Investigation of Air and Water Quality (Lahore, Rawalpindi, Islamabad)

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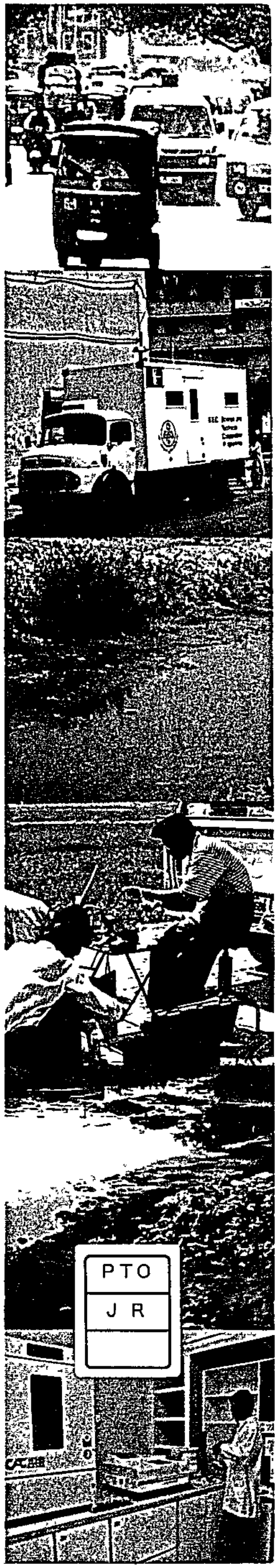

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Japan International Cooperation Agency

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Abbreviations

$\mu g/m^3$	Micro grams per cubic meter
µS/cm	Micro simons per centimeter
APHA	American Public Health Association
As	Arsenic
ASTM	American Society of Testing Materials
BOD	Biochemical Oxygen Demand
BRB	Bumbanwala Ravi Badian
Cd	Cadmium
CLEAN	Central Laboratory for Environmental Analysis
CNG	Compressed Natural Gas
CO	Carbon Monoxide
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
E-Coli	Escherichia-coli
EPAs	Environmental Protection Agencies
EPD	Environmental Protection Department
EU	European Union
HBP	Hagler Bailly Pakistan
HNO_3	Nitric Acid
IESE	Institute of Environmental Sciences and Engineering
ISI	Indian Standards Institution
JICA	Japan International Cooperation Agency
LPG	Liquefied Petroleum Gas
m/sec	Meter per second
m^3/sec	Cubic meter per second
METHCs	Methane Hydrocarbons
Mg/l	Milligram per Liter
MPN	Most Probable Number
mt/day	Metric tons/day
ND	Not Detected

NEQS	National Environmental Quality Standards
NH_3	Ammonia
NMETHCs	Non-Methane Hydrocarbons
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
NTU	Nephelometeric Turbidity Unit
NUST	National University of Science and Technology
O&G	Oil and Grease
O_3	Ozone
Pb	Lead
PCSIR	Pakistan Council of Scientific and Industrial Research
PEPA	Pakistan Environmental Protection Agency
ppb	Parts per Billion
ppm	Parts per Million
QC	Quality Control
RON	Research Octane Number
SO_2	Sulfur Dioxide
SOP	Standard Operating Procedure
SPM	Suspended Particulate Matter
TCU	True Color Unit
T-N	Total Nitrogen
TON	Threshold Odor Number
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UET	University of Engineering and Technology
USPH	United States Public Health
USPH	United States Public Health
WHO	World Health Organization
wm^{-2}	Watt per Square Meter
Zn	Zinc

1. Introduction

This report presents an investigation of the ambient air and river water quality in three cities—Lahore, Rawalpindi, and Islamabad. JICA environmental expert planned the investigation and prepared the outline for implementation. The study was programmed to grasp the actual contaminated condition in air and water quality, which is also a part of the Pakistan Environmental Protection Agency's (PEPA) program for establishing baseline conditions of ambient air and wastewater quality in selected cities of Pakistan. Financial support for this study was provided by the Government of Japan, in the 1999 budget of the Japan International Cooperation Agency (JICA).

The study was conducted by Hagler Bailly Pakistan (Pvt.) Ltd. for JICA.

1.1 Study Objectives

The study was conceived to determine the current status of ambient air quality and the water quality in rivers, lakes and natural streams in Lahore, Rawalpindi, and Islamabad. Its main objectives were to:

- Examine the actual environmental conditions in the cities of Lahore, Rawalpindi, and Islamabad
- Examine the current level of compliance with environmental regulations and the capacity of government agencies to enforce and implement the regulations
- Develop a strategy to strengthen environmental protection agencies (EPAs) for effective enforcement and implementation of environmental regulations.

1.2 Terms of Reference

Hagler Bailly Pakistan was provided the following terms of reference for the study:

- Analyze the existing situation of ambient air quality in Lahore, Rawalpindi, and Islamabad:
  - Conduct ambient air sampling at 10 locations in Lahore, Rawalpindi, and Islamabad on a 16-hour basis, using the Punjab EPA Mobile Station for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxide (NO), carbon monoxide (CO), suspended particulate matter (SPM), Ozone (O_3), and heavy metals (As, Cu, Pb, and Zn)
  - To provide assistance to the JICA environmental expert in conducting ambient air sampling at 10 locations in Lahore, Rawalpindi, and Islamabad using detector tubes for SO_2, NO_2, NO, CO, and Hydrocarbons (HC) mainly to crosscheck the results of the EPA Mobile Unit, and to determine other parameters that cannot be measured by the Unit.
- Analyze the existing quality of wastewater being discharged from industrial units and domestic sources in Lahore, Rawalpindi, and Islamabad:
  - Conduct wastewater sampling according to standard operating procedures (SOP) at 40 sites in Lahore, Rawalpindi, and Islamabad

- Conduct spot testing of wastewater at 40 locations in Lahore, Rawalpindi, and Islamabad; spot testing should include measurement of temperature, pH, dissolved oxygen (DO), conductivity, color, odor, turbidity, and flow at sampling site
- Conduct laboratory tests of wastewater samples for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total-nitrogen (T-N), Escherichia-coli (E-coli), and heavy metals.

- Analyze and compare the laboratory results of air and wastewater analysis with local and international environmental standards.

1.3 Organization of the Report

Section 2 (*Study Background*) describes existing air and water quality conditions in Lahore, Rawalpindi, and Islamabad. It looks at possible reasons for existing levels of pollution, and explains why the study had to be conducted. The methodology HBP adopted for this study is described in detail in **Section 3** (*Study Methodology*). Results obtained from the ambient air monitoring sites in the three cities are presented in **Section 4** (*Air Quality Results*). Spot testing and laboratory results for the wastewater sites are presented in **Section 5** (*Water Quality Results*). Finally, **Section 6** (*Observations and Recommendations*) presents Hagler Bailly Pakistan's observation and recommendations on the various aspects of the study including field and laboratory testing.

2. Study Background

The major cities of Pakistan are faced with a plethora of environmental problems. Among these are deteriorating ambient air quality and discharge of untreated domestic and industrial wastewater into rivers, lakes, and the sea. The problem is so widespread that exposure to air pollution and toxic wastewater discharges is almost an unavoidable feature of urban life throughout the country.

An accurate assessment of air and water pollution issues in metropolitan cities of Pakistan is rather difficult. The main reasons for this are:

- Dearth of reliable information and data on environmental parameters, such as BOD, COD, suspended solids, oil and grease, Escherichia-coli in wastewaters, and CO, NO_X, SO_2, particulate matter, ozone (O_3), hydrocarbons, and dissolved metals in ambient air; and
- Differences in the data collection methodologies adopted by research organizations such as Pakistan Council of Scientific and Industrial Research (PCSIR), local laboratories, the Public Health Engineering Departments, and environmental protection agencies.

For a closer examination of these issues, JICA, in collaboration with PEPA, initiated a preliminary study to determine the current status of ambient air and water quality in Lahore, Rawalpindi and Islamabad. A detailed account of the conditions that created the need for this study is presented below.

2.1 The Problem of Urban Air Pollution

Air pollution primarily affects urban areas, where the density of buildings, industry and vehicles prevents pollutants from being dispersed. Urban air pollutants include particulate matter, SO_2, CO, nitrogen dioxide, O_3, hydrocarbons, and heavy metals.

2.1.1 Industrial Air Pollution in the Three Cities

The level of air pollution in cities is still not known because very little information is available on industrial or vehicular emissions in Pakistan. Industry indiscriminately releases carcinogens such as asbestos and soot, particulate matter, and noxious gases (CO, SO_2, and hydrocarbons) into the air, causing air quality to decline and increasing the incidence of respiratory diseases.

One example of this situation is Islamabad, where residents in the vicinity of the Islamabad Industrial Estate are faced with serious air pollution and associated health problems.[1] They have lodged a complaint against the owners of steel mills releasing particulate matter and other toxic emissions in the area. SO_2 emissions from sulfuric acid plants, ammonia from fertilizer units, and hydrogen sulfide from gas purification operations in the area are reported to exceed safe levels.

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[1] Hagler Bailly Pakistan 1999. *Environmental Survey of Industrial Estate Islamabad.* Final report prepared for Sustainable Development Policy Institute (SDPI), Islamabad.

Heavy industrial activity without adequate air emission treatment or control is among the major causes of deteriorated ambient air quality in Lahore. There are about 3,000 industrial units in and around the city. Of these 1,300 emit obnoxious gases into the atmosphere through boiler stacks and chimneys. These units burn large quantities of gaseous, liquid, and solid fuels.

A study conducted in 1983 by the Institute of Public Health Engineering and Research, University of Engineering and Technology (UET), Lahore, revealed that industrial units in Lahore discharged approximately 4,406 tons of particulate matter, 285 tons of CO, 1,000 tons of hydrocarbons, 162 tons of nitrogen oxides, and 50 tons of SO_2 in 1979-80.[1] Industry was identified as the principal contributor to particulate matter emissions, which represent 68 percent of total air emissions. The contribution of all other industrial emissions, including CO, SO_2, hydrocarbons, and nitrogen oxides, remained below 5 percent. Data on industrial emissions for Rawalpindi and Islamabad are not available.

A systematic study of such problems requires detailed information on area population, meteorology, topography, industrial activity, type and nature of emission sources is necessary. Such general and environmental information pertaining to the three cities is summarized in **Table 2.1.**

A list indicating the type and number of industrial units in Lahore, Rawalpindi, and Islamabad is presented in **Appendix A.**

2.1.2 Winter Fog in Lahore

In the past few years, citywide winter fog, lasting two to three weeks from mid-December to early January, has become a regular phenomenon in Lahore. The fog not only causes extensive economic loss but also creates health problems, such as respiratory and cardiovascular diseases.

This fog is caused by industrial air pollution, which becomes more pronounced in winters because of the increased combustion of 'dirty' fuels, such as furnace oil, diesel oil, wood, and coal. The use of these fuels rises because natural gas, which is a cleaner alternative, is in short supply in winter—in Pakistan, domestic consumers' demand for natural gas is given priority over industrial requirements. Since domestic requirements for gas increase manifold in winter, there is a significant reduction in the supply to industry, which eventually forces factories to use alternative fuels (furnace oil, diesel oil, and coal) to meet their production targets. The combustion of these tends to discharge excessive amounts of particulate matter, SO_2, CO, and nitrogen oxides into the atmosphere. The main parameters responsible for excessive fog are particulate matter, comprising sulfate, nitrate and selenium ions that provide surfaces for water molecules to condense on. In calm wind conditions, the condensed layers can last for weeks.

