4. Air Quality Results

This section discusses the results of the ambient air monitoring conducted in Lahore, Rawalpindi, and Islamabad. Through PEPA, HBP requested the Punjab EPD to monitor the ambient air quality in the three cities using its mobile air monitoring station.

Data for the ambient air quality analysis were compiled graphically, and detailed results are attached in **Appendix C**. Traffic count data are presented in **Appendix D**.

4.1 Ambient Air Quality in Lahore

In Lahore, five sites were selected for ambient air quality monitoring. The Punjab EPD's Mobile Laboratory was used to monitor the following parameters:

- CO
- SO_2
- NO, NO_X
- O_3
- Particulate Matter (PM_{10})
- Total Suspended Particulates (TSP)
- Methane hydrocarbons (METHCs)
- Non-methane hydrocarbons (NMETHCs)
- Wind speed
- Wind direction
- Ambient air temperature
- Humidity
- Solar radiation.
- Heavy Metals (As, Cu, Pb and Zn)

The following sites were selected for ambient air quality monitoring in Lahore:

- Sampling Site 1: Chowk Yateem Khana, Multan Road
- Sampling Site 2: Azadi Chowk
- Sampling Site 3: Chowk Lohari Gate
- Sampling Site 4: Bank Square, Shahrah-e-Quaid-e-Azam
- Sampling Site 5: Qurtaba Chowk

4.1.1 Sampling Site 1: Chowk Yateem Khana

Chowk Yateem Khana is one of the busiest crossings in Lahore and presents a mixture of petrol and diesel driven vehicles, including passenger cars, motorcycles, rickshaws, buses, trucks, wagons, and long vehicles. Ambient air quality was monitored at this site for 17 hrs (from 0700 to 2415). To assess the impacts of vehicular exhaust on ambient air quality, an hourly count of both petrol driven and diesel driven vehicles was undertaken in parallel with ambient air quality measurement.

Discussion of Results

All parameters were measured on an hourly basis, from 0700 hrs to 2400 hrs.

Traffic Count: The minimum and maximum number of diesel vehicles recorded during the 17-hr count was 779 and 1,578 respectively, while the number of petrol vehicles ranged from 1,982 to 5,894. An increase in petrol vehicles was noted at 0800 hrs and the number rose to 5,894 at 2000 hrs. There was no significant variation in the number of diesel vehicles observed at this location site, except that the number rose to a maximum of 1,578 vehicles at 1900 hrs and a minimum of 779 at 2300 hrs.

Carbon Monoxide: The hourly average concentration of CO in the air was recorded at less than 5 ppm between 0800 to 1900 hrs and from 2300 to 2400 hrs. It went up to a maximum of 7 ppm at 2100 hrs, remaining at 5.5 ppm at 2000 and 2200 hrs. The increase in CO concentration was caused by a rise in the number of petrol vehicles passing through the site. The CO values of 0.5 to 7.0 ppm are far less than the international standards and guidelines of 35 ppm (1 hr average) set by US EPA, World Health Organization (WHO) and European Union (EU) countries.

Nitrogen Oxides: The hourly average concentration of both nitrogen monooxide (NO) and nitrogen oxides (NO_X) showed an identical trend, with NO ranging from 31.9 to 194 parts per billion (ppb) and NO_X from 99.2 to 356.9 ppb, while WHO's standard for nitrogen dioxide (NO_2) is 110 ppb (1 hr average). The values are higher than the standard guidelines. The increase in NO and NO_X concentration contents is due to the large number of petrol vehicles passing through the site.

Sulfur Dioxide: A similar trend was observed for hourly average concentration of SO_2, which ranged between 18.9 and 87.6 ppb, reaching a maximum value of 87.6 ppb at 2100 hrs. WHO and US EPA standards are 134 ppb and 130 ppb (24 hr average) respectively. The rise in SO_2 concentration was due to an increase in the number of diesel vehicles passing through the site.

Ozone: The hourly average concentration of O_3 started increasing from 0900 hrs, then decreased from 1800 hrs and remained constant between 2000 to 2400 hrs. Results for O_3 concentration range between 2.8 to 12.9 ppb, against the 90 ppb (1 hr average) standard set by WHO. The value of O_3 was highest at 1200 hrs (12.9 ppb), when solar radiation is at its peak.

Particulate Matter: The hourly average concentration of PM_{10} ranged between 578.4 and 1,362 micro grams per cubic meter ($\mu g/m^3$), with an average value of 1,048 $\mu g/m^3$, against the Japanese standard of 200 $\mu g/m^3$ (SPM). The concentration of PM_{10} was 1,362 $\mu g/m^3$ during maximum traffic hours.

Total Suspended Particles: The concentration of TSP at Chowk Yateem Khana was 3,045 $\mu g/m^3$, while the Japanese standard is 200 $\mu g/m^3$. The high volume air sampler collected samples for 3 hours from 1800 to 2100 hrs.

Figure 4.1 presents a graphical comparison of parameters such as CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at this site, while **Figure 4.2** compares NO_X, SO_2 and O_3 levels with solar radiation at the site.

4.1.2 Sampling Site 2: Azadi Chowk

This crossing was selected because the all traffic entering the city and leaving for northern areas normally passes it. All parameters were measured on an hourly basis from 0600 hrs to 2400 hrs. The number of petrol and diesel vehicles was counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhaust on the air quality on an hourly basis.

Figure 4.1: Air Pollution Comparison with **Traffic Count** at Chowk Yateem Khana (Lahore)

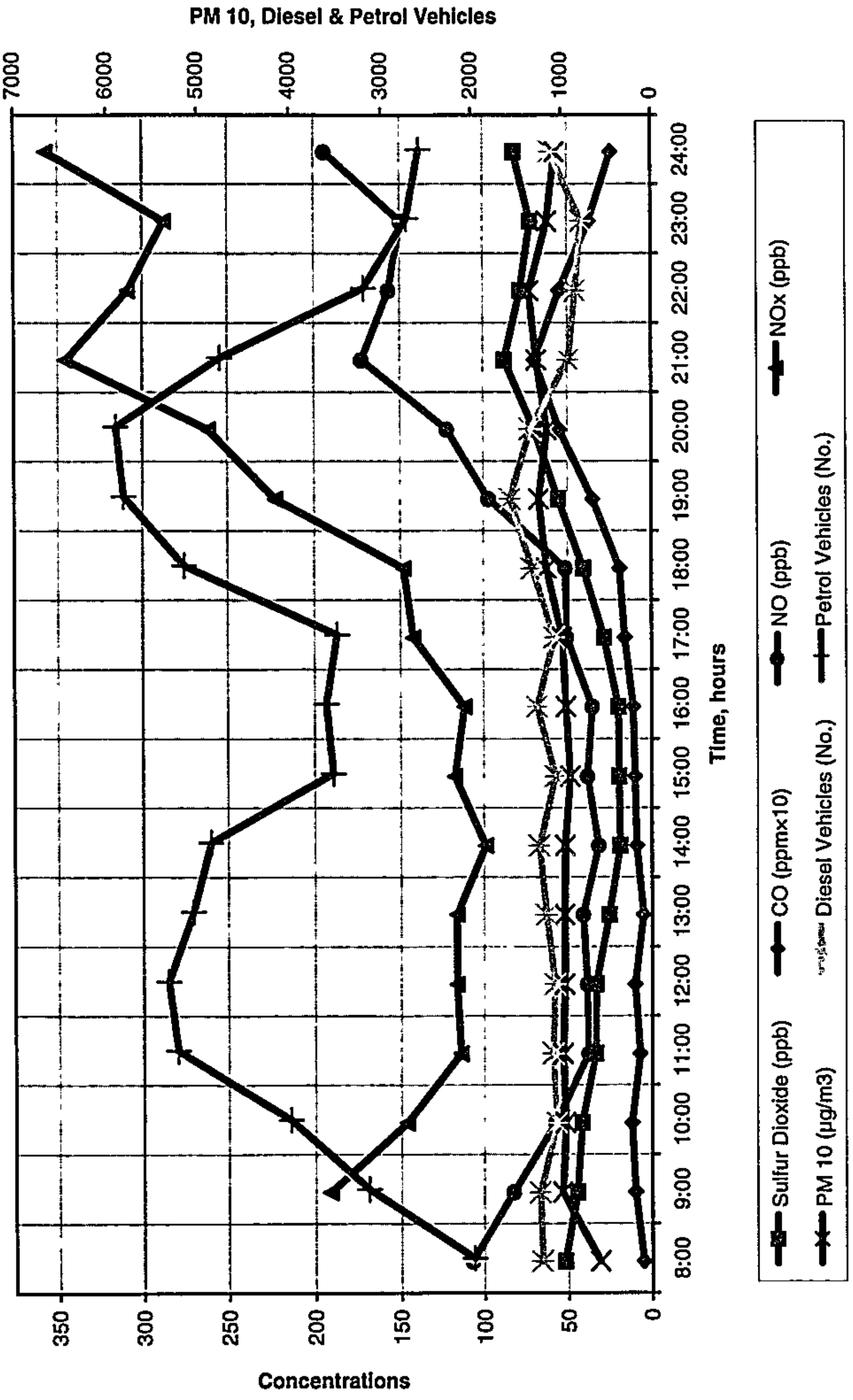
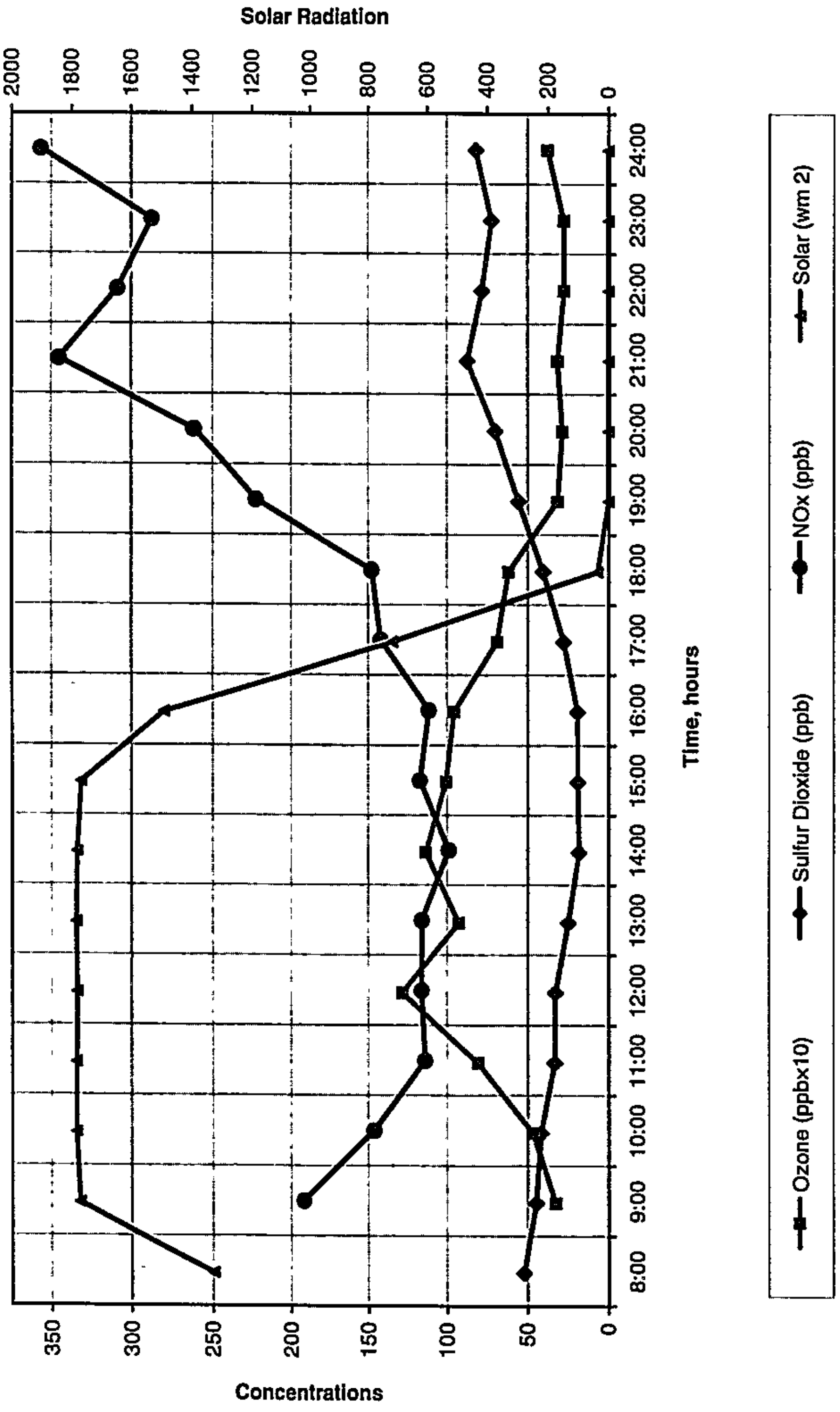


Figure 4.2: Air Pollution Comparison with **Solar Radiation** at Chowk Yateem Khana (Lahore)



Discussion of Results

All parameters were measured on an hourly basis, from 0600 hrs to 2400 hrs. Due to a technical problem in the mobile unit's data acquisition system, data could not be reported between 1300 hrs and 1400 hrs.

Traffic Count: The number of diesel and petrol vehicles passing in one day through this sampling site varied from 737 to 1,386 and 2,942 to 7,294 vehicles, respectively. The number of petrol vehicles started to increase at 0800 hrs, rising to a maximum of 7,294 vehicles at 1200 hrs and then decreasing to 4,294. The second swell started from 1700 hrs, reaching a maximum number of 5,166 at 2100 hrs. No significant variation in the number of diesel vehicles was noted at this site; a maximum of 1,386 vehicles was recorded at 1000 hrs and a minimum of 737 at 2100 hrs.

Carbon Monoxide: The hourly average concentration of CO at this site ranged from 0.1 ppm to 9.4 ppm, far less than the international standards and guidelines of US EPA, WHO, and EU countries. The CO concentration increased to a maximum of 9.4 ppm at 2300 hrs while a minimum value of 0.1 ppm was noted at 1200 hrs. The rise in CO concentration was due to an increase in the number of petrol vehicles passing through the site.

Nitrogen Oxides: The hourly average concentration of both NO and NO_X showed an identical trend, with NO values ranging from 7.4 ppb to 331.5 ppb and NO_X between 46.8 and 405 ppb. Most of the values were higher than WHO's 110 ppb standard for NO_2. NO and NO_X concentration rose to a maximum of 331.5 ppb and 405 ppb respectively at 0600 hrs (These values include calibration readings). The second highest concentration values for NO and NO_X were noted at 2300 hrs and were 217.3 ppb and 401 ppb respectively. The rise in NO and NO_X concentrations coincided with the increase in petrol vehicles passing through the site.

Sulfur Dioxide: A similar trend was observed for the hourly average concentration of SO_2, which ranged from 8.9 ppb to 72.4 ppb, less than the WHO standard (134 ppb). SO_2 concentration increased to a maximum value of 72.4 ppb at 2300 hrs and decreased to a minimum value of 8.9 ppb at 1600 hrs. The rise in SO_2 concentration was due to the increase in the number of diesel vehicles passing through the site.

Ozone: The hourly average concentration of O_3 started increasing from 0900 hrs, peaked at 1500 hrs, started decreasing from 1800 hrs, and remained constant between 2000 and 2400 hrs. The O_3 concentration range was 1.7-17 ppb, which is less than the WHO standard (90 ppb). The maximum concentration of 17 ppb was noted at 1600 hrs, and the minimum of 1.7 ppb at 0800 hrs. The decrease was caused by the decline in solar radiation.

Particulate Matter: The hourly average concentration of PM_{10} ranges from 109.5 to 1,349 $\mu g/m^3$, with an average value of 744.9 $\mu g/m^3$ which is ten times higher than the Japanese standard (200 $\mu g/m^3$). A maximum PM_{10} concentration of 1,349 $\mu g/m^3$ was noted at 2300 hrs.

Total Suspended Particles: The concentration of TSP at Azadi Chowk was 2,120 $\mu g/m^3$, which is higher than the Japanese standard (200 $\mu g/m^3$). The high volume air sampler collected samples from 1800 to 2000 hrs.

Methane and Non-Methane Hydrocarbons: The concentration for methane and non-methane hydrocarbons could not be obtained due to some technical problem in the analyzer in the Punjab EPD's mobile laboratory.

Figure 4.3 compares the measured parameters with the traffic count at Azadi Chowk, while a graphical comparison of NO_X, SO_2 and O_3 levels with solar radiation at the site is presented in **Figure 4.4.**

4.1.3 Sampling Site 3: Chowk Lohari Gate

Chowk Lohari gate was selected for ambient air monitoring because it is situated in the center of a major commercial market in Lahore and has a heavy traffic load during peak hours. Both petrol and diesel vehicles were counted in parallel with ambient air quality measurements to assess the impacts of vehicular exhausts on ambient air quality on an hourly basis.

Discussion of Results

All parameters were measured on an hourly basis from 0700 hrs to 2400 hrs.

Traffic Count: The number of diesel and petrol vehicles passing through this sampling site varied from 280 to 525 and 1,469 to 6,219 vehicles respectively. The number of petrol vehicles started to increase at 0800 hrs, reaching a maximum of 6,219 vehicles at 1100 hrs and then fell to a minimum of 4,791 vehicles at 1700 hrs. The second swell started from 1700 hrs, reaching a maximum of 5,697 vehicles at 1900 hrs. No significant variation was noted in the number of diesel vehicles at this site, except that the number rose to 525 at 1000 hrs and fell to 280 at 2300 hrs.

Carbon Monoxide: The hourly average concentration of CO ranged between 0.6 and 4.2 ppm, which was far less than the international standards and guidelines of US EPA, WHO and EU countries (35 ppm). CO concentration values peaked at 2100 hrs and reached their minimum at 2400 hrs. The increase in CO concentration was caused by the increase in the number of petrol vehicles passing through the site.

Nitrogen Oxides: The hourly average concentration of NO and NO_X showed an identical trend, with NO ranging from 8.6 to 25.0 ppb and NO_X from 51.9 to 95.5 ppb. These values are less than the WHO standard for NO_2 (110 ppb). The concentration for NO and NO_X reached a maximum of 25.0 ppb and 95.5 ppb at 2200 and 1000 hrs respectively. NO and NO_X concentration increased because of the rise in petrol vehicles passing through the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged between 0.0 and 210.9 ppb, which is less than the WHO standard (134 ppb). The SO_2 concentration went up to a maximum of 210.9 ppb at 1800 hrs and fell to a minimum concentration of 0.0 ppb at 2300 and 2400 hrs. SO_2 concentration rose because of the increase in the number of diesel vehicles passing through the site.

Ozone: The hourly average concentration of O_3 ranged between 1.6 and 43.9 ppb. The maximum concentration was noted at 0900 hrs and is less than the WHO standard (90 ppb). The increase to 43.9 ppb at 0900 hrs was due to increase in solar radiation.

Particulate Matter: The hourly average concentration of PM_{10} ranged between 373 and 1,324 $\mu g/m^3$, with an average concentration of 888 $\mu g/m^3$, which is more than the Japanese standard (200 $\mu g/m^3$). A maximum concentration of 1,324 $\mu g/m^3$ was noted at 1900 hrs, when traffic load at the site increased.

Figure 4.3: Air Pollution Comparison with Traffic Count at Azadi Chowk (Lahore)

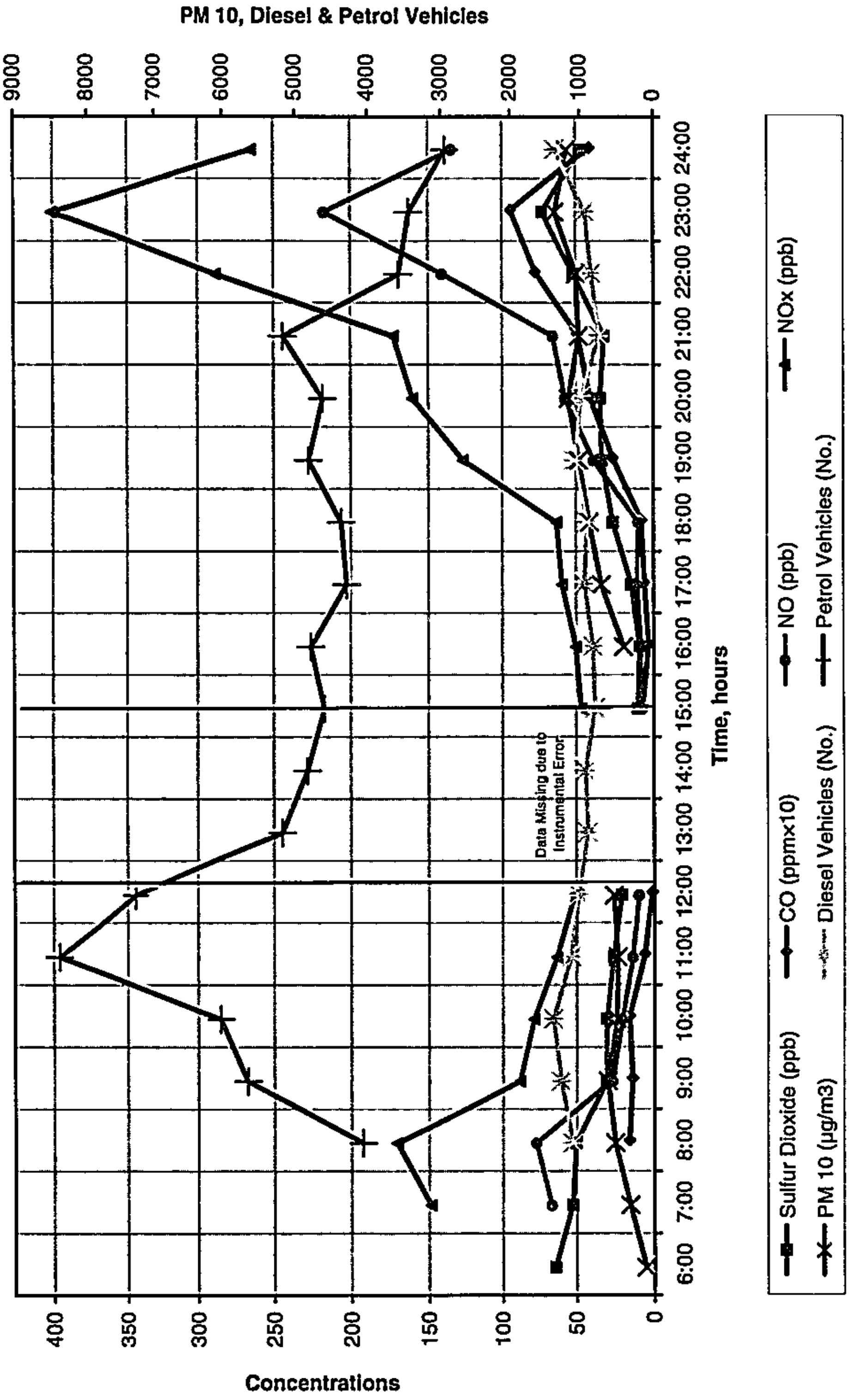
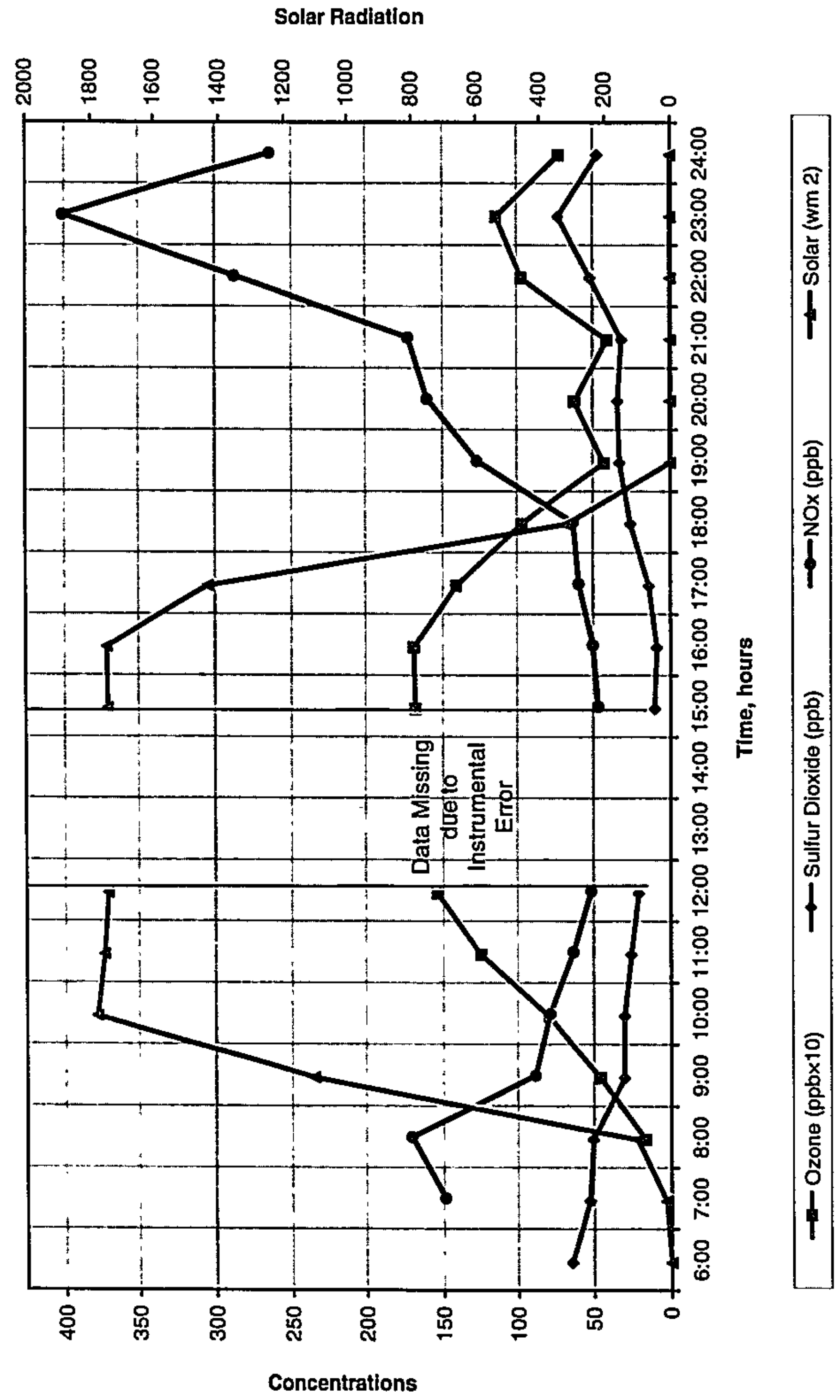


Figure 4.4: Air Pollution Comparison with **Solar Radiation** at Azadi Chowk (Lahore)



Total Suspended Particles: The TSP concentration at Chowk Lohari gate was 2,210 µg/m^3, which is more than the Japanese standard (200 µg/m^3).

Methane and Non-Methane Hydrocarbons: Concentration for methane and non-methane hydrocarbons could not be obtained due to a technical problem in the analyzer in Punjab EPD's mobile laboratory.

Figure 4.5 presents a graphical comparison of parameters like CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at Chowk Lohari gate, while **Figure 4.6** compares NO_X, SO_2, and O_3 levels with the solar radiation at the site.

4.1.4 Sampling Site 4: Bank Square, Shahrah-e-Quaid-e-Azam

Bank Square at the Mall Road was selected for ambient air monitoring because it is the approach road to a major commercial area of the city and has a heavy traffic load, mainly comprising petrol vehicles. Both petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhausts on ambient air quality on an hourly basis.

Discussion of Results

All parameters were measured on an hourly basis, from 0600 hrs to 2400 hrs.

Traffic Count: The number of diesel and petrol vehicles passing through this sampling site varied from 110 to 584 vehicles and 900 to 10,354 vehicles respectively. The number of petrol vehicles started increasing at 0800 hrs, reaching a maximum of 10,354 at 1300 hrs. A minimum of 2,669 vehicles was noted at 2400 hrs. No prominent variation was noted in the number of diesel vehicles at this site; the number rose to 584 vehicles at 1200 hrs and fell to 110 vehicles at 2400 hrs.

Carbon Monoxide: The hourly average concentration of CO ranged from 0.7 to 6.8 ppm. The maximum concentration, which developed at 1100 hrs, is far less than the international standards and guidelines of US EPA, WHO, and EU countries (35 ppm). CO concentration declined to its minimum level at 0800 hrs. It increased because of the rise in the number of petrol vehicles passing through the site.

Nitrogen Oxides: The hourly average concentration of both NO and NO_X showed an almost identical trend, with NO ranging between 4.0 and 296.0 ppb and NO_X ranging between 24.0 and 423.1 ppb (against the WHO standard of 110 ppb for NO_2). The maximum NO concentration developed at 0600 hrs (The value includes calibration readings). The second highest concentration for NO and NO_X were 243 ppb and 423 ppb respectively at 2300 hrs. NO and NO_X concentration increased with a rise in the number of petrol vehicles passing through the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged between 2.8 and 95.1 ppb, with the maximum concentration developing at 1800 hrs. The maximum was less than the WHO standard of 134 ppb. The minimum concentration was noted at 0600 hrs.

Ozone: The hourly average concentration of O_3 varied from 0.4 to 110.6 ppb as compared to WHO and US EPA standards (90 ppb and 120 ppb respectively). The maximum concentration was determined through calibration readings at 2100 hrs. At 1000 hrs the O_3 concentration increased to 7.6 ppb because of a rise in solar radiation. The minimum concentration was recorded at 2400 hrs.

Figure 4.5: Air Pollution Comparison with **Traffic Count** at Chowk Lohari Gate (Lahore)

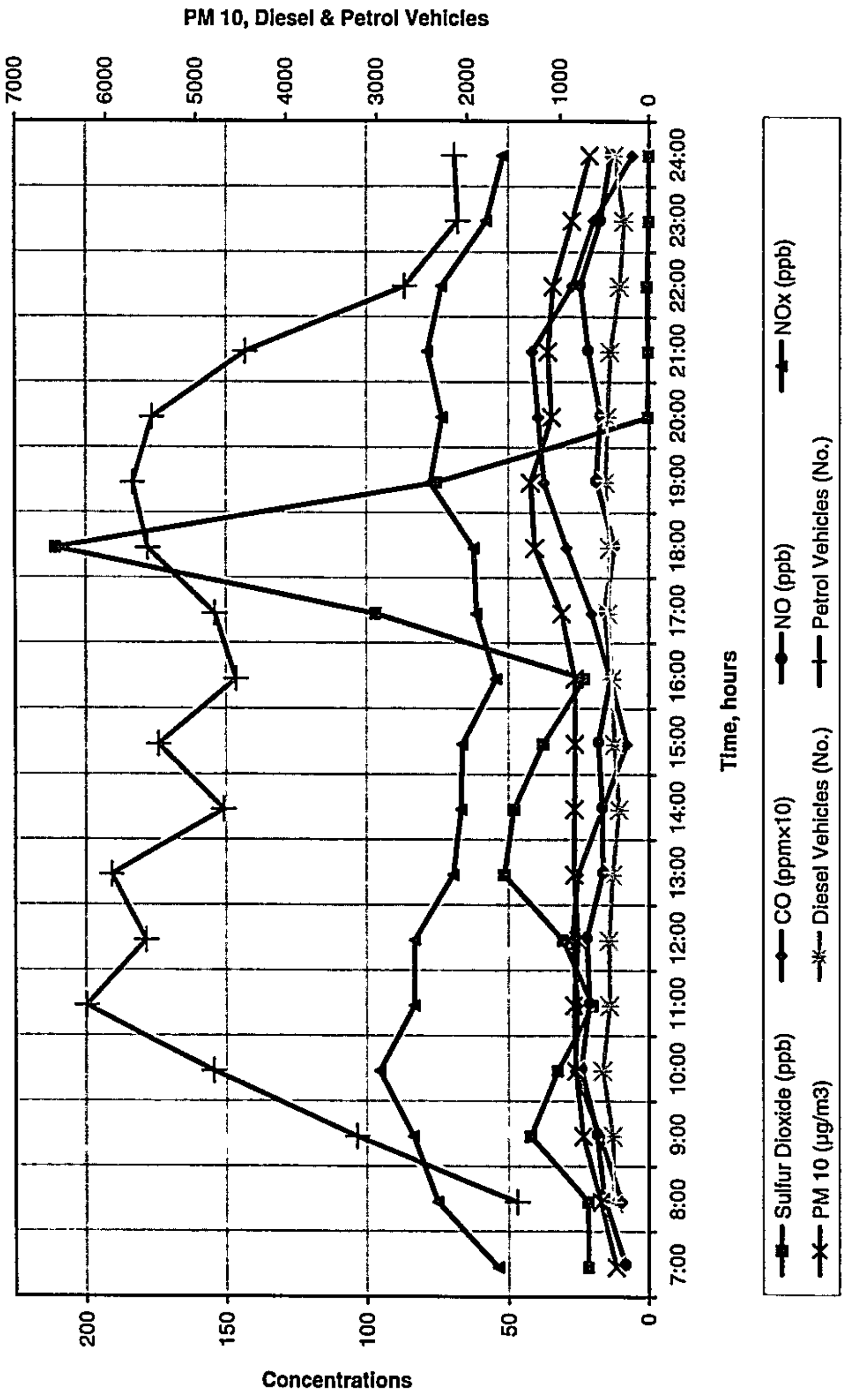
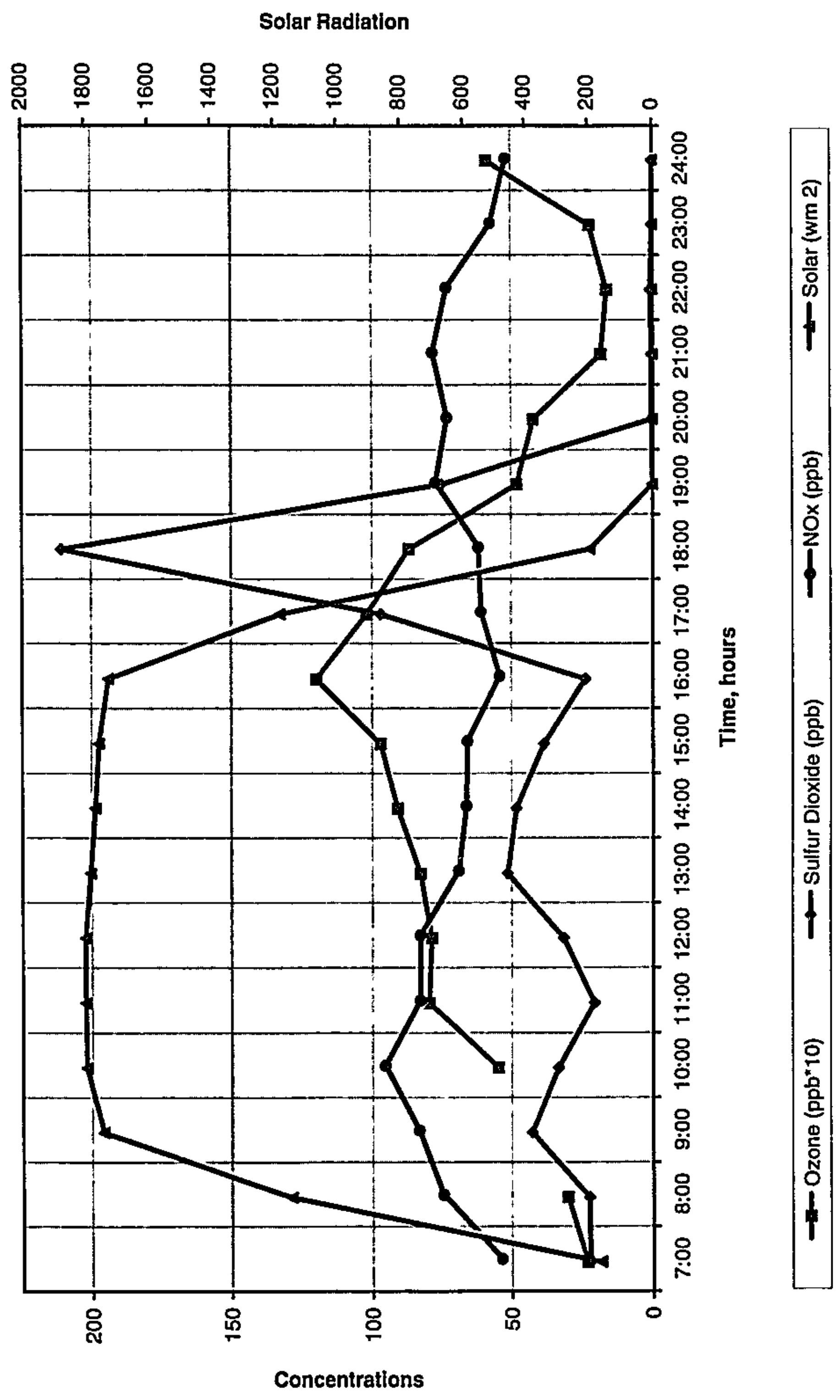


Figure 4.6: Air Pollution Comparison with **Solar Radiation** at Chowk Lohari Gate (Lahore)



Particulate Matter: The hourly average concentration of PM_{10} ranged from 68.4 to 1,400 $\mu g/m^3$, with an average concentration of 860.4 $\mu g/m^3$, which is more than the Japanese standard (200 $\mu g/m^3$). The maximum concentration was at noted 1900 hrs. The concentration of PM_{10} increased with a rise in traffic load at the site.

Total Suspended Particles: The concentration of TSP at Bank Square was 1,975 $\mu g/m^3$, which is higher than the Japanese standard (200 $\mu g/m^3$). The high volume air sampler collected samples for 8 hrs and 55 minutes from 1,520 to 0015 hrs.

Methane and Non-Methane Hydrocarbons: The concentration of methane and non-methane hydrocarbons could not be measured at this site due to a technical problem in the analyzer in EPD's mobile laboratory.

A graphical comparison of parameters like CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at Bank Square is shown in **Figure 4.7.** **Figure 4.8** compares NO_X, SO_2, and O_3 levels with the solar radiation at the site.

4.1.5 Sampling Site 5: Qurtuba Chowk

Qurtaba Chowk was selected for ambient air monitoring because it is at the center of a major commercial area of the city and has a heavy traffic load. The traffic at this point presents a mixture of petrol and diesel vehicles. Both petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhausts on ambient air quality on an hourly basis.

Discussion of Results

All parameters were measured on an hourly basis, from 0800 hrs to 2400 hrs. Readings could not be recorded at 2000 hrs due to a technical problem in the data acquisition system.

