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# Measurement of Sulphur Dioxide and PM10 at Korangi Industrial Area and Photochemical Oxidants at Uptown Area of Karachi

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Baseline measurements of sulphure dioxide and PM10 were carried out by Air Pollution Monitoring Mobile Laboratory in the Korangi Industrial Area of Karachi. This is the first study performed in this area. The highest concentration of $SO_2$ and PM10 was found to be 25.8 and 177.9 $\mu gm^{-3}$ respectively. Both $SO_2$ and PM10 shows similar variations throughout the measurement period, this indicates that these pollutants originate from a similar source. Traffic density at the sampling site was also low and it was concluded that the contribution of $SO_2$ and PM10 from mobile sources in this area is relatively small. The pollution found in this area is mostly within WHO threshold limits. Ozone and oxides of nitrogen were also measured at a sampling site located in the uptown area of Karachi. Average variations of $O_3$, NO, $NO_x$, and solar radiation have been presented for winter. The formation of ozone due to photochemical reactions has also been discussed. Ambient concentrations of NO, $NO_x$ and $O_3$, are strongly interrelated. It has been concluded that the level of photochemical oxidants found in this area during winter time is mainly due to vehicular traffic from near by super high way.

***Key words:*** Air pollution, $SO_2$, PM10, Photochemical oxidants.

## Introduction

Rapidly increasing population, factories, processing industries and transport fleet have adversely affected the quality of air, specially in urban areas of Pakistan. At the rate at which the cities are growing and with the general absence of pollution control measures, air pollution will probably worsen. The quality of life of many urban residents will continue to deteriorate. WHO commission for health and environment have identified urban air pollution as a major enviornmental health problem deserving high priority for rectification. Developing countries face a major challenge in trying to reconcile growth with urban air quality and global air quality. In some cities such as Mexico, Delhi and Bangkok, air quality problems are already acute, and are accompanied by severe traffic congestion, other major cities in rapidly developing countries could face a similar problem in future. The urban air quality monitoring and assessment program in GEMS/AIR within the frame work of WHO/UNEP selected some megacities for continous air pollution monitoring. Megacities are defined as urban agglomerates with current or projected populations of 10 millions or more. Karachi has also been declared as megacity among the 20 megacities of the world (Lyuba 1993).

The major cause of air pollution is combustion. Combustion of coal, wood, and oil, various industrial activities, and heavy vehicular traffic gives rise to air pollutants. Sulphur dioxide emission can be associated with suspended particulate matter releases leading a complex mixture of pollutants during fossil fuel combustion. Sulphur dioxide has a natural global biogeochemical cycle, (eg. volcanic emission) but emissions can be substantial 80% of all sulphur dioxide emissions due to fossil fuel combustion. Refineries and smelters also produce significant amount of sulphur dioxide. It has been estimated that about $127x10^6$ tonnes per year of sulphur dioxide is being emitted in the atmosphere by man of which 90% is produced in northern hemisphere (UNEP 1983). Sulphur dioxide disperse in air and reacts with other substances, eventually it reaches a 'SINK' which may be land surface, ocean or a receptor, such as plants or man. It also goes through the phenomenon of long range transportation of air pollution. $SO_2$ and its oxidation products can travel thousand of kilometers, and not only cross the national boundary but also create environmental problems for other countries. During transport and dispersion chemical oxidation to sulfuric acid along with dilution concentration lead to videly varying $SO_2$ in the air.

Solid and liquid aerosols suspended in the atmosphere are referred to as particulate matter. They arise either from condensation process or from dispersion process such as erosion, grinding, spraying, etc. Their size ranges from 0.0002μ to 500μ in diameter. Particulate larger than 10μ settles out of the air quite easily, while sub 10μ PM10 causes two major problems, deposition and adhesion. Adhesion of particulate refers more specifically as respiratory tissue adhesion. Most of the damages due to adhesion in respiratory tract is caused by particulate from 0.5 to 2.0 micron in diameter and these particle are