A recent study identified coal burning in India as the main cause of winter fog in the northern parts of India and Pakistan.[2] The wind pattern is such that industrial emissions traverse long distances and enter Lahore. To confirm this, concentrations of sulfate and nitrate ions were measured in Lahore during and after the fog. Sulfate ion concentrations up to 100 $\mu g/m^3$ were observed during fog conditions. In view of the high concentration of sulfate ions, the study suggests that detailed investigations be carried out for developing a mitigation strategy.

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[1] Tariq, M N , H Shaukat, and Wali Waheed 1983. *"A Study on Air Pollution in Lahore."* Institute of Public Health Engineering and Research, University of Engineering and Technology, Lahore.

[2] Hameed, R. Sultan et al. 1998-99 *The Sources of Widespread Winter Fog in Northern Pakistan and India.*

Table 2.1: Influences on the Environment in Lahore, Rawalpindi, and Islamabad

		Lahore	*Rawalpindi*	*Islamabad*
Topography	Altitude	216 m	506 m	507 m
	Land Features	Plain area between Rivers Ravi and Sutlej	Undulating ground rising gradually from 503 m to 610 m	Undulating ground rising gradually from 503 m to 610 m
Climate	Annual Avg. Wind Speed	1.98 m/s	0.93 m/s	0.93 m/s
	Annual Avg. Temperature	23.8°C	21.3°C	21 3°C
	Mean Annual Rainfall	500-1,000 mm	1,000-2,000 mm	1,000-2,000 mm
Size	Area	1,772 sq km	1,700 sq km	906 sq km
	Urban Population	5,129,000	1,406,214	524,500
Emissions Sources	Number of Vehicles	561,949	117,465	8,894
	Number of Factories	2,982 (in 1992)	399 (in 1992)	168 (in 1999)
Transport Fuel Usage	Petrol	315,430 mtons	61,223 mtons	10,338 mtons
	Diesel	860,275 mtons	300,473 mtons	17,653 mtons
	CNG	330,717 hm^3	162,648 hm^3	63,897 hm^3

Source Pakistan Meteorological Department. 1999. Atlas of Pakistan. Rawalpindi, Survey of Pakistan

2.1.3 Vehicular Pollution in the Three Cities

The total vehicle pool in Punjab has increased at 11.54 percent per year over the past seven years. The growth trend in vehicles types was: cars, 9.52 percent; motorcycles, 13.62 percent; light trucks, 9.83 percent; heavy trucks, 6.53 percent; and buses, 6.1 percent.[1] **Figure 2.1** gives a graphical representation of the vehicle population in Punjab and shows the growth trend for each vehicle type over the last seven years.

Motor vehicles in Pakistan currently consume an estimated 1.22 million tons of gasoline and 6.043 million tons of diesel fuel. Gasoline is largely used by private passenger cars (40 percent of total gasoline consumption), in addition to two-wheelers (17 percent), and taxicabs (up to 13 percent). In the consumption of diesel fuel, heavy trucks account for 60 percent, buses consume 27 percent, passenger cars and wagons 10 percent, and light trucks, around 3 percent.[2]

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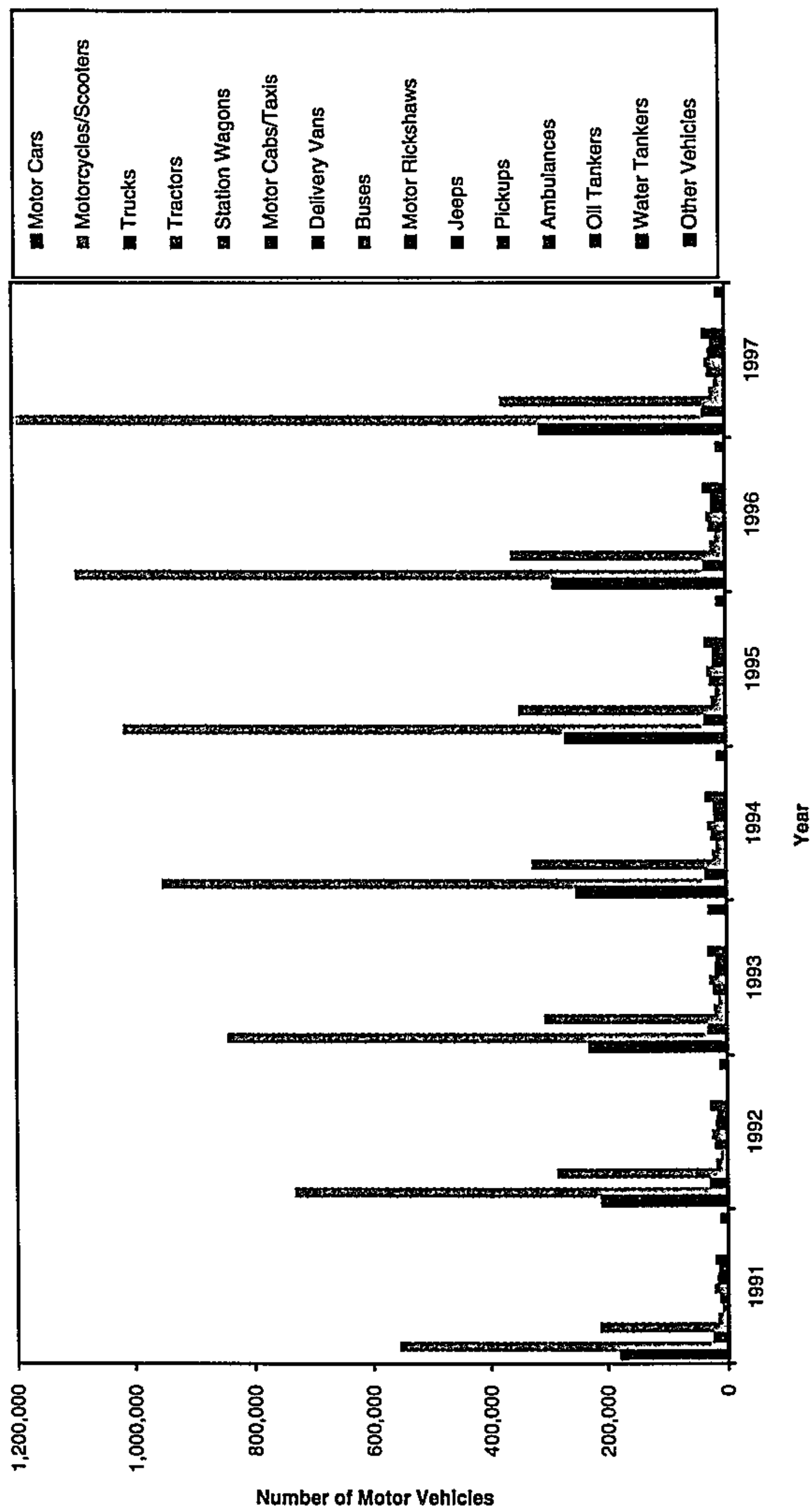
[1] National Transport Research Center, Islamabad. 1998.

[2] Faruqee, R., J. Coleman. 1996. "Pakistan Economic Policies, Institutions, and the Environment." *The World Bank Mission Report.*

Figure 2.1: Vehicle Population in Punjab



Regular gasoline, which has a lead content of 0.42 grams per liter, is used in older cars and in two- and three-wheelers and other two-stroke engines. Super and premier grades of gasoline are used in passenger cars designed for high octane rating fuels.

The lead concentration in these fuels is up to 0.63 g/liter. Low-lead gasoline is also available in the market and supplied in the market as "Premier Plus." **Table 2.2** shows the required lead concentration and research octane number (RON) of various grades of motor gasoline. **Table 2.3** presents sulfur contents in various industrial and vehicular fuels.

Alternative cleaner fuels are only now beginning to be introduced in the market. The government is encouraging the use of compressed natural gas (CNG) and has recently invited the private sector to set up CNG stations. The private sector has responded well and set up CNG stations throughout the country; in Rawalpindi and Islamabad, about 39 stations are in operation. The government has also recently allowed the import of liquefied petroleum gas (LPG) and the sale of low-lead gasoline.

Table 2.4 presents fuel consumption in Lahore, Rawalpindi, and Islamabad.

Vehicle emissions represent the greatest source of air pollution in Pakistan and reflect the rapid growth in vehicle use. Motor vehicle emissions account for about 90 percent of total emissions of hydrocarbons (smog), aldehydes, and CO. Other emissions include lead, SO_2 (the precursor to acid rain), and nitrogen oxides. Lead can cause mental retardation in young children, whereas, sulfur and nitrogen dioxides lead to acid rain and respiratory diseases.

In Lahore, there are 561,949 vehicles on the roads.[1] A distinctive feature of the provincial capital's vehicle population is two- and three-wheel vehicles (motorcycles and auto rickshaws), which are mostly driven by two-stroke engines and are an increasingly popular mode of transport. A complete breakdown of the vehicle types in the three cities is presented in **Table 2.5.**

The motor fleet in Lahore damages the ambient air quality of the city by discharging noxious gases such as CO, hydrocarbons, oxides of nitrogen, SO_2 and aldehydes. CO concentration in air has been reported at 92 percent; hydrocarbons, 89 percent; nitrogen oxides, 63 percent; SO_2, 50 percent; and aldehydes, 89 percent. Motor exhaust has a small share of 17 percent in the emissions of particulate matter.[2]

Table 2.2: Required Lead Concentration and RON of Motor Gasoline

Motor Gasoline Grade	*Lead Concentration (g/liter maximum)*	*RON Rating*
Regular	0.42	80
Super/Premier	0.63	87
Premier Plus	0.35	87
High Octane Blending Compound (HOBC)	0.84	97

[1] Bureau of Statistics. 1999 *Punjab Development Statistics, 1998* Lahore: Government of the Punjab.

[2] Tariq, M.N., H. Shaukat, and Wali Waheed. 1983 *A Study on Air Pollution in Lahore.* Institute of Public Health Engineering and Research, University of Engineering and Technology, Lahore.

Table 2.3: Sulfur Contents in Industrial and Vehicular Fuels

Fuel	*Sulfur Contents (%)*
Motor Gasoline	0.10 maximum
High Speed Diesel	1.10 maximum
Low Speed Diesel	1.80 maximum
Furnace Fuel Oil	3.50 maximum

Table 2.4: Fuel Consumption in Road Transportation

	Petrol (mtons)	*Diesel (mtons)*	*CNG (hm^3)*
Lahore	315,430	860,275	330,717
Rawalpindi	61,223	300,473	162,648
Islamabad	10,338	17,653	63,897

Source Bureau of Statistics. 1989 *Punjab Development Statistics 1998.* Lahore: Government of the Punjab, Lahore, Oil Companies Advisory Committee 1999 *Pakistan Petroleum Statistics 1998-99*, Sui Northern Gas Pipelines Limited. 1999. *SNGPL Activity Report June 99.*

Table 2.5: Vehicle Category Breakdown in Lahore, Rawalpindi, and Islamabad

	Total	*Motorcars and Jeeps*	*Motorcycles and Scooters*	*Trucks*	*Delivery Vans*	*Buses*	*Taxis*	*Auto Rickshaws*	*Others*
Lahore	561,949	189,756	306,880	4,465	22,119	5,380	1,606	9,615	22,128
Rawalpindi	117,465	41,247	52,995	3,919	8,909	5,889	3,609	721	176
Islamabad	8,894	5,836	1,880	70	626	414	35	–	33

Source Bureau of Statistics 1999 *Punjab Development Statistics, 1998.* Lahore. Government of the Punjab; Excise and Taxation Capital Development Authority, 1998

During a survey conducted by the Punjab Environment Protection Department (EPD) Research Laboratories, it was discovered that 33 percent of vehicles plying the roads in Lahore were discharging smoke. According to actual measurements taken, particulate matter is 4.35-9.8 mg/nm^3; lead, up to 1.16 mg/nm^3; and CO, up to 4.40 parts per million (ppm).[1]

According to the "CO Survey in Lahore," which was conducted by Punjab EPD Research Laboratories in 1993-94, the main sources of CO in the city are two- and three-wheelers driven by two- and four-stoke engines. The CO emission rate is 17 g/passenger-km for two-stroke and

[1] Nasir, K B , M. Khalil, Farah Adeeb. 1993-94. *Annual Progress Report of EPA Research Laboratories.*

20 g/passenger-km for four-stroke engines.[1] CO levels were recorded at the following locations in Lahore, and were found to be well above the threshold limit of 35 ppm set by USEPA:

- Assembly Hall, Mall Road, Lahore
- General Post Office, Mall Road, Lahore
- Lahore City Station
- Office of the Auditor General of Pakistan, Lahore
- Hall Road, Lahore.