Traffic Count: The number of diesel and petrol vehicles passing through Qurtaba Chowk varied from 328 to 2,097 and 3,669 to 16,626 vehicles respectively. Both petrol and diesel vehicles were counted in parallel to ambient air quality measurement to assess the impacts of vehicular exhausts on ambient air quality on hourly basis. The number of petrol vehicles started to increase at 0800 hrs, reaching the maximum number at 1300 hrs and then declined to the minimum at 1700 hrs. In the second swell the highest number of vehicles was 9,058 at 2100 hrs. The number of diesel vehicles increased to a maximum of 2,097 at 0900 hrs and then a regular decrease was observed till 2400 hrs when it fell to a minimum of328 vehicles.

Carbon Monoxide: The hourly average concentration of CO at this point ranged from 0.1 to 9.4 ppm, which is far less than the international standards and guidelines of US EPA, WHO and EU countries (35 ppm). CO concentration peaked at 2300 hrs and decreased to its minimum at 1900 hrs. It increased because of the rise in the number of petrol vehicles passing by the site.

Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged between 2.7 to 499.4 ppb and 32.8 to 555.9 ppb respectively (against the WHO standard of 110 ppb for NO_2). The maximum concentration for NO and NO_X were noted at 2300 hrs. This increase was because of the petrol vehicles µpassing by the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged from 9.6 to 95.2 ppb, which is less than WHO's standard (134 ppb). The concentration of SO_2 rose to its maximum at 2100 hrs and fell to its minimum at 1900 hrs.

Figure 4.7: Air Pollution Comparison with **Traffic Count** at Bank Square (Lahore)

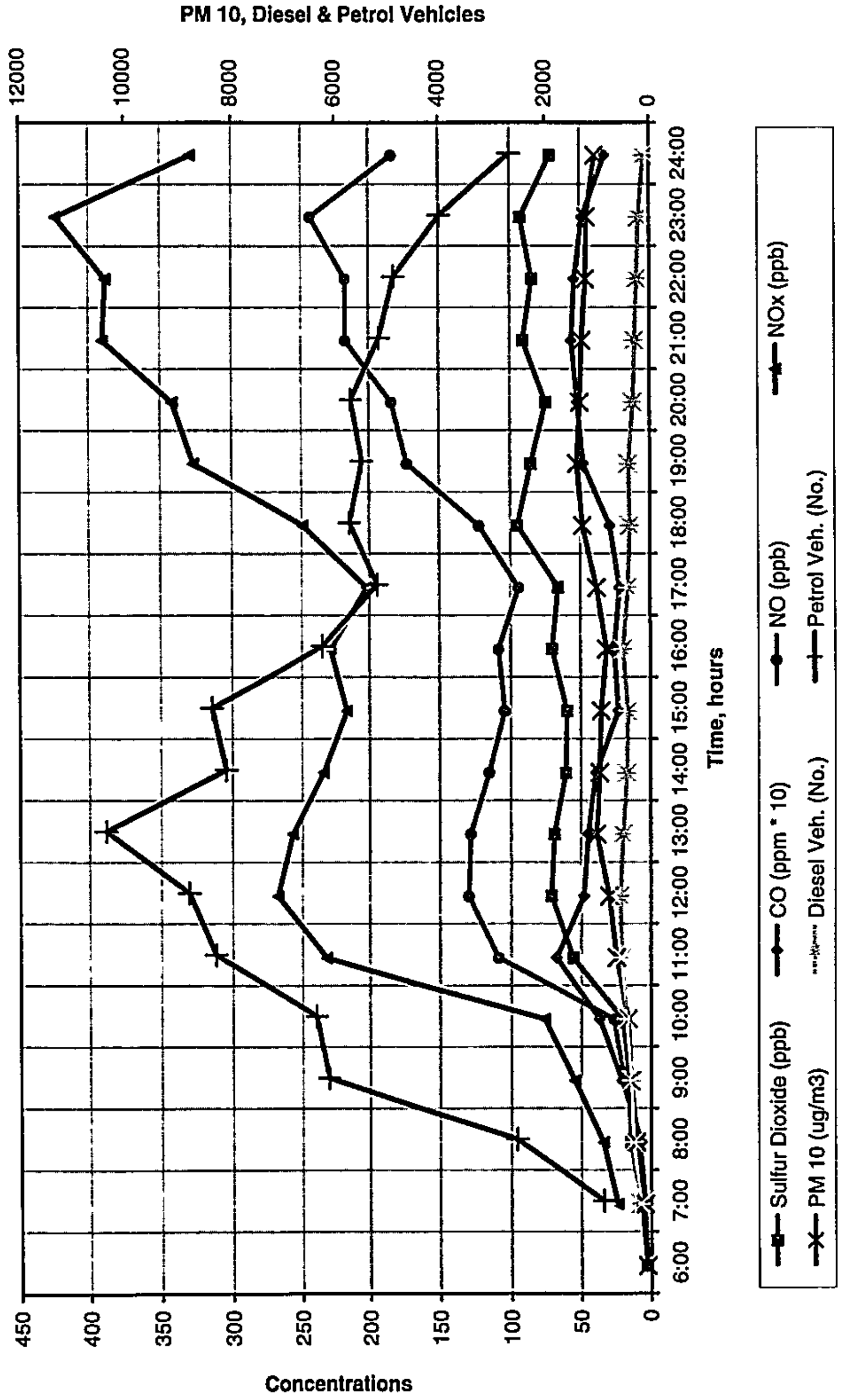
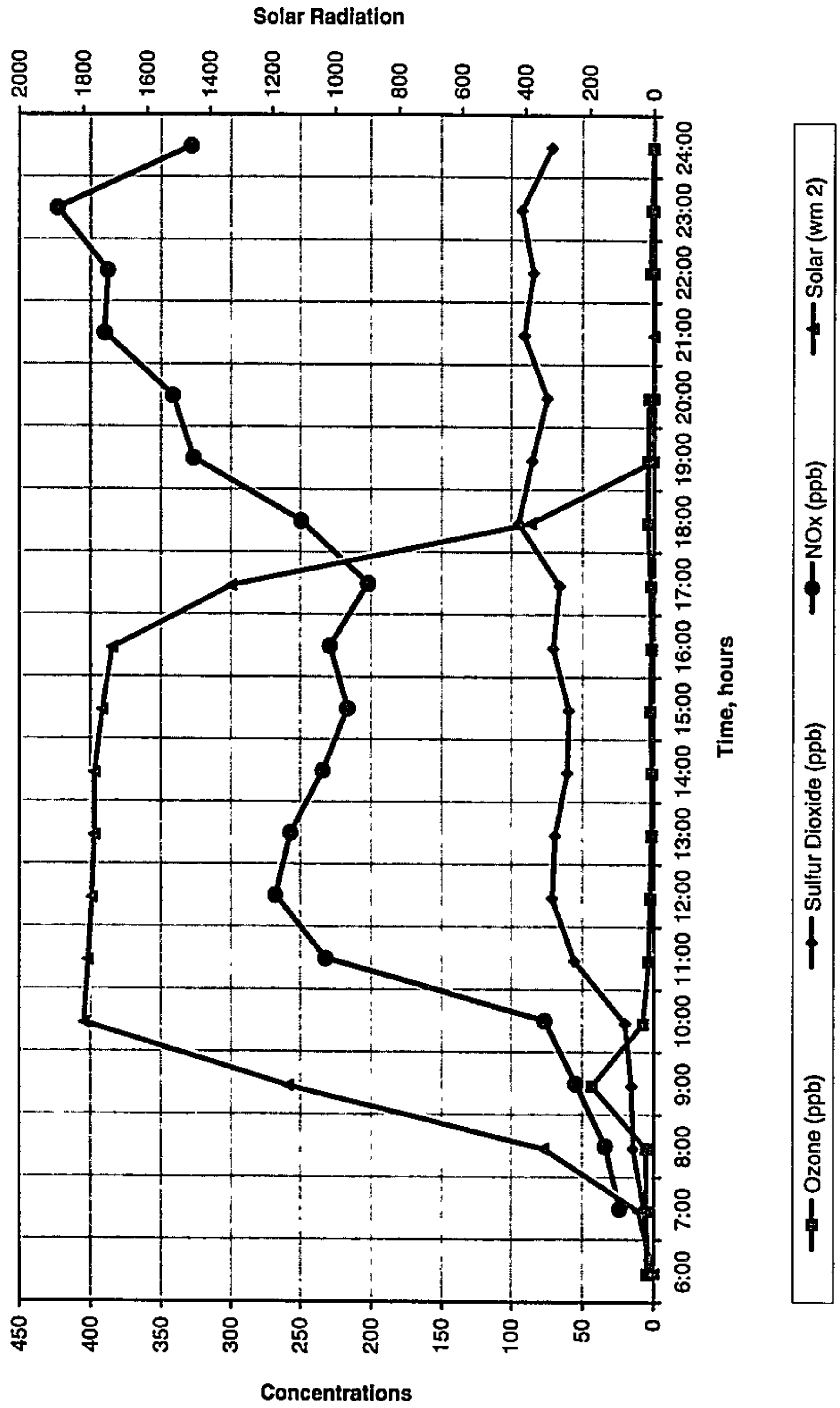


Figure 4.8: Air Pollution Comparison with **Solar Radiation** at Bank Square (Lahore)



Ozone: The hourly average concentration of O_3 varied from 0.1 to 48.5 ppb, which is less than the WHO and US EPA standards (90 ppb and 120 ppb respectively). The concentration of O_3 peaked at 1700 hrs. This increase was because of the rise in solar radiation at the site.

Particulate Matter: The hourly average concentration of PM_{10} ranged from 90.6 to 1,535 $\mu g/m^3$, with an average concentration of 931.8 $\mu g/m^3$, which is higher than the Japanese standard (200 $\mu g/m^3$). The concentration of PM_{10} increased to its maximum at 2200 hrs, because of the rise in traffic load at the site.

Total Suspended Particles: The value of TSP at Qurtaba Chowk was 2,230 $\mu g/m^3$, which is much higher than the Japanese standard (200 $\mu g/m^3$). The high volume air sampler collected samples for 3 hours from 1910 to 2210 hrs.

Methane and Non-Methane Hydrocarbons: Concentration for methane and non-methane hydrocarbons could not be measured at this site due to some technical problem in the analyzer in the Punjab EPD's mobile laboratory.

Figure 4.9 provides a graphical comparison of the measured parameters with the traffic count at Qurtaba Chowk, while **Figure 4.10** compares NO_X, SO_2, and O_3 levels with the solar radiation at the site.

4.1.6 Comparison of Air Quality Parameters in Lahore by Location

The following section compares measured values of ambient air quality parameters with international standards set by WHO, USEPA and EU countries. These parameters were monitored at selected locations in Lahore.

Carbon Monoxide

CO, an odorless and colorless gas, is produced from incomplete combustion of carbonaceous materials and is released through vehicle exhaust. It is a highly poisonous and gas and is generally classified as an asphyxiant. Vehicle exhausts are a major source of CO emissions and are mainly responsible for urban pollution. The international standards and guidelines for CO concentration of USEPA, WHO and EU countries is 35 ppm (1 hr).

CO concentration levels were found to vary from 0.1 to 9.4 ppm with an identical trend at all five sites. The first peak of CO concentration was observed in the morning from 0900 to 1200 hrs and the second peak from 2000 to 2300 hrs. The maximum CO concentration value was 9.4 ppm, recorded at Azadi Chowk and Qurtaba Chowk at 2300 hrs. A graphical comparison of CO values at the five sampling sites in Lahore is shown in **Figure 4.11**.

Nitrogen Oxides

NO_X in the ambient air consist primarily of NO and NO_2. These two forms of gaseous nitrogen oxides are significant pollutants in the lower atmosphere. NO is the predominant form of NO_X. NO is a colorless gas with a bad odor that readily converts to NO_2 by chemical reaction with O_2. Two peaks were observed for both NO and NO_X at all five locations in Lahore. The first was from 0700 to 0900 hrs and the second from 2000 to 2300 hrs. However, at Bank Square, the variation was somewhat different. The first peak was observed at 1200 hrs.

Figure 4.9: Air Pollution Comparison with **Traffic Count** at Qurtaba Chowk (Lahore)

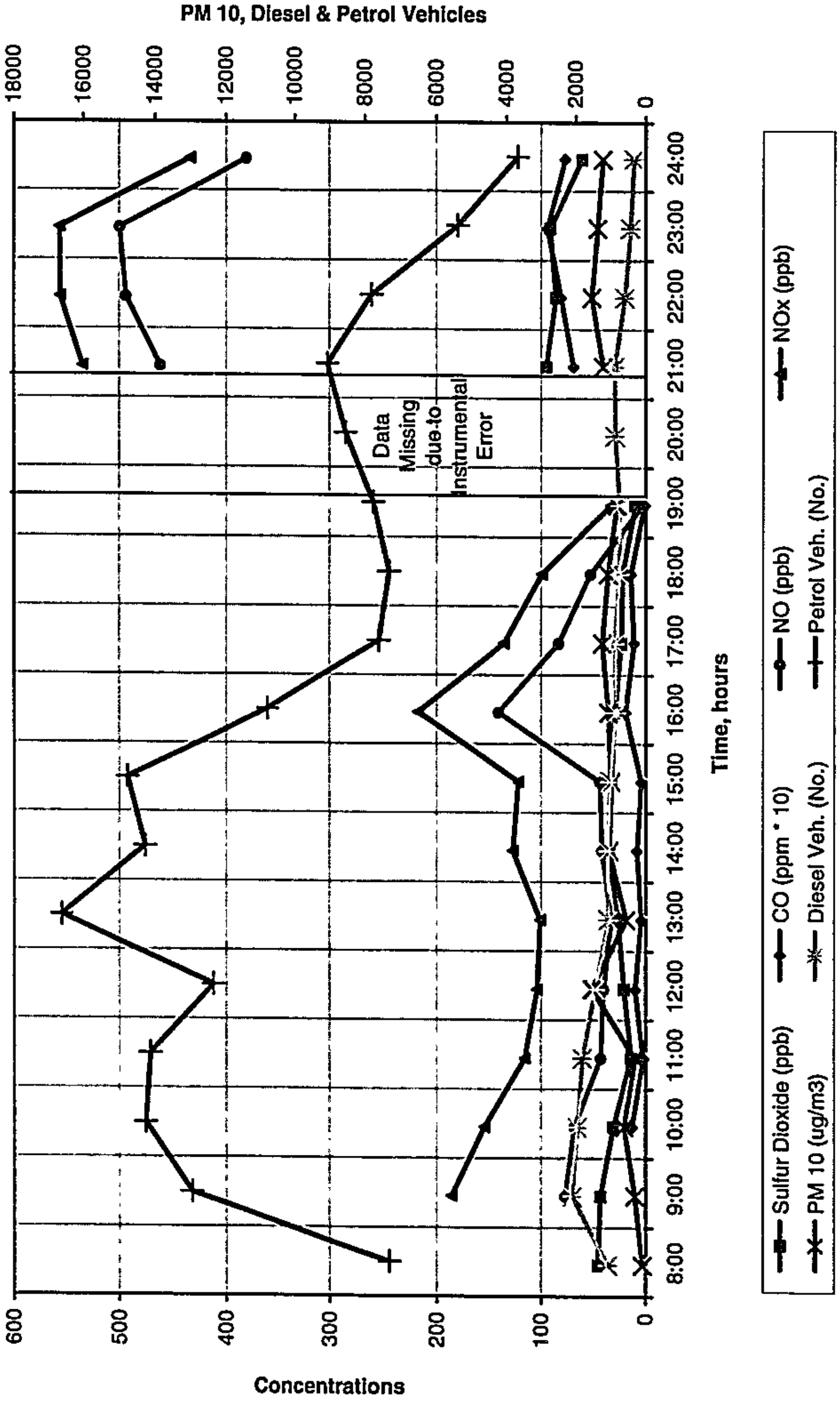


Figure 4.10: Air Pollution Comparison with **Solar Radiation** at Qurtaba Chowk (Lahore)

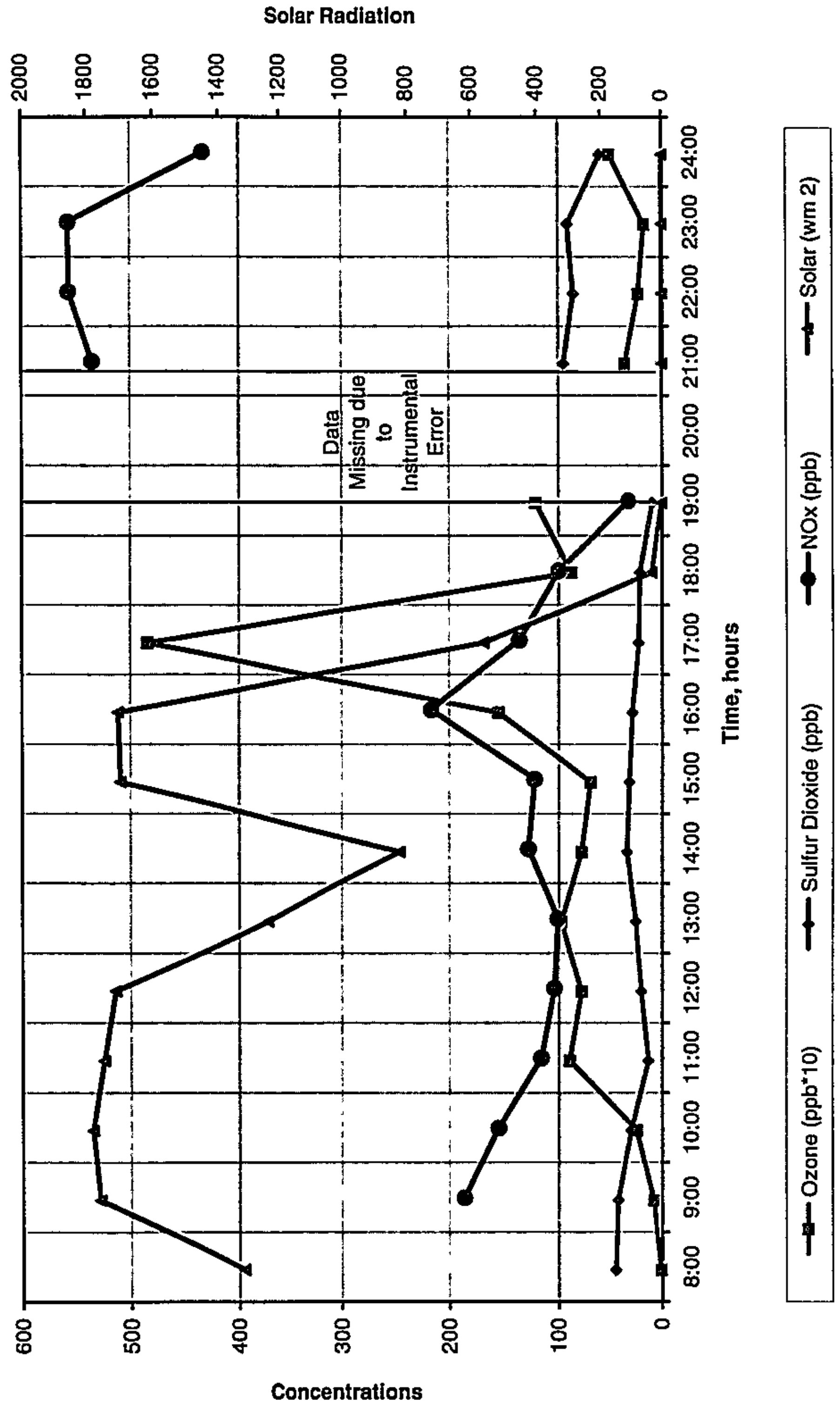
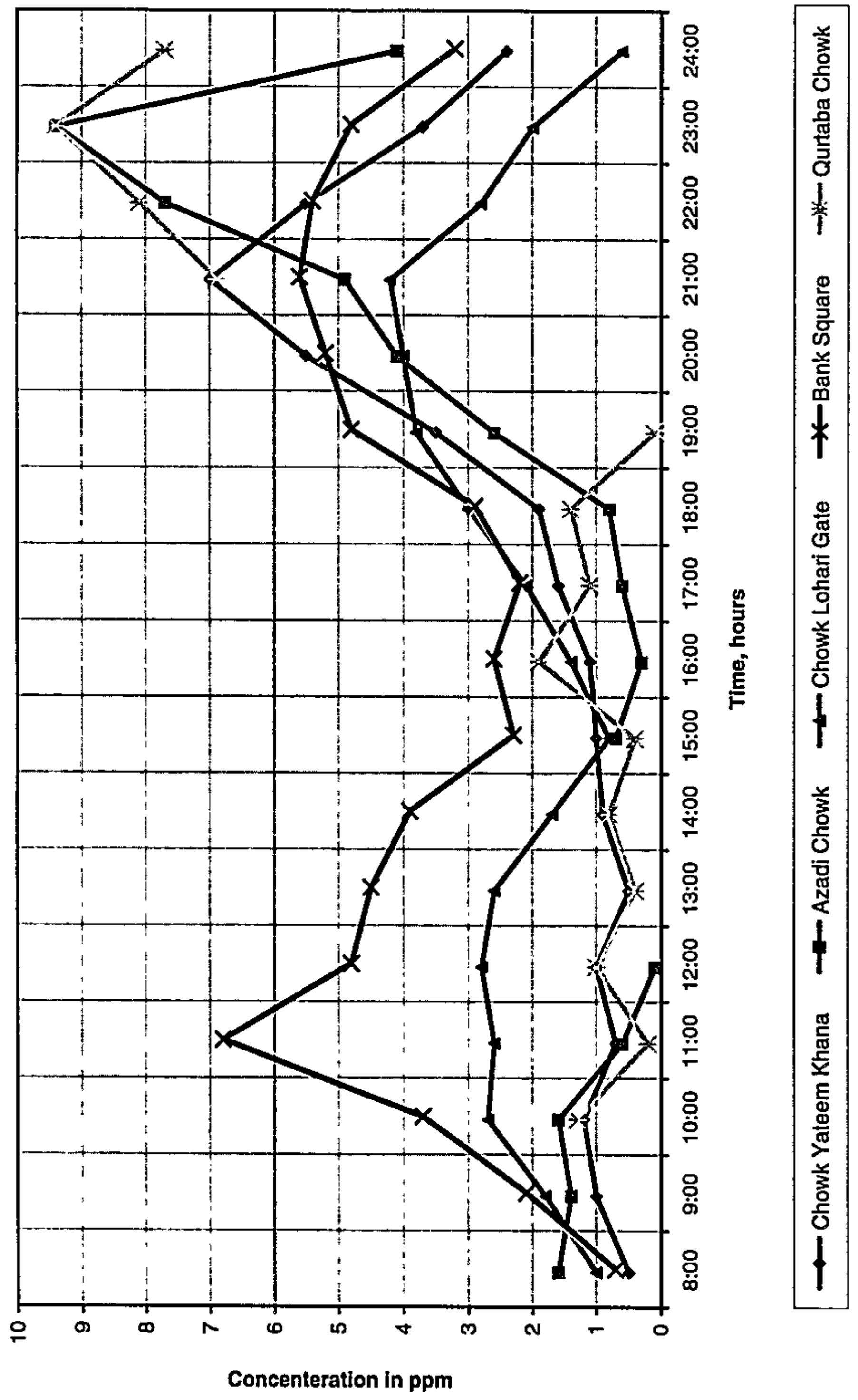


Figure 4.11: Carbon Monoxide Concentrations at the Sites in Lahore



The maximum values of NO and NO_X were 499.4 ppm and 555.9 ppm, respectively, at Qurtaba Chowk at 2300 hrs. Both the values are higher than the WHO standard for NO_2 (110 ppb, 1 hr). **Figure 4.12** and **Figure 4.13** present graphical comparisons of NO and NO_X, respectively, at the five sampling sites in Lahore.

Sulfur Dioxide

SO_2 is a colorless gas. It can be detected by smell if its concentration level ranges from 1000 to 3000 $\mu g/m^3$; at 10,000 $\mu g/m^3$, it has a pungent, unpleasant odor. SO_2 dissolves readily in the water present in the atmosphere to form sulfurous acid. The highest SO_2 value recorded was 210.9 ppb at Lohari gate at 1800 hrs. The SO_2 values varied from 10.2 to 210.9 ppb, which is less than the WHO standard (134 ppb). Only the maximum reading was higher than 100 ppb. All the other results were within the permissible limits in WHO guidelines. A graphical comparison of SO_2 at five sampling sites in Lahore is shown in **Figure 4.14**.

Ozone

The concentration of O_3 varied from 0.1 to 110.6 ppb (against WHO and US EPA standards of 90 ppb and 120ppb respectively). Only the maximum reading exceeded WHO's limit. Excluding this reading, O_3 measurements ranged from 40 to 50 ppb at three points. The rest of the readings were less than 20 ppb. A graphical comparison of O_3 at five sampling sites in Lahore is shown in **Figure 4.15**.

Particulate Matter

The readings for PM_{10} varied from 68.4 to 1,535 $\mu g/m^3$. Only four values were within the Japanese standard (200 $\mu g/m^3$) while the average value of PM_{10} remained high at all five stations. A graphical comparison of PM_{10} at the five sampling sites in Lahore is shown in **Figure 4.16**.

Meteorological Data

The Punjab EPD's mobile station was used to measure important meteorological data like wind direction, wind speed, humidity, temperature, solar radiation, and the barometric pressure at all the sampling sites. These data measurements are necessary as the meteorological parameters play a significant role in the variation of ambient air conditions. The key findings of the meteorological measurements taken at the sampling sites in Lahore are summarized below.

Wind speed at the five sampling sites in Lahore varied from 1.1 to 6.1 m/sec. The speed started increasing from 1100 hrs, reached a maximum of 1400/1500 hrs, and then started decreasing. Wind direction at all five sites remained about 15 to 25 degrees, ie, to the northeast. During the sampling period, humidity in Lahore ranged between 50-55 percent while temperature during this period varied from 18.6 to 37.8°C. The barometric pressure ranged from 975 to 985 m-bars.

Trace Metals

Total suspended particulates (TSP) samples were collected through high volume air sampler that was installed at the selected sampling sites in the three cities including Lahore, Rawalpindi and Islamabad and operated in parallel to mobile station. TSP samples were prepared for the analyses of toxic metals, which included Arsenic, Copper, Lead, and Zinc. Toxic metals were analyzed at Geoscience Laboratory, Islamabad. X-Ray fluorescence spectrometry (XRF) was used to analyze the trace metals. A brief discussion on each metal is presented in the following section. **Table 4.1**, shows concentration of trace metals in air at five locations in Lahore.