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most difficult to remove from atmosphere by pollution control equipment. Particles less than 10μ follow the motion of the gas in which they are borne and remain suspended for significantly longer period as their settling velocities are very small (Howard 1973). Suspended particulate matter also arise from other human activities such as dust raised by vehicular traffic. These pollutants constitute a major part of the urban air pollution in many places. Although there are many air pollutants of concern but only two have been extensively measured so far by GEMS/Air monitoring project and data for sulphur dioxide and particulate matter are available from 1973 (UNEP 1987). Natural production of nitrogen oxides has been estimated to be 990 x $10^6$ tonnes per year mainly from volcanic emission and bacterial activity. Man-made emissions of nitrogen oxides come principally from combustion of fossil fuels, which were estimated to be 48 x $10^6$ tonnes per year (UNEP 1983). $NO_x$ and other primary pollutants can react to form secondary pollutants referred to as photochemical oxidants, the major components of which include $NO_x$, ozone and per oxyacetyl nitrate (PAN). Nitric oxide (NO) plays an important role in the formation of nitrogen oxide ($NO_2$), which is an active compound in photochemical smog formation. In urban areas where traffic density is high, $NO_x$ ($NO+NO_2$), poses real danger and plays an active role in photochemical reactions. Vehicular emissions are of particular significance because of low emission heights. Seventy percent of $NO_2$ concentration in urban areas can be attributed to vehicle pollutants which causes 90% episode conditions (Simpson 1987; Simpson *et al* 1988).

## Experimental

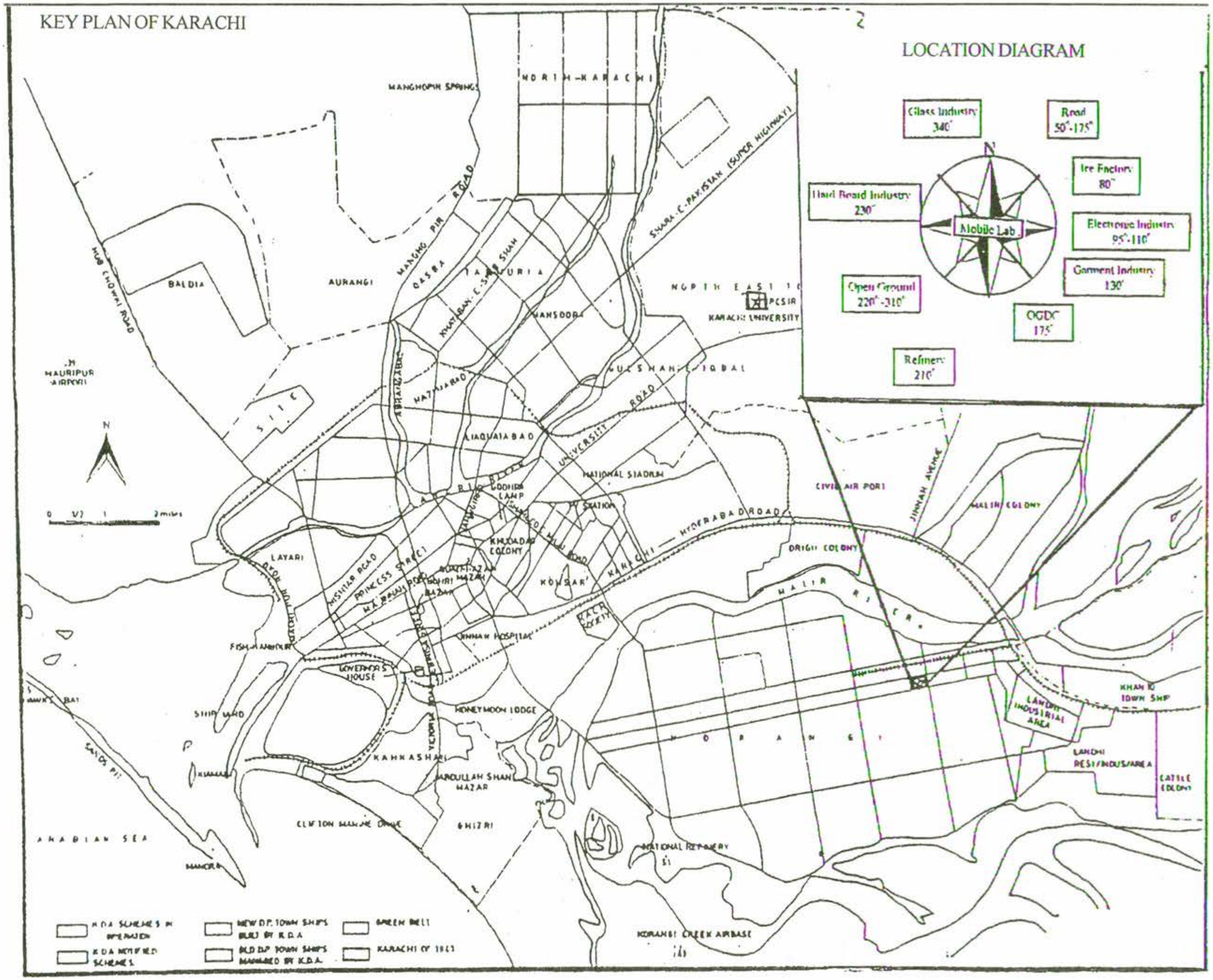
The ambient air quality measurements were made by Air Pollution Monitoring Mobile Laboratory designed and fabricated by Environmental S.A., France. The laboratory is fully equipped to measure low concentrations of pollutant gases such as $SO_2$, NO, $NO_x$, CO, $O_3$, HC and inhalable particulate (PM10) in suspension. Chemiluminescent analyser model AC 30M was used for the estimation of NO, $NO_x$ levels. AC30 analyser is of two channel type and measures NO and $NO_x$ simultaneously on the same sample. The interference due to hydrocarbons was eliminated by the use of optical filter. Ozone was measured by a UV photometric ozone monitor, model $O_3$ 41M, which provides continuous ozone measurements. Measurement of solar energy was made by Pyranometer. The laboratory is also equipped with meterological sensors mounted on a telescopic mast, data acquisition and processing system. These advanced technology sophisticated instruments are microprocessor regulated and define homogeneous and coherent range. This range of automatic and continuous analyzers enables to monitor ambient air continuously. An intelligent data logger SAM32 records site concentrations every second and accumulates these to provide 15 minute averages. The logger also monitors instrument alarm and diagnostic functions and controls zero/span response checks of every analyzer. A SCANAIR software was used for acquisition, editing and recording logical and analogical data from SAM32. Fifteen minutes average data of 15 days from Korangi industrial area for $SO_2$ and PM10 and Photochemical oxidants at uptown area of Karachi is presented in the form of Histogram and graphs.

