MONITORING OF SURFACE WATER, GROUND WATER AND SOIL IN PESHAWAR BASIN AGAINST TIME THE 3RD DIMENSION N.W.F.P PAKISTAN

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A thesis submitted to National Center of Excellence in Geology, University of Peshawar in Partial Fulfillment of the Requirement for the Degree of Doctor of Philosophy in Environmental Geology.

CENTER OF EXCELLENCE IN GEOLOGY
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DEDICATION

Dedicated to my caring mother, my loving father Sardar Bahdar Khan advocate, my beloved partner Dr. Zakirullah, my lovely daughter Nina Zakir and Late Prof. Dr. S. Hamidullah Ex Director National Centre of Excellence in Geology.

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ABSTRACT

Peshawar basin is an intra mountain basin (>5500 km^2) situated at the southern margin of the Himalayas and northwest of the Indus plain in the North West Frontier Province (NWFP) of Pakistan. It is bounded by the mountain ranges of Khyber in the west and northwest, Attock Cherat in the south and Swat in the north and northeast while the Indus river borders its southeastern side where it is open for discharge of water. Peshawar, the capital city of NWFP, Nowshera, Charsadda and Mardan are the major cities of this basin. It is mainly irrigated by the Kabul and Swat rivers and their tributaries. The Peshawar basin has Quaternary flanglomerates along the margins of the basin while the central part of the basin is generally covered with fluvial micaceous sand, gravels and lacustrine deposits. On the basis of varying lithologies, the Quaternary sediments, covered soils and hosting aquifers of the Peshawar basin are classified as Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine sediments, soils and aquifers respectively.

For the last two decades, the high rate of industrialization resulted in drastic and unplanned urbanization with heavy load of transportation together with a retarded rate of awareness / education in mainly poor masses have contributed much in creating pollution of all sorts including those of air, water and soil within the Peshawar basin in general and in the Peshawar metropolis in special. The present study is, therefore, based on the monitoring of the environmental degradation of the Peshawar basin, one of the largest basin of Pakistan, during the years 2003 and 2004 by considering mainly the physico-chemical parameters of waters and soils. In order to evaluate the increase and decrease of these parameters with the passage of time, the results of this research were also compared with the previous studies. Physical parameters such as pH, temperature (T), electrical conductivity (EC) and total dissolved solids (TDS) and the anions such as sulfate (SO_4), bicarbonate (HCO_3) and chloride (Cl) were determined in both surface and groundwater while cations such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) and the heavy and trace elements such as iron (Fe), copper (Cu), lead (Pb), chromium (Cr), nickel (Ni),

cadmium (Cd) and cobalt (Co) were determined in the waters and soils of the Peshawar basin. The physical as well as chemical parameters of the waters were compared with the permissible limits set by US-EPA and WHO and the chemical parameters of the soils were compared with that of the normal agricultural soils.

The aquifers of the Peshawar basin are generally categorized as alkaline earth fresh water with high contents of alkalis but in certain areas small input of alkaline freshwater has also been noticed. Among the physical parameters, pH of the waters of the Peshawar basin varies from acidic (pH = 4.5) to alkaline (pH = 10.1) while the EC and TDS are generally within the permissible limit with elevation in certain areas of the basin. In most parts of the basin both surface and ground waters have cations (Ca, Mg, Na, K) and anions (i.e, SO_4, Cl, HCO_3) within the permissible limit. However, in certain areas of the basin these cations and anions have high concentrations and could be considered hazardous. The high concentration of these cations and anions can be attributed to the percolation of these waters through the limestone, dolomite, gypsum and seams of sulfides, salts and coals within the Quaternary sediments. The heavy and trace elements (i.e., Fe, Cu, Pb, Cr, Ni, Cd, Co) in the waters of most of the areas of Peshawar basin are within the permissible limit but in certain areas of the basin the concentrations of Fe, Pb, Cr and Ni are too high and may pose a threat to the health of the people. Both anthropogenic and geogenic sources could be responsible for this contamination. The anthropogenic sources include the waste from the industrial Estates and many tannery industries in the Peshawar city and the corrosion of underground pipes while the geogenic sources include the sulfide seams and the mafic and ultramafic rocks in the northwest and northeast of the Peshawar basin. The physico-chemical studies of the surface and ground waters of the Peshawar basin further suggest that there is no significant change in the chemical concentration in these waters with the passage of time.

The chemical characteristics of the soils of Peshawar basin have been evaluated by comparing these with the normal agricultural soil values during this study. This study shows that among the major and minor element oxides, the SiO_2,

TiO_2 and Fe_2O_3 in majority of the soils of the basin are within the permissible limit for normal agricultural soil but Al_2O_3, CaO, Na_2O and K_2O in majority of the soils exceed the limit for normal agricultural soil. The geogenic sources such as the weathering of limestone, dolomite, mafic and ultramfic rocks and K-bearing clays in the surrounding mountains and water logging and salinity are considered to be the main cause of enrichment of Al, Na, Ca and Mg in certain areas of the basin. Among the heavy and trace elements in the soils of the Peshawar basin, relatively high concentrations of Cu, Pb, Ni and Cr have been found in the majority of the Peshawar floodplain soils while Zn is relatively high in the Peshawar piedmont soil. This concentration reached to a high toxicity level in the soils of certain areas, which may have drastic environmental impact on the ecosystem of the region. The high concentration of these elements in the soils of the basin can be attributed to the weathering and erosion of the sulfides, and mafic and ultramafic rocks in the surrounding mountainous regions with greater input from the rocks of the Kohistan island arc in northern regions of the Peshawar basin. This study further suggests that there is no significant change in the concentration of these metals in the soils of the basin with the increase or decrease of the depth and also with the passage of time.

The heavy metal concentrations in the aerosol / dustfall in the traffic congested areas of the Peshawar metropolitan have been investigated with the passage of time. It has been noticed that due to the greater influx of the vehicles in Peshawar, there is an increase in the air pollution in regard to the heavy metals. The multi-fold increase of Pb during the last several years in the ambient air aerosol samples at various places of Peshawar suggests that the vehicular emission is the main cause of the Pb pollution in the air.

The earlier studies suggest that the aquifers in the basin are generally replenished both by rain water and water from Kabul and Swat rivers. This suggests that the contamination in these rivers may have direct effect on the underground water, especially the shallow water (dug wells). As a major portion of the aquifer system of the basin has various cations and anions within permissible limit, it is

indicative of the fact that no significant contamination from the surface source has occurred so far. This clearly indicates that if the rivers and adjacent streams and canals of the basin got polluted due to anthropogenic sources in future, there are greater chances of pollution.in the major aquifers, even at deeper level, especially in the vicinity of these rivers. Like other metropolitan cities of the world, Peshawar also has most of the environmental problems. The air, water and soil pollution in Peshawar city and cantonment areas have already been reported in previous studies. These studies indicate that the air and sewerage system of the Peshawar metropolis is highly polluted by the heavy metals and are mainly drained in the Budni canal, which ultimately falls in the Kabul river. If the disposal of municipal and industrial waste is continuously falling in the Kabul and Swat rivers, which are irrigating most of the basin, there are greater chances that in future with the establishment of industrial zones, as proposed, in Peshawar, Swat and Nowshera, the aquifer system of the basin would be polluted to a greater extent.

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Shahida Zakir

CHAPTER 1

INTRODUCTION

General

Environmental pollution is an undesirable change in physical, chemical and biological properties of air, soil, and water that may or will affect human life and other organisms. Extremely polluted air and water can cause illness, death and other adverse impacts both in terrestrial and marine life. Soil pollution can affect the normal growth of plants and crops and can contaminate surface and ground waters and thus reduces the amount of land for cultivation and habitation (Srivastava, 1995).

Environmental pollution may be largely attributed to the abuse of natural resources for industrial development. The incorporation of poisonous industrial pollutants (gases, liquids and solids), municipal wastes and undesired noise, heat from these and other sources degrade the global atmosphere, hydrosphere and lithosphere. Heavy and trace metals are one of the environmental toxins released by metal-based industries, metal using projects and the vehicular traffic. These metals cause several carcinogenic impacts and other impairments both in animals and plants. Toxic metals are those metals whose concentration is now considered to be harmful (IARC, 1976; Baranowska, 1993).

Pakistan is one of the developing countries where the industries and unplanned urbanization are growing at fast rate. It has resulted in high rate of deforestation and expansion of un-metalled roads, poor sewerage system, and industries without treatment plants and widespread slums especially in and around the major cities. Such a scenario is the cause of the tremendous environmental pollution in air, water, and soils of these areas. Both stationary and mobile sources are responsible for the generation and dissemination of pollution. Stationary sources include small and large industrial plants, power generation plants, and construction projects and brick kilns. Mobile sources include cars, trucks rickshaws and aircrafts (Hamidullah et al., 1997a & b, 1999).

The present study is mainly based on the monitoring of environmental pollution in regard to water and soil with time in the Peshawar basin, situated in the north western portion of Pakistan adjacent to the Afghanistan border (Fig.1.1). Peshawar basin is occupied by the major cities of North West Frontier Province (NWFP) i.e., Peshawar, Charsadda, Nowshehra and Mardan and like other big cities of Pakistan the environment is being polluted ruthlessly and carelessly here too. The high rate of industrialization resulting into drastic and unplanned urbanization with heavy load of transportation together with a retarded rate of awareness /education in mainly poor masses have contributed to creating pollution of all sorts including those of air, water and soil. Peshawar is one of the major metropolis of the country and provincial capital of the NWFP. According to 1999 census, Peshawar district had a population of 1650941 with a growth rate of 4.1 (Population Census, 1999).

For over two decades the locals living in Peshawar basin, have been complaining about the pollution and its impacts on flora and fauna. The rivers of the basin and its tributaries have been blamed for a high prevalence of skin diseases in humans as well as maladies in live stock. Some people have also complained of reduced crop yields in fields irrigated with water polluted with industrial effluents. In this scenario, the scientific community got concerned with the poor quality of surface waters and began to take the issue and find out solution on sustainable grounds. Karn 1977 while investigating the water quality of river Kabul confirmed the adverse effect of industrial effluents on the water quality and recommended treating the effluents prior to discharge in the aquatic system. The river Kabul along with its tributaries was investigated in detail for the presence of pollution load by Department of Environmental Planning and Management (DEPM) and IUCN- the international for conservation of nature (1994). The investigations found the river polluted with cations, anions as well as with biological pollutants.

Some researches performed detail studies on the pollution-related issues of Peshawar metropolis and Peshawar basin (Hamidullah, et al., 1997a; Tariq, 2001). They discovered that air and upper soil of the Peshawar city was highly contaminated with heavy metals which makes their way towards river Kabul through Shahi katta, budni

canal and the sewerage passages. They also found that the soils of the basin are contaminated with heavy metals like copper, lead, and nickel (Hamidullah et al., 1997a). These workers have identified the sources of the pollutants as industrial, vehicular and even the rocks of the region in the surrounding.

The above studies though provided a baseline with respect to the time when these studies were performed, however, environmental issues need to be monitored regularly and, therefore, a time based study of all the components of the environment in the basin was felt to be initiated and carried out on regular intervals.

Existing Pollution Status in Peshawar Basin

An undesirable change in chemical, physical or biological characteristics of air, land and water, which can affect the flora, fauna and humans adversely, is termed as environmental pollution. The polluted air can negatively affect the human health, materials, buildings and plants. The soils contaminated with heavy metals, sewerage, toxic metals, pesticides and untreated wastewater can pose threat to various microorganisms and make the soils unfit for cultivation (Srivastava, 1994).

The high rates of urbanization, industrialization, heavy transportation and deforestation have produced tremendous environmental problems around the globe in air, water, and soil media. All these problems are of concern to the environmentalists. Pakistan is not an exception. Here population, industries, road systems, coupled with poor urbanization and deforestation are growing at an alarming rate, resulting in drastic degradation of environment. Peshawar basin consists of four big cities of northwest frontier province NWFP including Peshawar, Mardan, Nowshera, and Charsadda, which are highly polluted. Peshawar is one of the major metropolis of the country and the provincial capital of NWFP and because of the fast human influxes from the rest of the province and the major induction of the Afghan refugees its population has risen exponentially in the past two decades to three millions (Population Census,1999). As a result industries have grown and vehicular traffic has highly overburdened the road system. Sewerage system is outdated and broken. The vehicles have aggravated the situation to an extent that the visibility becomes low and breathing difficult in the city.

Large industrial plants, small metal workshops, power generation stations, auto workshops, old metal bridges, brick kilns, and domestic sewage are the stationary sources leading to the environmental degradation (Saifullah, 1997; Hamidullah et al., 1997b; 1998).

Peshawar Basin

Peshawar basin is situated at the southern foothills of Himalayas between the longitude 71^0 $15^/$ and 72^0 $45^/$ E and latitude 33° $45^/$ and 34° 30 $^/$N in the northwest frontier province (Fig.1.1). Major cities of the basin are Peshawar (capital), Mardan, Charsadda, and Nowshera (Fig. 1.2). The west east flowing river Kabul and its tributaries irrigates the basin and joins the Indus at eastern exit (Tariq, 2001).

Natural as well as anthropogenic sources have contributed a lot in polluting the surface and ground water of the basin. Previous studies have also confirmed the presence of pollutants in the river Kabul. In this regard, river Kabul is most significant one because it drains a major portion of the basin (i.e., from the west of Warsak to the east at Kherabad) and falls in the river Indus at Kherabad (Fig. 1.2). The monthly discharge of the Kabul River, measured at Warsak is 20500 cusecs, with low flow periods from September to April and high flow periods from May to July (Gresswell 1965). The river Kabul originates in Chitral (Pakistan) and flows via Arandu, Kabul, Jalalabad (Afghanistan) and Warsak, Nowshehra (Pakistan) and drops in Indus at Kherabad. Its major tributary in Afghanistan is Kunar river which joins it at Jalalabad. Its branches in Peshawar basin are Shahalam, Nauguman and Sardaryab. River Kabul irrigates a major part of Afghanistan and Peshawar basin through its branches and canal, replenish the underground water system. In these areas it provides water for drinking and other domestic uses directly. In addition, it is hosting a wide variety of fish both in Pakistan and Afghanistan.

Water pollution in this river system is not only a threat to the aquatic life within the river and its surroundings but also to the some types of biomes in and around Indus. The domestic water supply in the basin is largely served by ground water. In the rural areas dug wells are mainly used for such needs. Approximately 609 tube wells are

supplying water to the major towns and villages in the basin. Here the estimated total ground water withdrawal for domestic use reaches 24 million cubic meter per year for urban areas and 37 million cubic meters for rural areas (Wapda TNO 1994). To protect the aquatic system from contamination in the basin a regular monitoring of the surface and ground water is highly needed.

Soil is the ground underfoot, a relatively thin layer of earth crust that has been modified by the natural actions of agents such as weather, wind and water and organisms. Vast numbers and kinds of organisms inhabit soil and depend on it for shelter and food plants anchor themselves in the soil and from it they receive essential minerals and water. Terrestrial plants could not survive without soil, and humans cannot exist without soil either. Climate, parent material, topography, time, plants, and organic activities play significant role in the formation of the soils (Mason, 1966). Macro as well as micronutrients in the soil are essential for the growth of plant kingdom. The anthropogenic activities responsible for the introduction of various nutrients include the application of agrochemical, release of sludge, and wastewater from municipalities and industries. These activities pollute the soils (Sommers, 1977). Soil is the most important sink of the elements released from such activities and other once. The contaminants may stay behind in clay particles and serve as filters for pollutants (Bear, 1975). However such contaminants reach the soil horizon and ground waters, enter the food chain and posing threat to human health (Browelow, 1979). Major heavy and trace metals in air and ground surface soil has been studied by Hamidullah et al (1997 a & b) have reported that heavy and trace metals pollutants of the air of the Peshawar metropolis have contaminated at least the upper horizon of the soil in Peshawar. In this regard about 56 chowks were studied in the Peshawar city and contonment area (from Hayatabad turn till general bus stand i.e. Haji Camp Adda) for metals in the air (nose and ground level) surface clay, soil, sewerage mud, and sewerage water. These studies have shown higher values of these metals in different media in different localities of Peshawar metropolis as compared to those recommended by United State Environmental Protection Agency (EPA), World Health Organization (WHO), and Pakistan Environmental Protection

Agency (PEPA). Soil samples in the Peshawar basin investigated by Tariq (2001) were found to contain trace elements above permissible limits in the basin.

Geology of Peshawar Basin

Peshawar basin, covering an area of about 5500 km^2, is present at the southern margin of the Himalayas. It is surrounded by Khyber mountain ranges in the northwest, Swat mountain ranges in the northeast and Attock-Charat mountain ranges in the south (Fig. 1.2). The basin is mainly composed of the quaternary fanglomerates along the margin of the basin while the fluvial and lacustrine sediments occur in the central part of the basin. The fluvial deposits have a northern provenance and are probably deposited by the ancestral Kabul and Indus rivers. The fanglometrates and lacustrine deposits in the southern part of the basin are, however, derived from the Attock-Cherat and adjacent ranges. According to Burbank and Raynolds (1984), the sediments of Peshawar basin have been ponded by the uplift of Attock-Cherat Range and the movement of Main boundary Thrust (MBT). The paleomagnetic and fission-track data suggest the Plio-Pliestocene time for the filling up of basin (Burbank, 1982). This sedimentation in the basin terminated about 600,000 years ago due to accelerated uplift of the Attock-Cherat Range. However, along the courses of main streams and rivers, sedimentation is still continuing (Burbank, 1983). Burbank (1984) also identified at least 40 catastrophic floods which inundated the basin in pre-historic times.

The stratigraphic sequence exposed in the Peshawar basin can well be observed in the Nowshera, Ghandghar and Attock-Cherat Range. These are generally precambrian to devonian metasediments. Three structural blocks, separated by thrust faults, are present within the Attock-Cherat Range (Yeats and Hussain, 1987). The northern block is composed of the Precambrian Manki, Shahkot, Utch Khattak and Shekhai formation, the central block is largely made up of Precambrian Dakhner Formation, whereas the southern block consists of a north dipping homclinal sequence (i.e., Darwaza, Hisartang and Inzri formations) (Yeats and Hussain, 1987).

Physiography

Peshawar basin is surrounded by hills on all sides except in the south west where it is bounded by Indus river. It is fairly flat with average elevation of 300 m above mean sea level (MSL). The land is undulating near the mountains and the elevation rises to 500 or 700m above MSL (Wapda TNO 1994). The physiographical units consist of piedmont plain in the south west part, flood plain between the Kabul and Swat rivers, Loess plain in the central part of the plain west of Charsadda and north of Kabul river, and four important rivers.

Drainage

There are four important rivers nalas in the Peshawar basin i.e. Kabul river, Swat river, Bara river and Kalpani nala. Besides these rivers there are several perennial and non perennial nalas that contribute to the drainage of Peshawar basin and most of them discharge into the Kabul river.

The main river is Kabul river which drains almost the whole valley. It enters the plain near Warsak and falls in Indus river. It divides the basin in southern and northern parts. Swat river enters the plain in the north west near the village of Munda Qila and discharges into river Kabul near Charsadda. Bara river flows from the south and enters the basin near Jhansi post. The flow of the river is diverted by other canals and it is used for drinking and irrigating pupposes. Kalpani drains a large area in north and arises in basin itself ultimately discharging into river Kabul.

Climate

The climate ranges from the semi arid subtropical continental lowland type in the western part to the sub-humid to subtropical continental lowland type in the eastern part of the basin. The rainfall ranges from 340 mm to 630 mm. June and July are the hottest months with an average daily temperature of 40-48^{0}C. Coldest month is January with an average daily minimum temperature of -2^0 C. The mean annual potential evaporation is approximately 1200 mm in Mardan and Nowshera, 1100 mm in Charsadda and 1500 mm in Peshawar (WAPDA & TNO, 1994).

Population and domestic water supply

Peshawar basin has a total population of 4.8 millions excluding Afghan refugees. Peshawar and Mardan are densely populated areas having approximately 2 million inhabitants in Peshawar and 0.5 million in Mardan. The domestic water supply is served by ground water. Rural areas have open wells as well for domestic use. Public Health Engineering Department (PHED) has drilled 609 wells in the area. The water use of the urban population is 50 day but for rural areas it is 25 liter/day. The total withdrawal for urban areas reachs 24 Mm^3/yr (million cubic meters per year) and 37 Mm^3/yr for rural areas (WAPDA & TNO, 1994).

Agriculture

The majority of the population i.e. 53 percent is employed in agriculture. The cultivated area is 400000ha of which 65 percent is irrigated either with surface water or ground water, (WAPDA & TNO, 1994).

Irrigation with Surface Water

The surface water irrigation in the Peshawar basin depends on rivers and canals. The lower Swat canal takes off from the left bank of Swat river at Munda Qila head works in the northwest of the basin. Its commanded area is 54,200 ha lying between Charsadda and Mardan town. The upper Swat canal drains out from the left bank of Swat river at Amandara canal in the Swat area. It enters the basin near Dargai through a 3400 m long tunnel and it bifurcates in the Abazai and Machai branches. The former commands 28,000 ha in the northwest of the basin and the latter commands 84,000 ha in the north and east, (WAPDA & TNO, 1994).

The Warsak high level left bank canal takes off from the left bank of Kabul river just upstream of the Warsak Dam and its command area lies in Doaba between the Kabul and Swat rivers. Kabul river canal takes off from the right bank of the Kabul river near warsak, Warsak high level right bank canal takes off from the left bank of Kabul river upstream of Warsak between the left canal and the Kabul river canal.

In the northeast of the Peshawar basin, the Pehur canal takes off from the right bank of the Indus river 8 km downstream of Tarbela Dam. Its command area is 17,870 ha lying on both sides of the canal. The largest of the canal is Jue Sheikh canal constructed by the mughals in 17th century. The private canals and kathas are situated in the south and west of the basin. They irrigate the area between the Kabul and Swat rivers. No figures are available on the discharge of these canals (WAPDA & TNO, 1994).

Irrigation with groundwater

Irrigation with ground water is practiced in Peshawar basin through dug wells and tube wells. In dug wells the water is raised by Persian wheels or under waterpumps for small scale irrigation. A number of dug wells are used for irrigation in Mardan and Charsadda areas.

Irrigation Department operated about 190 tube wells within the Peshawar Basin. These tube wells are used for irrigation purposes which are needed to alleviate waterlogging and salinity of the area. According to the Roberts (1988) the total estimated area irrigated by groundwater is 21,200 ha during Rabi and Kharif crops (WAPDA & TNO, 1994, Tariq, 2001).

Scientific objectives

- To monitor the pollution load in surface and subsurface water and soils of the Peshawar basin with passage of time by repeating these studies at specific interval of time.
- To determine the sources of pollutants and propose suggestion and recommendations for the corrective measures
- Identification of anomalous concentration of trace elements and heavy metals in waters and soils of the basin and their relation to possible health hazard/negative environmental impacts in the basin.

Methodology

During the present study various promising areas of Peshawar Basin in regard to contamination/hazardous risks were selected for ground water, surface water and soil sampling and the concentration of various pollutants were determined in winter and summer seasons of 2003 and 2004. These samples were collected from the same places from where Tariq (2001) collected the samples of water and soil. (Appendix-I) About nineteen surface water, fifty-three deep aquifer ground water (tube wells), forty-two shallow aquifer ground water (dug wells) and thirty-eight soil samples were collected from Peshawar basin including Mardan, Charsadda, Nowshera and Peshawar. Various parameters for assessing the water quality i.e., pH, electric conductivity and temperature were carried out on site. Other parameters including total dissolved solids (TDS), sulfates (SO_4), bicarbonates (HCO_3), chlorides (C^-l), lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), chromium (Cr), cobalt (Co), nickle (Ni), manganese (Mn), sulphate (SO^{-2}_4), calcium (Ca), magnesium (Mg), iron (Fe) , sodium (Na) and potasium (K) were analyzed in the laboratory of National Centre Excellence in Geology by using atomic absorption and UV, IR spectrophotometer pH meter and conductivity meter (Appendix I). The results obtained from regular monitoring of the aforementioned samples were compared with the international standards.

Field Investigation

Water samples were collected during the months of January and June of 2003 and 2004 from each site in two cleaned polythene bottles. Water of one bottle was acidified with 5% HNO_3 while the other was kept as none acidified for further analysis in the laboratory. The soil samples from agricultural land of the basin were collected during January of 2003 and 2004 at two different depths or horizons (A = 0-20cm & B = 20-40cm) at each spot by hand auger. The soil samples were stored in polythene bags for further analysis in the laboratory.

Laboratory analysis

The acidified water samples were used for the determination of cations by using Perkin Elmer electro-thermal Atomic Absorption Spectrophotometer, UV/visible spectrophotometer while the none acidified water was used for the determination of anions by using Hatch DR-2000 spectrophotometer.

The soil samples were dried in air and then pulverized to 100 mesh size in the ball-mill. About 50 g powder of each soil sample was selected after quartering and coning technique. The samples were then dried overnight in the oven at 110°C for further analyses. Brief methodology for the determination of major, minor and trace and heavy elements are given below. Detail methodology is given in (Appendix-I).

Major element oxides: Two types of stock solutions (A & B) were prepared for the major element oxides. Stock solution A was prepared by mixing 0.05g of soil powder with NaOH in the nickel crucible and was fused on burner at high temperature for five minutes. The crucible was cooled to get the fusion cake. The fusion cake was then dissolved with 10N HCl and final solution of 1000ml was made with de-ionized water. This solution was used for the determination of SiO_2 by the method of ammonium molybdate and Al_2O_3 by the method of 8-Hydoxyquinoline by using the Pye-Unicam UV/visible spectrophotomer (Jeffery, and Hutchison 1986). Stock solution B was prepared by decomposing 0.5g of powder soil sample in Hydrofluoric-perchloric acids mixture and final dissolution to 250ml with de-ionized water (Jeffery and Hutchison 1986). This solution was used for the determination of Fe_2O_3, MgO, CaO, Na_2O and K_2O by using the Perkin Elmer atomic absorption spectrophotometer. The loss on ignition was determined by heating 2.g of powder soil sample in the porcelain crucible at 950°C in the muffle furnace, to remove organic matter, for four hours and the weight difference was calculated as loss on ignition.

Trace and heavy metals: About 1.g of the soil powder sample was taken in the tefelon beaker. About 5 ml of hydrofluoric acid was added to it and then heated for half

an hour and then about 15 ml of equa rigia was added and heated on low heat until final paste was obtained. The contents of the beaker were dissolved by the 2N HCl and then filtered through the whatman (No. 42) filter paper and the final solution was made to 25ml. This solution was used for the determination of Cu, Zn, Pb, Co, Ni and Cr by using the Perkin Elmer atomic absorption spectrophotometer under standardizing conditions.

All these analysis were carried out at the geochemistry laboratory of National Centre of Excellence (NCE) in Geology), University of Peshawar and cross checked in PCSIR laboratories Peshawar and department of environmental sciences University of Peshawar. The detail procedures are given in appendix A.

Previous work

The geology and tectonics of Peshawar basin is extensively studied in the past by various workers. Important among these are the studies of Vicary (1851), Waagen (1884), Griesbach (1892), Wadia (1930), Cotter (1933), Ahmad (1949), Nizami (1952), Stauffer (1968), Khan (1969); Khan et al 1970), Jan (1969), Meisner et al. (1974), Shah et al. (1980), Kazmi et al. (1984), Ahmad (1986), Calkins et al. (1975), Tahirkheli (1970), Burbank (1982), Yeats and Hussain (1990) and Hussain et al. (1987). According to Allen (1964), Nizami (1952), Haneef et al. (1986), WAPDA (1985, 1988, 1989) and Hussain et al. (1990), the Pleistocene sediments in the northeast of the Peshawar basin were deposited in a lacustrine environment. These sediments formed approximately 2.4 to 1.6 Ma ago and probably derived from the volcanic complex of Dasht-e-Nawar in the east central Afghanistan. These lacustrine sediments indicating rhythmic flooding and lake related depositional processes (Burbank, 1983).

Limited work on the drinking water chemistry has been done by Mehmood (1962), Riaz (1973), Khan, (1997), Hamidullah et al. (1997a). According to a study carried out by Tariq et al. (1999), the water and soil samples of certain areas of the Peshawar basin are showing high concentration of major trace and heavy metals in both water and soil samples while most of the areas are within the permissible limit.

Fig. 1.1 Map of Pakistan Showing the Study Area (i.e., Peshawar basin).

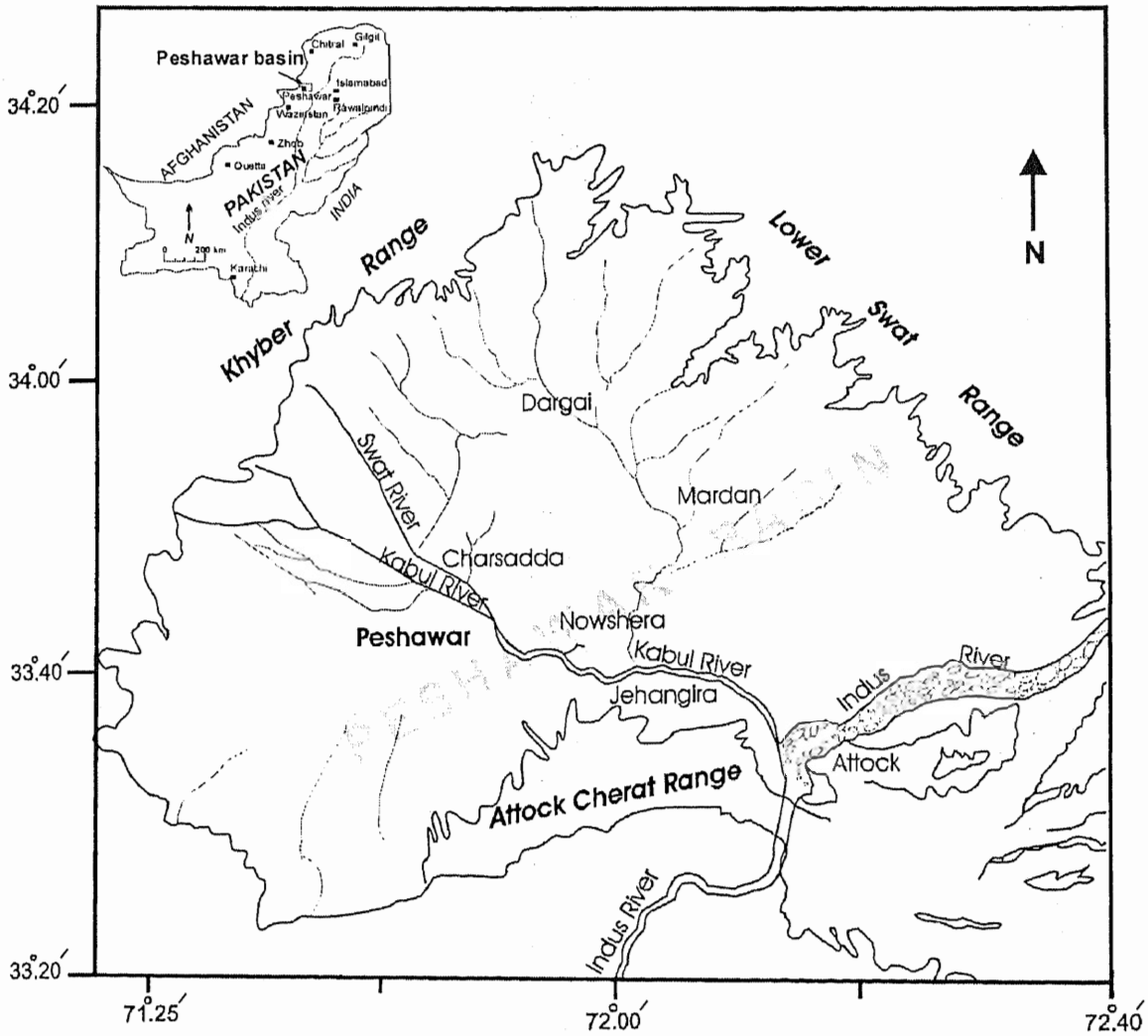


Fig. 1.2. A map showing the major cities and drainage of the Peshawar basin.

CHAPTER 2

HYDROGEOLOGY

As the present study is based on the quality of both surface and subsurface water of the Peshawar basin, therefore, it is pertinent to briefly describe the hydrogeology of the Peshawar basin. The detailed hydrogeology has been established by Tariq (2001) which is reproduced for better understating.

Aquifer condition in Peshawar basin

Peshawar basin is mainly composed of a thick sequence of alluvial sediments of Pleistocene age which may have provided better conditions for the development of best aquifers in the Peshawar basin. Tariq (2001) Freeze & Chery, (1979) has studied both surface and subsurface stratigraphy and lithology of borehole (tube wells) and determined the aquifer condition in the Peshawar basin. The borehole data suggest that the fluvial sediments, mainly composed of coarse deposits of sand and gravel, vary in thickness from few meters to about 150m. These fluvial sediments present in the foot hills of the mountains in the western (Khyber Agency) and southern (Attock-Cherat range) part of the Peshawar basin. The coarseness of these sediments increases from north to south of the basin (Tariq, 2001).

In the central part of the basin the alluvial sediments contain a relatively large proportion of fine material, where the sandy silt is interbedded with discontinuous alluvial sand and thin gravel layers of various thickness (WAPDA & TNO, 1994) (Tariq 2001)

Changes in the lithologies and aquifers in the basin

Tariq (2001) prepared the geological cross section (Fig. 2.1) from the lithological logs of the boreholes in the Peshawar basin. These logs are ranging in depth from 5m to 120m, however, the total thickness of Quaternary sediments are not known because non

of the borehole is penetrating the bedrock. It is clear from the Figure 2.1 that southwestern part of the basin is mainly composed of clay, gravel with sand, admixture types near the surface and gravel with subordinate clay and sand at the base. The southwestern part of the mainly consists of gravel, clay-sand, and gravel with alternate beds of clay and sand. The south and southwestern part of the basin shows mixture of gravel, clay and sand (Admixture type), gravel with subordinate clay and sand, clay and gravel with subordinate sand; and thin layer of clay. The coarse sediments are generally encountered at the top and base while the middle part has compact sand and clay lenses. The central part of the basin is mainly composed of lucastrine/loess sediments. These are ranging in thickness from few meters to about 15m.

The borehole data of the basin suggest that the stratification differs from borehole to borehole and it seems that coarse layers occur only as lenses and are not interconnected. However, the absence of significant changes in the groundwater level over short distance is an indication of hydraulic continuity between the gravel strata (WAPDA & TNO, 1994; Tariq, 2001). However, semi-confined aquifer condition is predominating, over most part of the Peshawar basin where the topographic gradient is steep (WAPDA & TNO, 1994). Artesian aquifer is also observed in the basin where the transmissivity of the deep aquifers rapidly decreases due to the decrease of average grain size, which resulted in the rise of piezmetric level of water above the land surface (Tariq, 2001).

The aquifer in the northwest part of the basin, generally occurs below the depth of 46m. It is mainly comprised of sand with mixed gravel. This indicates that these coarse sediments are the main aquifers in the basin which are generally present within the heterogeneous lithologies with a variable transmissibility over a wide range (WAPDA & TNO, 1994; Tariq, 2001).

The depth of water table is highly variable, it ranges between 1.5m to 15m along Kabul river, 5m to 30m towards the centre of the basin and relatively more deep along upper Swat canal towards north. However, in the southern part of the basin the depth of the groundwater varies from place to place with an average depth of 12m to 39m (Tariq,

2001). It is observed by the Tariq (2001) that due to the topographic elevation in the depth of water table exceeds 80m in the various localities of the basin. At several localities the aquifer is recharged through lateral flow from fracture zone of surrounding rocks and infiltration of runoff through permeable stream beds. The streams (khwars) in the alluvial sediments are useful sources of recharge during heavy rains in the basin.

According to Roberts (1988), the total recharge to the groundwater is 923 Mm^3/year over 6270 km^2 in the Peshawar basin which is mainly contributed from percolation of rainfall (151 Mm^3/y), surface water irrigation (734 Mm^3/y), groundwater-based irrigation (15 Mm^3/y) and runoff water (23 Mm^3/y).

Classification of Aquifer in Peshawar Basin

Peshawar basin is divided into various types of aquifers on the basis of two main lithologies of the area. These are briefly discussed below:

1. Peshawar Piedmont Aquifer

On the basis of mountain ranges around the Peshawar basin the aquifers in the marginal parts of the basin are classified as:

I. Khyber Mountain Range Piedmont Aquifer

II. Attock-Cherat Range Piedmont Aquifer

III. Lower Swat Range Piedmont Aquifer

I. Khyber Mountain Range Piedmont Aquifer

Khyber Mountain Range piedmont aquifer, generally composed of fluvial sediments of piedmont deposits in the form of alluvial fans, is present in the west and northwest of Peshawar basin. These sediments mainly consist of admixture of type of gravel, sand and clay layers forming a vast unconfined aquifer which is intervened occasionally by thin clay layers (Tariq, 2001) (WAPDA & TNO, 1994) (Freeze & Chery, 1979).

II. Attock-Cherat Range Piedmont Aquifer

The Attock-Cherat range piedmont aquifer is generally composed of fluvial sediments in the form of alluvial fans and is occurring in the southern parts of the basin. The fluvial deposits are composed of clast material derived from the boarding hills except along the river and main streams (khwars) where flood plain deposits are found. The aquifer in this area is characterized by both floodplain and piedmont deposits, mainly consisting of clast material, coarse sand, gravel, boulder, and interbedded clay layers (Tariq, 2001).

III. Lower Swat Range Piedmont Aquifer

The lower Swat range piedmont aquifer occurs in the northern margin of the Peshawar basin, forming both unconfined and confined aquifer separated by thick clay strata of low permeability. The unconfined aquifer of low permeability consists of silt, clay and rarely find sand strata, while the confined aquifer of high permeability is generally composed of sand and gravel strata from a depth of 30m to 150m. The low permeability and shallow groundwater of low capacity can be well observed in the dug wells of the area (Tariq, 2001).

2. Peshawar Lacustrine Aquifer

Peshawar lucastrine aquifers mainly occur in the central part of the Peshawar basin in Nowshera, Mardan and Swabi areas and is characterized by lacustrine deposits. The central part of the basin is mainly composed of fine sand, silt and clay interbedded with discontinuous alluvial sand and thin gravel layers of various thickness. However, coarse deposits of sand and gravel are present in the western part of the basin and along the river. The strata of the fine material indicate semi confined aquifer over most of the Peshawar basin (Tariq, 2001).

3. Peshawar Floodplain Aquifer

The Peshawar floodplain aquifer is confined to the vicinities of the current and past courses of Kabul and Swat rivers, where these rivers have deposited these sediments. These sediments consist of sand with intercalations of clay which spread out by river overflow during high floods. This type of aquifer is local and relatively shallow in comparison to the lacustrine aquifer of the basin (Tariq, 2001).

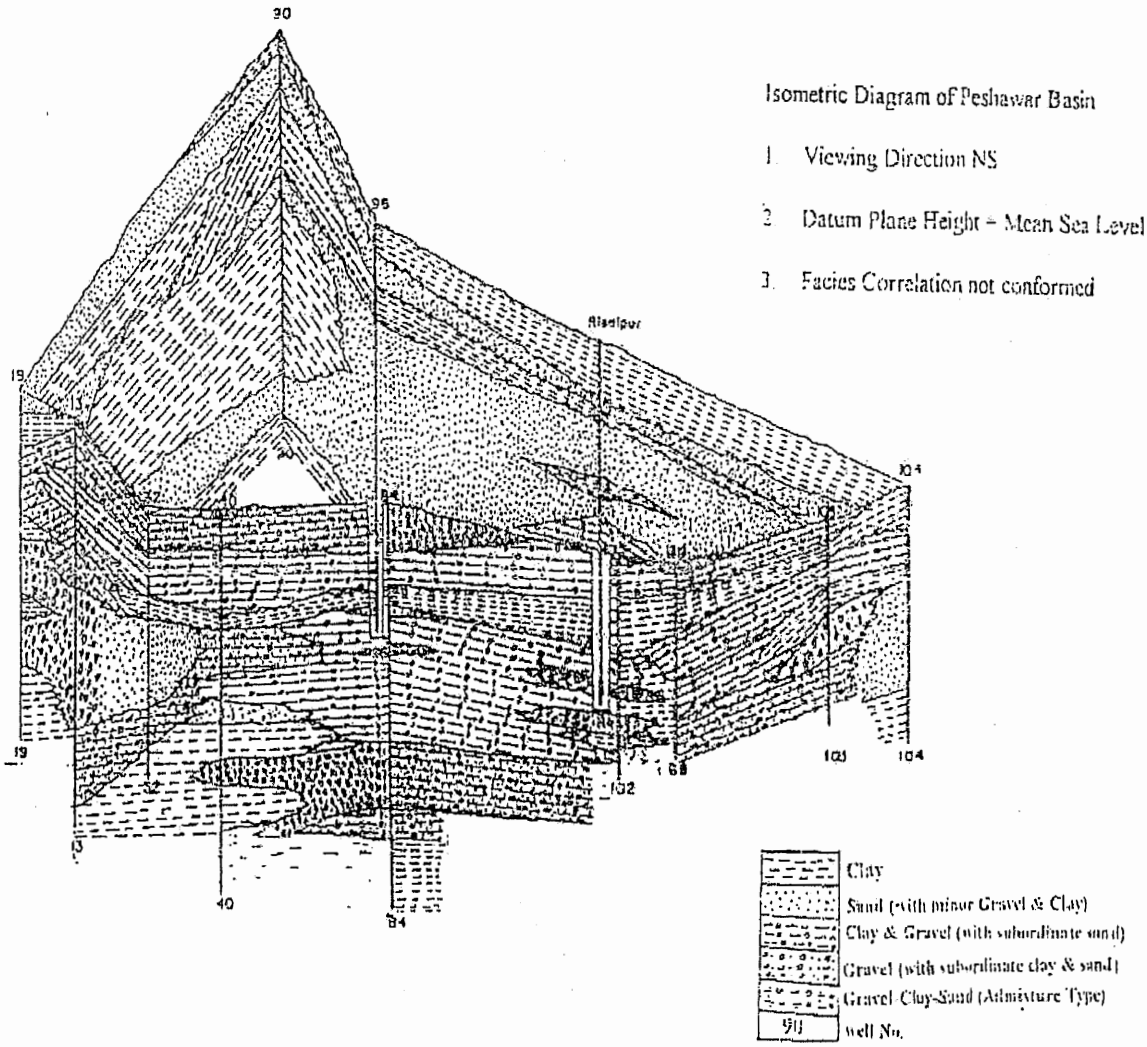


Fig. 2.1 Fence diagram showing the subsurface lithology of boreholes tubewells in Peshawar Basin (After Tariq, 2001).

CHAPTER 3

WATER CHEMISTRY

General

The principal source of water for domestic and agricultural use is the groundwater and the rivers Kabul and Swat in the Peshawar basin. The groundwater mainly occurs in basin in three types of semi-confined aquifers with water table varying from 2 to 2.5m below surface. According to Tariq (2001) the piedmont aquifers are generally of fluvial lacustrine and floodplain origin (Tariq 2001) and are considered to host good reserves of water. These are generally below 2.5m and less affected by the surface water. However, the lacustrine and floodplain aquifers are generally present at shallow depth (<2.5m) and can, therefore, possibly be affected by the seepage of canals, rivers, streams and direct infiltration of rainfall (WAPDA & TNO, 1994), (Hamidullah 1997a) (Piper, 1942), (Bundshchuh 1992).

The chemical study of both surface and groundwater of Peshawar Basin is aimed at several aspects on regional scale. These studies included regular monitoring of physio-chemical parameters of both surface and ground waters of the Peshawar basin in order to determine the extent of environmental degradation with the passage of time. As this study is the second of its type after Tariq (2001) in the Peshawar basin. Therefore, the water samples from the same localities were collected where from she has collected the water samples. The same kinds of physio-chemical parameters were also determined, so that enrichment or depletion of various hazardous elements can be monitored with passage of time. (US EPA, 1978)

Fifty three water samples from deep aquifers (i.e., tube wells), forty two from shallow aquifers (i.e., dug wells) and nineteen from surface water (i.e., river, stream and springs) were collected from Peshawar piedmonts and Peshawar floodplain and lacustrine aquifers of the basin. The locations of these samples are marked in Figure 3.1. The physical parameters such as temperature (T), pH, specific electrical conductance (EC)

and total dissolved solids (TDS), total organic substance and the chemical parameters (i.e., cations and anions) were determined in the water samples. The cations and anions determined in natural waters from various aquifers of the basin include calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co), lead (Pb) and cadmium (Cd) while the anions include sulphate, chloride, Bicarbonate (HCO_3^-), and chloride (Cl^-). Concentration of these chemical constituents in waters is essential for life and for the optimum health of all organisms. Their existence beyond the safe limit or Maximum Contaminants Level (MCL) of US Environmental Protection Agency (US, EPA, 1978) or that of the World Health Organization (WHO, 1975) may result in toxicity of hosting organism. Water quality, that satisfy the requirements of domestic, drinking and irrigation water is given in Table 3.1 for comparison.

Quality of the waters of Peshawar basin

The quality of the waters of Peshawar basin has been investigated on the basis of physical and chemical parameters. These are discussed here in detail.

Classification of groundwater

Hydrochemical data can be compiled in the triliniar Piper diagram which contains two triangular charts for depicting the proportions of cations and anions expressed in meq/l. The relative chemical composition of the water sample is indicated in a diagram which often forms the background for a description terminology of the chemical composition of groundwater. For example a calcium bicarbonate water type must plot near the left hand corner of the diagram while a sodium-bicarbonate type will be located closer to the bottom corner. The diamond diagram has further been divided into various fields such as 1) Na-K, C^-l-$S^{-2}O_4$ type, 2) $HC^{-1}O_3$, Ca-Mg type, 3) Cl SO_4, Na-K type, 4) Ca-Mg, $HC^{-1}O_3$ type, 5) Ca-Mg type, 6) Cl-SO_4 type, 7) Na-K type and 8) HC^-O_3-$CO^{-2}{}_3$ type.

The groundwater samples of both dug wells and deep wells of the Khyber piedmont aquifer of the Peshawar basin when plotted in the triliniar diagram of Piper (Fig. 3.2a), plot in the field of Ca-Mg, $HC^{-}O_3$ type The groundwater samples of the Peshawar floodplain aquifer show wide spread in the triliniar diagram (Fig. 3.2b) between the fields for Ca-Mg, HCO_3 type and Na-K, Cl-SO_4 type of the alkaline earth freshwater with high contents of alkalis. Two samples, however, plot in the fields of HCO_3, Ca-Mg type of alkaline fresh water. The majority of groundwater samples of Peshawar lacustrine aquifer also plot in the Ca-Mg, HCO_3 type and Na-K, Cl-SO_4 type of the alkaline earth freshwater with high contents of alkalis. Few of the samples plot in the filed of HCO_3, Ca-Mg type of alkaline fresh water (Fig. 3.2c). Similarly majority of the samples of the groundwater of the Attock-Cherat piedmont aquifer of the Peshawar basin plot in the field of Na-K, Cl-SO_4 type with few of the samples plot in the field of Ca-Mg, HCO_3 type of the alkaline earth freshwater with high contents of alkalis (Fig. 3.2d).

