Measurement of Major Ambient Air Pollutants at Urban Background Site of Karachi

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Summary: A study on air pollution was carried out in an urban background site of Karachi city to generate base line data for major gaseous pollutants; SO_2, CO, O_3, NO and NO_x in the ambient air along with the meteorological parameter. The data was collected in the year 2000. The collected data was analyzed for hourly average and 24h average and TWA values. Monthly average concentration of SO_2, CO, O_3, NO and NO_x during the year was determined to be in the range of 0.4 - 5.6 ppb, 0.2 - 0.8 ppm, 7.2 - 24.0 ppb, 1.5 - 28.6 ppb and 5.7 - 38.9 ppb, respectively. The results suggest that all the air pollutants at this particular sampling site were mainly caused due to the emission from motor vehicles, which were coming from main Super Highway.

Introduction

Air pollution is truly a global problem. It is an inescapable feature of environmental damage throughout the world. Developing countries face a major challenge in trying to reconcile the growth with the urban air quality and global air quality. Rapidly increasing population, factories, processing industries, motor vehicles and other sources of emission of hazardous gases are adversely affecting the quality of air, especially in urban areas. Therefore, in order to assess the problem of air pollution in the large cities of the world, World Health Organization (WHO) and United Nation Environment Programme (UNEP) have jointly initiated a detailed study in the mega cities of the world [1]. The proportion of the world's population living in large towns or cities has grown from around 50 to 55 % over the past two decades. Demographers estimate that by the year 2030 approximately two third of all people will live [2]

The most common air pollutants in urban environment are SO_2, CO, O_3, NO, NO_x and particulate matter containing harmful elements. Nitrogen oxides and ozone may be regarded as secondary pollutants; as both depend on the emission of NO. The main source of NO_x in the urban areas is motor vehicles [3]. In cities with high traffic density, the emission of NO in the presence of sunlight and hydrocarbons produces high concentration of NO_2 and O_3, whereas sulphur dioxide contributes to acid rain and sulphate aerosol. Particulate matter includes smog, dust, smoke, pollen spores, algal cell, solid and liquid aerosol and many other suspended materials. Ozone and carbon monoxide, all have proven adverse health effects [4].

At present, there exists no Ambient Air Quality Standard in Pakistan. Therefore, in order to have an assessment of ambient air quality in the urban background areas of Karachi city and generate baseline data on ambient air quality, air pollution monitoring was carried out in one of the urban background sites of Karachi city. Karachi is one of the largest cities of Pakistan, located on the coast of Arabian Sea between Latitude 25^0 North and Longitude 67^0 East. Its population is increasing rapidly because of its industrial and commercial activities and also for lesser job opportunities in the upcountry. In the Census of 1998, the population of mega city of Karachi was declared to be 9.2 million [5], which is now more than 9.5 million.

The Site selected for this study was "PCSIR Campus", located at some distance from the main sources of pollution and is therefore more representative of air pollution levels of general background exposure. This site is located at Latitude 24^0 $71'$ and Longitude 67^0 $08'$. It is about 20 Km down wind from the city centre and about 1Km from the main Super Highway. Its surrounding area are sparsely populated and there is no industrial zone in and around 2 Km. Air masses reach the sampling site, generally from Super Highway, where the traffic density is very high.

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The main object of this study was to generate baseline data for ambient air pollutants at urban background site of Karachi city. The data generated may be used by the future planners, scientist and technologist for taking appropriate measures against hazards of air pollution and also for the formulation of Air Quality Standards in the country.

Results and Discussion

Table-1 and 2 give the hourly average concentration of air pollutants at the selected urban background site, for the respective hour of the week and weekly average values in the months of May (summer) and November (winter) 2000, respectively. Table-3 gives the Time Weighted Average (TWA) concentration of SO_2, CO, O_3, NO_2 analyzed for the year, along with the permissible ambient air quality limits, allowed by the World Health Organization (WHO). Figures 1 to 5 present the monthly average concentration of SO_2, CO, O_3, NO and NO_x, respectively, recorded during the year 2000. These figures show that the average concentration of SO_2, CO, O_3, NO and NO_x during the year were found to be in the range of 0.4 - 5.6 ppb, 0.2 - 0.8 ppm, 7.2 - 24.0 ppb, 1.5 - 28.6 ppb and 5.6 - 38.9 ppb, respectively.