In another study, CO, O_3, SO_2, and NO_X emissions were measured in Lahore and Rawalpindi cities.[2] The results are presented in **Table 2.6.**

2.1.4 Local Meteorology and Air Pollution

Area meteorology and topography greatly influence the dispersion pattern of air emissions in relation to number and type of vehicles. Meteorological parameters, such as wind speed, wind direction, humidity, and the temperature differences that exist within an air mass, are the major governing factors. The most important among these is wind speed, which affects the horizontal dispersion efficiency. Wind direction determines the areas affected by the emissions, while vertical temperature variations determine the upward dispersion efficiency.

Another meteorological phenomenon that greatly influences air quality is the 'urban heat island.' The heat generated by a city causes the air above it to rise, drawing in colder and, possibly, more polluted air from surrounding industrial areas. On the other hand, suburban areas of the cities in warm, sunny locations with high traffic densities tend to be especially prone to O_3 formation.

The topography of large cities also influences the manner in which pollutants are transported and dispersed.

In this context, Lahore has a relatively level topography, ie, is a plain area, and its climate is not influenced by any nearby body of water or by mountains. As mentioned earlier, it experiences extremely foggy conditions in winters due to air pollution.

Rawalpindi has variable topography. Its climate is also not influenced by any nearby body of water or by surrounding mountains.

Islamabad has a variable topography and its climate is influenced by nearby bodies of water, such as Simly Dam and Rawal Lake. The surrounding Margalla Hills may also exercise a slight influence.

The presence of significant water bodies can lead to microclimatological effects and to on-shore and offshore diurnal wind patterns. Hills that surround cities often act as a downwind barrier, trapping pollution close to the city. When a city is surrounded by high-mountains, the pollutants may be trapped within the airshed for several days. However, such a situation does not exist in Lahore, Rawalpindi, or Islamabad.

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[1] Asif, Sinha K. and Varma Amiy. 1990. "Automotive Air Pollution – Issues and Options for Developing Countries." *Policy, Research and External Affairs, Working Papers (Transport)*, The World Bank,

[2] Punjab Environmental Protection Department. 1998-99. *Study on Ambient Air Quality in Lahore and Rawalpindi*

Table 2.6: Findings of Punjab EPD's Study of Ambient Air Quality in Lahore and Rawalpindi, 1999 and 1998

Sampling Location	*Ambient Air Quality Parameters (Hourly Maximum Concentrations)*			
	CO (ppm)	*O_3 (ppb)*	*SO_2 (ppb)*	*NO_X (ppb)*
Lahore				
Faisal Chowk	9.2	51	50	300
Canal Crossing, Mall Road	8	27	80	450
Rawalpindi				
Mareer Chowk	5.4	62	14	240
Faizabad Chowk	6 2	30	9	250
Satellite Town	1.2	27	4.5	25
Peshawar Road	4.6	38	27	180
Rawat Village	0.8	31	2	< 20

Buildings and other structures can have a great effect on air dispersion. The 'street canyon effect' occurs when dispersion of low level emissions is prevented by high rise buildings on each side of a busy road.

The wind rose for Lahore given in **Figure 2.2** shows that the most prevalent wind direction is northwest (NW), and that the average wind speed in this direction is 2.177 m/sec. Lahore receives approximately 360 mm of rain per year, mainly in July and August when southeasterly monsoons bring heavy showers. In the remaining months, the NW direction prevails. April to mid-June is the dry season, when strong winds blow and dust storms are a common feature. Meteorological data for Lahore City are presented in **Table 2.7.**

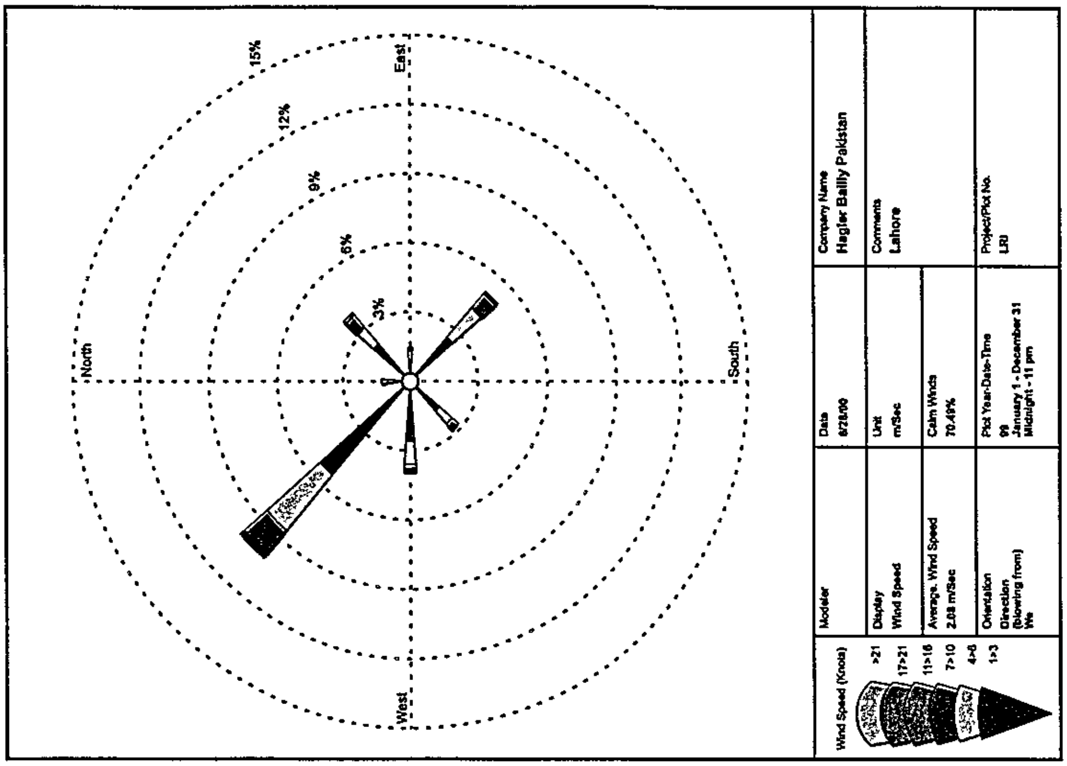
Rawalpindi and Islamabad are sister cities, only 25 km apart, and, therefore, experience more or less the same meteorological conditions. Relevant data are presented in **Table 2.8.**

2.2 The Problem of Wastewater Pollution

2.2.1 Current Wastewater Discharge Practices

The level of emissions of industrial pollutants is growing at a very rapid pace in Pakistan; the associated health and productivity impacts, which are already significant, are worsening. Indiscriminate discharge of industrial wastewater is causing serious environmental problems, among them contamination of groundwater, including the water drawn for drinking; contamination of sea water, affecting aquatic life and drinking water; and contamination of rivers, particularly in areas with low levels of mixing, such as harbors and estuaries.

Figure 2.2: Wind Roses for Lahore and Islamabad



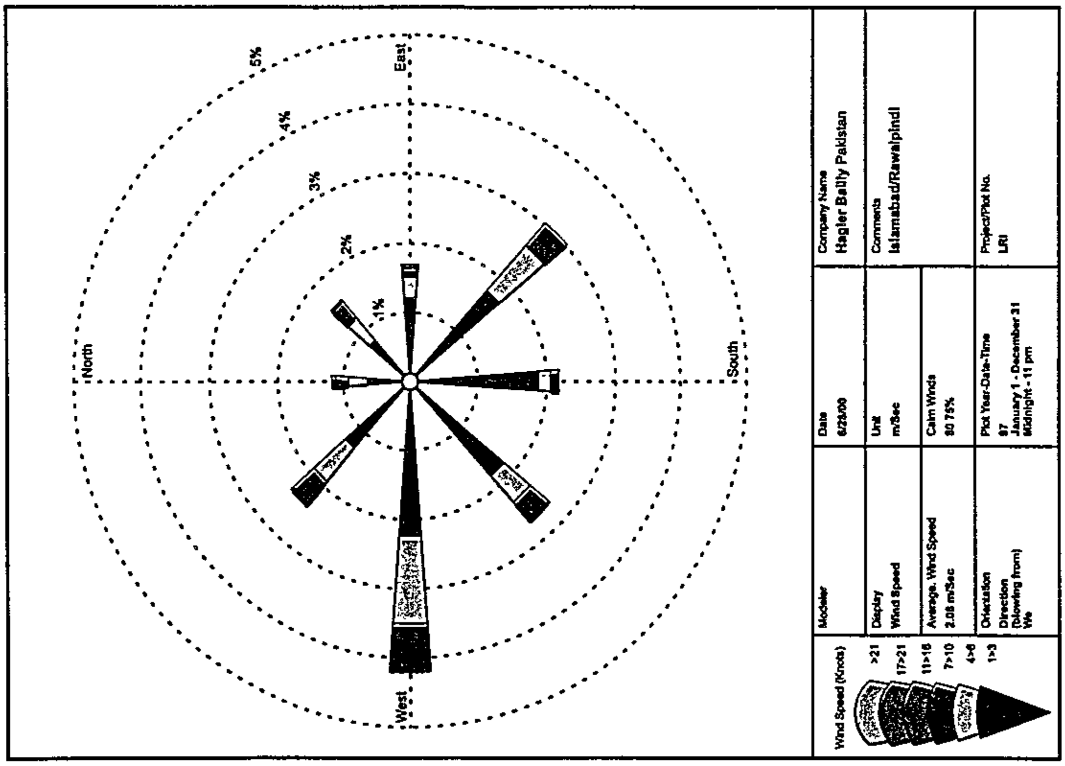


Table 2.7: Meteorological Data for Lahore

(Station: Lahore Airport; Period: 30 years)

