

## Air Quality in the Atmosphere of Karachi City – An Overview

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**Summary:** A study on the measurement of concentration of major components in the ambient air was carried out at five different stations in Karachi city and data was collected for O<sub>3</sub>, SO<sub>2</sub>, CO, NO and NO<sub>x</sub> along with the meteorological parameters. The data generated has been evaluated for Time Weighted Average (TWA) values. The results suggest that all the pollutants were mainly due to the emissions from industries, refineries, power generation plants and also from motor vehicles. Due to the absence of regulatory laws/standards about ambient air quality in Pakistan; the results have been discussed with reference to the ambient air quality limits recommended by the World Health Organization.

### Introduction

Air pollution is the presence of undesirable material in air. The presence of the undesirable material in large enough amount in the air may result in harmful effects on human, animals and vegetables and also on the building structures. A scientific understanding of the air pollutants and their after effects will aid society in making the appropriate decisions for the improvement in air quality. Elimination of all air pollutants is rather impossible; however some realistic compromises are therefore necessary. The subject of air pollution is a matter of paramount concern in urban and industrial areas. The proportion of the world population living in the large towns or cities has grown about 5 to 50% during the past two decades. Demographers estimate that by the year 2030, approximately two third of the world population will live in the large towns or cities [1].

High rate of urbanization has ultimately created a number of environmental problems, such as inadequacy in sewerage system, over congestion, inadequate transport, slums, haphazard and unplanned development, particularly for the metropolitan areas, like Karachi. Similarly rapid industrialization, particularly in developing countries, is responsible for adverse environmental conditions thereby adding many toxic pollutants to the atmosphere [2]. Karachi is the largest metropolitan city of Pakistan and according to the census of 1998, its population was above 9.2 million [3], which is at present being estimated to be more than 10 million. Therefore, due to the rapid increase of population and proportional increase in factories, processing industries, transport fleet, etc., total amount and complexity of toxic pollutants in the environment is multiplying at an alarming rate.

Karachi is located on the coast of Arabian Sea between latitude 25<sup>o</sup> North and longitude 67<sup>o</sup> East. The city is growing rapidly, because it is the largest industrial and commercial hub in Pakistan. Growing urban population, level of industrialization, deploring conditions of civic amenities and traffic congestion are the main causes of air pollution in Karachi.

Typical major ambient air pollutants include CO, NO, NO<sub>x</sub>, SO<sub>2</sub>, HC and PM<sub>10</sub>. CO is formed during combustion of carbon containing compounds. It is highly toxic and causes its harms by binding with the haemoglobin in the blood, forming carboxyhaemoglobin (COHb). Depending upon the blood hemoglobin converted to COHb, it may result adverse effects on cardiac function, blood flow, RBC concentration, visual impairment, headache, vision, etc. [4]. SO<sub>2</sub> is also generated by the combustion of sulphur containing fuels. SO<sub>2</sub> is toxic to human body especially for a person, having respiratory disease symptoms, such as emphysema, and it may also cause pneumonia. Nitrogen oxides are generated in the high temperature combustion situations. Their ultimate effect on human being is still not clearly understood, but they act as irritant to breathing and create discomfort to eyes and also destroy the cilia in the respiratory system. The present study was carried out in various industrial, residential and down town areas of Karachi city. This study have been carried out to generate base line data on ambient air quality in different areas and localities of Karachi city, and to identify the major sources of air pollution and their remedial measures. The data so generated may assist in the formulation of Air Quality Standards in the country.

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Table – I: Concentration of O<sub>3</sub>, SO<sub>2</sub>, CO and NO<sub>2</sub> evaluated for 1h, 8h and 24h (TWA) along with permissible limits (for ambient air) recommended by the World Health Organization.

Pollutant	Time Weighted Average Values					WHO Limit	Unit	Averaging Time
	Station I	Station II	Station III	Station IV	Station V			
O <sub>3</sub>	9.80	11.20	11.20	9.50	7.20	150-200	μg/m <sup>3</sup>	1 hour
	13.20	17.30	19.10	13.80	9.60			
SO <sub>2</sub>	7.30	4.60	12.20	0.97	0.24	350	μg/m <sup>3</sup>	1 hour
	7.40	4.90	9.30	0.98	0.24			
CO	0.55	0.56	0.45	0.32	0.14	30	mg/m <sup>3</sup>	1 hour
	0.47	0.51	0.40	0.33	0.13			
NO <sub>2</sub>	13.10	5.70	7.60	2.20	2.80	400	μg/m <sup>3</sup>	1 hour
	13.00	5.80	7.60	2.20	2.60			
						150		24 hours

## Results and Discussion

Hourly average variation of the pollutants, recorded at the five selected Stations I to V are graphically presented in Figures 1 to 5, respectively. Table I, gives the Time Weighted Average (TWA) values evaluated for 1, 8 and 24h, along with the permissible ambient air quality limits, recommended by the World Health Organization.