Table-1:Hourly Average Concentration of Air Pollutants recorded for the respective hour of the week in the month of May (summer) 2002, at the selected urban background site of Karachi city.

S. No.	Time (h)	SO_2 ppb	CO ppm	O_3 ppb	NO ppb	NO_x ppb
01	01:00	0.20	0.10	6.60	2.30	12.9
02	02:00	0.10	0.10	7.60	2.10	11.8
03	03:00	0.20	0.10	7.90	2.10	10.70
04	04:00	0.10	0.10	8.30	1.90	9.60
05	05:00	0.30	0.20	8.70	1.80	8.80
06	06:00	0.50	0.20	9.60	1.90	7.50
07	07:00	0.70	0.20	9.80	1.50	7.20
08	08:00	0.90	0.20	10.90	1.70	6.90
09	09:00	1.20	0.40	11.80	2.20	5.90
10	10:00	0.60	0.20	12.60	2.10	4.30
11	11:00	0.70	0.10	14.90	1.60	3.20
12	12:00	1.10	0.30	17.60	1.70	3.60
13	13:00	0.90	0.40	16.80	1.50	3.10
14	14:00	0.60	0.50	14.90	1.30	2.70
15	15:00	0.40	0.30	12.80	1.40	3.30
16	16:00	0.20	0.20	11.50	1.10	5.20
17	17:00	0.30	0.10	10.40	2.10	5.90
18	18:00	0.20	0.20	9.90	1.50	6.90
19	19:00	0.30	0.30	8.90	1.40	7.60
20	20:00	0.40	0.40	8.60	1.50	8.80
21	21:00	0.30	0.30	7.90	2.40	9.60
22	22:00	0.20	0.20	6.90	2.30	10.30
23	23:00	0.20	0.10	7.70	2.00	11.50
24	24:00	0.10	0.10	6.60	2.10	12.70
Average		0.4	0.2	10.4	1.8	7.5

Table-2:Hourly Average Concentration of Air Pollutants recorded for respective hour of the week in the month of November (winter), 2000, at the selected urban background site of Karachi city.

S. No.	Time (h)	SO_2 ppb	CO ppm	O_3 ppb	NO ppb	NO_x ppb
01	01:00	2.10	0.30	7.50	9.20	15.70
02	02:00	2.50	0.40	8.30	8.10	14.20
03	03:00	2.00	0.20	8.80	6.90	13.60
04	04:00	2.00	0.20	10.20	6.20	10.80
05	05:00	2.20	0.30	9.90	4.80	9.70
06	06:00	2.00	0.40	9.30	4.20	9.30
07	07:00	2.50	0.40	10.80	3.20	10.20
08	08:00	2.90	0.40	11.70	2.10	8.90
09	09:00	3.00	0.30	12.60	1.80	9.60
10	10:00	3.10	0.30	15.70	1.10	8.50
11	11:00	2.10	0.20	18.90	0.80	8.10
12	12:00	2.50	0.40	20.60	0.90	8.70
13	13:00	2.60	0.50	24.70	0.50	6.40
14	14:00	2.00	0.40	21.60	0.30	4.30
15	15:00	1.90	0.50	18.90	0.90	3.60
16	16:00	1.90	0.40	15.70	1.10	5.20
17	17:00	1.80	0.50	9.60	1.50	7.10
18	18:00	2.00	0.40	9.40	2.20	8.70
19	19:00	2.40	0.70	7.30	3.90	9.30
20	20:00	2.30	0.50	8.30	5.30	11.40
21	21:00	2.00	0.40	6.90	5.90	12.10
22	22:00	1.70	0.30	7.30	6.30	14.20
23	23:00	1.70	0.20	7.50	9.80	16.60
24	24:00	1.90	0.20	8.90	12.10	19.70
Average		2.2	0.4	12.1	4.1	10.2

Table-3:Time Weighted Average (TWA) Limit for Ambient Air Pollutants recommended by WHO and Recorded Values at the Urban Background Site of Karachi city

S. No.	Pollu-tant	TWA Limits recommended by WHO		TWA values recorded at Survey Site	
		$\mu g/m^3$	Averaging Time	$\mu g/m^3$	Averaging Time
1	SO_2	350	1 h	4.2	1 h
		100 – 150	24 h	---	---
2	CO	30	1 h	0.4	1h
		10	8 h	---	---
3	O_3	150 – 200	1 h	29.1	1h
		100 – 120	8 h	---	---
4	NO_2	400	1 h	12.6	1h
		150	24 h	---	---

During these measurements, ambient temperature was recorded in the range of 8.7 – 39.7 °C, with average values 17.5 – 33.2 °C and wind velocity in the range of 0.6 – 4.9 m/s, with average values in the range of 0.8 – 2.7 m/s, throughout the year.