Month	*Temperature (°C)*				*Rainfall (mm)*		*Mean Wind*			*Humidity (%)*	
			Mean Daily Extremes					*Direction*			
	Max.	*Min.*	*Max*	*Min.*	*Mean Total*	*Max. in 24 hours*	*Speed (m/sec)*	*0300*	*1200*	*0300 GMT*	*1200 GMT*
January	23.1	9 8	13.3	1.8	15.3	38.4	1.39	340	304	86	49
February	26.6	13.0	16.0	3.8	21.3	72.2	1.96	329	326	78	44
March	32.2	18.6	20.1	8.0	25 3	95.0	2.21	334	333	70	40
April	39.9	24.3	25.7	13.2	11.8	41.4	2.57	346	327	54	29
May	43.4	28.5	30.8	18.1	17.4	64.0	2.52	78	301	43	24
June	45.0	31.2	31.8	21.4	22 3	69.3	3 09	112	154	52	31
July	41 2	30.5	28.0	21.7	120.9	332.5	3.04	99	93	74	57
August	38.3	29.1	28.7	22 2	87.4	20 6	2.26	97	84	81	64
September	37.7	27.2	29.0	19.9	28 7	85.0	1 60	85	333	74	51
October	35.7	21.8	27.1	13.4	15.2	157.0	1.18	28	356	70	40
November	30.6	15 4	21 5	6.2	3.0	21.5	1.03	308	325	79	46
December	24.8	10.9	15.6	2.2	10.4	41.7	0.88	359	321	86	53

Source: Pakistan Meteorological Department, 1999

Table 2.8: Meteorological Data for Rawalpindi and Islamabad

(Station: Islamabad; Period: 30 years)

Month	*Temperature (°C)*				*Rainfall (mm)*		*Mean Wind*			*Humidity (%)*	
		Mean Daily Extremes			*Mean Total*	*Max. in 24 hours*	*Speed (m/sec)*	*Direction*		*0300 GMT*	*1200 GMT*
	Max	*Min.*	*Max.*	*Min*				*0300*	*1200*		
January	22 4	7.8	11.2	–0 7	34.2	62 5	0.72	170	284	85	42
February	24.7	10.4	11.6	0 9	43.3	78.7	1.18	81	289	83	41
March	30.3	15.5	15.3	4.6	54.3	63.5	1.39	22	296	75	38
Apnl	36.6	21.0	21.0	9.7	40.0	84 8	1..23	318	307	61	31
May	40.9	25.7	25 9	14.4	28.8	65.5	1.60	41	273	45	23
June	43 5	29.7	31.8	18.6	52.1	113.1	1.54	129	174	46	26
July	40 9	29.4	28.1	20.1	208.8	153.1	1.13	124	164	71	50
August	37.6	27.5	27.2	19.5	230.2	181 3	0.72	107	162	81	59
September	36.4	24.6	27.6	15.9	69.3	120 0	0.57	294	210	75	47
October	34.4	18.8	24.1	9.5	22.2	55.9	0.41	90	282	73	37
November	29.4	13.1	18.9	2.9	10.8	79.7	0 31	250	280	80	40
December	24.0	8.4	13.0	–0 2	24.7	50.8	0.36	225	292	85	45

Source: Pakistan Meteorological Department

Wastewater is disposed of in several ways. Generally, it is dumped into open drains, streams or ponds, shallow pits, or septic tanks connected to open drains that may lead directly to agricultural land; less often, it is dumped into sewers. Household refuse is also dumped into streams and drains, which, over time, have become overloaded. Direct disposal of municipal wastewater into streams reduces groundwater quality, disturbs the aquatic ecosystems, depletes aquatic resources, and affects agricultural uses of the surface water.

In Islamabad, a 22,730-m^3/day activated sludge plant was constructed in 1962 for the treatment of municipal wastewater. Important operational parameters, such as sludge age and return sludge values, were neither monitored nor reported regularly. As a result, sludge bulking problems started arising frequently soon after the plant's commissioning, indicating inadequate aeration.

Until recently, Lahore city sewage that had received only primary treatment and was routinely pumped into the River Ravi. After years of experimentation with low-cost facultative and maturation ponds, the Institute of Public Health Engineering has recommended the use of such ponds at six different locations around the city. Performance of the pilot facultative ponds was satisfactory, suggesting that a full-scale plant will successfully address the problem.

2.2.2 Water Quality in River Ravi

In Sheikhupura, industrial wastewater is mainly discharged into Barian Wala, a drain that normally flows at 105,203 cubic meters per day and outfalls into Chicho ki Malian, another drain that flows into River Ravi along with Deg Nullah.

According to a study conducted by Punjab EPD in 1993-94, industrial units located in the vicinity of Barian Wala are generating approximately 53,825 cubic meters per day of wastewater. The BOD_5 of wastewater originating from these industries ranges from 225 mg/l to 2,590 mg/l. Pollutant loadings (BOD_5) of Barian Wala were calculated before and after the wastewater addition into the drain: they were 37 tons/day and 1,910 tons/day, respectively.[1]

According to another study conducted in 1995, the drain is receiving liquid effluents from 14 industries at a rate of 88,077 cubic meters per day.[2] The majority of industry located in the vicinity of this drain comprises pulp and paper mills. A characterization of effluents from these units is shown in **Table 2.9.**

Other studies[3] found that the city of Lahore discharges 963,772 cubic meters per day of sewage into the River Ravi from its six disposal stations. The pollutant loading of sewage, in terms of BOD_5, was estimated at 200-250 tons/day. The Hudiara drain, flowing to the south of the city, receives wastewater from the industrial units located on the southern side. The BOD loading of this drain was reported at up to 30 tons/day; it outfalls into River Ravi 40 km away from Lahore.

2.2.3 Water Quality in Islamabad and Rawalpindi

The Leh catchment area lies in the cities and suburbs of Islamabad and Rawalpindi between 33° 00′ and 34° 00′ north and 72° 45′ and 73° 30′ east. Four small streams—Saidpur, Kanitanwali,

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[1] Nasir, K.B., M Khalil, Farah Adeeb 1993-94. *Annual Progress Report of EPA Research Laboratories.*

[2] Ahmad, Khurshid 1995 *Pollution of Bananwala Drain and Control Measures* Institute of Environmental Engineering and Research, University of Engineering and Technology, Lahore

[3] Nasir, K.B., M. Khalil, Farah Adeeb 1993-94. *Annual Progress Report of EPA Research Laboratories.*

Tenawali, and Bedranwali Kas—rise in the Margalla Hills, cross Islamabad, and converge to a junction upstream of Khayban e Sir Syed to constitute the main Leh. Another tributary, known as Nikki Leh, joins it from the west about 3.2 km downstream of the above confluence. About 20 other streams draining the city join it from both sides. Finally, it falls into River Soan after crossing the G T Road, where it approaches Rawalpindi.

Leh Nullah receives about 0.18 million cubic meter of partially treated wastewater and 0.29 million cubic meter of untreated wastewater per day. Potable water samples were collected along the Leh during a study:[1] 90 percent of the samples were found to be contaminated with coliforms and were unfit for human consumption. Samples collected from open groundwater wells along the Leh were invariably reported to contain coliforms.

Cadmium and lead levels were measured in soil and water samples collected from the Rawalpindi and Islamabad areas. The levels were lower in rural soil samples than those in samples from busy urban areas. **Table 2.10** presents laboratory results of soil and sludge samples.

Table 2.9: Industrial Wastewater Characterization

Parameter	*Unit*	*Value*
pH	No.	7.0-7.8
Total Solids	mg/liter	834-2,918
Suspended Solids	mg/liter	118-1,096
Total Dissolved Solids	mg/liter	708-2,193
Biochemical Oxygen Demand	mg/liter	964-2,000
Chemical Oxygen Demand	mg/liter	1, 755-3,494

Table 2.10: Cadmium and Lead Levels in Soil and Sludge Samples

Sample	*Sample Location*	*Cadmium (µg/g)*	*Lead (µg/g)*
S1	Rural Area	0.11± 0.01	21.4±1.5
S2	Busy Road	0.21±0.02	172.5±7.2
S3	Industrial Area	0.36±0.03	650.5±12.7
S4	City Center	0.55±0.02	85.7±3.5
S5	Sewage Sludge, Islamabad	0.45±0.03	36.5±1.6
S6	Sewage Sludge, Islamabad	0.48±0.06	38.9±2 1

Source Riaz Ahmad 1998. *Impact of Environmental Pollution in Rawalpindi-Islamabad.* 24th WEDC Conference, Islamabad

[1] Dr. Amir Haider Malik 1998. *Sustainable Groundwater Exploitation of the Leh Basin*, 24th WEDC Conference, Islamabad.

Simly Dam is the main reservoir for the water supplied to the residents of Islamabad. Residents of Rawalpindi are supplied from Rawal Dam. Both these reservoirs are located in the Islamabad area. The levels of cadmium in surface water samples from the reservoirs were lower than in groundwater samples. This is because surface waters have low mineral contents. However, the lead concentration in surface water samples was higher than groundwater samples, which is due to absorption of excessive lead in the atmospheric air. **Table 2.11** presents the cadmium and lead concentrations in surface water samples. Cadmium and lead concentrations in ground water samples are given in **Table 2.12.**

2.3 The Need for This Study

Data on ambient air and wastewater quality have been collected previously by various agencies. However, these are ambiguous on some counts and do not fully explain the behavior of certain parameters, such as CO, nitrogen oxides, SO_2, particulates, BOD, COD, and total nitrogen. These deficiencies can largely be attributed to shortcomings in the following areas:

- Identification of proper sampling and monitoring sites by air quality experts
- Calibration of monitoring instruments
- Correct installation of monitoring stations
- Monitoring of support data, such as traffic count, humidity, temperature, wind speed, wind direction, and composition of fuel being used in vehicles and industry
- Development of wastewater sampling plan with clear objectives
- Recording of spot testing information for wastewater samples.

These prerequisites were met in this study to present reliable and unambiguous data.

Table 2.11: Cadmium and Lead Levels in Surface Water Samples

Sample	*Sample Location*	*Cadmium (µg/g)*	*Lead (µg/g)*
R1	Simly Dam	0.01±0.001	3.43
R2	Simly Dam Inlet	0.014±0.001	3.85±0.72
R3	Simly Dam Outlet	-	4.05±0.22
R4	Sawan River	0.11±0.01	3.35±0.45
R7	Rawal Dam	-	5.07±0.06

Source Riaz Ahmad 1998 *Impact of Environmental Pollution in Rawalpindi-Islamabad* 24th WEDC Conference, Islamabad.

Table 2.12: Cadmium and Lead Levels in Groundwater Samples

Sample	Sample Location	*Cadmium (µg/g)*	*Lead , (µg/g)*
G1	Thanda Pani (well)	0.16±0.01	1.25±0 02
G2	Jhang Sydan (well)	0 13±0.01	1.65±0.11
G3	Alipur Frash (well)	0.1±0.05	0.66 ±0 12
G4	Tarli (well)	0 07±0 01	0.85±0.04
G5	Khanna (well)	0.06±0.001	4 1±0.05
G6	Rawal Dam Simble (well)	0.21±0 02	4.53±0.09
G7	Chirah Well (well)	0.11±0.01	0.86±0.03

Source Riaz Ahmad, Impact of Environmental Pollution in Rawalpindi-Islamabad, 24th WEDC Conference, Islamabad, 1998

3. Study Methodology

This section describes the methodology that was adopted to meet the study objectives. Broadly, the tasks undertaken included:

- Development of a sampling and spot testing plan for wastewater and ambient air quality monitoring in Lahore, Rawalpindi, and Islamabad
- Team organization for field sampling, spot testing, and laboratory testing
- Discussions and meetings with representatives of concerned agencies to finalize the implementation plan for ambient air and wastewater sampling and spot testing
- Identification of sampling sites in the three cities for ambient air and wastewater quality monitoring
- Implementation of quality control and assurance protocols during sampling, spot testing, sample handling, transportation, and laboratory testing.