Figure 4.12: Nitrogen Monoxide Concentrations at the Sites in Lahore

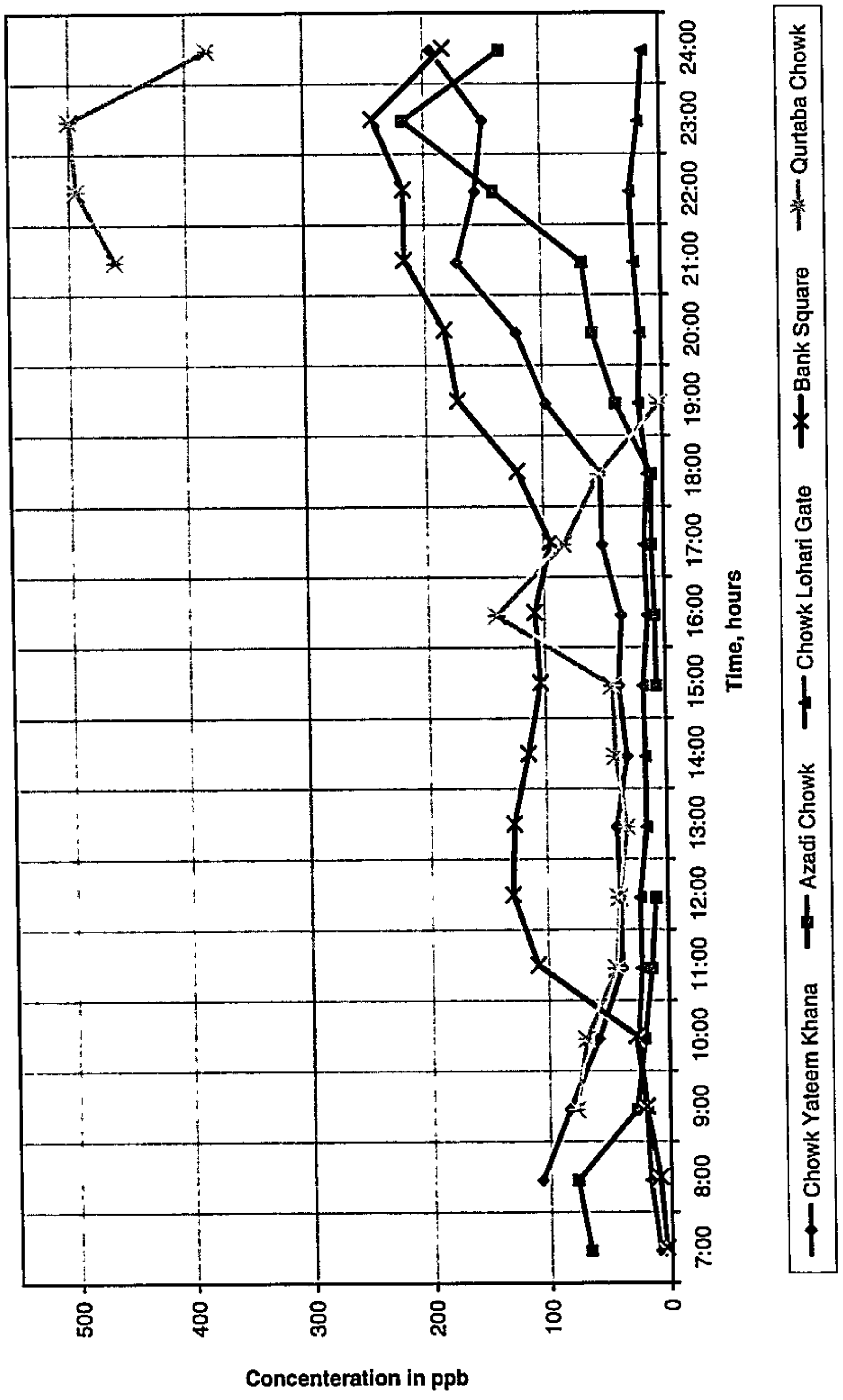


Figure 4.13: Nitrogen Oxides Concentrations at the Sites in Lahore

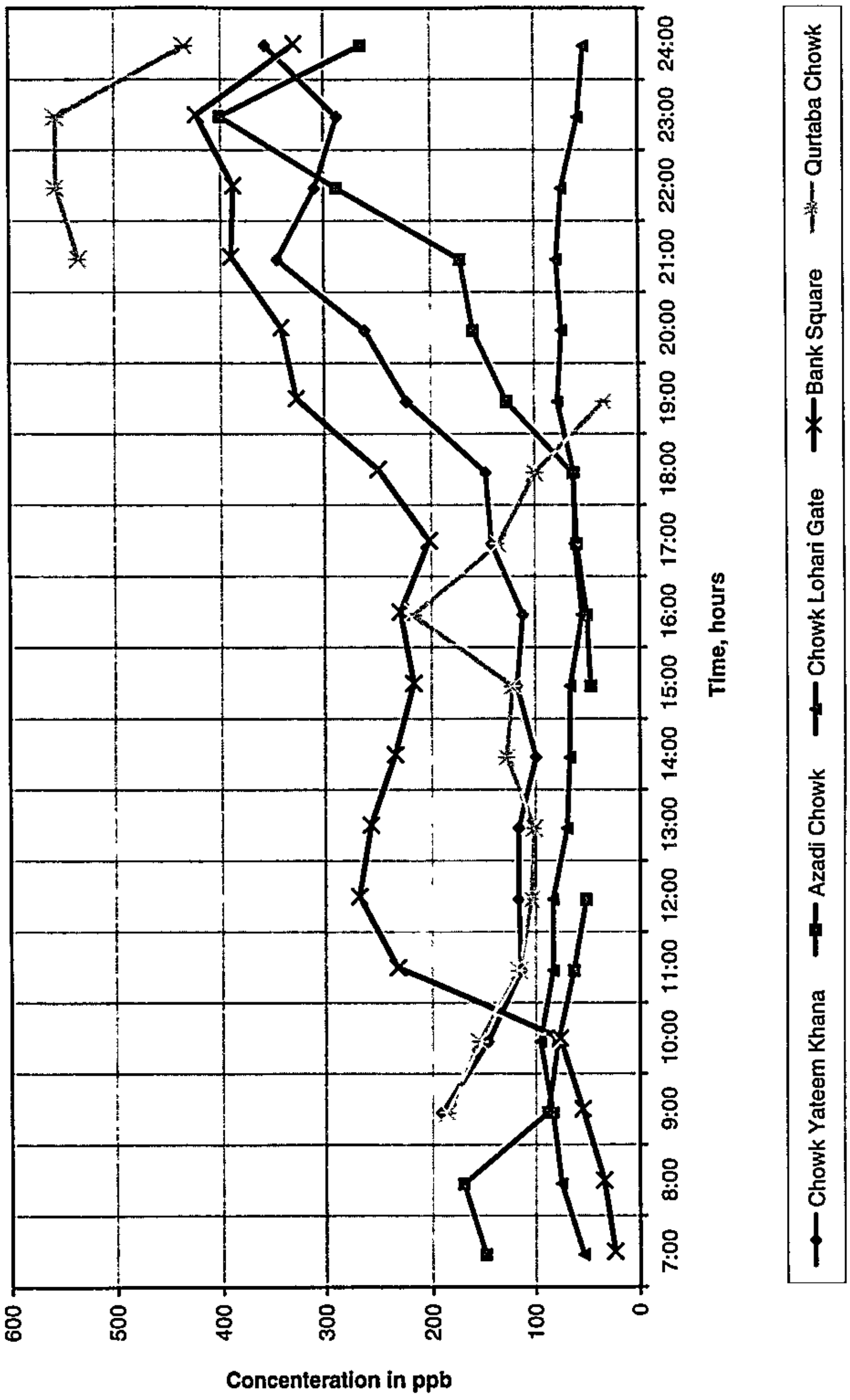


Figure 4.14: Sulfur Dioxide Cocentrations at the Sites in Lahore

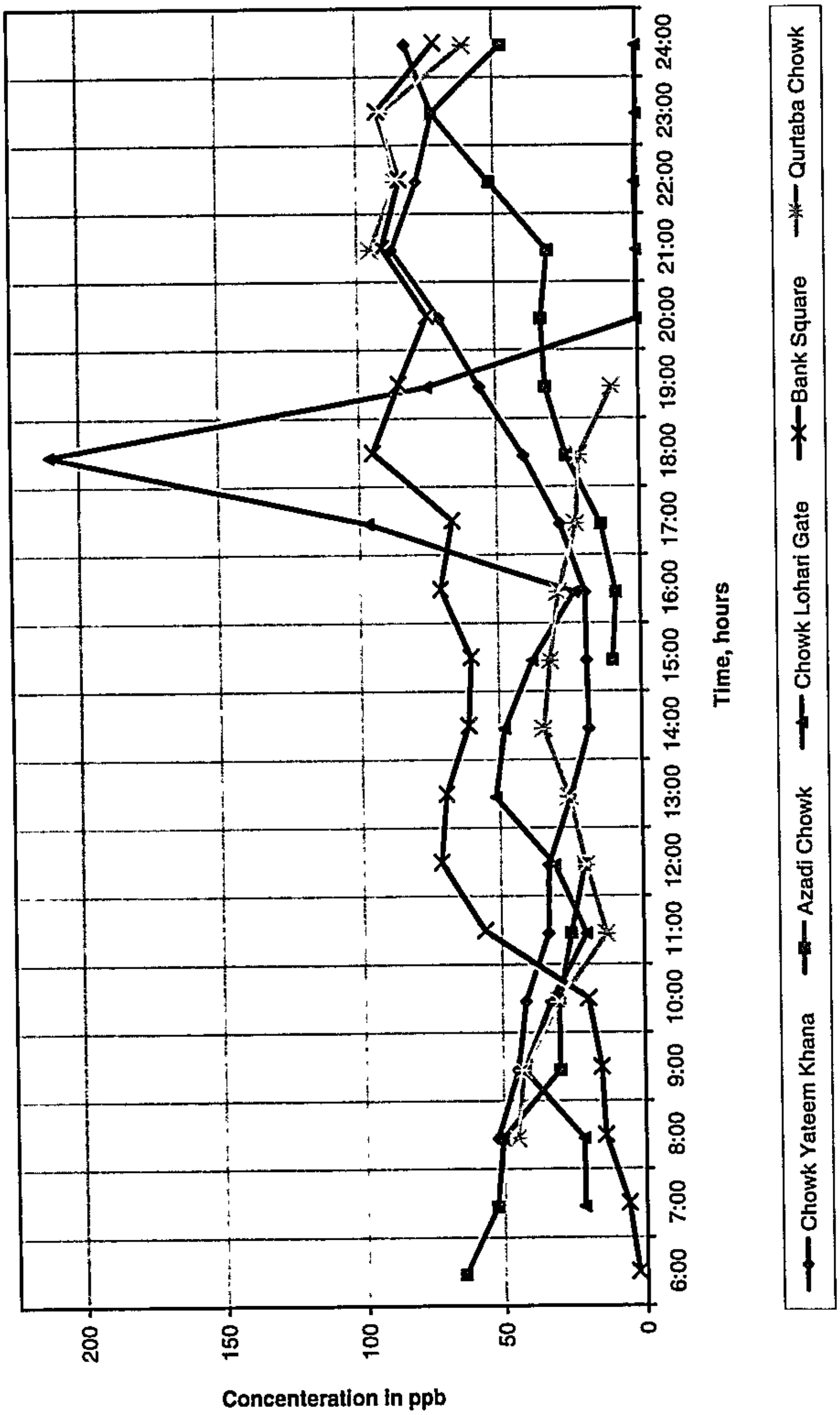


Figure 4.15: Ozone Coentrations at the Sites in Lahore

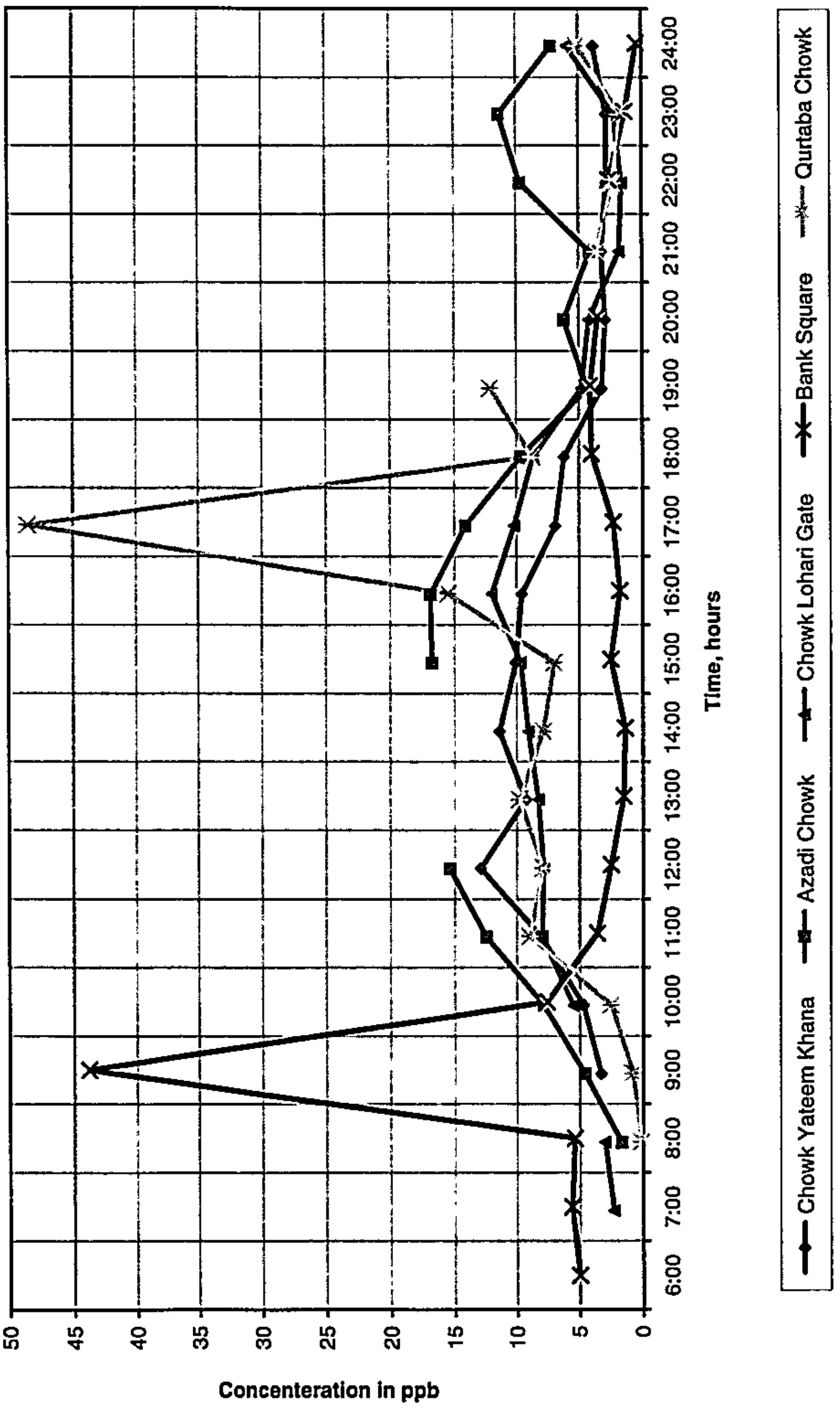


Figure 4.16: PM$_{10}$ Cooncentrations at the Sites in Lahore

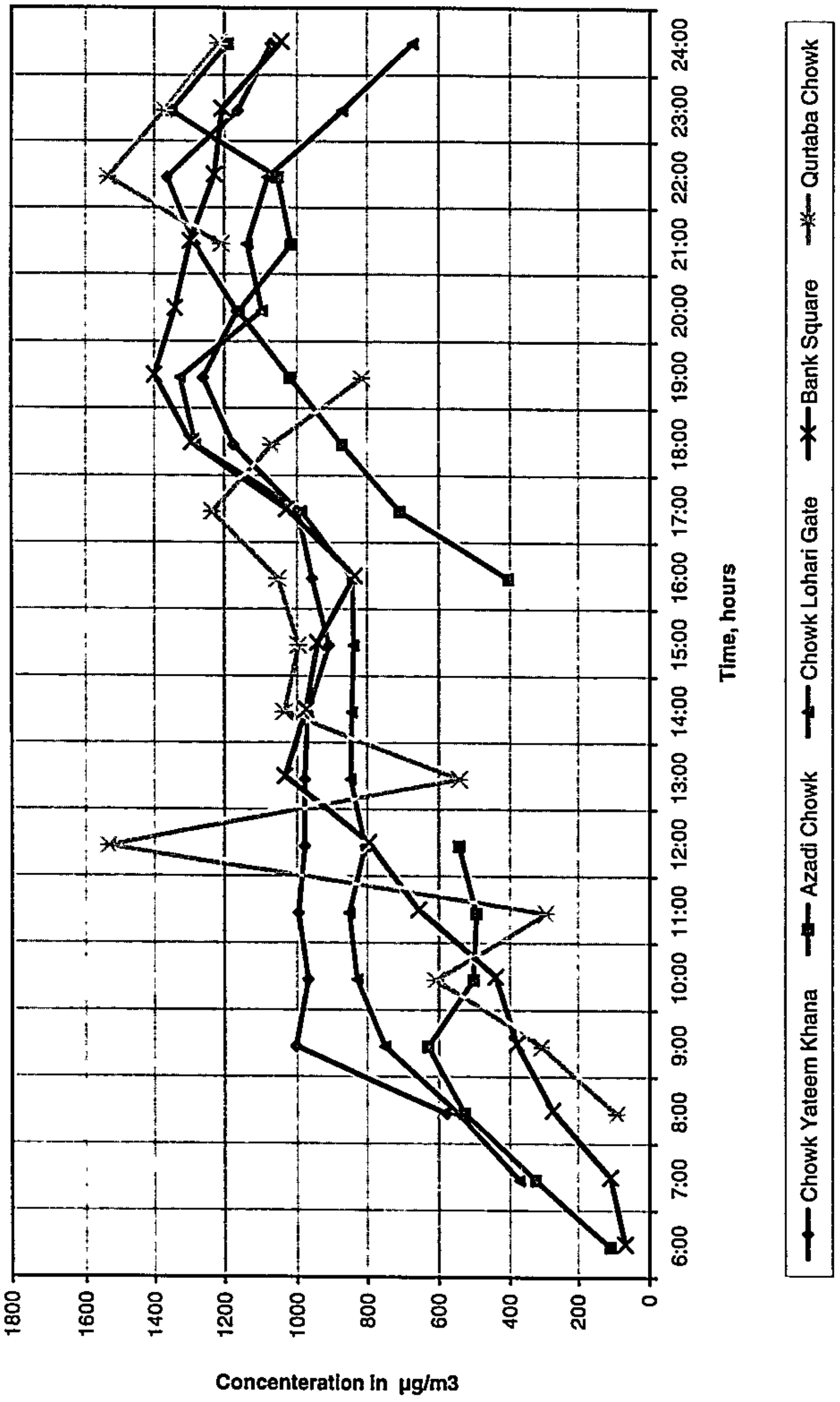


Table 4.1: Heavy metals in Ambient air samples from Lahore

No.	Sampling Sites	Arsenic ($\mu g/m^3$)	Copper ($\mu g/m^3$)	Lead ($\mu g/m^3$)	Zinc ($\mu g/m^3$)
1	Yateem Khana Chowk	1.73	6.39	6.18	5.82
2	Azadi Chowk	1.67	6.72	5.59	3 56
3	Lohari Gate	0.25	0.52	0.89	0 92
4	Bank Square	0.81	0.77	2.88	1.75
5	Qurtaba Chowk	2.23	0.54	7.85	1.51

Arsenic: Arsenic is a metalloid that is distributed widely in the earth's crust. Pure arsenic is rarely found in the environment. More commonly, it bonds with various elements such as oxygen, sulfur, and chlorine (forming inorganic arsenic compounds). Atmospheric arsenic exists primarily in inorganic form. The majority of anthropogenic arsenic emission originates from stationary sources including copper smelting, low-grade coal combustion and other non-ferrous metal industries. Airborne concentrations of arsenic range from a few nanograms (ng) to few tenth of micrograms per cubic meter ($\mu g/m^3$), however, concentrations may exceed 1 $\mu g/m^3$ near stationary sources. WHO does not specify ambient standards for arsenic, however, based on an Occupational Exposure Level (OEL), acceptable ambient air concentration guidelines for different states of United States were developed. According to these guidelines arsenic concentration in ambient air for Arizona State, is set at 0.32μg/m3 (1 hr average). Arsenic levels in ambient air at five sampling sites of Lahore varied from 0.25$\mu g/m^3$ to 2.23 $\mu g/m^3$. Out of 5 sites in Lahore, only one site that is Lohari Gate shows arsenic concentration less than the standard set for Arizona State. Japanese standard for arsenic, based on 24-hr average is set at less than 0.01 ppm. Ingestion is the main route of exposure to arsenic for general population. Arsenic when inhaled, acutely affects respiratory, gastrointestinal, cardiovascular, nervous and blood cells formation systems.

Copper: The contamination of air with copper primarily results from industrial emissions of non-ferrous metals manufacturing units. Additional sources of atmospheric copper include wood combustion and iron/steel production. Inhalation of air born copper causes irritation of the respiratory tract and metal fume fever, lung cancer may also develop after excessive exposure. Copper level in ambient air at five sampling sites of Lahore varied from 0.52 $\mu g/m^3$ to 6.72 $\mu g/m^3$. WHO does not specify any ambient standard for copper.

Lead: Lead is highly toxic and is naturally available in all environmental media in small concentrations. Lead is a serious cumulative body poison. A significant part of lead particles from emission sources is in the sub-micron size, which can be transported over large distances. Mining, smelting and processing of lead and lead-containing metal ores generate the majority of lead emissions from stationary sources. As a result of the extensive use of alkyl-lead compounds as fuel additives, vehicular traffic is the largest source of atmospheric lead in urban areas. The main pathways of lead to humans are ingestion and inhalation. Chronic exposure to lead causes weight loss, constipation and teeth loss. Children up to about six years of age constitute the population group that is at the highest risk from lead exposure through ingestion[1]. Lead level in ambient air at five sampling sites of Lahore varied from 0.89 µg/m^3 to 7.85 µg/m^3. The WHO guidelines for lead concentraion in ambient air based on annual average gives a range of 0.5µg/m^3 to 1.0µg/m3. The USEPA and EU set lead concentration in ambient air as 1.5µg/m3 and 2µg/m3, respectively, based on quarterly average. Out of 5 sites in Lahore, only one site that is Lohari Gate shows lead concentration less than the standard set by WHO, USEPA or EU. However, for true comparison continuous measurement of lead is required to achieve annual or quarterly average. Japanese standard for lead, based on 24-hr average is set at less than 0.01 ppm.

Zinc: Smelting of ores contributes appreciably to the atmospheric level of zinc. Municipal refuse and automobiles (tire wear, fuel additives, brake lining and motor oils) serve as additional pollution sources. Zinc at concentration over 15 mg/m^3 in air may produce metal fume fever. Large doses of zinc cause gastro-intestinal disorders including vomiting and diarrhea. Zinc level in ambient air at five sampling sites of Lahore varied from 0.92 µg/m^3 to 5.82 µg/m^3.

4.2 Ambient Air Quality in Rawalpindi

The following three locations were selected for ambient air monitoring in Rawalpindi:

- Sampling Site 1: Raja Bazaar, 500 meters from Fountain Chowk
- Sampling Site 2: Murree Road, near Maharaja Hotel, Committee Chowk, Rawalpindi
- Sampling Site 3: Pirwadhai Road, near New Karachi Hotel, in front of PCO.

4.2.1 Sampling Site 1: Raja Bazar

This site was selected because it is at the center of one of the more crowded commercial markets in Rawalpindi. The traffic at this location mainly comprises petrol vehicles, with some diesel vans and pickups. All parameters were measured on an hourly basis from 0800 hrs to 2400 hrs.

Discussion of Results

Carbon Monoxide: The hourly average concentration of CO ranged from 0.3 to 2.8 ppm, reaching the maximum at 2100 hrs. This is far less than the international standards and guidelines set by US EPA, WHO and EU countries (35 ppm).

Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged from 3.5 to 56.9 ppb and 19.2 to 109.9 ppb respectively, less than WHO's standard for NO_2(110 ppb). The maximum concentration of NO and NO_X were noted at 2100 hrs.

Sulfur Dioxide: The hourly average concentration of SO_2 at this site ranged from 0.0 to 7.8 ppb, (as against the WHO standard of 134 ppb). It rose to its maximum at 0800 hrs.

Ozone: The hourly average concentration of O_3 varied from 7.1 to 59.3 ppb, which is less than WHO and US EPA standards (90 ppb and 120ppb respectively). The maximum concentration was noted at 1500 hrs, and was caused by maximum solar radiation during this period.

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[1] The World Bank. 1998. *Pollution Prevention and Abatement Handbook* Report prepared by the World Bank Group in collaboration with UNIDO, UNEP and WHO.

Particulate Matter: The hourly average concentration of PM_{10} ranged from 372.1 to 1,166.5 µg/m^3, with an average concentration of 786.9 µg/m^3. This is much higher than the Japanese standard (200 µg/m^3). The maximum PM_{10} concentration was noted at 1300 hrs and was caused by the increase in traffic at the site.

Total Suspended Particles: The concentration of TSP at Raja Bazar was 675 µg/m^3 in the morning and 1,171 µg/m^3 in the evening. This is higher than the Japanese standard (200 µg/m^3). The high volume sampler collected samples for five hours and 20 minutes from 1015 to 1535 hrs and four hours and 45 minutes from 1805 to 2250 hrs respectively.

Methane and Non-Methane Hydrocarbons: The concentration of methane and non-methane hydrocarbons varied from 0.0 to 1.6 and 0.0 to 10.3 respectively.

The parameters measured at Raja Bazaar are graphically presented in **Figure 4.17**, while **Figure 4.18** presents a graphical comparison of parameters like NO_X, SO_2 and O_3 with the solar radiation at the site.

4.2.2 Sampling Site 2: Murree Road

The Murree Road is the main approach road for Rawalpindi. Both heavy and light vehicles use this road. Petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhaust on ambient air quality on an hourly basis.

Discussion of Results

Traffic Count: The number of petrol vehicles started to increase at 0700, reaching a maximum of 7,507 at 1100 hrs and decreased to 4,996 at 1600 hrs. In the second peak the maximum number reached was 7,151 at 1900 hrs. The highest number of diesel vehicles was 757 at 1100 hrs and then it decreased to 532 at 1500 hrs. In the second swell the number of diesel vehicles increased to 705 at 1900 hrs and decreased to a minimum of 208 at 2400 hrs.

Carbon Monoxide: The hourly average concentration of CO ranged from 0.3 to 6.7 ppm, which is far less than the international standards and guidelines of US EPA, WHO and EU countries (35 ppm). The CO concentration increased to its maximum at 2100 hrs and fell to its minimum value at 1500 hrs. The increase in CO concentration was because of the rise in the number of petrol vehicles passing through the site.

Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged between 46.1 to 207.3 ppb and 38.9 to 237.4 ppb respectively (as compared to the WHO standard for NO_2 of 110 ppb). The maximum concentration of NO was noted at 2000 hrs and the maximum concentration of NO_X was recorded at 1900 hrs. The rise in NO and NO_X concentration contents was caused by emissions from petrol vehicles passing through the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged from 10.1 to 46.7 ppb. This is less than WHO's standard for SO_2 (134 ppb). The concentration increased to its maximum at 2100 hrs and fell to its minimum at 1100 hrs. The rise in SO_2 concentration coincided with an increase in the number of diesel vehicles.

Ozone: The hourly average concentration of O_3 varied from 0.7 to 52.6 ppb, which is less than WHO and US EPA standards (90 ppb and 120ppb respectively). The highest concentration was noted at 1500 hrs and the minimum concentration at 2100 hrs. The increase in the ozone concentration coincided with the rise in solar radiation, NO_X and hydrocarbon concentrations.

Figure 4.17: Air Pollution Comparison with **Traffic Count** at Raja Bazaar (Rawalpindi)

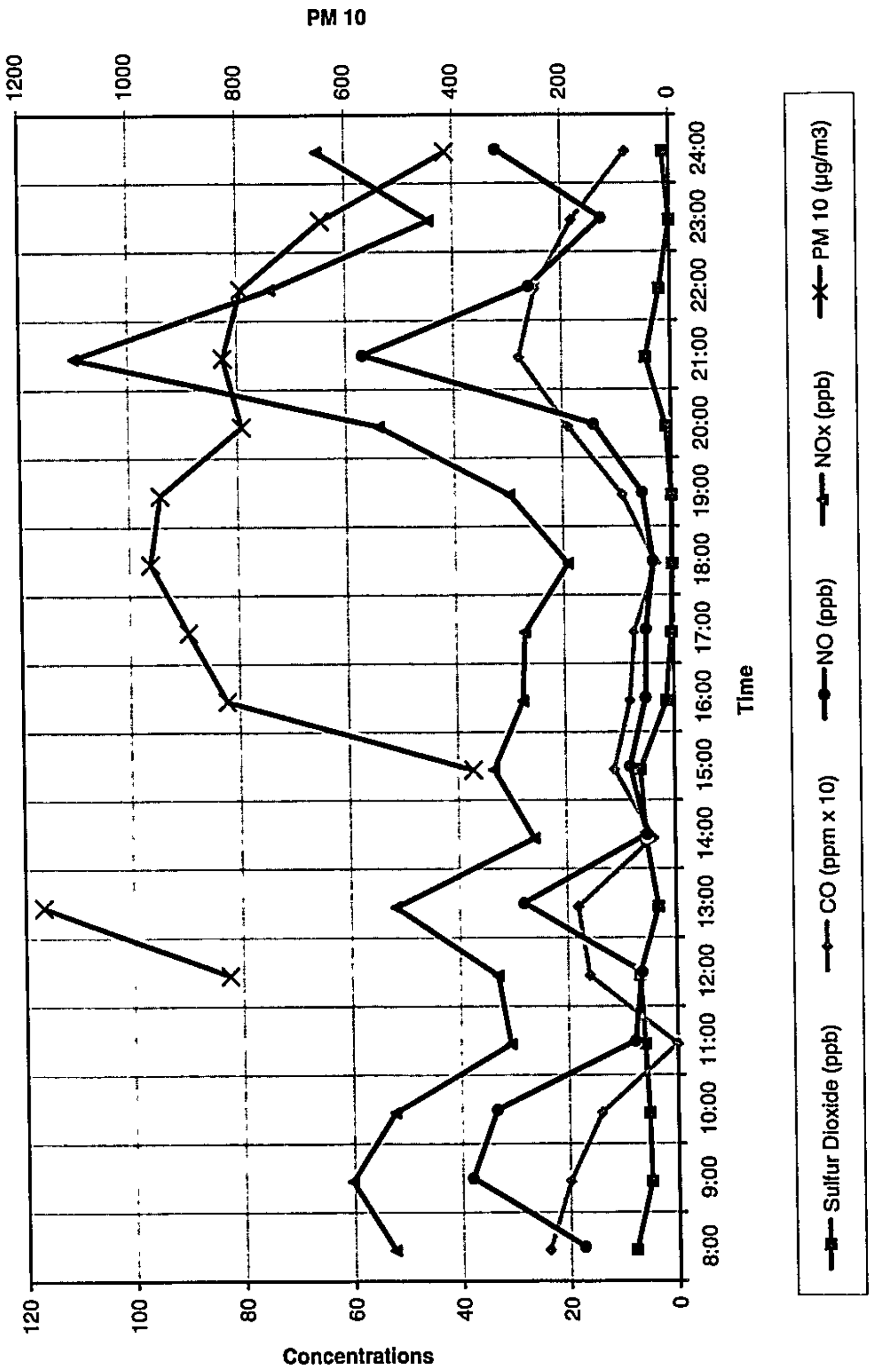
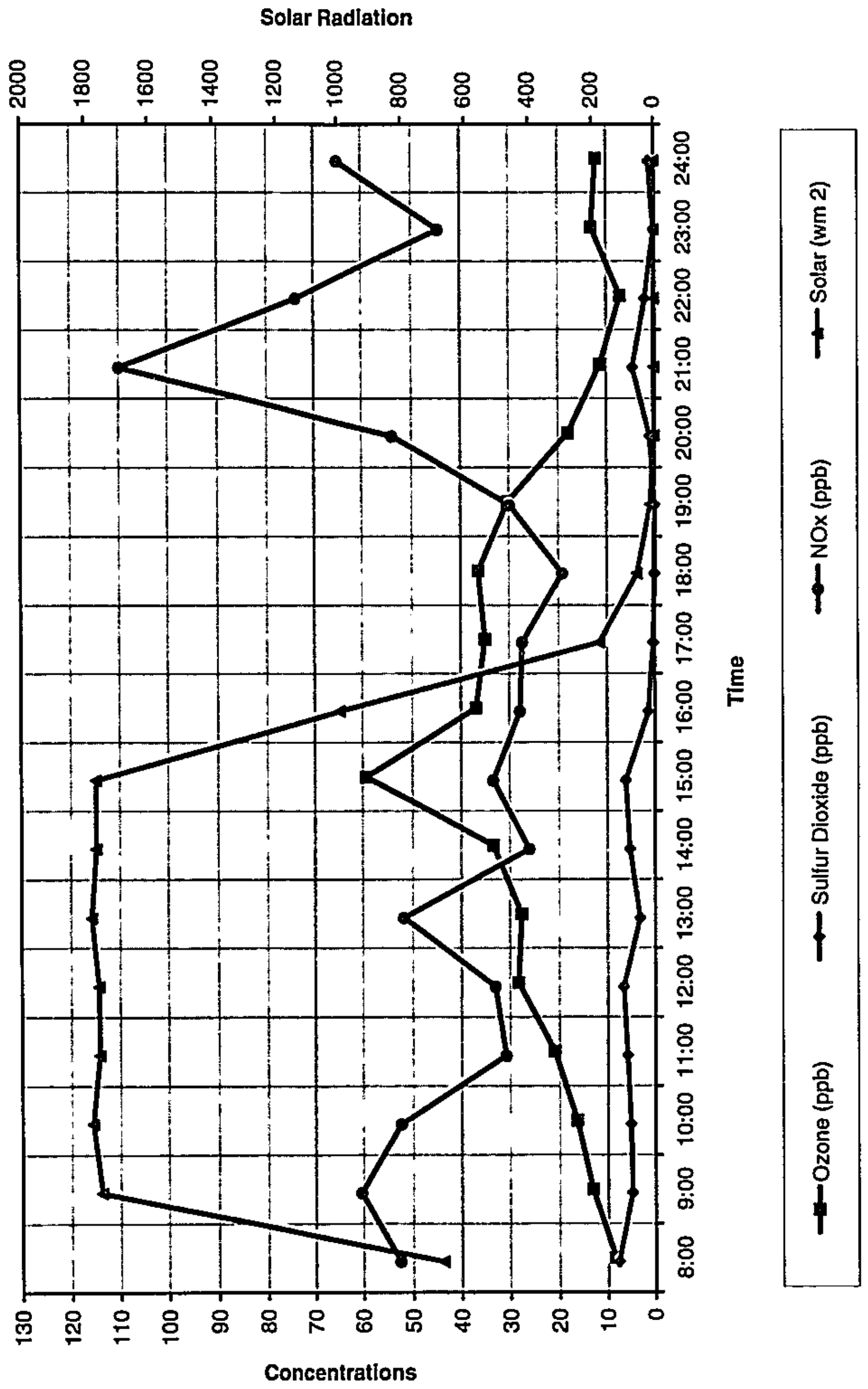


Figure 4.18: Air Pollution Comparison with **Solar Radiation** at Raja Bazaar (Rawalpindi)



Particulate Matter: The hourly average concentration of PM_{10} ranged from 39.6 to 1,214.4 µg/m^3, with an average concentration of 827.4 µg/m^3 as compared to the Japanese standard of 200 µg/m^3. The maximum concentration was noted at 2200 hrs and was caused by a decrease in wind speed.

Total Suspended Particles: The concentration of TSP at Murree road was 1,371 µg/m^3 in the morning and 2,744 µg/m^3 in the evening. This is higher than the Japanese standard (200 µg/m^3). The high volume air sampler collected samples for three hours 18 minutes from 1030 to 1348 hrs and one hour 5 minutes from 1935 to 2040 hrs respectively.

Methane and Non-Methane Hydrocarbons: The hourly average concentration of methane and non-methane hydrocarbons varied from 0.0 to 2.2 and 0.0 to 10.5 respectively.

Figure 4.19 presents a graphical comparison of parameters like CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at Murree Road near Committee Chowk, while **Figure 4.20** compares NO_X, SO_2 and O_3 levels with the solar radiation at the site.

4.2.3 Sampling Site 3: Pirwadhai Road

The site was selected because a large number of diesel vehicles traveling to and from Rawalpindi pass through this location. Both petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhaust on the ambient air quality on an hourly basis.

Discussion of Results

Traffic Count: The number of petrol vehicles started increasing at 0800, reaching 860 at 1300 hrs and then decreased to 747 at 1400 hrs. In the second swell the highest number of vehicles was 1,009 at 1600 hrs. Diesel vehicles increased to 484 at 1100 hrs and then decreased steadily to a minimum of 213 vehicles at 2400 hrs.

Carbon Monoxide: The hourly average concentration of CO ranged from 0.5 to 3.6 ppm. This is far less than the international standards and guidelines set by US EPA, WHO and EU countries (35 ppm). CO concentration peaked at 2100 hrs and fell to its minimum at 2400 hrs. The rise in CO concentration coincided with the increase in the number of petrol vehicles passing through the site and the accumulation effect caused by a decrease in wind speed.

Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged between 11.0 to 262.9 ppb and 24.3 to 95.0 ppb respectively (as compared to the WHO standard for NO_X of 110 ppb). The maximum NO and NO_X values were noted at 2100 hrs. The rise in NO and NO_X concentration contents was mainly caused by petrol vehicles passing through the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged from 12.2 to 61.0 ppb and remained within the permissible limit set by WHO (134 ppb). The concentration level went up to its maximum at 2200 hrs while the minimum value was noted at 1500 hrs.

Ozone: The hourly average concentration of O_3 varied from 0.5 to 54.9 ppb. This is less than WHO and US EPA standards (90 ppb and 120 ppb respectively). The maximum concentration was noted at 1500 hrs and the minimum concentration at 0800 hrs. The rise in the ozone concentration to 54.9 ppb was caused by the rise in solar radiation, NO_X and hydrocarbon concentrations.

Figure 4.19: Air Pollution Comparison with **Traffic Count** at Committee Chowk, Murree Road (Rawalpindi)

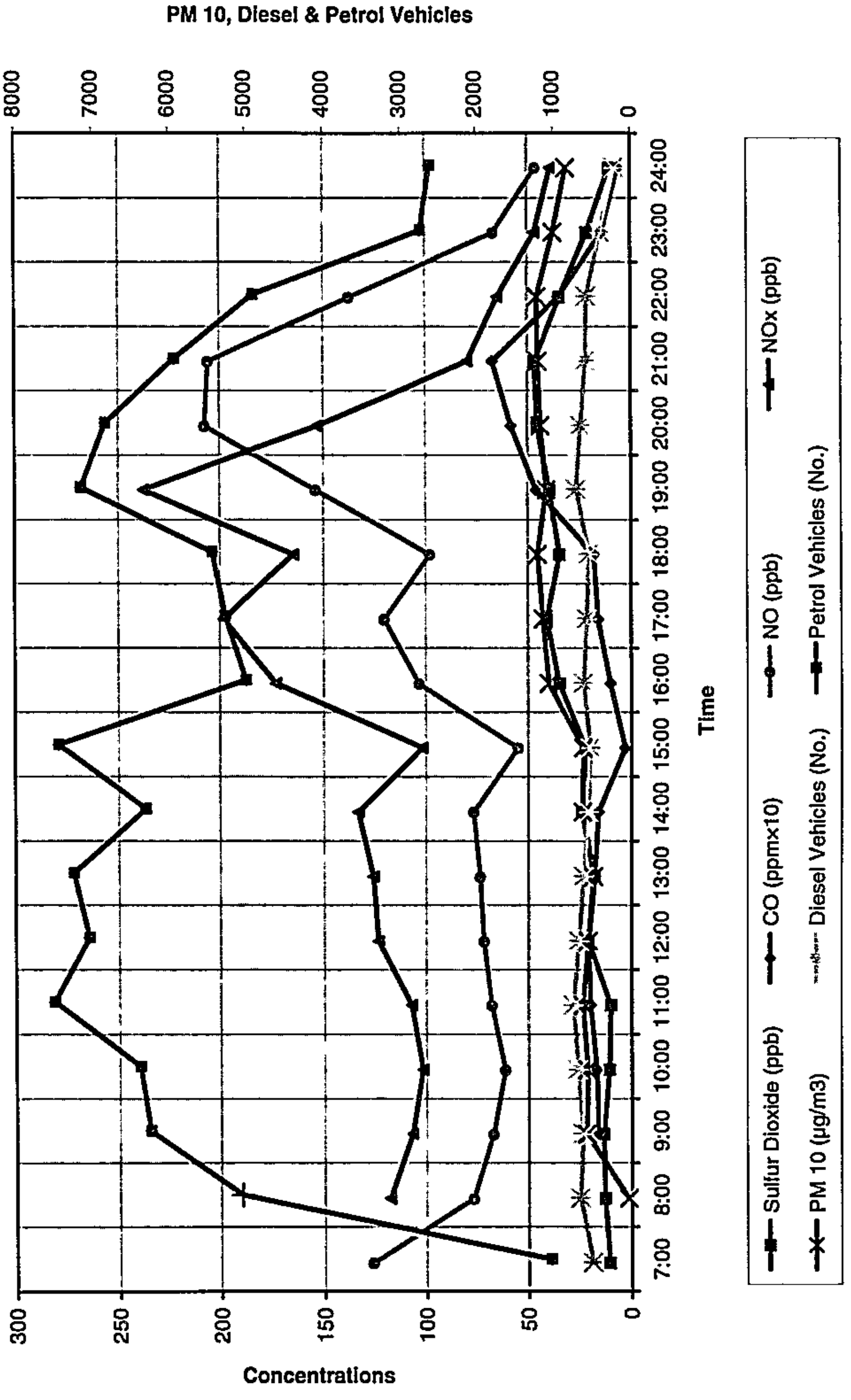
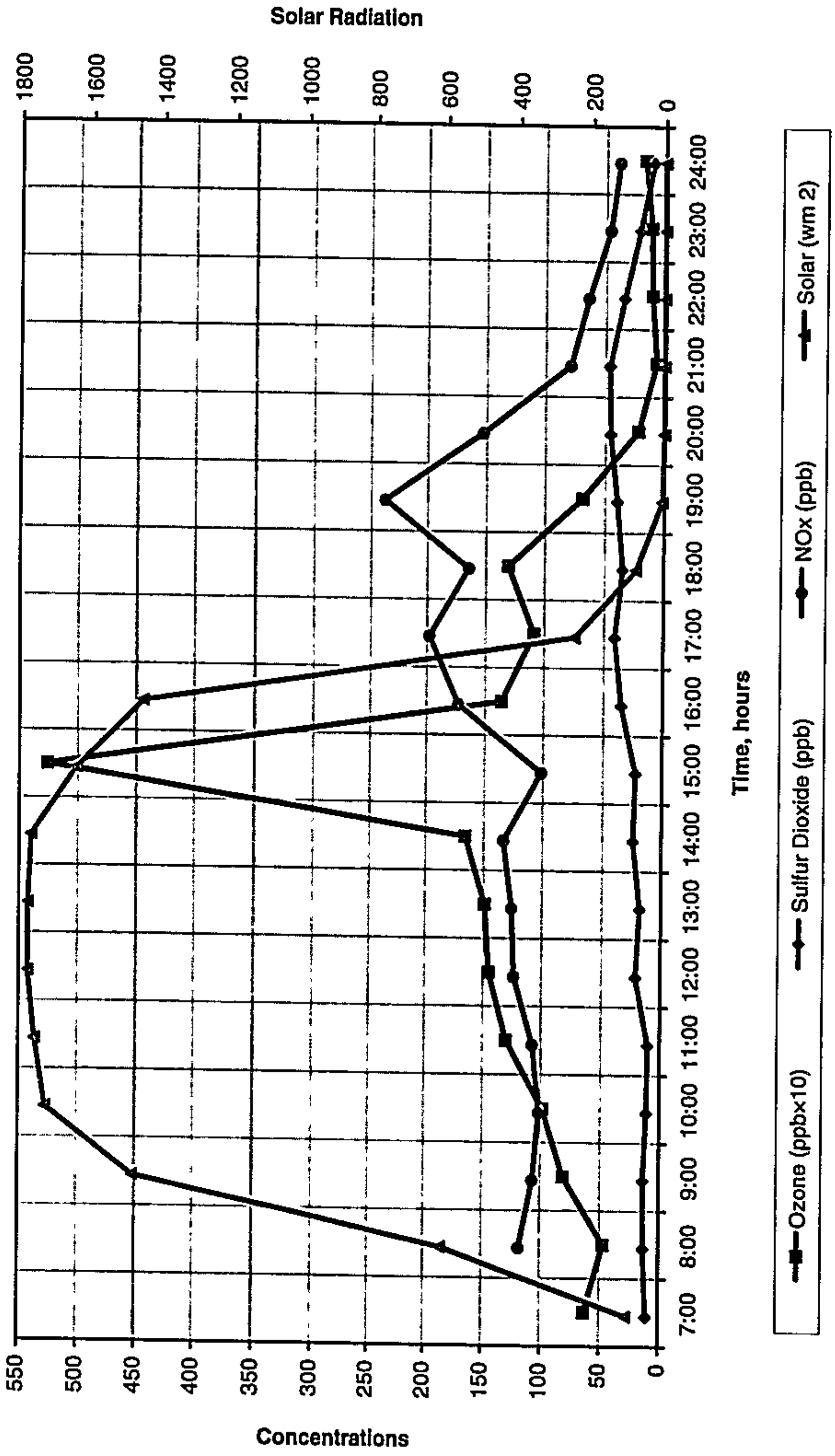


Figure 4.20: Air Pollution Comparison with **Solar Radiation** at Committee Chowk, Murree Road (Rawalpindi)



Particulate Matter: The hourly average concentration of PM_{10} ranged from 513.7 to 1,406.3 µg/m^3, with an average concentration of 910.4 µg/m^3, which is higher than the Japanese standard (200 µg/m^3). The maximum concentration was 1,406.3 µg/m^3 at 2200 hrs.

Total Suspended Particles: The concentration of TSP at Pirwadhai Chowk was 3,724 µg/m^3. This is much higher than the Japanese standard (200 µg/m^3). The high volume air sampler collected samples for three hours and one minute from 0602 to 0903 hrs.

Methane and Non-Methane Hydrocarbons: The hourly average concentration of methane and non-methane hydrocarbons varied from 0.0 to 0.7 and 0.0 to 4.7 respectively.

Figure 4.21 presents a graphical comparison of the measured parameters with the traffic count at Pirwadhai Chowk, while **Figure 4.22** compares NO_X, SO_2 and O_3 levels with the solar radiation at the site.

4.3 Ambient Air Quality in Islamabad

The capital of Pakistan, Islamabad, is a planned city and is not very congested. The following two locations were selected for ambient air monitoring in Islamabad:

- Sampling Site 1: Abpara Chowk, facing Melody Market
- Sampling Site 2: Industrial Area I-9, near Police Station

4.3.1 Sampling Site 1: Abpara Chowk, Facing Melody Market

Abpara Chowk is at the center of one of the main commercial areas in Islamabad. The traffic at this location comprises both diesel and petrol vehicles and all the public transport traffic traveling between Rawalpindi and Islamabad passes through this area. Both heavy and light vehicles use this crossing. Petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhausts on ambient air quality on an hourly basis.

Discussion of Results

Traffic Count: The number of petrol vehicles started to increase at 0700 hrs, reaching a maximum of 2,890 at 1200 hrs and then fell to a minimum of 1,552 at 1600 hrs. In the second swell the maximum number of vehicles was 1,822 at 2000 hrs. The variation in the number of diesel vehicles was similar to that in petrol vehicles. The maximum number of diesel vehicles was 973 at 1200 hrs and then the number kept decreasing till 1500 hrs. In the second swell the maximum number was 837 at 1800 hrs, and then it decreased steadily to a minimum of 170 at 2400 hrs.

Carbon Monoxide: The hourly average concentration of CO ranged from 0.1 to 3.0 ppm and is far less than the international standards and guidelines set by US EPA, WHO and EU countries (35 ppm). CO concentration peaked at 1900 hrs and decreased to its minimum value at 1200 hrs. The rise in CO concentration contents coincided with the increase in the number of petrol vehicles passing through the site.