It is clear from the chemical composition of the groundwater of the Peshawar basin that all the four aquifers of the basin are generally varying between alkaline earth fresh water to alkaline fresh water. These aquifers have Na-Ca-SO_4 and Na-MgHCO_3 type waters. This distribution probably reflects a difference in carbonate cement composition, Mg-enriched calcite or dolomite occurring in the sedimentary environment in the basin.

Physical Parameters

Temperature (^{o}C)

Temperature of water is an important parameter which is affecting aquatic organism by changing the solubility and relief of gases in river water. Water temperature also affects the availability of chemical parameters and the reproductive behavior and growth of fish and its food organism.

Temperatures of the aquifers of Peshawar basin were monitored during different times of the year 2003 and 2004 and the results are given in the (Table 3.2) along with that of Tariq (2001). The present study suggest that in January 2003, the temperature

ranges from 14.2°C to 24.5°C in Khyber Piedmont aquifer, from 18.00°C to 30.1°C in flood plain aquifer, from 19.2°C to 30.4°C in Peshawar lacustrine aquifer, and from 20.2°C to 26.2°C in Attock-Cherat piedmont aquifer. The temperature in January 2004 varies from 15.6°C to 23.8°C in Khyber piedmont aquifer, from 17.9°C to 22.5°C in floodplain aquifer, from 17.2°C to 25.5°C in Peshawar lacustrine aquifer, and from 18.6°C to 22.6°C in Attock-Cherat peidmont aquifer. In June 2003 the temperature ranges from 14.8°C to 25.5°C in the Khyber piedmont aquifer, from 17.1°C to 23.9°C in Peshawar floodplain aquifer, from 14.4°C to 23.1°C in the Peshawar lacustrine aquifer and from 19.1°C to 23.1°C in the Attock-Cherat piedmont aquifer. The temperature in June 2004 varies from 20.2°C to 25.4°C in the Khyber piedmont aquifer, from 18.4°C to 29.4°C in the Peshawar floodplain aquifer, from 21.8°C to 26.8°C in the Peshawar lacustrine aquifer and from 21.9°C to 26.5°C in the Attock-Cherat piedmont aquifer.

It is clear from Table 3.2 that the temperature of the surface and groundwater of the various types of aquifers in the Peshawar basin is highly variable. However, the temperature of groundwater is relatively higher in the January than in June.

pH of waters

pH is the measure of the hydrogen ion (acid) concentration in the water. The lower the pH value the more acidic the water and the higher the pH values, more alkaline the water. When the hydrogen ion concentration is greater than 1.0×10^{-6} moles per litre at 25°C, the solution is acidic in character. The lower the pH (1–3) of a body of water the more it is corrosive and, therefore, become polluted with metallic compounds. The acidic water is, therefore, more toxic with respect to the metals as compare to the basic water. It is generally believed that high pH values (i.e., above 8.5) are usually associated with the carbonate and bicarbonate of sodium in waters. Moderately low and very low pH value (4-6) is associated with free acids derived from oxidizing sulfide minerals (usually pyrite) in waters (Krauskopf, 1979).

The pH of the water samples of Peshawar basin are monitored during the different times of the year 2003 and 2004 and the results are given in Table 3.3 along with pH values reported by Tariq (2001). The variation of pH is graphically presented in Figure 3.3. Water samples show the greater variability of pH in waters of Peshawar basin. The pH of groundwater ranges from 4.5 to 9.9 in the Khyber piedmont aquifers, from 4.9 to 7.4 in Atock-Cherat piedmont aquifers. In the central part of the basin, pH is ranging from 4.5 to 8.7 in Peshawar lacustrine aquifer and 5.21 to 8.8 in Peshawar floodplain aquifers, respectively in January 2003. In January 2004, pH varies from 5.8 to 9.8 in the Khyber piedmont aduifer, from 5.2 to 8.5 in Peshawar flood plain aquifer, from 4.7 to 9.8 in Peshawar lacustrine aquifer, and from 4.8 to 7.4 in Attock-Cherat piedmont aquifer. In June 2003, pH varies from 5.1 to 10.1 in Khyber Piedmont aquifer, from 6.2 to 8.9 in Peshawar floodplain aquifer, from 4.6 to 9.5 in Peshawar lacustrine aquifer, and from 4.8 to 8.8 in Attock-Cherat piedmont aquifer. In June 2004, pH ranges from 5.3 to 9.8 in Khyber piedmont aquifer, from 5.2 to 8.9 in Peshawar floodplain aquifer, from 4.6 to 8.8 in Peshawar Lacustrine aquifer and from 4.8 to 7.6 in Attock-Cherat piedmont aquifer. The pH values reported by Tariq (2001) in the waters of Peshawar basin suggest that it varies from 4.9 to 9.2 in the Peshawar lacustrine aquifer and from 5.0 to 7.7 in Attock-Cherat piedmont aquifer.

This suggests that water of Peshawar basin is ranging from acidic to alkaline and this variation is noticed even at the local scale. The groundwater (both tube wells and dug wells) at Tehkal Bala, Jamrud Road, Adezai, Sorazai, Jehangir Abad, Landi arbab, Dabgari shuba, Hazara Khawani, Wadpaggga, Umer village, Zahirabad, Mattani, Adezai, Dagbasud, Aza Khel, Taila Band, chapri, Speen Khak and Musha Garh are having pH in the acidic range (Table 3.3). The water samples at Darwazgai (dug wells) from Attock-Cherat piedmont aquifer and from Zahirabad (dug wells) and Umer village (tube wells) from Peshawar lacustrine aquifer indicate high concentration of SO_4 (ranging from 385, 396, 398, and 402 mg/l for Darwazgai, 1302, 1298, 1306, 1313 mg/L (milligram per liter) in Urmar village and 1355, 1302, 1350 and 1298 mg/L in Zahirabad having low pH values. Such a correlation can be attributed to the dissolution of pyrite by the water

percolation through localized sulfide rich zone in these areas which resulted in lowering of pH.

Electrical Conductivity (EC) of water

The electrical conductivity (EC) in fresh water is the conductance of a cubic centimeter of water at a temperature of generally measured in siemen per centimeter (S/cm). It is a measure of water ability to conduct an electric current. The electrical conductivity (EC) of the groundwater is usually quite low, so it is measured in millisiemen per centimeter (m S/cm). It gives a general impression of the chemical behavior and chemical quality of waters. Conductivity shows marked changes with the change in temperature. Therefore, 25°C is taken as temperature for conductivity determination. The freshly distilled water has a conductivity of 0.5 to 2 m S/cm, which may increase to 4m S/cm, after storage for a few weeks (Jones and Buford, 1951).

The EC of the surface and ground waters of the Peshawar basin were monitored during different times of the years 2003 and 2004. The data is given in Table 3.4 along with that of Tariq (2001) and the variations in the EC during the two years time are graphically presented in Figure 3.4. The measured values of electrical-conductivity of water during January varies from 50 to 1517 m S/cm, from 57 to 1230 m S/cm in Peshawar floodplain aquifer, from 71 to 1838 m S/cm in Peshawar lacustrine aquifer and from 62 to 720 m S/cm in Attock-Cherat piedmont aquifer. In January 2004, the EC is ranging from 61 to 1526 m S/cm in Khyber piedmont aquifer, from 60 to 1240 m S/cm in Peshawar floodplain aquifer, from 92 to 2012 m S/cm in Peshawar lacustrine aquifer and from 81 to 990 m S/cm in attock-Cherat piedmont aquifer.

In June 2003, the EC values range from 50 to 1509 m S/cm, from 48 to 1810 m S/cm, from 85 to 2001 m S/cm and from 81 m S/cm to 990 m S/cm in Khyber Piedmont Aquifer, Peshawar floodplain aquifer, Peshawar lacustrine aquifer and Attock-Cherat piedmont aquifer respectively. In June 2004, EC ranges from 56 to 1828 m S/cm, from 61 to 1920 m S/cm, from 76 to 1851 m S/cm, and from 71 to 1801 m S/cm respectively in

Khyber piedmont aquifer, Peshawar floodplain aquifer, Peshawar lacustrine aqifer, and Attock-Cherat piedmont aquifer respectively.

It is clear from the table 3.4 and figure 3.4 that the EC of waters of majority of the areas of the basin exceeds the MCL (200-400 m S/cm). However, Urmar Bala, Mulazai, Regi, Shahi Bala, Wadpagga and Azakhel Bala are having very high (>1000 m S/cm) electrical conductivity.

Total Dissolved Solids

On the basis of total dissolved solids (TDS), the drinking water can be classified as fresh, slightly saline, moderately saline, very saline and brine (US Public Health, 1985).

1.	Less than 1,000 mg/l	Fresh
2.	1,000 – 3,000 mg/l	Slightly Saline
3.	3,000 – 10,000 mg/l	Moderately Saline
4.	10,000 – 35,000 mg/l	Very Saline
5.	More than 35,000 mg/l	Barine

Several processes are responsible for the increase of dissolved solid content of groundwater, that include, movement through rocks containing soluble mineral matter, concentration by evaporation, contamination due to industrial and municipal disposals etc. The concentration of total dissolved solids (TDS) in both surface and groundwater from various aquifers and the main rivers are presented in Table 3.5 along with TDS values reported by Tariq (2001) and are also graphically presented in Figures 3.5. The TDS values of the Peshawar basin varies from 44 to 973 mg/l, from 41 to 1402 mg/l, from 50 to 1308 mg/l and from 61 to 530 mg/l in the Khyber piedmont aquifer, Peshawar floodplain aquifer, Peshawar lacustrine aquifer and Attock-Cherat piedmont aquifer respectively in the month of January 2003. In January 2004, it is ranging from 52 to 984 mg/l in the Khyber piedmont aquifer, from 48 to 1412 mg/l in the Peshawar floodplain aquifer, from 81 to 1232 mg/l in the Peshawar lacustrine aquifer and from 75 to 751 mg/l

Attcok-Cherat piedmont aquifer. In June 2003, the TDS of Peshawar basin is ranging from 40 to 962 mg/l, from 65 to 1375 mg/l, from 75 to 1220 mg/l and from 70 to 731 mg/l in the Khyber piedmont aquifer, Peshawar floodplain aquifer, Peshawar lacustrine aquifer and Attock-Cherat piedmont aquifer respectively. TDS values in the Khyber piedmont aquifer is ranging from 45 to 978 mg/l, in Peshawar floodplain it is ranging from 48 to 828 mg/l, in Peshawar lacustrine aquifer it is ranging from 61 to 1120 mg/l and in Attock-Cherat piedmont aquifer it is ranging from 71 to 532 mg/l. Many of the samples from the aquifers of Peshawar basin have total dissolved solids below the Maximum Contaminant Levels (MCL) of US. EPA (<500). However, some of these have TDS values higher than the recommended values of US EPA (Table 3.5), (Figure 3.5) and some also exceed the MCL of WHO (>1000). Examples are Aman Kot, Pabbi, Shahi Bala and Zahirabad. Among the rivers, Kabul rivers at Warsak Dam is carrying the highest TDS (584, 598, 603, 614 mg/l) which is still lower than the MCL of US-EPA. Considering the MCL of US-EPA, WHO and Pak-EPA, except few samples from the Peshawar lacustrine and Peshawar floodplain aquifers the quality of the water in all the rivers and aquifers of Peshawar basin can be classified as "fresh". However, the few samples of the Peshawar lacucstrine and Peshawar floodplain aquifers in the central part of the basin can be classified as "slightly saline".

Chemical Parameters

2. ANIONS

Sulfate (SO_4)

The concentration of sulfate in groundwater can be caused by the natural deposits of sodium sulfate (glauber's Salt), calcium sulfate (gypsum) and magnesium sulfate (epsom salt). The origin of most sulfate compounds is the oxidation of sulfide ores, the presence of shales or the industrial wastes. Sulfate is one of the major dissolved components of rain. High concentration of sulfate in the drinking water can cause laxative effects when combined with calcium and magnesium. Climate has also important effect on accumulation of sulfate in the groundwater and soil. In arid and semi-arid

region the sulfate may accumulate in surface and groundwater due to low precipitation and inadequate drainage, while in the humid region they are removed by the runoff. According to US-EPA (1978) and WHO (1984), the permissible limit for sulfate in drinking water is 250 mg/l. Sulfate cannot be removed economically from the drinking water. However, it can be substantially removed from water by reverse osmosis.

The SO_4 concentration of both surface and ground waters of the various aquifers of the Peshawar basin are determined during different times of the years 2003 and 2004 and the results are given in the Table 3.6 and the data has been graphically presented in Figure 3.6. The data has also been compared with that of Tariq (2001). It is clear from the data that there is no significant difference in the concentration of SO_4 with the passage of time. Majority of the samples of groundwater (i.e., tube wells and dug wells) and the surface water have SO^{-2}_4 concentrations within the permissible limit (250 mg/l). However, there are certain tube wells and dug wells which are having alarming amount of SO^{-2}_4 in the drinking water, which should be avoided as far as the health hazards are concerned. These include the dug well of S. Umar Baba from Khyber piedmont aquifer, the tube well of Aman Kot from the Peshawar floodsplain aquifer, the tube wells of Akber Pura, Umar village and dug well of Zahirabad from the Peshawar lacustrine aquifer and the dug wells of Darwargai and Ghari Chandan from the Attock-Cherat piedment aquifer. These tube wells and dug wells have SO_4 contents up to > 1300 mg/l and need to be further investigated. This high concentration of sulfate can be attributed to the gypsum and sulfide seams in the localized area. The surface waters from various streams and rivers of the basin have SO_4 contents within the permissible limit.

Chloride (Cl)

Chloride is widely distributed in environment, generally as sodium chloride (NaCl), Potassium chloride (KCl) and calcium chloride (CaCl). The weathering and leaching of sedimentary rocks and soil and dissolution of salt deposits release chlorides into water. Chloride in groundwater can be naturally occuring in deep aquifers or caused by pollution from sea water, brine or industrial or domestic wastes (Davis, 1966).

According to US-EPA (1978) and WHO (1984), the recommended limit of chloride in drinking water is 250 mg/l. Excessive chlorides give the water a salty taste, usually noticeable over 500 mg/l. Chloride also appear to exert a significant effect on the rate of corrosion of steel and aluminum and can, therefore, effect some metals used in water handling system.

The chloride concentrations in the water samples of both surface and ground water from various aquifers of the Peshawar basin have been determined during the months of January and June in 2003 and 2004. The chloride concentrations of years 2003 and 2004 along with that of Tariq (2001) are given in the Table 3.7 and graphically presented in Figure 3.7. No significant change has been noticed in the chloride concentration in both surface and ground water of the various aquifers with the passage of time. Majority of the water samples of the various aquifers of the Peshawar basin are within the permissible limit of 250 mg/l. The water of the Khyber piedmont aquifers are having chloride contents within the permissible limit (>250 mg/l). One tube well of the Aman Kot from the Peshawar flood plain aquifer and one tube well of Akbar Pura and two dug wells of the Regi and Zahirabad from the Peshawar lacustrine aquifer are having the concentration of chloride above the permissible limit. The drinking water of these tube wells and dug wells could be hazardous for the inhabitants of the area. The chloride contents of the surface water are within the permissible limit.

Bicarbonate (HCO_3)

Bicarbonate ions in groundwater are derived from the carbon dioxide in the atmosphere, soil and solution of carbonate rocks which is increasing the alkalinity of water (Davis, 1966). The concentration of bicarbonate varies in rainwater (< 10 mg/l) and groundwater (>200 mg/l). If pH is less than 4.5 it causes the conversion of bicarbonates and if pH is over 8.2 then bicarbonates form carbonate (Davis, 1966). The high concentration of bicarbonate is usually considered with high pH, hardness and high dissolved solids and has adverse effects on plumbing systems especially in hot water system (water heaters, boilers, heat exchangers etc.) where excessive scale reduce the

transfer of heat to the water, thereby resulting in greater power consumption and increased cost. According to US-EPA (1978) and the WHO (1984) the maximum limit of HCO_3 in the drinking water is 250 mg/l.

The bicarbonates concentration in water samples of both surface and groundwater of various aquifers of the Peshawar basin, collected during the months of January and June of the years 2003 and 2004 along with carbonate contents reported by Tariq (2001) from the same site, are given in the Table 3.8 and the data is graphically presented in Figure 3.8. The data clearly show that there is no significant change in the concentration of bicarbonates in both surface and groundwater of the Peshawar basin with the passage of time. Majority of the water samples are having the bicarbonate contents within the permissible limit (i.e., 250 mg/l). However, some of the tube wells and dug wells in the Khyber piedmont aquifer (i.e., from Jamrud Road, Shabqadar, Matta Mughal Khel, Abazai and S. Umer Baba), in the Peshawar floodplain aquifer (i.e., from Kukar, Mandezai Srikh, Kandi Hayat, Mathra and Takht Bhai), in the Peshawar lacustrine aquifer (i.e., from Akbar Pura, Bashirabad, Shiggi, Regi, Pawaka, Hazar Khawani, Wadpagga, Zahirabad, Urmar Bela and Shahbaz Ghari) and in Attock-Cherat piedmont aquifer (i.e., from Dag Besud) have high concentration (> 250 mg/l) of bicarbonate. The spring waters from Malakand Pass, Dargai and Persai are have high concentration of bicarbonates. This high concentration can be attributed to the percolation of this water through limetrace /dolomite. Among the surface water sample collected from Kasul river at Nowshera bridge has bicarbonate contents above the permissible limit. The high concentration of bicarbonate in these tube wells and dug wells is localized phenomenon and, therefore, the whole aquifer systems in the basin is not affected.

CATIONS

Various cations, including light elements (i.e., Ca, Mg, Fe, Na, K, Mn) and heavy metals (i.e., Cu, Pb, Zn, Ni, Cr, Co, Cd) have been determined in the surface and groundwater of Peshawar basin and the detail is given below.

a. Light Elements

Calcium (Ca)

Calcium is an important constituent of water which is contributed by various rocks and minerals in to the aquifer. Calcite, dolomite and gypsum bearing rocks such as limestone and dolomite are of greater importance in this regard. Calcium is also present in the form of absorbed ions on negatively charged minerals in the surface soil and rocks. The calcium content in groundwater largely depends on the solubility of calcium carbonate, sulfate and rarely chloride. In alluvial and unconsolidated sediments the primary calcium source is usually present in various minerals and soils fractions (Driscoll, 1986; Balke, 1988). According to US-EPA (1978), the calcium content in the drinking water should not increase 75 mg/l. Water with very low Ca (i.e., low hardness) if used for long time by the inhabitants of the area can cause the cardiovascular disease, especially in the men and hence increase the mortality rate in the area.

Calcium concentrations of surface and groundwater from the different aquifers of the Peshawar basin are presented in Table 3.9 and are also graphically expressed in Figure 3.9. The calcium content of the majority of subsurface water samples from Peshawar basin falls in the normal range described by Maximum Contaminants Level (MCL, 75 mg/l) of US Environmental Protection Agency, (1978). However, some of the samples collected from tube wells show high concentration e.g., the tube well of Danishabad in the Khyber piedmont aquifers shows calcium concentration as 80 mg/l in January 2003, 101mg/L in January 2004, 93 mg/l in June 2003, and 85 mg/l in June 2004. Similarly a tube well sample from Akbarpura lying in the Peshawar lacustrine aquifers also show higher Ca (>80 mg/l) than allowed by the MCL of US-EPA (1978). Most of the dug wells in the basin indicate Ca content below the permissible limits of US-EPA (1978). However, on the basis of a local comparison with each other the Ca content in the dug well samples of Kot in Peshawar floodplain aquifer and Shahbaz Ghari in the Peshawar lacustrine aquifer exceed the permissible limit of US-EPA (1978). The surface water of the basin has Ca content within the permissible limit (Table 3.9).

Magnesium (Mg)

Magnesium is important constituent of water, is mainly contributed to the surface and ground water system by the Mg-rich sedimentary (dolomite and gypsum) and mafic and ultramafic igneous rocks. Magnesium concentration in the water system is generally low depending on the nature of the rocks where from it percolates or flows. However, water in contact with dolomite or with magnesium-rich evaporites and mafic and ultramafic rocks has very high concentration of Mg. Hardness of water is also characterized by the presence of calcium and magnesium. Magnesium content should not exceed 50 mg/l in water to be used for domestic and drinking purpose (US-EPA, 1978). However, very low concentration of Mg in the drinking water may increase the risk of cardiac arrhythmia and hence increase in the mortality rate (Rylander et al., 1991).

Magnesium concentration in the surface and ground water of various aquifers of Peshawar basin for the years 2003 and 2004 along with that of Tariq (2001) is given in Table 3.10. The data has also been graphically presented in Figure 3.10 for comparison. It is evident from Table 3.10 and Figure 3.10 that no significant change in the magnesium concentration in the surface and ground water of the various aquifers of the basin has been recognized with the passage of time. However, most of the groundwater samples from Peshawar basin are classified as normal with magnesium content within the permissible limit (<50 mg/l) of US-EPA (1978). Mg in majority of the waters of the tube wells of Peshawar basin are within the permissible limit. However, high magnesium content in the tube wells of Kandi Hayat in the Peshawar floodplain aquifer and Gulshan R. colony, Tehsil Gunj, Gulbahar Ni. 2 and Hazar Khawani in the Peshawar lacustrine aquifer exceeds the MCL of US-EPA (1978). Most of the dug wells of the basin have Mg content within the permissible limit. However, dug wells of S. Umar Bala, in the Khyber piedmont aquifer, Shagai, Pajagi, Surezai, Phander, Wadpagga, Zahirabad and Urmar Bala in the Peshawar floodplain aquifer and Darwazgai, Adezai, Aimal Chabutra and Ghari Chandan in the Attock-Cherat piedmont aquiferhave Mg contents above the permissible limit of US-EPA (1978). The higher magnesium concentration in all these dug wells and certain tube wells can be attributed to the local occurrence of soil derived

from the dolomitic-limstone or the ultramafic rocks surrounding the Peshawar basin. The surface water in the rivers, streams and springs of the Peshawar basin is having Mg concentration within the permissible limit.

Sodium (Na)

Sodium is an important member of the alkali metals and is the significant constituent of water. It is generally contributed in to the water system by the weathering of feldspar in the igneous rocks by mixing with salty connate water from deep percolation of marine origin and by the precipitation of sodium salts in the arid and semi-arid region (Karanth, 1993). It is present in the form of carbonate, bi-carbonate and chloride compounds in surface and subsurface water at the pH of 9 or more. The concentration of sodium and chloride increase with the increase of total dissolved solids. Sodium content is relatively high in the deep aquifer as compare to the shallow aquifer because of the very low groundwater velocity in the deep aquifer (Driscoll, 1986). The most significant effect of high sodium in water is related to irrigation water because Na ions replace the calcium and magnesium cations in a base-exchange reaction and forming alkaline soil considered impaired for the agriculture uses. High concentration of sodium cause disruption in the blood chemistry which has serious impacts on human health and cause hypertension (Craun, 1984).

Sodium concentration in the water samples of various aquifers of the Peshawar basin, collected during January and June of 2003 and 2004, along with the Na concentration from the same site reported by Tariq (2001) are shown in Table 3.11 and graphically presented in Figures 3.11. It is clear from the Table 3.11 and Figure 3.11 that there is no significant increase or decrease in the concentration of Na in the samples from the same site with the passage of time. The Na concentration in the samples of same sites reported by Tariq (2001) has greater similarity with that of the present study. Most of the tube well samples from the various parts of Peshawar basin have sodium content below the MCL (<50 mg/l) of US-EPA (1978). However, the water samples of tube wells from Kafir Dheri in the Khyber piedmont aquifer, Rajjar, Turangzai, Prang and Aman Kot in

the Peshawar floodplain aquifer, Akbar Pura, Pabbi, Urmar village in the Peshawar lacustrine aquifer and Dag Basud in the Attock-Cherat piedmont aquifer have Na concentration above the MCL of US-EPA (1978). Majority of the waters samples from the dug wells are also have Na below the MCL of US-EPA (1978). However, there are many dug wells of the Peshawar basin which are having high concentration (>50 mg/l) of Na. These are the dug wells from S. Umar Baba in the Khyber piedmont aquifer, from Shiggi, Mulazai, Regi, Shahi Bala, Kafir Dheri, Hazar Khawani, Wadpagga, Zahirabad, Urmar Payan, Azakhel Bala and Shahbaz Ghari in the Peshawar lacustrine aquifer and from Darwazgai, Adezai, Aimal Chabutra, Ghari Chandan and Musha Ghar in the Attock-Cherat piedmont aquifer. The surface water of rivers, streams and springs has Na concentration withing permissible limit. It is noted that the number of samples having high Na than the permissible limit are greater at shallow levels (dug wells) than at deeper levels. As stated in the case of calcium and magnesium these higher concentrations may be related to the high sodium content of the host Quaternary deposit. Higher sodium in dug wells than in tube wells may indicate the transportation of such cation from lower to higher levels and their concentration at shallow depth as may be expected from the history of water logging and salinity in the recent history of Peshawar basin due to the concentration of Warsak Dam. Several projects have been carried out to tackle the problem of water logging and salinity in these areas have been reduced to greater extent. However, evidence of salt concentration on surface and at shallow depth still remains in the area (Khan, et al, 1997; Bundschuh, 1992). All the major rivers of Peshawar basin have Na within permissible limit.

Potassium (K)

Potassium in the earth crust is generally contributed from the K-bearing minerals such feldspars, micas and clay minerals. It is relatively less abundant in water due to its very low solubility as compared to the other cations. According to Golditech (1938), potassium is present in the groundwater due to decomposition of clay mineral. The MCL of Potassium in the drinking water is considered as 10 mg/l (US-EPA, 1978; WHO, 1975).

The concentration of potassium in water samples from various aquifers of the Peshawar during the months of January and June of 2003 and 2004 along with the potassium concentration reported by Tariq (2001) from the sample has been given in Table 3.12 and graphically presented in Figure 3.12. It is clear from the Table 3.12 and Figure 3.12 that no significant change in the concentration of K in the various aquifers of the Peshawar basin with the passage of time. The concentration of K determined during the present study is also in agreement with that of Tariq (2001). Almost all the water samples, except from few dug wells, are having K concentration within the permissible limit. Few dug wells of the Peshawar lacustrine aquifer (i.e., the dug wells from Surazai, Phandu, Hazar Khawani and Wadpagga) are having alarming amount of Potassium (>20 mg/l) in regard to health hazard and, therefore, need further investigations. The surface water of the Peshawar basin is having relatively very low K concentration (Table 3.12). The low concentration of K as compared to that of Na in the ground water of Peshawar basin (Tables 3.12 & Fig. 3.12) suggest that NaCl has played a major role in transportation and concentration due to water logging and salanity, especially in the central part of the basin where the lacustraine aquifer is present.

Iron (Fe)

Iron is more abundant in the earth crust and is an important cation present in minor or trace amount in water. Iron normally occurs in water as ferrous or ferric iron. According to US-EPA (1978), its concentration upto 300 mg/l is the safe limit for the drinking water.

Iron concentration in the surface and groundwater of the various aquifers of the Peshawar basin, collected during the months of January and June of 2003 and 2004, is given in Table 3.13 along with the iron concentration reported by Tariq (2001). The data is graphically presented in Figure 3.13. It is evident from this table and figure that the concentration of iron remains more or less the same in different times of the year and no significant change is noticed with the passage of time in the concentration of iron from the same localities. The iron concentration in almost all the samples, except two, from surface and ground water of the basin is below the permissible limit (300 mg/l) of US-

EPA (1978). One sample from the tube well of Hayatabad Phase-3 in the Khyber piedment aquifer and one sample from the bore hole well of Jehangira area in the Attock-Cherat piedment aquifer are having high concentration (> 600 mg/l) of iron. This high concentration in the tube well water of Hayatabad Phas-3 and the bore hole well water of Jehangira seems to be local and related to rusting from the pumping facility. This interpretation is based on the sharp contrast of these high value data with the rest. On the basis of iron concentration the surface and groundwater from Peshawar basin can be classified as safe for drinking purposes.

b. Heavy and trace elements

Heavy metals (i.e., Cu, Pb, Zn, Ni, Cr, Cd, Co) occur in significant amount in the rocks and ores. Their concentration in rocks and soils range from about 10.0 to 100 mg/l. However, these concentration in the surface and groundwater are usually well below the amount that could potentially occur based on solubility. Consequently these metals, concentration in the geological material generally limits their concentration in groundwater. There are many anthropogenic sources of these metals which include the alloys, paints pigments, electroplating, batteries, automobile parts, coatings and electrical wiring. Copper and zinc are also used is insecticides or fungicides. All these metals are present in industrial waste and sewage sludges. These metals have little mobility in soil and anthropogenic impact to surface and groundwater are small. To determine the quality of the surface and groundwater of the Peshawar basin, the water samples collected from various localities have been analyzed for heavy metals and the results are discussed below.

Copper (Cu)

Copper contamination in the surface and groundwater can be contributed from both geogenic and anthropogenic sources but the anthropogenic sources can be held responsible for the major toxicity of copper in the drinking water. This toxicity can be originate from the, copper pipes, industrial waste, metallurgical processes, coal combustion, the water soluble salts and compounds (e.g., $CuSO_4$., H_2O) used in the agriculture as fungicides and bactericides and also from the copper made cooking

utensils (Dissanayake & Jayatilaka 1980; Luca shev et al, 1975). The contamination due to the grogenic sources usually occur from the percolating of groundwater through sulfide zones.

According to US-EPA (1978), the maximum contamination level of copper in the drinking water is 1000 μg/l. It is considered as essential element if present in permissible amount however, its toxicity can cause number of health problems in the community. These include digestive disturbances (nausea, vomiting, hemorrhagic gastritis) and liver, spleen and kidney damage (Patty, 1962; Baranowska, 1993; Berndt et a., 1993).

Copper concentration in the water samples, collected during the in months of January and June of 2003 and 2004, from various aquifers of Peshawar basin along with the data from the same sites reported by Tariq (2001) given in Table 3.14 and graphically presented in Figure 3.14. It is clear for these tables and figures that there is no significant change in the concentration of copper in the various aquifers of the Peshawar basin with the passage of time. However, very little increase in the amount of copper has been observed in certain samples which could be attributed to the instrumental error. The copper concentration in the aquifers of Khyber piedmont, Peshawar floodplain, Peshawar lacustrine and Attock Cherat piedmont is ranging from 1 to 36 mg/l, 1 to 69 mg/l , 1 to 48 mg/l and 1 to 35 mg/l respectively. The data show that both surface and groundwater of various aquifer of Peshawar basin have copper concentration within the permissible limit (1000 mg/l) of US-EPA (1978) and pose no environmental threat as for as the copper concentration in the waters of the Peshawar basin is concerned.

Lead (Pb)

Lead is naturally occurring element present in the earth crust as a chemical constituent of sulfide ores and other rocks. Its contamination in the drinking water can be caused due to the percolation of water through the sulfide zone in the areas having sulfide deposits or from the anthropogenic sources like storage batteries, paints, ink, ceramics gasoline and automobile industries (Robinson 1978). Environmental contamination of

lead in metropolitan area arises primarily from automobile emission and industries and sewage sludge (Sommers et al., 1976) and coal combustion and commercial fertilizers (Stenstrom & Vather, 1974, Mortvedt & Giordano, 1977; Williams, 1977). The US-Environmental protection Agency consider this metal to be highly toxic metal and is a major public health threat. According to US-EPA (1978), the maximum contamination level for lead is 50μg/l in the drinking water. If it is present above this safe limit in the drinking water, it can cause damage to both adults and children, although in the children the effects tend to be greater (i.e., mental retardation, kidney damage, delayed development, hypertension, weight loss neuromuscular disfunction and encephalopathy, carcinogenic renal tumors etc.) as is reported by various workers (Georgians et al., 1950; Keho, 1972; NIOSH, 1972; IARC, 1976; Angle, 1964).

The concentration of lead in the water samples collected during the months of January, and June during the year 2003 and 2004 from various aquifers of Peshawar basin is given in Table 3.15 along with the Pb concentration from the same localities by Tariq (2001). The data is also graphically represented in the Figure 3.15 for comparison. It is clear from the Table 3.15 and figure 3.15 that there is no significant increase or decrease of Pb concentration in the waters of all the aquifers of the Peshawar basin with the passage of time from 2001 to 2004. The Pb concentration is ranging from 1 to 43 μg/l, from 1 to 48 μg/l, from 1 to 71 μg/l and from 1 to 155 μg/l in the aquifer of Khyber piedmont, Peshawar floodplain, Peshawar lacustrine and Attock-Cherat piedmont respectively. All the water samples, except few, have Pb concentration within the permissible limit. However two samples from the tube well of the Gulbahar No.2 (up to 71 μg/l) from Peshawar lacustrine aquifer and the two from Mattani (up to 155 μg/l) and Chapri (up to 58 μg/l) from Attock-Cherat piedmont aquifers are having Pb contents up to hazardous level and need to be further investigated. The contaminations seem to be local either from the pipes etc. The surface water of the basin through having Pb concentration within the permissible limit but near Nowshera and Khairabad the Pb concentration in the Kabul river increase multifold and also the Pb contents of Indus water show elevated concentration. This indicates that the water of Kabul is receiving effluents from the industries and other waste of the Peshawar city.

Nickel (Ni)

Nickel is the dominant metal present in the ultramafic rocks and ores in the earth crust. It is not affected by water but is slowly attacked by dilute hydrochloric acid or sulfuric acid and is readily attacked by nitric acid. The primary natural source of nickel in the drinking water is leaching of nickel from ultramafic rocks and the soils derived from these rocks. The anthropogenic sources include production of electroplating, high grade steel alloy, fabrication, electronic component, automobiles, batteries, coins, jewellery, surgical implants, kitchen appliances, sinks and utensils (ATSOR, 1996). No safe limit of Ni for drinking water is recommended by the US-EPA (1978), however, the safe limit of 10μg/l has been recommended by Nielsen et al. (1999) and Clemente et al. (1980). Nickle has numerous toxic effects such as its contact with skin may cause a dermatitis disease and its inhalation can cause lung cance (Stamer et al., 1985). It is considered less toxic to the aquatic life than several other metals, although its toxicity depends on the pH, synergistic effects and other factor. Nickel may enter the aqueous environment and then to soil through discharges from metal ore smelting, sewage sludge, nickel salts, waste incineration and burning of fossil fuels (Stamer et al., 1985).

The concentration of nickel was determined both in tube wells, dug wells, and rivers water samples from various aquifers of Peshawar basin and the results along with that of Tariq (2001) are presented in Table 3.16. The data is graphically presented in Figure 3.16 for comparison. It is clear from this table and figure that there is no significant change of Ni concentration in the various aquifers of Peshawar basin with the passage of time. Majority of tube wells, dug wells, rivers and spring samples are show nickel contents below the permissible limit (<12μg/l). Some of the tube wells and dug wells have high concentration of Ni. These include the tube wells from Danishabad, Bara, Urmer village and the dug wells from Shahbaz Ghari and Musha Ghari. The surface water of the Peshawar basin has Ni concentration within the safe limit. The high concentration of Ni in some of the samples could be local either due to pipes or sewerage

waste or may be due to leaching of mafic and ultramafic phases in the Quaternary sediments.

Chromium (Cr)

Chromium and its salts are used in the leather tanning industry the manufacturing of catalysts, pigment and paints, fungicides, the ceramics and glass industry, and in photography and for chrome alloy and chromium metal production, chrome plating and corrosion control (US-EPA, 1987). The distribution of compounds, containing chromium (iii) and chromium (vi) depends on redox potential, the pH, the presence of oxidizing or reducing compounds, the kinetics of the redox reactions, the formation of chromium (iii) complexes or in soluble chromium (iii) salts, and the total chromium concentration. The average concentration of Cr in the rain water is in the range of 0.2-1 μg/l. Natural Cr concentration in sea water is usually 0.04-0.05 μg/l and in surface water it is approximately 0.5-2 μg/l (Shiller & Boyle, 1987). Chromium causes a nephritis and glycosuria diseases. The chromites dust produces skin ulcers and nasal mucosum (Major, 1992). However, chromium, present in safe limit in drinking water, is essential in human nutrition to maintain the normal glucose metabolism. According to WHO (1984) the permissible limit of Cr in drinking water is 50 μg/l.

Chromium concentration in the drinking waters of the various aquifers of the Peshawar basin during different times of the years 2003 and 2004 are given in Table 3.17 and graphically presented in Figure 3.17. It is clear from the table and figure that there is no significant variation in the chromium concentration with the passage of time in the various aquifers of the Peshawar basin. Most of the samples of drinking waters of the various aquifers of the basin are below the permissible limit of 50 mg/l. Chromium varies from 1 to 30μg/l, 1 to 179 μg/l, 1 to 155μg/l, and 1 to 96 μg/l in the Khyber piedmont aquifer, Peshawar flood plain aquifer, Peshawar lacustrine aquifer and Attock-Cherat piedmont aquifer respectively. All the water samples of the Khyber piedmont aquifer are having chromium concentration within the permissible limit. In the Peshawar floodplain aquifer the water samples of the tube wells of Turangzai and Takht Bhai have high

concentration (up to 84μg/l) of chromium. In the Peshawar lacustrine aquifer, water samples of the tube wells of Landi Arbab, Tehsil Gunj, Urmar village and Aza Khel Bala and those of dug wells from Surezai, Urmar Bala, Urmar Payan and Azakhel Bala are having chromium concentration above the permissible limits. In the Attock-Cherat piedmont aquifer the water samples of the dug wells from Darwazgai and Speen Khak have chromium above the permissible limit. The high concentration of Cr in tube wells and dug wells indicate the localized source of enrichment of chromium in these waters and have not the effected the various aquifers in large scale. This contamination need to be further investigated as the water of these areas could be hazardous for the inhabitants.

The surface water is generally having chromium below the permissible limit. However, the Kabul river at two localities i.e., Sardaryab and Shah Alam are having very high concentration (up to 179 μg/l) of Cr. One stream water at Pir Bala is also having Cr above the permissible limit. The high concentration of Cr in the Kabul river and the stream water at the above mentioned localities is due to the effluents added to the river and stream water from the municipality waste and leather industry. The high concentration of Cr in the river Kabul and other streams could be hazardous for the aqutic life and also cause contamination in the Khyber piedmont aquifer.

Cadmium (Cd)

Cadmium occurs naturally in zinc, lead, copper and other ores which can serve as sources to ground and surface waters, especially when in contact with soft acid waters. Major industrial releases of cadmium are due to waste streams and leaching of landfills and a variety of operations that involve cadmium or zinc. Cadmium can be released in drinking water from the corrosion of some galvanized plumbing and water main pipe material. The average concentration of cadmium in the earth crust is 0.15 – 0.20 mg/l (Fleisher et al., 1974). Cadmium is used as alloys, in auto industry, electroplating, in pigments, as stabilizers for polyvinyl plastics and in Ni-Cd batteries (Forstner, 1980). It can be used in many industries and significant amounts of cadmium may be released in the atmosphere from combustion of coal, oil, paper and urban organic trash. According to

Chino and Mori (1982), cadmium concentration of domestic waste waters from lavatory, kitchen, laundry, and bath is about 38 μg/l, 0.04 μg/l, 0.6 μg/l and 0.5 μg/l respectively. Cadmium arising from phosphate fertilizers and sewage sludge may reach to man through the food chain (Fleisher et al., 1974). According to US-EPA (1978), if people are exposed to cadmium for short periods of time, it can cause the health hazards such as nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury convulsions, shocks and renal failure. Long term cadmium exposure can cause certain effects such as kidney, liver, bone and blood damage (Kranjc et al., 1987; Oldiges et al., 1989; JECFA, 2000). The US-EPA (1978) the MCL for cadmium in drinking water is 10 μg/l while the WHO (1984) has the MCL as 5 mg/l.

The cadmium concentration in the surface and ground waters from the various aquifer of the Peshawar basin are determined during different times of the years 2003 and 2004 and the results are given in the Table 3.18 and the data has been graphically presented in the Figure 3.18. It is clear from the table and figure that no significant change in the Cd concentration has been noticed with the passage of time. The Cd concentration in both surface and ground water of all the aquifers of the Peshawar is within the permissible limit and have no health hazards related to cadmium can be expected in the region.

Cobalt (Co)

Cobalt is a hard ferromagnetic slivery white lustrous and brittle element. It is chemically active, forming many compounds. It is stable in air and unaffected by water, but is slowly attacked by dilute acids. Cobalt is used in many alloys, in magnetic recording media, as catalyst for petroleum and chemical industries, as drying agents for paints and inks. Cobalt is of relatively low abundance in the Earth crust and in natural waters from which it is precipitated as the highly insoluble cobalt sulfide.

Cobalt consumption is beneficial for human being because it is a part of vitamin B_{12}, which is essential for human health (Adriano, 1986). Low level of cobalt can cause

nutritional diseases in animals, known as the Bush sickness in cattle and sheep. About 0.07 mg/l of cobalt is essential in nutrition to maintain the normal health of animals. From various reports it is clear that cobalt is relatively nontoxic to animals and human being but may produce carcinogenic effects and also cause lungs, problems vomiting and nausea, vision and heart ailments if it taken in high quantity. The cobalt concentrations have been determined in the water samples of both surface and ground water of different locations of Peshawar basin during different times of the years 2003 and 2004. It is noticed that all the samples have Co contents below the detection limit (>1μg/l), therefore, the Co concentration has not been given in Table. Due to very low concentration of cobalt in the surface and ground water of the basin, no drastic health related hazards of Co could be observed in the ecosystem of the basin.

Table 3.1. The Maximum Permissible Level (MCL) for the drinking water.

Characteristics	MCL of US-EPA	MCL of WHO	MCL of EPA, Pakistan
Chloride	250mg/l	250mg/l	250mg/l
Bicarbonate	250mg/l	250mg/l	250mg/l
Sulfate	250mg/l	250mg/l	250mg/l
Calcium	75mg/l	75mg/l	75mg/l
Sodium	50 mg/l	50 mg/l	50 mg/l
Potassium	10 mg/l	10 mg/l	10 mg/l
Magnesium	50 mg/l	50 mg/l	50 mg/l
Iron	300ug/l	300ug/l	300ug/l
Total dissolved solid (TDS)	1000 mg/l	1000 mg/l	1000 mg/l
pH	7.0-8.0	6.5-8.5	6.5-9.0
Copper	1000 ug/l	1000 ug/l	1000ug/l
Zinc	5 mg/l	5 mg/l	5mg/l
Lead	50ug/l	50ug/l	50ug/l
Chromium	50ug/l	50ug/l	-
Cadmium	10ug/l	5ug/l	-
NO_3	10 (as N)	-	-
Aluminum	0.2mg/l	0.2mg/l	-
Manganese	300-50ug/l	-	-
Nickel	20ug/l	-	-
Cobalt	-	-	-

Source: US-EPA (1978); WHO (1984).