3.1 Sampling Plan

Prior to field sampling and testing, a sampling plan for ambient air and wastewater quality monitoring in Lahore, Rawalpindi, and Islamabad was developed in collaboration with an environmental expert from JICA. It was decided that 40 wastewater samples would be collected and analyzed from the three cities. **Table 3.1** and **Table 3.2** present details of the samples collected from various locations in the three cities.

In addition, the sampling plan included collection of four duplicate wastewater samples for quality control and assurance during testing. These samples were analyzed at the PCSIR and Institute of Environmental Sciences and Engineering (IESE) laboratories. Ten locations were identified in the three cities for ambient air quality monitoring. Details of the sampling sites and parameters identified for testing are presented in **Table 3.3**.

3.2 Team Organization

Wastewater sampling and spot testing activities were scheduled to be completed within a stipulated period of 10 days. To achieve this target, two teams were organized to undertake sampling and spot testing in the three cities simultaneously. Each team comprised a field chemist and a field assistant. One team was deployed in Lahore and the other in Rawalpindi and Islamabad. Each collected 20 wastewater samples from 20 identified sites.

Hourly traffic counts were conducted at each station by two traffic teams from HBP in conjunction with Punjab EPD's mobile station team. The study required 16-hour traffic count data for each location. Both diesel engine vehicles and petrol engine vehicles were counted by two teams working 8-hour shifts.

Two field chemists at the HBP laboratory in Islamabad tested the wastewater samples collected from the three cities. Dissolved metal testing was conducted at Geoscience Laboratory, Islamabad. **Table 3.4** gives a brief profile of the members of the four field teams.

Table 3.1: Wastewater Sampling and Testing Plan in Lahore

	Sampling Location	Spot Testing								Laborat5ry Testing											
		pH	DO	Conductivity	Color	Odor	Turbidity	Temperature	Flow	BOD	COD	TSS	O&G	Total-N	E-Coli	Pb	Cr	Zn	As	Cd	Cu
1	River Ravi BRB Ravi Syphon (along the bank)	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
2	River Bara Dari near Boat Station	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
3	River 200 m D/S of Badu Sabu Outfall	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
4	River 1 km D/S of Hudiara Drain	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
5	River 200 m U/S of Balloki Headworks	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
6	New Shadbag Sewage Drain, Bund Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
7	Main Outfall Drain, Bund Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
8	Babu Sabu Drain, Bund Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
9	Hudiara Drain, Multan Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
10	Bhed Nullah, Sheikhupura Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
11	Deg Nullah, Sheikhupura Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
12	Chotti Deg (Nullah), Sheikhupura Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
13	Chichokimallian Drain, Sheikhupura Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
14	Barian drain, 1 km off Sheikhupura Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
15	Sattokatla Drain, Defence Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
16	Hudiara Drain, Ferozepur Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
17	Hudiara Drain-River Ravi Junction at Khurdpur	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
18	Nullah Deg before entering River Ravi	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
19	Samundari Drain before entering River Ravi	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
20	Hudiara Drain after entering Pakistan	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						

Table 3.2: Wastewater Sampling and Testing Plan in Rawalpindi/Islamabad

	Sampling Location	Spot Testing								Laboratory Testing											
		pH	DO	Conductivity	Color	Odor	Turbidity	Temperatur	Flow	BOD	COD	TSS	O&G	Total-N	E-Coli	Pb	Cr	Zn	As	Cd	Cu
1	F 8/2 before Fatima Jinnah Park, near Street 24A	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
2	E 8 near Navy House, Karakoram Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
3	F 6/2 near Alkhizar Mosque, Margalla Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
4	F 5/2 near Azad Jammu Kashmir Secretariat	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
5	Near American Embassy	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
6	Peshawar Road (near Motorway Signpost)	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
7	I 10 Pirwadhai Crossing, Nullah 1	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
8	I 10 Pirwadhai Crossing, Nullah 2	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
9	I 10 Pirwadhai Crossing, 200 m after joining Nullah 1&2	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
10	Chattar Park 200 m D/S after joining 2 streams	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
11	Guwalmondi Bridge near Taj Company	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
12	Airport Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
13	River Soan Bridge near High Court Building Rawalpindi	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
14	300 m d/s of Soan Bridge, after Nullah Leh joins the Soan River	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
15	Leh before joining Soan near High Court Building Rawalpindi	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
16	Stream Islamabad Highway-Railway Crossing (Nullah Kura)	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
17	Stream Water Korang Nullah Lehtrar Road	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
18	Nullah Leh at Gulistan Colony Line 1	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
19	Rawal Dam outlet before entering Filtration Plant	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						
20	E 7 Hill side road opposite Street: 16	•	•	•	•	•	•	•	•	▲	▲	▲	▲	▲	▲						

• Spot Testing ▲ Laboratory Testing

Table 3.3: Ambient Air Sampling and Testing Plan

S.No	Sampling Location	*Field Testing by Mobile Unit*							*Field Testing Using Detector Tubes*						*Laboratory Testing*					
		SO_2	*NO_X*	*NOx*	*CO*	*SPM*	*PM_{10}*	*O_3*	*SO_2*	*NO_2+NO*	*CO*	*NH_3*	*Benzene*	*HC* (Toulene)*	*Pb*	*Cu*	*Zn*	*As*	*Cd*	*Cr*
Lahore																				
1	Chowk Yateem Khana, Multan Road	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
2	Azadi Chowk, G. T. Road	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
3	Chowk Lohari Gate, Circular Road	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
4	Bank Square, Shahrah-e-Quaid-e-Azam	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
5	Qurtaba Chowk, Mozang Chongi	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
Rawalpindi																				
1	Committee Chowk, Murree Road	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
2	Fountain Crossing, Raja Bazar	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
3	Chowk Pir Wadhai, Khayaban-e-Sir Syed	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
Islamabad																				
1	Aabpara Chowk	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		
2	I-9 Chowk, near Police Station	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	▲	▲	▲		

● Field Testing ▲ Laboratory Testing * HC: Hydrocarbons

Table 3.4: Project Team and Responsibilities

Name	*Position*	*Qualifications*	*Task*	*City*
Vaqar Zakaria	Project Advisor	MSc, Chemical Engineering	Project Advisor	
Qaiser Aijaz	Senior Manager	BSc, Chemical Engineering	Project Coordinator	
Irshad Ahmad Khan	Team Leader	PhD, Environmental Pollution Studies	Overall supervision and coordination with JICA, Pak-EPA, and Punjab EPD	Lahore/Rawalpindi/Islamabad
Aqib Salam	Field Coordinator	BE (Civil) and MBA	Field coordination	Lahore
Aamir Khurshid	Field Chemist	MSc, Chemistry	Wastewater sampling and spot testing	Lahore
Ahmad Zia	Field Assistant	MSc, Chemistry	Wastewater sampling and spot testing	Lahore
Asif Mahmood	Chemical Analyst	BSc, Chemistry	Laboratory testing and analysis	Islamabad
Naveed Alam	Chemical Analyst	MSc, Chemistry	Laboratory testing and analysis	Islamabad
Ghulam Sarwar	Field Chemist	MSc, Chemistry	Wastewater sampling and spot testing	Rawalpindi/Islamabad
Aamir Jamal	Field Assistant	BSc, Chemistry	Wastewater sampling and spot testing	Rawalpindi/Islamabad
Sajid Mahmood	Traffic Count Assistant	BSc, Chemistry	Traffic count	Lahore/Rawalpindi/Islamabad
Mohammed Zahid	Traffic Count Assistant	BSc/BA	Traffic count	Lahore/Rawalpindi/Islamabad
Niaz Mohammed	Traffic Count Assistant	BSc/BA	Traffic count	Lahore/Rawalpindi/Islamabad
Mohammed Tufail	Traffic Count Assistant	SSC	Traffic count	Lahore/Rawalpindi/Islamabad

3.3 Discussions and Meetings

Discussions and meetings were held with JICA's environmental expert, Punjab EPD, and Pak-EPA to finalize the wastewater sampling, spot testing, and ambient air quality monitoring plan. These discussions covered the following issues:

- Availability of the Punjab EPD Mobile station for ambient air quality monitoring in Lahore, Rawalpindi, and Islamabad
- Availability of Punjab EPD staff for identification of sampling sites
- Availability of field measurement equipment for spot testing
- Identification of laboratories for duplicate sampling
- Finalization of test methods and procedures for laboratory testing
- Availability of Geoscience Laboratory facilities for heavy metal testing.

3.4 Identification of Sampling Sites

JICA's environmental expert carried out a preliminary monitoring survey of the potential network of sampling sites in the three cities before the study was initiated. The following section presents a brief discussion on the sampling sites that were selected for ambient air and wastewater quality monitoring.

3.4.1 Sampling Sites for Wastewater Quality Monitoring

Sampling sites for wastewater quality monitoring in Lahore were selected to assess the water quality of Ravi River. The water quality of the river was checked at various locations between Bumbanwala Ravi Badian (BRB), the Link Canal Crossing at Siphon, and Balloki Headworks, along the main river as well as all the tributaries.

The sampling sites in Rawalpindi and Islamabad were selected to assess the water quality of natural streams originating from the Margalla hills; domestic and industrial wastewater receiving bodies, such as Nullah Leh; Rawal Lake; and Sawan River. Sampling sites for Lahore are listed in **Figure 3.1**, while **Figure 3.2** lists sampling sites in Rawalpindi and Islamabad.

3.4.2 Sampling Sites for Ambient Air Quality Monitoring

Air pollution problems of large cities differ greatly and are generally influenced by a number of factors, including topography, population, meteorology, and rate of industrialization and socioeconomic development. The relative contributions of mobile and stationary sources to air pollution vary from city to city and depend largely on the level of motorization, number of vehicles, vehicle age, and type of local industry. These points were taken into account while selecting sites for ambient air quality monitoring.

A two-day visit to Lahore was planned by Mr. Yoshihiro Shigeta, the JICA expert on environmental protection, to select five sites for representative ambient air quality monitoring in consultation with the staff of Punjab EPD. Sites were selected so as to cover:

- Roads with light and heavy traffic
- Roads with a heavy load of light traffic
- Roads with a heavy load of heavy traffic.