Figure-1 shows the variation trend of carbon monoxide at selected Stations of Karachi. The maximum average concentration of carbon monoxide were found to be 0.9, 0.8, 0.7, 0.5 and 0.3 ppm at

Stations I, II, III, IV and V respectively. The main sources of CO at Stations I, II and III may be combustion of fuel in nearby industries and power generation plants, whereas at Stations IV and V, it may be due to the motor vehicles plying on nearby main Super Highway and University Road, where traffic density is quite high.

Figure-2 shows the trend of the concentration of SO<sub>2</sub>. The maximum concentration of SO<sub>2</sub> was obtained as 13.1, 7.6, 15.1, 1.4 and 0.5 ppb at Stations I, II, III, IV and V respectively. Highest value of hourly average concentration of SO<sub>2</sub> was recorded 15.1 ppb, at Station III. The main cause of

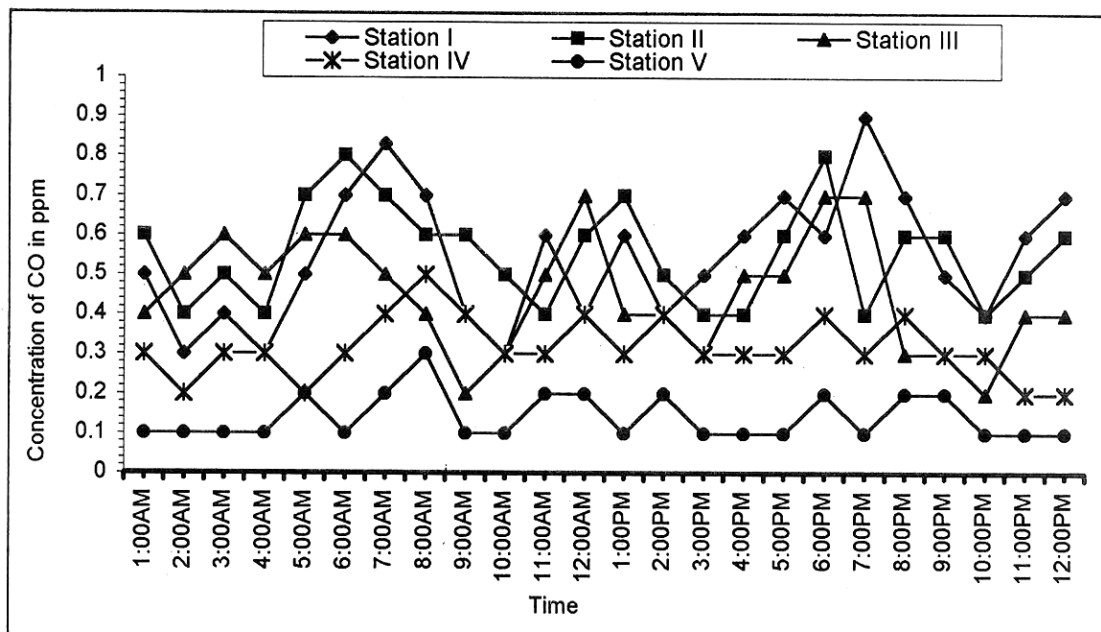


Fig. 1. Hourly average concentration of CO recorded in the atmosphere of Karachi city.