Figure 1 show, that maximum average concentration of SO_2 was found to be 5.6 ppb, once in the month of February, 2000. The total average concentration of SO_2 was observed to be 1.58 ppb

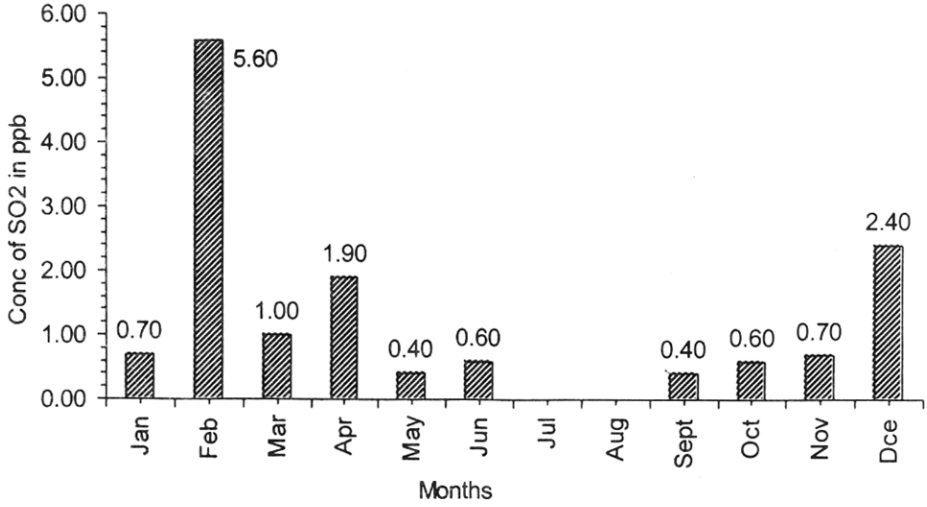

Fig. 1: Monthly average concentration of SO_2 observed during the year 2000.

(4.20 $\mu g/m^3$), which is relatively very low. The SO_2 concentration found at this location is well with in WHO limits (40 - 60 $\mu g/m^3$) [6]. The low level of SO_2 observed at this site might be due to the fact, that the use of coal in the urban area of Karachi is negligible.

Sulphur dioxide is one of the most wide spread and damaging part of the manmade air pollutants. The major sources of sulphur dioxide are the combustion of fossil fuel, coke ovens, metal smelting, wood and pulp production, petroleum refining and brick manufacture. According to IPCCS estimate revised in 1992, global emissions of sulphur dioxide by manmade sources account for 55 to 80% of the total SO_2 emission [7]. The estimated background concentration of SO_2 is 0.2 ppb and the calculated atmospheric residence time is four days [8]. High short-term level of SO_2 may increase respiratory diseases, lung function disturbance and mobility rates in adult and children [9]. Many epidemiological studies have further shown that daily variation in exposure to the major air pollution components, such as ozone, particulate matter and SO_2 are associated with health effects ranging from increased mortality and hospital admissions to subtle change in lung function at low to very low concentration [10].

Figure 2 shows that the maximum average concentration of CO was found to be 0.8 ppm in this area once in the month of October, 2000. The total average concentration was recorded to be 0.34 ppm (0.4 $\mu g/m^3$). WHO guidelines for carbon monoxide exposure allow 10 $\mu g/m^3$ over any 8 hours and 30 $\mu g/m^3$ for 1h [6]. The carbon monoxide found in this area is relatively very low. This may perhaps be due to the fewer numbers of motor vehicles plying in the residential area close to the monitoring site. Percentage contribution of anthropogenic emission sources in 1987 attributed 90% of carbon monoxide present in Los Angeles to transport [11]. The low values observed at our monitoring site are also due to low traffic density.