Figure 4.21: Air Pollution Comparison with **Traffic Count** at Pirwadhai Chowk (Rawalpindi)

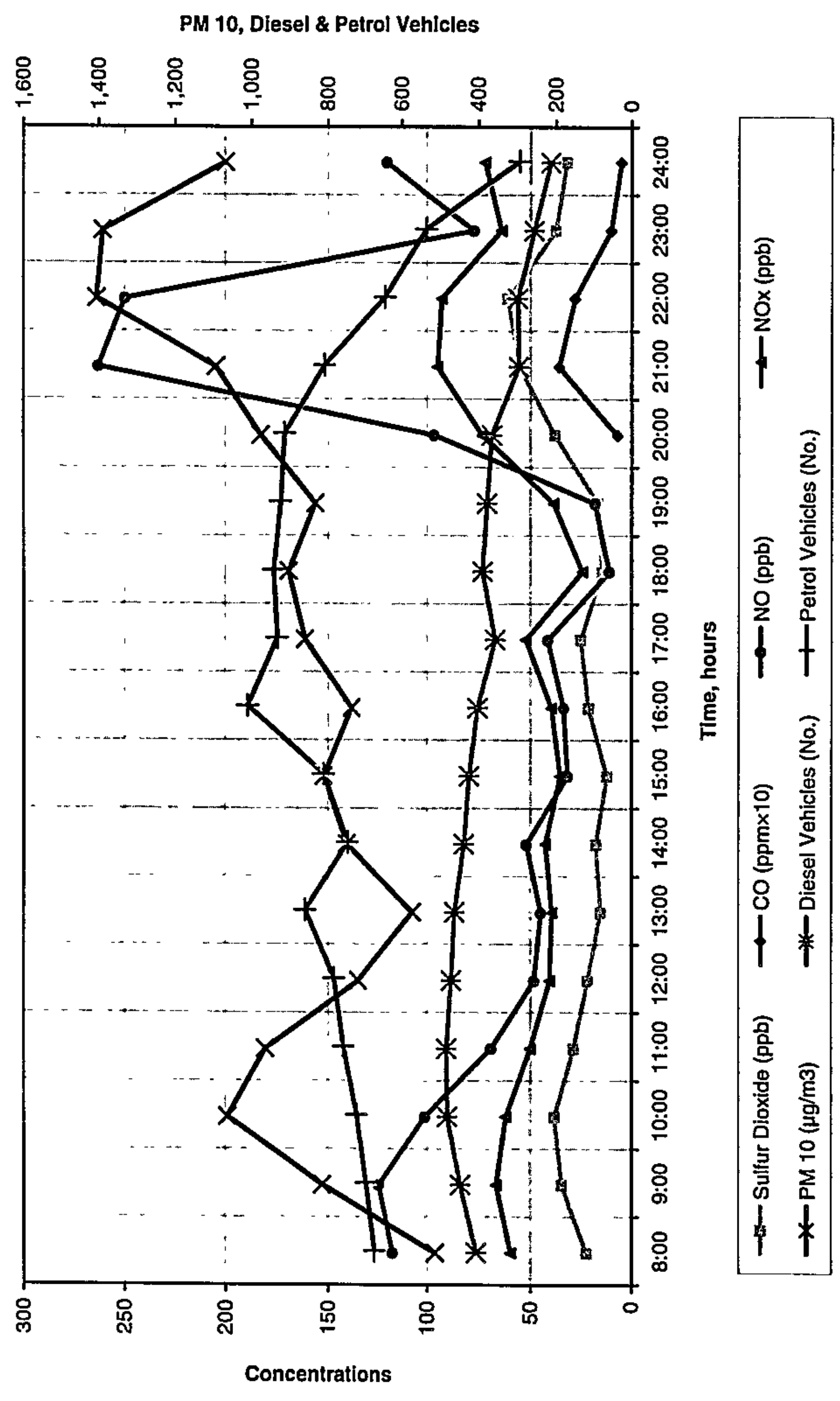
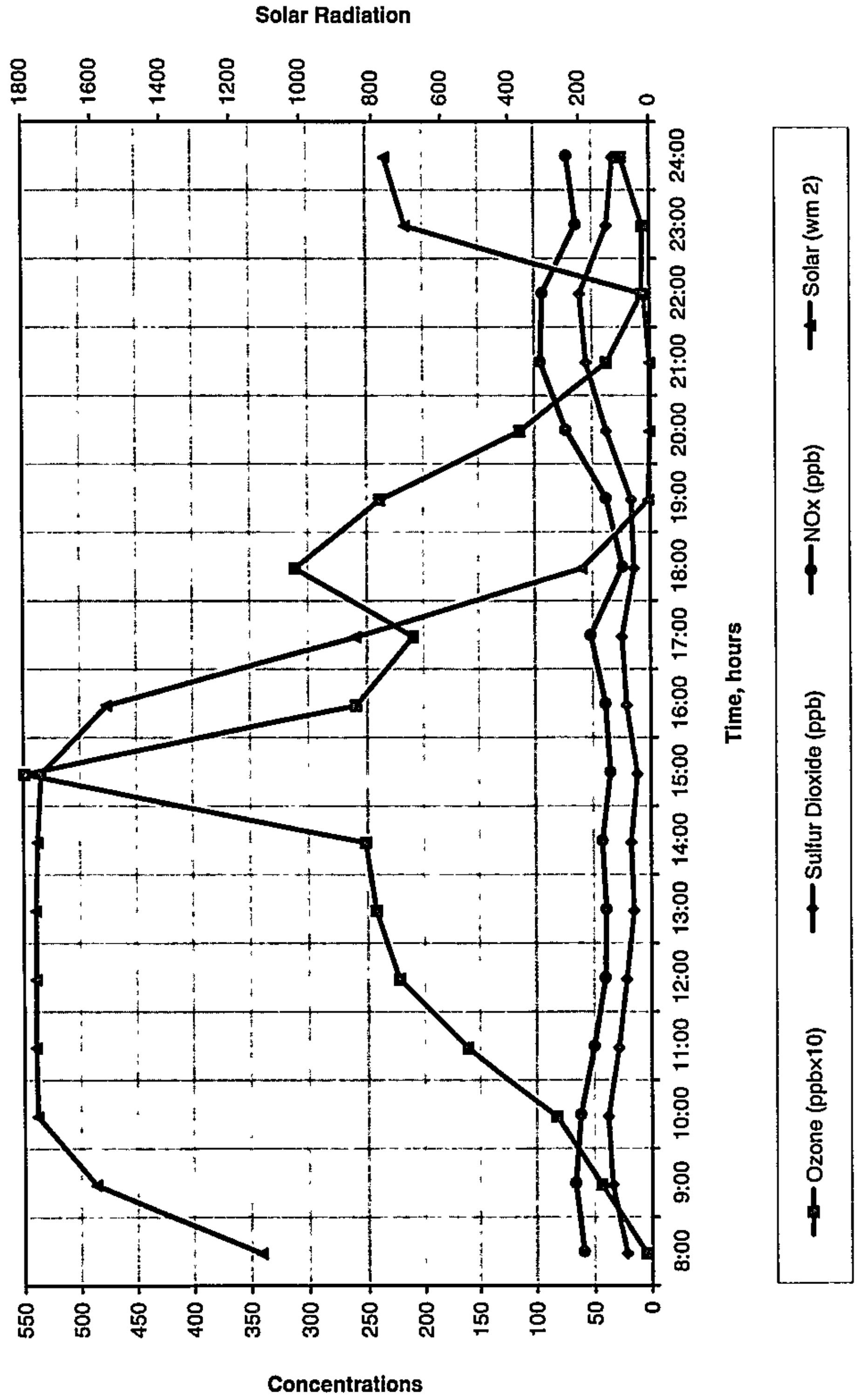


Figure 4.22: Air Pollution Comparison with **Solar Radiation** at Pirwadhai Chowk (Rawalpindi)



Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged from 53.0 to 355.2 ppb and 103.3 to 349.5 ppb respectively, as compared to the WHO's standard for NO_2 (110 ppb). The maximum NO concentration was noted at 0700 hrs (this value includes calibration reading also). The second highest value was 262.5 ppb for NO and 349.5 ppb for NO_X at 1900 hrs. The rise in NO and NO_X concentration contents was caused mainly by the petrol vehicles passing through the site.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged from 17.1 to 60.2 ppb which is far less than WHO's standard (134 ppb). SO_2 concentration rose to its maximum at 1900 hrs due to an increase in the number of diesel vehicles and decreased to its minimum because of the decline in diesel vehicles.

Ozone: The hourly average concentration of O_3 varied from 0.0 to 48.4 ppb, which is less than WHO and US EPA standards (90 ppb and 120 ppb respectively). The maximum concentration of O_3 was noted at 1500 hrs and the minimum concentration at 0700 and 0800 hrs. The O_3 concentration increased because of the rise in the solar radiation, NO_X and hydrocarbon concentrations.

Particulate Matter: The hourly average concentration of PM_{10} ranged from 107.9 to 937.8 $\mu g/m^3$, with an average concentration of 500.8 $\mu g/m^3$. This is higher than the Japanese standard (200 $\mu g/m^3$). The concentration rose to its maximum at 1600 hrs mainly due to the increase in traffic passing through the site.

Total Suspended Particles: The concentration of TSP at Abpara Chowk was 2,385 $\mu g/m^3$, which is more than the Japanese standard (200 $\mu g/m^3$). The high volume air sampler collected samples for two hours and five minutes from 0605 to 0810 hrs.

Methane and Non-Methane Hydrocarbons: The concentration of methane and non-methane hydrocarbons could not be obtained due to some technical problem in the analyzer in the Punjab EPD's mobile laboratory.

Figure 4.23 presents a graphical comparison of parameters like CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at Abpara Chowk and **Figure 4.24** compares NO_X, SO_2 and O_3 levels with the solar radiation at the site.

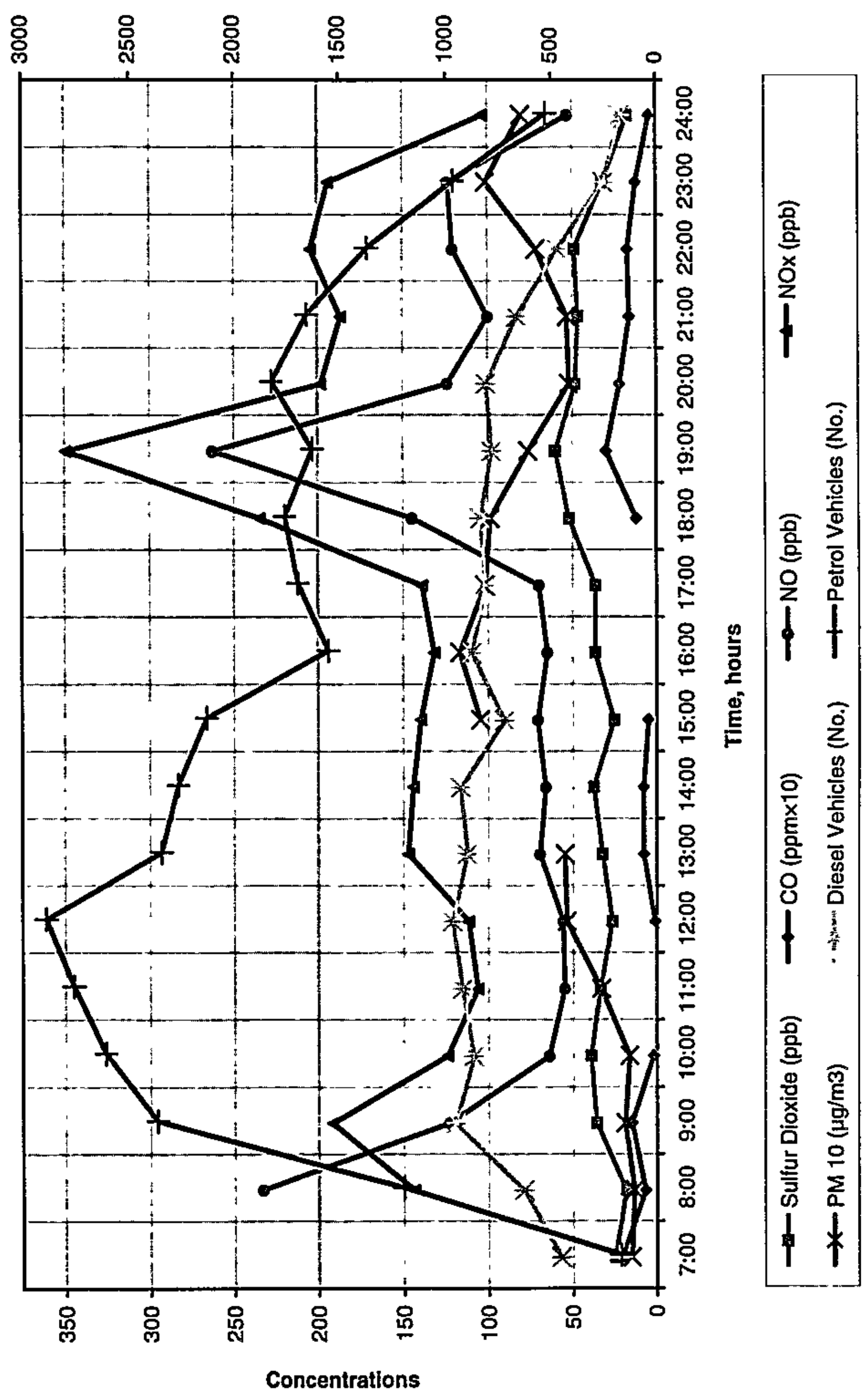
4.3.2 Sampling Site 2: I-9 Industrial Area Islamabad

This sampling location was selected as it lies between the residential and industrial areas of Islamabad. The traffic at this location comprises both diesel and petrol vehicles. Both heavy and light vehicles pass through this road. Petrol and diesel vehicles were counted in parallel with ambient air quality measurement to assess the impacts of vehicular exhaust on ambient air quality on an hourly basis.

Discussion of Results

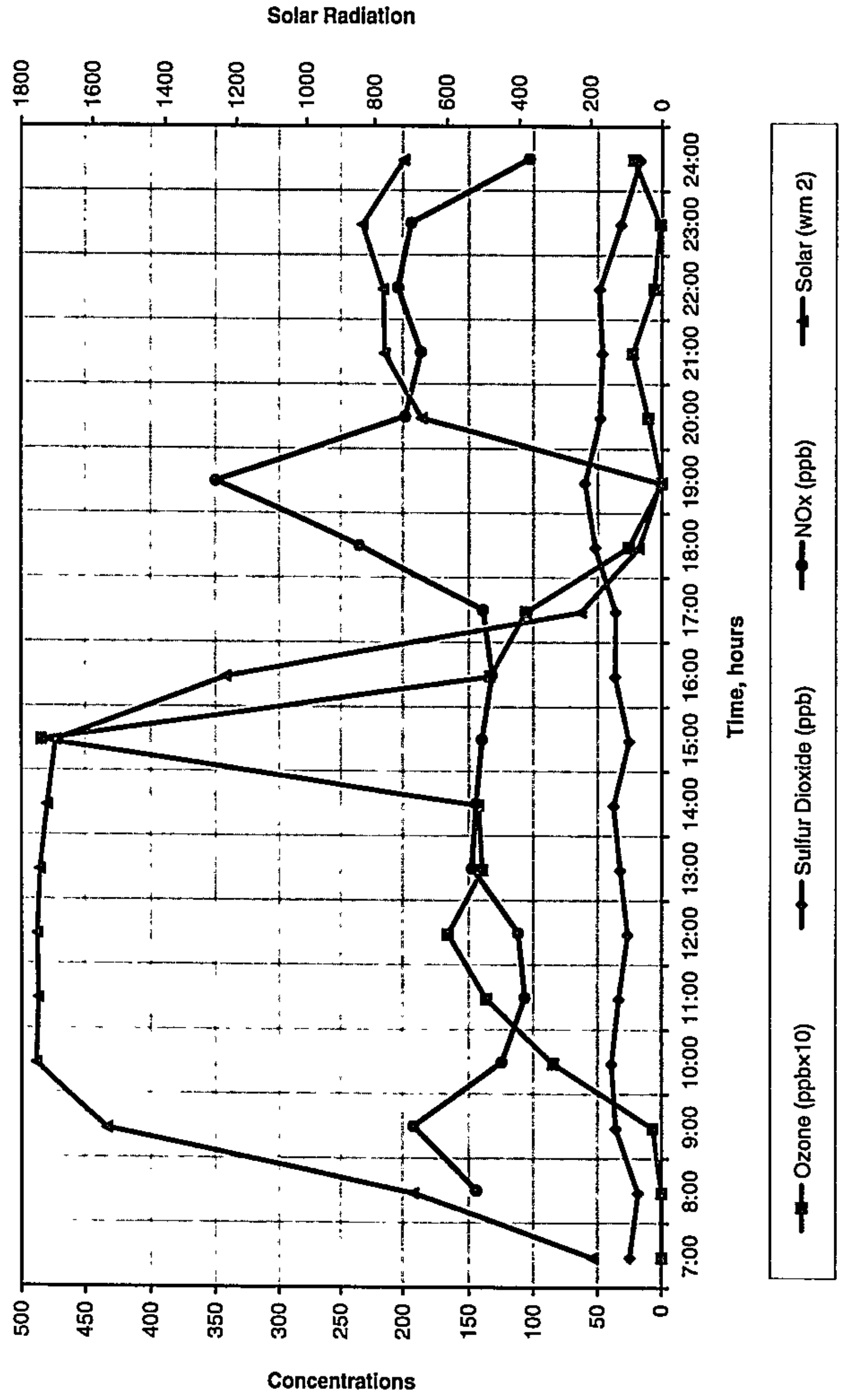
Traffic Count: The number of petrol vehicles started increasing at 0800 hrs, reaching a maximum number of 634 vehicles at 1200 hrs, and then decreased to 268 at 1500 hrs. In the second swell the maximum number of vehicles was 428 at 1900 hrs and then it decreased regularly to a minimum number of 54 vehicles at 2400 hrs. The number of diesel vehicles increased to a maximum of 226 at 1200 hrs, and then decreased steadily to 31 vehicles at 2400 hrs.

Figure 4.23: Air Pollution Comparison with **Traffic Count** at Abpara Chowk (Islamabad)



PM 10, Diesel & Petrol Vehicles

Figure 4.24: Air Pollution Comparison with **Solar Radiation** at Abpara Chowk (Islamabad)



Carbon Monoxide: The hourly average concentration of CO ranged from 0.8 to 3.6 ppm and is far less than the international standards and guidelines set by US EPA, WHO and EU countries (35 ppm). The CO concentration peaked at 1900 hrs and fell to its minimum of 0.8 ppm at 1400 hrs. The increase in CO concentration contents was because of the rise in the number of petrol vehicles passing through the site and the accumulation effect resulting from the decrease in wind speed.

Nitrogen Oxides: The hourly average concentration of NO and NO_X ranged from 10.0 to 191.5 ppb and 30.0 to 239.4 ppb, (against the WHO standard for NO_2 of 110 ppb). The maximum NO and NO_X concentrations were noted at 0700 hrs (these values include calibration readings also). The second highest NO and NO_X concentrations were 135 ppb and 226.8 ppb at 2100 hrs. The rise in NO and NO_X concentration was because of the petrol vehicles passing through the site and the accumulation effect resulting from the decrease in wind speed.

Sulfur Dioxide: The hourly average concentration of SO_2 ranged from 4.3 to 47.3 ppb, much less than WHO's standard (134 ppb). The SO_2 concentration increased to its maximum at 2200 hrs and fell to its minimum value at 1400 hrs.

Ozone: The average hourly concentration of O_3 varies from 0.1 to 52.5 ppb, far below the standards set by WHO and the US EPA (90 ppb and 120 ppb respectively). The maximum concentration of O_3 was noted at 1500 hrs and includes the calibration reading. The minimum concentration was noted at 2000 and 2100 hrs. The increase in the concentration of O_3 was caused by a rise in solar radiation.

Particulate Matter: The average hourly concentration of PM_{10} ranged from 80.7 to 853.6 $\mu g/m^3$, with an average concentration of 539 $\mu g/m^3$, which is higher than the Japanese standard of 200 $\mu g/m^3$. The maximum concentration was noted at 2000 hrs and was caused by an increase in traffic passing through the road.

Total Suspended Particles: The concentration of TSP at I-9 Islamabad was 2,230 $\mu g/m^3$, which is more than the Japanese standard (200 $\mu g/m^3$). The high volume air sampler collected samples for four hours and 45 minutes from 0630 to 1030 hrs.

Methane and Non-Methane Hydrocarbons: The concentration of methane and non-methane hydrocarbons could not be obtained due to some technical problem in the analyzer in the EPD's mobile laboratory.

Figure 4.25 presents a graphical comparison of parameters like CO, NO, NO_X, SO_2 and PM_{10} with the traffic count at I-9 Chowk and **Figure 4.26** compares NO_X, SO_2 and O_3 levels with the solar radiation at the site.

Figure 4.25: Air Pollution Comparison with **Traffic Count** at I-9 Chowk (Islamabad)

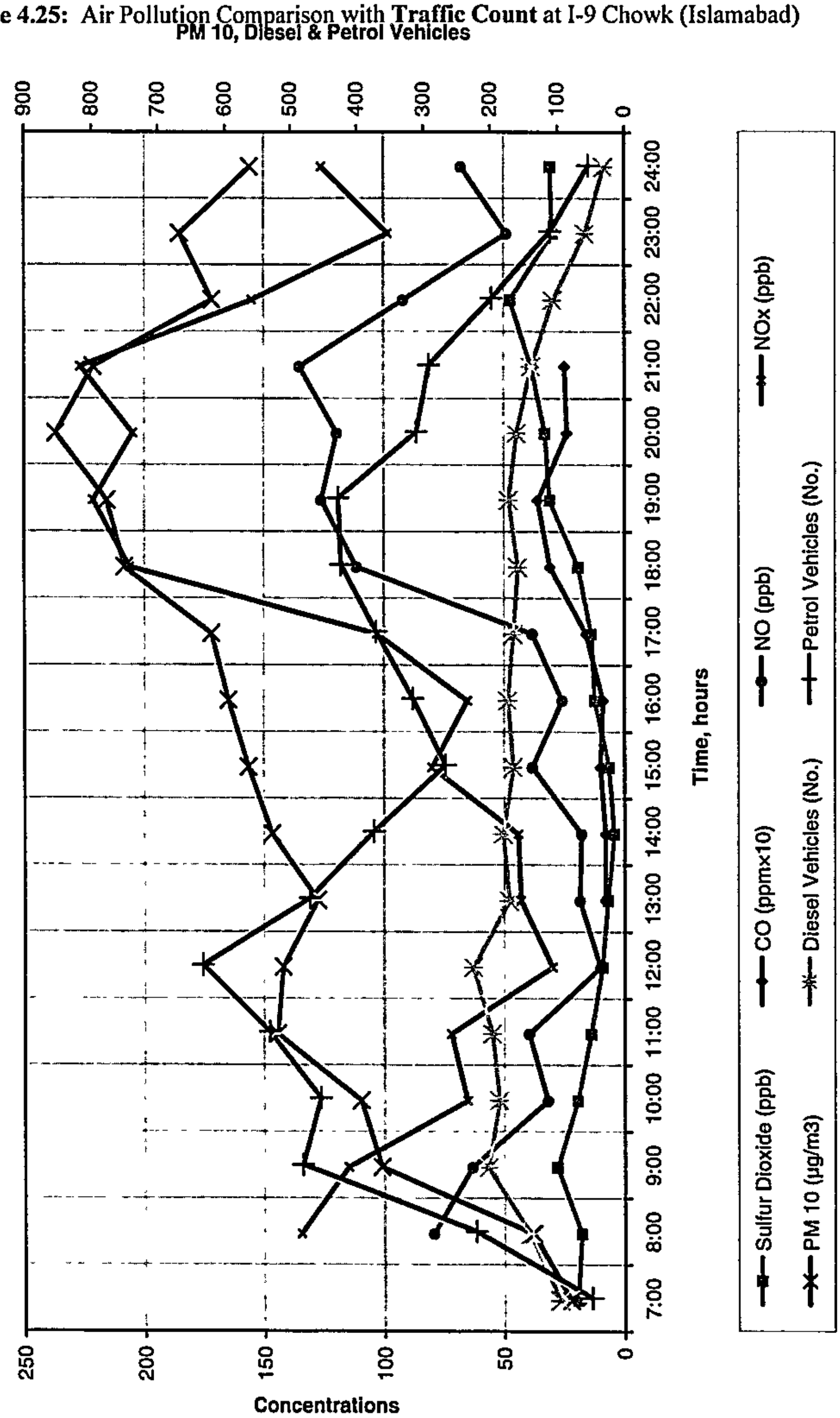
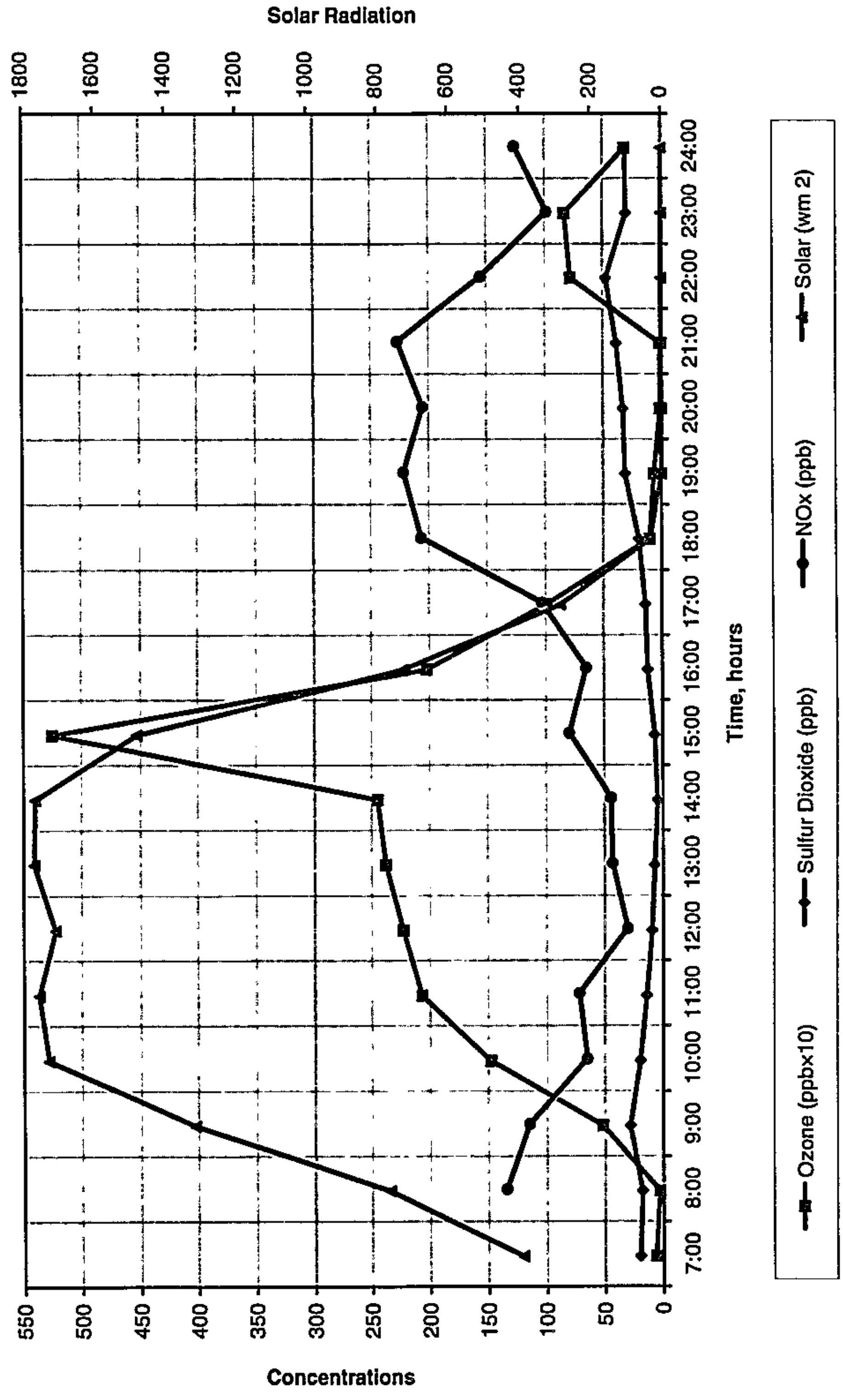


Figure 4.26: Air Pollution Comparison with **Solar Radiation** at I-9 Chowk (Islamabad)



Nitrogen Oxides

Two peaks were observed for both NO and NO_X at all five locations in Lahore. The first was observed from 0700 to 0900 hrs and the second from 1900 to 2200 hrs. A similar trend was observed at all five points in Rawalpindi and Islamabad. The maximum NO concentration value was 355.2 ppm and the highest NO_X concentration value was 349.5 ppm at Abpara Chowk at 0700 hrs and 1900 hrs respectively. Both these concentration values are higher than the WHO standard (110 ppb for NO_2). Most of the NO_X values were within the WHO limits. Graphical comparisons of NO and NO_X concentration at the five sampling sites in Rawalpindi and Islamabad are shown in **Figure 4.28** and **Figure 4.29** respectively.

Sulfur Dioxide

The concentration of SO_2 varied from 0.0 to 61.0 ppb, which is less than the standard of WHO (134 ppb). The trend in variation was almost similar at all points, except Raja Bazaar, where zero concentration was noted. All results are within WHO's permissible limit (100 ppb). **Figure 4.30** presents a graphical comparison of SO_2 concentration at the five sampling sites in Rawalpindi and Islamabad.

Ozone

Results of hourly average concentration of O_3 vary from 0.3 to 59.3 ppb, which is less than the standards of WHO and USEPA (90 ppb and 120 ppb, respectively). A similar variation trend was observed at all five sites, with a maximum peak at 1500 hrs. **Figure 4.31** presents a graphical comparison of O_3 concentration at the five sampling sites in Rawalpindi and Islamabad.

Particulate Matter

The hourly average concentration of PM_{10} varied from 0.0 to 1,406 µg/m^3 as compared to the Japanese standard of 200 µg/m^3. Only a few concentration values were less than the Japanese Standard, while the average concentration of PM_{10} remained higher than the standard at all five stations. **Figure 4.32** shows a graphical comparison of PM_{10} concentration at five sampling sites in Rawalpindi and Islamabad.

4.3.3 Comparison of Air Quality Parameters in Rawalpindi and Islamabad, by Location

Carbon Monoxide

Vehicle exhausts are a major source of CO emissions and are mainly responsible for urban pollution. The CO limit in international standards and guidelines of USEPA, WHO and EU countries is 35 ppm. The concentration of CO at all five sites in Rawalpindi and Islamabad was between 0.2 and 6.7 ppm. The sites had different increasing and decreasing trends. However, an increasing trend was recorded in the evening from 1800 to 2300 hrs. The maximum CO concentration was 6.7 ppm, noted at Murree Road near Committee Chowk at 2100 hrs. **Figure 4.27** presents a graphical comparison of CO concentration at the five sampling sites in Rawalpindi and Islamabad.

Figure 4.27: Carbon Monoxide Concentrations at the Sites in Rawalpindi/Islamabad

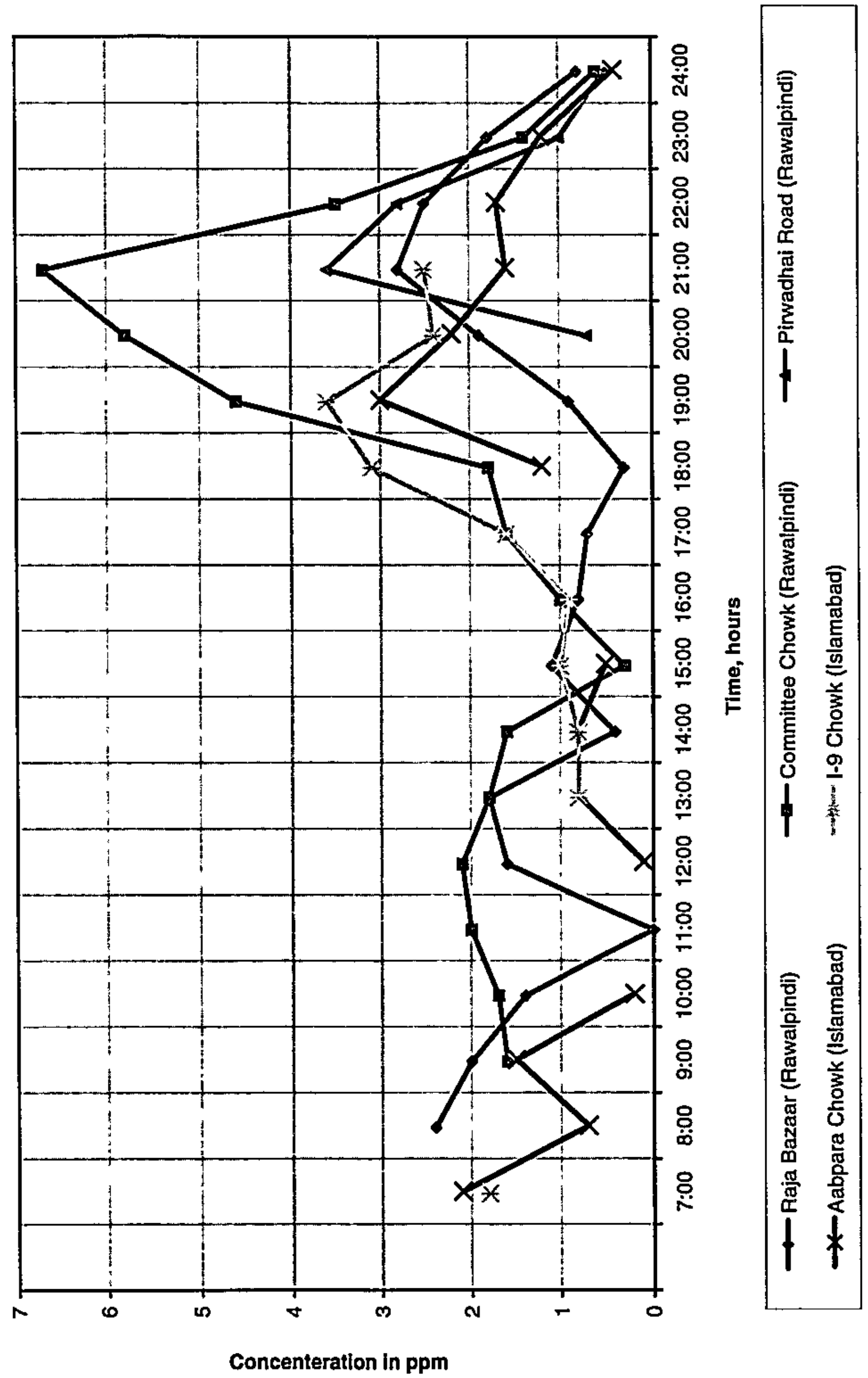


Figure 4.28: Nitrogen Monoxide Concentrations at the Sites in Rawalpindi/Islamabad