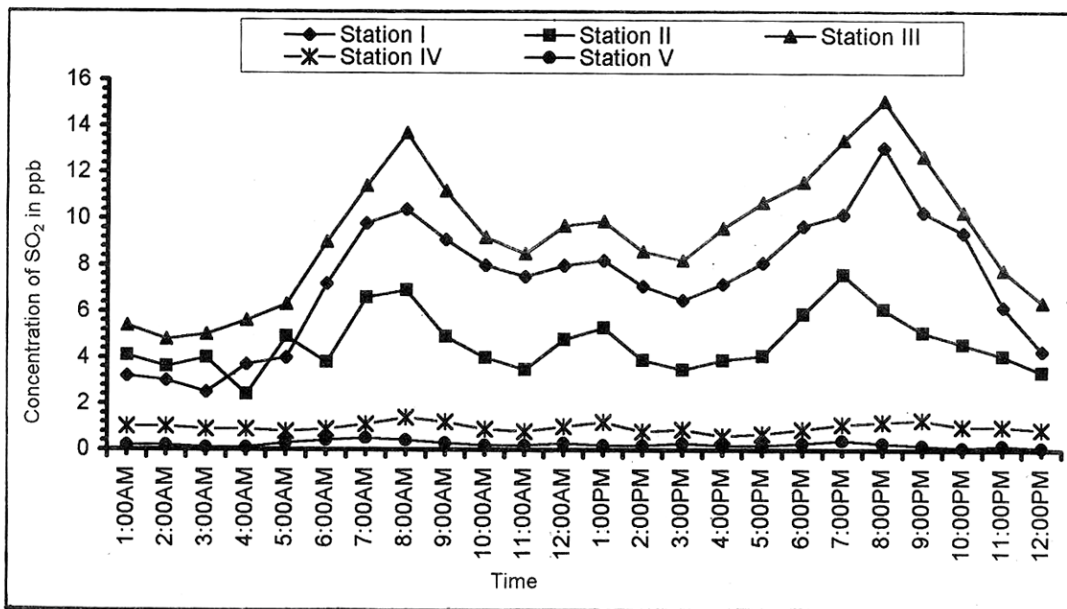


Fig. 2. Hourly average concentration of SO<sub>2</sub> recorded in the atmosphere of Karachi city.

this high concentration of SO<sub>2</sub> at this Station may be KESC Power Plant and Pakistan Steel Mill, as coal combustion accounts for approximately all the sulphur emission around the vicinity of Pakistan Steel Mill. At Stations I and II, the main cause was combustion from boilers and power generation plants and similarly at Stations IV and V, and the main cause of SO<sub>2</sub> may be emissions from vehicular traffic.

Figure-3 shows the trend of ozone concentration at different selected Stations. Highest concentration was found to be 16.7, 30.1, 27.2, 20.0 and 10.7 ppb at Stations I, II, III, IV and V respectively. Ozone is a photochemical oxidant and is generated by downward mixing of stratospheric ozone and also as a result of chemical reactions involving the absorption of solar radiation by nitrogen dioxide in the presence of volatile organic compounds and carbon monoxide [5]. It has been reported, that in the emitted plume, the reaction of NO, NO<sub>x</sub> and O<sub>3</sub> is very rapid at typical ambient ozone concentration. Concentration of ozone attains its maximum level in the mid afternoon and starts decreasing as the ultraviolet radiation from the sun declines. The reaction of photochemical oxidants has

time scale of one to a few minute [6]. At Station I, the ozone concentration was found to be low during the daytime. It is because, the main emission sources near the Station were emissions from Power Generation Plant and boiler of the industries, which were about 45 - 60 meter away from the receptor, having a time scale of less than one minute and the reaction was not completed due to lag of time. At Stations II and III, the emission sources were same as at Stations I, whereas at Stations IV and V, emission source was vehicular combustion. The time scale at Stations II to V, between receptor and effectors was more than one minute and hence the reaction got completed and high concentration of ozone was therefore found during the daytime.

Figure 4 shows the trend of NO at five selected Stations. The figure shows that the highest average concentration of NO was found to be 17.1, 11.0, 9.7, 6.0 and 1.8 ppb at Stations I, II, III, IV and V respectively. Figure 5 shows that the maximum average concentration of NO<sub>x</sub> was recorded 43.6, 26.7, 19.2, 9.3 and 5.3 ppb respectively at Stations I, II, III, IV and V respectively. NO and NO<sub>x</sub> are also photochemical oxidants. A distinct photochemical reaction between NO, NO<sub>x</sub> and solar energy has been