Carbon monoxide is almost entirely a man made pollutant. The incomplete burning of fuel produces carbon monoxide. This pollutant is most hazardous to human at concentration of 100 ppm or more, if experienced over a period of several hours [12]. At 100 ppm most of the people experience dizziness, headache. Cigarette smoke contains 400 to 450 ppm of CO. In case when the CO concentration exceeds 750 ppm, death may occur for a short period (few minutes) and at 250 to 500 ppm, people may experience the less of consciousness. Generally, busy traffic streets in urban areas contain around 5 - 20 ppm CO [13]. About one million ton of CO is released into the atmosphere each year, half of which is due to human activities. 90% of CO in the air is consumed in photochemical reaction that produces ozone [7]. Moreover, automobiles contribute to more than 80% of man made global CO emission, with a smaller amount resulting from other combustion processes [14].

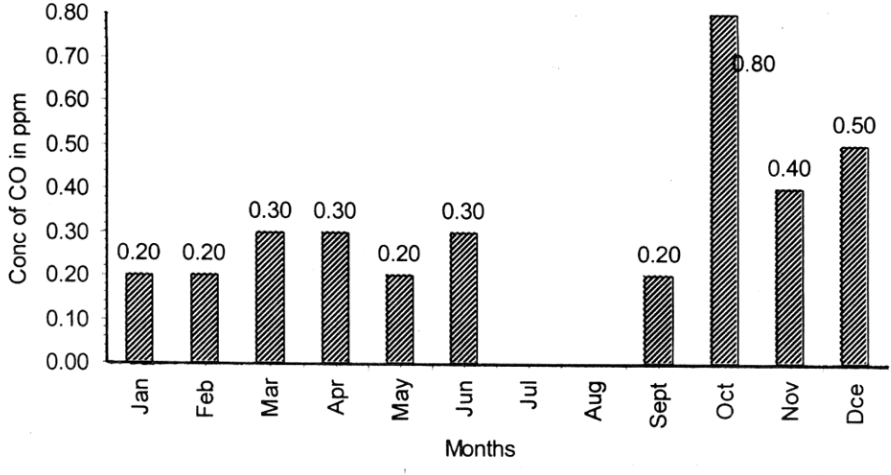

Fig. 2: Monthly average concentration of CO observed during the Year 2000.

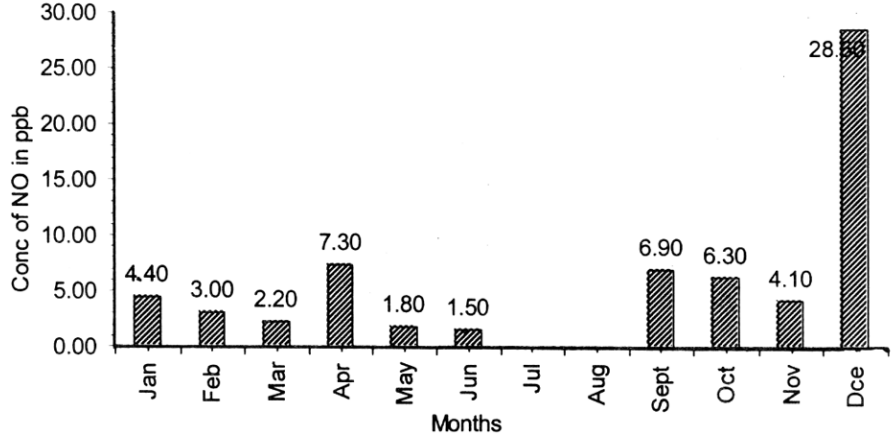

Fig. 3: Monthly average concentration of NO recorded during the year 2000.

Ozone is generated more significantly, as a result of chemical reaction involving the absorption of solar radiation by nitrogen dioxide (NO_2) in the presence of volatile organic compounds (VOCs) and carbon monoxide. The environmental impact of photo-chemically derived ozone was first studied in 1950 in Los Angeles during smog [15].

Nitrogen oxides are highly reactive gases and are formed when nitrogen in fuel or combustion air is heated to temperature above 650 ^{0}C in the presence of oxygen. The initial product, nitric oxide (NO) is oxidized further in the atmosphere to nitrogen dioxide (NO_2), which is an active compound in photochemical smog formation. Vehicular emissions are of particular significance, because of low emission heights. Seventy percent of NO_2 concentration found in ambient air environment of urban area can be attributed to vehicular pollutants [16, 17].