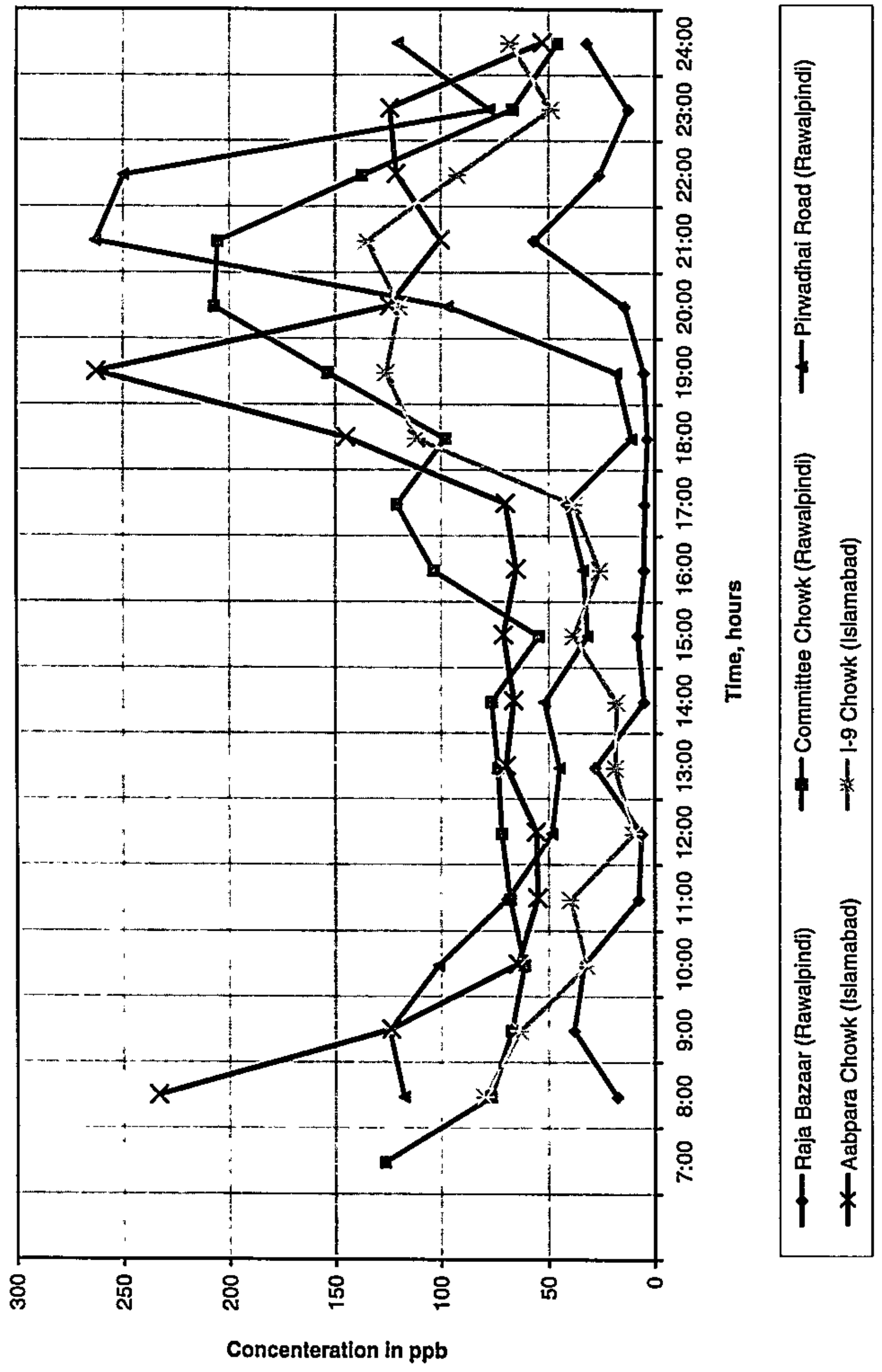


Figure 4.29: Nitrogen Oxides Concentrations at the Sites in Rawalpindi/Islamabad

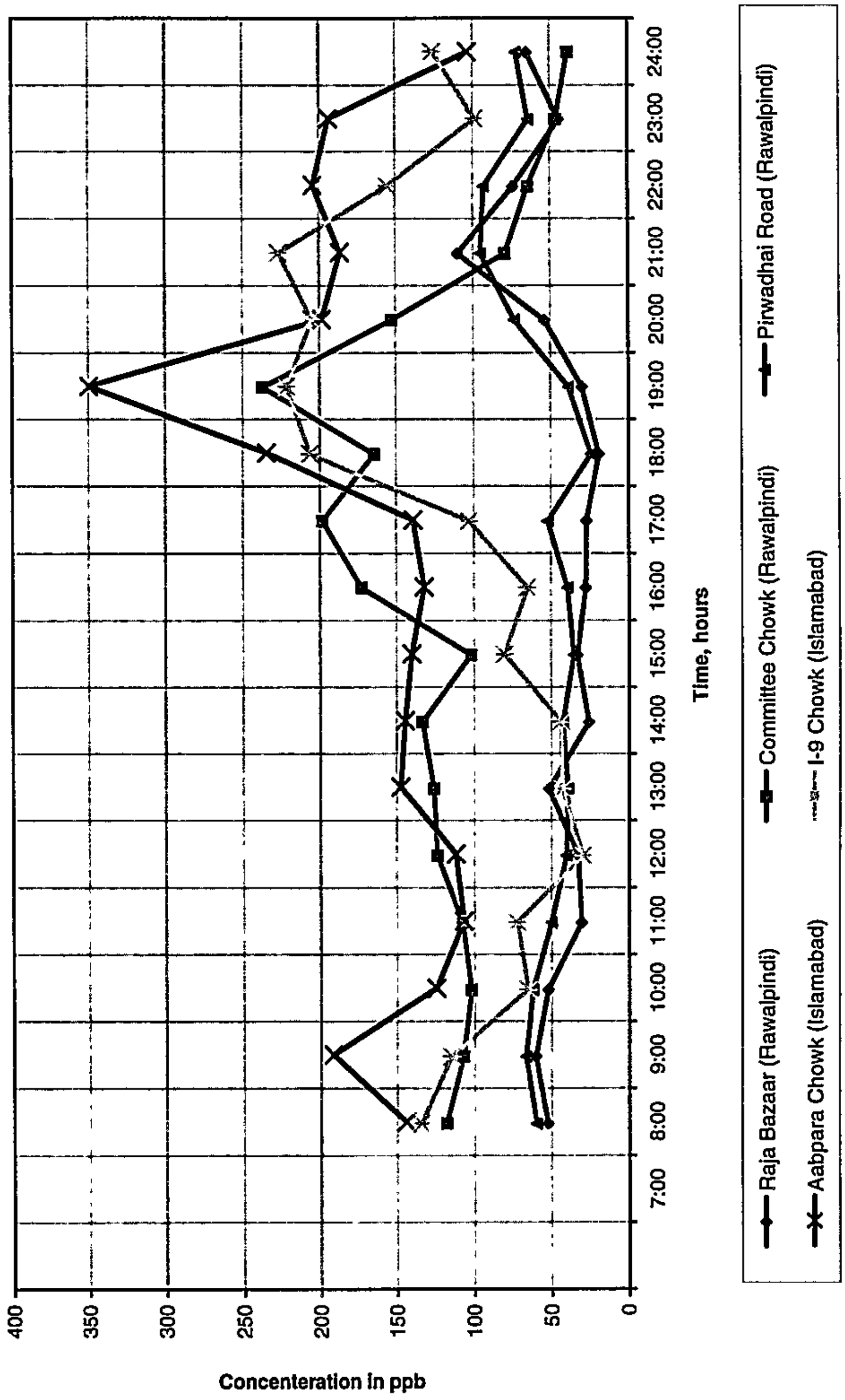


Figure 4.30: Sulfur Dioxide Concentrations at the Sites in Rawalpindi/Islamabad

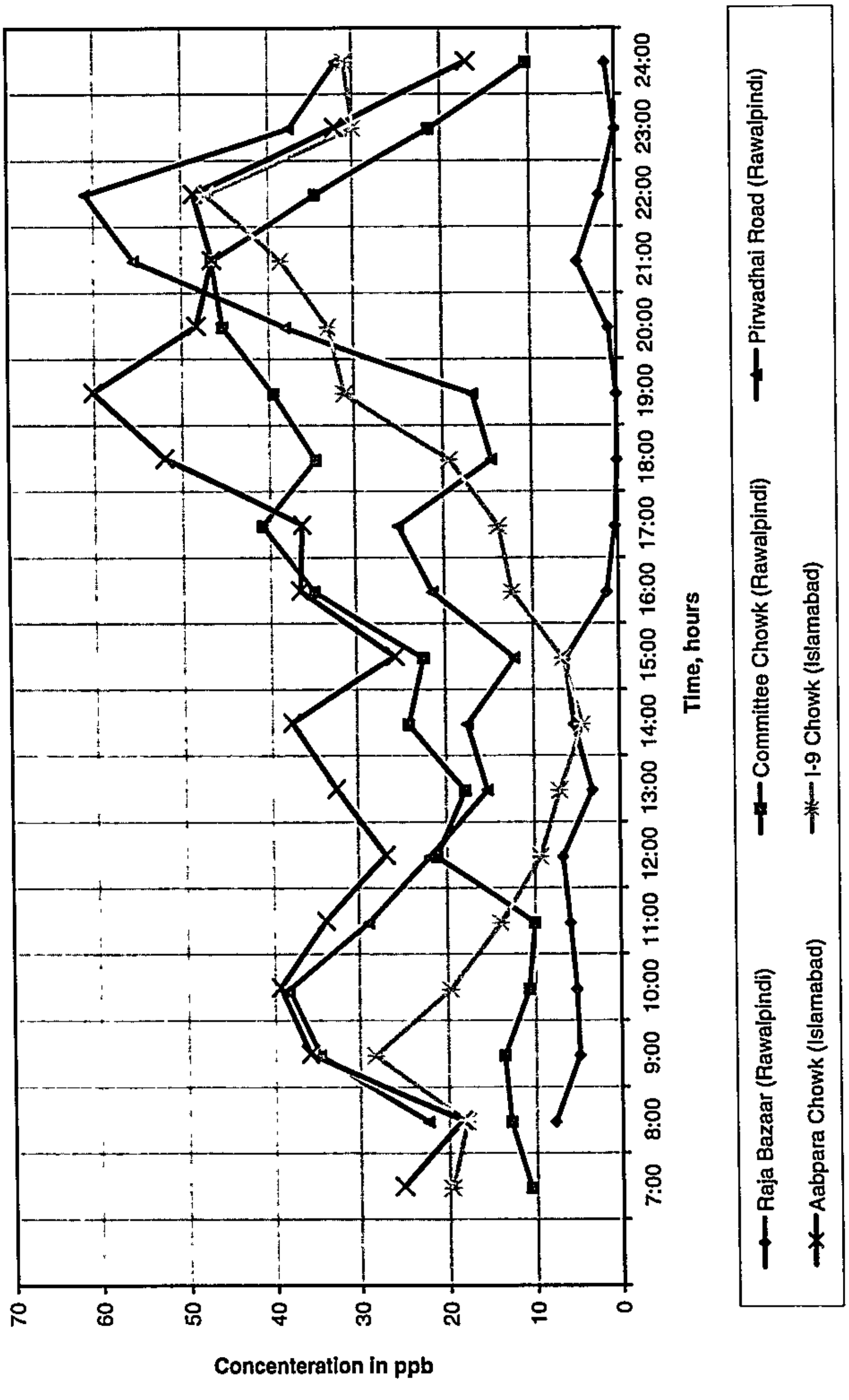


Figure 4.31: **Ozone** Concentrations at the Sites in Rawalpindi/Islamabad

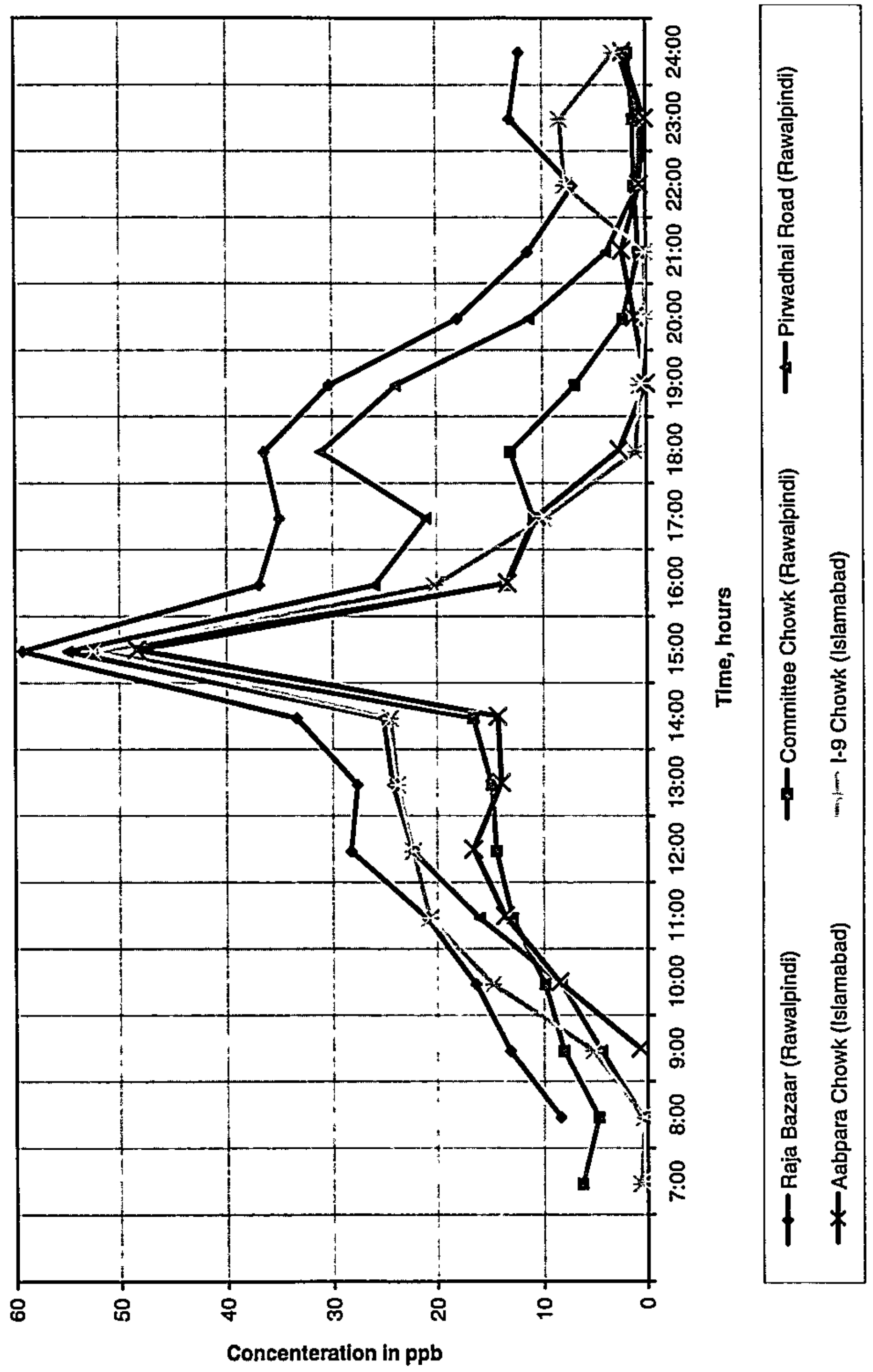
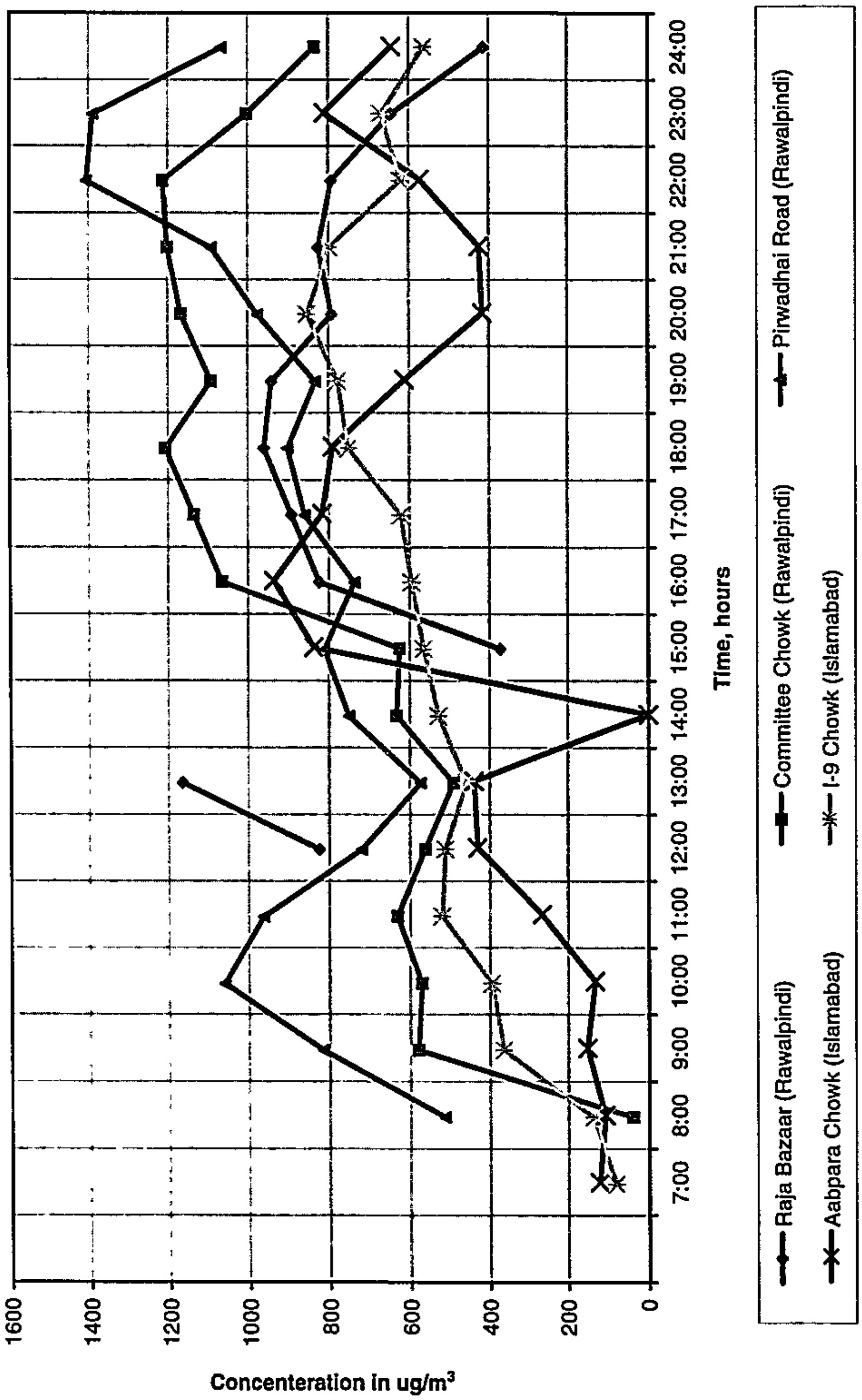


Figure 4.32: PM$_{10}$ Concentrations at the Sites in Rawalpindi/Islamabad



Meteorological Data

According to measurements taken by the Punjab EPD mobile station, wind speed at the five sampling sites in Rawalpindi and Islamabad varied from 1.0 to 6.7 m/sec. The speed increased after 1100 hrs, reaching a maximum at 1600-1800 hrs, and then decreased. Wind direction at all the five sites remained between 0 to 35 degrees, ie, to the northeast. During the sampling period, the humidity in Rawalpindi and Islamabad remained between 50-54 percent while temperature varied from 26.0 to 39.3°C. The barometric pressure varied from 941.2 to 954 m-bars.

Trace Metals

Heavy metals (As, Cu, Pb, Zn) were analyzed in all the five samples collected from five locations in Rawalpindi and Islamabad. The TSP samples were collected using a high volume air sampler installed at the five locations. Duplicate samples were collected from the Raja Bazar and Murree Road sites. All the samples were analyzed at the Geoscience Laboratory in Islamabad. **Table 4.2** shows the concentrations of trace metals in air at the five locations.

Arsenic: Arsenic level in ambient air at five sampling sites of Rawalpindi and Islamabad varied from 0.19 $\mu g/m^3$ to 3.12 $\mu g/m^3$. Maximum concentration of arsenic was measured at Abpara Chowk, Islamabad, whreas minimum concentration was measured at Raja Bazar, Rawalpindi. Only two sites one in Rawalpindi and one in Islamabad showed less concentration of arsenic in the ambient air compared to the guidelines set for State of Arizona, which is 0.32µg/m3. Japanese standard for arsenic, based on 24-hr average is set at less than 0.01 ppm.

Copper: Copper level in ambient air at five sampling sites of Rawalpindi and Islamabad varied from 0.53 $\mu g/m^3$ to 8.33 $\mu g/m^3$. Maximum Copper concentration was found in the duplicate sample from Murree Road, Rawalpindi and the minimum concentration was found in the sample from I-9 Chowk, Islamabad.

Lead: Lead level in ambient air at five sampling sites of Rawalpindi and Islamabad varied from 0.71 $\mu g/m^3$ to 10.93 $\mu g/m^3$. Maximum Lead concentration was found in the sample from Abpara Chowk, Islamabad and the minimum concentration was found in the sample from Raja Bazar, Rawalpindi. The WHO guidelines for lead concentraion in ambient air based on annual average gives a range of 0.5$\mu g/m^3$ to 1.0µg/m3. The USEPA and EU set lead concentration in ambient air as 1.5µg/m3 and 2µg/m3, respectively, based on quarterly average. All 5 sites in Rawalpindi and Islamabad, show lead concentration higher than the standards set by WHO, USEPA or EU. However, for true comparison continuous measurement of lead is required to achieve annual or quarterly average. Japanese standard for lead, based on 24-hr average is set at less than 0.01 ppm.

Zinc: Zinc level in ambient air at five sampling sites of Rawalpindi and Islamabad varied from 1.08 $\mu g/m^3$ to 4.48 $\mu g/m^3$. Maximum Zinc concentration was found in the sample from Murree Road, Rawalpindi and the minimum concentration was found in the sample from Pirwadhai Road, Rawalpindi. The WHO does not specify any standards for zinc in ambient air.

Table 4.2: Heavy metals in Ambient air samples from Rawalpindi and Islamabad

No.	*Sampling Sites*	*Arsenic ($\mu g/m^3$)*	*Copper ($\mu g/m^3$)*	*Lead ($\mu g/m^3$)*	*Zinc ($\mu g/m^3$)*
1a	Raja Bazar Rawalpindi	0.19	0.93	0.71	1.52
1b	Raja Bazar Rawalpindi	0.58	2.25	2.10	2.42
2a	Murree Road Rawalpindi	0.44	1.58	1.54	4.48
2b	Murree Road Rawalpindi	2.79	8.33	10.00	2.78
3	Pirwadhai Rawalpindi	1.39	0.84	4.93	1.08
4	Abpara Chowk Islamabad	3.12	1.38	10.93	2.53
5	I-9 Chowk Islambabad	0.24	0.53	0.96	2.16

5. Water Quality Results

This section of the report presents a discussion on the field and laboratory test results for water quality in Lahore, Rawalpindi, and Islamabad, and compares them with international standards, such as those of WHO and USEPA, and Indian Standards for Irrigation.

Details of the field results are provided in **Appendix E**, while spot and laboratory results are summarized in **Appendix F**. Photographs of sampling sites were also taken and recorded for future reference and are shown in **Appendix G**.

5.1 Water Quality in Lahore

The water quality of the Ravi River was assessed by obtaining step-by-step information on the degree of deterioration the river undergoes when wastewater from industrial and domestic sources is discharged into it at various locations. To gather representative environmental data pertaining to river water quality, 20 sites were logically selected for the collection of wastewater samples. The sampling area was distributed in the following three regions:

- **Eastern Side of the Ravi River.** This area receives wastewater from all tributaries originating from the eastern side of the Ravi River, ie, from Lahore. These include:
    - New Shadbagh Drain
    - Babu Sabu Outfall
    - Main Outfall
    - Satokatala Drain
    - Hudiara Drain.
- **Western Side of the Ravi River.** This area receives wastewater from all tributaries coming from the western side of the Ravi River and includes:
    - Bhed Nullah
    - Deg Nullah
    - Choti Deg
    - Chichoki Mallian Drain
    - Barian Drain
    - Deg Nullah II, joining after Balloki Headworks
    - Mundawana Drain, joining after Balloki Headworks.
- **Ravi River Bed.** The samples were collected from the following locations:
    - The siphon, before any drain joins the river
    - After the new Shadbagh Drain joins the river
    - Junction with Hudiara Drain

- About 1 km downstream of junction with Hudiara Drain
- Balloki Headworks.

The Ravi River enters Pakistan near Jassor (0 km), and joins the Chenab River after flowing for 640 km. It ultimately joins the Indus River. The river receives untreated wastewater from Lahore and nearby industrial areas from a number of discharge points. Tributaries carrying wastewater discharge from the districts of Sheikhupura and Faisalabad also add to the pollution. About 1.5 million cubic meters of wastewater from Lahore, with a BOD loading of 440 metric tons per day (mt/day),[1] are being discharged directly into the Ravi River.

Hudiara Drain enters Pakistan from India near Lalloh Rangers Post and discharges untreated industrial and domestic wastewater into the Ravi River. The estimated BOD loading of Hudiara Drain is 65 mt/day.[2] Similarly, the Deg Nullah carries wastewater from the Kala Shah Kaku industrial complex, contributing about 27.2 mt/day[3] of BOD. Factories located on the Lahore-Sheikhupura Road also discharge wastewater into the Deg Nullah, which eventually enters the Ravi River and carries a BOD load of 43 mt/day. Detailed information of the 20 sampling sites selected for the project is given in **Table 5.1.**

This study presents an assessment of the water quality in the river and different tributaries joining the river, over a distance of about 300 km.

5.1.1 Selected Parameters

Water quality is characterized by its physical, chemical, and biological properties. These characteristics undergo changes as time passes. Physical characteristics such as pH, turbidity, total suspended solids, and temperature are indicative of the general quality of water.

Dissolved oxygen, temperature, pH, conductivity, turbidity, odor and color were checked on spot at every sampling site. Other parameters, including chemical oxygen demand (COD), BOD, total suspended solids (TSS), total nitrogen (T–N), and oil and grease (O&G), were analyzed at Hagler Bailly's environmental laboratory. BOD loading at each sampling point was calculated in terms of mt/day.

A discussion on the results of these selected parameters is presented below.

Dissolved Oxygen

Oxygen in the river and other water bodies is depleted by bacterial oxidation of suspended and dissolved organic matter due to the oxygen demand of sludge and bentheic deposits.[4] The organic matter is discharged into the river and water bodies from both natural and anthropogenic activities. The level of dissolved oxygen (DO) in natural water and wastewater depends upon the physical, chemical, and biochemical activities taking place in the water body. DO determines whether or not biological changes are brought about by aerobic or anaerobic microorganisms.

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[1] K. Ahmad and W.Ali. 1998. *24th WEDC Conference.* Islamabad.

[2] Balfours 1987. *Lahore Wastewater Treatment Project.*

[3] Scott and Furphy. 1993. *Punjab Urban Environment Project.* Lahore: NESPAK.

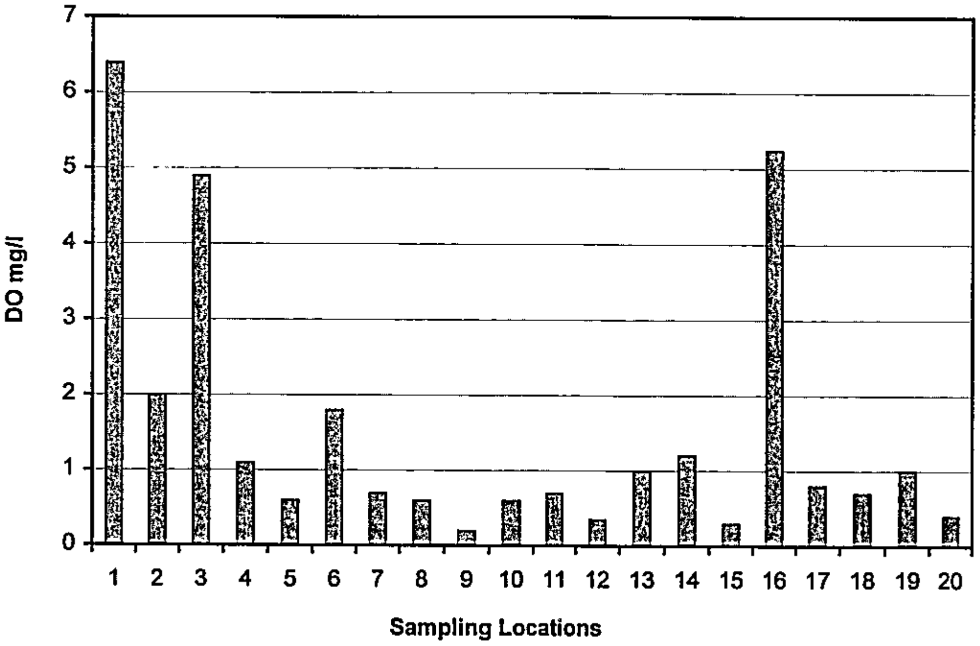
[4] SIDA and UNEP Network for Industrial Environmental Manamgement. 1993. *Receiving Water Quality Evaluation*, vol. 1.

Table 5.1: Wastewater Sampling Locations in Lahore

Serial No.	*Sampling Site No.*	*Location*
1	(SS-1)	River Ravi at BRB Siphon (along the river bank)
2	(SS-6)	New Shadbagh Sewage Drain at Bund Road
3	(SS-2)	River Ravi at Bara Dari near boat station
4	(SS-8)	Babu Sabu Drain at Bund Road
5	(SS-3)	Babu Sabu Outfall, before joining Ravi River
6	(SS-7)	Main Outfall Drain at Bund Road
7	(SS-11)	Deg Nullah at Sheikhupura Road
8	(SS-12)	Choti Deg Nullah at Sheikhupura Road
9	(SS-10)	Bhed Nullah at Sheikhupura Road
10	(SS-20)	Hudiara Drain after entering Pakistan from India
11	(SS-16)	Hudiara Drain at Ferozpur Road
12	(SS-15)	Satokatala Drain at Defence Road
13	(SS-9)	Hudiara Drain at Multan Road
14	(SS-17)	River Ravi at Junction with Hudiara Drain at Khurd Pur
15	(SS- 4)	River Ravi 1 km downstream of junction with Hudiara Drain
16	(SS-5)	River Ravi 200 m upstream of Balloki Headworks
17	(SS-13)	Chichoki Malian Drain at Sheikhupura Road
18	(SS-14)	Barian Drain, 1 km off Sheikhupura Road
19	(SS-18)	Deg Nullah, before joining the Ravi River, after Balloki HW
20	(SS-19)	Mundawana-Samundri Drain before joining the Ravi River

Water purity can be readily assessed by measuring DO. The DO concentration noted during spot tests at 20 points in Lahore ranged from 0.2 to 6.4 mg/l. The maximum DO concentration was observed at the siphon point of the Ravi River, and the minimum DO value was observed at Bhed Nullah, Sheikhupura Road. Sampling sites 1, 3 and 16 were located on the Ravi River. The flow of water at these points ranged from 340 to 480 m^3/sec. According to United States Public Health (USPH) Standards, DO in drinking water should range from 4.0-6.0 mg/l. The values observed at these three points are less than 4 mg/l and thus the water cannot be used for drinking purposes. A comparison of DO concentration at different points in Lahore is shown in **Figure 5.1.**

Figure 5.1: Comparison of DO at Sampling Sites in Lahore



Temperature

The temperature of a body of water has a number of indirect effects on the biota because a change in temperature changes the solubility of essential gases, including oxygen. A change in temperature also influences the metabolic rates. Temperature at the 20 sampling sites in Lahore was within the range of 26.1 to 35.5°C. The minimum temperature was noted at the siphon point of the Ravi River, while the maximum temperature was at the Bhed Nullah, Sheikhupura Road. This high temperature is caused by the industrial discharge in the Bhed Nullah. **Figure 5.2** presents a comparison of the temperature noted at the 20 sampling sites in Lahore.

pH

Because of the buffering capacity of the CO_3-HCO_3 system in water, the pH value is neutral (ie, 7.0) in most natural waters. The pH rises when the carbonates in the water are utilized by microorganisms such as algae, while decomposition of organic pollutants causes pH to drop to the acidic range. Wastewater pH noted at 20 sampling points in Lahore ranged from 7.0 to 9.3. The minimum pH was noted at Barian Drain while the maximum was at Bhed Nullah. Both the drains are industrial drains. According to USPH standards, pH should range from 6.0-8.5 in drinking water. WHO guidelines for aesthetic water quality specify a range of 6.5-8.5 pH, while, according to Indian standards, the pH of water should be 6.0-9.0 and the pH of sewage effluents discharged on land for irrigation should be 5.5-9.0. **Figure 5.3** compares the pH noted at the 20 sampling sites.

Figure 5.2: Comparison of Temperature at Sampling Sites in Lahore

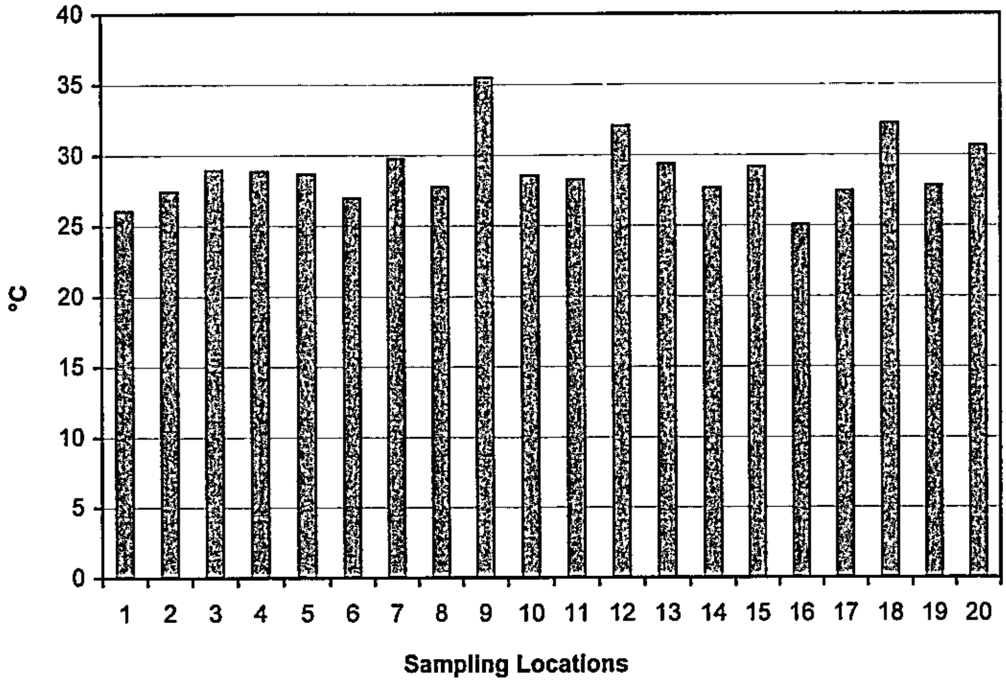
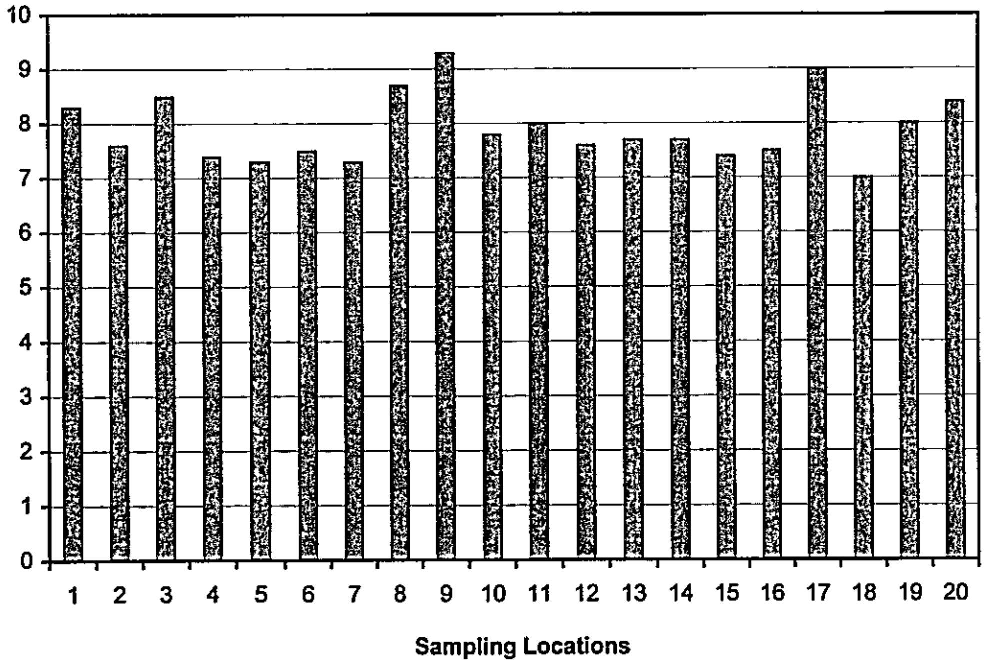


Figure 5.3: Comparison of pH Values at Sampling Sites in Lahore



Conductivity

Conductivity characterizes the gross chemical position of water and is a measure of the ability of water to conduct an electric current. The electric current is transported by the ions in any solution. A rise in the concentration of ions results in an increase in the conductivity of the solution. Conductivity values of the wastewater and river water samples collected from Lahore were observed to range from 227 to 5,310 micro simons per centimeter (µS/cm). The minimum value was 227 µS/cm, at the siphon of the Ravi River and the maximum value was 5,310 µS/cm at Deg Nullah II. According to USPH standards, the maximum limit of conductivity in drinking water should be 300 µS/cm. **Figure 5.4** below shows a comparison of conductivity noted at 20 sampling sites in Lahore.

Turbidity

Turbidity in water is caused by the suspended and colloidal matter present in it. It is checked by a Nephelometer and reported in NTU (Nephelometric Turbidity Unit). Results of turbidity at 20 sampling sites in Lahore varied from 21 to 237 NTU. The highest value was noted at Barian Drain. Paper industries in the Sheikhupura area discharge effluents into the drain, causing the high levels of turbidity at this point. According to WHO guidelines, the maximum limit of turbidity for aesthetic water quality is 5 NTU. **Figure 5.5** shows a comparison of turbidity noted at 20 sampling sites in Lahore.

Figure 5.4: Comparison of Conductivity at Sampling Sites in Lahore

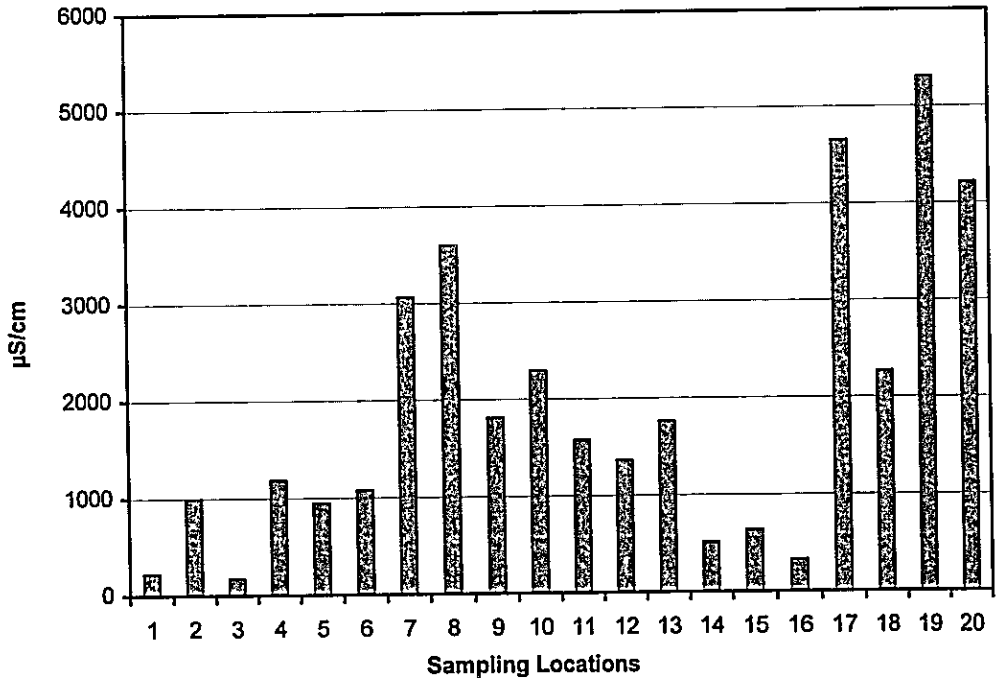
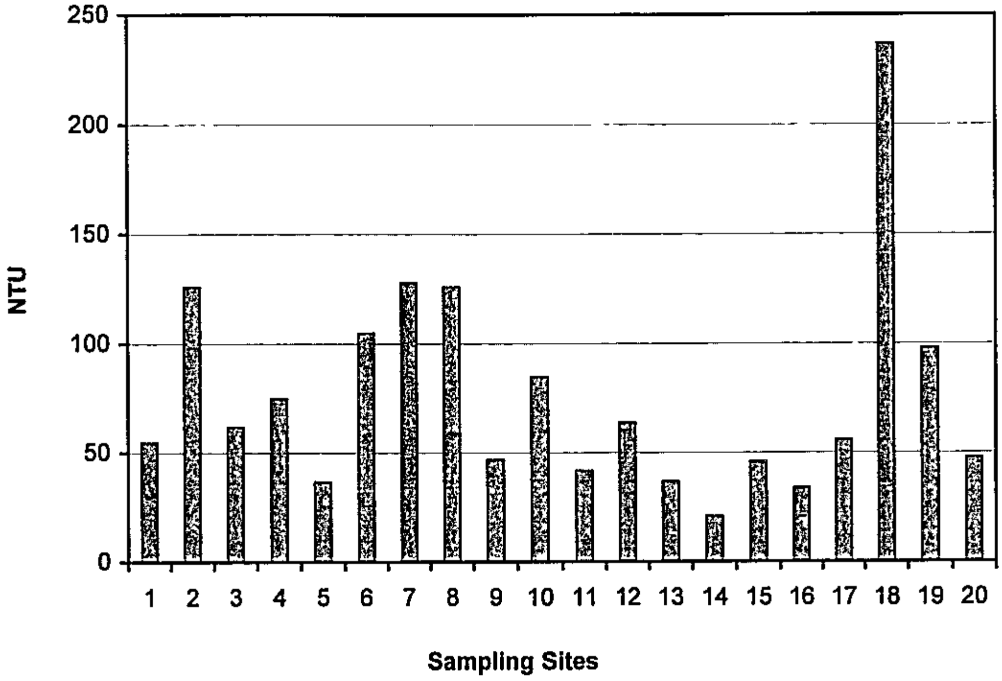


Figure 5.5: Comparison of Turbidity at Sampling Sites in Lahore



Color

Color in water is caused by the natural metallic ions (iron and manganese), bio-mass and peat materials, planktons, weeds, industrial and domestic wastes present in it. Many industrial wastes are colored and if not properly treated, can transfer color to the receiving stream as well. Surface water appears colored due to the colored suspended matter present in it. The true color of the samples collected was measured by the visual comparison method using the platinum-cobalt standard method. The results of the color measurements at the 20 sampling sites varied from 1.0 to 1000 True Color Units (TCU). Water at a few sites had a dirty, grayish color and so could not be visually compared. This has been reported as ND (not detected). The highest measurement was 1000 TCU, noted in the samples taken from the Deg Nullah, Hudiara Drain after entering Pakistan and Deg Nullah II. The minimum value was 21 at the junction of the Ravi River with the Hudiara Drain. According to the USPH standard for drinking water, water should be colorless. According to WHO guidelines, the maximum limit for color is 15 TCU for aesthetic quality of water. **Figure 5.6** shows a comparison of true color noted at 20 sampling sites in Lahore.