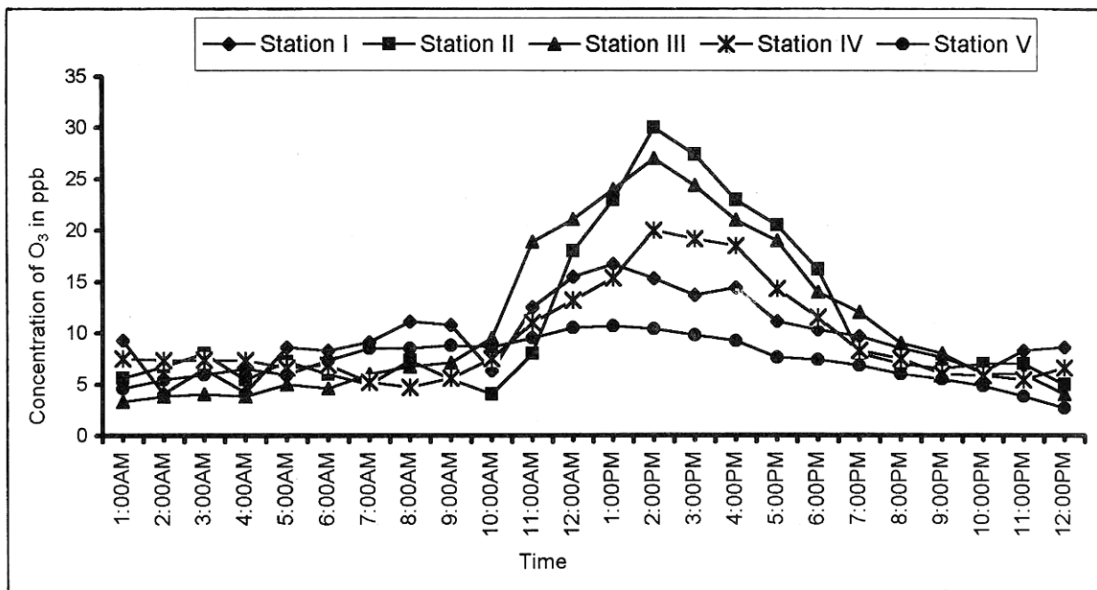


Fig. 3. Hourly average concentration of O<sub>3</sub> recorded in the atmosphere of Karachi city.

established and as the solar energy increases during the day time, the level of NO, NO<sub>x</sub> decreases. At Station I, the maximum value of hourly average concentration of NO and NO<sub>x</sub> was observed 17.1 and 43.6 ppb, respectively, between 7:00 to 9:00 AM, and then it gradually decreases to a minimum at midday and then increases again in the afternoon and reaches to its maximum at midnight due to lag of time and the reaction was not completed. At Stations II, III, IV and V, the maximum value of hourly average concentration of NO was recorded 11.0, 0.7, 6.0 and 1.8 ppb respectively, and concentration of NO<sub>x</sub> 26.7, 19.2, 9.3 and 5.3 ppb respectively, between 7:00 to 9:00 AM.

Carbon monoxide is produced by incomplete combustion of fuel (coal, oil, charcoal or gases), incineration of biomass, solid waste or particularly anaerobic decomposition of organic materials. CO is of primary concern, so it has direct effect on the human health. At Station I, the highest value of hourly average concentration of CO was recorded 0.9 ppm; with wind direction 154° - 207° S and wind speed, in the range of 1.2 to 3.4 m/sec from 5:00 to 8:00 PM. At Station II, hourly average concentration of CO was found to be 0.8 ppm, with wind direction 90° to 114° E and wind speed 1.4 to 2.1 m/sec, between 5:00 to 6:00 PM. The higher values of CO,

measured at Stations I and II, may be due to emissions from nearby industries, power generation plants and boilers of the industries. The highest concentration of CO at Station III was recorded to be 0.7 ppm, with wind direction between 82° to 112° NE and wind speed between 1.3 to 3.6 m/sec, during 6:00 to 7:00 PM. The main source of CO pollution at this station most probably was the evolution of combustion gases from Pakistan Steel Mill and KESC Power Plant, located in NW and NE direction of Station III. At Stations IV and V, the maximum value of hourly average concentration of CO was found to be in the range of 0.5 and 0.3 ppm, respectively between 7.00 to 9.00 A.M. The instance of carbon monoxide found at these stations may be due to motor vehicles. As the air currents were coming at Station IV from the main University road and at Station V from the main Super Highway, where traffic density is quite high.