Table 3.2. Temperature (°C) of the surface and groundwater samples of Peshawar basin during different times

SampleNo.	Area	Type of Sample	T °C Jan 03	T °C Jan 04	T °C June 03	T °C June 04	Average values Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	24.1	21.1	22.2	22.2	21.1
PBW2	WAPDA Colony	Tube Well	20.5	22.2	23.4	20.6	19.8
PBW3	Tehkal Bala	Tube Well	22.3	22.4	23.5	22.3	23.3
PBW4	Jamrud Road	Tube Well	20.9	21.5	22.8	23.5	21.3
PBW5	Industrial Estate	Tube Well	21.2	22.2	22.9	23.4	22.8
PBW6	Hayatatab Phase-3	Tube Well	19.8	20.5	20.0	22.8	19.6
PBW7	Danish Abad	Tube Well	23.5	23.5	24.6	23.4	25.2
PBW8	Bara	Tube Well	22.9	22.9	23.3	23.6	23.1
PBW9	Sar Band	Tube Well	22.7	22.8	23.2	22.9	22.9
PBW10	Shabqadar	Tube Well	24.5	20.5	23.5	22.8	25.0
PBW11	Matta Mughal Khel	Tube Well	24.3	23.8	25.5	25.4	25.0
PBW12	Abazai	Tube Well	20.3	20.4	20.0	23.2	19.0
PBW13	Tangi	Tube Well	20.1	20.6	19.5	22.2	20.0
PBW14	S. Umer Baba	Dug Well	19.5	20.6	20.2	22.1	18.4
PBW15	Hinder Kassi	Dug Well	17.7	19.3	18.3	20.2	16.8
PBW16	Jamrud Road	Hand Pump	23.9	22.1	24.3	21.1	24.4
PBW105	W. Dam Kabul river	Warsak Dam	14.2	15.6	23.0	22.9	13.5
PBW106	W. Dam Kabul river	Warsak Dam	14.9	18.3	14.8	23.1	12.3
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	28.0	22.4	24.2	24.3	25.0
PBW18	Mathra	Tube Well	18.0	18.8	18.8	19.8	19.7
PBW19	Khazana	Tube Well	23.0	22.5	23.1	22.8	23.0
PBW20	Kukar	Tube Well	24.1	20.5	23.9	23.4	24.2
PBW21	Mandezai Srikh	Tube Well	20.5	20.2	20.1	22.2	20.0
PBW22	Rajjar	Tube Well	20.3	19.8	19.5	21.3	20.0
PBW23	Turangzai	Tube Well	20.5	21.6	21.5	22.6	20.0
PBW24	Prang	Tube Well	20.2	18.7	19.7	21.8	22.0
PBW25	Kandi Hayat	Borehole well	21.3	21.5	22.1	23.2	22.0
PBW26	Aman Kot	Tube Well	23.0	20.4	22.9	23.1	24.0
PBW27	Mathra	Dug Well	18.1	18.5	17.8	18.4	18.2
PBW28	Charpariza	Dug Well	21.2	20.1	20.0	21.3	21.3
PBW29	Khazana	Dug Well	22.3	19.6	22.2	20.4	22.3
PBW30	Adezai	Hand Pump	24.3	22.6	23.3	22.5	24.3
PBW31	Mandazar	Dug Well	18.8	18.8	18.6	21.6	19.0
PBW32	Kot	Dug Well	19.4	19.4	19.2	22.0	19.0
PBW33	Aman Kot	Dug Well	20.3	20.4	22.4	23.1	22.0
PBW34	Takht Bhai	Hand Pump	20.1	22.1	19.8	23.5	20.0
PBW35	Pir Baba	Stream	29.4	17.9	17.1	22.3	17.0
PBW36	Pir Baba	Stream	30.1	20.2	18.8	28.3	16.0

Temperature (°C) of the surface and groundwater samples of Peshawar basin during different times

SampleNo.	Area	Type of Sample	T °C Jan 03	T °C Jan 04	T °C June 03	T°C June 04	Tariq (2001)
PBW37	Pir Baba	Stream	27.3	18.5	18.2	25.6	19.0
PBW48	Pir Baba	Stream	28.9	20.3	18.8	27.2	18.0
PBW39	Pir Baba	Stream	28.2	18.6	17.8	26.3	18.0
PBW40	Pir Baba	Stream	30.1	18.2	17.5	25.4	17.0
PBW107	Sardaryab	Kabul River	24.3	18.6	18.3	25.4	21.5
PBW108	Naguman	Kabul River	23.9	17.9	17.8	26.5	18.0
PBW109	Shah Alam	Kabul River	24.1	18.6	18.9	29.4	19.0
PBW110	Swat River	Kabul River	24	20	19	29	19
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	22	22	20	23	20
PBW42	Forest Colony	Tube Well	21	21	21	22	20
PBW43	Shahi Bala	Hand Pump	24	22	20	23	23.5
PBW44	Hashim Kili	Tube Well	23	22	20	26	19.1
PBW45	Gharibabad	Tube Well	23	22	21	26	22.7
PBW46	Badh Ber	Tube Well	22	22	21	25	21.3
PBW47	Sorezai	Tube Well	22	21	20	23	22.3
PBW48	Jahangir Abad	Tube Well	24	22	21	24	22.3
PBW49	Landi Arbab	Tube Well	23	21	21	23	21.8
PBW50	Saddar Stadium	Tube Well	22	21	21	23	22.4
PBW51	Defence Colony	Tube Well	22	22	22	23	22.9
PBW52	Dabgari Shuba	Tube Well	22	21	20	22	21.4
PBW53	Gulshan R. Colony	Tube Well	24	22	23	24	21.02
PBW54	Tehsil Gunj	Tube Well	23	22	22	24	21.9
PBW55	Gulbahar No.2	Tube Well	24	22	22	23	22.6
PBW56	Hazar Khawani	Tube Well	22	20	19	23	21.9
PBW57	Wadpagga	Tube Well	21	19	19	23	22.5
PBW58	Akbar Pura	Tube Well	23	19	18	23	23
PBW59	Pabbi	Tube Well	23	20	20	24	24.6
PBW60	Urmar Village	Tube Well	22	22	19	25	20.3
PBW61	Aza Khel Bala	Tube Well	25	23	20	25	27
PBW62	Bashirabad	Dug Well	20	19	19	22	19
PBW63	Shiggi	Dug Well	30	19	19	22	18
PBW64	Shiggi	H. Pump	20	19	14	22	19
PBW65	Pajagi	H. Pump	24	20	21	23	21
PBW66	Mulazai	Dug Well	20	20	19	24	18
PBW67	Regi	H. Pump	22	20	20	24	20
PBW68	Shahi Bala	Dug Well	20	18	18	23	16
PBW169	Kafir Dheri	Dug Well	20	19	19	23	16.9
PBW70	Pawaka	Bore Well	24	20	22	23	21.6
PBW71	Bazeed Khel	H. Pump	23	22	22	25	22
PBW72	Surezai	Dug Well	22	20	19	26	19
PBW73	Hazar Khawani	H. Pump	22	20	20	27	21.9

Temperature (°C) of the surface and groundwater samples of Peshawar basin during different times

SampleNo.	Area	Type of Sample	T °C Jan 03	T °C Jan 04	T °C June 03	T°C June 04	Tariq (2001)
PBW74	Phandu	Dug Well	20	19	18	23	18
PBW75	Hazarkhawani	Dug Well	22	20	19	22	17.8
PBW76	Wadpagga	Dug Well	20	18	18	23	17.6
PBW77	Zahirabad	Dug Well	20	20	20	25	20.3
PBW78	Urmar Bala	Dug Well	24	31	21	25	25.2
PBW79	Urmar Payan	Dug Well	22	21	21	22	22.4
PBW80	Azakhel Bala	Dug Well	23	21	22	23	24
PBW81	Shahbaz Garhi	H. Pump	20	19	19	33	20
PBW99	Malakand Pass	Spring	19	17	19	22	19
PBW100	Dargai	Spring	20	18	17	25	16
PBW101	Pirsai	Spring	22	18	19	22	16
PBW102	Nowshera Bridge	Kabul River	22	22	17	23	16.4
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	26	20	22	27	26
PBW83	Adezai	Tube Well	25	20	20	25	24.9
PBW84	Nowshera cantt.	Tube Well	22	20	20	24	24.6
PBW85	Jaluzai	Tube Well	24	23	20	24	24
PBW86	Dag Besud	Tube Well	24	21	23	23	25.4
PBW87	Manki Sharif	Tube Well	25	21	21	23	26
PBW88	Akora Khatta	Tube Well	25	22	20	25	25
PBW89	Jehangira	Bore Well	23	20	22	25	25
PBW90	Darwazgi	Dug Well	20	20	19	24	20.8
PBW91	Adezai	Dug Well	22	22	19	24	21.6
PBW92	Aimal Chabutra	H. Pump	21	20	20	23	19
PBW93	Garhi Chandan	Dug Well	21	20	20	25	20.4
PBW94	Aza Khel	Dug Well	22	22	20	24	20.6
PBW95	Taila Band	Dug Well	24	21	23	23	24
PBW96	Chapri	Dug Well	25	19	23	22	26
PBW97	Speen Khak	Dug Well	22	19	20	25	22
PBW98	Musha Ghar	Dug Well	23	22	20	24	23.4
PBW103	Khairabad	Kabul River	24	20	22	24	23
PBW104	Attock	Indus River	21	20	20	24	20

Table 3.3. pH of the surface and groundwater samples of Peshawar basin during different times

Sample No	Area	Type of Sample	pH Jan 03	pH Jan 04	pH June 03	pH June 04	Tariq (2001)
Khyber Piedmont Aquifer Khyber piedmont aquifer							
PBW1	Kafir Dheri	Tube Well	8.9	8.8	8.5	8.8	8.1
PBW2	WAPDA Colony	Tube Well	8.9	8.8	8.8	8.9	8.6
PBW3	Tehkal Bala	Tube Well	4.5	8.7	5.2	5.3	4.8
PBW4	Jamrud Road	Tube Well	8.3	7.8	7.9	8.7	8
PBW5	Industrial Estate	Tube Well	9.9	9.8	10.1	9.8	9.9
PBW6	Hayatatab Phase-3	Tube Well	6.7	6.8	6.5	6.6	6.3
PBW7	Danish Abad	Tube Well	8	8.2	7.8	7.9	8
PBW8	Bara	Tube Well	5.6	5.8	5.1	5.2	5.4
PBW9	Sar Band	Tube Well	7.6	7.7	7.2	7.3	7.5
PBW10	Shabqadar	Tube Well	7.3	7.5	7.3	7.4	7
PBW11	Matta Mughal Khel	Tube Well	7.3	7.4	7.1	7.2	7.2
PBW12	Abazai	Tube Well	7.2	7.3	7.3	7.4	7.3
PBW13	Tangi	Tube Well	7.3	7.4	7.1	7.3	7.3
PBW14	S. Umer Baba	Dug Well	8.8	8.9	8.7	8.9	8.5
PBW15	Hinder Kassi	Dug Well	8.5	8.6	8.3	8.6	8
PBW16	Jamrud Road	Hand Pump	6.1	6.3	5.9	5.8	6
PBW105	W. Dam Kabul river	Warsak Dam	9.5	9.6	9.2	9.6	8.9
PBW106	W. Dam Kabul river	Warsak Dam	9.5	9.4	9.6	9.7	8.9
Peshawar Floodplain Aquifer Peshawar floodplain aquifer							
PBW17	Pir Baba	Borehole well	6.8	6.8	6.7	6.9	6.1
PBW18	Mathra	Tube Well	8.3	8.4	6.2	8.3	8.1
PBW19	Khazana	Tube Well	7.5	7.6	8.2	7.4	7.6
PBW20	Kukar	Tube Well	7.7	7.8	8.1	7.3	7.7
PBW21	Mandezai Srikh	Tube Well	7.4	7.7	7.6	7.5	7
PBW22	Rajjar	Tube Well	9.6	9.8	7.2	7.6	7.3
PBW23	Turangzai	Tube Well	7.3	7.4	7.4	7.2	7.3
PBW24	Prang	Tube Well	7.1	7.3	7.1	7.4	7
PBW25	Kandi Hayat	Borehole well	7.1	7.2	6.9	7.2	7.1
PBW26	Aman Kot	Tube Well	7.1	6.9	6.9	7.2	7.1
PBW27	Mathra	Dug Well	7.7	7.7	6.8	7.7	7.8
PBW28	Charpariza	Dug Well	7.4	7.3	7.6	7.8	7.4
PBW29	Khazana	Dug Well	7.3	7.2	7.2	7.5	7.4
PBW30	Adezai	Hand Pump	5.2	5.2	7.2	5.2	5.3
PBW31	Mandazar	Dug Well	7.3	7.4	5.1	7.4	7
PBW32	Kot	Dug Well	6.6	6.6	7.2	6.7	6.7
PBW33	Aman Kot	Dug Well	7.5	7.4	6.5	7.4	7.1
PBW34	Takht Bhai	Hand Pump	7.7	7.6	7.3	7.5	7
PBW35	Pir Baba	Stream	7.5	7.5	7.3	7.5	ND
PBW36	Pir Baba	Stream	7.2	7.3	7.4	7.3	ND

pH of the surface and groundwater samples of Peshawar basin during different times

Sample No	Area	Type of Sample	pH Jan 03	pH Jan 04	pH June 03	pH June 04	Tariq (2001)
PBW37	Pir Baba	Stream	7.2	7.3	7.1	7.3	ND
PBW48	Pir Baba	Stream	7.2	7.2	7.1	7.4	ND
PBW39	Pir Baba	Stream	7.3	7.3	7.3	7.4	ND
PBW40	Pir Baba	Stream	7.3	7.4	7.1	7.4	ND
PBW107	Sardaryab	Kabul River	8.5	8.5	7.4	8.6	8
PBW108	Naguman	Kabul River	8.8	8.4	8.4	8.9	8.7
PBW109	Shah Alam	Kabul River	8.5	8.5	8.9	8.5	8.6
PBW110	Swat River	Kabul River	7.5	7.5	8.4	7.6	7.2
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	6.9	6.8	7.4	5.8	7
PBW42	Forest Colony	Tube Well	7.3	7.4	7.1	5.6	7.5
PBW43	Shahi Bala	Hand Pump	8	7.9	7.4	5.5	7.8
PBW44	Hashim Kili	Tube Well	7.9	7.8	7.9	5.4	7.7
PBW45	Gharibabad	Tube Well	8.5	8.3	7.8	5.3	8.1
PBW46	Badh Ber	Tube Well	5.2	5.3	8.4	5.6	5.3
PBW47	Sorezai	Tube Well	5	5.5	5	5.1	5.1
PBW48	Jahangir Abad	Tube Well	5.8	5.6	5.1	5.3	5.1
PBW49	Landi Arbab	Tube Well	4.5	4.8	4.9	4.6	4.9
PBW50	Saddar Stadium	Tube Well	7.2	7.3	4.6	7.3	7
PBW51	Defence Colony	Tube Well	6.9	6.9	7.1	7.1	6.9
PBW52	Dabgari Shuba	Tube Well	5	4.9	6.8	5.2	5.2
PBW53	Gulshan R. Colony	Tube Well	7.1	7.2	4.9	7.3	7
PBW54	Tehsil Gunj	Tube Well	9.4	9.6	7.1	9.5	9.2
PBW55	Gulbahar No.2	Tube Well	7.4	7.4	9.5	7.5	7
PBW56	Hazar Khawani	Tube Well	4.9	4.8	7.3	4.8	5.1
PBW57	Wadpagga	Tube Well	4.9	4.7	4.9	4.8	7.8
PBW58	Akbar Pura	Tube Well	7.6	7.4	4.8	7.6	7.6
PBW59	Pabbi	Tube Well	8.6	8.5	7.5	8.8	8.2
PBW60	Urmar Village	Tube Well	4.8	4.9	8.5	4.8	5.1
PBW61	Aza Khel Bala	Tube Well	7.5	7.4	4.7	7.6	7.2
PBW62	Bashirabad	Dug Well	7.2	7.2	7.4	7.3	7
PBW63	Shiggi	Dug Well	7.3	7.6	7.1	7.4	7.2
PBW64	Shiggi	H. Pump	7.5	7.4	7.5	7.6	7.4
PBW65	Pajagi	H. Pump	7.2	7.5	7.4	7.3	7.3
PBW66	Mulazai	Dug Well	7.8	7.8	7.1	7.9	7.8
PBW67	Regi	H. Pump	7.3	7.3	7.9	7.4	7.1
PBW68	Shahi Bala	Dug Well	7.8	7.8	7.2	7.7	7.7
PBW169	Kafir Dheri	Dug Well	7.9	7.7	7.9	7.8	7.8
PBW70	Pawaka	Bore Well	6.3	6.5	7.7	6.4	6.7
PBW71	Bazeed Khel	H. Pump	7.4	7.4	6.4	7.5	7.5
PBW72	Surezai	Dug Well	4.9	4.9	7.3	4.9	5.1
PBW73	Hazar Khawani	H. Pump	5.1	5.3	4.8	5	5.1

pH of the surface and groundwater samples of Peshawar basin during different times

Sample No	Area	Type of Sample	pH Jan 03	pH Jan 04	pH June 03	pH June 04	Tariq (2001)
PBW74	Phandu	Dug Well	6.4	6.4	5.2	7.4	6.9
PBW75	Hazarkhawani	Dug Well	5.2	5.2	6.3	5.3	6.4
PBW76	Wadpagga	Dug Well	7.9	8.2	5.1	7.9	7.6
PBW77	Zahirabad	Dug Well	5.2	4.8	7.8	4.9	5.1
PBW78	Urmar Bala	Dug Well	7.4	7.4	4.9	7.5	7.4
PBW79	Urmar Payan	Dug Well	7.4	7.4	7.5	7.4	7.2
PBW80	Azakhel Bala	Dug Well	7.2	7.2	7.3	7.3	7.1
PBW81	Shahbaz Garhi	H. Pump	7.3	7.4	7.1	7.3	ND
PBW99	Malakand Pass	Spring	7.5	7.5	7.1	7.4	ND
PBW100	Dargai	Spring	7.8	7.8	7.4	7.2	ND
PBW101	Pirsai	Spring	7.2	7.2	7.9	7.1	ND
PBW102	Nowshera Bridge	Kabul River	8.7	8.7	7.3	7.2	8.6
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	4.9	4.9	4.8	4.9	5
PBW83	Adezai	Tube Well	5.3	5.3	4.8	5.2	5.2
PBW84	Nowshera cantt.	Tube Well	5.5	5.5	5.1	5.6	7.7
PBW85	Jaluzai	Tube Well	5.2	5.2	5.6	5.3	5.4
PBW86	Dag Besud	Tube Well	5.7	5.7	5.1	5.6	5.5
PBW87	Manki Sharif	Tube Well	7.2	7.2	5.6	7.4	7.2
PBW88	Akora Khatta	Tube Well	7.1	7.4	7.3	7.2	7.1
PBW89	Jehangira	Bore Well	7.3	7.2	6.9	5.2	7.3
PBW90	Darwazgi	Dug Well	5.1	4.9	7.2	7.2	5
PBW91	Adezai	Dug Well	7.2	7.2	4.9	6.6	7.2
PBW92	Aimal Chabutra	H. Pump	6.5	6.7	7.1	7.1	6.9
PBW93	Garhi Chandan	Dug Well	7	7.2	6.8	4.8	7
PBW94	Aza Khel	Dug Well	4.9	4.9	4.1	4.9	4.9
PBW95	Taila Band	Dug Well	4.9	4.8	4.8	5.6	4.9
PBW96	Chapri	Dug Well	5.5	5.6	4.8	5.7	5.5
PBW97	Speen Khak	Dug Well	5.6	5.6	5.6	5.8	5.5
PBW98	Musha Ghar	Dug Well	5.9	5.9	5.6	5.9	6
PBW103	Khairabad	Kabul River	7.3	7.2	7.8	7.5	7.2
PBW104	Attock	Indus River	7.4	7.4	7.4	7.6	7.2

Table 3.4. Electrical conductivity (mS/cm) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ec mS/cm Jan 03	Ec mS/cm Jan 04	Ec mS/cm June 03	Ec mS/cm June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	830	836	801	806	760
PBW2	WAPDA Colony	Tube Well	640	648	620	625	600
PBW3	Tehkal Bala	Tube Well	97	101	90	925	70
PBW4	Jamrud Road	Tube Well	52	58	50	56	48
PBW5	Industrial Estate	Tube Well	55	60	54	59	48
PBW6	Hayatatab Phase-3	Tube Well	60	64	59	63	57
PBW7	Danish Abad	Tube Well	59	64	58	61	57
PBW8	Bara	Tube Well	56	61	52	56	48
PBW9	Sar Band	Tube Well	75	80	70	75	65
PBW10	Shabqadar	Tube Well	570	581	560	568	550
PBW11	Matta Mughal Khel	Tube Well	480	485	476	486	470
PBW12	Abazai	Tube Well	469	471	466	479	450
PBW13	Tangi	Tube Well	396	399	388	399	380
PBW14	S. Umer Baba	Dug Well	1517	1526	1509	1828	1310
PBW15	Hinder Kassi	Dug Well	720	728	701	741	605
PBW16	Jamrud Road	Hand Pump	69	82	61	602	51
PBW105	W. Dam Kabul river	Warsak Dam	820	828	809	845	750
PBW106	W. Dam Kabul river	Warsak Dam	920	820	910	801	440
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	125	110	106	135	82
PBW18	Mathra	Tube Well	780	784	773	789	760
PBW19	Khazana	Tube Well	873	881	860	880	820
PBW20	Kukar	Tube Well	1008	1011	996	1108	940
PBW21	Mandezai Srikh	Tube Well	57	60	48	61	30
PBW22	Rajjar	Tube Well	493	496	480	498	480
PBW23	Turangzai	Tube Well	477	479	463	482	430
PBW24	Prang	Tube Well	370	375	330	378	ND
PBW25	Kandi Hayat	Borehole well	1123	1128	1091	1131	890
PBW26	Aman Kot	Tube Well	1840	1844	1811	1920	650
PBW27	Mathra	Dug Well	890	893	851	8.99	645
PBW28	Charpariza	Dug Well	1230	1240	1016	1245	950
PBW29	Khazana	Dug Well	948	951	922	979	885
PBW30	Adezai	Hand Pump	791	794	763	798	710
PBW31	Mandazar	Dug Well	193	195	173	201	30
PBW32	Kot	Dug Well	805	810	783	809	710
PBW33	Aman Kot	Dug Well	1892	1846	1810	1851	1650
PBW34	Takht Bhai	Hand Pump	610	618	530	618	ND
PBW35	Pir Baba	Stream	224	229	208	231	69
PBW36	Pir Baba	Stream	203	206	180	214	54
PBW37	Pir Baba	Stream	232	243	218	238	54
PBW48	Pir Baba	Stream	246	249	231	250	66
PBW39	Pir Baba	Stream	201	206	185	210	94

Electrical conductivity (mS/cm) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ec mS/cm Jan 03	Ec mS/cm Jan 04	Ec mS/cm June 03	Ec mS/cm June 04	Tariq (2001)
PBW40	Pir Baba	Stream	193	149	12.1	148	58
PBW107	Sardaryab	Kabul River	593	598	560	598	490
PBW108	Naguman	Kabul River	571	589	553	579	480
PBW109	Shah Alam	Kabul River	555	558	536	558	470
PBW110	Swat River	Kabul River	501	506	490	506	240
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	173	178	140	181	78
PBW42	Forest Colony	Tube Well	629	632	603	635	490
PBW43	Shahi Bala	Hand Pump	653	658	638	661	510
PBW44	Hashim Kili	Tube Well	158	161	140	161	73
PBW45	Gharibabad	Tube Well	120	123	98	126	63
PBW46	Badh Ber	Tube Well	114	118	85	123	82
PBW47	Sorezai	Tube Well	73	102	98	81	50
PBW48	Jahangir Abad	Tube Well	58	76	69	75	55
PBW49	Landi Arbab	Tube Well	101	106	127	110	76
PBW50	Saddar Stadium	Tube Well	98	125	119	105	72
PBW51	Defence Colony	Tube Well	84	128	123	95	72
PBW52	Dabgari Shuba	Tube Well	122	130	84	126	85
PBW53	Gulshan R. Colony	Tube Well	121	148	144	128	92
PBW54	Tehsil Gunj	Tube Well	123	150	144	110	89
PBW55	Gulbahar No.2	Tube Well	105	243	239	105	82
PBW56	Hazar Khawani	Tube Well	91	124	120	103	81
PBW57	Wadpagga	Tube Well	745	921	913	751	780
PBW58	Akbar Pura	Tube Well	1838	2012	2001	1851	1670
PBW59	Pabbi	Tube Well	1003	1230	1220	1026	880
PBW60	Urmar Village	Tube Well	280	396	392	291	79
PBW61	Aza Khel Bala	Tube Well	90	124	120	105	60
PBW62	Bashirabad	Tube Well	105	128	124	109	84
PBW63	Shiggi	Dug Well	150	196	190	158	116
PBW64	Shiggi	Dug Well	71	92	89	76	57
PBW65	Pajagi	H. Pump	85	112	104	88	64
PBW66	Mulazai	H. Pump	1106	1536	1527	1125	1070
PBW67	Regi	Dug Well	1420	1740	1733	1431	1290
PBW68	Shahi Bala	H. Pump	1131	1213	1201	1134	800
PBW169	Kafir Dheri	Dug Well	966	1245	1239	973	830
PBW70	Pawaka	Dug Well	83	112	102	89	78
PBW71	Bazeed Khel	Bore Well	92	118	114	98	80
PBW72	Surezai	H. Pump	178	231	221	183	149
PBW73	Hazar Khawani	Dug Well	173	152	199	178	123
PBW74	Phandu	H. Pump	132	158	154	136	111
PBW75	Hazarkhawani	Dug Well	122	152	148	128	93
PBW76	Wadpagga	Dug Well	1632	1811	1809	1638	1540
PBW77	Zahirabad	Dug Well	705	811	809	711	648
PBW78	Urmar Bala	Dug Well	213	375	369	216	138
PBW79	Urmar Payan	Dug Well	92	178	171	117	114
PBW80	Azakhel Bala	Dug Well	801	1021	1010	810	897
PBW81	Shahbaz Garhi	Dug Well	185	345	230	210	ND
PBW99	Malakand Pass	H. Pump	209	414	410	189	ND
PBW100	Dargai	Spring	510	236	500	220	ND

Electrical conductivity (mS/cm) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ec mS/cm Jan 03	Ec mS/cm Jan 04	Ec mS/cm June 03	Ec mS/cm June 04	Tariq (2001)
PBW101	Pirsai	Spring	521	234	480	236	ND
PBW102	Nowshera Bridge	Spring	623	831	821	246	450
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	105	152	147	111	75
PBW83	Adezai	Tube Well	99	142	138	101	69
PBW84	Nowshera cantt.	Tube Well	720	1025	990	731	780
PBW85	Jaluzai	Tube Well	62	103	98	69	53
PBW86	Dag Besud	Tube Well	111	151	146	123	83
PBW87	Manki Sharif	Tube Well	494	706	701	502	470
PBW88	Akora Khatta	Tube Well	580	678	610	613	440
PBW89	Jehangira	Bore Well	630	609	790	241	470
PBW90	Darwazgi	Dug Well	230	261	259	151	159
PBW91	Adezai	Dug Well	140	168	160	160	99
PBW92	Aimal Chabutra	H. Pump	153	176	170	188	110
PBW93	Garhi Chandan	Dug Well	180	210	203	85	158
PBW94	Aza Khel	Dug Well	80	102	99	71	70
PBW95	Taila Band	Dug Well	65	86	81	82	62
PBW96	Chapri	Dug Well	71	98	93	91	72
PBW97	Speen Khak	Dug Well	85	102	111	96	64
PBW98	Musha Ghar	Dug Well	122	148	140	131	96
PBW103	Khairabad	Kabul River	410	527	520	423	360
PBW104	Attock	Indus River	180	346	340	1801	180

Table 3.5. Total dissolved solids (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No	Area	Type of sample	Mg/l Jan 03	Mg/l Jan 04	Mg/l June 03	Mg/l June 04	Tarq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	590	596	570	580	532
PBW2	WAPDA Colony	Tube Well	470	476	450	458	420
PBW3	Tehkal Bala	Tube Well	75	88	71	78	49
PBW4	Jamrud Road	Tube Well	50	60	45	49	34
PBW5	Industrial Estate	Tube Well	53	59	46	48	34
PBW6	Hayatatab Phase-3	Tube Well	48	52	45	48	40
PBW7	Danish Abad	Tube Well	48	53	46	49	40
PBW8	Bara	Tube Well	44	49	40	45	34
PBW9	Sar Band	Tube Well	52	55	49	53	46
PBW10	Shabqadar	Tube Well	526	531	508	513	497
PBW11	Matta Mughal Khel	Tube Well	395	400	390	396	385
PBW12	Abazai	Tube Well	180	183	173	178	168
PBW13	Tangi	Tube Well	345	351	330	352	315
PBW14	S. Umer Baba	Dug Well	973	984	962	978	917
PBW15	Dug Well	Dug Well	542	549	531	550	424
PBW16	Jamrud Road	Hand Pump	49	67	43	631	36
PBW105	W. Dam Kabul river	Warsak Dam	598	603	584	614	525
PBW106	W. Dam Kabul river	Warsak Dam	610	588	604	703	308
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	70	68	65	81	57
PBW18	Mathra	Tube Well	593	604	580	584	532
PBW19	Khazana	Tube Well	601	606	595	609	574
PBW20	Kukar	Tube Well	710	718	690	722	658
PBW21	Mandezai Srikh	Tube Well	41	48	32	48	21
PBW22	Rajjar	Tube Well	159	171	150	166	336
PBW23	Turangzai	Tube Well	369	371	340	374	301
PBW24	Prang	Tube Well	232	236	221	236	232
PBW25	Kandi Hayat	Borehole well	802	805	793	810	685
PBW26	Aman Kot	Tube Well	920	728	880	828	1155
PBW27	Mathra	Dug Well	571	574	553	578	452
PBW28	Charpariza	Dug Well	767	770	731	771	665
PBW29	Khazana	Dug Well	740	742	723	750	619
PBW30	Adezai	Hand Pump	310	318	245	318	58
PBW31	Mandazar	Dug Well	93	96	82	96	65
PBW32	Kot	Dug Well	571	576	543	578	497
PBW33	Aman Kot	Dug Well	1401	1412	1375	1410	1155
PBW34	Takht Bhai	Hand Pump	343	347	321	348	321
PBW35	Pir Baba	Stream	73	34	43	40	48
PBW36	Pir Baba	Stream	38	45	46	65	38
PBW37	Pir Baba	Stream	34	46	45	34	38
PBW48	Pir Baba	Stream	29	34	45	43	46
PBW39	Pir Baba	Stream	56	67	73	67	66
PBW40	Pir Baba	Stream	54	54	39	43	41
PBW107	Sardaryab river	Kabul River	441	446	420	446	343
PBW108	Naguman River	Kabul River	423	426	404	431	336
PBW109	Shah Alam River	Kabul River	397	398	381	402	329
PBW110	Swat River	Kabul River	405	409	384	408	329
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	56	67	78	56	55
PBW42	Forest Colony	Tube Well	373	376	353	379	343
PBW43	Shahi Bala	Hand Pump	382	386	369	391	357
PBW44	Hashim Kili	Tube Well	67	87	69	109	51
PBW45	Gharibabad	Tube Well	140	145	96	73	
PBW46	Badh Ber	Tube Well	53	47	48	82	44
PBW47	Sorezai	Tube Well	69	86	84	74	35
PBW48	Jahangir Abad	Tube Well	65	76	69	75	67

Total dissolved solids (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No	Area	Type of sample	Mg/l jan 03	Mg/l jan 04	Mg/l June 03	Mg/l June 04	Tarq (2001)
PBW49	Landi Arbab	Tube Well	65	92	89	69	53
PBW50	Saddar Stadium	Tube Well	56	92	84	61	50
PBW51	Defence Colony	Tube Well	63	94	89	68	60
PBW52	Dabgari Shuba	Tube Well	75	96	93	79	64
PBW53	Gulshan R. Colony	Tube Well	78	87	69	67	62
PBW54	Tehsil Gunj	Tube Well	56	54	76	65	57
PBW55	Gulbahar No.2	Tube Well	67	75	48	98	57
PBW56	Hazar Khawani	Tube Well	140	176	170	72	56
PBW57	Wadpagga	Tube Well	467	521	498	501	546
PBW58	Akbar Pura	Tube Well	1308	1480	1472	1317	1169
PBW59	Pabbi	Tube Well	589	623	598	580	616
PBW60	Urmar Village	Tube Well	512	467	437	478	454
PBW61	Aza Khel Bala	Tube Well	41	53	48	52	42
PBW62	Bashirabad	Tube Well	65	86	80	68	59
PBW63	Shiggi	Dug Well	80	130	125	88	81
PBW64	Shiggi	Dug Well	67	69	75	80	40
PBW65	Pajagi	H. Pump	50	84	80	56	45
PBW66	Mulazai	H. Pump	732	698	712	734	749
PBW67	Regi	Dug Well	850	845	830	858	903
PBW68	Shahi Bala	H. Pump	1090	1232	1220	1120	560
PBW169	Kafir Dheri	Dug Well	820	835	830	830	581
PBW70	Pawaka	Dug Well	72	78	67	726	55
PBW71	Bazeed Khel	Bore Well	63	81	76	75	55
PBW72	Surezai	H. Pump	59	79	75	65	56
PBW73	Hazar Khawani	Dug Well	164	184	180	172	104
PBW74	Phandu	H. Pump	111	123	133	123	86
PBW75	Hazarkhawani	Dug Well	108	125	120	111	78
PBW76	Wadpagga	Dug Well	92	118	110	98	65
PBW77	Zahirabad	Dug Well	1138	1245	1243	1140	1078
PBW78	Urmar Bala	Dug Well	490	522	510	498	454
PBW79	Urmar Payan	Dug Well	71	95	90	81	55
PBW80	Azakhel Bala	Dug Well	109	125	120	118	97
PBW81	Shahbaz Garhi	Dug Well	730	959	950	620	609
PBW99	Malakand Pass	H. Pump	111	500	140	140	134
PBW100	Dargai	Spring	45	47	76	56	43
PBW101	Pirsai	Spring	40	30	38	32	41
PBW102	Nowshera Bridge	Kabul River	325	298	324	220	315
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	45	57	68	59	53
PBW83	Adezai	Tube Well	81	78	95	88	48
PBW84	Nowshera cantt.	Tube Well	478	491	398	432	546
PBW85	Jaluzai	Tube Well	64	78	56	54	80
PBW86	Dag Besud	Tube Well	61	88	83	71	45
PBW87	Manki Sharif	Tube Well	328	298	312	345	329
PBW88	Akora Khatta	Tube Well	311	432	428	326	308
PBW89	Jehangira	Bore Well	398	438	499	403	329
PBW90	Darwazgi	Dug Well	123	154	123	121	111
PBW91	Adezai	Dug Well	118	224	220	120	69
PBW92	Aimal Chabutra	H. Pump	99	115	112	106	77
PBW93	Garhi Chandan	Dug Well	90	106	101	112	111
PBW94	Aza Khel	Dug Well	85	124	111	96	49
PBW95	Taila Band	Dug Well	78	86	82	86	43
PBW96	Chapri	Dug Well	45	56	49	51	37
PBW97	Speen Khak	Dug Well	61	78	73	75	50
PBW98	Musha Ghar	Dug Well	61	79	80	69	61
PBW103	Khairabad	Kabul River	213	236	221	82	252
PBW104	Attock Indus River	Indus River	134	98	102	142	126

Table 3.6. Concentration SO_4 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	SO_4 Jan 03	SO_4 Jan 04	SO_4 June 03	SO_4 June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	100	126	120	108	80
PBW2	WAPDA Colony	Tube Well	65	60	80	70	52
PBW3	Tehkal Bala	Tube Well	35	46	40	38	25
PBW4	Jamrud Road	Tube Well	38	46	42	40	26
PBW5	Industrial Estate	Tube Well	29	44	39	31	26
PBW6	Hayatatab Phase-3	Tube Well	35	41	39	38	30
PBW7	Danish Abad	Tube Well	29	33	32	31	22
PBW8	Bara	Tube Well	22	28	25	26	16
PBW9	Sar Band	Tube Well	28	34	30	31	32
PBW10	Shabqadar	Tube Well	25	25	30	28	25
PBW11	Matta Mughal Khel	Ty`ube Well	19	23	22	21	16
PBW12	Abazai	Tube Well	18	23	20	118	7
PBW13	Tangi	Tube Well	22	34	30	21	20
PBW14	S. Umer Baba	Dug Well	255	284	280	259	246
PBW15	Hinder Kassi	Dug Well	110	120	100	95	78
PBW16	Jamrud Road	Hand Pump	48	40	45	40	36
PBW105	W. Dam Kabul river	Warsak Dam	40	40	38	35	47
PBW106	W. Dam Kabul river	Warsak Dam	39	35	36	39	44
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	110	124	121	115	104
PBW18	Mathra	Tube Well	70	74	79	75	68
PBW19	Khazana	Tube Well	79	90	87	82	77
PBW20	Kukar	Tube Well	59	63	61	61	81
PBW21	Mandezai Srikh	Tube Well	6	10	8	12	4
PBW22	Rajjar	Tube Well	30	38	35	32	27
PBW23	Turangzai	Tube Well	21	26	22	24	17
PBW24	Prang	Tube Well	8	12	10	10	4
PBW25	Kandi Hayat	Borehole well	28	35	32	30	22
PBW26	Aman Kot	Tube Well	275	294	291	281	266
PBW27	Mathra	Dug Well	59	68	63	62	50
PBW28	Charpariza	Dug Well	135	154	149	139	130
PBW29	Khazana	Dug Well	73	84	81	78	69
PBW30	Adezai	Hand Pump	98	105	101	12	92
PBW31	Mandazar	Dug Well	8	14	12	16	7
PBW32	Kot	Dug Well	8	10	9	10	7
PBW33	Aman Kot	Dug Well	163	174	172	167	163
PBW34	Takht Bhai	Hand Pump	18	25	22	22	0
PBW35	Pir Baba	Stream	55	64	61	58	48
PBW36	Pir Baba	Stream	49	55	53	52	47
PBW37	Pir Baba	Stream	49	53	51	51	45
PBW48	Pir Baba	Stream	51	55	53	70	53

Concentration SO_4 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	SO_4 Jan 03	SO_4 Jan 04	SO_4 June 03	SO_4 June 04	Tariq (2001)
PBW39	Pir Baba	Stream	89	95	93	92	86
PBW40	Pir Baba	Stream	60	68	65	63	58
PBW107	Sardaryab	Kabul River	31	35	32	34	27
PBW108	Naguman	Kabul River	25	31	28	28	41
PBW109	Shah Alam	Kabul River	35	40	38	32	48
PBW110	Swat River	Kabul River	41	48	44	45	20
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	22	25	24	26	37
PBW42	Forest Colony	Tube Well	29	33	31	32	18
PBW43	Shahi Bala	Hand Pump	48	58	55	51	24
PBW44	Hashim Kili	Tube Well	27	35	31	30	45
PBW45	Gharibabad	Tube Well	29	34	32	33	18
PBW46	Badh Ber	Tube Well	60	64	63	64	53
PBW47	Sorezai	Tube Well	38	50	46	40	24
PBW48	Jahangir Abad	Tube Well	27	31	29	28	24
PBW49	Landi Arbab	Tube Well	31	58	36	35	27
PBW50	Saddar Stadium	Tube Well	48	38	56	51	37
PBW51	Defence Colony	Tube Well	28	38	35	29	20
PBW52	Dabgari Shuba	Tube Well	61	69	68	65	57
PBW53	Gulshan R. Colony	Tube Well	59	68	66	63	51
PBW54	Tehsil Gunj	Tube Well	88	94	91	91	85
PBW55	Gulbahar No.2	Tube Well	80	39	84	84	73
PBW56	Hazar Khawani	Tube Well	70	80	75	73	64
PBW57	Wadpagga	Tube Well	65	80	75	68	60
PBW58	Akbar Pura	Tube Well	378	391	389	381	368
PBW59	Pabbi	Tube Well	118	126	123	121	110
PBW60	Urmar Village	Tube Well	1298	1313	1302	1306	1287
PBW61	Aza Khel Bala	Tube Well	228	240	232	245	226
PBW62	Bashirabad	Dug Well	48	57	54	51	42
PBW63	Shiggi	Dug Well	178	184	182	180	171
PBW64	Shiggi	H. Pump	60	69	68	63	43
PBW65	Pajagi	H. Pump	48	55	52	50	40
PBW66	Mulazai	Dug Well	78	78	75	73	131
PBW67	Regi	H. Pump	182	110	108	104	94
PBW68	Shahi Bala	Dug Well	68	88	85	70	60
PBW169	Kafir Dheri	Dug Well	128	140	133	131	120
PBW70	Pawaka	Bore Well	40	50	46	44	34
PBW71	Bazeed Khel	H. Pump	41	48	46	43	36
PBW72	Surezai	Dug Well	90	94	95	95	82
PBW73	Hazar Khawani	H. Pump	178	187	185	181	166
PBW74	Phandu	Dug Well	115	124	120	121	106
PBW75	Hazarkhawani	Dug Well	68	88	80	71	63
PBW76	Wadpagga	Dug Well	175	186	180	178	169
PBW77	Zahirabad	Dug Well	1298	1355	1350	1302	1287
PBW78	Urmar Bala	Dug Well	100	108	105	103	92
PBW79	Urmar Payan	Dug Well	180	193	190	185	175

Concentration SO_4 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	SO_4 Jan 03	SO_4 Jan 04	SO_4 June 03	SO_4 June 04	Tariq (2001)
PBW80	Azakhel Bala	Dug Well	71	83	79	76	57
PBW81	Shahbaz Garhi	H. Pump	6	9	8	8	1
PBW99	Malakand Pass	Spring	32	38	35	34	20
PBW100	Dargai	Spring	15	25	20	14	1
PBW101	Pirsai	Spring	12	20	18	10	1
PBW102	Nowshera Bridge	Kabul River	48	58	55	49	35
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	55	65	61	58	48
PBW83	Adezai	Tube Well	30	70	35	33	26
PBW84	Nowshera cantt.	Tube Well	40	48	45	45	36
PBW85	Jaluzai	Tube Well	231	251	240	233	221
PBW86	Dag Besud	Tube Well	32	96	92	94	62
PBW87	Manki Sharif	Tube Well	159	171	168	172	146
PBW88	Akora Khatta	Tube Well	88	102	98	92	83
PBW89	Jehangira	Bore Well	21	32	26	28	18
PBW90	Darwazgi	Dug Well	385	396	391	398	370
PBW91	Adezai	Dug Well	88	98	95	90	80
PBW92	Aimal Chabutra	H. Pump	129	142	139	132	123
PBW93	Garhi Chandan	Dug Well	469	461	451	442	433
PBW94	Aza Khel	Dug Well	70	81	78	78	66
PBW95	Taila Band	Dug Well	70	79	76	75	56
PBW96	Chapri	Dug Well	30	38	35	39	23
PBW97	Speen Khak	Dug Well	90	98	95	102	83
PBW98	Musha Ghar	Dug Well	118	130	125	121	114
PBW103	Khairabad	Kabul River	20	28	25	26	14
PBW104	Attock	Indus River	59	71	68	63	52

Table 3.7. Concentration Cl (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cl Jan 03	Cl Jan 04	Cl June 03	Cl June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	83	121	109	89	83
PBW2	WAPDA Colony	Tube Well	41	56	53	48	33
PBW3	Tehkal Bala	Tube Well	51	59	63	54	44
PBW4	Jamrud Road	Tube Well	28	59	41	31	25
PBW5	Industrial Estate	Tube Well	25	43	38	27	25
PBW6	Hayatatab Phase-3	Tube Well	29	40	51	35	46
PBW7	Danish Abad	Tube Well	45	51	49	48	39
PBW8	Bara	Tube Well	31	37	35	36	25
PBW9	Sar Band	Tube Well	30	45	35	34	31
PBW10	Shabqadar	Tube Well	32	35	41	34	28
PBW11	Matta Mughal Khel	Tube Well	29	32	31	32	21
PBW12	Abazai	Tube Well	33	45	43	61	30
PBW13	Tangi	Tube Well	30	52	48	36	33
PBW14	S. Umer Baba	Dug Well	93	104	101	98	80
PBW15	Hinder Kassi	Dug Well	32	103	45	36	30
PBW16	Jamrud Road	Hand Pump	25	39	36	28	21
PBW105	W. Dam Kabul river	Warsak Dam	40	44	42	46	32
PBW106	W. Dam Kabul river	Warsak Dam	39	49	45	49	32
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	58	64	60	61	51
PBW18	Mathra	Tube Well	36	38	51	39	40
PBW19	Khazana	Tube Well	39	47	45	41	36
PBW20	Kukar	Tube Well	31	38	36	33	46
PBW21	Mandezai Srikh	Tube Well	12	18	15	29	10
PBW22	Rajjar	Tube Well	83	111	95	84	84
PBW23	Turangzai	Tube Well	89	101	98	92	88
PBW24	Prang	Tube Well	82	103	91	93	77
PBW25	Kandi Hayat	Borehole well	58	78	71	61	53
PBW26	Aman Kot	Tube Well	221	234	231	234	210
PBW27	Mathra	Dug Well	38	48	40	41	30
PBW28	Charpariza	Dug Well	88	94	91	91	85
PBW29	Khazana	Dug Well	39	53	49	39	35
PBW30	Adezai	Hand Pump	32	44	40	18	25
PBW31	Mandazar	Dug Well	14	20	18	16	11
PBW32	Kot	Dug Well	14	18	16	364	37
PBW33	Aman Kot	Dug Well	361	369	365	363	357
PBW34	Takht Bhai	Hand Pump	114	124	122	118	93
PBW35	Pir Baba	Stream	58	68	66	61	53
PBW36	Pir Baba	Stream	62	62	61	64	46
PBW37	Pir Baba	Stream	49	54	52	50	46
PBW48	Pir Baba	Stream	53	60	58	55	51
PBW39	Pir Baba	Stream	74	78	76	76	72
PBW40	Pir Baba	Stream	51	58	55	54	49
PBW107	Sardaryab	Kabul River	41	49	43	46	39
PBW108	Naguman	Kabul River	18	23	20	20	37

Concentration Cl (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cl Jan 03	Cl Jan 04	Cl June 03	Cl June 04	Tariq (2001)
PBW109	Shah Alam	Kabul River	30	33	30	28	33
PBW110	Swat River	Kabul River	13	16	12	15	7
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	39	50	48	41	39
PBW42	Forest Colony	Tube Well	51	61	58	54	32
PBW43	Shahi Bala	Hand Pump	42	52	49	45	47
PBW44	Hashim Kili	Tube Well	45	61	48	48	40
PBW45	Gharibabad	Tube Well	60	66	64	67	40
PBW46	Badh Ber	Tube Well	60	65	63	63	56
PBW47	Sorezai	Tube Well	43	58	55	45	56
PBW48	Jahangir Abad	Tube Well	31	33	32	33	39
PBW49	Landi Arbab	Tube Well	50	54	52	54	40
PBW50	Saddar Stadium	Tube Well	74	54	82	76	61
PBW51	Defence Colony	Tube Well	49	60	51	54	42
PBW52	Dabgari Shuba	Tube Well	51	63	59	53	47
PBW53	Gulshan R. Colony	Tube Well	49	54	52	54	42
PBW54	Tehsil Gunj	Tube Well	61	71	68	65	57
PBW55	Gulbahar No.2	Tube Well	70	79	75	76	67
PBW56	Hazar Khawani	Tube Well	58	68	61	60	53
PBW57	Wadpagga	Tube Well	60	70	68	63	51
PBW58	Akbar Pura	Tube Well	268	274	270	270	255
PBW59	Pabbi	Tube Well	136	148	145	148	130
PBW60	Urmar Village	Tube Well	86	94	91	91	81
PBW61	Aza Khel Bala	Tube Well	67	88	75	88	60
PBW62	Bashirabad	Dug Well	51	58	56	54	46
PBW63	Shiggi	Dug Well	10	16	14	12	1
PBW64	Shiggi	H. Pump	40	48	45	49	38
PBW65	Pajagi	H. Pump	6	9	8	8	5
PBW66	Mulazai	Dug Well	81	101	90	84	123
PBW67	Regi	H. Pump	461	476	472	465	452
PBW68	Shahi Bala	Dug Well	76	84	82	78	74
PBW169	Kafir Dheri	Dug Well	80	88	85	84	76
PBW70	Pawaka	Bore Well	98	59	55	31	44
PBW71	Bazeed Khel	H. Pump	40	52	49	42	37
PBW72	Surezai	Dug Well	71	92	78	76	67
PBW73	Hazar Khawani	H. Pump	115	133	128	118	109
PBW74	Phandu	Dug Well	78	86	83	81	75
PBW75	Hazarkhawani	Dug Well	76	92	88	80	71
PBW76	Wadpagga	Dug Well	120	138	130	126	116
PBW77	Zahirabad	Dug Well	891	902	900	901	882
PBW78	Urmar Bala	Dug Well	128	136	132	131	111
PBW79	Urmar Payan	Dug Well	227	241	238	230	219
PBW80	Azakhel Bala	Dug Well	119	132	129	123	109
PBW81	Shahbaz Garhi	H. Pump	81	95	90	85	74
PBW99	Malakand Pass	Spring	35	42	40	36	28
PBW100	Dargai	Spring	31	40	38	18	24

Concentration Cl (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cl Jan 03	Cl Jan 04	Cl June 03	Cl June 04	Tariq (2001)
PBW101	Pirsai	Spring	15	17	16	14	4
PBW102	Nowshera Bridge	Kabul River	50	59	58	53	40
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	48	55	53	49	32
PBW83	Adezai	Tube Well	31	64	38	40	25
PBW84	Nowshera cantt.	Tube Well	71	85	80	76	67
PBW85	Jaluzai	Tube Well	55	73	69	57	51
PBW86	Dag Besud	Tube Well	98	108	103	104	94
PBW87	Manki Sharif	Tube Well	58	66	64	69	43
PBW88	Akora Khatta	Tube Well	40	49	45	48	36
PBW89	Jehangira	Bore Well	48	62	58	55	41
PBW90	Darwazgi	Dug Well	110	125	118	120	105
PBW91	Adezai	Dug Well	104	118	115	132	95
PBW92	Aimal Chabutra	H. Pump	124	130	128	128	118
PBW93	Garhi Chandan	Dug Well	101	120	110	111	92
PBW94	Aza Khel	Dug Well	68	75	71	73	50
PBW95	Taila Band	Dug Well	60	69	69	68	53
PBW96	Chapri	Dug Well	38	78	45	45	35
PBW97	Speen Khak	Dug Well	50	57	55	60	46
PBW98	Musha Ghar	Dug Well	128	136	133	125	114
PBW103	Khairabad	Kabul River	33	40	38	134	23
PBW104	Attock	Indus River	8	12	10	10	4