Odor

The threshold odor test was carried out at the sampling sites using odor-free water for comparison. The sample volume was diluted to 200 ml for comparison with odor-free water. Results are reported in TON (Threshold Odor Number). Results of the odor tests at 20 sampling sites varied from 1.01 to 100 TON. The maximum value was 100 TON at the Mundawana Drain, which is due to the excessive amount of industrial effluents present in the drain. According to USPH standards for drinking water, water should be odorless. According to WHO guidelines, the odor should be inoffensive to most consumers. A comparison of the odor noted at the 20 sampling sites is shown in **Figure 5.7**.

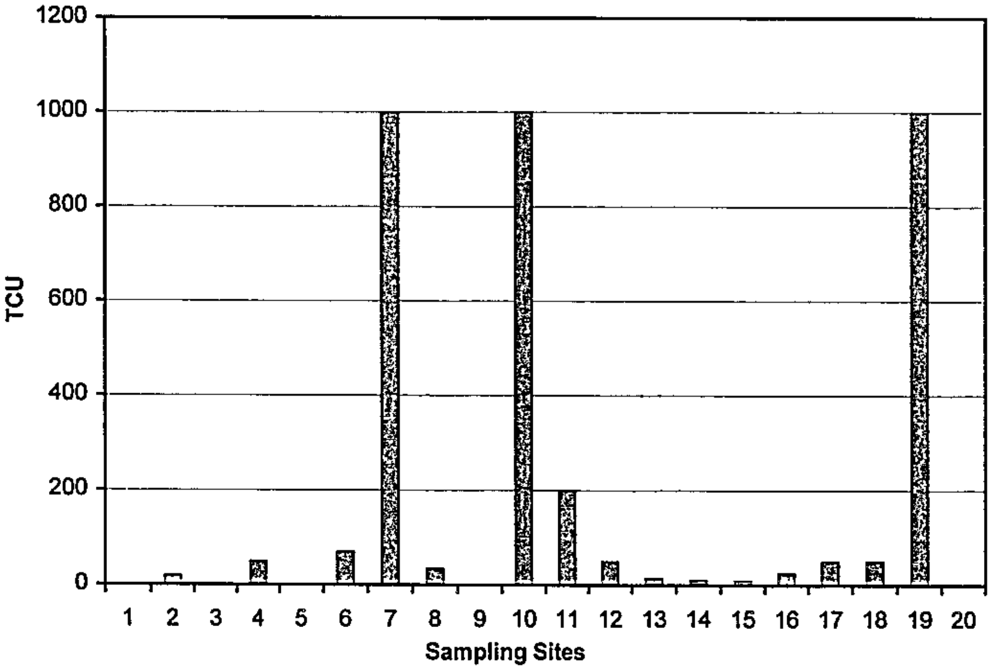
DO, BOD, COD, T-N in water are the most important pollution indicators. Determination of DO is the basis of the BOD test, which is commonly used to evaluate the pollution load of wastewater.

BOD

BOD represents the quantity of oxygen required by bacteria and other microorganisms during biochemical degradation and transformation of organic matter present in wastewater, under aerobic conditions. The BOD test is important in the analysis of sewage, industrial effluent, and polluted water. In spite of its inherent limitations, it is the best available method for assessing organic pollution and is the most important parameter used in stream pollution control.[1] The test is widely used to determine the pollution load of domestic and industrial wastewater, in terms of oxygen required, if being discharged into the natural watercourses.

Test results of BOD at 20 points in Lahore varied from 7.1 to 449 mg/l. The minimum value was 7.1 mg/l, noted at the Ravi River, 200 m upstream of Balloki Headworks. The maximum value was 449 mg/l, noted at Hudiara Drain just after it enters Pakistan. According to Indian standards, the maximum limit of BOD for sewage effluents discharged on land for irrigation is 180 mg/l. **Figure 5.8** shows a comparison of BOD noted at the 20 sampling sites in Lahore.

Figure 5.6: Comparison of Color at Sampling Sites in Lahore



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[1] S.S. Dara. 1997. *Environmental Chemistry and Pollution Control*. New Delhi.

Figure 5.7: Comparison of Odor at Sampling Sites in Lahore

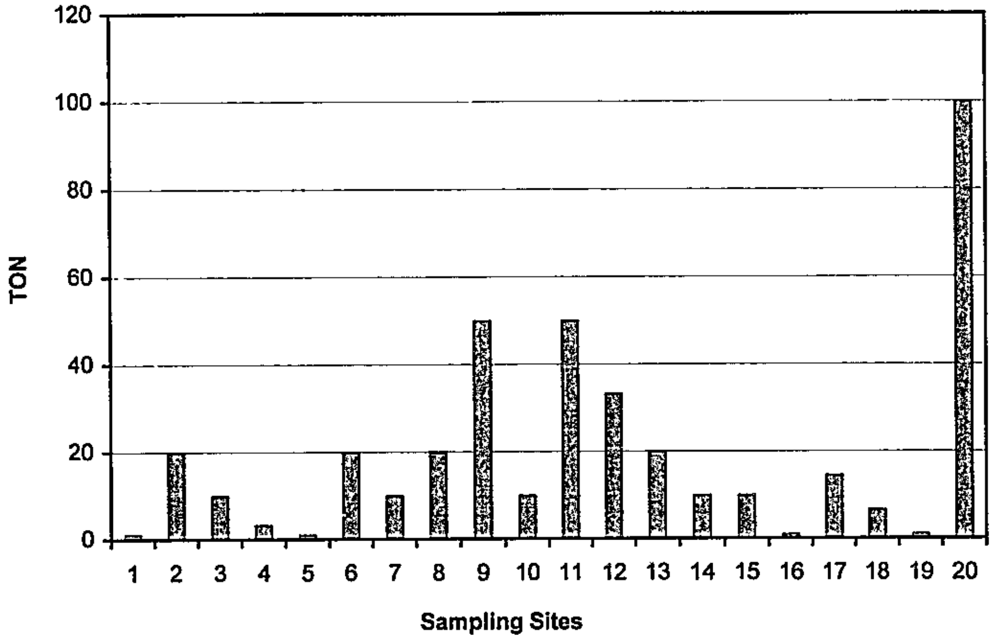
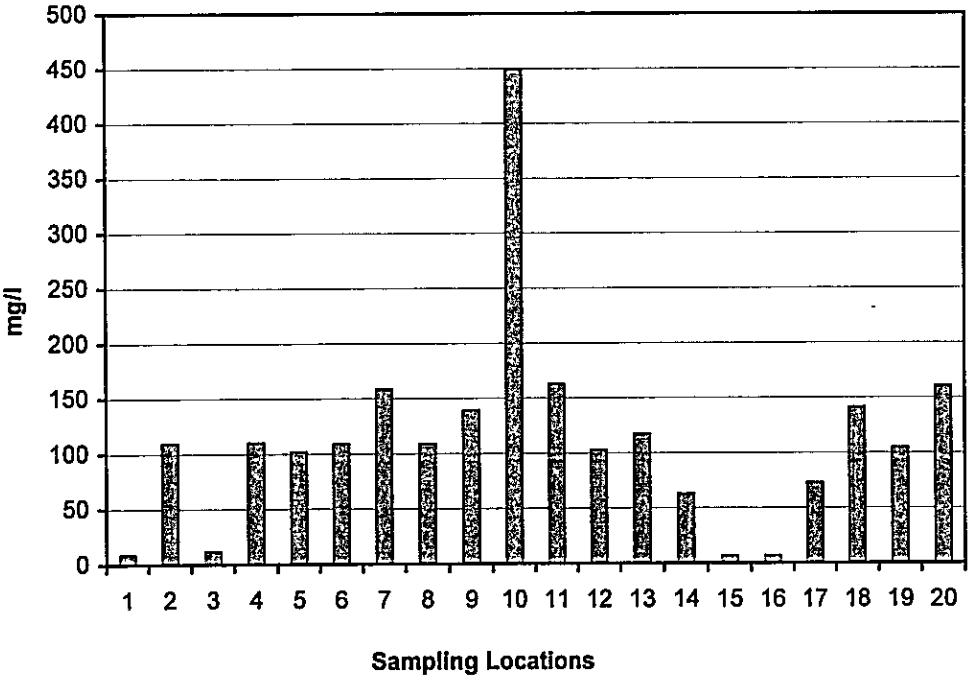


Figure 5.8: Comparison of BOD at Sampling Sites in Lahore



COD

COD is a measure of oxygen equivalent to the portion of organic matter in wastewater that is susceptible to oxidation by potassium dichromate. COD is an important test and gives a quick measure of the pollution load of stream, sewage and industrial wastewater samples. It allows wastewater measurement in terms of total quantity of oxygen required for oxidation to carbon dioxide and water.

COD concentration noted at 20 sampling locations in Lahore varied from 16.93 to 2,383 mg/l. The minimum value was 16.93 mg/l, noted at the siphon of the Ravi River, while the maximum value was 2,383 mg/l, at the Barian Drain. The high value of COD in Barian Drain is because of the untreated effluents from the paper industries in the area present in the water. According to USPH standards, the maximum limit of COD in drinking water is 4.0 mg/l. **Figure 5.9** shows a comparison of COD noted at 20 sampling sites in Lahore.

TSS

All contaminants in water, other than dissolved gases, contribute to the solid load and can be classified by their size, state, and chemical characteristics. Solids found in water typically include silt and clay from riverbanks, and organic matter and microorganisms from natural or human sources. The TSS values observed at the 20 sampling sites varied from 80 to 5,982 mg/l. The minimum value, 80 mg/l, was observed at the Ravi River at Balloki Headworks, while the maximum value, 2,383 mg/l, was in the Barian Drain. According to USPH standards, the maximum limit of TSS in drinking water is 5.0 mg/l. **Figure 5.10** shows a comparison of TSS at the 20 sampling sites in Lahore.

Figure 5.9: Comparison of COD at Sampling Sites in Lahore

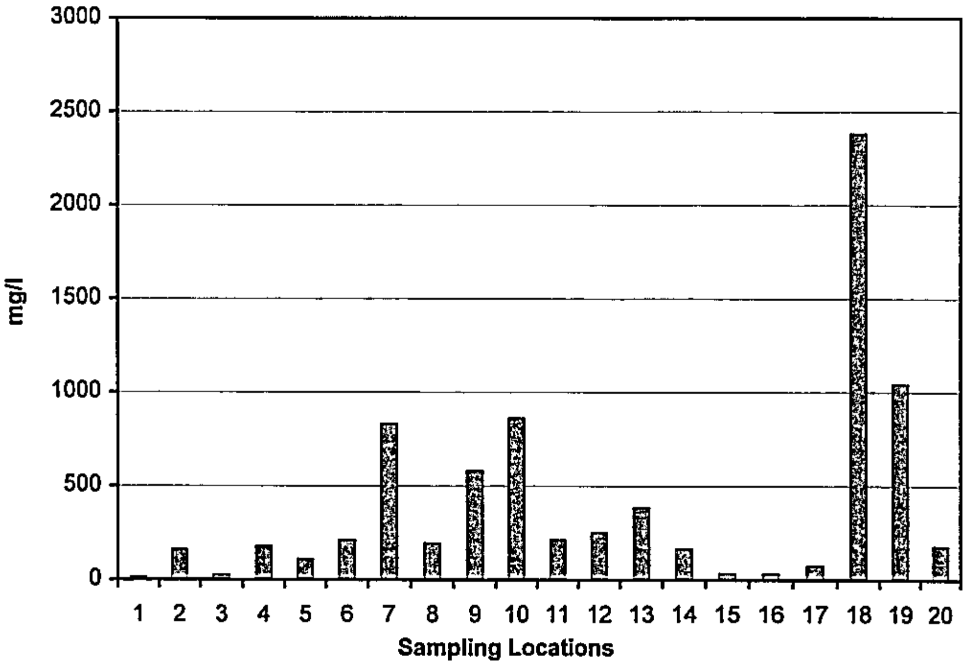
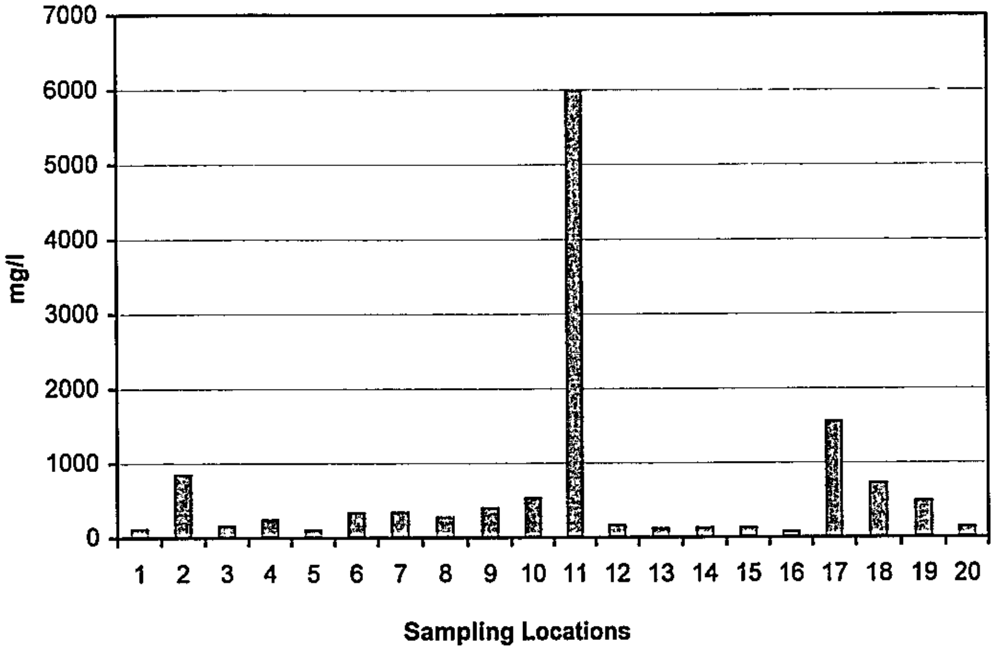


Figure 5.10: Comparison of TSS at Sampling Sites in Lahore



T-N

Nitrogen compounds in river and wastewater are important pollution indicating parameters. Nitrogen is considered a pollutant since it requires oxygen for oxidation in its unoxidized state, and because it contributes to the eutrophication of natural waters. The values of T-N detected in the 20 samples in Lahore varied from 1.12 to 64.96 mg/l; in two samples, it could not be detected. The minimum T-N value was 1.12 mg/l, which was detected in the sample from the siphon in the Ravi River, while the maximum value, 64.96 mg/l, was detected in the sample from the Chichoki Mallian Drain. The high concentration of T-N in Chichoki Mallian Drain is caused by the discharge from a fertilizer industry in the vicinity of the drain. **Figure 5.11** presents a comparison of the T-N values noted at the 20 sampling sites in Lahore.

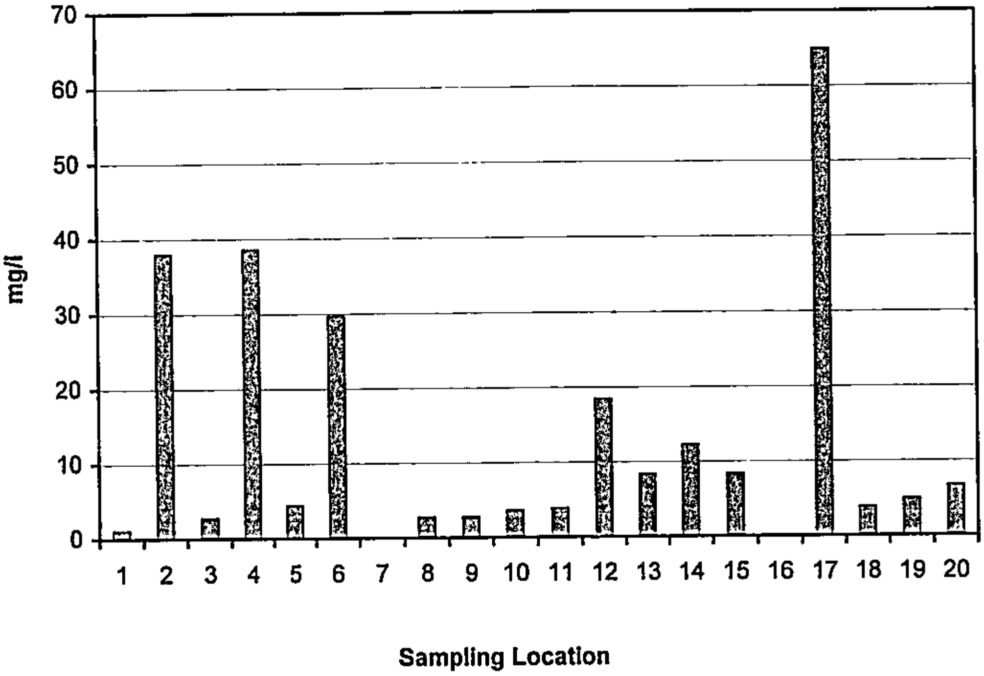
O&G

O&G in the wastewater interferes with the oxygenation of the receiving water streams. While testing the wastewater samples in Lahore, 53.3 mg/l of O&G was noted in Barian Drain. In all the other samples, the concentration was below the detection limit of 5 mg/l. According to Indian standards, O&G in sewage effluents for irrigation should not be higher than 30 mg/l. The high O&G concentration in the Barian Drain is caused by heavy industrial discharge in the drain.

E-Coli

E-Coli, the cloakroom group of organisms, is used as an indicator of the presence of pathogenic organisms in water. From the results, it can be seen that only one sample from the siphon at Ravi River has E-Coli less than 10 most probable number (MPN)/100 ml, while all other samples have a greater E-Coli level than 180 MPN/100 ml. E-Coli in Deg Nullah II was noted to be 160 MPN/100 ml.

Figure 5.11: Comparison of T-N at Sampling Sites in Lahore



Heavy Metals

Metals are found in industrial wastes in a variety of forms. When these metals are introduced into the surface water, they react with water and soil in several physico-chemical processes to produce appreciable concentrations and, thus, decrease the quality of water. Sampling sites at various streams containing industrial effluent were selected for heavy metal analysis in Lahore. Samples for heavy metal testing were collected from the following eight sites:

- Hudiara Drain at Multan Road
- Hudiara Drain at Ferozepur Road
- Hudiara Drain at the junction with Ravi River
- Bhed Nullah at Sheikhupura Road
- Deg Nullah at Sheikhupura Road
- Chotti Deg at Sheikhupura Road
- Chichoki Mallian Drain at Sheikhupura Road
- Barian Drain at a point 1 km off Sheikhupura Road.

Six heavy metals, arsenic (As), cadmium (Cd), chromium, copper (Cu), lead (Pb) and zinc (Zn), were tested in the eight samples collected from Lahore.

Arsenic: Arsenic, with other toxic inorganic contaminants, is one of the problems in water pollution. It can exist in both organic and inorganic forms. Only inorganic arsenic in +III or +V valence state has been found to be significant in water. Results of arsenic in eight samples from Lahore vary from 10 to 28 ppb. The NEQS limit for the concentration of arsenic is 1,000 ppb

(1.0 mg/l). According to WHO guidelines for aesthetic quality of water, the concentration of arsenic should not be higher than 500 ppb.

Cadmium: Cadmium is a relatively rare soft metal that occurs in a natural environment, typically in association with zinc ore and, to a lesser extent, with lead and copper. Some inorganic compounds are soluble in water, while cadmium oxides and cadmium sulfides are almost insoluble. The production of nickel-cadmium batteries, fossil fuel combustion, and dust from industrial processes like cement manufacturing are the main sources of cadmium contamination. Eight samples collected from Lahore were tested for cadmium. Less than 0.1 ppm was found in all the samples. According to the NEQS, cadmium in industrial effluents should not be higher than 0.1 ppm, while the WHO guidelines for aesthetic quality of water state that it should not be greater than 0.005 ppm.

Chromium: Chromium (Cr) occurs in water in its VI and III valence states, Cr III being more common. The presence of reducible organics affects the valence state of chromium. Primary sources of chromium in water are mines, wastewater from chrome plating operations, leather tanning, and fossil fuel combustion. In the eight samples from Lahore, chromium was found to be less than 0.5 ppm in all except the sample collected from Choti Deg, Sheikhupura Road. It was found to be 2.5 ppm in this sample, which is much higher than the NEQS limit of 1.0 ppm. According to the standard guidelines of WHO for aesthetic quality of water, the concentration of chromium in water should not exceed 0.05 ppm.

Copper: Copper is commonly found in drinking water. Although some industrial effluents also contain copper contamination, the principal source of contamination in water supplies is corrosion of brass and copper pipes. In the eight samples collected from Lahore, copper concentration was found to be 0.8 ppm in the Bhed Nullah, Sheikhupura Road sample and 2.0 ppm in the Barian Drain, Sheikhupura Road sample. In the rest of the samples, it was less than 0.5 ppm. The concentration of copper in Barian Drain, Sheikhupura Road is double the NEQS allowable limit of 1.0 ppm. According to WHO's standard guidelines for aesthetic quality of water, the concentration of copper in water should not be greater than 10 ppm.

Lead: Lead is naturally available in all environmental media in small concentrations. Lead is transferred from the atmosphere to soil, water, and vegetation by dry and wet deposition. A significant amount of lead particles from industrial and vehicular emissions are transported over large distances. Atmospheric deposits are the largest sources of lead in surface water. Lead content was found to be less than 0.2 ppm in seven out of eight samples collected from Lahore. The sample from Barian Drain, Sheikhupura Road contains 0.2 ppm lead, which is within the NEQS allowable limit of 0.5 ppm in industrial effluents. According to the standard guidelines of WHO for aesthetic quality of water, the concentration of lead in water should not be greater than 0.05 ppm.

Zinc: Zinc commonly occurs in source water but can occur in finished water as well, due to corrosion of metal pipes. In six out of the eight samples collected from Lahore, the concentration of zinc was found to be less than 0.2 ppm. It was 0.3 ppm in the sample from Barian Drain and 0.9 ppm in the sample from Bhed Nullah, Sheikhupura Road. According to the NEQS, the maximum allowable limit of zinc concentration in industrial effluents is 5.0 ppm. According to WHO's standard guidelines for the aesthetic quality of water, the concentration of zinc in water should not be greater than 0.05 ppm.

5.1.2 Influx Points

The 20 sampling sites in Lahore comprised river water, sewage, and industrial wastewater sites. The sampling sites have, therefore, been divided into three categories for discussion on test results, nature of water, sources of pollution and the extent of pollution being carried out by the sampling sites. The categories are:

- Tributaries on the Eastern (Lahore) Side of the River
- Tributaries on the Western (Sheikhupura) Side of the River

Tributaries on the Eastern (Lahore) Side of the River

The new Shadbagh sewage drain discharges into the Ravi River between the BRB siphon and Ravi bridge. The flow rate of this drain point is 6.8 m^3/sec. Spot test results show a low DO value of 2.0 mg/l. Laboratory test results of the sample indicate high COD and BOD values of 162.3 and 109.9 mg/l, respectively, while the concentration of total nitrogen at this sampling point is 38.08 mg/l.

Babu Sabu Drain at Bund Road is one of the major discharge drains in Lahore, carrying both domestic sewage and industrial effluent. The flow rate of the drain at this point is 9.0 m^3/sec. As the drain contains both domestic and industrial discharges, spot test results show a low DO value of 1.1 mg/l and high conductivity of 1,191 µS/cm. Laboratory test results of the sample show high COD and BOD values of 179.8 and 110.4 mg/l, respectively, while the concentration of total nitrogen at this sampling point is 38.64 mg/l.

The Babu Sabu Outfall Drain flows through the city before joining the Ravi River. The selected sampling site is located right before the point where the drain joins the river. The flow rate of the drain at this point is 7.3 m^3/sec and the water has a dirty gray color. Spot test results show a very low DO value of 0.6 mg/l. Laboratory test results of the sample show high COD and BOD values of 11.8 and 102.1 mg/l, respectively.

The main outfall drain at Bund Road is one of the major discharge drains in Lahore, containing both domestic sewage and industrial effluents. The water in the drain flows at 2.2 m^3/sec at this point. The color of the water is 70 TCU and odor is 20 TON. Spot test results show 1.8 mg/l DO and 1,082 µS/cm conductivity. Laboratory test results of the sample show high COD and BOD values of 214.4 and 109.5 mg/l, respectively while the concentration of total nitrogen at this point is 29.68 mg/l.

Satokatala Drain passes though the township industrial area before joining Hudiara Drain at Defense Road. The flow rate of the drain at Defense Road is 6.5 m^3/sec. Spot test results show a very low DO value of 0.35 mg/l and high conductivity of 1,369 µS/cm. The odor of the water at this point is 33 TON and color is 50 TCU. Laboratory test results of the sample indicate high COD and BOD values of 252.7 and 103.4 mg/l, respectively. The high BOD and COD values are due to the industrial effluents present in the water.

Hudiara Drain enters Pakistan from India near the Lalloh rangers post. The sample was collected from the drain at the point where it enters Pakistan. The flow rate of the drain at this point is 3.6 m^3/sec. Spot test results show a very low DO value of 0.6 mg/l, high conductivity of 2,300 µS/cm, and 1,000 TCU color. Laboratory test results of the sample indicate very high COD and BOD values of 862 and 449 mg/l, respectively. The concentration of TSS at this point is 537 mg/l, which is higher than other drains.

After entering Pakistan, Hudiara Drain passes through Ferozepur Road in Lahore where domestic and industrial effluents are discharged into it from the city. The flow rate of the drain at this point is 8.3 m^3/sec. Spot test results show a low DO value of 0.7 mg/l, high conductivity value of 1,579 µS/cm, odor of 50 TON, and color of 200 TCU. Laboratory test results of the sample indicate high COD and BOD values of 215 and 163 mg/l, respectively. The concentration of TSS at this point is 5,982 mg/l, which is very high. Various domestic drains join Hudiara Drain as it passes through the residential areas of Lahore.

After joining the Satokatala Drain, the Hudiara Drain passes through Multan Road where the city's domestic and industrial effluents are discharged into it. The flow rate of the drain at this point is 9.1 m^3/sec. Spot test results show a low DO value and high conductivity value of 1,765 µS/cm. Laboratory test results of the sample indicate high COD and BOD values of 387.8 and 117.3 mg/l, respectively. The high COD concentration at this point is due to the industrial discharge from the Multan Road into the drain. Hudiara Drain ultimately joins the Ravi River 186 km from the point where the river enters Pakistan.

The results of all the samples from the tributaries on the eastern side of the Ravi River are compared in **Table 5.2.**

Table 5.2: Comparison of Results of Sample Points on the Eastern Side of the Ravi River

Parameters	*Shad-Bagh*	*Babu Sabu Drain*	*Babu Sabu Outfall*	*Main Outfall*	*Hudiara Drain from India*	*Hudiara Drain Ferozpur Road*	*Satokatala Drain Defence Road*	*Hudiara Drain Multan Road*
Flow (m^3/sec)	6.8	9.0	7.3	2.2	3.6	8.3	6.5	9.1
Temperature (°C)	27.5	28.9	28.7	27.0	28.6	28.3	32.1	29.4
pH	7.6	7.4	7.3	7.5	7.8	8.0	7.6	7.7
DO (mg/l)	2.0	1.1	0.6	1.8	0.6	0.7	0.4	1.0
Conductivity (µS/cm)	998.0	1,191.0	953.0	1,081.0	2,300.0	1,579.0	1,369.0	1,765.0
Turbidity (NTU)	126.0	75.0	37.0	105.0	85.0	42.0	64.0	37.0
Odor (TON)	20.0	3.3	1.1	20.0	10.0	50.0	33.3	20.0
Color (TCU)	20.0	50.0	ND	70.0	1,000.0	200.0	50.0	15.0
BOD$_5$ (mg/l)	109.9	110.4	102.1	109.5	449.0	163.0	103.4	117.3
COD (mg/l)	162.3	179.8	111.8	214.4	862.0	215.0	252.7	387.8
TSS (mg/l)	855.0	249.0	110.0	342.0	537.0	5,982.0	170.0	126.0
O&G (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T-N (mg/l)	38.1	38.6	4.5	29.7	3.6	3.9	18.5	8.4
E-Coli (MPN)	>180.0	>180.0	>180.0	>180.0	>180.0	>180.0	>180.0	>180.0

BDL: Below detection limit

ND. Not detected

Tributaries on the Western (Sheikhupura) Side of the River

Bhed Nullah originates from the Kala Shah Kaku industrial area and carries wastewater discharged by the industries in that area. It then passes through the Lahore-Muridke Road and the Lahore-Sheikhupura Road before joining Deg Nullah. A sample of this drain was taken from the Lahore-Sheikhupura Road. The flow rate of the *nullah* (natural stream of water) at this point is 0.5 m^3/sec. Spot test results show a high temperature of 35.5°C, high pH of 9.3, high conductivity value of 1,815 µS/sec, and a very low DO value of 0.2 mg/l. The odor of the sample is 50 TON and it has a dirty gray color. Laboratory test results of the sample indicate high COD and BOD of 582.4 and 139.5 mg/l, respectively. Most of the industries on the Lahore-Sheikhupura Road discharge their effluents into this *nullah.*

Deg Nullah carries wastewater from the Kala Shah Kaku industrial area and passes through the Lahore-Sheikhupura Road. Major industries in the area, such as Ittehad Chemicals, Ravi Rayon, Kohinoor Textile Mills and some tanneries, discharge effluents into it. Some industries on the Lahore-Sheikhupura Road also discharge wastewater into this *nullah.* After joining the Upper Chenab Canal, the Deg Nullah flows into the Ravi River. This confluence is 102 km from the point where the river enters Pakistan, as shown in **Figure 3.4**. The flow rate of the *nullah* at this point is 1.9 m^3/sec. Spot test results show a low DO value of 0.7 mg/l, high conductivity of 3,070 µS/cm, and color of 1,000 TCU. Laboratory test results of the sample indicate a very high COD value of 831.1 mg/l and high BOD value of 159 mg/l. The high concentrations of BOD, COD, and TSS at this point are caused by the industrial effluents discharged from the Kala Shah Kaku industrial area.

Choti Deg originates from the Lahore-Gujranwala Road and passes though the Lahore-Sheikhupura Road. It carries wastewater from some small and medium industries. Choti Deg joins Deg Nullah after crossing the Lahore-Sheikhupura Road. The flow rate of the Drain at this point is 0.9 m^3/sec. Spot test results show a low DO value of 0.6 mg/l and high conductivity of 3,600 µS/cm, caused by the presence of industrial effluents. Laboratory test results of the sample give COD and BOD values of 196.8 and 109.5 mg/l, respectively.

Many industries situated on the Lahore-Muridke Road and the Lahore-Sheikhupura Road discharge their effluents into the Chichoki Mallian Drain. The Chichoki Mallian Drain joins Barian Drain about 11 km south of the Lahore-Sheikhupura Road. The sample from this drain was taken from the Lahore-Sheikhupura Road. The flow rate of the drain at this point is 0.4 m^3/sec. Spot test results indicate a DO value of 0.8 mg/l and a very high conductivity value of 4,660 µS/cm. BOD and COD values are 73.0 and 77.6 mg/l, respectively. The concentration of TSS at this point is 1,562 mg/l, which is very high compared to the results of tests at other drains. Similarly, the concentration of total nitrogen at this point is 64.96 mg/l. The concentration of total nitrogen in the drain is high due to effluents discharged into it from the fertilizer industry.

Various paper industries on the Lahore-Sheikhupura Road discharge untreated effluents into the Barian Drain, making it highly polluted. In 1961, the Punjab Irrigation Department constructed the Barian Drain, which originates from the Shahdara-Sheikhupura section and passes through Deg siphon, ultimately discharging into the Ravi River and increasing the pollution there. A sample of the drain was taken about 1 km off the Sheikhupura Road. The flow rate of the drain at this point is 1.8 m^3/sec. Spot test results show a low DO value of 0.7 mg/l and high conductivity value of 2,270 µS/cm. Industrial wastes are discharged into Barian Drain, resulting in a high COD value of 2,383 mg/l and high BOD value of 141.5 mg/l. The turbidity of the sample was 237 NTU, and it had a high TSS concentration of 736 mg/l.

After joining the Jaranwalla Main Drain, Deg Nullah II flows into the Ravi River. The Ravi River and the *nullah* converge at a point about 290 km from where the river enters Pakistan. This *nullah* carries both domestic and industrial discharges. A sample was taken from the drain just before it falls into the river. The flow rate of the *nullah* at this point is 1.05 m³/sec. Spot test results indicate a low DO value of 1.0 mg/l and very high conductivity of 5,310 µS/cm. The color of the sample is 1,000 TCU, indicating that the drain is contaminated by industrial discharge. The Barian Drain, after joining the Chichoki Mallian Drain, passes through the industrial area of the Faisalabad District where it receives various industrial discharges, before falling into the Deg Nullah. The industrial effluents are the cause of the high COD value (1,046 mg/l) in the drain.

After joining the Samundari Drain, the Mundawana Drain enters the Ravi River at a point 363 km from where the river enters Pakistan. The sample was taken from a point just before the drain enters the river. The flow rate of the drain at this point is 1.3 m³/sec. Spot test results show a very low DO value of 0.4 mg/l and high conductivity value of 4,220 µS/cm. BOD and COD values are also high at this point.

Table 5.3 presents a comparison of the results of all the samples taken from the tributaries on the western side of the Ravi River.

Table 5.3: Comparison of Results of All Sample Points on the Western Side of the Ravi River

Parameters	*Bhed Nullah*	*Deg Nullah*	*Choti Deg*	*Chichoki Malian Drain*	*Barian Drain*	*Deg Nullah II*	*Mundawana Drain*
Flow, (m³/sec)	0.5	1.91	0.9	0.4	1.8	1.0	1.3
Temperature (°C)	35.5	29.8	27.8	27.5	32.3	27.9	30.7
pH	9.3	7.3	8.7	9.0	7.0	8.0	8.4
DO (mg/l)	0.2	0.7	0.6	0.8	0.7	1.0	0.4
Conductivity (µS/cm)	1,815.0	3,070.0	3,600.0	4,660.0	2,270.0	5,310.0	4,220.0
Turbidity (NTU)	47.0	128.0	126.0	56.0	237.0	98.0	48.0
Odor (TON)	50.0	10.0	20.0	14.5	6.7	1.1	100.0
Color (TCU)	ND	1,000.0	35.0	50.0	50.0	1,000.0	ND
BOD$_5$ (mg/l)	139.5	159.0	109.5	73.0	141.5	104.8	160.7
COD (mg/l)	582.4	831.1	196.8	77.6	2,383.0	1,046.0	180.1
TSS (mg/l)	405.0	348.0	278.0	1,562.0	736.0	495.0	152.0
O&G (mg/l)	BDL	BDL	BDL	BDL	53.3	BDL	BDL
T-N (mg/l)	2.8.0	BDL	2.8	65.0	3.9	5.00	6.7
E-Coli (MPN)	>180.0	>180.0	>180.0	>180.0	>180.0	161.0	>180.0

BDL: Below detection limit

Ravi River

BRB Link Canal crosses the Ravi River at a distance of 12.6 km from where the river enters Pakistan. This location lies upstream of Lahore, before any drain joins the river. The flow rate of the river at this point is 335.5 m^3/sec. Spot test results show a DO value of 6.4 mg/l. All laboratory test results are within the WHO limits for drinking water.

Bara Dari is an old monument dating back to the Mughal period, situated in the center of the river near Ravi Bridge. It has now been developed into a picnic spot and a boat station has been built there for tourists to go sailing in the river. The flow rate of the river at this point is 88.0 m^3/sec. This sample was taken from a point after the Shadbagh sewage drain joins the river. The drain has a flow of 6.8 m^3/sec. The DO of the river at this point is less than the level at the siphon point, while the BOD and COD values are more than the level at the siphon point.

Hudiara Drain joins the Ravi River near Khurd Pur village. This point is at a distance of 186 km from the entrance of the river in Pakistan. The flow rate of the river at this point is 480 m^3/sec. BOD and COD values at this point are less than those at the Bara Dari point. This is because the water is diluted after the Hudiara Drain enters the river.

The sampling location on the river was 1 km downstream of the Hudiara Drain, about 200 km away from the point where the river enters Pakistan. Before this point, the river is joined on both sides by different streams carrying polluted water. The flow rate of the river at this point is 78.9 m^3/sec. BOD and COD concentrations decrease further at this point because the water from the drain mixes entirely with the river water.

At the Balloki Headworks, water is drawn from the Ravi River for irrigation purposes. The sampling location is 200 m upstream of the headworks, and was selected because it lies downstream of Lahore. The flow rate of the river at this point is 340 m^3/sec. The values of BOD and COD are the least at this point due to an increase in the flow rate of the river.

The results of the tests at all points on the Ravi River are compared in **Table 5.4.**

5.1.3 Pollution Load

Concentrations of DO, BOD, COD and total nitrogen in river and wastewater are the most significant pollution indicators. Results from 20 sampling sites in Lahore show that BOD_5 (20°C) varies from 9.17 to 449 mg/l, while BOD load calculated at these points varies from 2.0 to 449 mt/day.