Sulphur dioxide is a man made pollutant; its emission in the form of SO<sub>2</sub> arises mostly from combustion of trace amount of inorganic and organic sulphur, contained in the fuel. All the sulphur emissions around the vicinity of Pakistan Steel was due to coal combustion. 80% of the city's total consumption of furnace oil is being used in KESC Power Generation Plant at Port Qasim, which is the

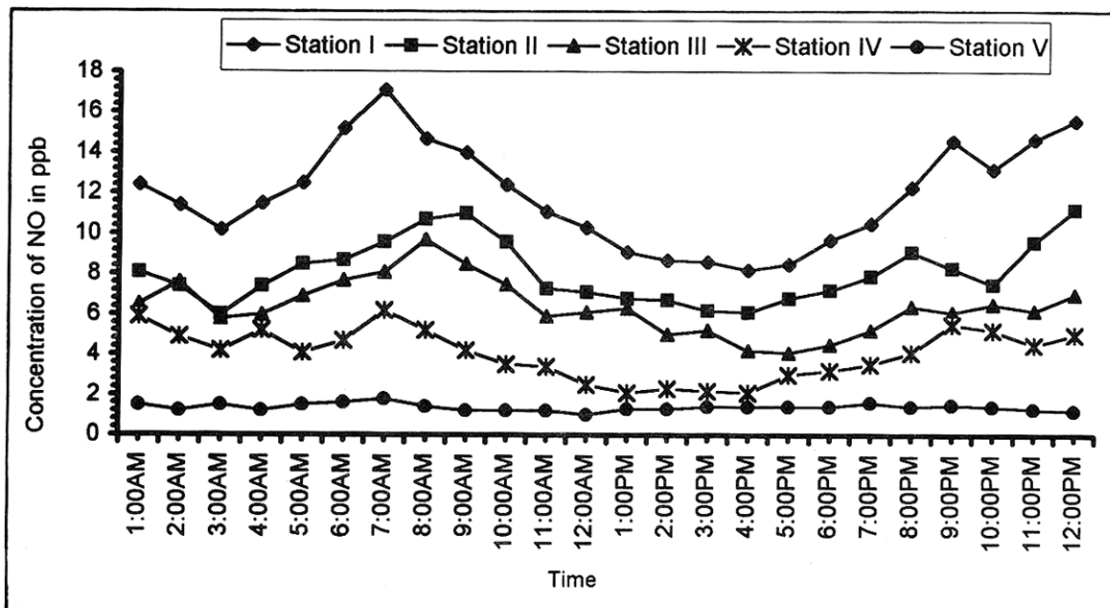


Fig. 4. Hourly average concentration of NO recorded in the atmosphere of Karachi city.

main source of  $\text{SO}_2$  emission [7]. Highest value of concentration of  $\text{SO}_2$  found at Stations I, II and III was found to be 13.1, 7.6 and 15.1 ppb, respectively, between 6:00 to 9:00 PM. The main source of  $\text{SO}_2$  at Station I was power plant and boilers of nearby industries, located in SW direction, at Station II, a large oil refinery located in SW direction and at station III, Steel Mill and KESC Power Plants located in NW and NE directions. Relatively high concentration of  $\text{SO}_2$  obtained at stations I, II and III, during the specified periods, may be attributed to combustion gases of nearby industrial units. Pollution generated at these stations may accumulate during the night beneath a very stable atmospheric condition, a few hundred meter high, and then be carried down to the ground in the morning. The concentration of  $\text{SO}_2$  at Stations IV and V was 1.4 and 0.5 ppb respectively between 6.00 to 9.00 A.M. At these stations, the source of pollution of  $\text{SO}_2$  may be due to the fuel combustion generated by vehicular traffic.

Stations I, II and III were all located in industrial areas, but the hourly average concentration of ozone found at Station I was found lesser than that recorded at Stations II and III. The lower values of ozone obtained at Station I may be due to the emissions from nearby Power Generation Plant and boiler of industries, about 45 – 60 meters away from

the receptor. As a result the chemical reaction between the two mixing species was not completed due to lag of time and thus a lower concentration of ozone was found at Station I.

Stations II and III were also located in industrial areas and higher values of ozone were obtained here as compared to Station I. It was because, the main emission sources at Station II were KESC power plant of 80 MW/hr and the boiler of industries, whereas at Station III, the main emission source were Steel Mill and KESC Power Plant of 350 MW/hr and the distance between emitter and receptor has a time scale of one to a few minute to complete the reaction.