## Results and Discussion

The quantum of air pollution caused by industrial and transport sector is still not known in Pakistan. This is the first baseline study carried out for the measurement of air pollutants in Korangi industrial area. There are more than 20,000 small and large industrial units working in various industrial estates of Karachi, such as Sindh industrial Trading Estate (SITE), Landhi Industrial Trading Estate (LITE), Korangi Industrial Trading Estate (KITE) etc. Korangi industrial area is located in the South East of Karachi (Lat:24°-51'/Long:67°-11') in the district East. It has a total area of 34.4 sq.Km and approximately 2000 various types of industries are located in this area, which include tanneries (more than 100 units), pharmaceutical, textile, chemical and refineries etc. Continuous measurements of PM10 and $SO_2$ were carried out for fifteen days in the month of March, 1994. Fifteen minutes average concentration of PM10 and $SO_2$ is presented in the form of Figs 1 & 2. Adequate quality control procedures were followed during the measurements to ensure the validity of the data collected. The validity criterion was 75%.

Greater attention is being paid for characterising the nature of suspended particulate matter because of the heterogeneous nature of the pollutant. The data collected as total suspended particulate matter have only limited value for health effect assessment. Therefore monitoring objectives have been narrowed to determine specific size fractions of particulate matter, such as matter less then 10 micrometers in diameter (PM10), which is in the respirable size range. Sulphur dioxide and PM10 usually occur together representing a complex mixture of by-products of combustion of fossil fuels. On the basis of observation, WHO evaluated jointly $SO_2$ & PM10 in air quality guidelines (WHO 1987).

Measurements of $SO_2$ and particulate matter were carried out in a multinational pharmaceutical industry locatedc in sector 20-21 of Korangi industrial area. Location diagram of Air Pollution Monitoring Mobile laboratory is given in guide map.