Table 3.8. Concentration HCO_3 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	HCO_3 Jan 03	HCO_3 Jan 04	HCO_3 June 03	HCO_3 June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	127	151	145	132	120
PBW2	WAPDA Colony	Tube Well	133	164	160	138	132
PBW3	Tehkal Bala	Tube Well	163	184	170	167	156
PBW4	Jamrud Road	Tube Well	269	284	368	271	290
PBW5	Industrial Estate	Tube Well	170	371	180	176	168
PBW6	Hayatatab Phase-3	Tube Well	86	184	98	88	116
PBW7	Danish Abad	Tube Well	93	105	101	98	84
PBW8	Bara	Tube Well	91	109	102	95	88
PBW9	Sar Band	Tube Well	191	294	220	196	180
PBW10	Shabqadar	Tube Well	280	294	290	284	260
PBW11	Matta Mughal Khel	Tube Well	281	296	291	286	260
PBW12	Abazai	Tube Well	272	280	280	294	208
PBW13	Tangi	Tube Well	183	194	190	226	178
PBW14	S. Umer Baba	Dug Well	331	351	348	341	328
PBW15	Hinder Kassi	Dug Well	125	352	130	129	116
PBW16	Jamrud Road	Hand Pump	160	184	180	163	165
PBW105	W. Dam Kabul river	Warsak Dam	132	144	140	144	128
PBW106	W. Dam Kabul river	Warsak Dam	120	132	128	151	116
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	1	3	2	3	1
PBW18	Mathra	Tube Well	197	201	203	201	192
PBW19	Khazana	Tube Well	248	250	241	250	236
PBW20	Kukar	Tube Well	280	284	279	275	288
PBW21	Mandezai Srikh	Tube Well	325	338	331	332	316
PBW22	Rajjar	Tube Well	199	210	204	201	194
PBW23	Turangzai	Tube Well	194	208	199	196	184
PBW24	Prang	Tube Well	21	41	36	26	21
PBW25	Kandi Hayat	Borehole well	620	671	669	628	568
PBW26	Aman Kot	Tube Well	220	231	229	231	210
PBW27	Mathra	Dug Well	273	289	281	278	260
PBW28	Charpariza	Dug Well	128	145	141	142	116
PBW29	Khazana	Dug Well	135	136	137	139	128
PBW30	Adezai	Hand Pump	122	135	131	159	135
PBW31	Mandazar	Dug Well	153	165	161	158	142
PBW32	Kot	Dug Well	256	278	321	305	224
PBW33	Aman Kot	Dug Well	61	71	69	65	56
PBW34	Takht Bhai	Hand Pump	359	376	372	363	352
PBW35	Pir Baba	Stream	2	4	3	6	1
PBW36	Pir Baba	Stream	1	3	2	3	1
PBW37	Pir Baba	Stream	2	4	3	5	1
PBW48	Pir Baba	Stream	2	3	2	3	1
PBW39	Pir Baba	Stream	1	2	1	3	1
PBW40	Pir Baba	Stream	1	3	2	2	1

Concentration HCO_3 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	HCO_3 Jan 03	HCO_3 Jan 04	HCO_3 June 03	HCO_3 June 04	Tariq (2001)
PBW107	Sardaryab	Kabul River	71	83	79	78	70
PBW108	Naguman	Kabul River	159	163	161	161	104
PBW109	Shah Alam	Kabul River	90	170	90	170	68
PBW110	Swat River	Kabul River	134	142	156	172	178
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	153	170	166	158	134
PBW42	Forest Colony	Tube Well	161	171	16.9	165	152
PBW43	Shahi Bala	Hand Pump	159	165	163	162	156
PBW44	Hashim Kili	Tube Well	131	49	139	135	152
PBW45	Gharibabad	Tube Well	131	141	138	134	128
PBW46	Badh Ber	Tube Well	108	128	121	121	128
PBW47	Sorezai	Tube Well	121	138	133	125	100
PBW48	Jahangir Abad	Tube Well	148	154	152	152	132
PBW49	Landi Arbab	Tube Well	164	182	176	169	128
PBW50	Saddar Stadium	Tube Well	168	245	179	171	156
PBW51	Defence Colony	Tube Well	238	250	241	241	220
PBW52	Dabgari Shuba	Tube Well	86	102	98	89	84
PBW53	Gulshan R. Colony	Tube Well	90	102	99	98	88
PBW54	Tehsil Gunj	Tube Well	89	96	94	91	84
PBW55	Gulbahar No.2	Tube Well	158	172	165	161	148
PBW56	Hazar Khawani	Tube Well	98	168	103	100	140
PBW57	Wadpagga	Tube Well	95	106	102	98	92
PBW58	Akbar Pura	Tube Well	298	366	362	302	288
PBW59	Pabbi	Tube Well	178	191	185	181	172
PBW60	Urmar Village	Tube Well	101	115	112	106	90
PBW61	Aza Khel Bala	Tube Well	203	125	210	213	200
PBW62	Bashirabad	Dug Well	342	353	350	346	332
PBW63	Shiggi	Dug Well	238	210	202	302	293
PBW64	Shiggi	H. Pump	215	223	320	218	208
PBW65	Pajagi	H. Pump	170	181	178	175	168
PBW66	Mulazai	Dug Well	198	210	208	201	308
PBW67	Regi	H. Pump	529	535	533	534	520
PBW68	Shahi Bala	Dug Well	202	218	215	206	192
PBW169	Kafir Dheri	Dug Well	232	249	240	236	228
PBW70	Pawaka	Bore Well	251	264	259	256	248
PBW71	Bazeed Khel	H. Pump	181	195	190	189	172
PBW72	Surezai	Dug Well	220	240	228	231	216
PBW73	Hazar Khawani	H. Pump	268	285	278	270	260
PBW74	Phandu	Dug Well	98	109	102	103	84
PBW75	Hazarkhawani	Dug Well	158	169	165	159	146
PBW76	Wadpagga	Dug Well	401	423	412	410	396
PBW77	Zahirabad	Dug Well	360	368	365	368	354
PBW78	Urmar Bala	Dug Well	381	392	390	384	370
PBW79	Urmar Payan	Dug Well	105	386	112	108	92
PBW80	Azakhel Bala	Dug Well	188	204	199	189	178
PBW81	Shahbaz Garhi	H. Pump	251	366	362	360	342
PBW99	Malakand Pass	Spring	251	264	260	254	236
PBW100	Dargai	Spring	445	458	451	366	432
PBW101	Pirsai	Spring	340	368	362	361	342

Concentration HCO_3 (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	HCO_3 Jan 03	HCO_3 Jan 04	HCO_3 June 03	HCO_3 June 04	Tariq (2001)
PBW102	Nowshera Bridge	Kabul River	280	296	290	285	274
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	152	198	193	188	172
PBW83	Adezai	Tube Well	225	201	230	236	216
PBW84	Nowshera cantt.	Tube Well	80	92	88	86	76
PBW85	Jaluzai	Tube Well	145	156	153	148	132
PBW86	Dag Besud	Tube Well	260	274	270	269	254
PBW87	Manki Sharif	Tube Well	181	194	190	202	176
PBW88	Akora Khatta	Tube Well	189	203	198	192	180
PBW89	Jehangira	Bore Well	60	72	69	65	56
PBW90	Darwazgi	Dug Well	135	152	142	139	128
PBW91	Adezai	Dug Well	98	106	102	142	88
PBW92	Aimal Chabutra	H. Pump	90	107	97	99	88
PBW93	Garhi Chandan	Dug Well	100	112	108	108	92
PBW94	Aza Khel	Dug Well	58	64	61	63	48
PBW95	Taila Band	Dug Well	91	95	99	101	88
PBW96	Chapri	Dug Well	142	154	150	148	136
PBW97	Speen Khak	Dug Well	121	126	125	132	115
PBW98	Musha Ghar	Dug Well	135	148	145	131	128
PBW103	Khairabad	Kabul River	41	53	50	140	32
PBW104	Attock	Indus River	121	128	125	126	118

Table 3.9. Concentration Ca (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ca Jan 03	Ca Jan 04	Ca June 03	Ca June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	31	46	42	33	21
PBW2	WAPDA Colony	Tube Well	49	66	60	51	40
PBW3	Tehkal Bala	Tube Well	45	65	58	48	36
PBW4	Jamrud Road	Tube Well	41	65	55	45	32
PBW5	Industrial Estate	Tube Well	58	60	61	61	52
PBW6	Hayatatab Phase-3	Tube Well	51	64	62	54	40
PBW7	Danish Abad	Tube Well	80	101	93	85	79
PBW8	Bara	Tube Well	49	56	53	51	37
PBW9	Sar Band	Tube Well	38	45	42	41	42
PBW10	Shabqadar	Tube Well	61	53	72	65	52
PBW11	Matta Mughal Khel	Tube Well	39	51	49	43	37
PBW12	Abazai	Tube Well	34	48	45	42	26
PBW13	Tangi	Tube Well	21	29	25	24	15
PBW14	S. Umer Baba	Dug Well	14	19	16	17	8
PBW15	Hinder Kassi	Dug Well	49	18	51	50	35
PBW16	Jamrud Road	Hand Pump	38	53	49	39	30
PBW105	W. Dam Kabul river	Warsak Dam	28	36	35	29	29
PBW106	W. Dam Kabul river	Warsak Dam	42	51	49	30	32
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	39	44	41	40	31
PBW18	Mathra	Tube Well	18	23	20	19	13
PBW19	Khazana	Tube Well	13	18	15	15	9
PBW20	Kukar	Tube Well	45	54	51	47	18
PBW21	Mandezai Srikh	Tube Well	24	38	36	25	27
PBW22	Rajjar	Tube Well	12	17	15	14	9
PBW23	Turangzai	Tube Well	12	16	14	13	10
PBW24	Prang	Tube Well	30	42	39	33	29
PBW25	Kandi Hayat	Borehole well	68	75	71	69	53
PBW26	Aman Kot	Tube Well	45	56	50	48	34
PBW27	Mathra	Dug Well	48	54	51	51	42
PBW28	Charpariza	Dug Well	38	46	43	41	33
PBW29	Khazana	Dug Well	29	34	31	32	23
PBW30	Adezai	Hand Pump	49	55	53	28	41
PBW31	Mandazar	Dug Well	26	33	30	28	22
PBW32	Kot	Dug Well	76	81	80	98	75
PBW33	Aman Kot	Dug Well	12	21	18	14	14
PBW34	Takht Bhai	Hand Pump	43	50	49	45	41
PBW35	Pir Baba	Stream	49	53	50	51	47
PBW36	Pir Baba	Stream	38	46	44	39	34
PBW37	Pir Baba	Stream	41	47	45	42	39
PBW48	Pir Baba	Stream	58	63	61	30	54

Concentration Ca (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ca Jan 03	Ca Jan 04	Ca June 03	Ca June 04	Tariq (2001)
PBW39	Pir Baba	Stream	26	37	35	29	19
PBW40	Pir Baba	Stream	21	26	24	22	9
PBW107	Sardaryab	Kabul River	41	47	46	42	38
PBW108	Naguman	Kabul River	28	34	30	29	40
PBW109	Shah Alam	Kabul River	30	36	35	32	32
PBW110	Swat River	Kabul River	34	39	22	22	25
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	20	24	30	29	12
PBW42	Forest Colony	Tube Well	28	33	30	31	20
PBW43	Shahi Bala	Hand Pump	28	32	42	44	27
PBW44	Hashim Kili	Tube Well	41	44	51	51	37
PBW45	Gharibabad	Tube Well	66	54	30	29	41
PBW46	Badh Ber	Tube Well	28	34	52	22	22
PBW47	Sorezai	Tube Well	20	24	28	27	18
PBW48	Jahangir Abad	Tube Well	28	30	35	34	29
PBW49	Landi Arbab	Tube Well	32	36	36	32	31
PBW50	Saddar Stadium	Tube Well	30	44	40	39	13
PBW51	Defence Colony	Tube Well	38	34	32	32	35
PBW52	Dabgari Shuba	Tube Well	30	33	32	31	27
PBW53	Gulshan R. Colony	Tube Well	29	35	26	23	13
PBW54	Tehsil Gunj	Tube Well	20	28	12	12	6
PBW55	Gulbahar No.2	Tube Well	9	15	58	60	48
PBW56	Hazar Khawani	Tube Well	58	56	36	33	28
PBW57	Wadpagga	Tube Well	31	39	22	20	11
PBW58	Akbar Pura	Tube Well	81	91	93	93	84
PBW59	Pabbi	Tube Well	90	96	31	27	18
PBW60	Urmar Village	Tube Well	25	40	25	23	16
PBW61	Aza Khel Bala	Tube Well	21	28	50	25	32
PBW62	Bashirabad	Dug Well	46	30	65	70	56
PBW63	Shiggi	Dug Well	58	69	46	38	34
PBW64	Shiggi	H. Pump	37	50	58	53	48
PBW65	Pajagi	H. Pump	50	59	45	41	37
PBW66	Mulazai	Dug Well	39	47	48	42	23
PBW67	Regi	H. Pump	40	49	12	13	5
PBW68	Shahi Bala	Dug Well	10	14	60	57	41
PBW169	Kafir Dheri	Dug Well	55	65	22	18	10
PBW70	Pawaka	Bore Well	16	26	36	36	29
PBW71	Bazeed Khel	H. Pump	34	40	49	93	36
PBW72	Surezai	Dug Well	42	53	46	41	38
PBW73	Hazar Khawani	H. Pump	40	49	15	13	7
PBW74	Phandu	Dug Well	10	18	58	51	44
PBW75	Hazarkhawani	Dug Well	48	61	36	33	26

Concentration Ca (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ca Jan 03	Ca Jan 04	Ca June 03	Ca June 04	Tariq (2001)
PBW76	Wadpagga	Dug Well	30	39	40	38	27
PBW77	Zahirabad	Dug Well	32	44	88	81	74
PBW78	Urmar Bala	Dug Well	34	36	32	38	24
PBW79	Urmar Payan	Dug Well	28	35	30	26	22
PBW80	Azakhel Bala	Dug Well	24	34	58	50	37
PBW81	Shahbaz Garhi	H. Pump	89	79	85	79	72
PBW99	Malakand Pass	Spring	60	65	62	63	52
PBW100	Dargai	Spring	67	70	71	68	64
PBW101	Pirsai	Spring	45	48	50	46	37
PBW102	Nowshera Bridge	Kabul River	41	49	48	40	34
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	39	50	48	42	32
PBW83	Adezai	Tube Well	41	52	45	42	36
PBW84	Nowshera cantt.	Tube Well	40	56	45	42	33
PBW85	Jaluzai	Tube Well	40	48	39	36	29
PBW86	Dag Besud	Tube Well	34	40	28	29	14
PBW87	Manki Sharif	Tube Well	19	30	38	41	29
PBW88	Akora Khatta	Tube Well	32	40	35	33	25
PBW89	Jehangira	Bore Well	30	38	45	36	31
PBW90	Darwazgi	Dug Well	39	48	46	49	67
PBW91	Adezai	Dug Well	61	70	65	68	41
PBW92	Aimal Chabutra	H. Pump	49	58	40	34	27
PBW93	Garhi Chandan	Dug Well	31	45	52	49	68
PBW94	Aza Khel	Dug Well	61	63	70	72	52
PBW95	Taila Band	Dug Well	69	76	45	41	30
PBW96	Chapri	Dug Well	38	48	66	64	46
PBW97	Speen Khak	Dug Well	60	68	60	56	44
PBW98	Musha Ghar	Dug Well	52	62	38	53	22
PBW103	Khairabad	Kabul River	30	40	40	38	29
PBW104	Attock	Indus River	35	43	34	30	24

Table 3.10. Concentration Mg (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Mg Jan 03	Mg Jan 04	Mg June 03	Mg June 04	Tariq (2001)
Khyber Piedmont Aquif							
PBW1	Kafir Dheri	Tube Well	29	48	45	30	28
PBW2	WAPDA Colony	Tube Well	28	51	49	30	30
PBW3	Tehkal Bala	Tube Well	33	53	47	36	35
PBW4	Jamrud Road	Tube Well	31	53	39	36	27
PBW5	Industrial Estate	Tube Well	30	42	35	34	28
PBW6	Hayatatab Phase-3	Tube Well	28	38	31	29	24
PBW7	Danish Abad	Tube Well	30	38	33	34	27
PBW8	Bara	Tube Well	38	44	42	41	22
PBW9	Sar Band	Tube Well	29	34	32	33	31
PBW10	Shabqadar	Tube Well	22	31	25	24	17
PBW11	Matta Mughal Khel	Tube Well	27	31	28	29	16
PBW12	Abazai	Tube Well	19	24	22	51	18
PBW13	Tangi	Tube Well	18	24	20	22	19
PBW14	S. Umer Baba	Dug Well	72	89	83	75	63
PBW15	Hinder Kassi	Dug Well	32	86	40	34	29
PBW16	Jamrud Road	Hand Pump	28	39	35	29	29
PBW105	W. Dam Kabul river	Warsak Dam	28	35	33	30	21
PBW106	W. Dam Kabul river	Warsak Dam	21	36	34	32	22
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	49	55	54	50	45
PBW18	Mathra	Tube Well	42	48	45	44	38
PBW19	Khazana	Tube Well	42	51	48	44	39
PBW20	Kukar	Tube Well	65	67	58	61	66
PBW21	Mandezai Srikh	Tube Well	16	21	18	18	11
PBW22	Rajjar	Tube Well	20	25	22	22	18
PBW23	Turangzai	Tube Well	21	24	22	23	18
PBW24	Prang	Tube Well	28	33	30	30	22
PBW25	Kandi Hayat	Borehole well	59	72	69	63	52
PBW26	Aman Kot	Tube Well	38	53	48	43	40
PBW27	Mathra	Dug Well	31	37	35	33	29
PBW28	Charpariza	Dug Well	49	60	58	51	46
PBW29	Khazana	Dug Well	49	56	53	53	47
PBW30	Adezai	Hand Pump	48	57	54	14	43
PBW31	Mandazar	Dug Well	11	16	14	13	9
PBW32	Kot	Dug Well	22	27	25	26	19
PBW33	Aman Kot	Dug Well	45	50	48	46	40
PBW34	Takht Bhai	Hand Pump	30	34	32	33	28
PBW35	Pir Baba	Stream	38	45	40	39	36
PBW36	Pir Baba	Stream	38	41	39	40	31

Concentration Mg (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Mg Jan 03	Mg Jan 04	Mg June 03	Mg June 04	Tariq (2001)
PBW37	Pir Baba	Stream	32	37	35	33	29
PBW48	Pir Baba	Stream	39	46	44	45	33
PBW39	Pir Baba	Stream	59	65	63	60	58
PBW40	Pir Baba	Stream	49	54	52	51	43
PBW107	Sardaryab	Kabul River	27	31	29	29	23
PBW108	Naguman	Kabul River	12	17	15	14	22
PBW109	Shah Alam	Kabul River	20	22	20	25	25
PBW110	Swat River	Kabul River	42	47	45	44	8
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	31	38	36	33	38
PBW42	Forest Colony	Tube Well	38	44	42	39	28
PBW43	Shahi Bala	Hand Pump	39	42	40	41	25
PBW44	Hashim Kili	Tube Well	36	41	38	38	36
PBW45	Gharibabad	Tube Well	52	57	56	54	32
PBW46	Badh Ber	Tube Well	30	64	32	32	48
PBW47	Sorezai	Tube Well	41	46	45	43	26
PBW48	Jahangir Abad	Tube Well	29	34	32	31	29
PBW49	Landi Arbab	Tube Well	39	42	42	43	39
PBW50	Saddar Stadium	Tube Well	37	68	38	38	34
PBW51	Defence Colony	Tube Well	51	65	60	54	39
PBW52	Dabgari Shuba	Tube Well	45	54	50	47	42
PBW53	Gulshan R. Colony	Tube Well	58	64	61	60	51
PBW54	Tehsil Gunj	Tube Well	58	68	65	62	52
PBW55	Gulbahar No.2	Tube Well	53	59	57	60	49
PBW56	Hazar Khawani	Tube Well	56	64	60	61	49
PBW57	Wadpagga	Tube Well	56	65	61	58	52
PBW58	Akbar Pura	Tube Well	38	50	45	39	34
PBW59	Pabbi	Tube Well	29	35	33	31	26
PBW60	Urmar Village	Tube Well	41	46	45	43	35
PBW61	Aza Khel Bala	Tube Well	29	50	35	48	21
PBW62	Bashirabad	Dug Well	51	60	58	54	43
PBW63	Shiggi	Dug Well	81	90	88	84	73
PBW64	Shiggi	H. Pump	38	49	48	40	31
PBW65	Pajagi	H. Pump	50	58	56	53	46
PBW66	Mulazai	Dug Well	49	60	58	50	44
PBW67	Regi	H. Pump	20	27	25	22	14
PBW68	Shahi Bala	Dug Well	38	40	36	37	37
PBW169	Kafir Dheri	Dug Well	32	38	35	34	29
PBW70	Pawaka	Bore Well	40	46	45	42	37
PBW71	Bazeed Khel	H. Pump	49	43	42	44	41
PBW72	Surezai	Dug Well	42	46	43	44	78
PBW73	Hazar Khawani	H. Pump	69	79	75	71	66
PBW74	Phandu	Dug Well	68	73	71	70	59

Concentration Mg (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Mg Jan 03	Mg Jan 04	Mg June 03	Mg June 04	Tariq (2001)
PBW75	Hazarkhawani	Dug Well	48	55	52	49	40
PBW76	Wadpagga	Dug Well	75	86	80	77	68
PBW77	Zahirabad	Dug Well	164	180	175	168	153
PBW78	Urmar Bala	Dug Well	85	101	94	88	76
PBW79	Urmar Payan	Dug Well	41	46	43	42	33
PBW80	Azakhel Bala	Dug Well	30	40	38	33	28
PBW81	Shahbaz Garhi	H. Pump	32	38	35	33	29
PBW99	Malakand Pass	Spring	31	43	39	33	27
PBW100	Dargai	Spring	30	35	32	31	26
PBW101	Pirsai	Spring	20	39	38	33	26
PBW102	Nowshera Bridge	Kabul River	28	36	32	29	22
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	40	37	38	42	35
PBW83	Adezai	Tube Well	40	62	44	42	34
PBW84	Nowshera cantt.	Tube Well	36	43	40	37	30
PBW85	Jaluzai	Tube Well	29	33	31	30	22
PBW86	Dag Besud	Tube Well	36	40	39	39	30
PBW87	Manki Sharif	Tube Well	28	29	25	28	13
PBW88	Akora Khatta	Tube Well	20	32	28	24	16
PBW89	Jehangira	Bore Well	19	28	25	28	14
PBW90	Darwazgi	Dug Well	60	72	68	64	59
PBW91	Adezai	Dug Well	55	61	58	68	49
PBW92	Aimal Chabutra	H. Pump	53	65	60	58	49
PBW93	Garhi Chandan	Dug Well	80	90	88	88	78
PBW94	Aza Khel	Dug Well	35	41	38	38	32
PBW95	Taila Band	Dug Well	40	50	48	43	30
PBW96	Chapri	Dug Well	22	34	30	26	19
PBW97	Speen Khak	Dug Well	25	32	30	28	20
PBW98	Musha Ghar	Dug Well	40	48	47	42	37
PBW103	Khairabad	Kabul River	20	30	28	22	15
PBW104	Attock	Indus River	8	12	10	10	6

Table 3.11. Concentration Na (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Na Jan 03	Na Jan 04	Na June 03	Na June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	56	71	68	65	57
PBW2	WAPDA Colony	Tube Well	18	40	38	21	22
PBW3	Tehkal Bala	Tube Well	27	42	38	28	27
PBW4	Jamrud Road	Tube Well	22	42	25	26	18
PBW5	Industrial Estate	Tube Well	22	28	24	24	19
PBW6	Hayatatab Phase-3	Tube Well	39	26	41	42	31
PBW7	Danish Abad	Tube Well	32	39	34	36	28
PBW8	Bara	Tube Well	28	32	30	80	18
PBW9	Sar Band	Tube Well	18	33	30	25	22
PBW10	Shabqadar	Tube Well	25	30	28	28	21
PBW11	Matta Mughal Khel	Tube Well	21	32	29	23	15
PBW12	Abazai	Tube Well	32	41	39	39	22
PBW13	Tangi	Tube Well	21	29	26	24	24
PBW14	S. Umer Baba	Dug Well	60	69	67	64	55
PBW15	Hinder Kassi	Dug Well	22	69	30	31	21
PBW16	Jamrud Road	Hand Pump	18	34	20	20	15
PBW105	W. Dam Kabul river	Warsak Dam	22	33	30	24	20
PBW106	W. Dam Kabul river	Warsak Dam	20	33	31	26	20
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	36	43	40	38	34
PBW18	Mathra	Tube Well	35	43	40	37	30
PBW19	Khazana	Tube Well	28	33	30	31	25
PBW20	Kukar	Tube Well	27	31	29	28	32
PBW21	Mandezai Srikh	Tube Well	9	13	10	10	8
PBW22	Rajjar	Tube Well	53	68	66	55	56
PBW23	Turangzai	Tube Well	51	66	64	54	58
PBW24	Prang	Tube Well	59	64	62	62	51
PBW25	Kandi Hayat	Borehole well	35	43	40	38	35
PBW26	Aman Kot	Tube Well	158	168	164	161	151
PBW27	Mathra	Dug Well	27	32	30	30	22
PBW28	Charpariza	Dug Well	68	74	71	70	60
PBW29	Khazana	Dug Well	27	32	29	29	24
PBW30	Adezai	Hand Pump	18	23	20	12	16
PBW31	Mandazar	Dug Well	9	15	13	13	10
PBW32	Kot	Dug Well	26	29	28	28	27
PBW33	Aman Kot	Dug Well	275	285	282	292	272
PBW34	Takht Bhai	Hand Pump	70	73	72	72	68
PBW35	Pir Baba	Stream	35	46	45	38	37
PBW36	Pir Baba	Stream	37	41	39	38	31
PBW37	Pir Baba	Stream	33	35	34	35	31

Concentration Na (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Na Jan 03	Na Jan 04	Na June 03	Na June 04	Tariq (2001)
PBW48	Pir Baba	Stream	40	44	42	40	33
PBW39	Pir Baba	Stream	42	45	43	41	48
PBW40	Pir Baba	Stream	40	43	42	42	33
PBW107	Sardaryab	Kabul River	30	34	32	32	28
PBW108	Naguman	Kabul River	8	12	10	10	25
PBW109	Shah Alam	Kabul River	15	16	15	12	23
PBW110	Swat River	Kabul River	26	34	30	29	6
Peshawar Lacustrine Aquife							
PBW41	Bashirabad	Tube Well	19	24	22	23	27
PBW42	Forest Colony	Tube Well	29	33	30	31	18
PBW43	Shahi Bala	Hand Pump	29	33	31	32	32
PBW44	Hashim Kili	Tube Well	27	30	28	27	26
PBW45	Gharibabad	Tube Well	42	48	45	45	26
PBW46	Badh Ber	Tube Well	40	46	44	43	38
PBW47	Sorezai	Tube Well	30	35	32	33	38
PBW48	Jahangir Abad	Tube Well	26	29	28	28	24
PBW49	Landi Arbab	Tube Well	22	46	28	24	23
PBW50	Saddar Stadium	Tube Well	40	46	43	43	39
PBW51	Defence Colony	Tube Well	38	48	43	39	27
PBW52	Dabgari Shuba	Tube Well	33	39	36	35	32
PBW53	Gulshan R. Colony	Tube Well	30	38	36	34	29
PBW54	Tehsil Gunj	Tube Well	40	48	46	46	39
PBW55	Gulbahar No.2	Tube Well	50	56	54	63	46
PBW56	Hazar Khawani	Tube Well	41	49	47	44	37
PBW57	Wadpagga	Tube Well	39	46	42	43	35
PBW58	Akbar Pura	Tube Well	185	193	191	187	182
PBW59	Pabbi	Tube Well	91	102	99	94	88
PBW60	Urmar Village	Tube Well	61	68	65	62	57
PBW61	Aza Khel Bala	Tube Well	48	42	46	40	44
PBW62	Bashirabad	Dug Well	38	50	48	39	33
PBW63	Shiggi	Dug Well	50	58	55	56	45
PBW64	Shiggi	H. Pump	30	40	32	33	24
PBW65	Pajagi	H. Pump	30	35	32	33	26
PBW66	Mulazai	Dug Well	85	98	96	87	86
PBW67	Regi	H. Pump	312	324	321	316	303
PBW68	Shahi Bala	Dug Well	59	64	61	61	54
PBW169	Kafir Dheri	Dug Well	58	66	61	60	50
PBW70	Pawaka	Bore Well	33	40	36	35	28
PBW71	Bazeed Khel	H. Pump	25	29	29	27	23
PBW72	Surezai	Dug Well	48	46	45	49	46
PBW73	Hazar Khawani	H. Pump	80	88	85	84	72
PBW74	Phandu	Dug Well	60	68	65	62	51
PBW75	Hazarkhawani	Dug Well	48	46	50	50	41
PBW76	Wadpagga	Dug Well	91	106	100	94	83
PBW77	Zahirabad	Dug Well	648	660	656	651	638
PBW78	Urmar Bala	Dug Well	81	89	96	84	75
PBW79	Urmar Payan	Dug Well	168	178	176	171	151

Concentration Na (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Na Jan 03	Na Jan 04	Na June 03	Na June 04	Tariq (2001)
PBW80	Azakhel Bala	Dug Well	84	90	90	87	76
PBW81	Shahbaz Garhi	H. Pump	59	65	63	61	51
PBW99	Malakand Pass	Spring	30	40	36	32	20
PBW100	Dargai	Spring	22	28	25	23	19
PBW101	Pirsai	Spring	8	14	10	10	5
PBW102	Nowshera Bridge	Kabul River	30	38	35	33	27
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	28	32	30	29	22
PBW83	Adezai	Tube Well	22	41	26	23	18
PBW84	Nowshera cantt.	Tube Well	49	63	59	51	46
PBW85	Jaluzai	Tube Well	40	46	45	41	39
PBW86	Dag Besud	Tube Well	75	88	85	88	64
PBW87	Manki Sharif	Tube Well	35	40	38	40	30
PBW88	Akora Khatta	Tube Well	30	34	32	34	26
PBW89	Jehangira	Bore Well	30	40	38	38	29
PBW90	Darwazgi	Dug Well	79	88	85	81	73
PBW91	Adezai	Dug Well	75	83	80	82	65
PBW92	Aimal Chabutra	H. Pump	83	94	90	89	79
PBW93	Garhi Chandan	Dug Well	68	78	75	71	65
PBW94	Aza Khel	Dug Well	35	43	40	38	34
PBW95	Taila Band	Dug Well	38	44	42	42	36
PBW96	Chapri	Dug Well	30	38	35	33	25
PBW97	Speen Khak	Dug Well	48	56	51	51	32
PBW98	Musha Ghar	Dug Well	78	90	88	81	70
PBW103	Khairabad	Kabul River	21	28	25	23	17
PBW104	Attock	Indus River	6	9	8	8	3

Table 3.12. Concentration K (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	K 3-Jan	K Jan 04	K June 03	K June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	2	5	4	4	2
PBW2	WAPDA Colony	Tube Well	7	10	9	9	6
PBW3	Tehkal Bala	Tube Well	3	6	4	5	2
PBW4	Jamrud Road	Tube Well	2	6	3	3	2
PBW5	Industrial Estate	Tube Well	2	5	3	3	2
PBW6	Hayatatab Phase-3	Tube Well	2	4	4	3	3
PBW7	Danish Abad	Tube Well	3	6	4	5	2
PBW8	Bara	Tube Well	4	6	5	6	3
PBW9	Sar Band	Tube Well	4	6	5	6	2
PBW10	Shabqadar	Tube Well	5	8	5	7	4
PBW11	Matta Mughal Khel	Tube Well	6	8	7	8	5
PBW12	Abazai	Tube Well	2	5	4	5	2
PBW13	Tangi	Tube Well	4	7	6	6	4
PBW14	S. Umer Baba	Dug Well	6	6	8	8	5
PBW15	Hinder Kassi	Dug Well	14	12	14	12	20
PBW16	Jamrud Road	Hand Pump	3	5	4	4	2
PBW105	W. Dam Kabul river	Warsak Dam	5	7	6	7	4
PBW106	W. Dam Kabul river	Warsak Dam	4	6	5	8	5
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	3	6	5	5	3
PBW18	Mathra	Tube Well	10	9	10	10	9
PBW19	Khazana	Tube Well	8	9	8	8	7
PBW20	Kukar	Tube Well	8	10	10	10	4
PBW21	Mandezai Srikh	Tube Well	2	4	3	4	1
PBW22	Rajjar	Tube Well	4	6	5	6	3
PBW23	Turangzai	Tube Well	3	6	5	5	4
PBW24	Prang	Tube Well	6	9	8	10	5
PBW25	Kandi Hayat	Borehole well	3	6	5	4	3
PBW26	Aman Kot	Tube Well	2	4	3	5	1
PBW27	Mathra	Dug Well	10	9	10	8	9
PBW28	Charpariza	Dug Well	18	23	20	21	16
PBW29	Khazana	Dug Well	3	8	7	5	5
PBW30	Adezai	Hand Pump	10	8	9	6	9
PBW31	Mandazar	Dug Well	3	5	4	4	2
PBW32	Kot	Dug Well	3	5	4	5	2
PBW33	Aman Kot	Dug Well	3	5	4	4	1
PBW34	Takht Bhai	Hand Pump	1	3	2	3	1
PBW35	Pir Baba	Stream	6	8	7	8	5
PBW36	Pir Baba	Stream	5	7	6	6	4
PBW37	Pir Baba	Stream	4	6	5	6	3

Concentration K (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	K 3-Jan	K Jan 04	K June 03	K June 04	Tariq (2001)
PBW48	Pir Baba	Stream	3	5	4	3	5
PBW39	Pir Baba	Stream	2	5	4	4	2
PBW40	Pir Baba	Stream	5	7	6	7	5
PBW107	Sardaryab	Kabul River	5	7	6	6	5
PBW108	Naguman	Kabul River	2	4	3	4	5
PBW109	Shah Alam	Kabul River	3	6	4	6	5
PBW110	Swat River	Kabul River	4	6	5	6	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	3	5	4	5	3
PBW42	Forest Colony	Tube Well	3	6	4	5	2
PBW43	Shahi Bala	Hand Pump	4	6	5	6	2
PBW44	Hashim Kili	Tube Well	3	5	4	5	3
PBW45	Gharibabad	Tube Well	3	6	5	5	3
PBW46	Badh Ber	Tube Well	3	5	4	5	4
PBW47	Sorezai	Tube Well	2	4	3	4	3
PBW48	Jahangir Abad	Tube Well	5	7	6	8	4
PBW49	Landi Arbab	Tube Well	3	7	4	4	2
PBW50	Saddar Stadium	Tube Well	5	6	6	7	4
PBW51	Defence Colony	Tube Well	4	6	5	5	3
PBW52	Dabgari Shuba	Tube Well	4	7	6	5	4
PBW53	Gulshan R. Colony	Tube Well	8	9	10	10	7
PBW54	Tehsil Gunj	Tube Well	6	8	7	7	4
PBW55	Gulbahar No.2	Tube Well	6	9	8	8	5
PBW56	Hazar Khawani	Tube Well	5	7	6	5	54
PBW57	Wadpagga	Tube Well	5	8	6	7	4
PBW58	Akbar Pura	Tube Well	9	10	10	10	8
PBW59	Pabbi	Tube Well	5	7	6	7	4
PBW60	Urmar Village	Tube Well	5	7	6	6	3
PBW61	Aza Khel Bala	Tube Well	4	8	5	7	3
PBW62	Bashirabad	Dug Well	6	9	8	8	4
PBW63	Shiggi	Dug Well	10	9	8	8	9
PBW64	Shiggi	H. Pump	5	7	6	6	3
PBW65	Pajagi	H. Pump	4	6	5	5	3
PBW66	Mulazai	Dug Well	6	9	10	7	5
PBW67	Regi	H. Pump	3	5	4	5	1
PBW68	Shahi Bala	Dug Well	8	10	10	9	8
PBW169	Kafir Dheri	Dug Well	8	9	10	10	5
PBW70	Pawaka	Bore Well	3	6	4	4	2
PBW71	Bazeed Khel	H. Pump	3	5	4	4	2
PBW72	Surezai	Dug Well	30	41	42	40	40
PBW73	Hazar Khawani	H. Pump	20	27	25	23	18
PBW74	Phandu	Dug Well	25	33	30	28	21
PBW75	Hazarkhawani	Dug Well	6	10	8	8	4

Concentration K (mg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	K 3-Jan	K Jan 04	K June 03	K June 04	Tariq (2001)
PBW76	Wadpagga	Dug Well	26	20	36	23	20
PBW77	Zahirabad	Dug Well	10	8	10	10	7
PBW78	Urmar Bala	Dug Well	10	9	8	8	9
PBW79	Urmar Payan	Dug Well	10	9	8	10	10
PBW80	Azakhel Bala	Dug Well	6	10	8	8	4
PBW81	Shahbaz Garhi	H. Pump	4	8	5	6	2
PBW99	Malakand Pass	Spring	4	6	5	5	2
PBW100	Dargai	Spring	2	4	3	3	1
PBW101	Pirsai	Spring	3	6	4	5	1
PBW102	Nowshera Bridge	Kabul River	6	6	8	7	5
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	3	6	5	4	2
PBW83	Adezai	Tube Well	4	8	6	5	2
PBW84	Nowshera cantt.	Tube Well	5	8	6	6	3
PBW85	Jaluzai	Tube Well	4	8	6	5	3
PBW86	Dag Besud	Tube Well	5	9	7	10	4
PBW87	Manki Sharif	Tube Well	4	6	5	6	2
PBW88	Akora Khatta	Tube Well	4	6	5	5	3
PBW89	Jehangira	Bore Well	4	8	5	6	2
PBW90	Darwazgi	Dug Well	3	6	4	4	2
PBW91	Adezai	Dug Well	4	8	5	6	2
PBW92	Aimal Chabutra	H. Pump	2	6	3	4	1
PBW93	Garhi Chandan	Dug Well	4	7	5	6	2
PBW94	Aza Khel	Dug Well	5	8	6	8	3
PBW95	Taila Band	Dug Well	6	8	7	8	3
PBW96	Chapri	Dug Well	3	6	4	5	2
PBW97	Speen Khak	Dug Well	3	6	4	5	2
PBW98	Musha Ghar	Dug Well	3	6	4	5	2
PBW103	Khairabad	Kabul River	5	8	6	8	3
PBW104	Attock	Indus River	2	3	4	4	2

Table 3.13. Concentration Fe (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Fe Jan 03	Fe Jan 04	Fe June 03	Fe June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	11	29	20	14	15
PBW2	WAPDA Colony	Tube Well	8	13	12	12	7
PBW3	Tehkal Bala	Tube Well	6	13	8	7	6
PBW4	Jamrud Road	Tube Well	10	13	12	13	8
PBW5	Industrial Estate	Tube Well	180	40	191	185	170
PBW6	Hayatatab Phase-3	Tube Well	662	693	678	687	790
PBW7	Danish Abad	Tube Well	7	9	8	9	5
PBW8	Bara	Tube Well	10	40	12	12	8
PBW9	Sar Band	Tube Well	7	10	9	9	3
PBW10	Shabqadar	Tube Well	7	9	8	9	5
PBW11	Matta Mughal Khel	Tube Well	6	9	8	8	5
PBW12	Abazai	Tube Well	10	15	12	3	6
PBW13	Tangi	Tube Well	8	12	10	16	6
PBW14	S. Umer Baba	Dug Well	12	16	14	15	9
PBW15	Hinder Kassi	Dug Well	8	17	10	10	7
PBW16	Jamrud Road	Hand Pump	43	60	55	46	48
PBW105	W. Dam Kabul river	Warsak Dam	50	60	55	52	33
PBW106	W. Dam Kabul river	Warsak Dam	41	48	45	56	30
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	1	2	1	2	0
PBW18	Mathra	Tube Well	18	24	22	20	17
PBW19	Khazana	Tube Well	35	44	42	38	36
PBW20	Kukar	Tube Well	9	40	12	11	30
PBW21	Mandezai Srikh	Tube Well	10	14	12	3	9
PBW22	Rajjar	Tube Well	1	3	2	2	1
PBW23	Turangzai	Tube Well	136	148	141	139	134
PBW24	Prang	Tube Well	14	19	16	22	12
PBW25	Kandi Hayat	Borehole well	20	34	22	25	18
PBW26	Aman Kot	Tube Well	59	65	63	64	51
PBW27	Mathra	Dug Well	12	16	14	14	9
PBW28	Charpariza	Dug Well	8	12	9	10	7
PBW29	Khazana	Dug Well	201	215	211	209	196
PBW30	Adezai	Hand Pump	39	48	46	31	38
PBW31	Mandazar	Dug Well	27	34	31	29	21
PBW32	Kot	Dug Well	12	70	16	18	13
PBW33	Aman Kot	Dug Well	15	23	20	18	11
PBW34	Takht Bhai	Hand Pump	3	6	5	4	3
PBW35	Pir Baba	Stream	14	17	16	16	10
PBW36	Pir Baba	Stream	11	13	12	15	3
PBW37	Pir Baba	Stream	3	5	4	5	1

Concentration Fe (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Fe Jan 03	Fe Jan 04	Fe June 03	Fe June 04	Tariq (2001)
PBW48	Pir Baba	Stream	1	3	2	4	1
PBW39	Pir Baba	Stream	1	2	1	3	4
PBW40	Pir Baba	Stream	1	2	1	3	1
PBW107	Sardaryab	Kabul River	28	41	30	29	25
PBW108	Naguman	Kabul River	74	80	78	75	25
PBW109	Shah Alam	Kabul River	45	88	30	82	10
PBW110	Swat River	Kabul River	1	2	1	3	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	4	6	5	6	3
PBW42	Forest Colony	Tube Well	39	45	42	43	35
PBW43	Shahi Bala	Hand Pump	28	33	31	33	25
PBW44	Hashim Kili	Tube Well	50	54	53	53	45
PBW45	Gharibabad	Tube Well	139	152	148	142	135
PBW46	Badh Ber	Tube Well	19	24	22	22	15
PBW47	Sorezai	Tube Well	28	34	30	32	23
PBW48	Jahangir Abad	Tube Well	13	17	15	16	9
PBW49	Landi Arbab	Tube Well	2	6	4	3	3
PBW50	Saddar Stadium	Tube Well	3	1	4	5	2
PBW51	Defence Colony	Tube Well	3	1	0	2	0
PBW52	Dabgari Shuba	Tube Well	115	127	123	119	111
PBW53	Gulshan R. Colony	Tube Well	38	45	41	42	29
PBW54	Tehsil Gunj	Tube Well	48	58	55	51	47
PBW55	Gulbahar No.2	Tube Well	20	26	25	26	19
PBW56	Hazar Khawani	Tube Well	256	262	260	259	240
PBW57	Wadpagga	Tube Well	8	12	10	11	4
PBW58	Akbar Pura	Tube Well	90	98	95	93	86
PBW59	Pabbi	Tube Well	1	4	2	3	1
PBW60	Urmar Village	Tube Well	4	6	5	11	3
PBW61	Aza Khel Bala	Tube Well	5	6	6	14	5
PBW62	Bashirabad	Dug Well	1	3	2	3	0
PBW63	Shiggi	Dug Well	30	38	35	40	27
PBW64	Shiggi	H. Pump	168	168	165	163	153
PBW65	Pajagi	H. Pump	30	58	35	34	28
PBW66	Mulazai	Dug Well	100	111	108	102	14
PBW67	Regi	H. Pump	24	29	27	26	17
PBW68	Shahi Bala	Dug Well	103	113	110	107	99
PBW169	Kafir Dheri	Dug Well	61	69	68	63	51
PBW70	Pawaka	Bore Well	136	149	140	139	129
PBW71	Bazeed Khel	H. Pump	44	54	50	45	30
PBW72	Surezai	Dug Well	50	60	56	53	44
PBW73	Hazar Khawani	H. Pump	26	30	28	28	17
PBW74	Phandu	Dug Well	40	38	46	43	39
PBW75	Hazarkhawani	Dug Well	60	68	65	64	54
PBW76	Wadpagga	Dug Well	42	52	48	45	39
PBW77	Zahirabad	Dug Well	4	8	6	6	3
PBW78	Urmar Bala	Dug Well	21	32	28	27	11

Concentration Fe (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Fe Jan 03	Fe Jan 04	Fe June 03	Fe June 04	Tariq (2001)
PBW79	Urmar Payan	Dug Well	75	88	85	78	70
PBW80	Azakhel Bala	Dug Well	3	6	4	5	1
PBW81	Shahbaz Garhi	H. Pump	2	3	2	3	1
PBW99	Malakand Pass	Spring	5	8	6	7	3
PBW100	Dargai	Spring	6	10	8	8	3
PBW101	Pirsai	Spring	21	28	25	24	16
PBW102	Nowshera Bridge	Kabul River	51	64	61	54	48
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	38	49	48	41	31
PBW83	Adezai	Tube Well	4	54	6	5	2
PBW84	Nowshera cantt.	Tube Well	24	35	30	28	16
PBW85	Jaluzai	Tube Well	15	20	18	16	12
PBW86	Dag Besud	Tube Well	3	8	5	6	0
PBW87	Manki Sharif	Tube Well	130	140	138	41	125
PBW88	Akora Khatta	Tube Well	48	58	55	47	40
PBW89	Jehangira	Bore Well	650	681	670	651	620
PBW90	Darwazgi	Dug Well	28	30	25	26	17
PBW91	Adezai	Dug Well	30	42	38	32	21
PBW92	Aimal Chabutra	H. Pump	30	10	36	36	25
PBW93	Garhi Chandan	Dug Well	21	31	28	29	15
PBW94	Aza Khel	Dug Well	5	9	7	8	3
PBW95	Taila Band	Dug Well	18	4	21	22	10
PBW96	Chapri	Dug Well	20	29	25	29	16
PBW97	Speen Khak	Dug Well	6	10	8	8	5
PBW98	Musha Ghar	Dug Well	30	37	35	38	26
PBW103	Khairabad	Kabul River	13	17	15	20	9
PBW104	Attock	Indus River	165	173	170	173	155

Table 3.14. Concentration Cu (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cu Jan 03	Cu Jan 04	Cu June 03	Cu June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	3	6	5	5	3
PBW2	WAPDA Colony	Tube Well	2	3	35	4	1
PBW3	Tehkal Bala	Tube Well	2	3	1	2	1
PBW4	Jamrud Road	Tube Well	2	3	2	3	1
PBW5	Industrial Estate	Tube Well	20	23	22	22	16
PBW6	Hayatatab Phase-3	Tube Well	35	25	36	37	37
PBW7	Danish Abad	Tube Well	4	6	5	6	4
PBW8	Bara	Tube Well	1	1	1	2	1
PBW9	Sar Band	Tube Well	1	1	1	1	1
PBW10	Shabqadar	Tube Well	1	1	1	1	1
PBW11	Matta Mughal Khel	Tube Well	1	1	1	1	1
PBW12	Abazai	Tube Well	10	15	12	3	5
PBW13	Tangi	Tube Well	8	9	10	13	7
PBW14	S. Umer Baba	Dug Well	25	33	30	28	22
PBW15	Hinder Kassi	Dug Well	8	8	10	10	7
PBW16	Jamrud Road	Hand Pump	1	1	1	4	1
PBW105	W. Dam Kabul river	Warsak Dam	1	3	2	4	1
PBW106	W. Dam Kabul river	Warsak Dam	2	4	3	4	2
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	1	3	2	3	1
PBW18	Mathra	Tube Well	1	2	1	2	0
PBW19	Khazana	Tube Well	0	2	1	8	0
PBW20	Kukar	Tube Well	1	3	2	3	2
PBW21	Mandezai Srikh	Tube Well	11	13	12	15	16
PBW22	Rajjar	Tube Well	3	5	4	3	2
PBW23	Turangzai	Tube Well	8	6	10	4	7
PBW24	Prang	Tube Well	30	48	31	35	21
PBW25	Kandi Hayat	Borehole well	6	9	8	8	5
PBW26	Aman Kot	Tube Well	28	32	30	32	23
PBW27	Mathra	Dug Well	1	2	1	3	1
PBW28	Charpariza	Dug Well	2	4	3	4	2
PBW29	Khazana	Dug Well	1	3	2	3	1
PBW30	Adezai	Hand Pump	1	4	2	6	1
PBW31	Mandazar	Dug Well	4	7	6	6	3
PBW32	Kot	Dug Well	4	7	6	62	2
PBW33	Aman Kot	Dug Well	58	69	67	60	51
PBW34	Takht Bhai	Hand Pump	10	14	12	14	9
PBW35	Pir Baba	Stream	8	12	10	12	7
PBW36	Pir Baba	Stream	8	11	9	10	1
PBW37	Pir Baba	Stream	2	3	2	4	1
PBW48	Pir Baba	Stream	2	4	3	5	1