At Station IV, the emission may be due to the exhaust gases of motor vehicles. The air currents were coming from the main University road, which is about 20 Km down wind from the receptor, whereas at Station V, the emission may also be due to the motor vehicles and air currents were coming from Super Highway, which is about 1Km down wind from the receptor.

Nitrogen oxides are of great concern, because of their role as a precursor of ozone production in the presence of sunlight. NO and  $\text{NO}_2$  are emitted

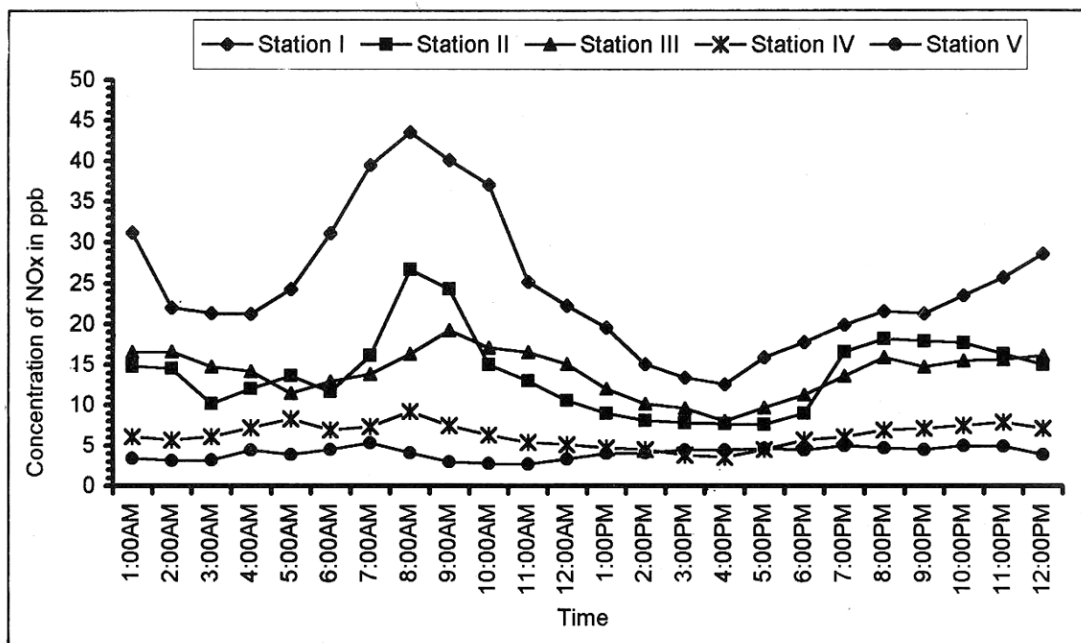


Fig. 5. Hourly average concentration of NOx recorded in the atmosphere of Karachi city.

together from combustion sources and exist equilibrium in the atmosphere and usually referred as NOx. The diurnal pattern of NO and NOx has correlation with solar energy. A distinct photochemical reaction between NO, NOx and solar energy has been established, as the solar energy increases during the daytime and the level of NO and NOx decreases. The reaction of photochemical oxidants has a time scale of one to a few minute [8].

At Station I, the highest values of hourly average concentration of NO and NOx was found to be 17.1 and 43.6 ppb respectively, between 07.00 to 09.00 AM. The NO and NOx, mainly emitted at this station from the combustion of industries and power plants, and were about 45 - 60 meters away from the receptor. The reaction is therefore even more rapid here; having a time scale of only few seconds and the chemical reaction between the two mixing species was not completed due to lag of time and shows the higher concentration of NO and NOx during the day time. However at Stations II, III, IV and V, the highest value of hourly average concentrations of NO and NOx were found before the sun rise and starts decreasing as the ultra violet radiation from the sun increases and again increases as ultra violet

radiation from the sun declines. The main contributor of NO and NOx at Stations II and III were found to be the combustion gases emitted by industries, whereas at Station IV and V, the main source was the combustion emitted by the vehicular traffic. At all of these four stations, the distance between emitter and receptor was more than one minute, so the reaction between the two mixing species was completed and shows the lower concentration of NO and NOx during the day time.

Table I shows the Time Weighted Average value of all the measured pollutants, found at the selected stations, in comparison to WHO recommended Air Quality Guidelines. The Table indicates that the concentrations of ambient air pollutants found at these stations are well within the WHO limits.