Pollution Load Contribution from Lahore Side

Pollution indicating parameters like DO, BOD, COD and total nitrogen at the sampling sites on the eastern (Lahore) side of the river are listed in **Table 5.5.**

Table 5.4: Comparison of Results at Sample Points on the Ravi River

Parameters	*BRB Siphon*	*Bara Dari*	*Junction of Hudiara Drain*	*1 km Downstream of Hudiara Drain*	*200 m Upstream of Balloki HW*
Flow (m^3/sec)	336.0	88.0	78.9	480.0	340.0
Temperature (°C)	26.1	29.0	29.2	27.7	25.1
pH	8.3	8.5	7.4	7.7	7.5
DO (mg/l)	6.4	4.9	0.3	1 2	5.3
Conductivity (µS/cm)	227.0	180.0	645.0	516.0	333.0
Turbidity (NTU)	55.0	62.0	21.0	46.0	34.0
Odor (TON)	1.1	10.0	10.0	10.0	1.0
Color (TCU)	1.0	1.0	10.0	10.0	25.0
BOD_5 (mg/l)	9.2	12.1	63.0	7.1	7.1
COD (mg/l)	16.9	26.6	165.6	36.4	33.4
TSS (mg/l)	124.0	162.0	133.0	134.0	80.0
O&G (mg/l)	BDL	BDL	BDL	BDL	BDL
T-N (mg/l)	1.1	2.8	8.4	12.3	BDL
E-Coli (MPN)	<1.0	>180.0	>180.0	>180.0	>180.0

BDL: Below detection limit

Table 5.5: BOD and COD Load from Lahore Side

Parameters	*Shad-Bagh*	*Babu Sabu Drain*	*Babu Sabu Outfall*	*Main Outfall*	*Hudiara Drain from India*	*Hudiara Ferozpur Road*	*Satokatala Defence Road*	*Hudiara Multan Road*
Flow (m^3/sec)	6.8	9.0	7.3	2.2	3.6	8.3	6.5	9.1
DO (mg/l)	2.0	1.1	0.6	1.8	0.6	0.7	0.35	1.0
BOD_5 (mg/l)	109.9	110.4	102.1	109.6	449.0	163.0	103.4	117.3
BOD_5 (mt/day)	65.0	86.0	64.0	21.0	138.0	116.0	58.0	92.0
BOD Load (%)	3.2	4.3	3.2	1.0	6.8	5.8	2.9	4.6
COD (mg/l)	162.3	179.8	111.8	214.4	862.0	215.0	252.7	387.8
COD (mt/day)	95.0	140.0	71.0	41.0	265.0	153.0	141.0	305.0
COD Load (%)	1.5	2.3	1.1	0.7	4.3	2.5	2.3	4.9
BOD:COD	1:1.5	1:1.6	1:1.1	1:2	1:1.9	1:1.3	1:2.4	1:3.3
T-N (mg/l)	38.1	38.6	4.5	29.7	3.6	3.9	18.5	8.4

The Shadbagh Drain contributes about 65 mt/day of BOD load to the Ravi River. BOD load from the Babu-Sabu Drain at Bund Road is 86 mt/day, decreasing to 64 mt/day before it joins the river. This is because the water in the drain is mixed with domestic washings. The main outfall in Lahore contributes about 21 mt/day of BOD in the Ravi River. The Hudiara Drain carries a BOD load of 138 mt/day when it enters Pakistan from India. At Ferozepur Road, the BOD load in the Hudiara Drain is 116 mt/day. The BOD load in the Satokatala Drain, before it joins Hudiara Drain, is 58 mt/day. The BOD load in the Hudiara Drain at Multan road, after the Satokatala Drain joins it, decreases further to 92 mt/day. Therefore, the final BOD load contribution of Hudiara Drain in the Ravi River is 92 mt/day. Total BOD contribution to the Ravi River from the eastern (Lahore) side is 242 mt/day. This total contribution has been calculated by summing up all the individual contributions.

Pollution Load Contribution from Sheikhupura Side

Pollution indicating parameters like DO, BOD, COD and total nitrogen for sampling sites on the western (Sheikhupura) side of the river are given in **Table 5.6.**

BOD load contributions to the river from all the individual drains on the western (Sheikhupura) side are given in the above table. The Ravi River receives a total of 90 mt/day of BOD. The total contribution has been calculated by summing up all the individual contributions.

Pollution Load in River Ravi

Pollution indicating parameters for sampling sites in the Ravi River are given in **Table 5.7.**

The BOD load in the Ravi River at BRB siphon is 266 mt/day, which decreases to 65.0 mt/day at Bara Dari, near the boat station. This decrease is caused by the reduction in the flow rate of the river from 336 to 88 m^3/sec. Hudiara Drain's BOD load contribution at the point where it joins the Ravi River increases the BOD load of the river to 429 mt/day. However, the load decreases again to 294 mt/day 1 km downstream of the junction. The BOD load of the river 200 m upstream of Balloki Headworks is 209 mt/day.

Table 5.6: BOD and COD Load from Sheikhupura Side

Parameters	*Bhed Nullah*	*Deg Nullah*	*Choti Deg*	*Chichoki Malian Drain*	*Barian Drain*	*Deg Nullah II*	*Mundawa Drain*
Flow (m^3/sec)	0.5	1.9	0.9	0.4	1.8	1.0	1.3
DO (mg/l)	0.2	0.7	0.6	0.8	0.7	1.0	0.4
BOD_5 (mg/l)	139.5	159.0	109.5	73.0	141.5	104.8	160.7
BOD_5 (mt/day)	5.0	26.0	8.0	2.0	22.0	9.0	18.0
BOD Load (%)	0.3	1.3	0.4	0.1	1.1	0.5	0.9
COD (mg/l)	582.4	831.1	196.8	77.6	2,383.0	1,046.0	180.1
COD (mt/day)	23.0	137.0	15.0	3.0	371.0	94.0	20.0
COD Load (%)	0.4	2.2	0.4	0.04	6.0	1.5	0.3
BOD:COD	1:4.6	1:5	1:1.9	1:1.5	1:16	1:10	1:1.1
T-N (mg/l)	2.8	BDL	2.8	65.0	3.9	5.0	6.7

BDL: Below detection limit

Table 5.7: BOD and COD Load from All Sample Points on the River Ravi

Parameters	*BRB Siphon*	*Bara Dari*	*Junction of Hudiara Drain*	*1 km Downstream of Hudiara Drain*	*200 m Upstream of Balloki HW*
Flow (m^3/sec)	336.0	88.0	78.9	480.0	340.0
DO (mg/l)	6.4	4.9	0.3	1.2	5.3
BOD_5 (mg/l)	9.2	12.1	63.0	7.1	7.1
BOD_5 (mt/day)	266.0	92.0	429.0	294.0	209.0
BOD Load (%)	13.2	4.6	21.2	15.5	10.3
COD (mg/l)	16.9	26 6	165.6	36.4	33.4
COD (mt/day)	491.0	202.0	1,129.0	1,511.0	982.0
COD Load (%)	7.9	3.3	18.2	24.4	15.9
Ratio BOD:COD	1:1.8	1:2.2	1:2.6	1:5	1:4.6
T-N (mg/l)	1.1	2.8	8.4	12.3	BDL

BDL: Below detection limit

5.1.4 Water Quality Parameters and Standards

Table 5.8 lists the parameters for water quality characterization and their permissible limits as laid down in the USPH drinking water standards, WHO standard guidelines for aesthetic quality of water, and the Indian Standards Institution's (ISI) standards for water quality. The NEQS do not specify any standards for the measurement of drinking water quality. Indian Standards for sewage effluents discharged on land for irrigation are listed in **Table 5.9.**

5.2 Water Quality in Rawalpindi and Islamabad

Nullah Leh's catchment area lies in the cities and suburbs of Rawalpindi and Islamabad. Nullah Leh and its tributaries originate from the Margalla Hills, which border Islamabad on the north. It passes through the Islamabad area, receiving sewage from the city, and is joined by a number of tributaries before it enters the Rawalpindi area. Nullah Leh then flows through the flatter area of Rawalpindi and, passing through the heart of the city, joins the Soan River. It drains an area of about 211 km^2, of which 55 percent lies in Islamabad (up to Khyaban-e-Sir Syed, ie, I-10/Pirwadhai crossing), and the remaining 45 percent lies in Rawalpindi and the cantonment area.[1]

The catchment area of Rawal Lake consists of numerous tributaries from the Murree Hills. Some of the natural streams of the Margalla Hills also flow into the lake. The Rawal Lake outlet and Nullah Kurang combine and discharge into Nullah Kura, which ultimately flows into the Soan River.

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[1] A.H. Malik. 1998. *Sustainable Groundwater Exploitation of the Lai Basin*, 24th WEDC Conference.

Table 5.8: Water Quality Standards[a]

Parameters (Unitsb)	*USPH Standard*	*WHO Guidelinesc*	*ISI Standard*
Color	Colorless	15 TCU	–
Odor	Odorless	Inoffensive	
pH	6 0-8.5	6.5-8.5	6.0-9.0
Specific conductance	300µmho cm-1	–	–
Dissolved oxygen (DO)	4.0-6.0 (ppm)	No value speicified	3.0
Suspended solid	5.0	–	–
Arsenic	0.05	0.05	0.2
Cadmium	0.01	0.005	–
Chromium (VI)	0.05	0.05	0.05
Copper	1.0	1.0	–
Lead	<0.05	0.05	0.1
Zinc	5.5	5.0	–
COD	4.0	–	
Coliform Cells/100 ml	100	–	<5000
Total Bacteria Count/100 ml	1×106	–	–

The official Journal of the European Committees, L 229, p. 16-21 (1980) quotes figures close to those of USPH. The ISI values are considerably higher, and therefore open to question, and do not cover all the parameters

Unless otherwise mentioned, all units, except pH and specific conductance, are in ppm or mg/l.

Source: AWWA 1990. *Water Quality and Treatment.* 4th edition.

Table 5.9: Indian Standards for Sewage Effluents

Parameters	*Tolerance Limit (Maximum)*
pH	5.5-9.0
Oil and Grease	30 mg/l
BOD_5	180 mg/l
Coliform cells/100 mL	20,000
Faecal Coliform cells/100 mL	4,000

Twenty sampling locations were selected in Rawalpindi and Islamabad to check the quality of surface and wastewater in the area and to estimate the nature and extent of pollutants in them. Logically, these sampling locations can be distributed into two areas:

- The Leh Basin

  Sewage and industrial effluents are drained into Nullah Leh through different streams, which include:

  - Nullah in E-8 area, near Navy House Karakoram Road, Islamabad
  - Nullah in E-7 area, opposite Street 16, Hillside Road, Islamabad
  - Nullah in F-8/2 area, near Street 24A, before Fatima Jinnah Park, Islamabad
  - Nullah in F-6/2 area, near Alkhizar Mosque, Margalla Road, Islamabad
  - Nullah in F-5/2 area, near AJK Secretariat, Islamabad
  - Nullah Peshawar Road, near the Motorway 18 km signboard, Islamabad
  - Nullah 1, I-10/Pirwadhai crossing
  - Nullah II, I-10/Pirwadhai crossing
  - Nullah I and II, 200 m after joining at I-10/Pirwadhai crossing
  - Nullah Leh, near Gawalmandi Bridge, Rawalpindi
  - Nullah Leh, near Jhanda Chichi, Airport Road, Rawalpindi
  - Nullah Leh, near Murree Brewery, Gulistan Colony, Rawalpindi
  - Nullah Leh, before joining River Soan, Rawalpindi
- Soan Basin

  The following natural water streams join the Soan River:

  - Nullah near American Embassy
  - Stream near Chattar Park, Murree Road
  - Rawal Dam outlet, before filtration station
  - Stream water, Korang Nullah, Lehtrar Road
  - Nullah Kura, Shahrahe-Islamabad, near railway crossing
  - River Soan, before joining Nullah Leh.
  - River Soan 300 m after joining Nullah Leh.

5.2.1 Selected Parameters

DO, temperature, pH, conductivity, turbidity, odor and color were checked on spot at every sampling site. COD, BOD, TSS, T-N, and O&G were checked in HBP's laboratory. The findings are discussed below.

Dissolved Oxygen

The DO concentration observed during spot tests at the 20 sampling locations in Rawalpindi and Islamabad varied within the range of 0.05 to 7.58 mg/l. The maximum DO value was 7.58 mg/l, observed at the Soan River, while the minimum DO value was 0.05 mg/l at Nullah Leh at Pirwadhai Road and Airport Road. The DO concentration at sampling locations in Rawalpindi and Islamabad is shown in **Figure 5.12.**

Temperature

Temperature at the 20 sampling locations varied from 16.0 to 30.0°C. The minimum temperature was 16.0°C at the F-6/2 stream, while the maximum temperature was 30.0°C at Nullah Leh downstream of Murree Brewery. The high temperature at Nullah Leh is caused by weather conditions and the industrial discharge from Murree Brewery.

A comparison of surface and wastewater temperatures noted at the 20 sampling locations in Rawalpindi and Islamabad is shown in **Figure 5.13.**

pH

pH values of surface and wastewater at the 20 sampling points ranged from 7.05 to 8.18. The minimum pH was 7.05 at Nullah Leh, while the maximum pH was 8.18, noted at the Soan River. A comparison of the pH values is shown in **Figure 5.14.**

Figure 5.12: Comparison of DO at Sampling Locations in Islamabad and Rawalpindi

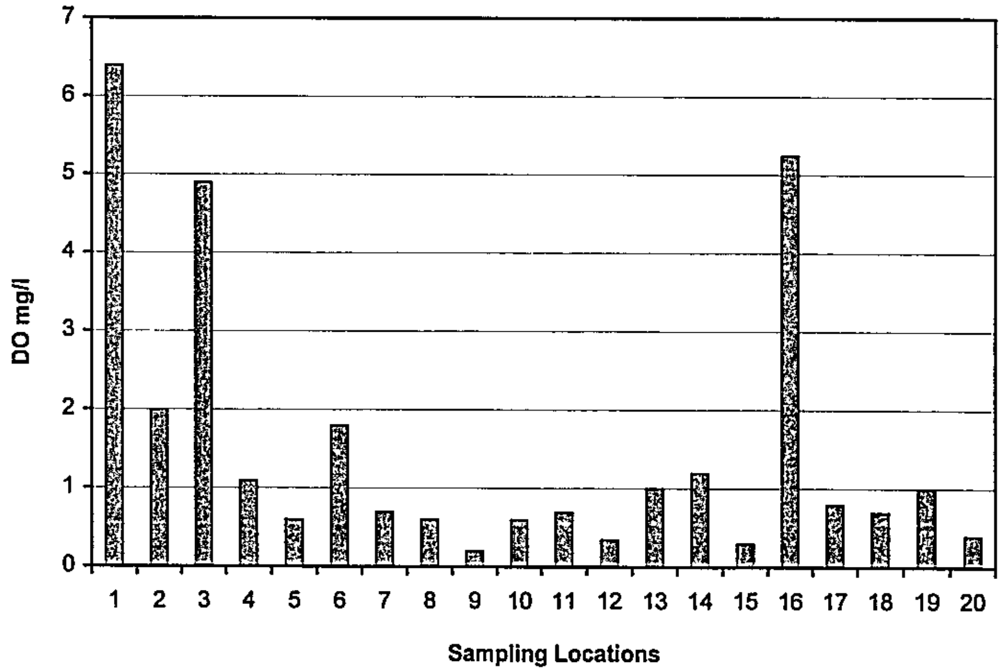


Figure 5.13: Comparison of Temperature at Sampling Locations in Islamabad and Rawalpindi

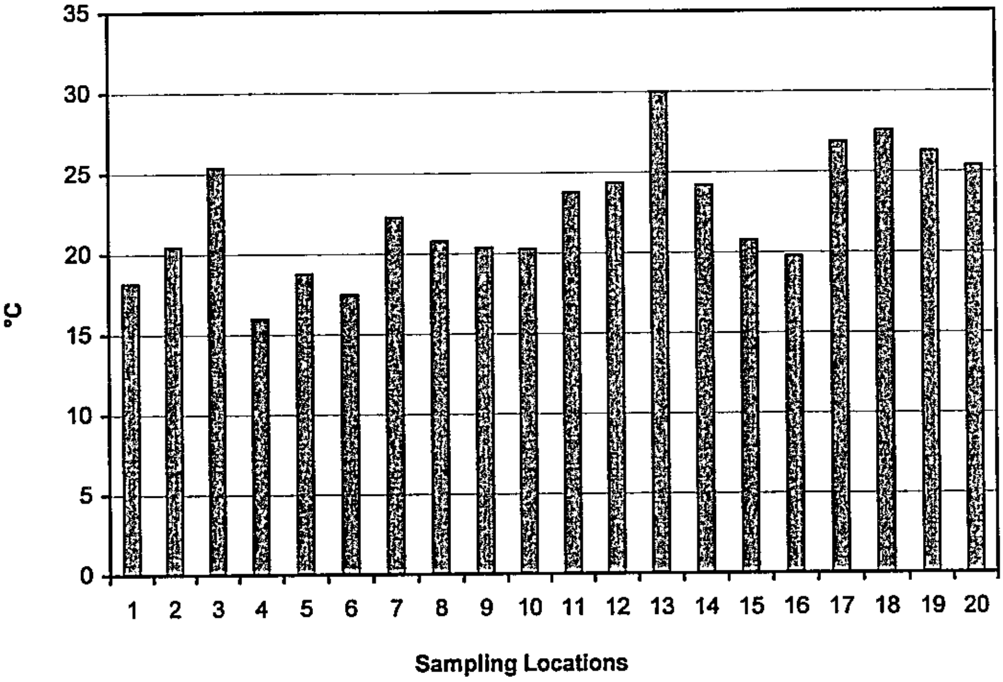
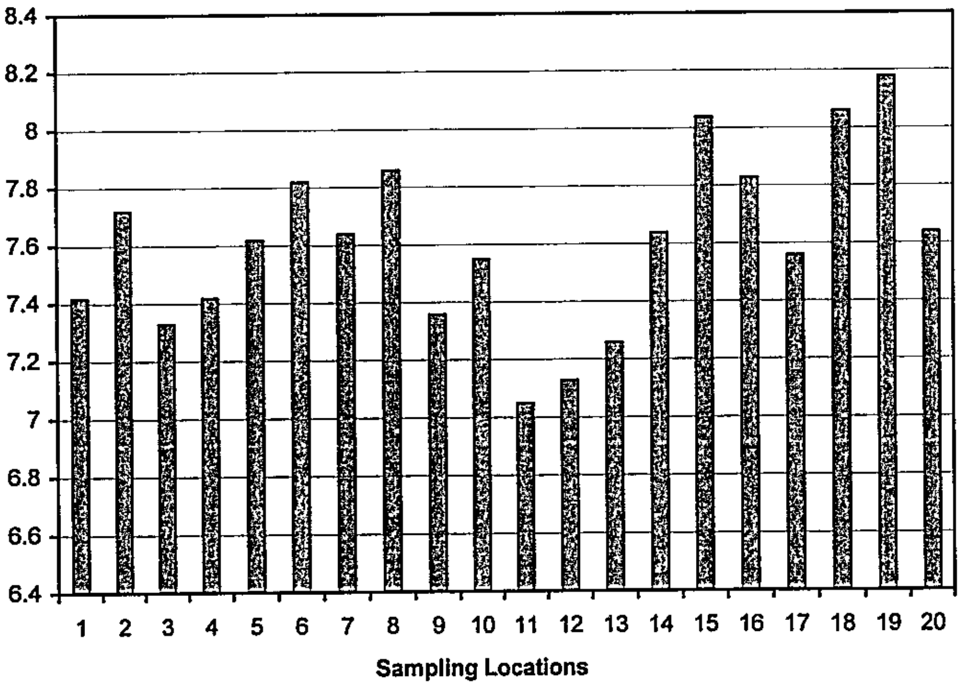


Figure 5.14: Comparison of pH at Sampling Locations in Islamabad and Rawalpindi



Conductivity

Conductivity of the waste and river water samples ranged from 58 to 1,590 µS/cm. The minimum value was 58 µS/cm at the sampling site at the Korang Nullah and the maximum value was 1,590 µS/cm, noted at Nullah Leh before it joins the Soan River. A comparison of conductivity at the sampling sites is shown in **Figure 5.15.**

DO, BOD, COD, T-N in water are the most important pollution indicators.

BOD

The BOD concentration of the 20 samples from Rawalpindi and Islamabad was found to range from 0 to 139.3 mg/l. No BOD concentration was detected at the Rawal Lake outlet. The maximum value of 139.3 mg/l was noticed in the sample from Nullah Leh at Airport Road. A comparison of BOD concentrations in the samples is given in **Figure 5.16.**

COD

The COD concentration of the 20 samples was found to be in the range of 18.4 to 357.5 mg/l. The minimum value was observed in the sample from Nullah Kura, while the maximum value was found in the sample from Nullah Leh near Gawalmandi bridge. A comparison of COD concentrations in the samples is given in **Figure 5.17.**

Figure 5.15: Comparison of Conductivity at Sampling Sites in Islamabad and Rawalpindi

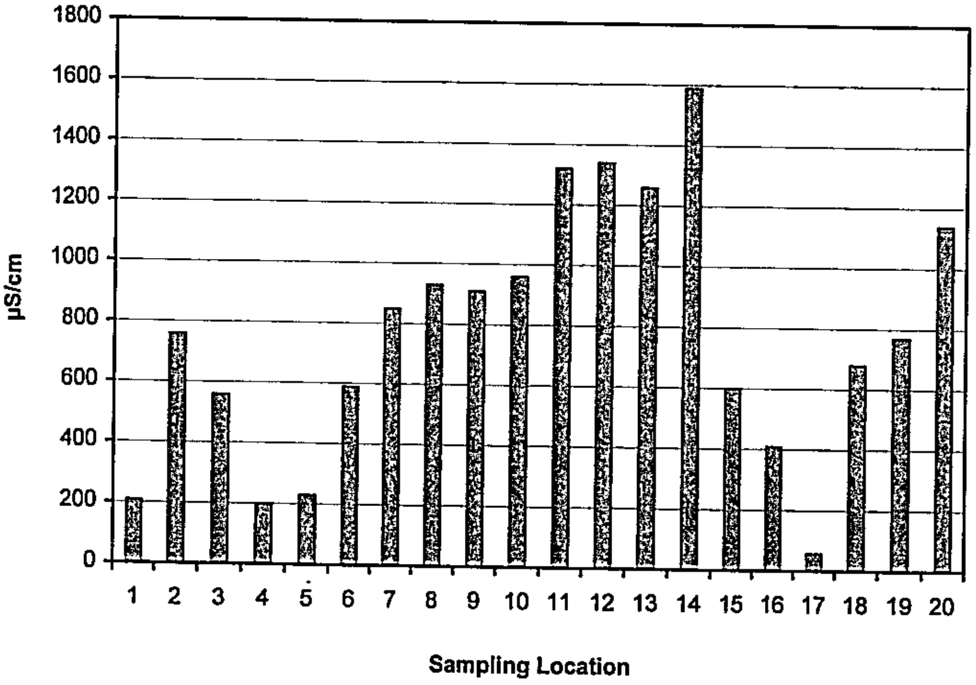


Figure 5.16: Comparison of BOD Levels at Sampling Sites in Islamabad and Rawalpindi

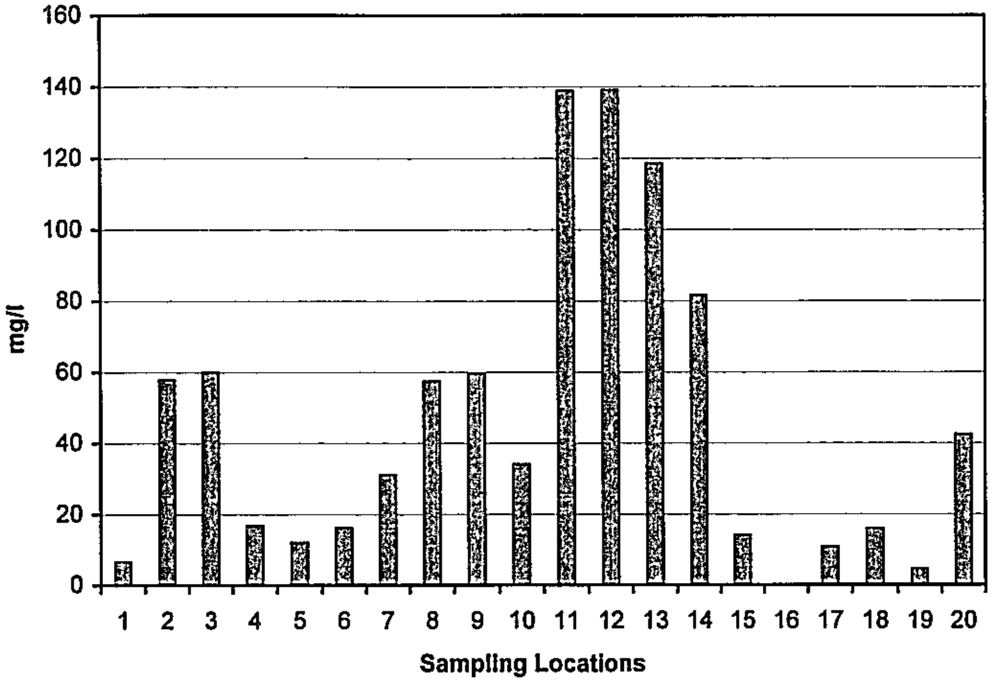
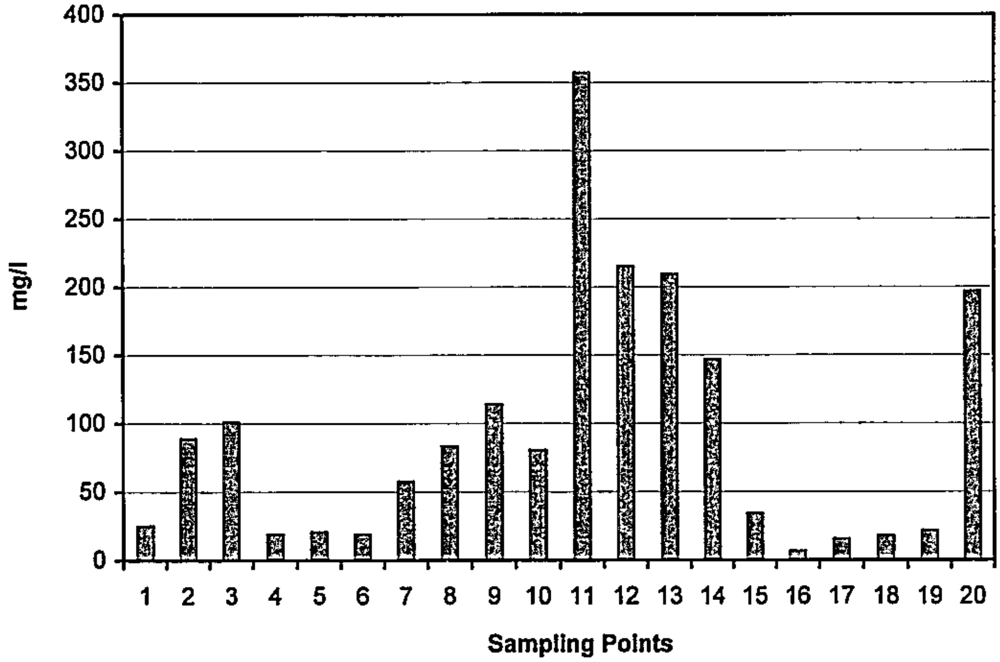


Figure 5.17: Comparison of COD Levels at Sampling Sites in Islamabad and Rawalpindi



TSS

The concentration of TSS in the 20 samples ranged from 22 to 16,154 mg/l. The minimum value was found in the sample from the Soan River, while the maximum concentration was in the sample from the *nullah* before Fatima Jinnah park. A comparison of TSS concentrations in the 20 samples is given in **Figure 5.18**.

T-N

Concentration of T-N, detected in 11 samples from Rawalpindi and Islamabad, ranged from 1.68 to 50.96 mg/l. The minimum concentration was found in the sample from a *nullah* at Peshawar Road, while the maximum value was 50.96 mg/l in the sample from Nullah Leh before it joins the Soan River.

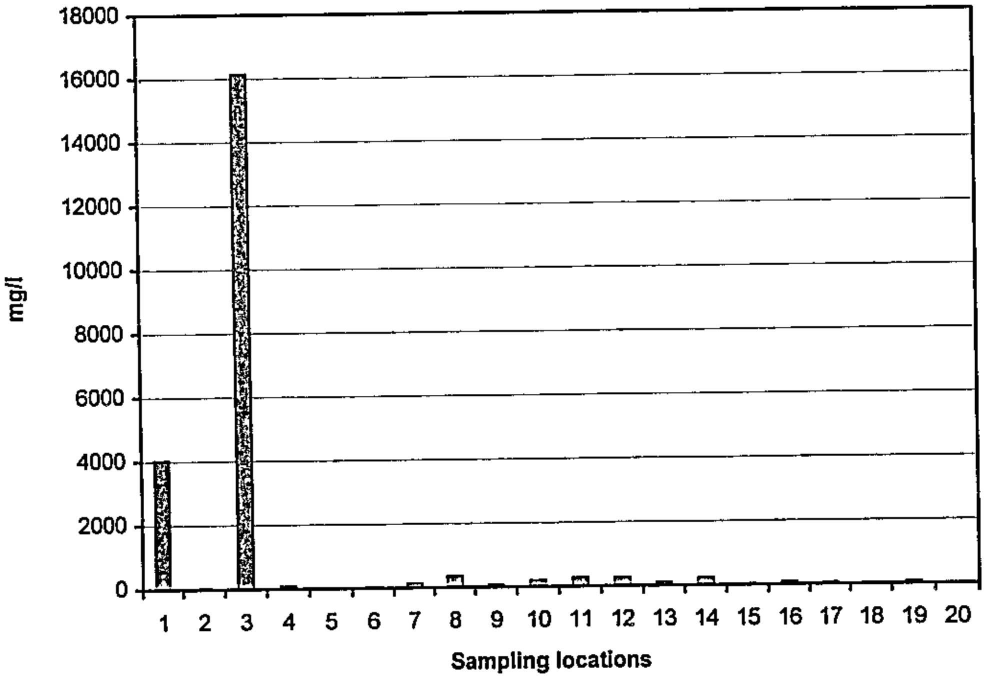
O&G

O&G was found to be below the detection limit of 5 mg/l in all the 20 samples from Rawalpindi and Islamabad.

E-Coli

The value of E-Coli was greater than 18 MPN/100 ml in 19 of the samples; it was not detected in the sample from the F-6/2 *nullah* near Al-Khizar mosque.

Figure 5.18: Comparison of TSS Levels at Sampling Sites in Islamabad and Rawalpindi



Heavy Metals

Seven sampling sites containing industrial effluents were selected for heavy metal analysis in Rawalpindi and Islamabad. The seven sampling sites were:

- Nullah 1 at I-10/Pirwadhai crossing
- Nullah 2 at I-10/Pirwadhai crossing
- Combined stream of Nullah 1 and Nullah 2 at I-10/Pirwadhai crossing
- Nullah Leh near Gawalmandi bridge
- Soan River, after being joined by Nullah Leh
- Nullah Leh, before joining the Soan River
- Nullah Kura at Shahrah-e-Islamabad.

The seven samples were checked for six heavy metals: arsenic, cadmium, chromium, copper, lead, and zinc.

Arsenic: The concentration of arsenic in the six samples was less than 10 ppb; in the sample from Nullah Leh before it joins the Soan River, the concentration was 11 ppb. According to NEQS, the concentration of arsenic should not be greater than 1,000 ppb (1.0 mg/l) in industrial wastes.

Cadmium: Cadmium concentration in all seven samples was less than 0.1 ppm. The NEQS limit for cadmium concentration in industrial effluents is 0.1 ppm.

Chromium: Chromium concentration in all seven samples was found less than 0.5 ppm. The NEQS limit for industrial effluents is 1.0 ppm.

Copper: Copper concentration in five samples was less than 0.5 ppm. However, it was 0.5 ppm in the sample collected from the Soan River after it is joined by the Nullah Leh, and 3.0 ppm in the sample from Nullah Leh before it joins the Soan River. The NEQS limit for copper concentration in industrial effluents is 1.0 ppm.

Lead: Lead concentration less than 0.2 ppm in five samples. It was 0.2 ppm in the sample collected from the Soan River after it is joined by Nullah Leh, and 0.3 ppm in the sample from Nullah Leh before it joins the Soan River. The NEQS limit for industrial effluents is 0.5 ppm.

Zinc: Zinc concentration in four samples was less than 0.2 ppm. It was 0.3 ppm in the sample taken from Nullah Leh near Gawalmandi, 0.2 ppm in the sample from the Soan River after it is joined by Nullah Leh, and 0.3 ppm in the sample from Nullah Leh before it joins the Soan river. The NEQS limit for the industrial effluents is 5.0 ppm.

5.2.2 Influx Points

The 20 sampling sites in Rawalpindi and Islamabad contain river water, sewage, and industrial wastewater sites. The following discussion on them has been divided into two parts:

- Tributaries of Nullah Leh
- Natural Water Streams Joining the Soan River

Tributaries of Nullah Leh

The *nullah* in the E-8 area flows near Navy House, Karakoram Road, Islamabad. It is a natural stream that emerges from the Margalla Hills and passes through Islamabad's E-8 sector. The flow rate of the *nullah* at this point is 0.06 m^3/sec. Spot test results indicate a DO value of 5.65 mg/l, while BOD and COD test results of the samples are 6.77 and 25.55 mg/l, respectively.

The *nullah* in the E-7 area flows opposite Street 16, Hillside Road, Islamabad. It emerges from the Margalla Hills and passes through the residential area of E-7, receiving sewage from the area, which produces a bad odor around it. The flow rate of the *nullah* at this point is 0.04 m^3/sec. Spot test results indicate a very low DO value of 0.66 mg/l. Laboratory test results of the sample show high COD and BOD values of 89.26 and 58.01 mg/l respectively. The high BOD and COD values are due to the domestic wastewater released into the *nullah.*

The *nullah* in sector F-8/2 flows near street 24A, before Fatima Jinnah Park, Islamabad. It too emerges from the Margalla Hills and passes through F-8, which is a residential area, receiving sewage from the area. The flow rate of the *nullah* at this point is 0.113 m^3/sec. Spot test results show a low DO value of 3.81 mg/l. Laboratory test results indicate high COD and BOD values of 101.3 and 60.06 mg/l respectively. The values of BOD and COD are high due to domestic drains discharge into this *nullah.*

The *nullah* in sector F-6/2 flows near Al-Khizar Mosque, Margalla Road, Islamabad. It is a natural stream that comes down the Margalla Hills and passes through F-6/2. The flow rate of the *nullah* at this point is 0.05 m^3/sec. Spot test results show a DO value of 5.8 mg/l. Laboratory test results give COD and BOD values of 19.5 mg/l and 17.0 mg/l, respectively.

The *nullah* in sector F-5/2 flows near the AJK Secretariat in Islamabad. It is a natural stream that emerges from the Margalla Hills and passes through F-5/2. The flow rate of the *nullah* at this point is 0.074 m^3/sec. Spot test results indicate a DO value of 4.6 mg/l. Laboratory test results of the sample show BOD and COD values of 12.15 mg/l and 20.93 mg/l, respectively.

The *nullah* on Peshawar Road flows near the Motorway 18-km signboard, Islamabad. This *nullah* passes through the F-9, F-10, G-9, and G-10 residential areas in Islamabad, crosses Peshawar Road, and then joins Nullah Leh. The flow rate of the *nullah* at this point is 0.05 m^3/sec. Spot test results show a low DO value of 2.16 mg/l. Laboratory test results of the sample indicate COD and BOD values of 58.16 mg/l and 31.29 mg/l respectively.

Nullah 1 at I-10/Pirwadhai crossing passes through the residential and industrial areas in Islamabad before joining Nullah Leh. The flow rate of the *nullah* at this point is 2.08 m^3/sec. Spot test results show a very low DO value of 0.5 mg/l. Laboratory test results indicate COD and BOD of 83.73 mg/l and 57.55 mg/l, respectively. The concentration of TSS at this point is 358 mg/l, which is high.

Nullah II at I-10/Pirwadhai crossing passes through the residential and industrial areas in Islamabad before joining Nullah Leh. The flow rate of the *nullah* at this point is 7.06 m^3/sec. Spot test results show a very low DO value of 0.09 mg/l. Laboratory test results indicate high COD and BOD values of 114.3 mg/l 59.54 mg/l, respectively.

Nullah I and II join Nullah Leh at the I-10/Pirwadhai crossing. Nullah Leh and its tributaries emerge from the Margallah Hills bordering Islamabad on the north. This is a fairly typical mountain *nullah.* After draining Islamabad, Nullah Leh flows to the flatter area in Rawalpindi. The flow rate of the *nullah* at this point is 2.72 m^3/sec. Spot test results show a very low DO of

0.05 mg/l. Laboratory test results of the sample indicate COD and BOD of 80.96 mg/l and 34.19 mg/l, respectively.

Nullah Leh passes through the residential areas of Rawalpindi receiving domestic sewage. A sample was taken from the *nullah* near Gawalmandi Bridge. The flow rate of the *nullah* at this point is 10.79 m^3/sec. Spot test results show a very low DO value of 0.28 mg/l, high conductivity value of 1,320 μS/cm, 64 TON odor, and 70 TCU color. Laboratory test results show high BOD and COD values of 139.1 and 357.5 mg/l, respectively.

A sample was taken from Nullah Leh near Jhanda Chichi, Airport Road after it passes through the residential and cantonment areas in Rawalpindi. The flow rate of the *nullah* at this point is 7.84 m^3/sec. Spot test results indicate a very low DO value of 0.05 mg/l. Laboratory test results show COD and BOD values of 215.4 mg/l and 139.3 mg/l.

A sample was taken from Nullah Leh near Gulistan Colony Line 1 after it passes through Murree Brewery and the residential and industrial areas of Gulistan Colony, Rawalpindi. The flow rate of the *nullah* at this point is 8.63 m^3/sec. Spot test results indicate a DO level of 1.87 mg/l. Laboratory test results indicate BOD and COD levels of 118.8 mg/l and 209.6 mg/l, which are comparatively high due to the effluents discharged into the *nullah* from Murree Brewery, a beverages manufacturing concern.

Before joining the Soan River, Nullah Leh passes though Rawalpindi's cantonment area receiving domestic sewage. It then joins the Soan River near the Soan bridge. The flow rate of the *nullah* before joining the Soan River is 9.6 m^3/sec. Spot test results indicate a DO level of 2.14 mg/l and laboratory test results indicate BOD and COD levels of 81.67 mg/l and 209.6 mg/l, respectively.

Table 5.10 compares the spot test and laboratory test results of the samples from the tributaries of Nullah Leh.

Natural Water Streams Joining the Soan River

A natural water stream near the American Embassy emerges from the Margalla hills and passes through the Bari Imam area in Islamabad. The flow rate of the *nullah* at this point is 0.54 m^3/sec. Spot test results indicate a DO value of 6.52 mg/l and laboratory test results of the sample show BOD and COD values of 16.31 mg/l and 19.34 mg/l respectively.