Concentration Cu (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cu Jan 03	Cu Jan 04	Cu June 03	Cu June 04	Tariq (2001)
PBW39	Pir Baba	Stream	8	11	9	10	7
PBW40	Pir Baba	Stream	4	6	5	6	3
PBW107	Sardaryab	Kabul River	1	4	2	3	1
PBW108	Naguman	Kabul River	1	2	1	2	1
PBW109	Shah Alam	Kabul River	1	3	1	4	1
PBW110	Swat River	Kabul River	0	1	0	2	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	7	9	8	9	0
PBW42	Forest Colony	Tube Well	5	6	8	8	6
PBW43	Shahi Bala	Hand Pump	4	6	5	6	13
PBW44	Hashim Kili	Tube Well	3	2	4	5	3
PBW45	Gharibabad	Tube Well	4	6	5	6	2
PBW46	Badh Ber	Tube Well	5	7	6	8	1
PBW47	Sorezai	Tube Well	1	2	1	3	1
PBW48	Jahangir Abad	Tube Well	1	2	1	3	1
PBW49	Landi Arbab	Tube Well	1	1	1	2	1
PBW50	Saddar Stadium	Tube Well	1	1	1	1	1
PBW51	Defence Colony	Tube Well	1	1	1	1	1
PBW52	Dabgari Shuba	Tube Well	1	1	1	1	1
PBW53	Gulshan R. Colony	Tube Well	2	4	3	4	1
PBW54	Tehsil Gunj	Tube Well	41	51	48	46	32
PBW55	Gulbahar No.2	Tube Well	2	4	3	4	1
PBW56	Hazar Khawani	Tube Well	1	4	2	3	6
PBW57	Wadpagga	Tube Well	1	3	2	3	1
PBW58	Akbar Pura	Tube Well	41	48	45	43	33
PBW59	Pabbi	Tube Well	8	9	9	10	7
PBW60	Urmar Village	Tube Well	5	7	6	7	4
PBW61	Aza Khel Bala	Tube Well	7	6	8	7	6
PBW62	Bashirabad	Dug Well	1	3	2	3	0
PBW63	Shiggi	Dug Well	6	9	8	7	5
PBW64	Shiggi	H. Pump	4	6	5	5	2
PBW65	Pajagi	H. Pump	2	4	3	4	0
PBW66	Mulazai	Dug Well	1	2	1	3	12
PBW67	Regi	H. Pump	32	39	36	36	28
PBW68	Shahi Bala	Dug Well	1	2	1	3	0
PBW169	Kafir Dheri	Dug Well	10	16	12	12	9
PBW70	Pawaka	Bore Well	1	2	1	3	1
PBW71	Bazeed Khel	H. Pump	1	2	2	3	1
PBW72	Surezai	Dug Well	1	3	1	3	1
PBW73	Hazar Khawani	H. Pump	14	18	16	16	12
PBW74	Phandu	Dug Well	3	5	4	5	2
PBW75	Hazarkhawani	Dug Well	2	5	3	4	1
PBW76	Wadpagga	Dug Well	8	16	12	9	7
PBW77	Zahirabad	Dug Well	6	10	7	8	4
PBW78	Urmar Bala	Dug Well	4	6	5	6	3
PBW79	Urmar Payan	Dug Well	13	20	15	16	6
PBW80	Azakhel Bala	Dug Well	18	25	20	22	14

Concentration Cu (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cu Jan 03	Cu Jan 04	Cu June 03	Cu June 04	Tariq (2001)
PBW81	Shahbaz Garhi	H. Pump	13	18	15	15	9
PBW99	Malakand Pass	Spring	10	16	12	12	7
PBW100	Dargai	Spring	6	9	8	8	3
PBW101	Pirsai	Spring	3	15	12	12	7
PBW102	Nowshera Bridge	Kabul River	3	6	4	4	1
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	6	10	8	8	3
PBW83	Adezai	Tube Well	1	12	2	2	1
PBW84	Nowshera cantt.	Tube Well	10	16	12	13	7
PBW85	Jaluzai	Tube Well	2	6	3	3	1
PBW86	Dag Besud	Tube Well	1	6	2	4	1
PBW87	Manki Sharif	Tube Well	19	28	26	29	16
PBW88	Akora Khatta	Tube Well	8	15	10	10	6
PBW89	Jehangira	Bore Well	6	10	8	12	4
PBW90	Darwazgi	Dug Well	3	8	5	4	2
PBW91	Adezai	Dug Well	3	8	4	5	1
PBW92	Aimal Chabutra	H. Pump	18	25	20	20	14
PBW93	Garhi Chandan	Dug Well	19	25	22	25	15
PBW94	Aza Khel	Dug Well	1	4	2	3	0
PBW95	Taila Band	Dug Well	20	35	30	25	17
PBW96	Chapri	Dug Well	3	6	5	5	1
PBW97	Speen Khak	Dug Well	1	4	2	3	1
PBW98	Musha Ghar	Dug Well	2	4	3	3	1
PBW103	Khairabad	Kabul River	15	20	18	4	10
PBW104	Attock	Indus River	41	51	48	45	32

Table 3.15. Concentration Pb (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Pb Jan 03	Pb Jan 04	Pb June 03	Pb June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	1	2	1	3	1
PBW2	WAPDA Colony	Tube Well	1	3	2	2	1
PBW3	Tehkal Bala	Tube Well	2	3	2	4	1
PBW4	Jamrud Road	Tube Well	3	3	3	2	1
PBW5	Industrial Estate	Tube Well	39	40	41	41	35
PBW6	Hayatatab Phase-3	Tube Well	2	2	1	1	1
PBW7	Danish Abad	Tube Well	3	2	3	2	34
PBW8	Bara	Tube Well	3	5	4	4	1
PBW9	Sar Band	Tube Well	143	140	142	142	134
PBW10	Shabqadar	Tube Well	41	38	39	40	41
PBW11	Matta Mughal Khel	Tube Well	58	64	61	62	47
PBW12	Abazai	Tube Well	9	8	7	5	5
PBW13	Tangi	Tube Well	8	4	6	7	7
PBW14	S. Umer Baba	Dug Well	1	3	2	2	1
PBW15	Hinder Kassi	Dug Well	1	3	2	3	1
PBW16	Jamrud Road	Hand Pump	1	5	2	2	1
PBW105	W. Dam Kabul river	Warsak Dam	1	2	1	3	1
PBW106	W. Dam Kabul river	Warsak Dam	1	2	1	4	1
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	1	5	2	2	2
PBW18	Mathra	Tube Well	8	7	6	9	21
PBW19	Khazana	Tube Well	7	3	4	2	31
PBW20	Kukar	Tube Well	4	5	4	6	1
PBW21	Mandezai Srikh	Tube Well	1	4	1	4	16
PBW22	Rajjar	Tube Well	3	7	4	2	2
PBW23	Turangzai	Tube Well	7	8	8	8	21
PBW24	Prang	Tube Well	23	31	28	26	5
PBW25	Kandi Hayat	Borehole well	7	9	8	7	23
PBW26	Aman Kot	Tube Well	26	30	28	29	3
PBW27	Mathra	Dug Well	3	5	4	5	1
PBW28	Charpariza	Dug Well	1	3	2	2	2
PBW29	Khazana	Dug Well	2	4	3	5	3
PBW30	Adezai	Hand Pump	4	7	6	3	1
PBW31	Mandazar	Dug Well	1	3	2	2	1
PBW32	Kot	Dug Well	1	2	1	6	1
PBW33	Aman Kot	Dug Well	2	4	3	4	1
PBW34	Takht Bhai	Hand Pump	7	7	8	9	6
PBW35	Pir Baba	Stream	2	4	3	4	1
PBW36	Pir Baba	Stream	2	3	2	4	2
PBW37	Pir Baba	Stream	3	5	4	6	2
PBW48	Pir Baba	Stream	2	4	3	4	1

Concentration Pb (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Pb Jan 03	Pb Jan 04	Pb June 03	Pb June 04	Tariq (2001)
PBW39	Pir Baba	Stream	2	3	2	4	1
PBW40	Pir Baba	Stream	1	2	1	3	1
PBW107	Sardaryab	Kabul River	3	6	5	6	4
PBW108	Naguman	Kabul River	2	3	2	4	3
PBW109	Shah Alam	Kabul River	2	4	3	6	4
PBW110	Swat River	Kabul River	1	2	1	4	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	1	3	2	2	0
PBW42	Forest Colony	Tube Well	1	2	1	3	1
PBW43	Shahi Bala	Hand Pump	1	2	1	3	1
PBW44	Hashim Kili	Tube Well	2	3	5	6	1
PBW45	Gharibabad	Tube Well	1	2	1	3	51
PBW46	Badh Ber	Tube Well	2	3	4	5	1
PBW47	Sorezai	Tube Well	39	48	42	42	30
PBW48	Jahangir Abad	Tube Well	1	3	2	3	35
PBW49	Landi Arbab	Tube Well	1	3	2	2	1
PBW50	Saddar Stadium	Tube Well	1	2	2	2	1
PBW51	Defence Colony	Tube Well	1	2	1	6	1
PBW52	Dabgari Shuba	Tube Well	1	1	11	1	1
PBW53	Gulshan R. Colony	Tube Well	2	3	3	4	1
PBW54	Tehsil Gunj	Tube Well	1	3	2	3	1
PBW55	Gulbahar No.2	Tube Well	60	71	67	66	59
PBW56	Hazar Khawani	Tube Well	1	2	2	3	1
PBW57	Wadpagga	Tube Well	2	4	3	3	1
PBW58	Akbar Pura	Tube Well	1	3	2	3	1
PBW59	Pabbi	Tube Well	48	46	50	47	44
PBW60	Urmar Village	Tube Well	3	5	4	5	1
PBW61	Aza Khel Bala	Tube Well	8	6	10	4	6
PBW62	Bashirabad	Dug Well	1	3	2	3	0
PBW63	Shiggi	Dug Well	1	3	2	2	0
PBW64	Shiggi	H. Pump	2	3	2	4	0
PBW65	Pajagi	H. Pump	1	3	2	2	0
PBW66	Mulazai	Dug Well	1	3	2	2	0
PBW67	Regi	H. Pump	1	2	1	2	1
PBW68	Shahi Bala	Dug Well	1	3	1	2	1
PBW169	Kafir Dheri	Dug Well	1	4	1	2	1
PBW70	Pawaka	Bore Well	1	3	1	2	1
PBW71	Bazeed Khel	H. Pump	1	4	2	4	1
PBW72	Surezai	Dug Well	30	36	32	40	25
PBW73	Hazar Khawani	H. Pump	1	4	2	3	1
PBW74	Phandu	Dug Well	2	2	3	3	1
PBW75	Hazarkhawani	Dug Well	1	4	2	3	1
PBW76	Wadpagga	Dug Well	39	48	42	43	31
PBW77	Zahirabad	Dug Well	3	6	4	4	1

Concentration Pb (μg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Pb Jan 03	Pb Jan 04	Pb June 03	Pb June 04	Tariq (2001)
PBW78	Urmar Bala	Dug Well	3	6	4	5	1
PBW79	Urmar Payan	Dug Well	1	5	2	3	1
PBW80	Azakhel Bala	Dug Well	18	26	20	22	14
PBW81	Shahbaz Garhi	H. Pump	29	39	35	32	27
PBW99	Malakand Pass	Spring	18	28	25	20	16
PBW100	Dargai	Spring	30	35	32	5	22
PBW101	Pirsai	Spring	2	33	30	5	22
PBW102	Nowshera Bridge	Kabul River	40	48	45	43	39
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	140	155	149	144	134
PBW83	Adezai	Tube Well	2	2	3	3	1
PBW84	Nowshera cantt.	Tube Well	48	58	51	51	39
PBW85	Jaluzai	Tube Well	1	4	2	2	1
PBW86	Dag Besud	Tube Well	39	42	45	48	30
PBW87	Manki Sharif	Tube Well	25	45	30	38	22
PBW88	Akora Khatta	Tube Well	22	30	26	27	16
PBW89	Jehangira	Bore Well	31	42	38	30	27
PBW90	Darwazgi	Dug Well	1	4	2	3	0
PBW91	Adezai	Dug Well	2	8	3	2	1
PBW92	Aimal Chabutra	H. Pump	1	4	2	2	1
PBW93	Garhi Chandan	Dug Well	1	4	2	2	1
PBW94	Aza Khel	Dug Well	2	6	3	4	1
PBW95	Taila Band	Dug Well	3	8	4	5	1
PBW96	Chapri	Dug Well	58	56	50	52	55
PBW97	Speen Khak	Dug Well	15	25	20	20	13
PBW98	Musha Ghar	Dug Well	2	4	3	4	1
PBW103	Khairabad	Kabul River	25	6	29	4	21
PBW104	Attock	Indus River	45	47	43	45	41

Table 3.16. Concentration Ni (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ni 03 Jan	Ni Jan 04	Ni 03 June	Ni June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	2	2	3	2	2
PBW2	WAPDA Colony	Tube Well	1	4	3	2	1
PBW3	Tehkal Bala	Tube Well	4	6	5	5	3
PBW4	Jamrud Road	Tube Well	1	6	2	2	1
PBW5	Industrial Estate	Tube Well	3	3	4	5	3
PBW6	Hayatatab Phase-3	Tube Well	2	4	2	2	1
PBW7	Danish Abad	Tube Well	46	51	49	49	34
PBW8	Bara	Tube Well	2	3	2	4	1
PBW9	Sar Band	Tube Well	40	46	55	48	39
PBW10	Shabqadar	Tube Well	4	6	5	6	3
PBW11	Matta Mughal Khel	Tube Well	3	5	4	5	2
PBW12	Abazai	Tube Well	2	4	3	3	2
PBW13	Tangi	Tube Well	1	3	2	4	1
PBW14	S. Umer Baba	Dug Well	1	3	2	2	1
PBW15	Hinder Kassi	Dug Well	2	3	3	3	2
PBW16	Jamrud Road	Hand Pump	2	4	3	4	2
PBW105	W. Dam Kabul river	Warsak Dam	2	5	4	5	3
PBW106	W. Dam Kabul river	Warsak Dam	3	5	4	4	1
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	1	3	2	2	1
PBW18	Mathra	Tube Well	3	4	4	4	3
PBW19	Khazana	Tube Well	4	6	5	5	4
PBW20	Kukar	Tube Well	3	5	4	4	1
PBW21	Mandezai Srikh	Tube Well	1	3	2	2	1
PBW22	Rajjar	Tube Well	1	6	4	2	1
PBW23	Turangzai	Tube Well	7	9	8	8	1
PBW24	Prang	Tube Well	1	3	2	3	1
PBW25	Kandi Hayat	Borehole well	6	9	8	7	5
PBW26	Aman Kot	Tube Well	1	2	1	3	1
PBW27	Mathra	Dug Well	2	5	4	4	3
PBW28	Charpariza	Dug Well	4	7	6	6	3
PBW29	Khazana	Dug Well	3	7	6	5	4
PBW30	Adezai	Hand Pump	1	4	3	2	1
PBW31	Mandazar	Dug Well	1	3	2	2	1
PBW32	Kot	Dug Well	1	2	1	3	1
PBW33	Aman Kot	Dug Well	1	2	1	3	1
PBW34	Takht Bhai	Hand Pump	1	2	1	2	1
PBW35	Pir Baba	Stream	5	8	6	6	4
PBW36	Pir Baba	Stream	3	6	5	6	1
PBW37	Pir Baba	Stream	2	3	2	4	2
PBW48	Pir Baba	Stream	2	4	3	2	1

Concentration Ni (μg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ni 03 Jan	Ni Jan 04	Ni 03 June	Ni June 04	Tariq (2001)
PBW39	Pir Baba	Stream	1	2	1	3	1
PBW40	Pir Baba	Stream	3	5	4	4	2
PBW107	Sardaryab	Kabul River	1	4	2	3	1
PBW108	Naguman	Kabul River	1	3	2	3	3
PBW109	Shah Alam	Kabul River	2	4	2	4	2
PBW110	Swat River	Kabul River	4	6	5	6	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	2	3	2	3	3
PBW42	Forest Colony	Tube Well	3	4	4	4	2
PBW43	Shahi Bala	Hand Pump	4	6	5	6	3
PBW44	Hashim Kili	Tube Well	2	4	3	4	12
PBW45	Gharibabad	Tube Well	3	5	4	5	2
PBW46	Badh Ber	Tube Well	3	5	4	5	3
PBW47	Sorezai	Tube Well	3	5	4	4	3
PBW48	Jahangir Abad	Tube Well	1	3	2	3	1
PBW49	Landi Arbab	Tube Well	1	3	2	3	1
PBW50	Saddar Stadium	Tube Well	2	2	2	3	1
PBW51	Defence Colony	Tube Well	1	2	1	2	1
PBW52	Dabgari Shuba	Tube Well	1	2	4	2	4
PBW53	Gulshan R. Colony	Tube Well	2	3	2	3	2
PBW54	Tehsil Gunj	Tube Well	3	6	5	4	3
PBW55	Gulbahar No.2	Tube Well	2	3	2	4	3
PBW56	Hazar Khawani	Tube Well	2	3	3	3	3
PBW57	Wadpagga	Tube Well	4	6	5	5	2
PBW58	Akbar Pura	Tube Well	3	6	4	5	4
PBW59	Pabbi	Tube Well	2	5	4	4	2
PBW60	Urmar Village	Tube Well	51	61	58	56	47
PBW61	Aza Khel Bala	Tube Well	1	8	2	4	1
PBW62	Bashirabad	Dug Well	2	4	3	3	1
PBW63	Shiggi	Dug Well	2	4	3	3	1
PBW64	Shiggi	H. Pump	5	7	6	8	3
PBW65	Pajagi	H. Pump	4	6	5	3	3
PBW66	Mulazai	Dug Well	4	6	5	5	3
PBW67	Regi	H. Pump	3	6	4	4	2
PBW68	Shahi Bala	Dug Well	4	6	5	5	3
PBW169	Kafir Dheri	Dug Well	3	5	4	4	2
PBW70	Pawaka	Bore Well	3	6	4	4	2
PBW71	Bazeed Khel	H. Pump	2	6	3	3	2
PBW72	Surezai	Dug Well	2	6	3	3	1
PBW73	Hazar Khawani	H. Pump	2	4	2	3	1
PBW74	Phandu	Dug Well	6	10	8	8	4
PBW75	Hazarkhawani	Dug Well	3	6	4	3	2
PBW76	Wadpagga	Dug Well	4	10	6	5	2
PBW77	Zahirabad	Dug Well	4	8	5	6	1
PBW78	Urmar Bala	Dug Well	2	5	3	3	1
PBW79	Urmar Payan	Dug Well	28	36	30	30	21

Concentration Ni (μg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Ni 03 Jan	Ni Jan 04	Ni 03 June	Ni June 04	Tariq (2001)
PBW80	Azakhel Bala	Dug Well	3	6	4	5	21
PBW81	Shahbaz Garhi	H. Pump	22	26	23	23	1
PBW99	Malakand Pass	Spring	1	4	2	3	1
PBW100	Dargai	Spring	3	6	4	4	1
PBW101	Pirsai	Spring	3	4	3	3	1
PBW102	Nowshera Bridge	Kabul River	5	8	6	6	1
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	3	6	4	4	1
PBW83	Adezai	Tube Well	5	5	6	6	4
PBW84	Nowshera cantt.	Tube Well	5	8	6	6	3
PBW85	Jaluzai	Tube Well	1	4	2	3	1
PBW86	Dag Besud	Tube Well	2	6	3	4	1
PBW87	Manki Sharif	Tube Well	2	6	2	3	1
PBW88	Akora Khatta	Tube Well	1	4	2	2	1
PBW89	Jehangira	Bore Well	1	4	2	3	1
PBW90	Darwazgi	Dug Well	6	9	8	8	4
PBW91	Adezai	Dug Well	5	8	6	9	3
PBW92	Aimal Chabutra	H. Pump	3	6	5	4	2
PBW93	Garhi Chandan	Dug Well	5	8	6	6	4
PBW94	Aza Khel	Dug Well	4	6	5	5	3
PBW95	Taila Band	Dug Well	5	6	6	8	2
PBW96	Chapri	Dug Well	3	5	4	5	1
PBW97	Speen Khak	Dug Well	1	3	2	3	1
PBW98	Musha Ghar	Dug Well	35	34	45	35	30
PBW103	Khairabad	Kabul River	5	9	8	3	4
PBW104	Attock	Indus River	8	7	9	8	7

Table 3.17. Concentration Cr (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cr Jan 03	Cr Jan 04	Cr 03 June	Cr June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	1	2	1.5	2	1
PBW2	WAPDA Colony	Tube Well	2	4	3	4	1
PBW3	Tehkal Bala	Tube Well	16	20	18	18	14
PBW4	Jamrud Road	Tube Well	14	20	20	16	10
PBW5	Industrial Estate	Tube Well	7	6	8	8	5
PBW6	Hayatatab Phase-3	Tube Well	8	10	10	10	1
PBW7	Danish Abad	Tube Well	8	10	9	11	7
PBW8	Bara	Tube Well	2	3	2	4	1
PBW9	Sar Band	Tube Well	11	6	12	13	9
PBW10	Shabqadar	Tube Well	4	4	5	5	3
PBW11	Matta Mughal Khel	Tube Well	2	4	3	4	2
PBW12	Abazai	Tube Well	8	12	10	5	6
PBW13	Tangi	Tube Well	9	30	11	9	5
PBW14	S. Umer Baba	Dug Well	2	4	3	4	2
PBW15	Hinder Kassi	Dug Well	1	4	1	1	1
PBW16	Jamrud Road	Hand Pump	5	3	6	7	4
PBW105	W. Dam Kabul river	Warsak Dam	1	2	1	2	1
PBW106	W. Dam Kabul river	Warsak Dam	1	1	1	3	1
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	3	6	4	4	2
PBW18	Mathra	Tube Well	18	21	20	20	11
PBW19	Khazana	Tube Well	18	23	22	20	19
PBW20	Kukar	Tube Well	46	36	51	48	3
PBW21	Mandezai Srikh	Tube Well	2	11	3	5	0
PBW22	Rajjar	Tube Well	3	6	6	4	4
PBW23	Turangzai	Tube Well	76	74	80	74	70
PBW24	Prang	Tube Well	20	36	33	28	29
PBW25	Kandi Hayat	Borehole well	38	40	45	48	48
PBW26	Aman Kot	Tube Well	1	3	2	3	1
PBW27	Mathra	Dug Well	48	50	45	43	44
PBW28	Charpariza	Dug Well	5	7	6	7	2
PBW29	Khazana	Dug Well	18	24	22	23	16
PBW30	Adezai	Hand Pump	19	24	21	7	12
PBW31	Mandazar	Dug Well	5	7	6	7	3
PBW32	Kot	Dug Well	4	7	6	3	1
PBW33	Aman Kot	Dug Well	1	3	2	3	1
PBW34	Takht Bhai	Hand Pump	78	84	81	81	73
PBW35	Pir Baba	Stream	69	76	71	73	68
PBW36	Pir Baba	Stream	18	20	25	21	17
PBW37	Pir Baba	Stream	18	23	20	22	11
PBW48	Pir Baba	Stream	10	14	12	13	9

Concentration Cr (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cr Jan 03	Cr Jan 04	Cr 03 June	Cr June 04	Tariq (2001)
PBW39	Pir Baba	Stream	5	7	6	8	5
PBW40	Pir Baba	Stream	1	2	1	3	1
PBW107	Sardaryab	Kabul River	169	179	170	172	168
PBW108	Naguman	Kabul River	10	13	12	14	21
PBW109	Shah Alam	Kabul River	58	55	57	55	54
PBW110	Swat River	Kabul River	6	7	7	8	8
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	1	2	1	2	2
PBW42	Forest Colony	Tube Well	1	3	2	3	1
PBW43	Shahi Bala	Hand Pump	0	7	6	1	1
PBW44	Hashim Kili	Tube Well	20	24	22	24	0
PBW45	Gharibabad	Tube Well	21	18	19	17	18
PBW46	Badh Ber	Tube Well	50	43	48	46	48
PBW47	Sorezai	Tube Well	30	34	32	33	45
PBW48	Jahangir Abad	Tube Well	1	2	1	2	0
PBW49	Landi Arbab	Tube Well	78	78	88	79	71
PBW50	Saddar Stadium	Tube Well	18	11	25	21	11
PBW51	Defence Colony	Tube Well	7	11	9	8	7
PBW52	Dabgari Shuba	Tube Well	10	14	12	12	9
PBW53	Gulshan R. Colony	Tube Well	1	3	2	4	42
PBW54	Tehsil Gunj	Tube Well	80	87	85	86	75
PBW55	Gulbahar No.2	Tube Well	28	33	30	39	23
PBW56	Hazar Khawani	Tube Well	39	35	41	41	34
PBW57	Wadpagga	Tube Well	38	44	42	40	30
PBW58	Akbar Pura	Tube Well	9	12	10	12	6
PBW59	Pabbi	Tube Well	1	3	2	3	1
PBW60	Urmar Village	Tube Well	88	96	94	92	83
PBW61	Aza Khel Bala	Tube Well	147	145	155	152	136
PBW62	Bashirabad	Dug Well	1	3	2	3	0
PBW63	Shiggi	Dug Well	8	13	10	9	6
PBW64	Shiggi	H. Pump	2	4	3	4	0
PBW65	Pajagi	H. Pump	1	3	2	2	0
PBW66	Mulazai	Dug Well	1	2	1	3	1
PBW67	Regi	H. Pump	2	3	2	3	1
PBW68	Shahi Bala	Dug Well	1	3	1	2	1
PBW169	Kafir Dheri	Dug Well	1	3	1	2	3
PBW70	Pawaka	Bore Well	1	6	2	2	1
PBW71	Bazeed Khel	H. Pump	1	2	1	3	1
PBW72	Surezai	Dug Well	110	125	120	115	104
PBW73	Hazar Khawani	H. Pump	4	8	6	6	3
PBW74	Phandu	Dug Well	20	29	16	30	10
PBW75	Hazarkhawani	Dug Well	6	9	8	8	4
PBW76	Wadpagga	Dug Well	12	19	16	13	8
PBW77	Zahirabad	Dug Well	4	6	5	6	3
PBW78	Urmar Bala	Dug Well	120	132	129	136	117
PBW79	Urmar Payan	Dug Well	68	86	80	70	63
PBW80	Azakhel Bala	Dug Well	114	130	125	116	106

Concentration Cr (μg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cr Jan 03	Cr Jan 04	Cr 03 June	Cr June 04	Tariq (2001)
PBW81	Shahbaz Garhi	H. Pump	2	4	3	3	1
PBW99	Malakand Pass	Spring	8	11	10	9	4
PBW100	Dargai	Spring	4	8	6	3	4
PBW101	Pirsai	Spring	25	7	5	4	4
PBW102	Nowshera Bridge	Kabul River	1	4	3	8	1
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	1	4	1	3	1
PBW83	Adezai	Tube Well	1	4	2	2	1
PBW84	Nowshera cantt.	Tube Well	26	35	30	29	23
PBW85	Jaluzai	Tube Well	28	30	38	30	23
PBW86	Dag Besud	Tube Well	14	25	18	20	10
PBW87	Manki Sharif	Tube Well	28	38	30	35	22
PBW88	Akora Khatta	Tube Well	6	32	8	8	5
PBW89	Jehangira	Bore Well	15	22	18	10	10
PBW90	Darwazgi	Dug Well	80	91	89	90	71
PBW91	Adezai	Dug Well	1	5	2	3	1
PBW92	Aimal Chabutra	H. Pump	2	6	3	4	1
PBW93	Garhi Chandan	Dug Well	2	5	3	3	1
PBW94	Aza Khel	Dug Well	2	6	4	3	2
PBW95	Taila Band	Dug Well	20	28	25	28	15
PBW96	Chapri	Dug Well	6	11	8	8	4
PBW97	Speen Khak	Dug Well	90	96	93	96	83
PBW98	Musha Ghar	Dug Well	16	21	17	19	23
PBW103	Khairabad	Kabul River	3	6	4	3	1
PBW104	Attock	Indus River	4	8	5	6	2

Table 3.18. Concentration Cd (μg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cd 03 Jan	Cd 04 Jan	Cd 03 June	Cd June 04	Tariq (2001)
Khyber Piedmont Aquifer							
PBW1	Kafir Dheri	Tube Well	1	3	2	2	1
PBW2	WAPDA Colony	Tube Well	1	2	1	2	1
PBW3	Tehkal Bala	Tube Well	2	5	3	3	2
PBW4	Jamrud Road	Tube Well	4	5	4	4	5
PBW5	Industrial Estate	Tube Well	3	4	4	4	2
PBW6	Hayatatab Phase-3	Tube Well	3	5	4	5	3
PBW7	Danish Abad	Tube Well	2	4	3	4	2
PBW8	Bara	Tube Well	2	4	3	3	2
PBW9	Sar Band	Tube Well	2	4	3	4	1
PBW10	Shabqadar	Tube Well	2	4	3	4	2
PBW11	Matta Mughal Khel	Tube Well	3	4	3	5	2
PBW12	Abazai	Tube Well	2	4	3	5	1
PBW13	Tangi	Tube Well	1	3	2	4	2
PBW14	S. Umer Baba	Dug Well	1	1	1	2	1
PBW15	Hinder Kassi	Dug Well	1	1	2	2	1
PBW16	Jamrud Road	Hand Pump	2	4	3	3	1
PBW105	W. Dam Kabul river	Warsak Dam	2	5	3	5	1
PBW106	W. Dam Kabul river	Warsak Dam	2	4	3	5	2
Peshawar Floodplain Aquifer							
PBW17	Pir Baba	Borehole well	3	4	4	4	2
PBW18	Mathra	Tube Well	3	4	4	4	1
PBW19	Khazana	Tube Well	3	5	4	5	3
PBW20	Kukar	Tube Well	4	5	5	5	1
PBW21	Mandezai Srikh	Tube Well	5	2	4	3	2
PBW22	Rajjar	Tube Well	2	5	4	4	2
PBW23	Turangzai	Tube Well	2	3	3	4	2
PBW24	Prang	Tube Well	3	3	4	5	4
PBW25	Kandi Hayat	Borehole well	1	3	2	3	1
PBW26	Aman Kot	Tube Well	1	3	2	3	1
PBW27	Mathra	Dug Well	4	6	5	6	3
PBW28	Charpariza	Dug Well	1	5	4	3	1
PBW29	Khazana	Dug Well	3	4	4	5	2
PBW30	Adezai	Hand Pump	4	7	6	3	3
PBW31	Mandazar	Dug Well	1	3	2	3	1
PBW32	Kot	Dug Well	1	3	2	6	1
PBW33	Aman Kot	Dug Well	2	4	3	4	1
PBW34	Takht Bhai	Hand Pump	4	5	5	5	6
PBW35	Pir Baba	Stream	1	5	3	3	1
PBW36	Pir Baba	Stream	2	3	2	3	2
PBW37	Pir Baba	Stream	3	5	4	4	2
PBW48	Pir Baba	Stream	2	3	2	2	1

Concentration Cd (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cd 03 Jan	Cd 04 Jan	Cd 03 June	Cd June 04	Tariq (2001)
PBW39	Pir Baba	Stream	1	3	2	3	1
PBW40	Pir Baba	Stream	1	3	2	3	1
PBW107	Sardaryab	Kabul River	5	4	3	4	4
PBW108	Naguman	Kabul River	2	4	3	8	3
PBW109	Shah Alam	Kabul River	3	3	4	4	4
PBW110	Swat River	Kabul River	1	4	3	3	1
Peshawar Lacustrine Aquifer							
PBW41	Bashirabad	Tube Well	1	4	2	3	0
PBW42	Forest Colony	Tube Well	1	2	1	3	1
PBW43	Shahi Bala	Hand Pump	1	2	1	3	1
PBW44	Hashim Kili	Tube Well	1	5	2	3	0
PBW45	Gharibabad	Tube Well	1	3	2	3	1
PBW46	Badh Ber	Tube Well	3	5	4	4	1
PBW47	Sorezai	Tube Well	4	3	5	5	3
PBW48	Jahangir Abad	Tube Well	1	2	1	2	0
PBW49	Landi Arbab	Tube Well	1	2	2	3	1
PBW50	Saddar Stadium	Tube Well	1	5	1	3	1
PBW51	Defence Colony	Tube Well	3	5	4	6	2
PBW52	Dabgari Shuba	Tube Well	1	3	2	3	1
PBW53	Gulshan R. Colony	Tube Well	5	5	4	5	9
PBW54	Tehsil Gunj	Tube Well	3	5	4	5	2
PBW55	Gulbahar No.2	Tube Well	4	4	3	3	5
PBW56	Hazar Khawani	Tube Well	2	4	3	4	1
PBW57	Wadpagga	Tube Well	1	3	2	2	1
PBW58	Akbar Pura	Tube Well	1	3	2	3	1
PBW59	Pabbi	Tube Well	1	3	2	3	1
PBW60	Urmar Village	Tube Well	2	4	3	3	1
PBW61	Aza Khel Bala	Tube Well	6	5	7	2	5
PBW62	Bashirabad	Dug Well	5	7	6	7	2
PBW63	Shiggi	Dug Well	1	2	1	3	0
PBW64	Shiggi	H. Pump	2	4	3	4	1
PBW65	Pajagi	H. Pump	1	3	2	3	0
PBW66	Mulazai	Dug Well	2	4	3	4	0
PBW67	Regi	H. Pump	1	3	2	3	1
PBW68	Shahi Bala	Dug Well	1	5	2	3	1
PBW169	Kafir Dheri	Dug Well	2	4	2	4	1
PBW70	Pawaka	Bore Well	2	5	3	4	1
PBW71	Bazeed Khel	H. Pump	2	4	2	3	1
PBW72	Surezai	Dug Well	1	4	2	2	1
PBW73	Hazar Khawani	H. Pump	1	4	2	4	1
PBW74	Phandu	Dug Well	1	4	2	3	1
PBW75	Hazarkhawani	Dug Well	5	4	4	5	2
PBW76	Wadpagga	Dug Well	2	5	3	3	1
PBW77	Zahirabad	Dug Well	2	4	2	4	1
PBW78	Urmar Bala	Dug Well	5	4	4	4	3
PBW79	Urmar Payan	Dug Well	1	3	2	2	1
PBW80	Azakhel Bala	Dug Well	3	3	4	4	2

Concentration Cd (µg/l) of the surface and groundwater samples of Peshawar basin during different times

Sample No.	Area	Type of Sample	Cd 03 Jan	Cd 04 Jan	Cd 03 June	Cd June 04	Tariq (2001)
PBW81	Shahbaz Garhi	H. Pump	1	4	2	3	1
PBW99	Malakand Pass	Spring	5	4	4	3	2
PBW100	Dargai	Spring	2	5	3	4	1
PBW101	Pirsai	Spring	4	4	4	4	3
PBW102	Nowshera Bridge	Kabul River	3	4	4	4	2
Attock-Cherat Piedmont Aquifer							
PBW82	Mattani	Tube Well	1	4	2	3	1
PBW83	Adezai	Tube Well	5	4	3	6	1
PBW84	Nowshera cantt.	Tube Well	5	5	5	5	3
PBW85	Jaluzai	Tube Well	5	4	3	3	3
PBW86	Dag Besud	Tube Well	1	4	2	4	1
PBW87	Manki Sharif	Tube Well	3	4	4	5	2
PBW88	Akora Khatta	Tube Well	4	4	3	3	3
PBW89	Jehangira	Bore Well	4	4	5	5	2
PBW90	Darwazgi	Dug Well	3	5	4	4	5
PBW91	Adezai	Dug Well	3	5	4	9	1
PBW92	Aimal Chabutra	H. Pump	1	4	2	3	1
PBW93	Garhi Chandan	Dug Well	1	4	2	3	1
PBW94	Aza Khel	Dug Well	2	5	3	3	1
PBW95	Taila Band	Dug Well	4	4	5	6	1
PBW96	Chapri	Dug Well	4	5	4	4	3
PBW97	Speen Khak	Dug Well	2	3	3	3	1
PBW98	Musha Ghar	Dug Well	1	3	2	3	1
PBW103	Khairabad	Kabul River	4	3	5	3	2
PBW104	Attock	Indus River	4	4	5	4	4

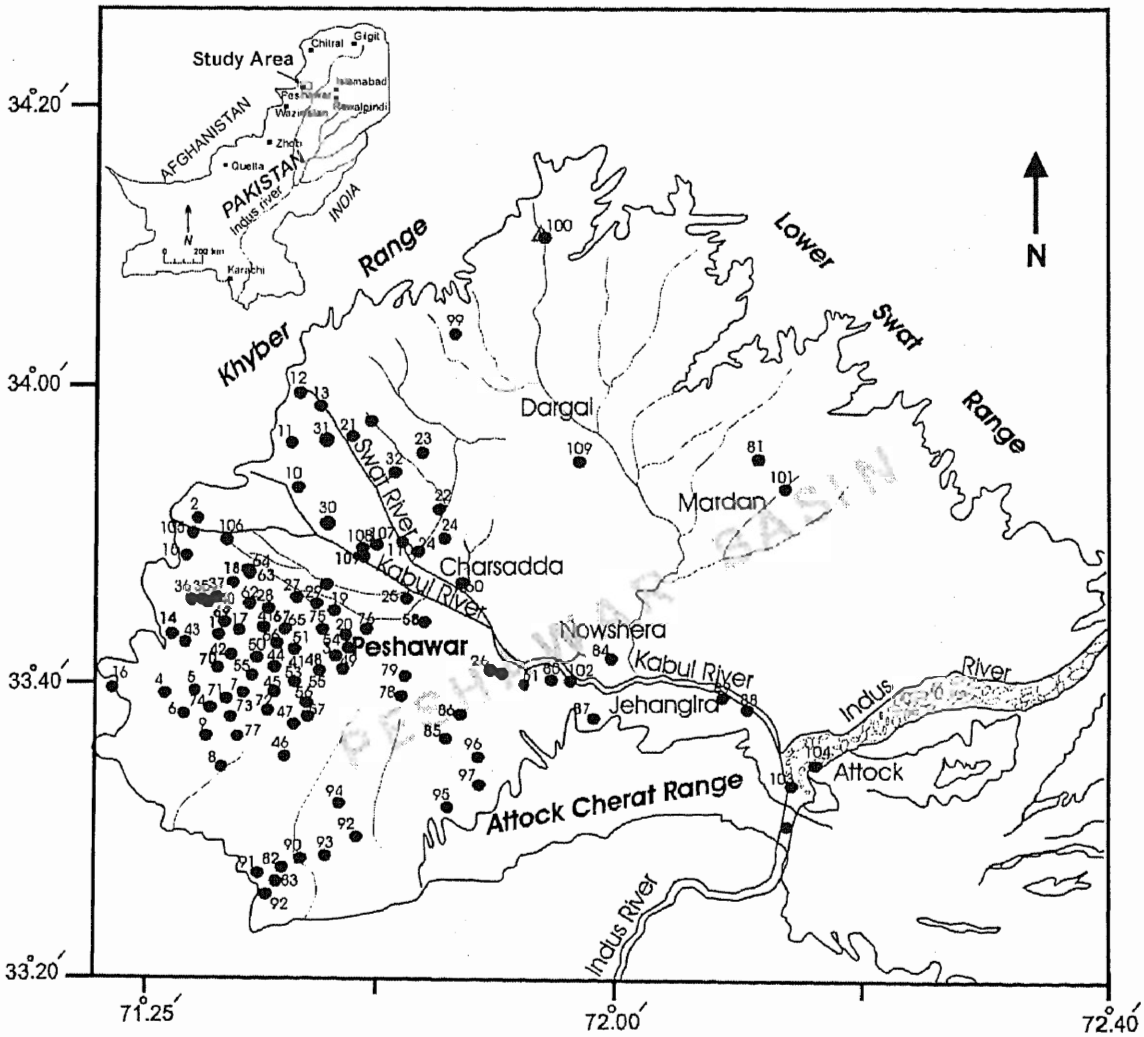
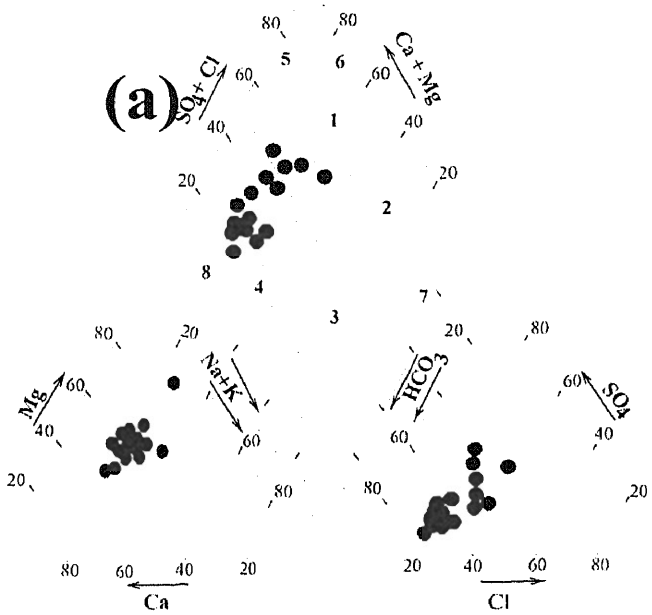
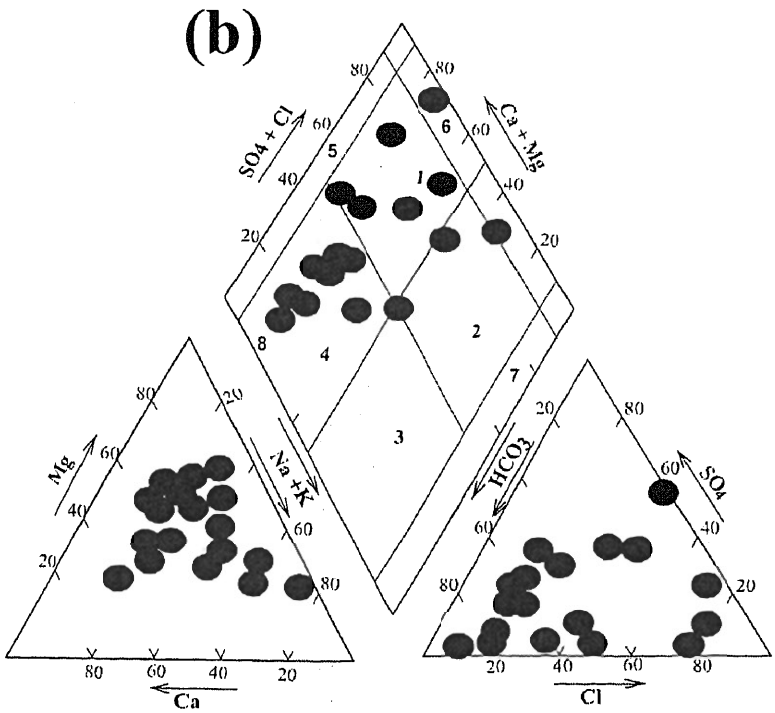


Fig. 3.1. Map showing the location of water samples from Peshawar basin


(a)
SO4+Cl
Ca+Mg
Mg
Na+K
HCO3
SO4
Ca
Cl


(b)
SO4+Cl
Ca+Mg
Mg
Na+K
HCO3
SO4
Ca
Cl

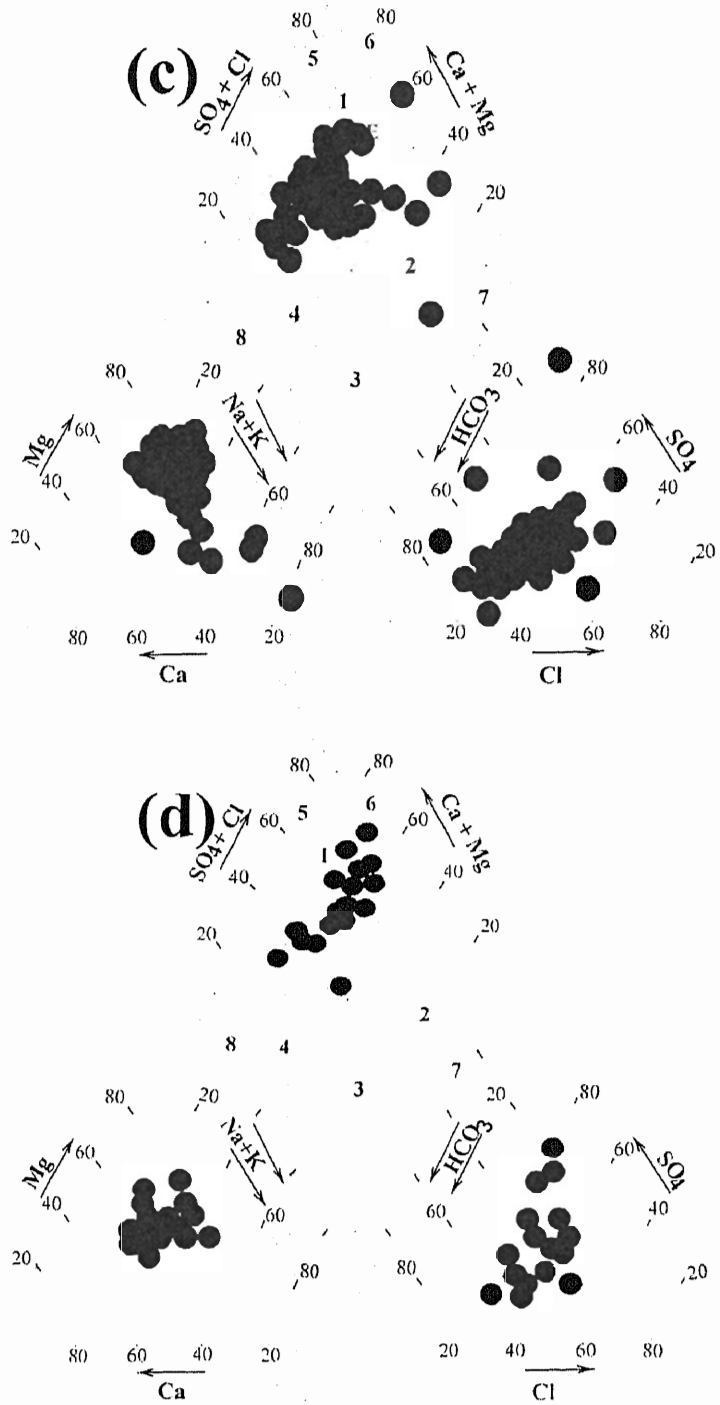


Fig. 3.2. Piper triliniar diagram for the groundwater samples of Peshawar basin

a = Khyber piedmont aquifer ; b = Peshawar floodplain aquifer

c = Peshawar lacustrine aquifer; c = Attock-Cherat range aquifer

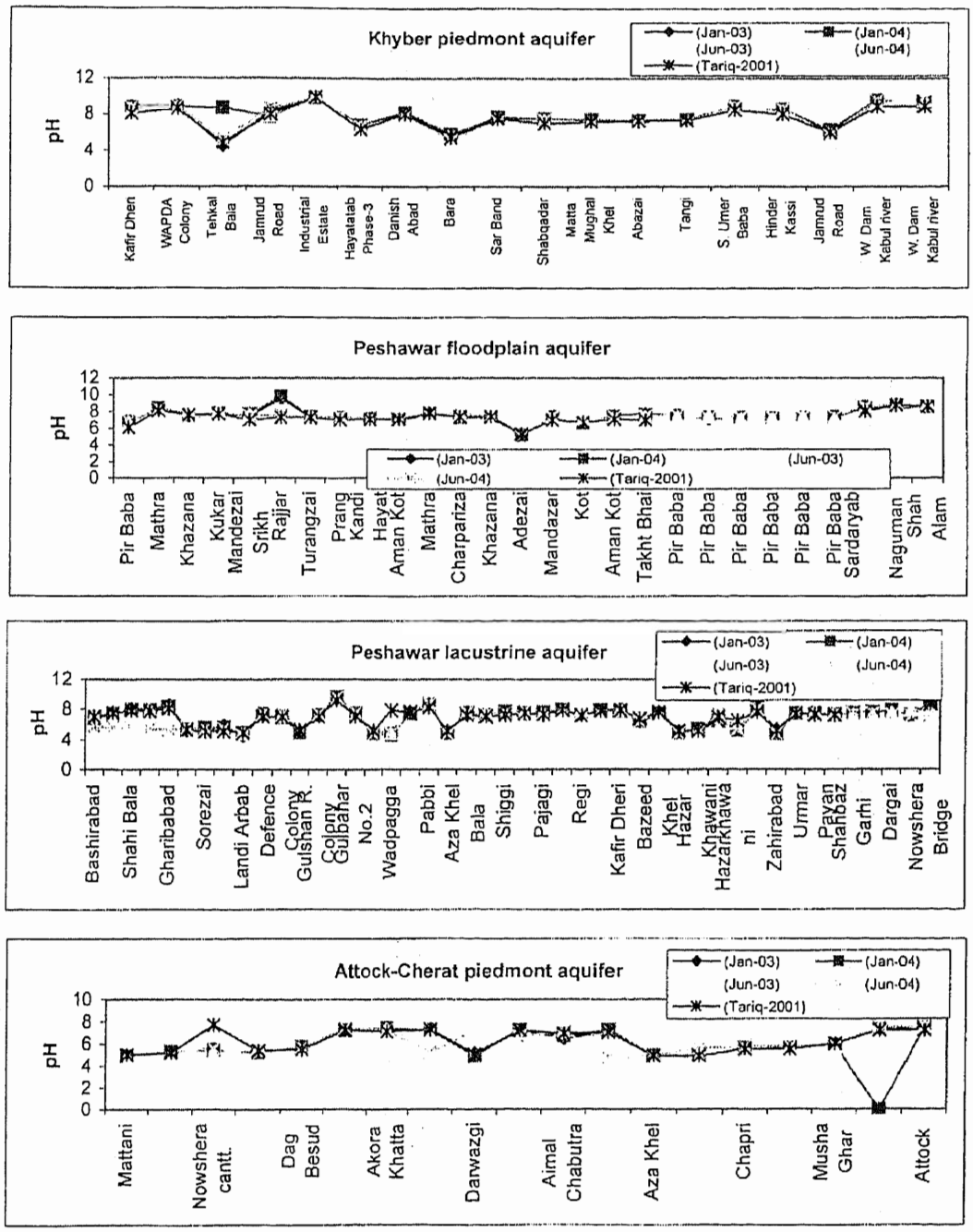


Fig. 3.3. Variation in pH of the surface and groundwater samples of the Peshawar basin during different times.