KEY PLAN OF KARACHI
LOCATION DIAGRAM
Glass Industry 340°
Road 50°-175°
Ice Factory 80°
Hard Board Industry 230°
Mobile Lab
Electronic Industry 95°-110°
Garment Industry 130°
Open Ground 220°-310°
OGDC 175°
Refinery 210°
N
NORTH-KARACHI
MANGHOPIR SPRINGS
BALDIA
AURANGI
MANSOORA
NORTH EAST
PCSIR
KARACHI UNIVERSITY
LIAQUATABAD
NATIONAL STADIUM
CIVIL AIR PORT
JINNAH AVENUE
MALIR COLONY
DRIGH COLONY
LAYARI
JINNAH HOSPITAL
GOVERNOR'S HOUSE
HONEYMOON LODGE
KAHKASHAN
ABDULLAH SHAH MAZAR
CLIFTON MARINE DRIVE
ARABIAN SEA
MANORA
NATIONAL REFINERY
KORANGI CREEK AIRBASE
LANDHI INDUSTRIAL AREA
LANDHI RESI/INDUS/AREA
CATTLE COLONY
KHAN TO TOWN SHIP
SANDS PIT
HYDERABAD ROAD
UNIVERSITY ROAD
KORANGI
MALIR RIVER
FISH HARBOUR
0 1/2 1 2 miles

Guide map.

The maximum average concentration 179 µgm$^{-3}$ of PM10 was observed between 10 to 20 h. Fig 1 shows average variations of PM10 in the Korangi industrial area. PM10 shows significant relationship with the weather variables. The wind speed increased with the increase in temperature during day time where as the humidity decreases. The increase in the PM10 may be due to the increase in wind speed and decrease in himidity which tends to blow the particles in the air and remained suspended for longer period.

Topographical features and meteorological conditions play a vital role in the transportation and dispersion of air pollutants. Mountains and ridges can also serve as barriers to air pollutants transport.

Karachi has a relatively level topography and its climate is influenced by a body of water. The presence of a significant body of water can lead to microclimatological effect and to onshore and offshore diuranal wind patterns. Karachi is located in a semiarid zone and 40-60 percent of the suspended particulate matter is usually wind blown dust (Yousufzai *et al* 1991). Measures to control the anthropogenic suspended particulate matter emission in such areas have only limited effect.

Very little work has been published relating to the health effects of inhalable particles (PM10) and no study was published till 1995 (Bert *et al* 1995). Many recent studies have emphasized that particles may exert ill effects on health even in the absence of high levels of sulphur dioxide (Wieslaw 1995). It has been observed that 24 h PM10 levels were significantly associated with all respirable admissions, cardio-vascular disease admission, bronchitis admission, chronic obstructive pulmonary disease (COPD) deaths and pneumonia. WHO has established guideline 150-230µgm$^{-3}$ for suspended particulate matter (UNEP 1987), where as United States, EPA promulgated 24 h PM10 National Ambient Air Quality Standard of 150µgm$^{-3}$ without consideration of concurrent levels of $SO_2$ (USEPA 1987).

In United Kingdom EPAQS recommended 50µgm$^{-3}$ PM10 as standard in 1995 (Air Health Strategy 1996). The health effect study carried out for EPAQS in UK observed that a 10µgm$^{-3}$ rise in PM10 would result in 2.4% increase in respiratory ad-