Figure 3.1: BOD Loading at Wastewater Sampling Sites in Lahore

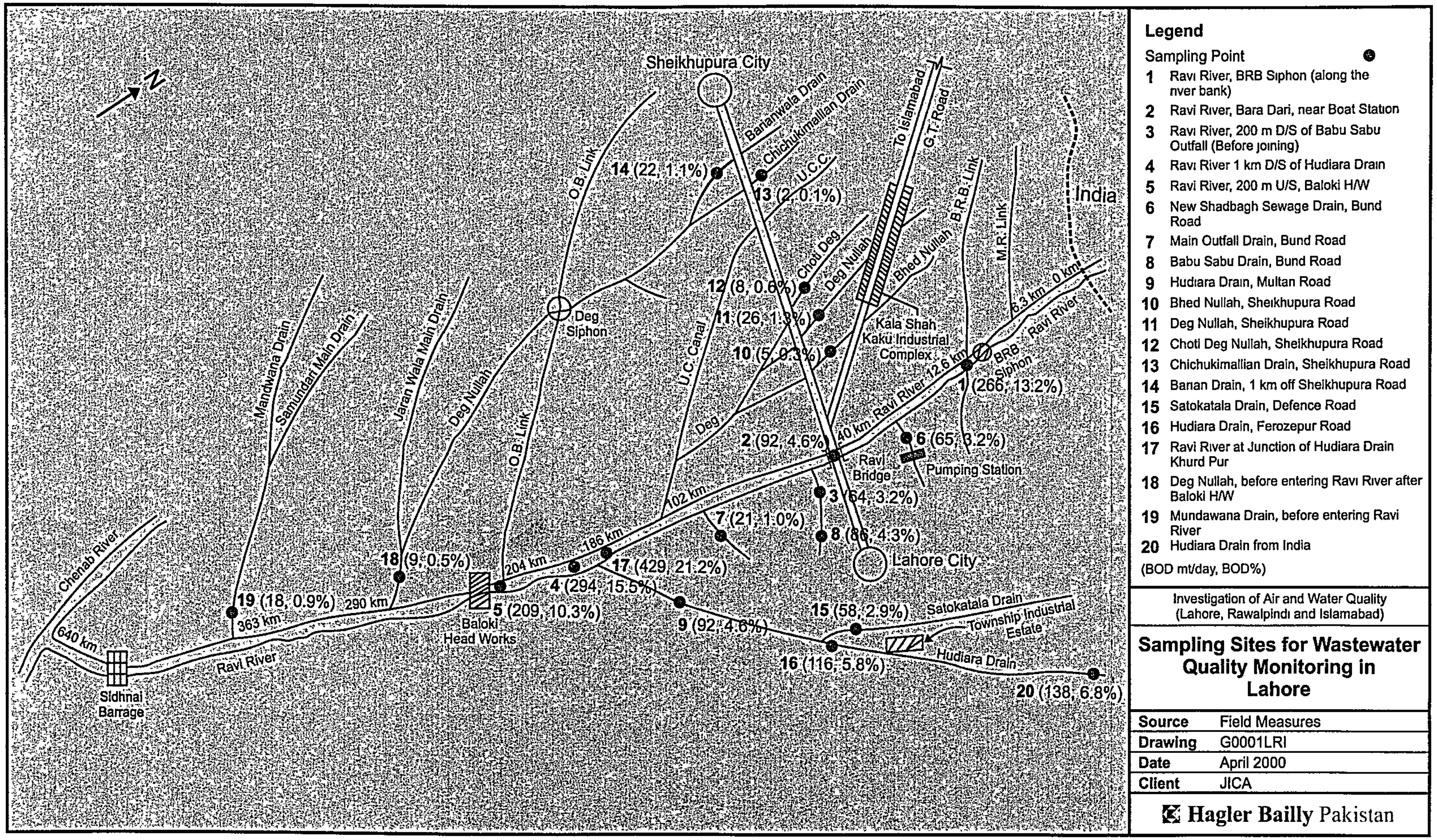
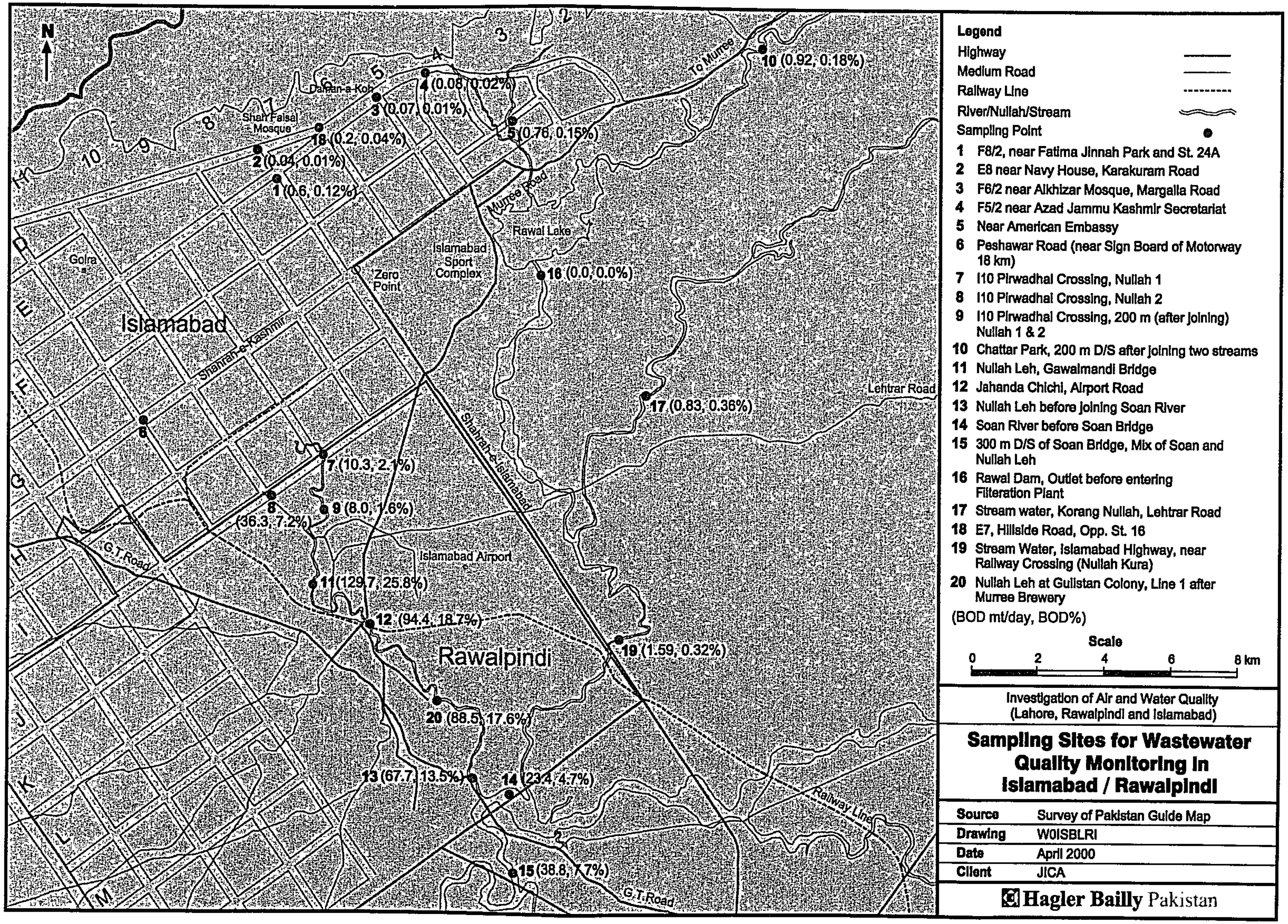


Figure 3.2: BOD Loading at Wastewater Sampling Sites in Rawalpindi/Islamabad



The installation of ambient air monitoring stations at selected sites is vital in the collection of representative data. These stations were installed in consultation with JICA experts, keeping in view the 24-hour wind direction pattern at the sites.

The sites selected for ambient air quality monitoring in the three cities are presented in **Figure 3.3** and **Figure 3.4**.

3.5 Quality Control and Assurance

HBP's Environmental Monitoring Laboratory and Punjab, Environmental Protection Department, Laboratory follow methods and procedures prescribed by USEPA, American Public Health Association (APHA), and American Society of Testing Materials (ASTM) for wastewater testing and analysis. To ensure quality control and assurance throughout spot and laboratory testing, the following steps were taken:

- USEPA procedures were followed for sampling wastewater
- Duplicate samples were collected and tested at PCSIR and IESE laboratories
- Field and laboratory instruments were calibrated according to manufacturers' instructions prior to testing and measurements
- Laboratory testing was conducted by competent and experienced staff who ensured precision and accuracy at all stages, from receipt of samples to reporting of results
- To validate the testing of total nitrogen, standard solutions of known concentration were analyzed
- Quality control charts were prepared for BOD and COD testing and analysis. Samples of different known concentrations were checked to observe the percentage variation from the standard (Control charts for BOD_5 and COD are presented in **Figure 3.5** and **Figure 3.6**).
- To maintain confidentiality of sample origin, all samples were given identification numbers before they were sent to different laboratories.

3.6 Quality Control Charts

Control charts are used to gage the quality of test performed for various parameters at the laboratory. A brief description of BOD and COD control charts is presented below:

BOD_5 Test Quality Control Chart: For BOD_5, test performance quality, the USEPA defines upper working limit (UWL) and lower working limit (LWL) as ± 15%. To maintain better test quality performance HBP tries to remain within upper and lower working limits as defined by USEPA. For this purpose HBP follows upper control limit (UCL) and lower control limit (LCL), which are set at ±10%.

At HBP laboratory, four water samples of known BOD concentration were prepared and analyzed to check percentage deviation from known values. The results of four samples were plotted on QC charts, as shown in Figure 3.5. BOD values of three water samples are within control limits, whereas result of only one sample falls between lower control limit (HBP) and lower working limit (USEPA). However, none of water samples crosses upper control or working limits.