The air pollution has become a world wide public health problem, particularly in large towns and cities of the developing countries. People in developing countries are normally exposed daily to very high levels of pollution for 3 - 7 hours for the last so many years [9]. An estimated 130,000 premature deaths and 50 - 70 million incidents of

respiratory illnesses occur each year due to episodes of urban air pollution in developing countries and half of them are only in East Asia region [10]. Air pollution increases the risk of chronic obstructive pulmonary diseases and acute respiratory infections, lungs and chest cancer, tuberculosis, prenatal outcomes, including low birth weight and eye diseases. The number of lung cancer cases, by air pollution is also on the increase, in which there are mostly male cases. The worst affected age group is of between 50 - 60 years, but now instances of vulnerability to air pollution have also been found in lower age group of 45 - 55 years. It is mainly because of increasing level of air pollution. Effect of air pollution on human health varies according to the intensity, duration of exposure and health status of exposed population.

### Experimental

In order to assess the load of air pollutants in the atmosphere of Karachi city, monitoring of different ambient air pollution components was carried out to assess the trend of air pollution in the city. For this purpose, five locations were selected and categorized as follows:

- Station I Industrial Area in District West
- Station II Industrial Area in District East
- Station III Industrial Area along the sea coast
- Station IV Residential Area in District East
- Station V Down town Area

Station I is an industrial area in District South of Karachi, Station II is an industrial area in District East of Karachi, whereas station III is an industrial area along the coast of sea, which is going to be one of the biggest industrial area of Karachi in the near future. Station IV is a residential area in District East and the population living around this station belongs to the middle and high-income groups. Station V is down town area of Karachi city and was selected as a control site for the pollution measurement. At each station, monitoring of O<sub>3</sub>, SO<sub>2</sub>, CO, NO and NO<sub>x</sub> in the ambient air was carried out continuously for eight days and nights. This study was conducted in winter season.

At all stations, data was collected using Air Pollution Monitoring Mobile Laboratory (Environ-

mental SA, France). This Mobile Laboratory is designed to measure quite low concentrations of gases, such as O<sub>3</sub>, SO<sub>2</sub>, CO, NO, NO<sub>x</sub>, HC and PM<sub>10</sub>. The Laboratory is fitted with NO and NO<sub>x</sub> Analyzer (Chemi-luminescent AC-31M Analyzer), UV Fluorescent SO<sub>2</sub> Analyzer (Model AF-21M), Gas Filter Correlation CO Analyzer (Model CO-11M), Ambient Suspended Particulate Beta Gauge Monitor (Model MPSI-100), Solar Radiation Monitor (Obsermet-CM5), Barometric Pressure Sensor (Obsermet OMC-506), Wind Speed/direction Sensor (Obsermet OMC-160) and, Humidity and Temperature Sensor (Obsermet PMC-402). Calibrations were made by NO<sub>2</sub>, SO<sub>2</sub> Permeation Tube Oven and Zero Gas Generator. Ozone analyzer O<sub>3</sub>41M has its own ozone generator for span gas.

An Intelligent Data Logger SAM-32, fitted in the Laboratory records spot concentrations of each parameter at every second and provides 15 minutes averages. The logger also monitors instrument alarm and diagnostic function and control daily instrument zero/span response check. CO11M was calibrated by standard span gas supplied and certified by M/s. Alphagaz, France. A SCANAIR, software installed in the system was used for acquisition, editing and recording logical and analogical data from the Intelligent Data Logger SAM32. The 15 minute average values for O<sub>3</sub>, SO<sub>2</sub>, CO, NO, NO<sub>x</sub> concentrations were calculated for daily hourly average values. The daily hourly average concentration values were further averaged for hourly average values for the respective hour of the measuring time, i.e., 8 days and also for Time Weighted Average (TWA) values for 1h, 8h and 24h for each Station.

### Conclusions

The baseline data generated for major ambient air pollution components at different selected sites in the atmosphere of Karachi city shows that the concentration of ambient air pollutants such as O<sub>3</sub>, SO<sub>2</sub>, CO, NO and NO<sub>x</sub> are all well within the permissible limits, recommended by the World Health Organization. This study shows that NO and NO<sub>x</sub> are being emitted from combustion of fuel in vehicles, power generation plants and boilers of industries, whereas O<sub>3</sub>, SO<sub>2</sub> and CO is mainly emitted from vehicles and from industrial processes. In future, high rising trend of motor vehicles and industries may result in adverse effects on the environment in the atmosphere of Karachi city.

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