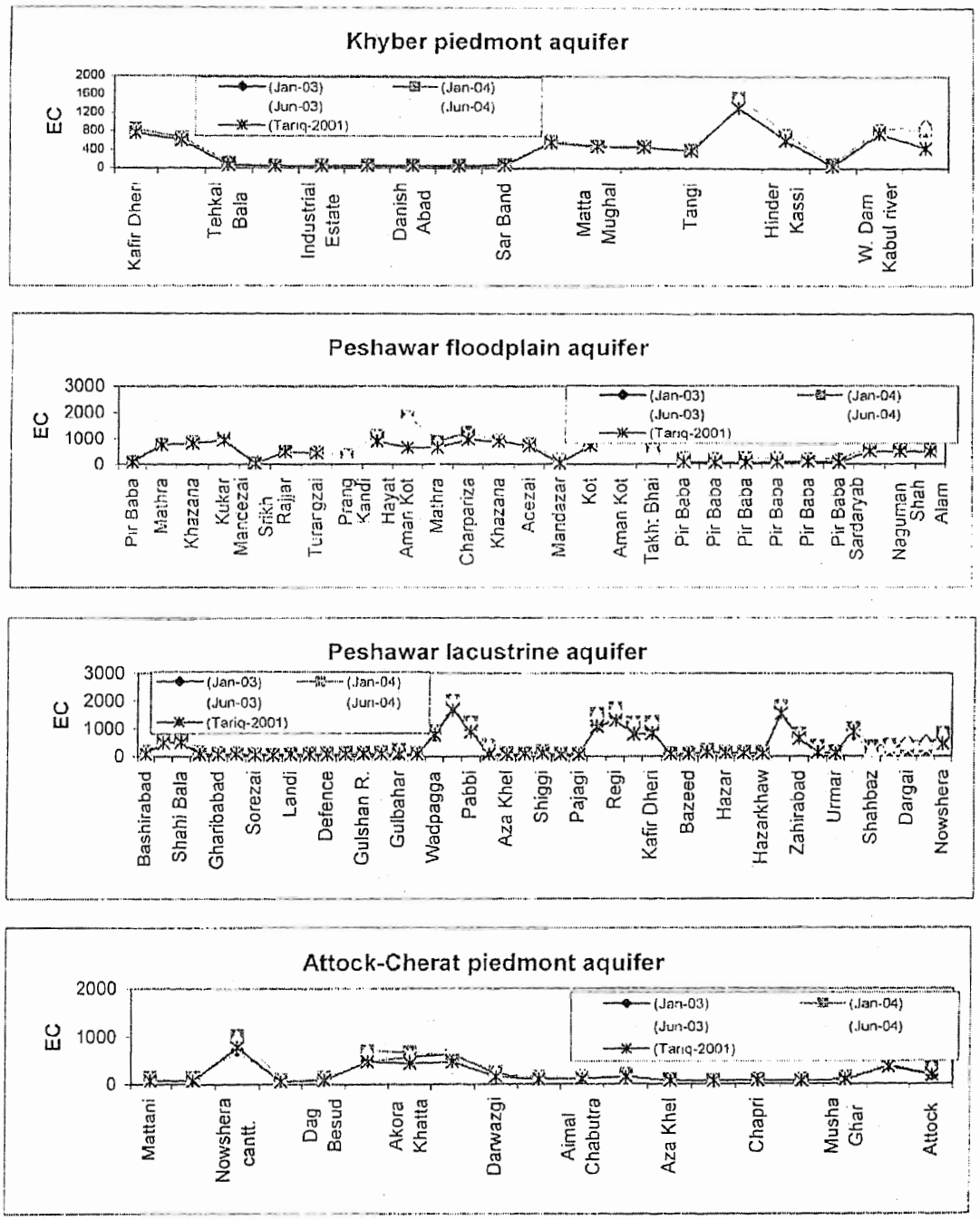


Fig. 3.4. Variation in electrical conductivity (EC) of the surface and groundwater samples of the Peshawar basin during different times.

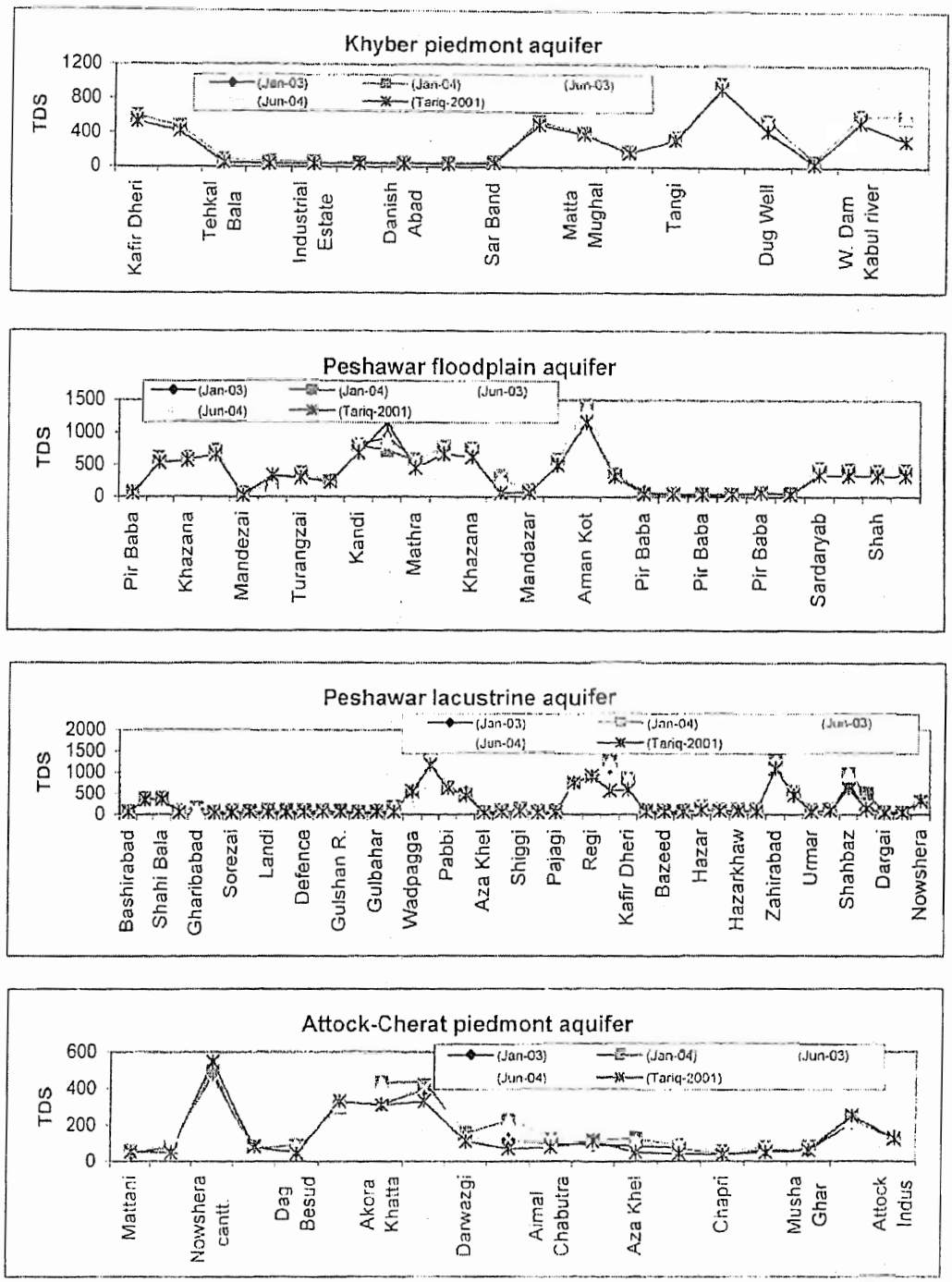


Fig. 3.5. Variation in total dissolved solids (TDS) of the surface and groundwater samples of the Peshawar basin during different times.

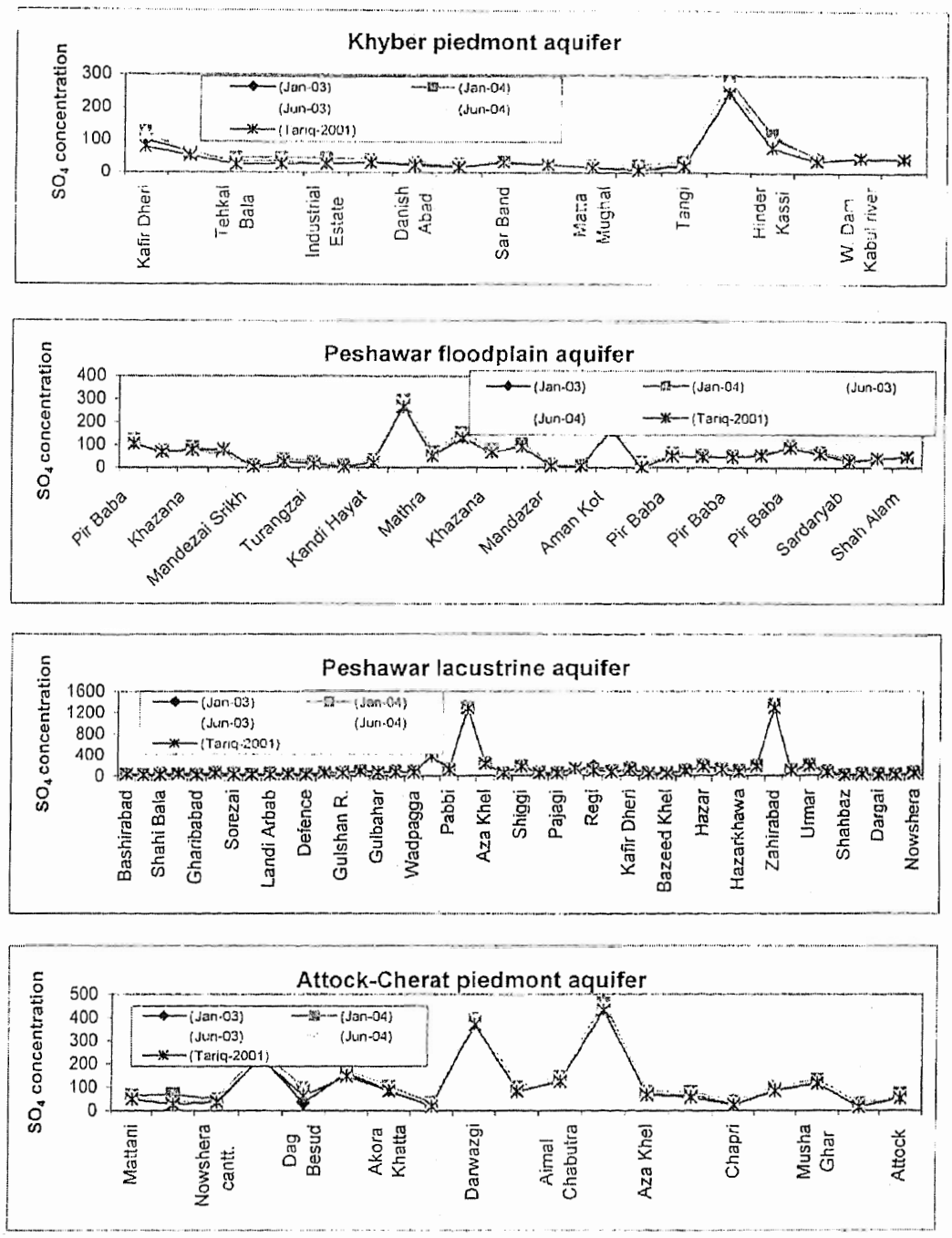


Fig. 3.6. Variation in concentration of SO_4 (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

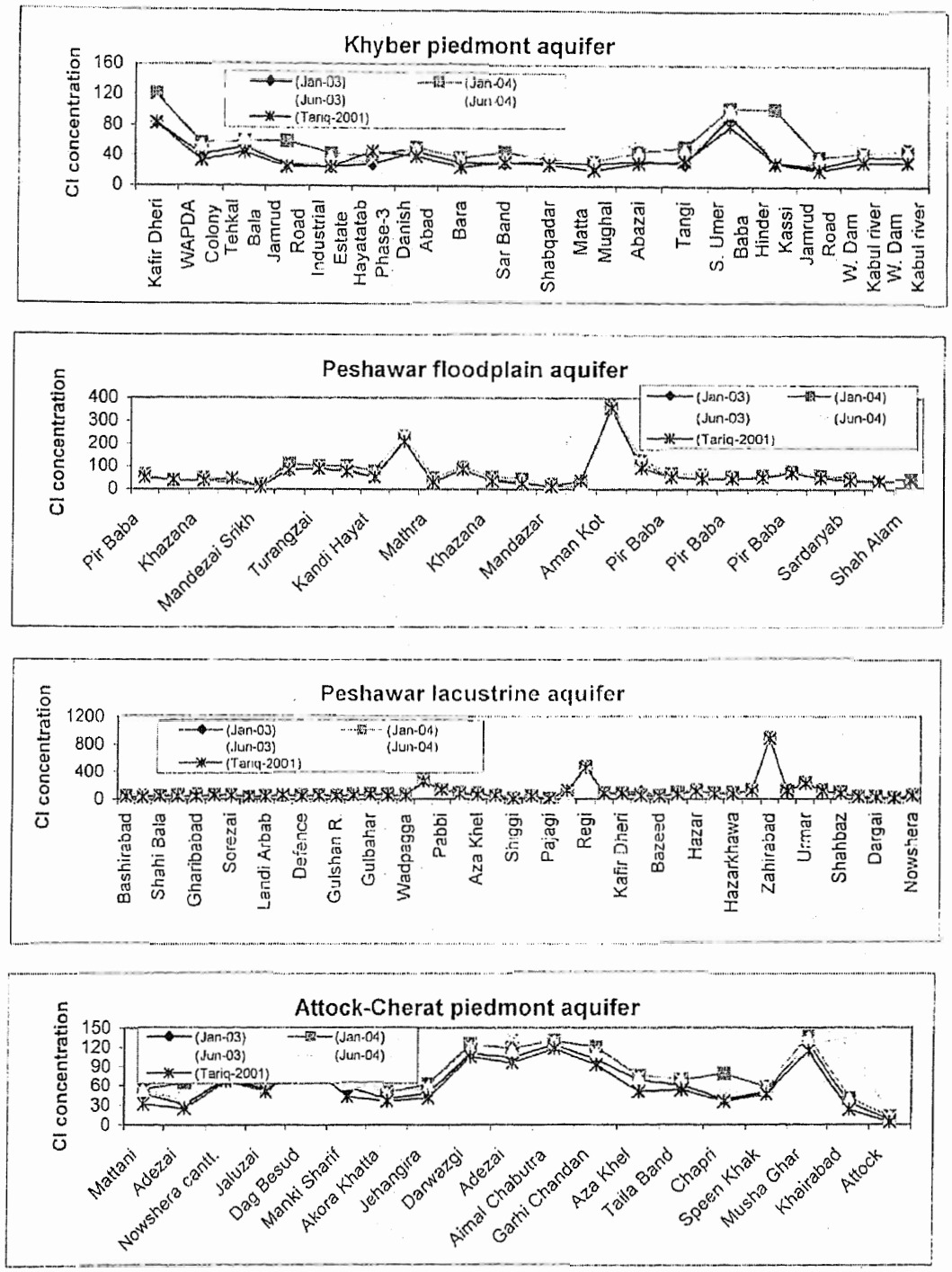


Fig. 3.7. Variation in concentration of Cl (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

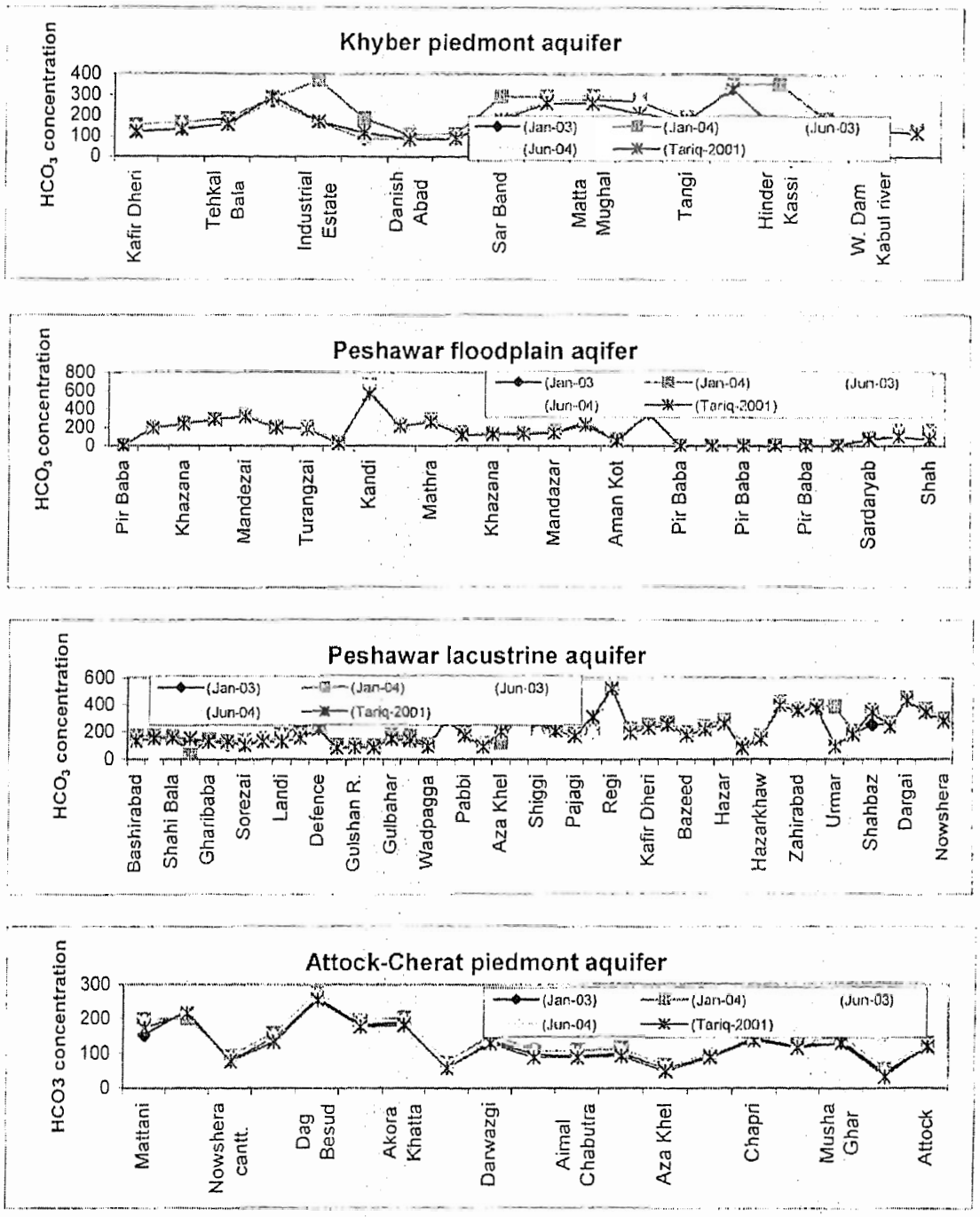


Fig. 3.8. Variation in concentration of HCO_3 (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

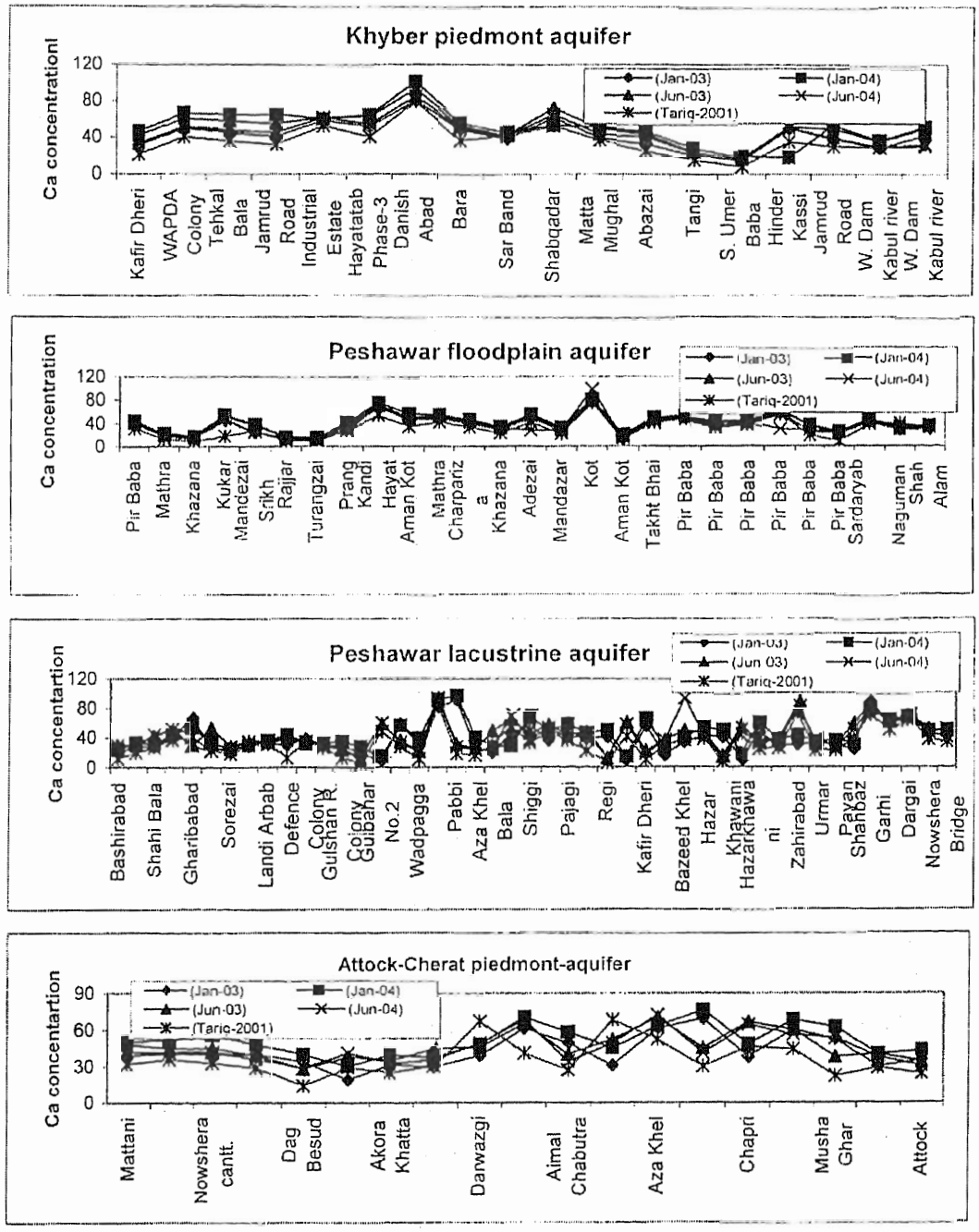


Fig. 3.9. Variation in concentration of Ca (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

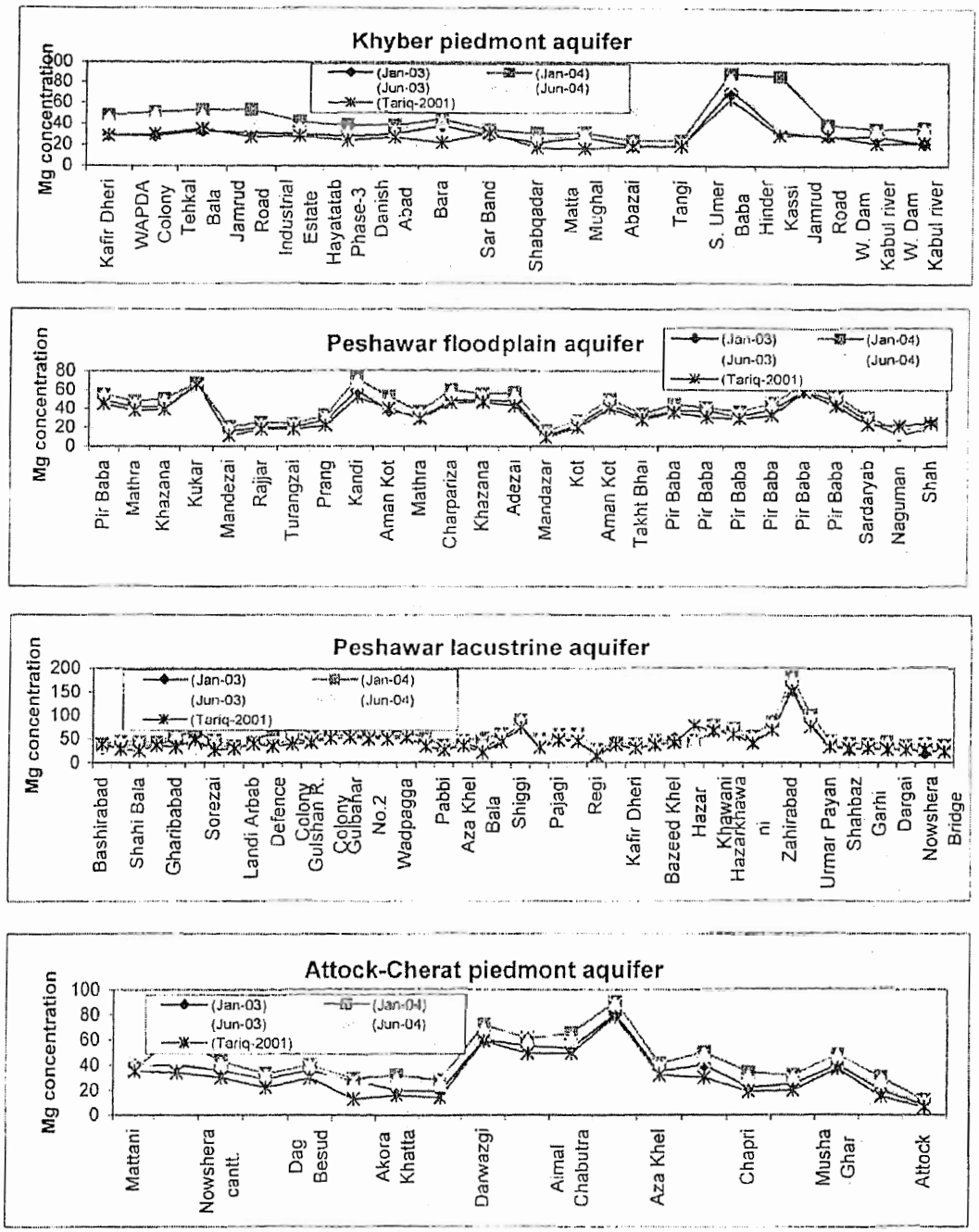


Fig. 3.10. Variation in concentration of Mg (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

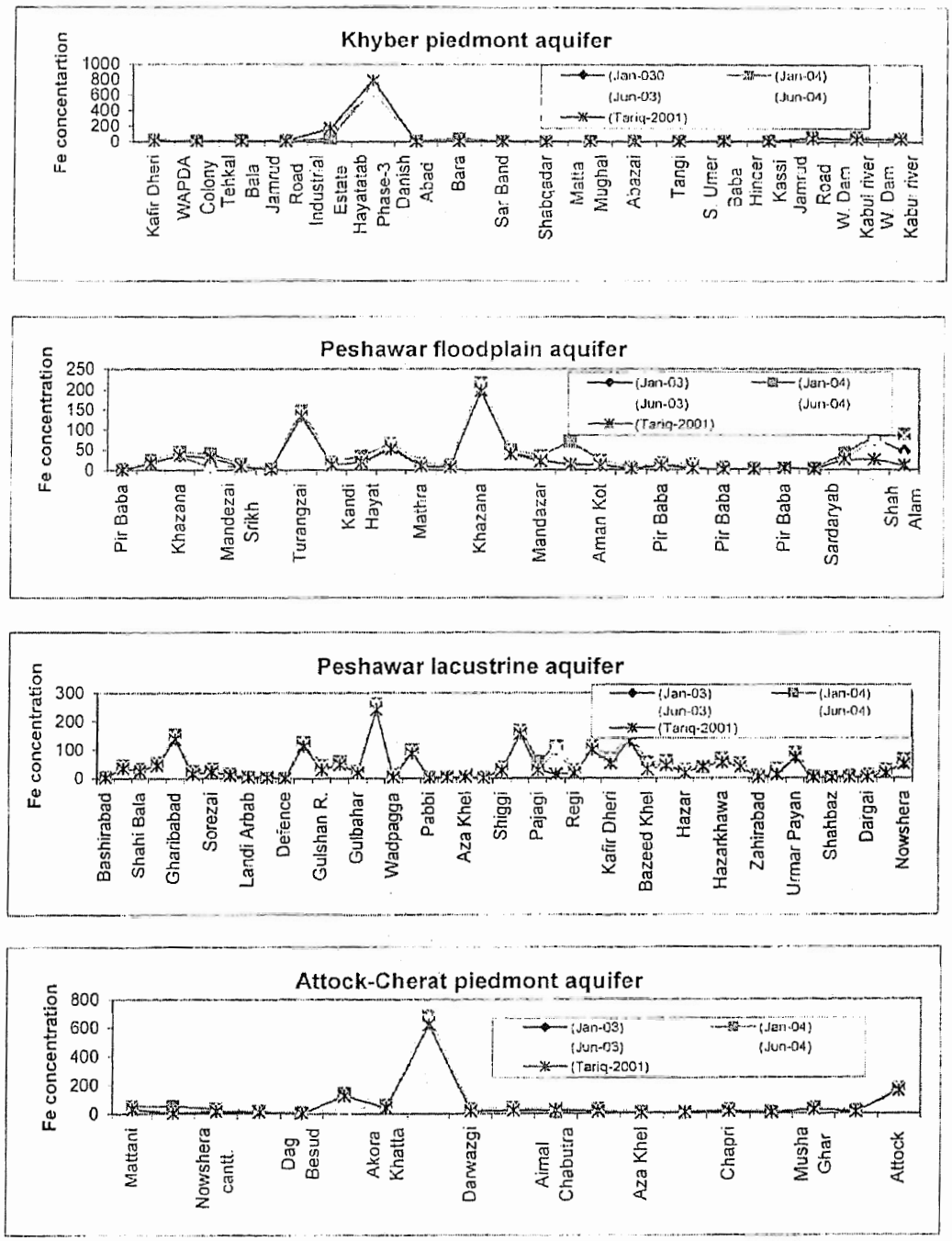


Fig. 3.11. Variation in concentration of Fe (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

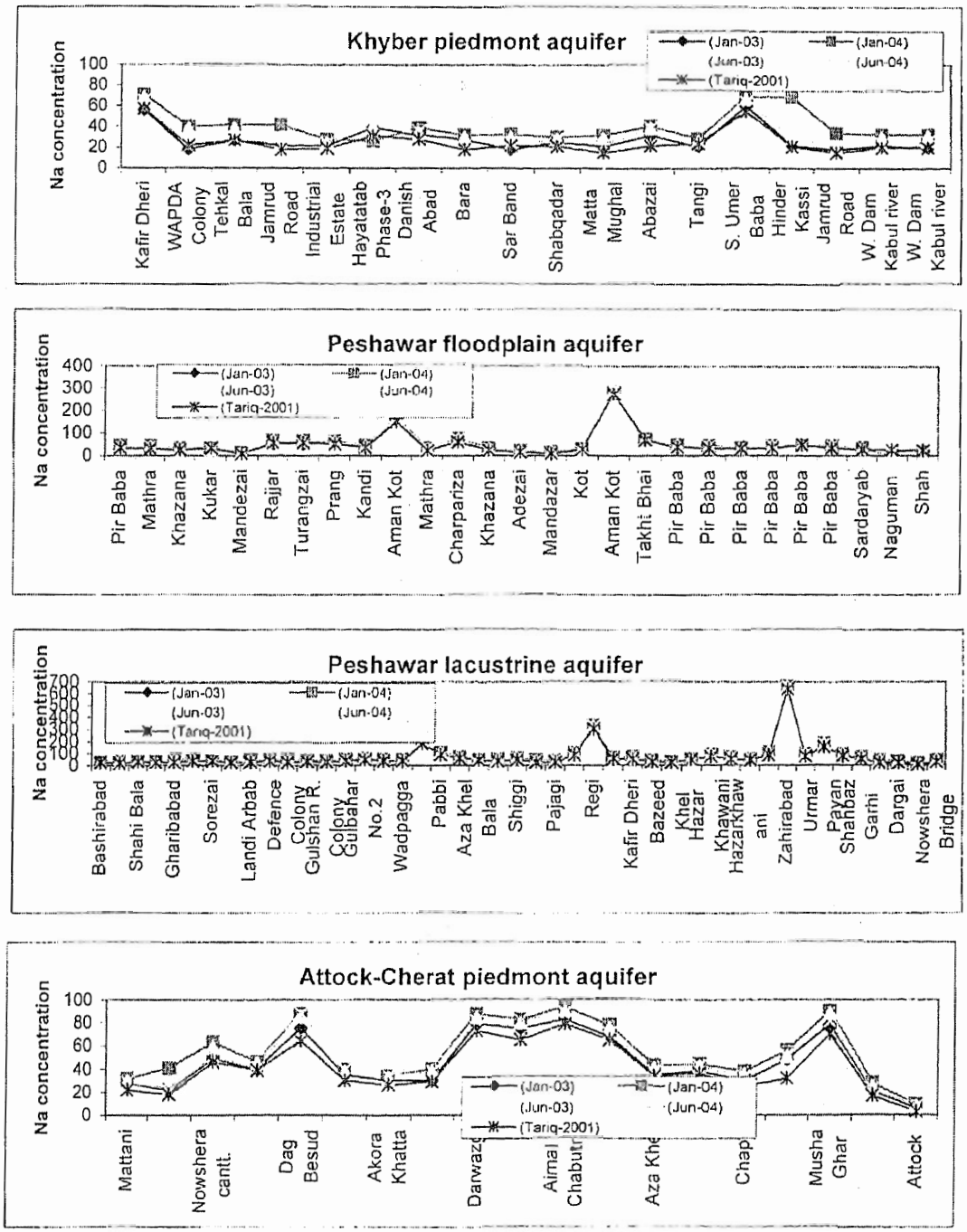


Fig. 3.12. Variation in concentration of Na (mg/l) of the surface and groundwater samples of the Peshawar basin during different times.

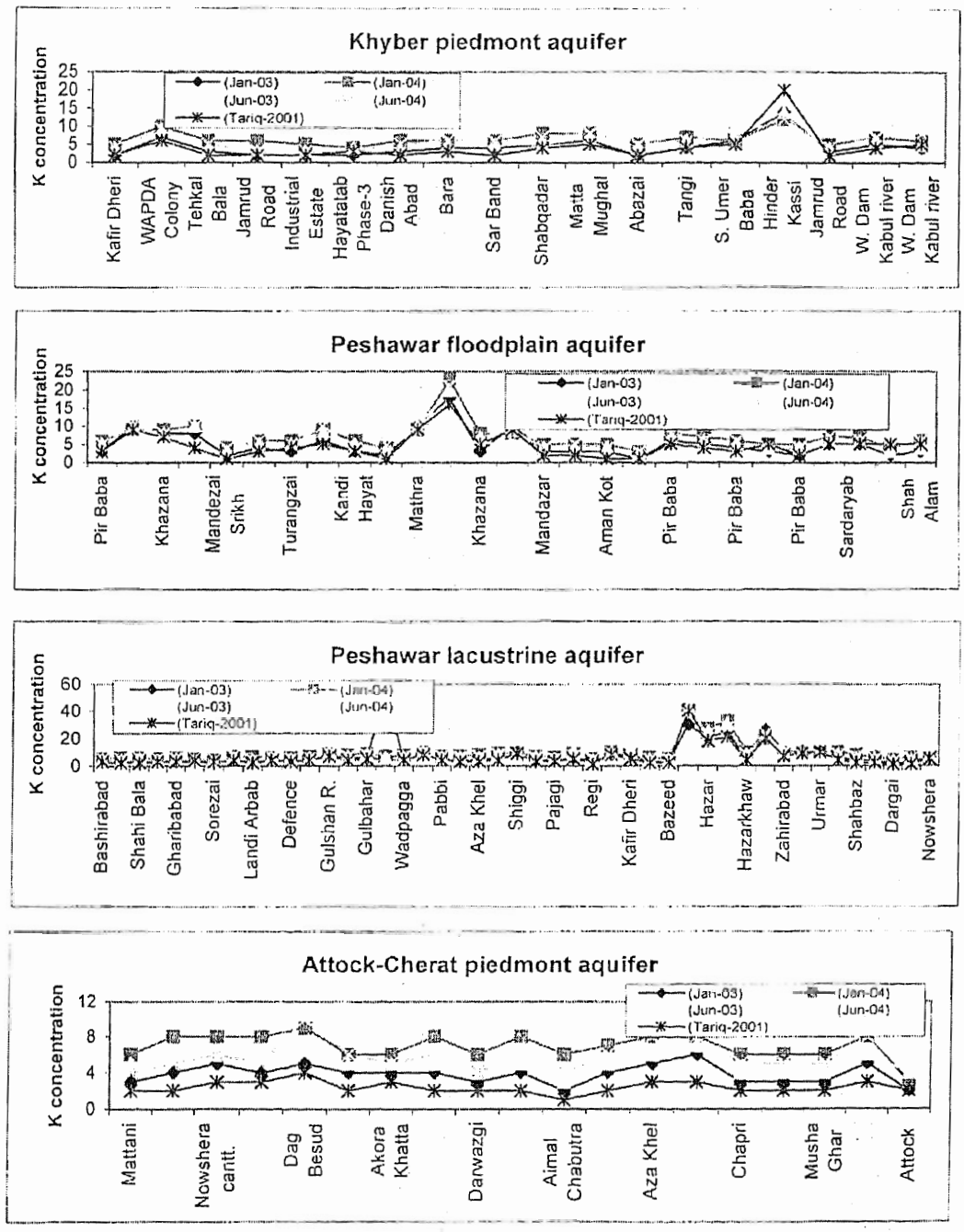


Fig. 3.13. Variation in concentration of K (µg/l) of the surface and groundwater samples of the Peshawar basin during different times.

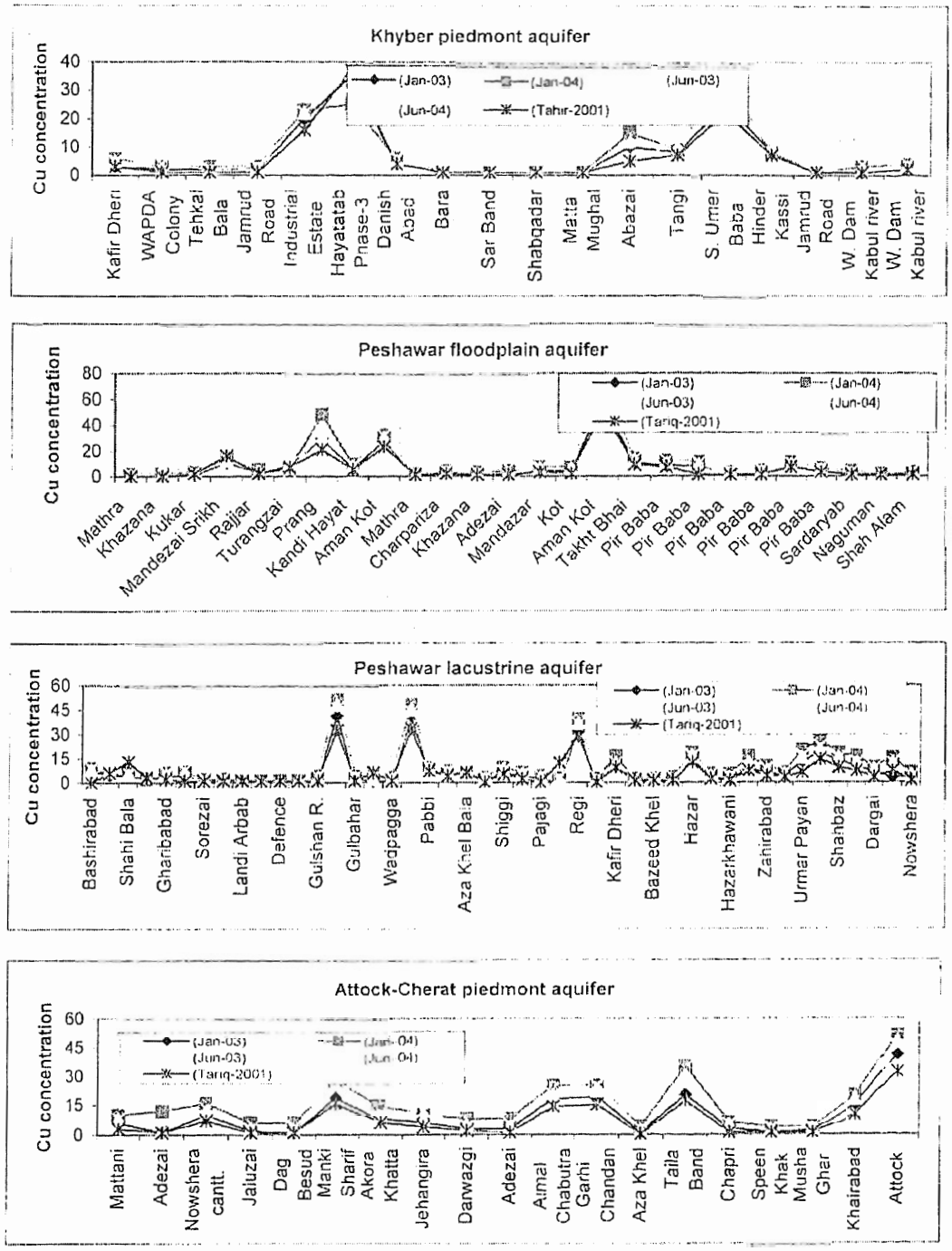


Fig. 3.14. Variation in concentration of Cu (µg/l) of the surface and groundwater samples of the Peshawar basin during different times.

