the residential areas located near highly commercial areas. The presence of high concentration of particulate pollutants showed a significant negative impact on the ambient air quality status of Karachi city in terms of Air Quality Index. The main source of the pollutants appears to be vehicular emission as its concentration is highest in the sites located in the busy commercial areas of the city with high traffic density. From the studies, it is evident that development and planning of the transport system and social awareness can play a major role in improving the quality of air in the city.

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