Another stream flows down the Murree Hills passes through Rawal Dam's catchment area and flows into the lake. The flow of the stream at Chattar Park is 0.75 m^3/sec.

Rawal Dam is a 24.3 meters high masonry dam with a lake that has a surface area of about 9 square kilometers. Rawal Lake was conceived as a source of water supply for the twin cities of Rawalpindi and Islamabad (I-9 area only). The dam has been built in a natural bowl, which now forms the lake. The flow rate of the channel flowing out of Rawal Lake is 1.215 m^3/sec.

The Korang Stream originates from Simly Dam and joins Nullah Kura before falling into the Soan River. The flow rate of the stream at Lehtrar Road is 1.94 m^3/sec. Spot test results show that the water is polluted, because a low DO value of 2.44 mg/l was observed.

Nullah Kura, after joining the Kurang Nullah, crosses Shahrah-e-Islamabad near the railway crossing. It ultimately falls into the Soan River. The flow of the stream at the point near the railway crossing is 1.15 m^3/sec. Spot test results show a DO value of 4.78 mg/l.

Table 5.10: Comparison of Results at all Sample Points from Leh Basin

Parameters	*E-8 Karakuram Road*	*E-7 Hill Side Road*	*F-8/2 Near St. 24A*	*F-6/2 Margalla Road*	*F-5/2 Near AJK Sectt*	*Peshawar Road*	*Nullah-1, Pir-wadhai*	*Nullah-2, Pir-wadhai*	*Mixed Nullah I and II, Pirwadhai*	*Nullah Leh Gawalmandi*	*Nullah Leh Airport Road*	*Nullah Leh Gulstan Colony*	*Nullah Leh before Soan*
Flow (m^3/sec)	0.06	0.04	0.11	0.05	0.07	0.05	2.1	716	2.7	10.8	7.8	8.6	9.6
Temperature (°C)	18.2	20.5	25.4	16.0	18.8	22.3	20.8	20.4	20.3	23.8	24.4	30.0	24.2
pH	7.4	7.7	7.3	7.4	7.6	7.6	7.9	7.4	7.6	7.1	7.13	7.3	7.6
DO (mg/l)	5.7	0.66	3.8	5.8	4.6	2.2	0.5	0.09	0.05	0.28	0.05	1.9	2.1
Conductivity (µS/cm)	210	760	560	200	230	850	930	910	960	1320	1340	1260	1590
Turbidity (NTU)	13.7	9.9	49	9.3	11.4	6.4	6.4	18.5	17	41.5	65	64.5	59.3
Odor (TON)	4.0	16	64	1.0	4.0	16	16	16	16	64	64	64	64.0
Color (TCU)	0	10	70	0	1.0	70	70	70	70	70	70	70	50.0
BOD_5 (mg/l)	6.8	58.0	60.1	17.0	12.2	31.3	57.6	59.5	34.2	139	139	119	81.7
COD (mg/l)	25.6	89.3	101.3	18.4	20.9	58.2	83.7	114.3	81	358	215	210	147
TSS (mg/l)	4,041	50	16,145	107	42	146	358	89	210	284	272	127	255
O&G (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T-N (mg/l)	BDL	18.4	12.3	BDL	BDL	1.7	10.1	3.4	5.1	6.7	5.6	37.5	51
E-Coli (MPN)	18+	18+	18+	0.0	18+	18+	18+	18+	18+	18+	18+	18+	18+

BDL: Below Detection Limit

The Soan River from the Potohar area passes though the Rawalpindi district before joining the Indus River at Barotha in District Attock. The flow rate of the river before it joins Nullah Leh is 10.08 m^3/sec.

Wastewater from domestic and industrial areas in Rawalpindi and Islamabad is carried by Nullah Leh, which joins the Soan River at Soan Bridge. The flow of the river before it joins Nullah Leh is 10.54 m^3/sec. Spot test results indicate a DO value of 5.39 mg/l.

Table 5.11 presents a comparison of the spot and laboratory test results of natural water streams joining the Soan River.

5.2.3 Pollution Loading

Data from the 20 sampling sites in Rawalpindi and Islamabad show that BOD_5 (20°C) varies from 6.77 to 139.3 mg/l except for the sample from the Rawal Dam outlet in which BOD was not detected. The BOD loading at these points varies from 0.04 to 129.68 mt/day.

Pollution Contribution to Leh Basin in Islamabad and Rawalpindi

Pollution at sampling sites in the Nullah Leh Basin and their BOD and COD loading contributions are given in **Table 5.12.**

Table 5.11: Comparison of Results for Sample Points from Soan Basin

Parameters	*Near American Embassy*	*Chattar Park*	*Rawal Dam Outlet*	*Korang Nullah*	*Kura Nullah*	*River Soan*	*Soan after Nullah Leh Joins*
Flow (m^3/sec)	0.54	0.75	1.22	1.9	1.15	10.1	10.5
Temperature (°C)	17.5	20.8	19.8	26.9	27.6	26.3	25.4
pH	7.8	8.0	7.8	7.6	8.1	8.2	7.6
DO (mg/l)	6.5	6.1	6.0	2.4	4.8	7.6	5.4
Conductivity (µS/cm)	590	600	410	58	680	770	1140
Turbidity (NTU)	4.0	0.5	2.6	22.6	7.7	6.1	43 5
Odor (TON)	1.0	1.0	1.0	4	2.0	4.0	16
Color (TCU)	10	0	0	70	0	20	20
BOD5 (mg/l)	16.3	14.2	ND	10.9	16.0	26.9	42.6
COD (mg/l)	19.3	34.8	7.0	15.8	18.4	45.6	68.7
TSS (mg/l)	47	43	106	77	36	94	22
O&G (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T-N (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL
E-Coli (MPN)	18+	18+	18+	18+	18+	18+	18+

BDL: Below detection limit
ND. Not detected

Table 5.12: Comparison of Results for Sampling Points of Nullah Leh Basin

Parameters	*E-8 Karakoram Road*	*E-7 Hill Side Road*	*F-8/2 Near St. 24A*	*F-6/2 Margalla Road*	*F-5/2 Near AJK Sectt.*	*Peshawar Road*	*Nullah-1, Pirwadhai*	*Nullah-2 Pirwadhai*	*Mixed Nullah I & II Pirwadhai*	*Nullah Leh Gawal Mandi*	*Nullah Leh Airport Road*	*Nullah Leh Gulistan Colony*	*Nullah Leh before Soan*
Flow (m^3/sec)	0.06	0.04	0.11	0.05	0.07	0.05	2.08	7.06	2.72	10.79	7.84	8.63	9.6
DO (mg/l)	5.7	0.66	3.8	5.8	4.6	2.2	0.5	0.09	0.05	0.28	0.05	1.9	2.1
BOD_5 (mg/l)	6.8	58.0	60.1	17.0	12.2	31.3	57.6	59.5	34.2	139.1	139.3	118.8	81.7
BOD_5 (mt/day)	0.04	0.2	0.6	0.07	0.08	0.14	10.3	36.3	8.0	129.7	94.4	88.5	67.7
BOD Load (%)	0.01	0.04	0.12	0.01	0.02	0.03	2.1	7.2	1.6	25.8	18.7	17.6	13.5
COD (mg/l)	25.6	89.3	101.3	18.4	20.9	58.2	83.7	114.3	81.0	357.5	215.4	209.6	147.1
COD (mt/day)	0.13	0.28	0.99	0.08	0.13	0.25	15.1	69.7	19.0	333.3	145.9	156.3	122.0
COD Load (%)	0.01	0.03	0.10	0.01	0.01	0.03	1.55	7.2	1.95	34.2	15.0	16.1	12.5
BOD:COD Ratio	1:3.3	1:1.6	1:1.7	1:1.1	1:1.6	1:1.8	1:1.5	1:1.9	1:2.4	1:2.6	1:1.6	1:1.8	1:1.8
T-N (mg/l)	BDL	18.4	12.3	BDL	BDL	1.7	10.1	3.4	5.1	6.7	5.6	37.5	51.0

BDL: Below Detection Limit

The BOD load contribution of individual streams is shown in **Table 5.12**. The loading of Nullah 1 and 2 at the I-10/Pirwadhai crossing is 10.34 mt/day and 36.32 mt/day respectively. The contribution decreases to 8.03 mt/day after the two *nullahs* join. The maximum BOD load was 129.68 mt/day at Nullah Leh near Gawalmandi Bridge, and was due to the excessive sewage and industrial wastewater discharged into the *nullah* from Rawalpindi. The BOD loading of Nullah Leh at Airport Road is 94.36 mt/day, which decreases to 88.54 mt/day at Gulistan Colony. This decrease occurs because the water in the *nullah* is diluted with washing water from the residential areas in the city. The BOD loading of Nullah Leh decreases further to 67.74 mt/day before it joins the Soan River.

Pollution Contribution to Soan Basin in Islamabad and Rawalpindi

Pollution levels and BOD and COD load at sampling sites in the Soan Basin are given in **Table 5.13**.

The BOD loading of the *nullah* near the American Embassy is 0.76 mt/day and the load of the stream near Chattar Park is 0.92 mt/day. No BOD was detected in the sample from the Rawal Lake outlet. BOD load contributions from the Nullahs Korang and Kura were 1.83 and 1.59 mt/day respectively. The BOD loading of the Soan River and Nullah Leh before they converge is 23.40 mt/day and 38.79 mt/day respectively.

Table 5.13: BOD Loading of Different Streams of the Soan River Basin

Parameters	*Near American Embassy*	*Chattar Park*	*Rawal Dam Outlet*	*Korang Nullah*	*Kura Nullah*	*River Soan*	*Soan After joining Nullah Leh*
Flow (m^3/sec)	0.54	0.75	1.22	1.94	1.15	10.08	10.54
DO (mg/l)	6.5	6.1	6.0	2.4	4.8	7.6	5.4
BOD_5 (mg/l)	16.3	14.2	ND	10.9	16.0	26.9	42.6
BOD_5 (mt/day)	0.76	0.92	–	1.83	1.59	23.40	38.79
BOD Load (%)	0.15	0.18	0.0	0.36	0.32	4.7	7.7
COD (mg/l)	19.3	34.8	7.0	15.8	18.4	45.6	68.7
COD (mt/day)	0.9	2.3	0.7	2.7	1.8	39.7	62.5
COD Load (%)	0.09	0.23	0.08	0.27	0.19	4.1	6.4
BOD:COD Ratio	1:1.2	1:2.5	–	1:1.5	1:1.2	1:1.7	1:1.6
T-N (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL: Below detection Limit

ND: Not detected

5.3 Quality Assurance

During this study, HBP adopted various quality control (QC) measures to produce credible results.[1] These included the following:

- Competence of HBP chemists and analysts was ensured
- Known additions during analysis were recovered
- Standard samples were analyzed
- Reagent blanks were analyzed
- Calibration of instruments with standards was ensured
- Duplicate analysis was performed
- Control charts were used.

Quality assessment is the process of using external and internal QC measures to determine the quality of the data produced by the laboratory. It includes performance evaluation of samples and comparison of sample analyses from different laboratories. These were applied to test the recovery, bias, precision, detection limit, and adherence to standard operating procedures.

For inter-comparison of the same samples from different laboratories, four samples of wastewater, two each from Lahore and Rawalpindi/Islamabad, were sent to the PCSIR laboratory in Lahore, for analysis of COD, BOD, TSS, T-N, O&G, and E-Coli. A comparison of the results from the HBP and PCSIR laboratory are shown in **Table 5.14**.

Table 5.14: Comparison of Results from HBP and PCSIR Laboratories

Sample ID No.	*Lab.*	*COD mg/l*	*BOD_5 mg/l*	*TSS mg/l*	*T-N mg/l*	*O&G mg/l*	*E-Coli MPN/100ml*
Lahore E000077	HBP	2,383	141.5	736	3.9	53.3	>180
	PCSIR	2,826	965	1,092	0.3	2.2	1.0
Lahore E000080	HBP	33.4	7.1	80	BDL	< 5.0	>180
	PCSIR	15.1	6.2	20	0.1	0.6	1.0
Rawalpindi E000105	HBP	147.1	81.7	255	BDL	< 5.0	>180
	PCSIR	1,676	256	253	0.2	0.4	–
Islamabad E000106	HBP	18.4	16.0	36	BDL	< 5.0	>180
	PCSIR	31.6	12.5	15	0.4	0.1	ND

BDL: Below Detection Limit
ND: Not detected

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[1] Quality assurance is a set of operating principles which, if strictly followed during sample collection and analysis, produce data of a known and defensible quality. By adhering to the quality assurance procedures, the accuracy of the analytical results can be stated with a high level of confidence. Quality assurance includes quality control and quality assessment. Internal quality assurance is called quality control (QC), while external quality assurance is known as quality assessment.

COD, BOD, TSS, T-N and O&G results of river water samples like E80 (Ravi River at Balloki Headworks) and E106 (Soan River) are comparable, but there is a lot of variation in the results for the same parameters in wastewater samples. E-Coli tests were carried out by the Institute of Public Health in Lahore and by Excel Laboratory in Islamabad. The results from the two sources are very different. To verify the variation observed in BOD, COD, T-N and E-Coli in samples taken from Barian Drain, the JICA environmental expert recommended repeat sampling and analysis by HBP, PCSIR, and Punjab EPD laboratories. The results are shown in **Table 5.15.**

Analysis of arsenic, copper, chromium, cadmium, lead and zinc was carried out by the Geoscience Laboratory in Islamabad. For comparison of the results, the same sample was also sent to the National University of Science and Technology (NUST), Rawalpindi. The results are shown in **Table 5.16.**

As evident from the table, the laboratories' results for all metals, except copper, are comparable. Geosciences Laboratory reports copper concentration as 2.0 ppm and 3.0 ppm in samples E000077 and E000105, respectively, while the NUST results are less than 0.5 ppm for both samples.

Table 5.15: Comparison of Results by HBP, PCSIR, and EPD Lahore

Laboratory	*BOD mg/l*	*COD mg/l*	*T-N mg/l*	*E-Coli MPN/100ml*
HBP	358	1,692	5.04	–
PCSIR	567	2,642	2.16	
EPD Punjab	870	2,000	800	>180

Table 5.16: Comparison of Results of Geoscience Laboratory, Islamabad and NUST, Rawalpindi

Sample ID No.	*Laboratory*	*As (ppb)*	*Cu (ppm)*	*Cd (ppm)*	*Cr (ppm)*	*Pb (ppm)*	*Zn (ppm)*
Lahore E000077	Geoscience	14	2.0	< 0.1	< 0.5	0.2	0.3
	NUST	< 0.5 ppm	< 0.5	< 0.5	< 0.5	< 0.5	< 1.0
Rawalpindi E000105	Geoscience	11	3.0	< 0.1	< 0.5	0.3	0.3
	NUST	< 0.5 ppm	< 1.0	< 0.5	< 0.5	< 0.5	< 1.0
Islamabad E000106	Geoscience	<10	< 0.5	< 0.1	< 0.5	< 5.0	< 0.2
	NUST	< 0.5 ppm	< 1.0	< 0.5	< 0.5	< 0.5	< 0.5

6. Observations and Recommendations

In an attempt to assess the deterioration in air and water quality in the major cities of Pakistan, JICA and Pakistan EPA undertook a project to measure air and water quality in three cities, Lahore, Rawalpindi, and Islamabad. This study forms the initial part of the agencies' plan to stem the deterioration.

The air and water quality monitoring that was conducted in the three cities provided a basic understanding of issues associated with standard field sampling, measurement, and laboratory test methods and procedures.

Based on the analysis carried out in this report, HBP identified some observations and recommendations, which are presented below.

6.1 Ambient Air Quality Monitoring

Urban air quality results of the three cities present an alarming situation as two of the criteria air pollutants (CO, SO_2, NO_X, PM_{10} and Pb), including PM_{10} and NO_X, exist in higher levels than the WHO limits. This situation calls for a well-structured, countrywide air quality monitoring program.

Some observations made during the study are briefly discussed below:

- Air quality monitoring is the first step in determining the magnitude and characteristics of air pollution problems. The monitoring capacity, in terms of equipment (field and laboratory) and trained staff, is limited, and therefore representative data and information on air quality across the country is non-existent.
- Correct interpretation of air quality data is essential for formulating policy recommendations to improve air quality. The current staff capacity to correctly synthesize and analyze air quality data is minimal, with the result that whatever little information and data *is* available on air quality is not used properly to develop an appreciation of air quality issues.
- There is a lack of uniformity in the test methods and procedures of environmental laboratories in the public and private sectors. This leads to controversies in quality control and assurance issues. The laboratory test methods for sampling and measuring air pollutants are not chosen carefully and do not take into account the purpose of measurement or available resources. In addition, the following points are generally ignored:
  - The method should be widely accepted
  - The method should be precise and accurate
  - The method should be economical and time conserving
  - The method should give results that can be used for inter-laboratory comparison.
- Emission inventories and air quality monitoring are the scientific foundations upon which air quality plans are built. The monitoring data help in identifying the emission sources and intensity of problems, while emission inventories show the relative contribution of different sources. Emission inventories are used to:

  - ▷ Predict air quality impacts of emission reductions;
  - ▷ Determine which type of control measures are needed to lower the ambient air pollution levels in a specific area; and
  - ▷ Show emission trends over time and provide inputs to health risk assessments.

- ▶ No air quality management program can be successful without identification of emission sources, and development of emission inventories based on local emission factors, such as pollutant emitted per ton of fuel burned or distance traveled by motor vehicle.
- ▶ Local ambient air quality standards are necessary for protection against potential adverse effects of air pollution. Currently, national ambient air quality standards do not exist. These need to be developed and introduced to assess the level of pollution in urban areas, in terms of air quality indices (AQI). This activity calls for online air quality monitoring in most air-polluted cities; the information obtained will provide sufficient grounds for legislation and identification of legal strategies, such as enactment of a 'Pakistan Clean Air Act.'

6.2 Water Quality Monitoring

Natural streams, canals, rivers, and the sea are the main receptors of untreated domestic and industrial wastewaters in Pakistan. The water quality monitoring results of Lahore, Rawalpindi, and Islamabad cities present a scary situation, as, out of 40 wastewater samples tested, only one was declared fit for human consumption. The river water quality in Lahore, Rawalpindi, and Islamabad necessitates a well-designed, countrywide water quality monitoring program.

Some observations made in the course of this study are briefly discussed below:

- ▶ The information and data generated from previous studies should provide guidelines for future studies on similar subjects. Several studies on water quality have been conducted by a number of research institutes and individuals in major cities of Pakistan. However, environmental information and data generated through these studies were not placed at a central location, and access to them was denied to researchers and the general public. Research in this area could therefore not build up. The need for a central databank for all such information is strongly felt. Currently, such a system does not exist in the country.
- ▶ Like air monitoring, water quality monitoring also identifies the magnitude and characteristics of water pollution problems. In Pakistan, water quality monitoring capacity, in terms of field and laboratory equipment and trained staff, is also limited, so only very scanty representative data and information on water quality across the country is available.
- ▶ Spot sampling and testing play a significant role in providing representative data on water quality. Currently, little attention is paid to standard sampling and spot testing procedures during the collection of water samples from natural streams, canals, lakes, and rivers. Concerned agencies and their relevant staff require essential hands-on training on spot sampling and testing procedures.
- ▶ Current pollution levels in canals, lakes, and rivers provide enough reasons for enacting a Pakistan Clean Water Act. Periodic water quality monitoring of canals, lakes, and rivers can generate essential data that can be used to develop water quality indices (WQI) for all receptors. This information should be made public so it is aware of the current water quality of canals, lakes, and rivers.

Appendices

Appendix A: List of Industries in Lahore, Rawalpindi and Islamabad

A.1 List of Industries in Lahore

No.	*Industry*	*No. of Units*
1.	Air-conditioners	1
2.	Automotive Parts	74
3.	Artificial Leather and Rexine	3
4.	Beverages	6
5.	Batteries	10
6.	Blades	1
7.	Bakery Products	33
8.	Bus Bodies	45
9.	Cycle Assembly	5
10.	Cycle Tyres and Tubes	8
11.	Cycle Parts	30
12.	Ceramics	9
13.	Concrete Mixer	1
14.	Cosmetics	10
15.	Carpet Knitting Yarn	3
16.	Deep Freezer/Fridge	6
17.	Textile Dyeing, Finishing and Printing	35
18.	Diesel Engines	20
19.	Dyes/Color	7
20.	Dry Battery	1
21.	Electric Bulbs	2
22.	Electric Furnace (MS, Ingots/Billets)	38
23.	Electric Meters	2
24.	Electric Motors	20
25.	Electric Appliances	26
26.	Electric Fans	8
27.	Electroplating	20
28.	Foundaries	100
29.	Foam	4
30.	Flour Mills	31

No.	Industry	No. of Units
31.	Fruit Juices	6
32.	Flour Mill Machinery	10
33.	Forging	5
34.	Fibre Glass	4
35.	Fire Fighting Equipment	1
36.	Gas Appliances	15
37.	Glass Products	9
38.	Hospital/Surgical Instruments	4
39.	Homoeopathic Medicines	4
40.	Industrial Gases	10
41.	Insecticides and Pesticides	6
42.	Icecream	3
43	Industrial Chemicals	12
44.	Ice and Cold Storage Machinery	12
45.	Jewellery	8
46.	Leather Board	4
47.	Leather Footwear	110
48.	Light Engineering	300
49.	Milk Processing and Dairy Products	3
50.	M.S. Pipes	14
51.	Matches	2
52.	Miscellaneous Machinery and Equipments	30
53.	Machine Tools	40
54.	Metal Container	50
55	Nuts, Bolts and Hinges	100
56.	Opticals	4
57.	Paper and Paper Board	4
58.	Pharmaceutical	41
59.	Plastic Footwear	205
60.	Plywood	4
61.	Plastic Products	60
62.	Polypropylene Yarn	1
63.	Packaging	46
64.	Poultry Feed	8
65.	PVC Pipes	10
66.	Printing Press	384
67.	Paint and Varnish	50

No	*Industry*	*No. of Units*
68.	Power Press	5
69.	Potato Chips/Crisp	3
70.	Printing Inks	5
71.	Road Rollers	1
72	Readymade Garments/Hosiery	70
73.	Rubber Products	50
74.	Resin and Turpentine	2
75	Steel Re-rolling	275
76.	Sewing Machine and Parts	45
77.	Soap	64
78.	Sugar Mill Machinery	4
79.	Steel Furniture	50
80.	Sanitary Ware/Fitting	20
81.	Stationery	25
82.	Tractor (Assembling)	2
83.	TV and Radio Sets/Parts	3
84.	Transformers and Parts	10
85.	Tentage	8
86.	Textile Machinery Parts	9
87.	Tractors Parts	32
88.	Tanneries	3
89.	Tin Containers	20
90.	Vegetable Ghee/Cooking Oil	5
91.	Woollen Textile (Spinning)	11
92.	Woollen Carpet	10
93.	Wire and Cables	60
94.	Wire and Wire Nails	20
95.	Wood Working Machinery	8
96.	Weight and Measures	4
97.	Zari	20

Source: Directorate of Industries and Mineral Development, Punjab 1992.

A.2 List of Industries in Rawalpindi

No	*Industry*	*No. of Units*
1	Arms and Ammunition	1
2	Brewery/Distillery	1
3	Fruit and Vegetable Processing	1
4	Cotton Textile (Spinning and Weaving)	5
5.	Cement	1
6.	Cigarettes	1
7.	Casting and Forging	1
8.	Cement Products	25
9	Flour Milling	15
10	Fruit and Food Preservation	8
11	Fire Bricks	1
12	Glass Products	1
13.	Gas Appliances	1
14.	Heavy Industrial Machinery and Parts	1
15.	Hosiery Goods	20
16.	Industrial Gases	2
17.	Light Engineering	15
18.	Lime Kiln	12
19	Mineral Processes	1
20	Marble Cutting and Polishing	40
21	Pharmaceutical	5
22	Poultry Feed	2
23.	Paint and Varnish	6
24.	PVC Footwear	32
25	Petroleum Oil Refinery	1
26	Rexine Cloth and Products	2
27	RCC Pipes and Jalies	50
28.	Specialized Tex	2
29.	Steel Re-rolling	2
30	Stone Crushing	38
31	Sewing Machines	2
32	Tyre Retreading	2
33.	Woollen Textile (Spinning and Weaving)	2

Source. Directorate of Industries and Mineral Development, Punjab 1992.

A.3 List of Industries in Islamabad

No	*Industry*	*No. of Units*
1.	Steel Melting Furnaces	8
2	Steel Re-rolling	12
3.	Flour Mills	25
4	Oil and Ghee Mills	6
5.	Marble Cutting and Polishing Units	34
6.	Metal Working and Engineering Units	23
7.	Pharmaceuticals	19
8	Plastic Molding Units	4
9.	Beverages	3
10.	Cotton Textile (Spinning and Weaving)	1
11	Cement	1
12.	Chemicals (Pen Ink)	1
13.	Pre-Cast Factory	1
14.	Fruit and Food Preservation	3
15.	Foundary	1
16.	Glass Products	2
17.	Icecream	1
18.	Industrial Geysers	1
19	Leather Factory	1
20.	Poultry Feed	4
21.	Paint and Varnish	2
22.	Paper and Board	1
23	Plastic Bags	1
24.	RCC Pipes	1
25.	Toys Factory	1
26.	Wood Industry	2
27	Automotive Parts	1
28	Lubricants	1
29	Pesticides	1
30.	Electonics	3
31.	Furnishers	3

Source. Hagler Bailly Pakistan, *Physical Survey*

Appendix B: Field Sampling and Laboratory Test Methods and Procedures

B.1 Water Sampling Procedures

The sampling methods used for wastewater are presented in **Table B.1**.

Table B.1: Standard Methods for Wastewater Sampling

No.	*Sampling Method*	*Description*
1.	ASTM D 3858-95	Open Channel Flow Measurement, Velocity Area Method
2.	ASTM D 5612-94	Quality Planning and Field Implementation of a Water Quality Measurement Program
3.	ASTM D1066-82 (1990)	Water Sampling in a Stream
4.	ASTM D 3370-95a	Sampling Type (Grab/Composite)
5.	ASTM D 3856-95	Guide for Sampling and Analysis of Water
6.	APHS 1060 B (1992)	Collection of Water Sample (US-EPA SW-846 1986)
7.	APHS 1060 C (1992)	Preservation of Water Sample (US-EPA No 209 1984)
8.	ASTM D 1971-91	USEPA HACH-86 (1997) Digestion for Metal Analysis
9.	APHS 1070 B (1992)	Laboratory Apparatus
10.	APHS 3030 (1992)	Preliminary Treatment of Samples

APHS American Public Health Standards
ASTM American Standards for Testing Materials

B.1.1 USEPA Sampling Protocols

Accurate assessment of the concentration of pollutants in water depends primarily upon the samples drawn for the analysis. Representative grab/composite samples from the surface water were collected by the Hagler Bailly field staff, supervised by JICA environmental expert.

As pH, conductivity, DO, color, odor transparency and temperature were measured onsite, sample preservation and holding was not required. A 500-ml sample was collected for site analysis and 100 ml for composite sample in a standard plastic bottle with screwed cap. The composite sample was collected, filtered and preserved in a plastic bottle with a screwed cap for BOD, COD, SS, Total-N, E-Coli, and heavy metal analysis. The same sampling procedures was adopted for all sampling points. **Table B.2** summarizes the sampling procedures, including all parameters, sample size, container and sample preservation methods.

Standard plastic containers of 1,000-ml capacity were used for collection of grab (analytical laboratory) samples and site analysis. The 100-ml grab samples were stored in a 2,000-ml plastic bottle for composite sampling on hourly basis.

Table B.2: Methods for Testing Various Parameters in Wastewater Samples

No.	*Parameter*	*Standard Method*	*Sample Size*	*Container*	*Preservation*
1.	pH	ASTM D1293-95 APHA 4500 H^+	100 ml	Plastic, Glass	Refrigerate
2.	Conductivity	ASTM D1125-95 APHA 2510 B	500 ml	P, G	Refrigerate
3.	Temperature	APHA 2550 B		P, G	Analyze immediately
4.	DO	ASTM D888-92 / 8215 APHA 4500O (1992)	300 ml	Glass, BOD Bottle	Analyze immediately
5.	BOD	APHA 5210B (1992)/8043	1000 ml	Plastic, Glass	Refrigerate
6.	COD	ASTM D1252-95 / 8000 APHA 5220C (1992)	100 ml	Plastic, Glass	Analyze immediately
7.	SS	APHA 2540D / 8006	500 ml	P, G	
8.	Oil	APHA 5520D / 10056	1000 ml	Glass	Add H_2SO_4 to pH <2.0
9.	E-Coli	HACH 10029	200 ml	P, G	Refrigerate
10.	Total-N	APHA 4500B/ 8075	500 ml	P, G	Refrigerate
11.	Color	APHA 2120	500 ml	500 ml	Refrigerate
12.	Transparency	APHA 2130B / 8195		P, G	Refrigerate
13.	Odor	ASTM D1292-86 (1995) APHA 2150	500 ml	Glass	Analyze immediately
14.	Arsenic	ASTM D2972 -93 APHS 3500 (1992) USEPA 206 4	500 ml for all metals	Plastic, Glass bottles rinsed with 1+1 HNO_3	Filter immediately add HNO_3 to pH <2.0
15.	Cadmium	ASTM D3557 -95 APHA 3111 (1992) HACH 8017			
16.	Chromium	ASTM D1687 -92 APHA 3111 (1992) HACH 8024			
17.	Copper	ASTM D1688 -90 APHA 3111 (1992) HACH 8143			
18.	Lead	ASTM D3559 -95 APHA 3111 (1992) HACH 8317			
19.	Zinc	ASTM D1691 -95 APHA 3111 (1992)			

B.1.2 Transportation of Samples to Analytical Laboratory

The following steps were taken for transportation of samples from site to the analytical laboratory.

B.1.3 Labeling

Each sample was properly labeled and an effluent sample record Performa were filled.

B.1.4 Field Log Book

Field survey record and onsite analysis results were recorded.

B.1.5 Analysis Request

An analysis request sheet for the laboratory was sent along with the samples to perform analysis.

B.1.6 Transportation to Lab

The preserved sample was transported to the laboratory in the custody of a responsible person, who handed over these samples to the supervisor of the laboratory responsible for analysis.

B.1.7 Receipt and Logging in Lab

After receiving the preserved samples and inspection of conditions (proper storage and integrity) of sample bottles, the samples were stored properly for analysis.

B.2 Water Analysis

Wastewater analytical procedures for various parameters, including quality control checks that are followed by HBP during spot and laboratory testing, and which were observed for this study, are briefly discussed below.

B.2.1 pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. At a given temperature, the intensity of the acidic or basic character of water is indicated by pH. Onsite measurement of pH should be conducted using the following equipment:

- Apparatus: A pH meter consisting of potentiometer, a glass electrode, a reference electrode and a temperature compensating device.
- Reagents: Standard Buffer solutions (pH 4.0 and 7.0).
- Precision and Bias: Careful use of a Laboratory pH meter with good electrodes can lead to a precision of ±0.02 pH unit and an accuracy of ±0.05 pH.

B.2.2 Conductivity

Conductivity is a measure of the ability to carry an electric current. This ability depends upon the presence of ions; on their total concentrations, valences; and on the temperature of measurement.

- Apparatus: A conductivity meter with dip type cell is used for the measurement of conductivity.
- Reagents: Standard KCl solutions.

B.2.3 Temperature

The temperature of surface water has significant ecological impacts. Normally, temperature can be measured by a standard calibrated mercury filled Celsius thermometer.

B.2.4 Dissolved Oxygen

DO is an important index for water pollution by organic substances. The Membrane Electrode method was used to avoid interference from chlorine, merceptans, hypochlorite and organic substances.

B.2.5 BOD

The biological oxygen demand (BOD) method entails a 5-day incubation of the sample at 20°C. DO is measured before and after the incubation and BOD is computed from the difference between the initial and final dissolved oxygen; this requires the presence of microorganisms capable of oxidizing the biodegradable organic matter in the sample. Domestic wastewater, industrial wastewater and surface waters receiving wastewater discharges contain sufficient microbial populations. For samples not containing microorganisms, in this case seeding is necessary.

B.2.6 COD

The chemical oxygen demand (COD) is a measure of the oxygen equivalent of organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The sample is refluxed in a strong acid solution with a known excess of potassium dichromate. After digestion, the remaining unreduced dichromate is titrated with standard ferrous ammonium sulfate solution to determine the amount of consumed dichromate. The oxidizable organic matter is calculated in terms of oxygen equivalent.

B.2.7 Suspended Solids

A well-mixed known volume of sample is filtered through a weighed glass fiber filter 934 AH. The residue is dried to a constant weight at 105°C. The increase in weight of the filter represents the total suspended solids.

B.2.8 Oil and Grease

In the determination of oil and grease, an absolute quantity of a specific substance is not measured. Rather, groups of substances with similar physical characteristics are determined quantitatively on the basis of their common solubility in an organic extracting solvent. N-hexane is used as solvent for the extraction of oil from the polluted water.

B.2.9 E-Coli

To identify the waterborne digestive contagious diseases that contaminate drinking water, it is important to test Escherichia Coli (E-Coli). Different types of biological media are used to grow Escherichia Coli. After inoculation, the media are incubated at 35°C for two days (for fecal coliform, the incubation temperature is 45°C).

B.2.10 Total-N

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. The Kjeldahl method is used for the determination of total nitrogen.

B.2.11 Color

Here, 'color' means the color of water after removing turbidity. The standard true color comparison method was used.

The Nephelometric method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions.

B.2.12 Odor

Odor depends on the contents of stimulating substances with the appropriate human receptor cell. For odor measurement samples are diluted with odor free water until a dilution until the odor is barely perceptible to each tester.

B.3 Heavy Metals Analysis

Requirement for determining metals by Atomic Absorption Spectrometry vary with metal and/or concentration to be determined. The method is used according to the concentration of different metals. Standard test methods that were followed by Geoscience laboratory Islamabad for the detection of As, Cd, Cr, Cu, Pb, and Zn in water samples are given in **Table B.3**.

Table B.3: Standard Test Methods

No.	*Parameters*	*Standard Methods*
1.	Arsenic	ASTM D2972 -93/ APHS 3500 (1992) / USEPA 206.4
2.	Cadmium	ASTM D3557 -95 / APHA 3111 (1992) / HACH 8017
3.	Chromium	ASTM D1687 -92 / APHA 3111 (1992) / HACH 8024
4.	Copper	ASTM D1688 -90 / APHA 3111 (1992) / HACH 8143
5.	Lead	ASTM D3559 -95 / APHA 3111 (1992) / HACH 8317
6.	Zinc	ASTM D1691 -95 / APHA 3111 (1992)

B.4 Air Sampling

Air sampling techniques that Hagler Bailly routinely adopts, and which were followed during ambient air sampling, are briefly discussed below.

B.4.1 Representative Sampling

In order to obtain a representative sample, various relevant factors should carefully be considered. The volume of the sample gets smaller as pollutant concentration and sensitivity of the analytical method increase. In general, a sample of about 10 m^3 is required. There are five basic considerations for minimizing error and optimizing efficiency in air sampling:

1. The sample collected must be representative in terms of time, location, and conditions.
2. The volume of the collected sample must be large enough to allow accurate analysis. This depends upon the expected contaminant concentration as well as sensitivity of the analytical method.
3. The sampling rate must be such that it ensures maximum efficiency in collection.
4. The duration of sampling period and the frequency of sampling must reflect accurately the occurrence of fluctuations in pollution levels. Continuous sampling and analysis are preferable.
5. The contaminant must not be charged or modified in the process of collection.
6. To avoid any inconvenience, standard terminology relating to sampling and analysis of atmosphere is followed for ambient air analysis.

B.5 Air Monitoring

SO_2, NO_2, NO, CO, O_3, methane hydrocarbons, non-methane hydrocarbons, meteorological data, PM_{10} and heavy metals were measured by the Punjab EPD Mobile Air Monitoring Station. TSP samples were collected by a high volume air sampler. The TSP samples were then handed over to Geoscience Laboratory for analysis of toxic metals. Atomic absorption spectrometric method was used for the detection of these metals.

The instruments used in the study are based on recommended principles and techniques for instrumentation and analytical procedures. The accuracy and precision of the instruments was maintained by regularly calibrating them.

All the analyzers in the mobile station have a built-in system for zero calibration. The calibration was performed at least once every 24 hours. Zero calibration can be performed any time during the operation of the analyzers.

Air pollution monitoring mobile station is also equipped with standard and certified span gases to conduct span calibration for O_3, CO, NO, NO_X, methane and non-methane hydrocarbon analyzers. The mobile station has also a calibration unit to calibrate the SO_2 analyzer. The ozone analyzer has an ozone generator, which produces ozone of known concentration for calibration. All the instruments were calibrated for given span gases at least once a week during operations. methane and non-methane hydrocarbon analyzers were calibrated every 4 hours during operation.

All the analyzers were calibrated on April 10, 2000 while performing ambient air monitoring at Qurtaba Chowk. The SO_2 analyzer, however, could not be calibrated due to a technical fault in its display LCD screen.

The dust (PM_{10}) monitoring analyzer was calibrated once every 24 hours during its operation. The analyzer is programmed for automatic calibration by the analyzer manufacturer.

The measurements of PM_{10} were taken by the MPSI 100 analyzer of the mobile station. MPSI 100 analyzer uses a sampling procedure which allows rejection of dust particles greater than 10 microns, and thus, measurement of the concentration of PM_{10} only.

B.5.1 Suspended Particulate Matter

PM_{10} was collected on Whatman filter paper, using a high volume air sampler at a flow rate of 0.6 m^3/min.

B.5.2 Particulate Matter High Volume Method

Applicability

This method is applicable for measurement of total suspended PM_{10} in ambient air.

Principle

An air sampler properly located at the measurement site draws a measured quantity of ambient air into a covered housing and through a filter paper during a 24-hour sampling period.

Range

The approximate concentration range of the method is 2-750 $\mu g/m^3$.

Precision

Based upon collaborative testing, the relative standard deviation (coefficient of variation) by single analyst precision (repeatability) of the method is about 3 percent.

Accuracy

The absolute accuracy of the method is undefined because of the complex nature of atmospheric PM concentration.

Efficiency

Collection Efficiency is 99 percent.

Apparatus

- High Volume Air Sampler
- Glass Fiber Filter Papers

Calibration of the high volume air sampler's flow control device is necessary to establish adaptability of the field measurement to a primary standard.

Calculation and Reporting

The USEPA procedure for calculating and reporting (ER31A1.93, 025) is followed.