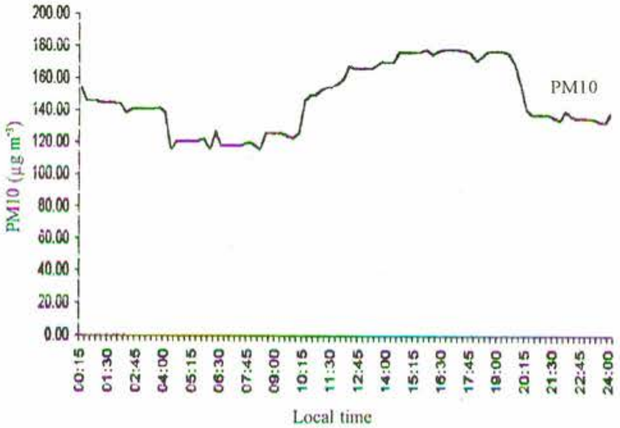


**Fig 1.** Average variation of PM10 at Korangi industrial area.

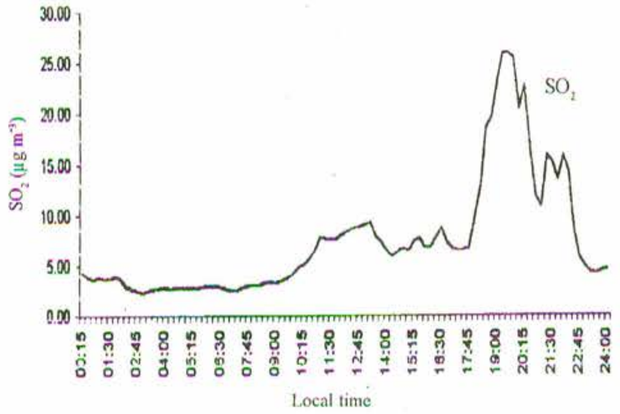


**Fig 2.** Average variation of $SO_2$ at Korangi industrial area.

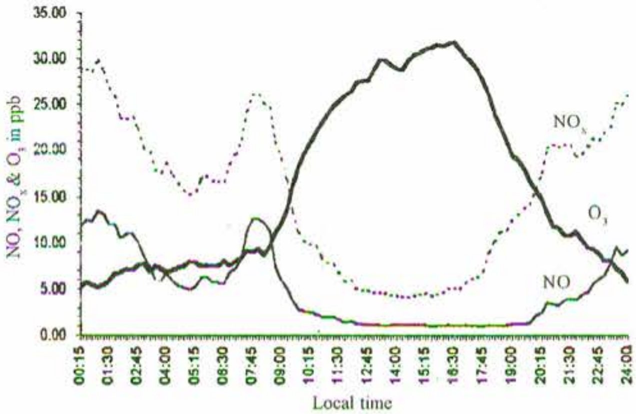


**Fig 3.** Average variation of NO, $NO_x$ & $O_3$ in winter at up town area.

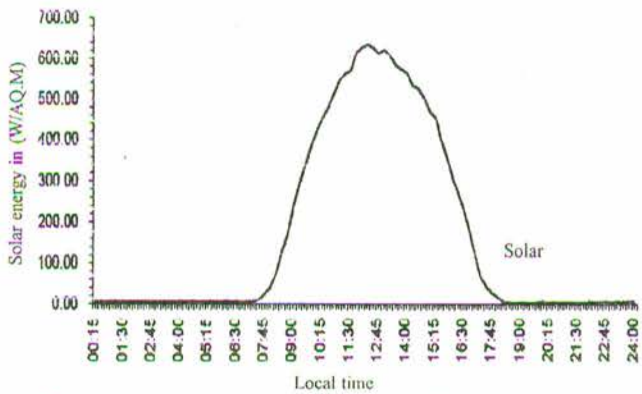


**Fig 4.** Average variation of solar power in winter at up town area.

missions, 2.1 increase in cardiovascular disease admissions and 1.1% increase in all cause mortality (Wordley *et al* 1995). The low levels of exposure at which effects on health need re-evaluation in WHO air quality guidelines.

Sulphur dioxide can be oxidised to form sulphate containing compounds including sulphuric acid and ammonium sulphate. It is this heterogeneous mixture that produces the various health and environmental effects in many areas. Exposure to sulphur dioxide and sulphate aerosol results in respiratory ailment in humans particularly in urban areas. Estimated background concentration of sulphur dioxide is 0.2ppb and calculated atmospheric residence time is 4 days (Kenneth and Cecil 1976).

Figure 2 shows the average variation of $SO_2$ in the Korangi industrial area. Maximum average concentration of $SO_2$ was recorded between 1800 to 2200 h. The wind direction during this period was between 200 to 250° and average wind speed was between 2.34 to 3.96 $msec^{-1}$. Higher concentration of $SO_2$ observed here may be due to the refinery which is about 1 km away in SW direction of the receptor (Fig 1). The lowest average concentration of $SO_2$ was $2.35 \mu gm^{-3}$ at 3:00 hour, during this period wind direction was 106° and wind speed was 1.6 m $sec^{-1}$.

Low level of $SO_2$ was observed between 0-9 h the concentration of $SO_2$ gradually increased and reached to the maximum at 16:45 h. Most of the industries in this area are working on single shift basis from 9:00 h to 5:00 h and almost all industries are using natural gas for boilers and other combustion purposes. The gas (Sui gas) supplied is almost free from sulphur. This may be one of the causes for low level of $SO_2$ found in the atmosphere of this area.