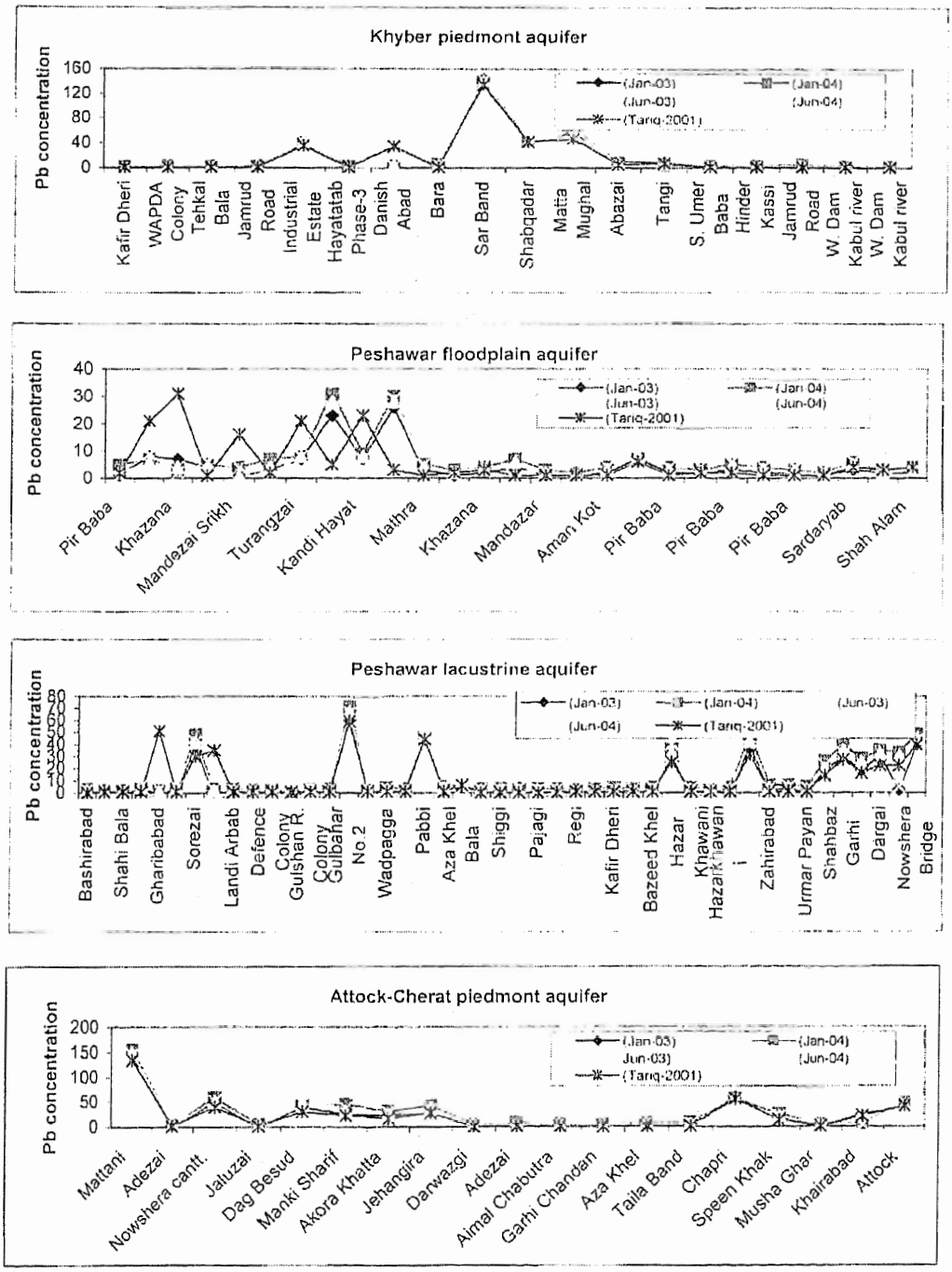


Fig. 3.15. Variation in concentration of Pb (μg/l) of the surface and groundwater samples of the Peshawar basin during different times.

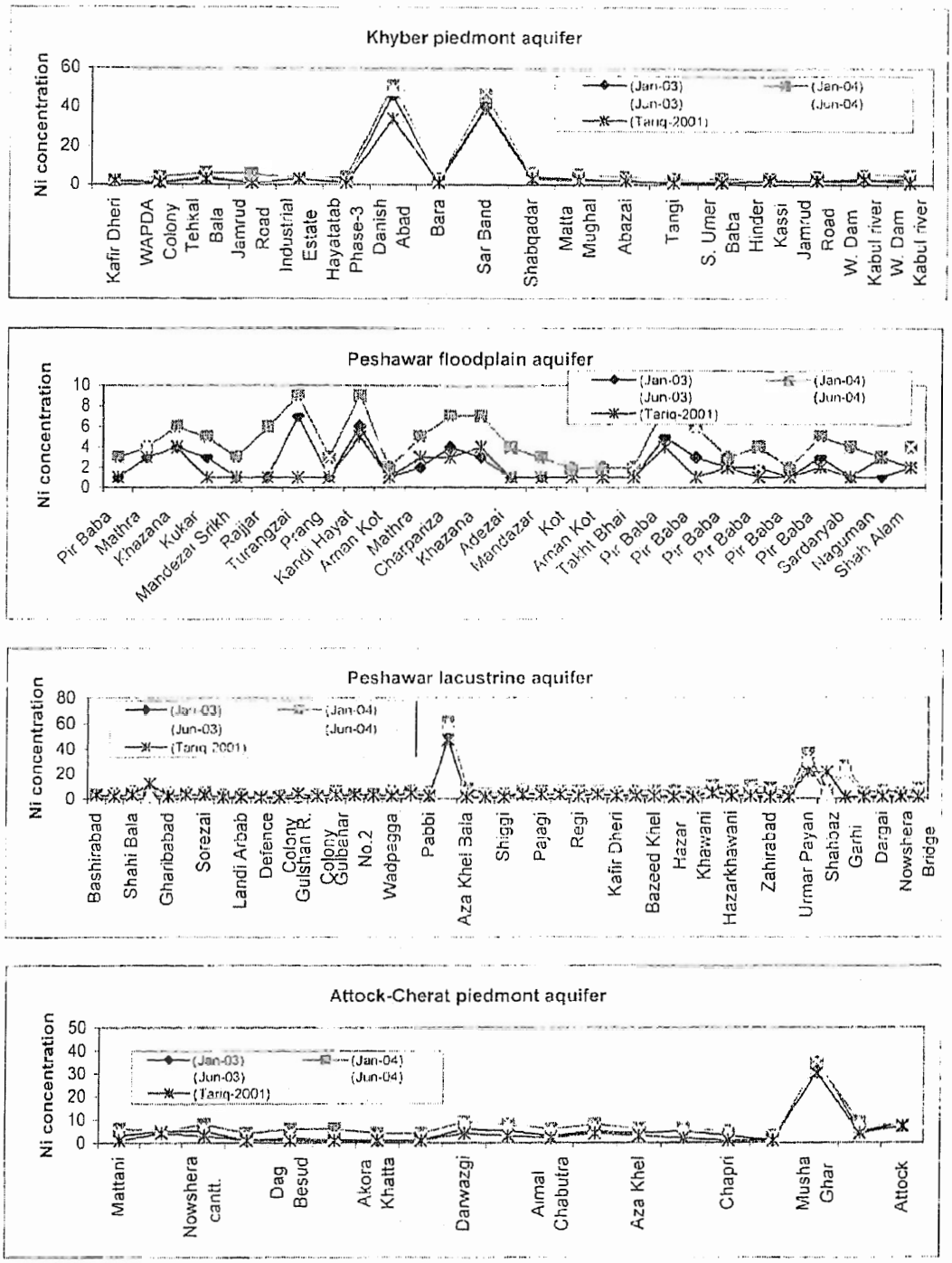


Fig. 3.16. Variation in concentration of Ni (μg/l) of the surface and groundwater samples of the Peshawar basin during different times.

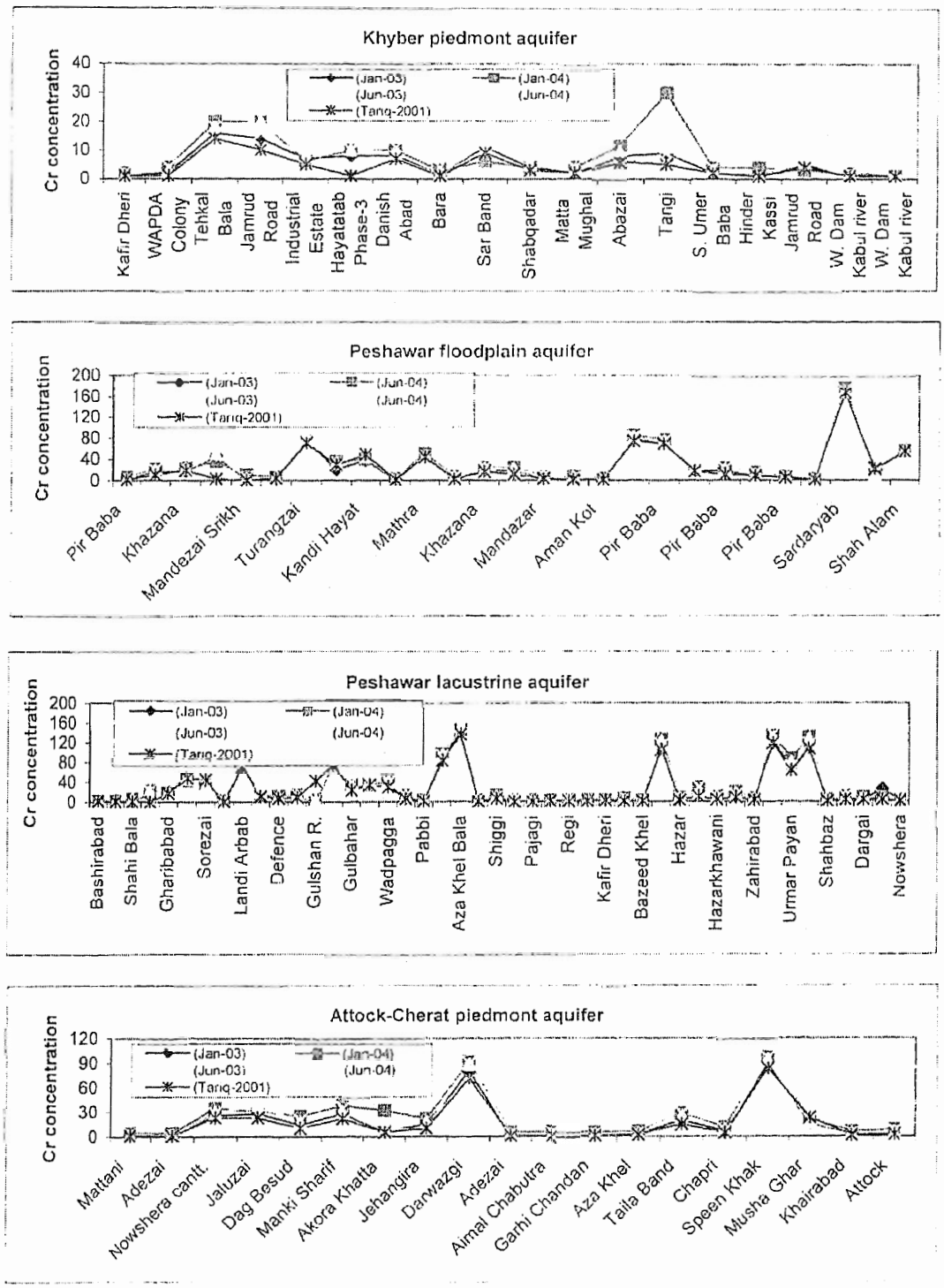


Fig. 3.17. Variation in concentration of Cr (μg/l) of the surface and groundwater samples of the Peshawar basin during different times

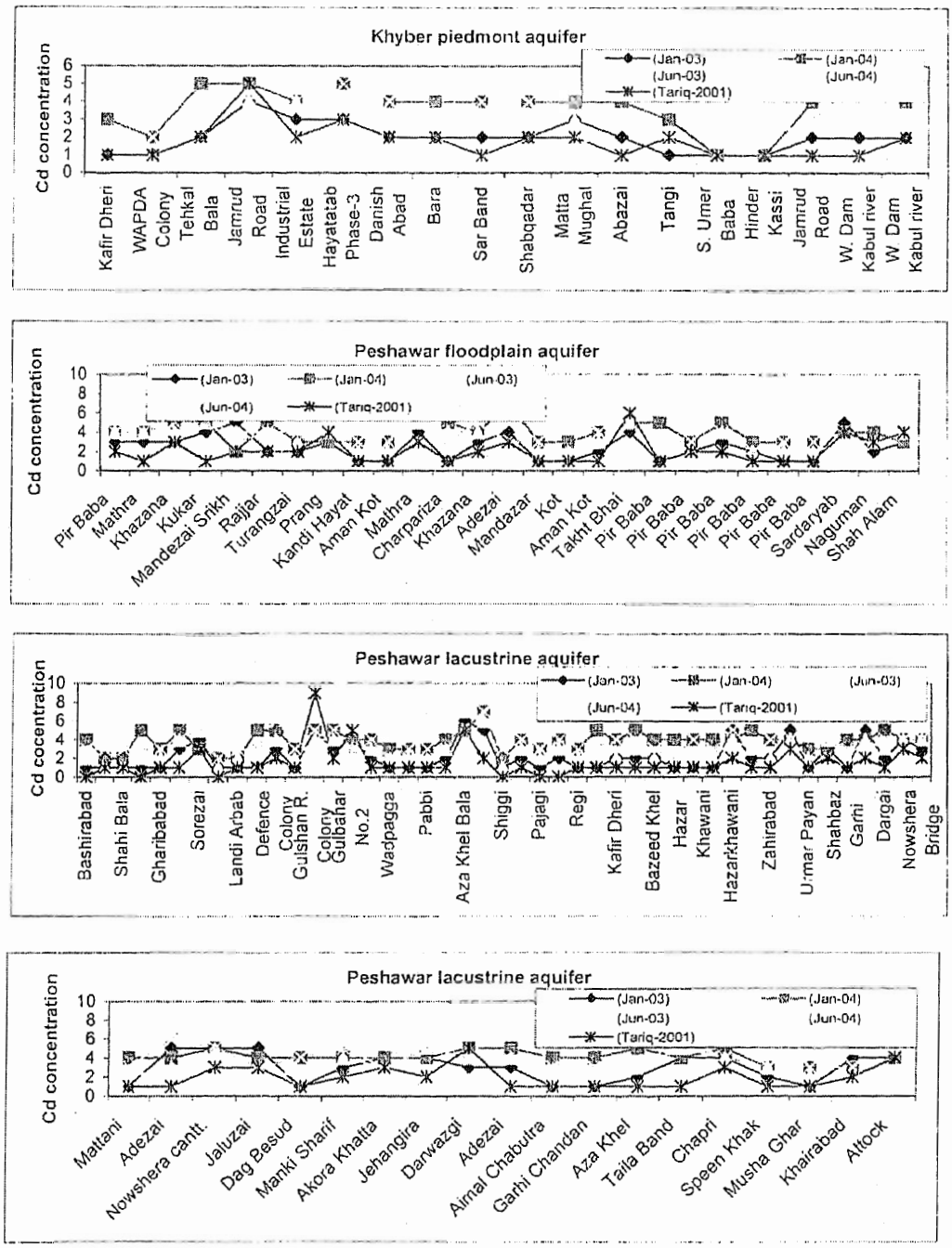


Fig. 3.18. Variation in concentration of Cd (μg/l) of the surface and groundwater samples of the Peshawar basin during different times.

CHAPTER 4

SOIL CHEMISTRY

General

Soil is a mixture of inorganic and organic solids, air, water, micro-organism and plants roots. All these phases influence each other. Climate, parent material, topography, plants and organic activities play significant roles in the formation of soil (Mason, 1966). After its formation, the soil is generally altered by chemical, physical and biological processes which support rooted plant life. Due to these chemical changes the chemistry of soil has greater importance in regards to agricultural and environmental point of view. There are certain major, minor, trace and heavy metals (i.e., Silicon, Aluminum, Calcium, Magnesium, Iron, Sodium, Potassium, manganese, Phosphorus, Titanium, Copper, Lead Zinc, Nickel Chromium, Cobalt etc.) in the soil. However, certain plant species concentrate excess amount of these metals in their tissues which pose greater risk for contamination of food chain (Christensen, 1995). These elements are mainly released from parent material of soil, fertilizers, living organisms, sewage sludge, chemical industries, irrigation water, pesticides, coal combustion residues and from many other sources (Page, 1974; (Sommers, 1977). These elements could be the significant source of soil nutrients, if present in permissible limit, while the high concentration of these nutrients at certain level are toxic to the agricultural land and produce soil pollution Hermposer, 1997; Prasad & Nazareth, 2000). Soil is one of the most important sinks of the elements in the environments and may retain contaminants in clay particles and serve as filters for the pollutants (Bear, 1975). This soil pollution disturbs the natural composition of the thin layer of fertile soil, which covers the land, essential for the growing plants. Soil pollution may also contaminate surface and subsurface water system and hence render the land unhygienic for living purposes (Browelow, 1979).

There is a greater concern nowadays that the metal polluted soil might result in human exposure to environmental toxicants (Calabrese, 1997; Bohn et al., 2001). The present study is, therefore, conducted on the environmental assessment of soil of the

Peshawar basin in regard to major, minor, trace and heavy metals pollution in the ecosystem of the region.

Classification of soil of Peshawar basin

The locations of representative soil samples of horizon A and B of the agricultural land, collected during the month of January in 2003 and 2004, are shown in Figure 4.1. These soils of the Peshawar basin are classified as (1) Peshawar piedmont soil, (2) Peshawar lacustrine soil and (3) Peshawar flood plain soil are briefly discussed below:

Peshawar piedmont soil

Peshawar piedmont soil is mainly present at the marginal parts of the basin and has been divided into low and high permeability strata (Tariq, 2001). The soil of low permeability strata consists of silt, clay and rarely fine-sand, while the soil of high permeability is generally composed of sand and gravel from a depth of 30m to 150m. Thick clay strata of low permeability often separate the aquifers in the area. Dug wells in this area also indicate the low permeability and shallow groundwater of low capacity.

Peshawar floodplain soil

Peshawar floodplain soil is confined to the vicinities of the current and past courses of Kabul and Swat rivers, where these rivers have deposited these sediments. These sediments consist of sand with intercalations of clay which spread out by river overflow during high floods.

Peshawar lacustrine soil

Peshawar lacustrine soil is classified on the basis of lacustrine deposits that mainly occur in the central part of the basin in Nowshera, Mardan and Swabi areas. Such deposits are probably the latest lake deposits of the catastrophic floods along Indus, deposited in the lake environment.

Chemistry of the soils of Peshawar basin

The chemistry of the Peshawar piedmont soils, Peshawar floodplain soils and the Peshawar lacustrine soils of the Peshawar basin are evaluated for the following aspects during this study:

a) Identify the natural and anthropogenic sources of contamination, within the soils of the basin.

b) Evaluate the soil chemistry in regard to its effects on groundwater.

c) Identify the character of soil for the growth of plant in the area.

d) Compare the various parameters for soil quality with the previous data.

e) Monitoring the changes in the chemistry of soils for two years time 2003-2004.

The chemical data of the soils of the Peshawar basin are given in Tables 4.1 to 4.15 and graphically presented in Figures 4.2 to 4.16. In order to avoid confusion, the soil samples have also been grouped, in similar way as for the water samples into Peshawar piedmont soil, Peshawar floodplain soil and Peshawar Lacustrine soil. The chemical characters of these soils of the Peshawar basin are discussed below: -

Major and Minor Element Oxides

The major element oxides (i.e., SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O and K_2O) and the minor element oxides (i.e., TiO_2, MnO, P_2O_5) in various types of soil samples of the Peshawar basin are evaluated in regard to their variation with time and also their possible effects on the agricultural soils.

Silica (SiO_2)

Silica is the backbone of soil and rock mineral structures. It is necessary to plants and animals in trace amount and is very beneficial to plants. Silica lodges in cell walls and provide physical strength and resistant to insects and fungal attacks. Silica may also add in overcoming plant injury and from soil salinity. These benefits are more evident in hydroponics because many growth solutions lack silicon. Silicon is also essential for animals and only in trace amount. The silica concentration in the normal soil is 70.29 (Bohn et al., 2001).

The silica concentration in the various types of soils of the Peshawar basin collected during the month of January in the years 2003 and 2004 along with that reported by Tariq (2001) is given in Table 4.1 and the data is graphically presented in Figure 4.2). It is clear from the Table 4.1 and Figure 4.2, that there is no systematic increase or decrease of silica with change in depth from horizon A to horizon B and also there is no significant variation in the silica contents of the soils of basin with the passage of time. The SiO_2 contents are ranging from 40 to 59 wt% , 44 to 59 wt% and 45 to 57 wt% in the soils of Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine respectively. No significant change in the silica contents of the horizon A and B are noticed. The data suggest that SiO_2 concentration of the soils of Peshawar basin is within the range of normal soil and are, therefore, considered safe for agricultural use.

Titanium oxide (TiO_2)

TiO_2 in the soils is normally contributed from the accessory minerals (such as rutile, sphenes, titanomagnetite etc.) of all the major rock types. The normal soil has up to 0.88 wt% TiO_2 (Bohn et al 2001). TiO_2 concentration in the various types of soils of the Peshawar basin collected during the months of January of 2003 and 2004 are given in Table 4.2 and graphically presented in Figure 4.3. The TiO_2 contents of Tariq (2001) for the same types of soil of the basin are also given in Table 4.2 for comparison. It is clear from the table and figure that there is no significant change in the concentration of TiO_2

with the increase or decrease of depth and also no significant change in the concentration of TiO_2 with the passage of time. Most of the samples of the Peshawar basin have TiO_2 contents within the permissible limit (0.83 wt%) but in same areas the TiO_2 contents exceeds this limit to an acceptable amount (< 99 wt%).

Alumina (Al_2O_3)

Al_2O_3 in the soil is closely connected to soil acidity which is the reaction of water with exchangeable Al^{+3} on the surface of soil particles. The Al^{+3} is tightly bound to clay surface; the exchangeability of Al^{+3} depends on the concentration and action change of the salts in the extracting solution. While other major exchangeable cations are leached from soils during weathering, Al is retained in soils as solid-phase $(Al\ OH)_3$. The amount of each exchangeable and water soluble ions increase with acidity. Only Al^{+3} is a common exchangeable cation in soils and is significant only in moderately to strongly acid soils (Black, 1968; Bohn et al., 2001).

The normal soil usually has Al_2O_3 contents below 13.22 wt% (Bohn et al., 2001). The Al_2O_3 content of the soil samples collected during the month of January in 2003 and 2004 from the Peshawar piedmont, Peshawar floodpain and Peshawar lacnstrine of the Peshawar basin along with the Al_2O_3 concentration obtained by Tariq (2001) from the similar soils are given in Table 4.3 and graphically presented in Figure 4.4. It is evident from the table and figure that the Al_2O_3 contents varies with the depth in most of the soils but there is no significant change in the concentration of Al_2O_3 with the passage of time. The Al_2O_3 contents varies from 12 to 24 wt% in the Peshawar piedmont soils, from 13 to 24 wt% in the Peshawar flood plain soil and from 11 to 24 wt % in the Peshawar lacustrine soil of the Peshawar basin. The data show that the soils of the Peshawar piedmont are relatively enriched in Al_2O_3. Majority of the soils samples of the Peshawar basin have Al_2O_3, content higher than the normal soil and, therefore, need precautionary measure for agricultural use.

Iron (Fe_2O_3)

Iron is common constituent in many primary and secondary minerals and is generally not deficient in many soils. It is also the major constituent of soils with iron content between o.5 to 5 wt% depending on the parent material of the soil type. The presence of iron in the soils is very essential because it is an important component of chlorophyll-protein complexes in plants and terminal respiration. It is also required for nitrate and sulfate reduction and assimilation. If iron is unavailable to the plants from the soil, the chlorophyll-protein complex is incomplete, causing a yellowing (chlorosis) of the plant tissues instead of the healthy normal green color.

If iron is present in high concentration (>10 wt%) in the soil, its availability to plants is high and hence cause toxicity in the growing plants. Its toxicity include the increase in polyphenol oxidase activity, causing of leaf bronzing and reducing the root oxidation power (Dobermann & Fairhust, 2001). According to Bohn et al. (2001), the normal agricultural soil is having iron upto about 5.77 wt%. However, the USDA (1957), Fe_2O_3 content of most of the normal soils are less than 10 wt%.

The Fe_2O_3 concentration in the soil samples of horizon A & B, collected during the month of January in 2003 and 2004, from the Peshawar piedmont soils, Peshawar floodplain soils and Peshawar lacustrine soils of the Peshawar basin are given in Table 4.4 and graphically presentd in Figure 4.5. The Fe_2O_3 contents of the soils reported by Tariq (2001) from the same sites are also given for comparison of the data.

It is evident from the data that there is no significant change in the iron concentration with the increase and decrease of depth and also with the passage of time. The Peshawar piedmont soils have iron contents in the range of 2.85 to 7.98 wt%, the Peshawar floodplain soils have iron in the range of 4.25 to 7.85 wt% and the Peshawar lacustrine soils have iron in the range of 3.6 to 5.31 wt%. all these soils have iron contents within the range of normal agricultural soil. However, the soils from Peshawar piedmont and Peshawar floodplain have relatively high concentration of iron. The iron

contents of the Peshawar basin suggest that there is no iron deficiency or iron toxicity in the soils of the basin which can have any drastic effect on the ecosystem of the region.

Manganese oxide (MnO)

Manganese occurs generally in the accessory minerals in many of the rocks. In the igneous rocks, the Mn is present in the silicates. During weathering the Mn separates out as Mn oxides in the soil (Norrish, 1975). In soil, it can occur as dark nodules and coatings. In nature Mn chemically behaves similarly to Fe. In the reducing environment Mn (II) species are most stable, which in oxidizing environments the most stable compound is in the oxide (MnO_2) (Mortvedt et. al., 1972; Adriano, 1986). Manganese has several functions in plants. It activates many enzyme reaction involved in the metabolism of organic acid, phosphorus and nitrogen. It is also involved in photosynthesis. Manganese deficiencies have been observed in various crops through out the world. Its deficiency is common in various crops and cause various types of disceases (Adriano, 1986).

According to Bohn et al., (2001), the MnO contents in the normal soil are generally below 0.1 wt%. The various soils of horizon A& B from the Peshawar, collected during the month of January in 2003 and 2004, have been analyzed for MnO and the results are shown in the Table 4.5 and graphically presented in Figure 4.6. MnO contents reported by Tariq (2001) from the same localities of the basin are also given in Table 4.5 for comparison. The data suggest that there is no change of MnO concentration with depth and also no significant change in Mn concentration occurs with the passage of time. The MnO concentration varies from 0.02 to 0.15 wt% in the soils of Peshawar piedmont, Peshawar floodplain and the Peshawar lacustrine of the Peshawar basin. Majority of the samples have MnO concentration within the range of normal soil. However, MnO in the soils of Warsak colony, Kafer Dheri, Mathra, Landi Arbab and Phando are exceeding that of normal soil. This suggests that the soils of Peshawar basin are generally safe for agriculture use as far as the Mn concentration is concerned.

Magnesium oxide (MgO)

Magnesium is the least studied ion though it is the second most abundant exchangeable cation in soils. Excessive or deficient amounts are uncommon. Mg deficiencies in plants have been reported in some acid sandy soils and are a concern in northern Europe as a by-product of the large amount of acid rain during the past century and continuing. (Bohn et al., 2001) The deficiency of Mg in the agricultural soil can be improved by the addition of agricultural limestone which is containing appreciable amount of Mg impurities. Dolomite or lime containing dolomite is a satisfactory liming material (Black, 1968). The MgO concentration in the normal agricultural soil is 0.99 wt% (Bohn et al., 2001).

The MgO concentrations in the various soils of horizon A and B, collected during the month in January of 2003 and 2004, form the Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine within the Peshawar basin have been given in Table 4.6 and graphically presented in Figure 4.7. The MgO concentrations reported by Tariq (2001) from the same localities are also given in Table 4.6 for comparison. It is clear from the Table 4.6 and Figure 4.7 that there is no significant change in MgO concentration with the depth and also with the passage of time. The MgO varies from 0.59 to 3.58 wt%, from 1.25 to 3.83 wt% and from 1.36 to 1.73 wt% in the soils of Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine respectively. The soils of Peshawar piedmont and Peshawar flood plain are relatively enriched in MgO as compared to that of Peshawar lacustrine. However, the MgO contents of all the soils of the basin are exceeding that of the normal agricultural soil. This soil, therefore, need to be further evaluated as for as the toxicity of magnesium is concerned on the ecosystem of the area.

Calcium oxide (CaO)

Most economic crops yield best in soils when Ca^{+2} dominates the exchangeable cations. High Ca indicates a near-neutral pH, which is desirable for most of the plants and soil microorganisms. Calcium is an essential element for plants and animals and the

amounts are rarely deficient in soils. Other problems appear before the Ca itself is deficient. However, the high concentration of Ca in the soil can also be not suitable for the growth of the plants. Although Ca is very important in plant nutrition, but the soils derived from limestone parent material can be unproductive (Russell, 1973, Bohn et al., 2001) The CaO concentration in the normal agricultural soil is reported up to 1.44 wt% by Bohn et al., (2001).

The CaO concentration of the various soil samples of horizon A and B of the Peshawar basin, collected during the month of January 2003 and 2004 along with the CaO concentration reported by Tariq for the soils of the same locations have been given in Table 4.7 and graphically presented in Figure 4.8. It is clear from data that there is no significant change of CaO concentration with depth and also with the passage of time. The CaO is ranging from 2.3 to 27.41 wt% in the soils of Peshawar piedmont; from 4.35 to 13.06 wt% in the soils of Peshawar flood plain and from 8.12 to 11.99 wt% in the soils of Peshawar lacustrine. Almost all the soils of the Peshawar basin are very high in CaO contents as compared to that of the normal agricultural soil, especially the soils of the Peshawar piedmont has very high concentration in CaO. This can be attributed to the larger input from the weathering of limestone and dolomite from the surrounding rocks of the basin. The soil of the Peshawar basin should, therefore, be further evaluated in detail for its effect on the ecosystem of the region.

Sodium oxide (Na_2O)

Sodium in the soil can accumulate to greater extent in the areas inundated by seawater in arid areas where salts naturally accumulate from evaporation of incoming of surface or groundwater and in irrigated soil because irrigation water often contains high Na. Na is not required by plants but can replace part of the K requirement of some plant species. Saline soils are problem for plants because the high osmotic potential of the soil solution makes it unavailable for plants. The plant has to expend so much energy to take up water that little energy is left for growth and crop yield (Bohn et al., 2001). Na is toxic to some plants at high concentrations, but for most plants this is relatively minor problem

compared with the restricted water uptake and movement that normally precede Na toxicity (Mortvedt et al., 1972).

The concentration of Na in the normal agricultural soil is reported as 0.99 by Bohn et al. (2001. The Na concentration in the various types of soil samples, collected during the month of January of 2003 and 2004, from Peshawar piedmont, Peshawar flood plain and Peshawar lacustrine of the Peshawar basin are given in Table 4.8 and graphically presented in Figure 4.9. The Na contents reported by Tariq (2001) from the same localities have also been given in Table 4.8 Figure 4.9 for comparison.

It is clear from the table and figure that generally no significant change in the concentration of Na occur with depth and also with the passage of time. The Na contents in the Peshawar piedmont is ranging from 0.91 to 2.65 wt%, in the Peshawar floodplain is ranging from 1.45 to 2.46 wt% and in the Peshawar lacustrine is ranging from 1.16 to 2.34 wt%. Almost all the soils of Peshawar piedmont, Peshawar flood plain and Peshawar lacustrine of the Peshawar basin are having high concentration as compared to that of the normal soil for agriculture. This Na enrichment can be attributed to the water logging and salinity noticed in many parts of the basin. The increasing amount of Na in the soils of Peshawar basin can pose environmental threat to the ecosystem of the region which need to be further investigated.

Potassium oxide (K_2O)

Potassium is the third most important fertilizer element, in terms of amounts added as fertilizer, after nitrogen and phosphorus. Many soils of humid and temperate regions are unable to supply sufficient K for agronomic crop. Soils retain K^+ more strongly than Na^+, because the hydrated K ion is smaller than the hydrated Na ion. In addition, K fits well between the sheets of several soil clay minerals, while Na does not, so these minerals contain high concentration of K (Black, 1968). The K concentration in soil solutions is low but is replenished by K diffusion from between the sheets of these clay minerals, from the slower weathering of K-containing feldspar minerals and from decay of soil organic matter. Continued K fertilization is necessary for K-deficient soils.

Fixed K is released back to the soil solution too slowly to satisfy plant needs (Russell, 1975; Bohn et al., 2001). The contraction of K_2O in normal agricultural soil is generally 1.2wt% (Bohn et al., 2001).

The K concentration in the various types of soils of Peshawar basin, collected during the month of January in 2003 and 2004, have been analyzed and the results along with that of Tariq (2001) from the same localities are shown in Table 4.9 and Figure 4.10. It is clear from the data that K_2O concentration is highly variable and no significant change with increase in the depth and also with the passage of time has been noticed. K_2O is ranging from 0.58 to 2.62 wt% in the Peshawar piedmont soil, from 1.32 to 3.12 wt% in the Peshawar floodplain soil and from 1.70 to 2.45 wt% in the Peshawar lacustrine soil. It is evident from this data that K_2O contents in almost all the samples of the soils from Peshawar basin exceed that of the normal agricultural soil. This can be attributed to the high amount of K-bearing clay mineral in the soils of the basin. The high concentration of K_2O in the soils of the Peshawar basin can be unsuitable for agriculture in the region and need to be further evaluated in detail.

Phosphorous penta-oxide (P_2O_5)

Phophorous occurring in the form of phosphate (PO_4) is the major fertilizer element. Phosphate added to soils is first adsorbed quickly and is later "fixed" into increasingly less soluable status as time increases. Phosphate is increasingly unavailable as soil acidity increase, due to retention by Al and Fe. The decay of phosphate in organic matter bypasses the inorganic soil fraction to some extent and maintain some phosphate availability to plants over the whole range of soil pH (Russell, 1973). The rate of phosphate loss from soil by weathering is about the same as the over all weathering rate, so that amount of phosphate in soil tends to remain constant throughtout soil development. The availability of phosphate to plants, however, decreases as soils become more acidic and the proportion of phosphorous as aluminum and iron phosphate increases (Mortvedt et al., 1972; Bohn et al., 2001). The normal agricultural soil contain about 0.18 wt% of P_2O_5 (Bohn et al., 2001).

The P_2O_5 concentration in the various types of soils of the Peshawar basin collected during the month of January of 2003 and 2004 along with the P_2O_5 contents reported by Tariq (2001) from the same sites are given in the Table 4.10 and graphically presented in Figure 4.11. It is evident from the data that the P_2O_5 contents show significant change with the increase of depth but no significant change in P_2O_5 contents occur in these soils with the passage of time. There is generally a decreasing trend of P_2O_5 with depth. The P_2O_5 contraction in the Peshawar piedmont soils varies from 0.25 to 2.56 wt%, in the Peshawar flood plain soils it varies from 2.12 to 6.90 wt% and in the Peshawar lacustrine soils it varies from 0.20 to 0.68 wt%. The Peshawar floodplain soil relatively have high concentration while the Peshawar lacustrine soils have relatively low concentration of P_2O_5. However, almost all the samples of soils of the Peshawar basin have high concentration of P_2O_5. This increase of P_2O_5 in the studied soils can be attributed to the use of fertilizers and also to the weathering of alkaline rocks present in the northwestern and northeastern position of the basin. The concentration of P_2O_5 in the soils of the basin can cause drastic negative effects on the ecosystem of the region and need to be further evaluated.

Heavy and Trace Elements

Various heavy and trace elements (i.e., Cu, Pb, Zn, Co, Ni and Cr) have been determined in the soils of horizons A and B from the Peshawar piedmont, Peshawar floodplain and Peshawar lacurstrine of Peshawar basin. These samples were collected during the months of January and June of 2003 and 2004. The concentrations of these elements have been evaluated to look at the changes with the passage of time.

Copper (Cu)

Copper occurs in the form of sulfides, sulphates, sulfosalts, carbonates and other compounds in nature (Cox, 1979). It also occur as the native metal. The level and distribution of total extractable Cu in the soil profile can be expected to vary with soil

types and parent materials from which the soils are derived (Blecker & Austin, 1970). The amount of Cu in a given form can vary according to extraction time and chemical extractant (Adriano, 1986). Copper is among these micronutrients which are essential for the normal growth of plants if present in less than 4 ppm but if more than 20 ppm than it is considered as toxic (Jones, 1972). Cu has been established as a consitituent of a number of plant enzymes. Bussler (1981) reported that a lack of Cu affects a multitude of physiological processes in plant. It may also affect ion up take and plant differentiation in early developmental stages. Copper deficiency in plants has frequently appeared in many parts of the world whenever acid histosols were brought into agricultural production (Kubota & Allaway, 1972). The Term "reclamation disease" referes to severe Cu deficiency that appear in newly drained and developed acid histosols. In most of the plant species, Cu deficiency is characterized by chlorosis, necrosis, leaf distortion and terminal die back with symptoms occurring first in young shoot tissues (Robson & Reuter, 1981; Adriano, 1986) Absorption rates of Cu by plant roots are among the lowest for the essential elements (Graham, 1981). However, the absorption process has been recognized as active. The most common Cu toxicity symptoms include reduced growth vigor, poorly developed and discolored root system, and leaf chlorosis (Robson & Reutor, 1981).The Cu toxicity also causes stunting, reduced branching, thickening, and usually dark coloration in the rootlets of many plants (Reuther & Labanauskas, 1965). The Cu concentration for the normal agricultural soil has been reported as 20 ppm (Adriano, 1986).

The Cu concentration in the soil samples of horizon A and B collected during the month of January in 2003 and 2004, from various types of soils of the Peshawar basin has been given in the Table 4.11 and graphically presented in Figure 4.12. The Cu concentrations reported by Tariq (2001) in the soils from the same sites are also given in Table 4.11 for comparison. It is clear from the data that there is no systematic increase or decrease of Cu with the increase or decrease of depth. However, no significant change has been noticed in the Cu concentration with the passage of time. Cu is ranging from 71 to 631 parts per million (ppm) in the Peshawar piedmont soils, from 67 to 588 ppm in the Peshawar floodplain soils and from 46 to 188 ppm in the Peshawar lacustrine soils. The

soils of Peshawar piedmont and Peshawar lacuntrine are relative highly enriched in copper. The Cu concentration in the soils of certain areas (such as Khairabad, Shabqadar, Mandezai Srikh, Tarangzai and Aman Kot) of Peshawar basin is higher than that of the normal agricultural soil. This increase of the Cu concentration in the soils of Peshawar basin can be attributed to the weathering of sulfides in the surrounding mountainous areas around Peshawar basin. This concentration of Cu in certain areas is reaching to alarming level. The soils of Peshawar lacustrine are highly contaminated with geogenic Cu and this should be evaluated in detail.

Zinc (Zn)

Zinc content of the soils depends on the nature of the parent rocks, organic matter, texture, and pH. Soils formed from basic rocks are rich in Zn, whereas soils from grainites, gneisses etc are poorer (Vinogradov, 1959; Adriano, 1986). Zinc is one of the essential nutrients for plants growth. It is required only in minute amount (<50 ppm). Zn deficiency is more common than deficiency of any other micronutrient. Its very low concentration can cause retardation in various species of crops (Yoshida et al., 1973). If there is excessive up take of Zn by the plant it cause toxicity. The high concentration of Zn in the agriculture soil can cause severe toxicity in the plants and disturb the ecosystem (Jones, 1972). Zinc is relatively less toxic insignificant, since, therefore, neither WHO/FAO nor the US-FDA give guide lines for Zn other than as an essential micronutrient. However, about 50 ppm Zn concentration has been reported by Bohn et al. (2001) for the normal agricultural soil.

Zinc concentration in the soils of Peshawar basin has been determined the soil samples collected during the month of January in 2003 and 2004 and the results along with those reported by Tariq (2001) are given in Table 4.12 and graphically presented in Figure 4.13. The data clearly show that there is unsystemic increase or decrease of Zn with the increase or decrease in depth. However, no significant change in the concentration of Zn in the soil of Peshawar has been noticed with the passage of time. The Zn concentration in soils of Peshawar basin is highly variable. It is ranging from 88

to 601 ppm in the Peshawar piedmont soil, from 93 to 181 ppm in the Peshawar floodplain soil and from 75 to 240 ppm in the Peshawar lacustrine soil. The Peshawar piedmont soil is relatively enriched in Zn. This high concentration of Zn can be attributed to the weathering of sulfide mineralization in the surrounding rocks of the Peshawar basin. Many fold high concentration of Zn in the soils of certain areas (i.e., Darwazgai, Speen Khak, Khairabad Kafir Dheri, Shabqadar and Mandezai Srikh) of Peshawar basin reaches to toxic level for in the plants and hence greater environmental impact in the ecosystem of the region is expected.

Lead (Pb)

Lead in the agricultural soil has a wide range, depending on a number of factors, such as parent material and anthropogenic input (Andrieano, 1986). As with most trace element, total Pb in soils is not a good indicator of Pb phytoavailability. Therefore, extractable Pb is normally used as the indicator of amounts available for plant uptake. In plants Pb is generally accumulated in roots with very little in shoots (Wallace & Romney, 1977). Apparently, Pb uptake by plants from soil is a passive process that proceeds rapidly until exchange sites in the root-free space are equilibrated with the solution concentation (Zimdahl & Arivk, 1973). The toxicity of Pb in the plants can be observed in the plants growing in the soils having high concentration of Pb. Such plants can develop phytotoxicity which usually result in the death or slow growth of the plants. Excess of Pb in plants alters secured physiological and biochemical processes within the plants. The Pb concentration in the normal agricultural soil has been reported as 10 ppm (Bohn et al., 2001; Adriano 1986).

Lead concentration in the soil samples, collected during January in 2003 and 2004, from the Peshawar piedmont soils, Peshawar flood plain soils and Peshawar lacustrine soils of the Peshawar basin are presented in Table 4.13 and Figure 4.14. The Pb contents reported by Tariq (2001) in the soils from the same localities of the Peshawar basin are also given for comparison. It is clear from the data that there is no systematic increase or decrease of Pb with the increase or decrease of depth. However, there is no

significant change occurring in the concentration of Pb in these soils occur with the passage of time. The Pb concentration in almost all the soils of the Peshawar basin is many fold high as compare to that of the normal agricultural soil. This enrichment of Pb in the soil of Peshawar can be attributed to the weathering and leaching of sulfides in the mountainous regions surrounded by Peshawar basin. There could be less anthropogenic input in this regard. The toxicity of Pb in the agricultural lands in certain areas (such as Landiarbab, Shabqadar, Mathra, Mandezai Srikh and Tarangzai) of the basin is imparative and need to be investigated in detail.

Nickel (Ni)

Nickel concentration in the soil varies with the variation in the parent material and also an input from the anthropogenic sources. Considerable variation in the Ni content especially occur in the soil from metamafic rocks. The essentiality of Ni has not been established for higher plants. However, some beneficial effects of Ni on plants growth have been reported (Adriano, 1986). High Ni content of the soil, particularly when the exchangeable form is also high, accelerates the absorption of this element by the plants when other conditions are also favorable (Meinser & Kar, 1974). Ni concentration in the normal agricultural soil has been reported as 40 ppm (Adriano, 1986; Bhon et al., 2001). The increasing concentration of Ni from 50 ppm in the soil may produce toxicity in the plants grown on it. The toxicity symptoms in the plants include chlorosis, stunting, phytoxicity and even death of the plants.

Nickel (Pb) concentration in the various soils (horizon A & B) of Peshawar basin, collected during the month of January in 2003 and 2004 are given in Table 4.14 and graphically presented in Figure 4.15. The Ni contents reported by Tariq (2001) from the same sites of the soils of Peshawar basin are also given in Table 4.14 for comparison. It is evident from the data in the Table 4.14 and Figure 4.15 that no correlation of Ni concentration is present with the increase or decrease of depth. However, it is clear from the data that there is no significant change has been observed in the Ni concentration with the passage of time. The Ni is highly variable in the soils of Peshawar basin. It is ranging

from <0.5 to 378 ppm in the Peshawar piedmont soil, from 7 to 206 ppm in the Peshawar floodplain soil and <0.5 to 232 ppm in the Peshawar lacustrine soil. The Ni concentration in the Speen Khak and Hayatabad Phase-3 of the Peshawar piedmont, in the Amon Kot and Khazana of Peshawar floodplain and in the Baszid Khel and Urmar Payan of Peshawar lacustrine of the Peshawar basin is very high. The soils of these areas have alarming concentration of Ni as far as the toxicity of Ni on the plants and animals are concerned. The Ni enrichment in the soils of Peshawar basin can be attributed to the weathering and erosion of ultramafic and mafic rocks exposed in the north west and north of the Peshawar basin, especially those of Dargai mafic and ultramafic complex (Ahmad, 1971). The toxicity of Ni in the soils of the Dargai and surrounding areas has also been reported by Kafayatullah et al. (2001).

Chromium (Cr)

Chromium occurs in nature in any of the two oxidation states from II to VI, but it is not commonly found in oxidation states other than O, III, and Vi, the III being the most stable (Mertz, 1969). The variation of Cr in the soil is dependent on the composition of parent material and also on the anthropogenic source. The soils obtained from the ultramafic rocks, however, have highly variable maximum concentration of Cr. Extractable Cr, just like any extractable trace element, is the form most commonly used to indicate Cr availability to plants. Cr in required amount in the soil is an essential element in many plant species and hence also for animals and human nutrition (Mertz, 1969; Adriano, 1986). Stimulatory effects of Cr has also been reported in plant growth (Pratt, 1966). The visual symptoms of Cr toxicity commonly observed are: stunted growth, poorly developed root system and curled and disclosed leaves (Pratt, 1966; Adriano 1986). Chromium concentration in the normal agriculture soil has been reported as 20 ppm (Adriano 1986; Bohn et al., 2001).

Chromium contents of the soils samples of the horizons A & B, collected during the month of January in 2003 and 2004, from Peshawar piedmont soil, Peshawar floodplain soil and Peshawar lacustrien soil of the Peshawar basin are given in Table 4.15

and graphically presented in Figure 4.16. The Cr concentrations in the soils from the same sites of the Peshawar basin reported by Tariq (2001) are also given in Table 4.15 for comparison. It is clear from the data that the Cr concentration exhibits no correlation with the increase or decrease of depth. The amount of Cr in both the horizons of soils of the Peshawar basin is highly variable. There is no significant change in the Nickel contents of these soils with the passage of time. Chromium is ranging from <0.5 to 602 ppm in the Peshawar piedmont soils, from <0.5 to 651 ppm in the Peshawar floodplain soils and from <0.5 to 165 ppm in the Peshawar lacustrine soils (Table 4.15). Majority of the soils of the Peshawar basin are having multifold high concentration of Cr as compared to that of normal agricultural soils. In some of the soils (i.e., Khairabad and Shabqadar of Peshawar piedmont and Mandezai Srikh, Tarangzai and Amankot of Peshawar flood plain) of the Peshawar basin have Cr to an alarming level and can produce highly toxic effects on the plants and other living organisms of the area. This Cr enrichment can also be attributed to the weathering and erosion of the mafic and ultramafic rocks occurring in the north and north west of the basin, especially from the dargai ultramfic complex (Ahmad 1971). The toxicity of Cr in the soil of Dargai and surrounding areas has also been reported by Kafayatullah et al. (2001).

Cobalt (Co)

Cobalt has not been demonstrated to be essential for the growth of plants. However, it is essential to many beneficial bacteria that are involved in nitrogen fixation of legumes. Although Co is not essential in plants, its level in plant tissue is in general common because of its essentiality in animal nutrition. It is constituent of vitamin B_{12} which is essential to most of the animals and possibly in plants (Adriano, 1986; 2001). This element is relatively nontoxic to animals and human beings. A deficiency of Co is of far greater concern than potential toxic levels in plants (Adriano, 1986; 2001). The cobalt content of the normal agricultural soil has been reported as 8ppm by Bohn et al. (2001).