Figures 3, 4 and 5 show that maximum average concentration of NO, NO_x and O_3 were found to be 24.0, 28.6 and 38.9 ppb, respectively, in the month of December, whereas their total average concentrations were found to be 14.6, 6.61, and 13.22 ppb throughout the year. The formation of ozone is evident during daytime and highest concentration was found when solar radiations were at its peak level. Ambient concentration of NO, NO_x and O_3 are

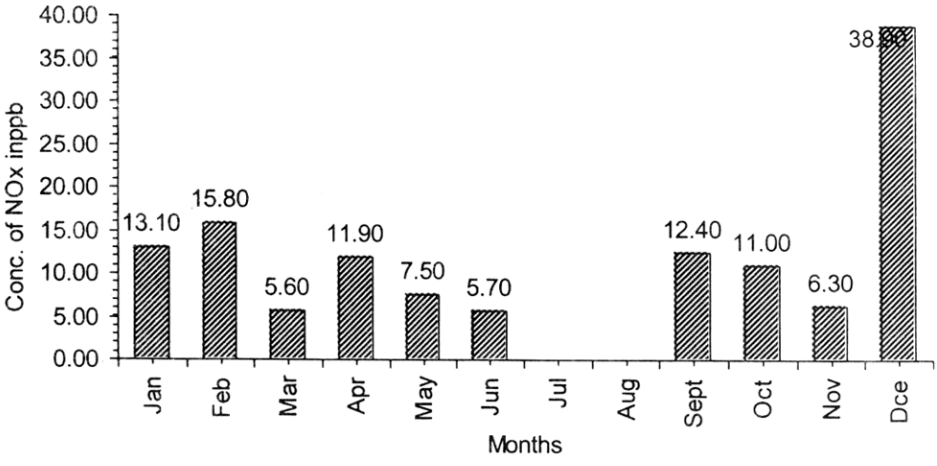

Fig. 4: Monthly average concentration of NOx observed during the year 2000.

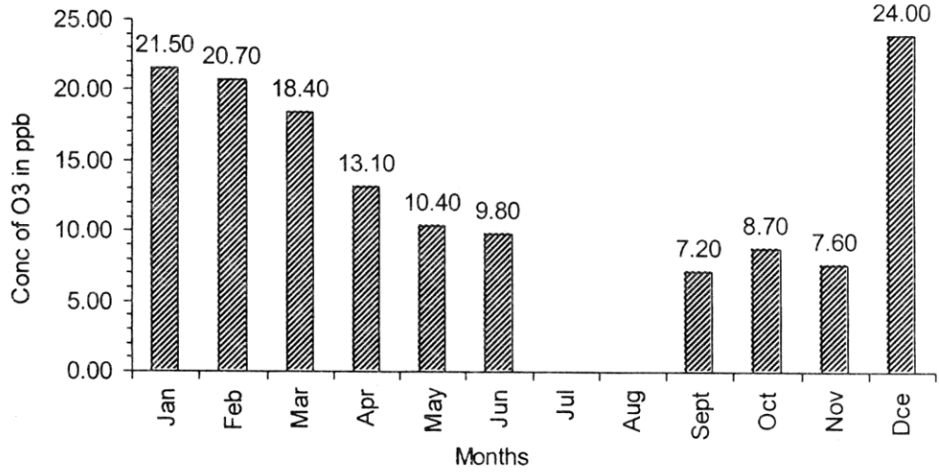

Fig. 5: Monthly average concentration of O_3 observed during the Year 2000.

strongly interrelated. Photo-chemically generated ozone and equilibrium between NO, NO_x and O_3 is quickly established in the absence of emission from local pollutant emissions. This equilibrium is reached within few minutes, typically in well-mixed air. Clark [18] has reported, that at typical ambient air NO concentration, the reaction has a time scale of one to a few minutes, while in recently emitted plume, the reaction of NO with O_3 is even more rapid having a time scale of only few second at typical ambient ozone concentration. Any ozone, which mixes into the plume, is thus expected to be rapidly destroyed as soon as it comes into molecular contact with NO [18].

Tables-1 and 2 show that the average concentrations of SO_2, CO, O_3, NO and NO_x in May (summer) were 0.4 ppb, 0.2 ppm, 10.4 ppb, 1.8 ppb and 7.5 ppb respectively and in November (winter), their average concentration were 2.2 ppb, 0.4 ppm, 12.1 ppb, 4.1 ppb and 10.3, respectively.