The variation of both in sulphur dioxide and PM10 in the Korangi industrial area shows similar variations through out the measurement period, which indicates that these pollutants originate from similar sources. Average concentration of PM10 and $SO_2$ was found to be 147.2 $\mu gm^{-3}$ and $7.4 \mu gm^{-3}$, maximum average concentration during the monitoring period was 177.9 and 25.8 $\mu gm^{-3}$, where as minimum average concentration measured were 114.9 and 2.3 $\mu gm^{-3}$, for PM10 and $SO_2$ respectively.

Although the motor vehicle traffic is also a significant source of air pollution in all the megacities of the world. Karachi has more than 650 thousand registered motor vehicles (Yousufzai 1991), but the traffic density near by road of sampling site at Korangi industrial area is quite low. Traffic density survey conducted by the Traffic Engineering Bureau, Karachi Development Authority has observed that total number of 7934 vehicles per day are plying on this road between 7:00 to 22:00 h. The road was quite wide and open. The relative contribution of mobile source on the measured concentration of PM10 and sulphur dioxide seems to be small.

Measurement of NO, $NO_2$ and $O_3$ were carried out at sub-tropical city of Karachi. The sampling site was located at Lat.: 24°71' and Long: 76°08' in the uptown area about 20 kilometres downwind from the city centre (Fig 1 site 2). Continuous measurements of NO, $NO_2$ and $O_3$ for fifteen days were carried out in the month of January 94. Fifteen minutes average concentration of NO, $NO_2$ and $O_3$ for winter is presented in the form of Figs 3 & 4.

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 compound (VOC) and carbon monoxide. It behaves as a greenhouse gas as well as a respiratory irritant and potentially damaging to plants. There is evidence to suggest that tropospheric level of ozone have roughly doubled in rural parts of Europe since the turn of century. This increase is widely attributed to human activities (UNEP 1994). The environmental impact of photochemically derived ozone was first studied in 1950 in Los Angeles during smog. Reactions with other pollutants were also observed during the photochemical formation of ozone (Howard 1973). Ambient concentration of NO, $NO_x$ and $O_3$ are strongly interrelated. Photochemically generated ozone and equilibrium between NO, $NO_x$ and $O_3$ is quickly established in the absence of local pollutant emissions. This equilibrium is reached in few minutes typically in well mixed air. The concentrations of photo oxidants in ambient atmosphere is also influenced by the rate at which the chemical mechanisms proceed.

Figure 3 shows average variations of $O_3$, NO, $NO_x$ in winter. The formation of ozone is evident during day and highest concentration of ozone was found when solar radiations were at its peak level as shown in graph IV. The sampling site is about 1 Km away from the super highway. Wind direction during winter is mostly NS and average wind velocity during winter was found to be 1.86 meter per second, low wind speed usually accompany inversion, so there was little horizontal dispersion of pollutants. Air masses reaching the sampling site were generally coming from super highway. The maximum average concentration of NO, $NO_x$ and $O_3$ was found to be 13.5, 29.6 and 31.8, ppb whereas minimum average concentration was recorded as 0.9, 4.0 and 5.1 ppb respectively. The amount of NOx emitted from vehicles varies as a function of speed as well as dependent on the type of vehicle. Emission of $NO_x$ from road traffic have increased significantly over past 20 years. $NO_x$ is now a major contributor to poor urban air quality both as a toxic gas and as a precursor in the photochemical production of ozone. $NO_x$ also plays a significant role in acidification . There is no residential or industrial area in and around two kilometre of the sampling site. Total number of vehicles playing of the super highway was recorded to be 50015 vehicles per day (Traffic Engg Bureau 1993). The main sources of air pollution in this particular area are motor vehicles. All the observed quantities can be attributed to motor vehicle plying on the super highway.

## Conclusion

The measurement of sulphur dioxide and PM10 carried out at the Korangi industrial area was mostly within the WHO threshold limits. The air masses during the measurement period were usually coming from the sea and the emissions from the industries were also diluted because of topographical condition. It was also concluded that the relative contribution of mobile sources on the measured concentration of PM10 and $SO_2$ was not significant. Total NO, $NO_x$ levels at any location were dependent primarily on emission and meterological conditions. The level of photoxidants found in the uptown area was mainly due to the vehicular traffic of super highway. Ambient concentration of NO, $NO_x$ and ozone are strongly correlated with solar radiation.

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