Figure 3.3: Ambient Air Quality Monitoring Sites in Lahore

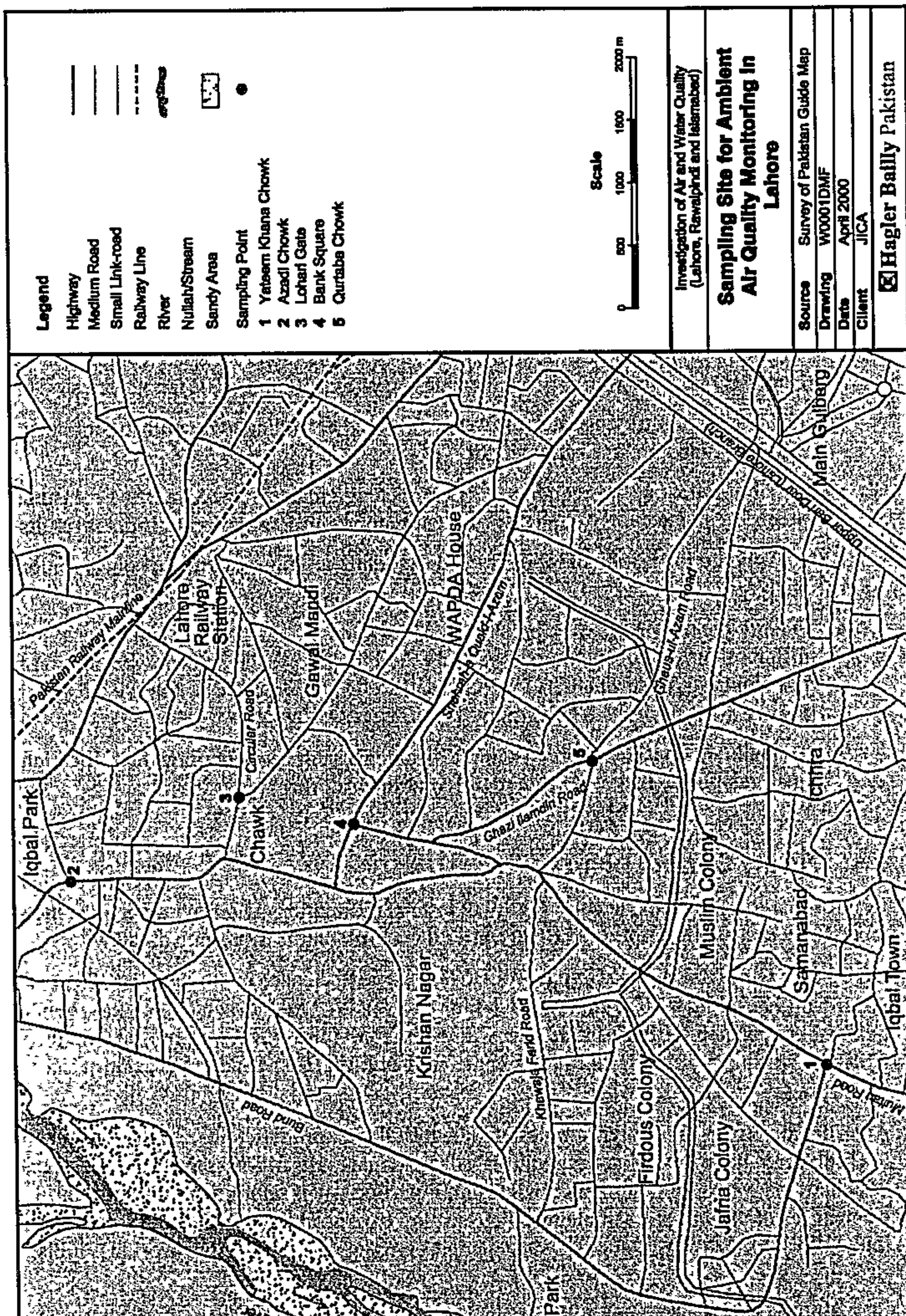


Figure 3.4: Ambient Air Quality Sites in Rawalpindi/Islamabad

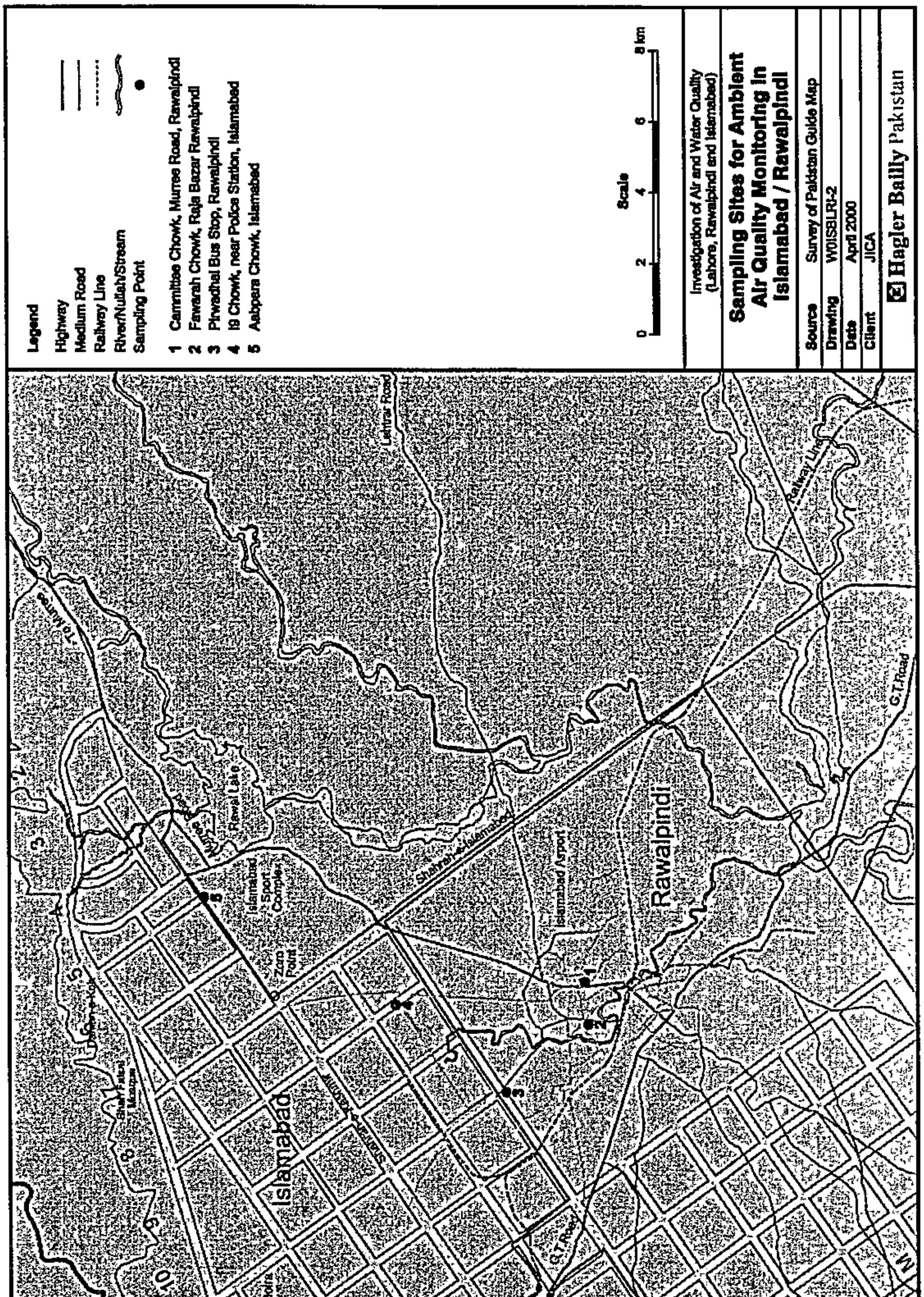


Figure 3.5: BOD Test Quality Control Chart (Upper, Lower Control, and Warning Limits)

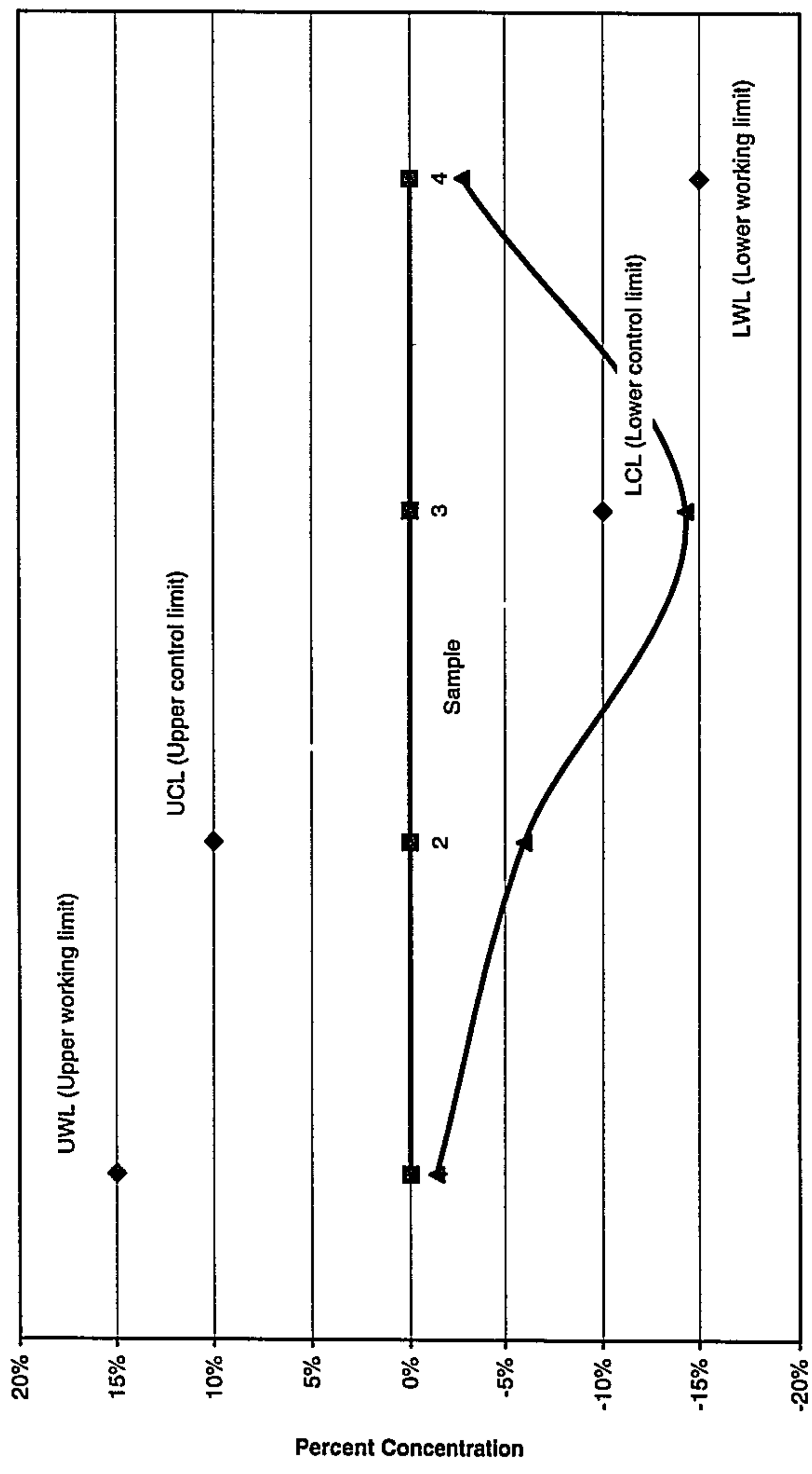
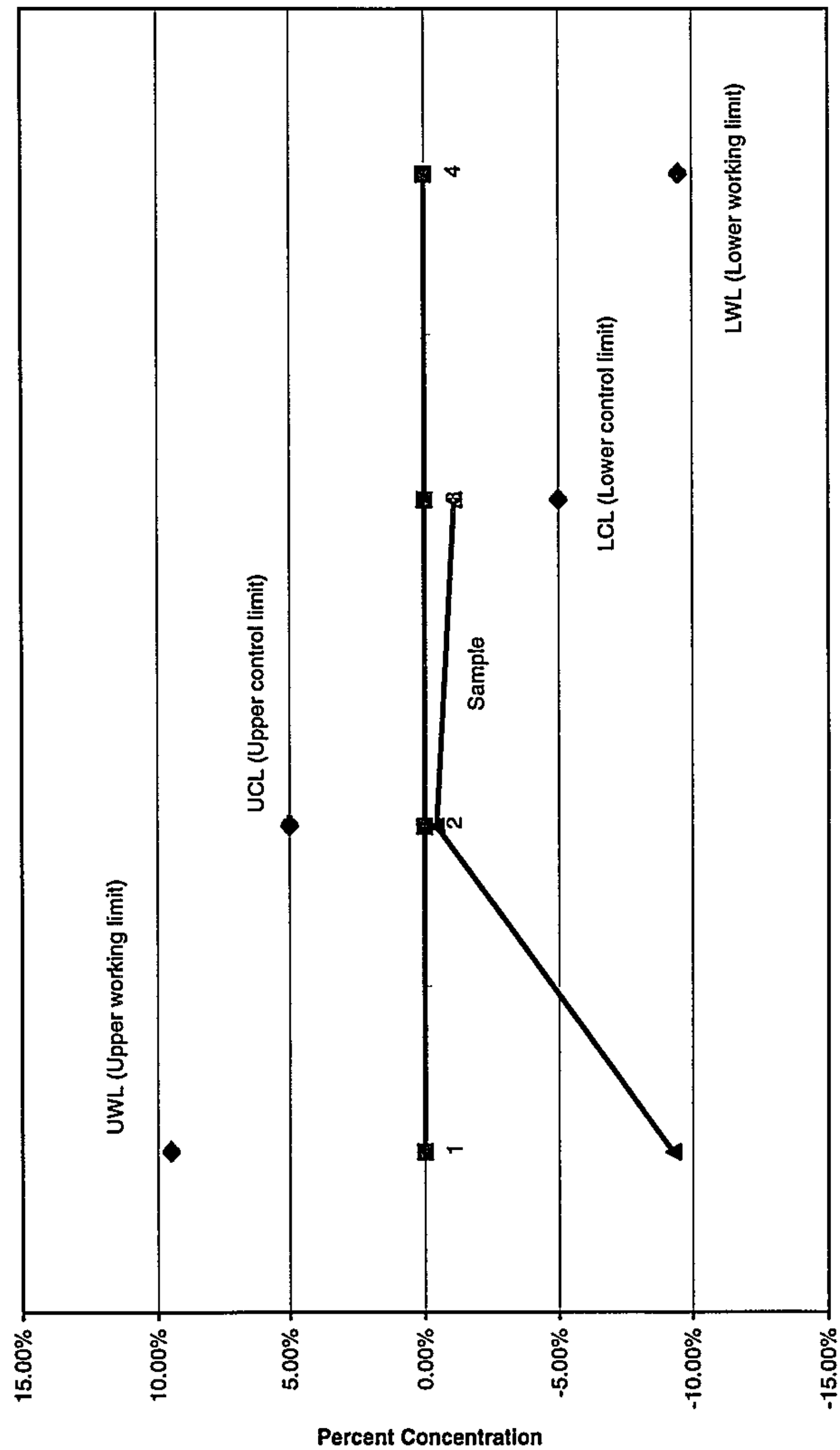


Figure 3.6: COD Test Quality Control Chart (Upper, Lower Control, and Warning Limits)



COD Test Quality Control Chart: For COD, test performance quality, the USEPA defines upper working limit (UWL) and lower working limit (LWL) as ± 10%. HBP follows upper and lower control limits, which are set at ±5%.