The sampling site was about 1 Km away from the Super Highway. The area around the site was sparsely populated and there is no industrial area in and around 2km of site. Air masses reaching the sampling site were generally coming from Super Highway, where traffic density is very high. In 1993, total number of vehicles plying on the Super High Way was recorded to be 50015 per day [19]. Karachi has westerly wind in summer and easterly wind in winter [14]. The wind direction during winter is mostly NS and average wind velocity during winter was found to be in the range of 0.8 – 1.2 m/s, which

is low. This low wind speed is usually accompanied by inversion and shows little horizontal dispersion of pollutants. The wind direction during summer is SW and average wind speed is in the range of 2.4 – 2.7 m/s, which is high, the air masses reaching the sampling site from Super Highway were thus diluted and well mixed and thus the influence of vehicular gaseous emission on super highway was minimum during the summer. As a result, the level of pollutants at this urban background site was found to be low during the summer as compared to the winter, because in winter the atmospheric conditions are more stable which reduces the mixing depth and consequently results in the poor dispersion of pollutants. The observed values of these pollutants in atmosphere can be attributed to vehicular emission.

Air pollution can adversely affect the human health and the most common air pollutants directly affect the respiratory and cardiovascular system. Increased mortality, morbidity and impaired /weaken pulmonary function have been reported with elevated levels of SO_2, CO, NO, NO_x and O_3 in the ambient air. The direct effects of air pollution on human health vary with respect to intensity, duration of exposure and also the health status of population exposed. During several episodes of extreme air pollution in various countries, an increase in morbidity and mortality was observed, suggesting that ambient air pollution adversely affect the human health [20]. Exposure to elevated concentrations or long-termed exposure to low levels of ambient air pollutants have received increasing attention due to wide range of affects of air pollutants on ecological systems and human health [21].

The effects of air pollutants on human health were got noticed after a large number of epidemiological studies. These studies have demonstrated the effects of major air pollutants on health at concentrations below existing WHO guidelines and Standards. These studies suggest that health effect can occur at levels far below the EPA (US) standards.

Experimental

The ambient air quality measurements were carried out by using Air Pollution Monitoring Mobile Laboratory (Environmental SA, France). This Laboratory is fitted with UV Fluorescent SO_2 Analyzer (Model AF21M), Gas Filter correlation CO Analyzer (Model CO11M), UV Photometric Ozone Analyzer (Model 0341M), NO and NO_x Analyzer (Model AC31M) for the analysis of SO_2, CO, O_3, NO and NO_x in the ambient air. The laboratory is also equipped with meteorological sensors mounted on a telescopic mast. The Intelligent Data Logger (SAM32), fitted in the Lab, records spot concentrations at every second and accumulates these to provide 15-minute averages. The logger also monitors instrument alarm and diagnostic functions and control daily instrument zero/span response checks. The analyzers for NO, NO_x and SO_2 were regularly calibrated by using NO_2 / SO_2 permeation tube oven and zero gas generator. Ozone analyzer O_3 41M has its own ozone generator for span gas. CO Analyzer (CO11M) was calibrated by standard CO span gas, supplied and certified by M/S Alphagaz, France.

Monitoring of ambient air quality at the selected site was carried out in every month, during the year 2000, with the exception of July and August, when due to some adverse climatic conditions and other circumstances, data could not be generated. In each month, ambient air quality was monitored continuously for one week (7 days and night, i.e., for 168 hr) and data was collected for SO_2, CO, O_3, NO and NO_x from mid night (00:00 h) of the beginning day to the mid night (00:00 h) of the ending day of the week. The data recorded have been analyzed for hourly average concentration for the respective hours of the week, total average for the year and also for Time Weighted Average (TWA) concentration of SO_2, CO, O_3 and NO_2. During these measurement periods, metrological data was also collected for wind speed, wind direction, humidity, temperature, barometric pressure and solar flux.

Conclusions

The baseline data generated for major ambient air pollutants at urban background site of Karachi shows that the concentration of ambient air pollutants, namely O_3, SO_2, CO, NO and NO_x, were all within permissible limits recommended by the World Health Organization. The observed values during measurements period show that these pollutants are emitted from motor vehicles. The generated data will play a part in the formulation of appropriate Ambient Air Quality Standards in the country.

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