At HBP laboratory, three water samples of known COD concentration were prepared and analyzed to check percentage deviation from known values. The results of four samples were plotted on QC charts, as shown in Figure 3.6. COD values of two water samples are within control limits, whereas result of only one sample falls between lower control limit (HBP) and lower working limit (USEPA). However, none of water samples crossed upper control or working limits.

3.6.1 Sampling Procedures

Standard sampling procedures were followed at each site to ensure the integrity of the samples collected and validity of test results.

Prior to sampling and laboratory testing, discussions were held with JICA's environmental expert, and representatives of Pakistan EPA and Punjab EPD sampling, sample handling, transportation, and transfer procedures, including collection of representative samples, use of appropriate clean containers, preservation, identification, and transportation of the samples.

The sampling procedures followed by HBP teams throughout field testing are briefly outlined below:

- The wastewater sampling and spot testing teams were given complete instructions on the importance and significance of correct sampling procedures. Polyethylene bottles were used to collect wastewater samples. For E-Coli sampling, sterilized glass containers were used.
- Manual sampling procedures were adopted for the collection of wastewater samples. In accordance with the standard manual sampling procedure, a surface sampler consisting of a plastic household bucket tied to a rope was used for sampling wastewater from rivers, lakes, and deep streams. Wide-mouthed glass bottles were used for shallow streams and drains.
- Samples from rivers, lakes, channels and natural streams were collected at locations where the water was well mixed, homogenized, and flowing. Samples were collected from the middle of the channels or natural streams, and at 40 to 60 percent depth where the velocity of the flow was average or higher than average and there were minimum chances of solid settling.
- Composite sampling was carried out at two locations by collecting a series of 500-ml samples on an hourly basis for 16 hours and combining them to form a composite sample.
- The concentration of the sample constituents starts changing from the moment a sample is collected and continues to do so till it is analyzed. As a general rule, it is best to analyze the sample as soon as possible after collection. Samples were preserved in an ice-box at or near 4°C immediately after collection.
- Nitric acid (HNO_3) was added to the sampling bottles in quantities sufficient to lower the pH of the samples to just about 2, to stabilize the concentration of total and dissolved metals for a maximum of 28 days.
- Standard sample transfer procedures were followed to avoid confusion in sample identification, including labeling, identification, and safe transportation to the HBP laboratory, Geoscience laboratory, Excel Labs, and PCSIR laboratories.

- Sampling bottles were given identification numbers immediately after the samples were collected. A custody transfer record, containing the following information, was attached to the sampling bottle:
    - Sample identification
    - Sample origin
    - Sample date and time
    - Sample type (composite or grab)
    - Sampling conditions (source, site, temperature, pH and flow)
    - Sample preservation (for dissolved metals, biochemical oxygen demand, and total suspended solids)
    - Analysis required
    - Sample shipping time
    - Sample integrity (sealed, leaks, tagged, iced)
    - Sampler name.
- All wastewater samples collected from Lahore were transported to the HBP Laboratory by Daewoo Cargo Service buses, which run between Lahore and Rawalpindi after every hour. Through this service, all samples were sent to HBP laboratory on time (in less than 12 hours) and in good condition.

Detailed information on these sampling procedures is presented in **Table 3.5.**

3.6.2 Spot Test Methods and Procedures

Certain physical and chemical properties of wastewater, such as color, odor, pH, temperature, conductivity, and dissolved oxygen, tend to change significantly with time and, therefore, require on-site testing. Portable equipment was used for *in situ* testing of the following parameters:

- Temperature
- pH
- Dissolved oxygen
- Color
- Odor
- Conductivity.

Portable equipment used in this study was checked and calibrated for accuracy and precision of the field results. A brief description of the calibration procedures for field equipment is presented below.

Temperature

Temperature measurements were made with a high-caliber mercury thermometer. The thermometers used for field measurements were calibrated against a standard thermometer. Thermometers were calibrated for total immersion.

Table 3.5: Required Containers, Preservation Techniques, and Preserving Times

	Parameter	*Containers*[a]	*Preservation*[b] *and Transportation*[e]	*Maximum Holding Time*[c]
1.	Ammonia	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
2.	Biochemical oxygen demand	P, G	Cool, 4°C	48 hours
3.	Chemical oxygen demand	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
4.	Chloride	P, G	None required	28 days
5.	Chlorine	P, G	None required	Analyze immediately
6.	Cyanide	P, G	Cool, 4°C NaOH to pH >12 0.6g ascorbic acid	14 days
7.	Fluoride	P	None required	28 days
8.	Hydrogen ion (pH)	P, G	None required	Analyze immediately
9.	Chromium VI	P, G	Cool, 4°C	24 hours
10.	Mercury	P, G	HNO_3 to pH <2	28 days
11.	Oil and grease	G	Cool, 4°C H_2SO_4 to pH<2	28 days
12.	Phenols	G only	Cool, 4°C H_2SO_4 to pH<2	28 days
13.	Residue, Filterable	P, G	Cool, 4°C	7 days
14.	Residue, Non-filterable (TSS)	P, G	Cool, 4°C	7 days
15.	Residue, settleable	P, G	Cool, 4°C	48 hours
16.	Sulfate	P, G	Cool, 4°C	28 days
17.	Sulfide	P, G	Cool, 4°C, add zinc acetate plus sodium hydroxide to pH>9	7 days
18.	Surfactants	P, G	Cool, 4°C	48 hours
19.	Temperature	P, G	None required	Analyze immediately
20.	Phenols	G, Teflon lined cap	Cool, 4°C 0.008% $Na_2S_2O_3$	7 days before extraction, 40 days after extraction
21.	Metals	P, G	HNO_3 to pH<2	6 months[d]

Notes:

a. Polyethylene (P) or Glass (G).

b Sample preservation should be performed immediately after collection.

c. Samples should be analyzed as soon as possible after collection. This column shows the maximum time that samples may be kept before analysis and still considered valid. Samples may be kept for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for longer time periods. Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if it knows that this is necessary to maintain sample stability.

d. Samples for dissolved metals should be filtered immediately, at the site, before adding preservative.

e. When a sample is to be shipped by common carrier, the sender must notify the nature and type of sample to the transporter. The person offering such material for transportation is responsible for ensuring compliance.

pH

pH was measured using PHSCAN-2, an instrument manufactured in Singapore. The meters were calibrated at two points against buffer solutions of 4 and 7 pH prior to each measurement.

Dissolved Oxygen

Dissolved oxygen (DO) measurements were made using ORION 810, an instrument of US make. The manufacturer's calibration procedure was followed to obtain the guaranteed precision and accuracy. The DO meters were calibrated before each measurement. The instrument was also calibrated against a sample of known dissolved oxygen values using the iodometric method.

Conductivity

Conductivity of the spot samples was measured with another instrument developed in the US, ORION 115. The manufacturer's calibration procedure was followed to obtain the guaranteed precision and accuracy. The conductivity meters were calibrated before each measurement against a standard solution of potassium chloride (KCl) of known conductivity (1413 µS per cm).

Color

'True Color' measurements were made by visual comparison of the samples with platinum cobalt standards. Wastewater samples were filtered before the measurements were made for color. Standard solutions prepared for on-site color measurements are presented in **Table 3.6.** The standard color solution was kept in an airtight brown reagent bottle and proper dilutions were made before the color measurement.

Table 3.6: Standard Solutions for Color Measurement

Standard Solutions Diluted to 50 ml with Distilled Water	*Color in Chloroplatinate Units*
0.0	0
0.5	5
1.0	10
1.5	15
2.0	20
2.5	25
3.0	30
3.5	35
4.0	40
4.5	45
5.0	50
6.0	60
7.0	70

Odor

Odor is recognized as a key quality parameter, which affects the acceptability of water for specific usage. For *in situ* odor measurements, the 'Threshold Odor Method' was used. **Appendix B** presents a detailed description of the test method.

Turbidity

The Nephelometric method was used for turbidity measurement. This method compares the intensity of light scattered by the sample with the intensity of light scattered by a standard reference suspension under defined conditions. The manufacturer's operating and calibration instructions were followed for accuracy and precision of results.

3.6.3 Laboratory Test Methods and Procedures

Several analytical methods and techniques may be used to determine a parameter. For quality control and assurance, it was important that uniform methods and procedures be used at all laboratories involved in analytical testing.

Table 3.7 summarizes the parameters set for this study and the test methods employed for testing at various laboratories. Detailed descriptions of the analytical methods used are presented in **Appendix B.**

Table 3.7: Test Parameters, Methods, and Laboratory Facilities

Test	*Test Method*	*Summary of Methods*
pH	US EPA150.1	Electrometric, using combination electrode
Dissolved Oxygen	US EPA 360.1	Membrane Electrode method
Conductivity	US EPA120.1	Conductivity meter
Color	APHA 2120B	Visual comparison with standard colors
Odor	US EPA140.1	Threshold odor number (TON) by dilution method
Turbidity	US EPA180.1	Comparison of the intensity of light
Temperature	US EPA170 1	Centigrade scale mercury thermometer
Flow	Standard	Floating
BOD_5	US EPA 405.1	5 days incubation, reduction on DO is measured
COD	US EPA 410.1	Colorimetric method
TSS	US EPA 160 2	Gravimetric, dried at 105 °C
Total Nitrogen	US EPA 351 3	Digestion, distillation and titrimetry
E-Coli	APHA 9221 C	Estimation of Bacterial density in terms of MPN
Oil (n-hexane)	US EPA 413 1	Extraction, evaporation and gravimetry
Lead	US EPA 239.2	Atomic Absorption Spectroscopy (AAS)
Chromium	US EPA 218.2	AAS
Zinc	US EPA 289.2	AAS
Arsenic	US EPA 206.2	AAS
Cadmium	US EPA 213.2	AAS
Copper	US EPA 220.2	AAS