Various types of soils of the Peshawar basin, collected during the month of January in 2003 and 2004, have Co contents less than 1ppb. Tariq (2001) has also

reported that Co concentration in the soils of the basin from the same sites is below the detection limit (<1ppb). This suggest that there is a greater deficiency of Co in the soils of Peshawar basin which can have drastic effects on the plants and also on the human beings as these soils have no capability of enhancing the important component of vitamin B12, therefore, this soil should be further investigated.

Table 4.1. Concentration of SiO_2 (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	47.66	47.98	47.95	48.23	47.02	47.45
PBS2	Tila Band	52.56	53.40	52.81	54.01	56.23	52.99
PBS3	Speen Khak	50.56	43.40	48.81	42.01	50.34	40.75
PBS4	Khairabad	55.79	56.12	56.34	57.41	56.34	58.56
PBS5	Kafir Dheri	48.61	51.36	49.31	52.60	47.56	50.45
PBS6	W. Colony	55.98	55.30	56.10	54.21	54.23	56.45
PBS7	Jamrud Road	52.32	58.54	53.41	58.64	50.78	56.34
PBS8	Hayatabad Phase-3	47.23	48.35	49.12	49.40	46.67	47.34
PBS9	Sar Band	49.57	48.84	51.53	50.81	48.57	47.85
PBS10	Shabqadar	53.33	51.45	52.40	52.22	51.34	50.00
Peshawar floodplain soil							
PBS11	Mathra	56.98	54.99	58.12	55.39	55.67	54.86
PBS12	Khazana	56.63	54.12	56.05	58.71	55.23	56.78
PBS13	Mandezai Srikh	44.85	50.22	48.25	52.45	47.70	50.12
PBS14	Tarangzai	48.80	48.25	46.99	51.36	47.23	50.12
PBS15	Amankot	47.90	43.99	48.13	44.24	44.12	45.12
Peshawar lacustrine soil							
PBS16	Bazid Khel	46.68	45.65	47.01	46.08	46.34	45.53
PBS17	Landi Arbab	53.01	55.12	53.98	56.10	52.57	54.79
PBS18	Pando	55.35	53.01	57.11	54.02	55.12	52.89
PBS19	Urmar Payan	45.52	49.45	46.66	50.33	45.32	49.02

Table 4.2. Concentration of TiO_2 (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	0.96	0.84	0.98	0.88	0.86	0.73
PBS2	Tila Band	0.83	0.96	0.89	0.98	0.77	0.85
PBS3	Speen Khak	0.86	0.89	0.88	0.92	0.72	0.76
PBS4	Khairabad	0.78	0.64	0.80	0.68	0.69	0.54
PBS5	Kafir Dheri	0.89	0.99	0.91	0.98	0.72	0.98
PBS6	W. Colony	0.96	0.80	0.97	0.81	0.90	0.67
PBS7	Jamrud Road	0.73	0.63	0.74	0.65	0.62	0.59
PBS8	Hayatabad Phase-3	0.51	0.85	0.52	0.86	0.47	0.79
PBS9	Sar Band	0.99	0.93	0.98	0.92	0.98	0.89
PBS10	Shabqadar	0.86	0.99	0.87	0.99	0.74	0.98
Peshawar floodplain soil							
PBS11	Mathra	0.69	0.90	0.68	0.93	0.63	0.86
PBS12	Khazana	0.49	0.92	0.45	0.39	0.41	0.83
PBS13	Mandezai Srikh	0.82	0.98	0.91	0.99	0.81	0.93
PBS14	Tarangzai	0.88	0.59	0.85	0.60	0.80	0.52
PBS15	Amankot	0.51	0.70	0.54	0.73	0.43	0.62
Peshawar lacustrine soil							
PBS16	Bazid Khel	0.71	0.99	0.79	0.93	0.67	0.97
PBS17	Landi Arbab	0.45	0.92	0.47	0.93	0.40	0.85
PBS18	Pando	0.05	0.92	0.06	0.94	0.03	0.86
PBS19	Urmar Payan	0.60	0.85	0.64	0.90	0.52	0.79

Table 4.3. Concentration of Al_2O_3 (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	22.46	17.78	23.05	18.32	22.29	17.55
PBS2	Tila Band	12.81	14.88	13.92	15.1	12.69	14.03
PBS3	Speen Khak	13.39	21.99	13.88	22.4	13.12	21.89
PBS4	Khairabad	14.55	15.71	15.23	15.98	16.34	16.02
PBS5	Kafir Dheri	29.01	26.86	29.56	27.1	28.05	25.97
PBS6	W. Colony	17.8	18.9	18.18	18.99	19.56	18.79
PBS7	Jamrud Road	21.45	23.11	22.2	23.58	21.39	22.89
PBS8	Hayatabad Phase-3	16.97	16.82	17.02	16.92	16.78	16.45
PBS9	Sar Band	16.8	18.8	17.21	19.21	16.6	18.46
PBS10	Shabqadar	18.6	23.51	18.63	23.68	18.67	23.23
Peshawar floodplain soil							
PBS11	Mathra	14.88	21.21	15.2	22.12	18.45	19.12
PBS12	Khazana	17.84	19.19	18.9	20.2	18.12	18.12
PBS13	Mandezai Srikh	22.68	18.25	23.71	17.33	22.58	19.45
PBS14	Tarangzai	17.19	20.22	18.92	21.31	16.23	20.18
PBS15	Amankot	16.01	13.41	15.55	14.11	14.34	14.12
Peshawar lacustrine soil							
PBS16	Bazid Khel	24.2	21.23	24.4	21.43	23.09	20.12
PBS17	Landi Arbab	14.21	11.25	14.32	11.34	13.56	10.89
PBS18	Pando	13.56	4.81	14.11	15.03	12.74	13.57
PBS19	Urmar Payan	15.9	15.69	14.55	14.02	15.13	15.34

Table 4.4. Concentration of Fe_2O_3 (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	3.99	4.53	4.12	4.84	3.79	4.20
PBS2	Tila Band	2.98	4.25	3.11	4.45	2.60	4.03
PBS3	Speen Khak	3.80	3.60	4.05	4.10	3.63	3.45
PBS4	Khairabad	3.98	4.91	3.32	4.01	3.45	3.65
PBS5	Kafir Dheri	5.10	5.20	4.55	4.90	4.47	4.86
PBS6	W. Colony	4.20	2.92	4.20	2.22	3.72	2.13
PBS7	Jamrud Road	4.80	2.85	4.65	3.41	4.22	2.11
PBS8	Hayatabad Phase-3	3.48	3.55	3.23	3.32	3.07	3.25
PBS9	Sar Band	4.78	4.75	4.98	4.10	4.52	4.45
PBS10	Shabqadar	6.91	7.98	6.11	7.78	6.65	7.11
Peshawar floodplain soil							
PBS11	Mathra	4.56	4.52	4.78	4.51	4.29	4.56
PBS12	Khazana	4.27	4.25	5.02	5.15	4.07	4.18
PBS13	Mandezai Srikh	7.25	6.90	7.85	7.11	7.04	6.86
PBS14	Tarangzai	5.70	5.68	6.20	6.11	5.42	5.58
PBS15	Amankot	5.09	5.50	6.02	6.30	4.90	5.33
Peshawar lacustrine soil							
PBS16	Bazid Khel	4.45	4.99	4.84	4.95	4.38	4.91
PBS17	Landi Arbab	4.35	5.18	4.65	5.31	4.27	5.04
PBS18	Pando	4.81	4.72	5.02	5.13	4.68	4.61
PBS19	Urmar Payan	3.87	3.68	3.99	4.12	3.77	3.59

Table 4.5. Concentration of MnO (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	0.10	0.11	0.09	0.10	0.09	0.09
PBS2	Tila Band	0.10	0.09	0.10	0.09	0.09	0.08
PBS3	Speen Khak	0.10	0.10	0.09	0.10	0.08	0.08
PBS4	Khairabad	0.08	0.10	0.09	0.11	0.09	0.09
PBS5	Kafir Dheri	0.14	0.13	0.10	0.13	0.11	0.10
PBS6	W. Colony	0.12	0.08	0.12	0.08	0.10	0.04
PBS7	Jamrud Road	0.02	0.07	0.08	0.08	0.07	0.03
PBS8	Hayatabad Phase-3	0.08	0.08	0.09	0.08	0.10	0.08
PBS9	Sar Band	0.09	0.10	0.10	0.09	0.09	0.09
PBS10	Shabqadar	0.09	0.09	0.09	0.08	0.08	0.09
Peshawar floodplain soil							
PBS11	Mathra	0.13	0.10	0.15	0.13	0.10	0.08
PBS12	Khazana	0.11	0.09	0.10	0.08	0.09	0.08
PBS13	Mandezai Srikh	0.08	0.07	0.08	0.07	0.06	0.05
PBS14	Tarangzai	0.09	0.11	0.08	0.08	0.08	0.09
PBS15	Amankot	0.09	0.09	0.09	0.08	0.09	0.08
Peshawar lacustrine soil							
PBS16	Bazid Khel	0.11	0.11	0.02	0.13	0.09	0.10
PBS17	Landi Arbab	0.10	0.12	0.13	0.11	0.09	0.10
PBS18	Pando	0.10	0.10	0.13	0.10	0.09	0.09
PBS19	Urmar Payan	0.09	0.09	0.09	0.10	0.08	0.08

Table 4.6. Concentration of MgO (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A 4-Jan	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	1.50	1.88	1.61	1.98	1.32	1.62
PBS2	Tila Band	1.30	1.40	1.45	1.53	1.18	1.21
PBS3	Speen Khak	1.40	1.55	1.54	1.81	1.32	1.35
PBS4	Khairabad	2.40	2.42	2.60	2.62	2.26	2.22
PBS5	Kafir Dheri	1.45	1.25	1.65	1.55	1.33	1.15
PBS6	W. Colony	1.18	1.26	1.42	1.38	1.09	1.16
PBS7	Jamrud Road	1.65	0.59	1.86	0.79	1.59	0.42
PBS8	Hayatabad Phase-3	0.99	0.99	1.12	1.11	0.95	0.96
PBS9	Sar Band	1.50	1.74	1.68	1.83	1.41	1.65
PBS10	Shabqadar	3.50	3.58	3.75	3.65	3.38	3.48
Peshawar floodplain soil							
PBS11	Mathra	1.25	1.28	1.40	1.51	1.19	1.18
PBS12	Khazana	1.41	1.36	1.61	1.72	1.36	1.28
PBS13	Mandezai Srikh	3.62	3.63	3.84	3.91	3.52	3.40
PBS14	Tarangzai	3.70	3.35	3.78	3.76	3.58	3.21
PBS15	Amankot	3.60	3.35	3.83	3.68	3.52	3.25
Peshawar lacustrine soil							
PBS16	Bazid Khel	1.56	1.46	1.38	1.53	1.47	1.35
PBS17	Landi Arbab	1.58	1.45	1.68	1.58	1.45	1.39
PBS18	Pando	1.49	1.48	1.55	1.59	1.37	1.36
PBS19	Urmar Payan	1.36	1.62	1.45	1.73	1.24	1.52

Table 4.7. Concentration of CaO (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	8.50	9.93	8.84	9.98	8.07	9.73
PBS2	Tila Band	8.20	9.67	8.41	9.80	8.06	9.42
PBS3	Speen Khak	11.88	12.98	12.02	13.01	11.62	12.74
PBS4	Khairabad	5.65	5.46	5.85	5.91	5.49	5.24
PBS5	Kafir Dheri	2.30	4.79	2.36	4.90	2.12	4.68
PBS6	W. Colony	5.38	26.21	6.40	27.41	5.24	4.78
PBS7	Jamrud Road	6.40	3.40	7.42	4.10	6.33	3.23
PBS8	Hayatabad Phase-3	13.39	12.51	13.56	14.59	13.09	12.43
PBS9	Sar Band	8.95	8.36	9.20	9.33	8.87	8.20
PBS10	Shabqadar	5.35	3.18	6.25	3.25	5.21	2.99
Peshawar floodplain soil							
PBS11	Mathra	4.52	4.35	5.02	5.18	4.39	4.21
PBS12	Khazana	6.68	5.96	7.34	6.51	6.57	5.89
PBS13	Mandezai Srikh	4.99	4.38	5.26	5.01	4.79	4.21
PBS14	Tarangzai	12.12	10.25	13.06	11.20	11.40	10.10
PBS15	Amankot	12.85	11.35	13.05	12.40	12.66	11.26
Peshawar lacustrine soil							
PBS16	Bazid Khel	9.29	8.70	9.40	8.88	9.02	8.58
PBS17	Landi Arbab	9.02	8.98	9.56	9.02	8.95	8.88
PBS18	Pando	8.12	8.60	8.43	8.91	7.92	8.49
PBS19	Urmar Payan	9.56	11.68	9.88	11.99	9.44	10.56

Table 4.8. Concentration of Na_2O (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	1.50	1.75	1.63	1.81	1.38	1.45
PBS2	Tila Band	1.69	1.30	1.86	1.45	1.39	1.09
PBS3	Speen Khak	1.55	1.55	1.71	1.68	1.35	1.36
PBS4	Khairabad	2.61	2.33	2.70	2.38	2.33	2.02
PBS5	Kafir Dheri	1.76	1.45	1.88	1.78	1.62	1.30
PBS6	W. Colony	2.30	0.88	2.55	0.91	2.19	0.72
PBS7	Jamrud Road	0.99	0.38	1.11	0.51	0.93	0.22
PBS8	Hayatabad Phase-3	1.50	0.89	1.56	1.01	1.38	0.77
PBS9	Sar Band	1.19	1.21	1.31	1.41	1.03	1.09
PBS10	Shabqadar	1.80	1.80	1.98	1.98	1.72	1.72
Peshawar floodplain soil							
PBS11	Mathra	1.99	1.36	2.03	1.85	1.87	1.20
PBS12	Khazana	2.25	2.10	2.40	2.34	2.00	1.96
PBS13	Mandezai Srikh	2.30	2.21	2.46	2.35	2.16	2.06
PBS14	Tarangzai	1.82	1.58	2.03	1.86	1.60	1.42
PBS15	Amankot	1.45	1.71	1.54	1.92	1.30	1.42
Peshawar lacustrine soil							
PBS16	Bazid Khel	1.42	1.23	1.96	1.43	1.21	1.06
PBS17	Landi Arbab	1.32	1.18	1.48	1.25	1.23	1.13
PBS18	Pando	1.16	1.19	1.25	2.34	1.01	1.08
PBS19	Urmar Payan	1.89	1.69	1.99	1.88	1.64	1.48

Table 4.9. Concentration of K_2O (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	2.32	2.10	2.48	2.34	2.06	1.94
PBS2	Tila Band	1.58	1.90	1.78	2.01	1.38	1.72
PBS3	Speen Khak	1.89	1.65	1.99	1.80	1.78	1.55
PBS4	Khairabad	2.35	2.23	2.55	2.41	2.08	2.02
PBS5	Kafir Dheri	2.68	2.45	0.93	2.62	2.42	2.30
PBS6	W. Colony	1.99	1.35	1.18	1.91	1.88	1.23
PBS7	Jamrud Road	2.46	0.82	2.58	0.78	2.36	0.72
PBS8	Hayatabad Phase-3	1.58	1.65	1.12	1.71	1.46	1.55
PBS9	Sar Band	2.01	2.02	2.81	1.92	1.97	1.96
PBS10	Shabqadar	1.86	1.88	1.58	1.32	1.79	1.82
Peshawar floodplain soil							
PBS11	Mathra	2.93	2.40	3.10	3.56	2.60	2.23
PBS12	Khazana	2.48	2.29	3.12	2.14	2.18	2.21
PBS13	Mandezai Srikh	1.90	1.88	2.02	2.11	1.78	1.73
PBS14	Tarangzai	2.22	2.26	2.45	2.01	2.03	2.14
PBS15	Amankot	1.93	1.99	2.01	2.05	1.64	1.76
Peshawar lacustrine soil							
PBS16	Bazid Khel	1.98	2.30	2.03	2.43	1.89	2.00
PBS17	Landi Arbab	2.33	2.12	2.39	2.18	2.11	1.97
PBS18	Pando	2.37	2.13	2.45	2.26	2.17	1.99
PBS19	Urmar Payan	1.96	1.70	2.13	1.88	1.76	1.54

Table 4.10. Concentration of P_2O_5 (wt%) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazgai	0.28	0.35	0.29	0.38	1.80	2.10
PBS2	Tila Band	0.25	0.25	0.29	0.30	1.10	0.40
PBS3	Speen Khak	0.30	0.28	0.34	0.29	0.75	1.25
PBS4	Khairabad	0.10	0.09	0.16	0.10	0.90	0.75
PBS5	Kafir Dheri	0.01	0.15	0.03	0.16	2.42	2.30
PBS6	W. Colony	1.15	1.85	1.17	1.88	1.88	1.23
PBS7	Jamrud Road	0.41	0.25	0.48	0.30	2.36	0.72
PBS8	Hayatabad Phase-3	0.90	0.52	1.01	0.60	1.46	1.55
PBS9	Sar Band	2.56	1.89	2.83	1.98	1.97	1.96
PBS10	Shabqadar	1.48	0.28	1.61	0.34	1.79	1.82
Peshawar floodplain soil							
PBS11	Mathra	2.70	2.39	2.82	2.86	0.95	3.65
PBS12	Khazana	2.29	2.28	2.89	3.65	1.90	2.15
PBS13	Mandezai Srikh	3.28	4.25	2.40	4.88	3.15	4.15
PBS14	Tarangzai	2.20	2.12	4.55	2.51	2.60	1.95
PBS15	Amankot	6.90	2.21	6.81	2.56	6.20	6.12
Peshawar lacustrine soil							
PBS16	Bazid Khel	0.59	0.31	0.68	0.46	4.12	0.25
PBS17	Landi Arbab	0.29	0.21	0.36	0.31	2.30	1.90
PBS18	Pando	0.20	0.50	0.36	0.40	1.95	4.65
PBS19	Urmar Payan	0.28	0.29	0.38	0.35	2.30	2.20

Table 4.11. Concentration of Cu (ppm) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazagai	121	128	70	76	90	50
PBS2	Tela Band	123	145	131	148	100	110
PBS3	Speen Khak	95	67	101	65	65	55
PBS4	Khair Abad	611	539	631	556	595	510
PBS5	Kafir Dheri	161	141	163	145	135	105
PBS6	W. Colony	81	95	86	98	75	85
PBS7	Jamrud Road	85	130	86	133	65	70
PBS8	Hayatabad Phase-3	135	90	138	95	1120	70
PBS9	Sar Band	133	71	124	72	110	55
PBS10	Shabqadar	595	703	598	768	575	695
Peshawar floodplain soil							
PBS11	Mathra	96	155	98	157	80	130
PBS12	Khazana	88	67	90	68	75	55
PBS13	Mandezai Srikh	552	480	562	485	500	465
PBS14	Tarangzai	541	455	550	480	500	435
PBS15	Amankot	495	561	501	588	488	540
Peshawar lacustrine soil							
PBS16	Bazid Khel	109	123	135	146	95	120
PBS17	Landi Arbab	112	46	130	49	100	35
PBS18	Pandu	145	122	188	178	130	100
PBS19	Urmar Payan	74	110	89	122	55	95

Table 4.12. Concentration of Zn (ppm) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazagai	292	296	99	105	260	80
PBS2	Tela Band	89	125	91	138	75	105
PBS3	Speen Khak	410	331	422	345	390	315
PBS4	Khair Abad	167	594	173	601	145	575
PBS5	Kafir Dheri	280	123	286	125	260	105
PBS6	W. Colony	95	88	98	91	80	80
PBS7	Jamrud Road	133	81	136	84	105	45
PBS8	Hayatabad Phase-3	189	60	193	64	165	45
PBS9	Sar Band	134	275	136	278	120	130
PBS10	Shabqadar	277	251	286	254	256	255
Peshawar floodplain soil							
PBS11	Mathra	138	132	141	138	115	100
PBS12	Khazana	174	75	183	82	155	65
PBS13	Mandezai Srikh	230	138	240	145	200	120
PBS14	Tarangzai	101	122	111	132	90	100
PBS15	Amankot	130	135	136	140	110	120
Peshawar lacustrine soil							
PBS16	Bazid Khel	122	126	155	163	110	140
PBS17	Landi Arbab	170	120	181	126	160	105
PBS18	Pandu	118	101	123	119	100	100
PBS19	Urmar Payan	104	93	108	101	80	80

Table 4.13. Concentration of Pb (ppm) in the soils of Peshawar basin during different times.

Sample No.		A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazagai	137	145	6	8	105	<0.5
PBS2	Tela Band	123	128	131	135	105	90
PBS3	Speen Khak	59	10	66	12	45	<0.5
PBS4	Khair Abad	35	120	48	136	25	95
PBS5	Kafir Dheri	88	138	90	141	60	105
PBS6	W. Colony	65	43	68	24	45	20
PBS7	Jamrud Road	55	49	58	53	30	35
PBS8	Hayatabad Phase-3	70	54	75	58	55	35
PBS9	Sar Band	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
PBS10	Shabqadar	390	210	394	216	360	195
Peshawar floodplain soil							
PBS11	Mathra	205	64	218	59	185	45
PBS12	Khazana	<0.5	121	<0.5	130	<0.5	90
PBS13	Mandezai Srikh	220	499	231	503	395	485
PBS14	Tarangzai	298	270	312	278	280	255
PBS15	Amankot	81	75	86	83	70	55
Peshawar lacustrine soil							
PBS16	Bazid Khel	14	16	18	20	<0.5	<0.5
PBS17	Landi Arbab	220	65	232	71	190	45
PBS18	Pandu	119	<0.5	124	<0.5	90	<0.5
PBS19	Urmar Payan	12	14	22	26	40	<0.5

Table 4.14. Concentration of Ni (ppm) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazagai	<0.5	<0.5	215	230	<0.5	155
PBS2	Tela Band	<0.5	110	<0.5	130	<0.5	100
PBS3	Speen Khak	160	378	170	360	145	360
PBS4	Khair Abad	120	92	130	98	90	75
PBS5	Kafir Dheri	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
PBS6	W. Colony	30	45	31	46	15	25
PBS7	Jamrud Road	178	142	180	146	120	105
PBS8	Hayatabad Phase-3	241	185	251	191	220	105
PBS9	Sar Band	6	<0.5	7	6	<0.5	<0.5
PBS10	Shabqadar	170	191	175	193	140	175
Peshawar floodplain soil							
PBS11	Mathra	81	10	88	14	70	<0.5
PBS12	Khazana	140	7	151	8	125	300
PBS13	Mandezai Srikh	145	138	150	145	130	125
PBS14	Tarangzai	138	140	143	151	110	120
PBS15	Amankot	199	155	206	168	170	135
Peshawar lacustrine soil							
PBS16	Bazid Khel	156	212	157	232	135	200
PBS17	Landi Arbab	55	64	59	61	35	35
PBS18	Pandu	<0.5	153	<0.5	160	<0.5	130
PBS19	Urmar Payan	211	145	220	149	195	105

Table 4.15. Concentration of Cr (ppm) in the soils of Peshawar basin during different times.

Sample No.	Area	A Jan 03	B Jan 03	A Jan 04	B Jan 04	A Tariq (2003)	B
Peshawar piedmont soil							
PBS1	Darwazagai	6	8	176	181	<0.5	155
PBS2	Tela Band	81	77	89	87	70	60
PBS3	Speen Khak	101	<0.5	110	<0.5	100	<0.5
PBS4	Khair Abad	343	498	351	501	320	485
PBS5	Kafir Dheri	105	160	107	171	90	135
PBS6	W. Colony	101	46	104	48	80	25
PBS7	Jamrud Road	133	67	136	69	110	20
PBS8	Hayatabad Phase-3	<0.5	35	<0.5	45	<0.5	20
PBS9	Sar Band	123	3	128	6	110	<0.5
PBS10	Shabqadar	344	591	351	602	315	570
Peshawar floodplain soil							
PBS11	Mathra	85	41	91	11	65	20
PBS12	Khazana	4	6	6	8	<0.5	<0.5
PBS13	Mandezai Srikh	331	440	340	445	315	415
PBS14	Tarangzai	271	215	291	225	260	196
PBS15	Amankot	631	320	651	330	620	290
Peshawar lacustrine soil							
PBS16	Bazid Khel	176	<0.5	170	<0.5	100	<0.5
PBS17	Landi Arbab	62	99	68	102	155	155
PBS18	Pandu	133	150	138	165	70	100
PBS19	Urmar Payan	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

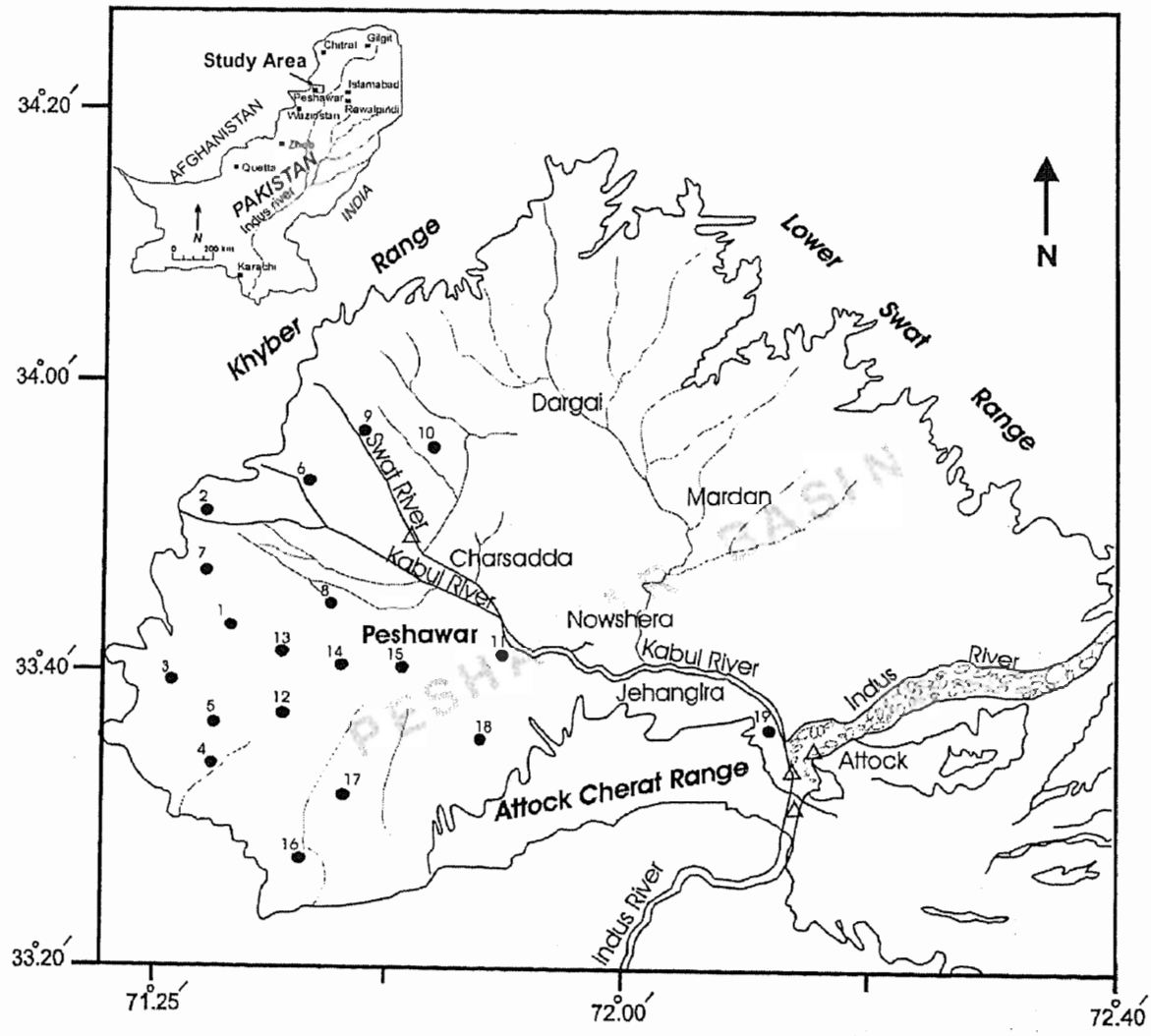


Fig. 4.1. Location map of the soil samples of the Peshawar basin (modified after Tariq, 2001)

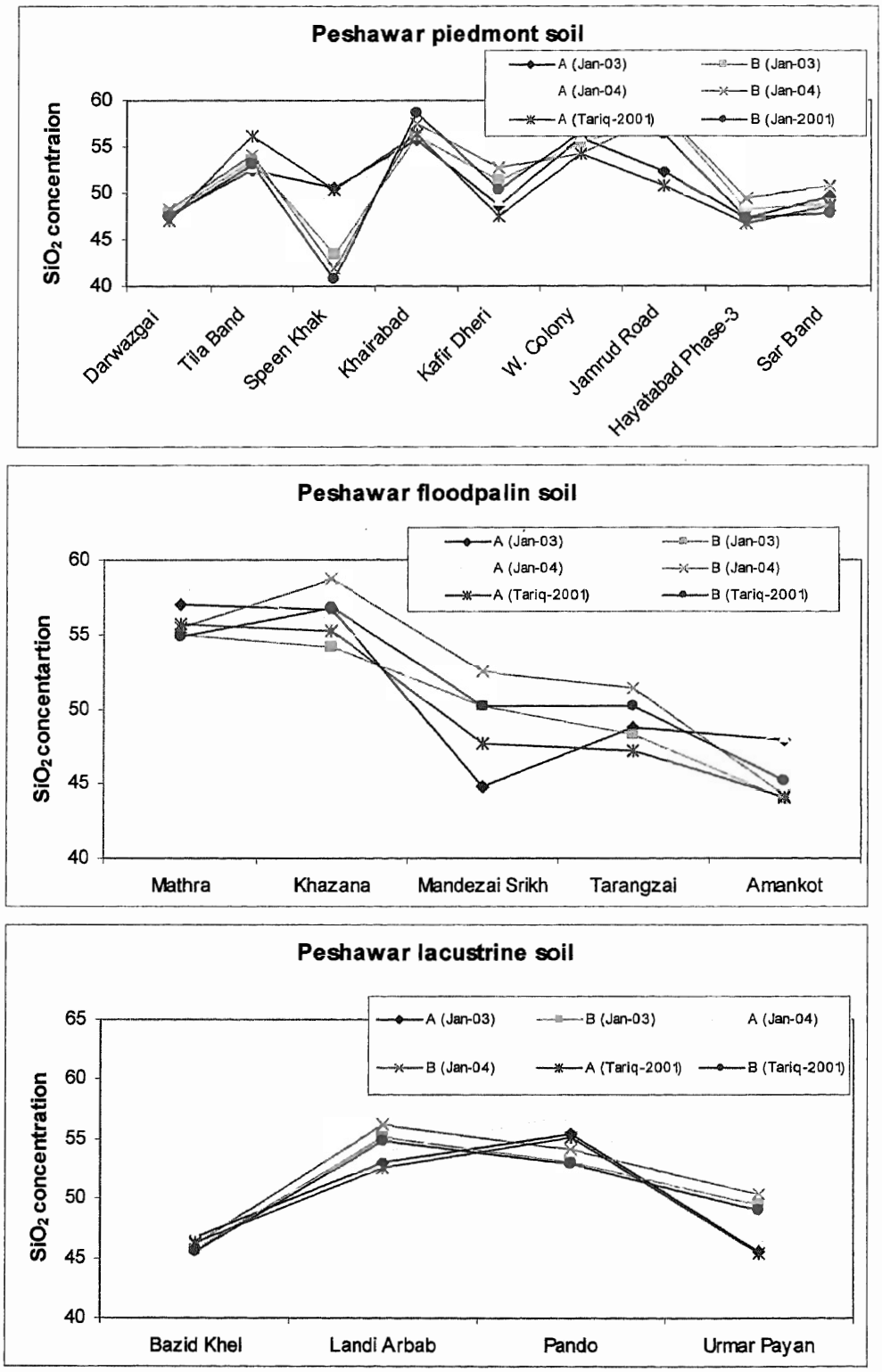
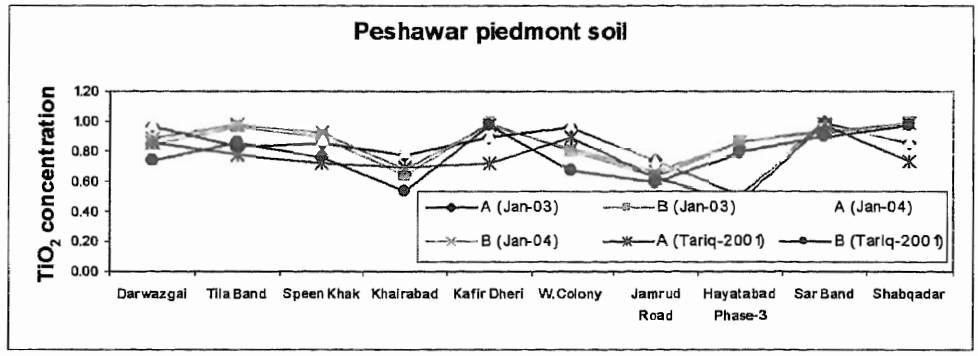
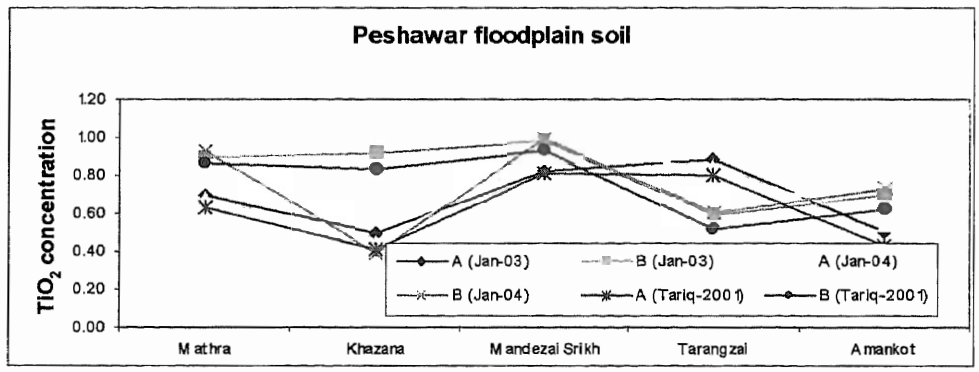


Fig. 4.2. Variation in concentration of SiO_2 (wt%) in the soils of Peshawar basin during different times.





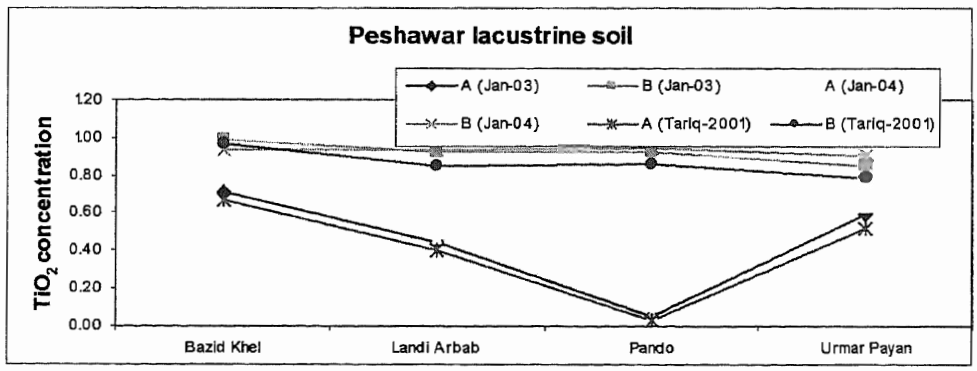


Fig. 4.3. Variation in concentration of TiO_2 (wt%) in the soils of Peshawar basin during different times.

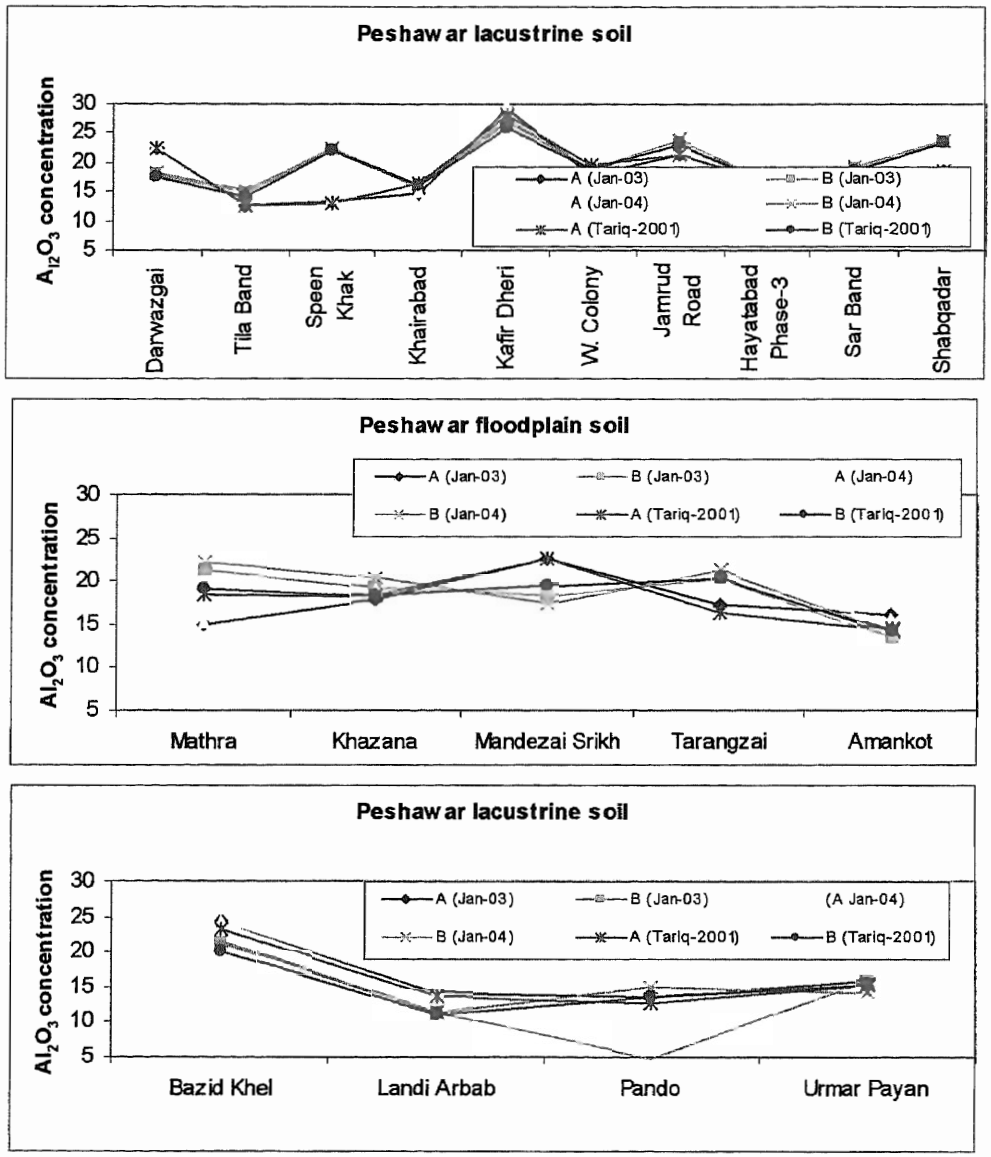


Fig. 4.4. Variation in concentration of Al_2O_3 (wt%) in the soils of Peshawar basin during different times.

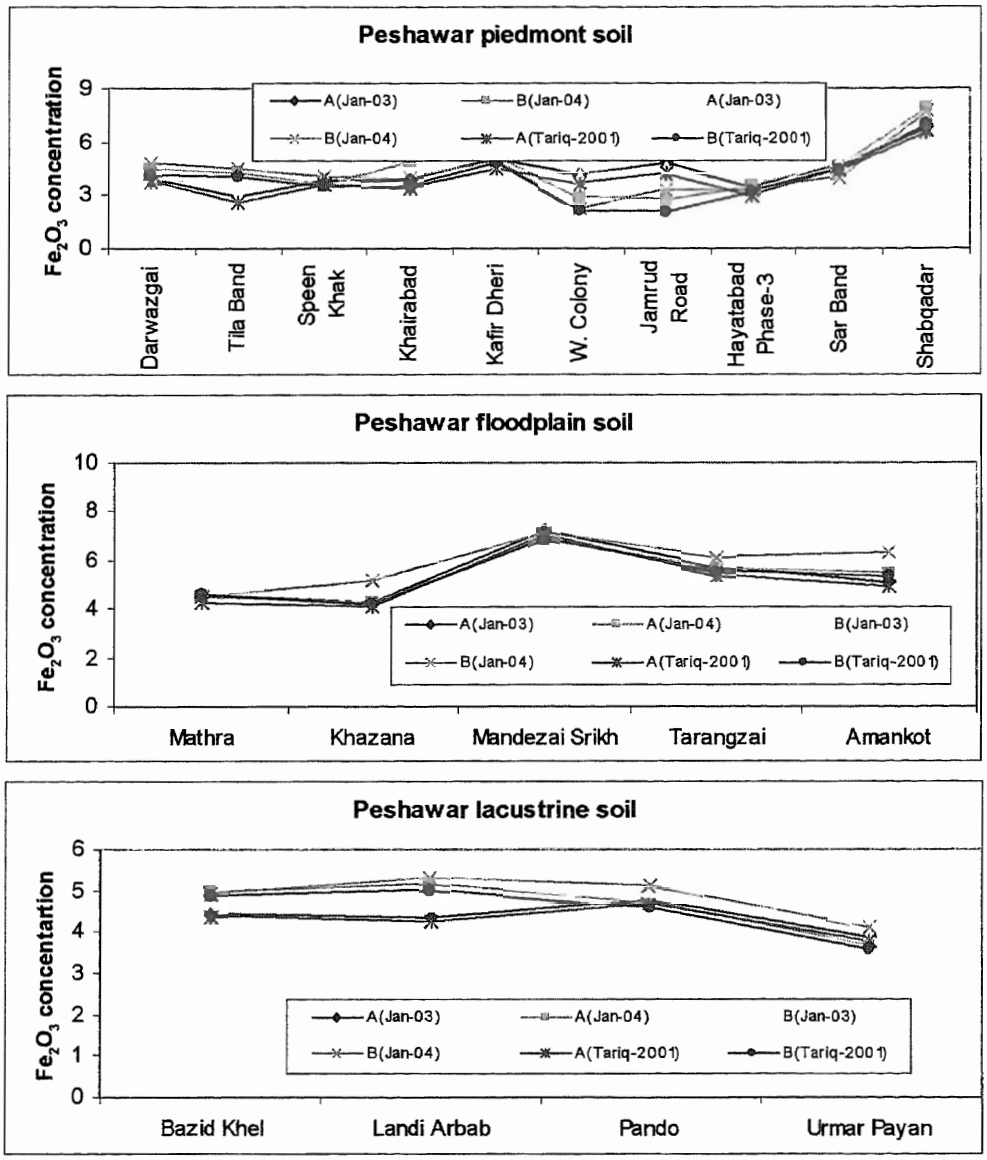


Fig. 4.5. Variation in concentration of Fe_2O_3 (wt%) in the soils of Peshawar basin during different times.

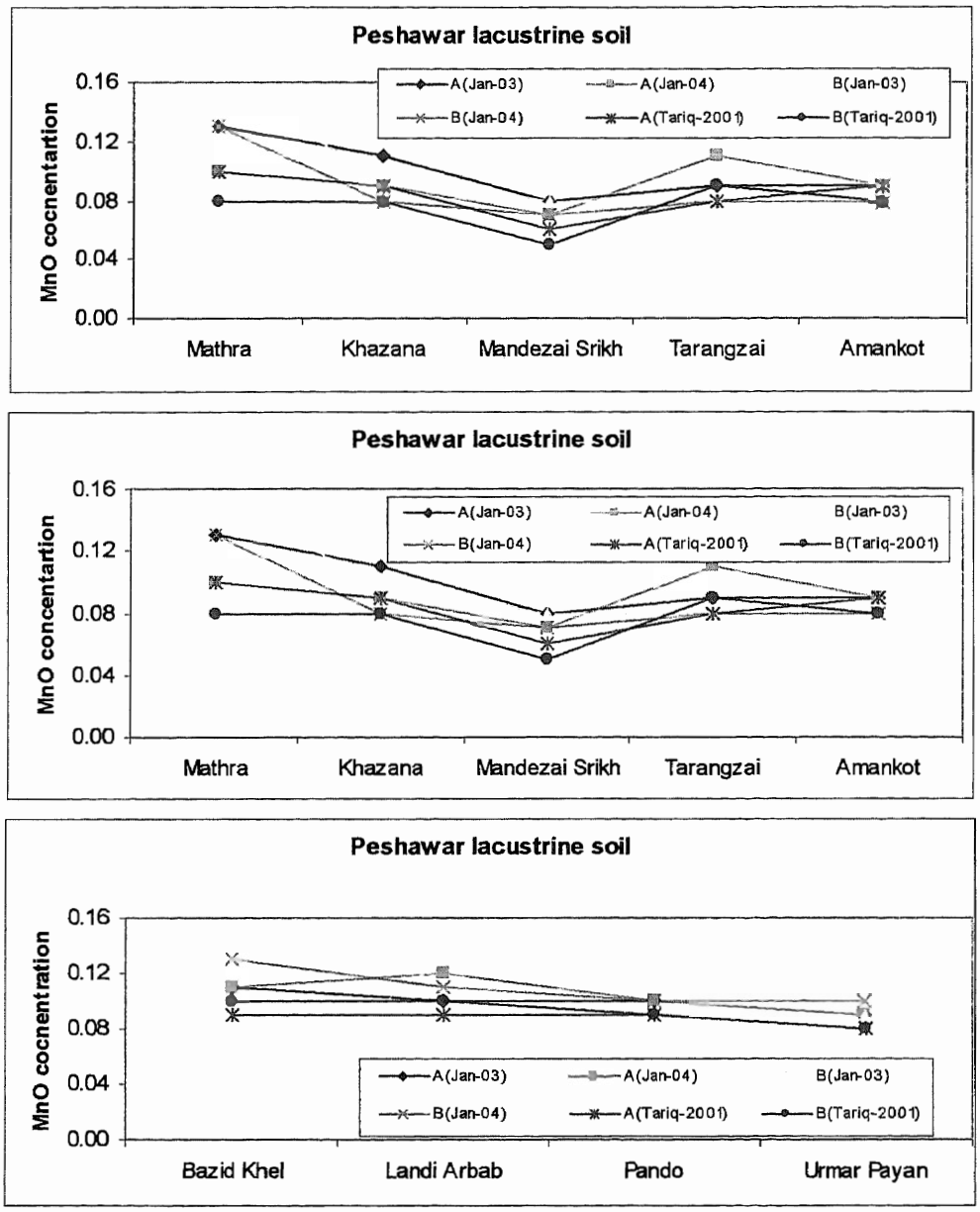


Fig. 4.6. Variation in concentration of MnO (wt%) in the soils of Peshawar basin during different times.

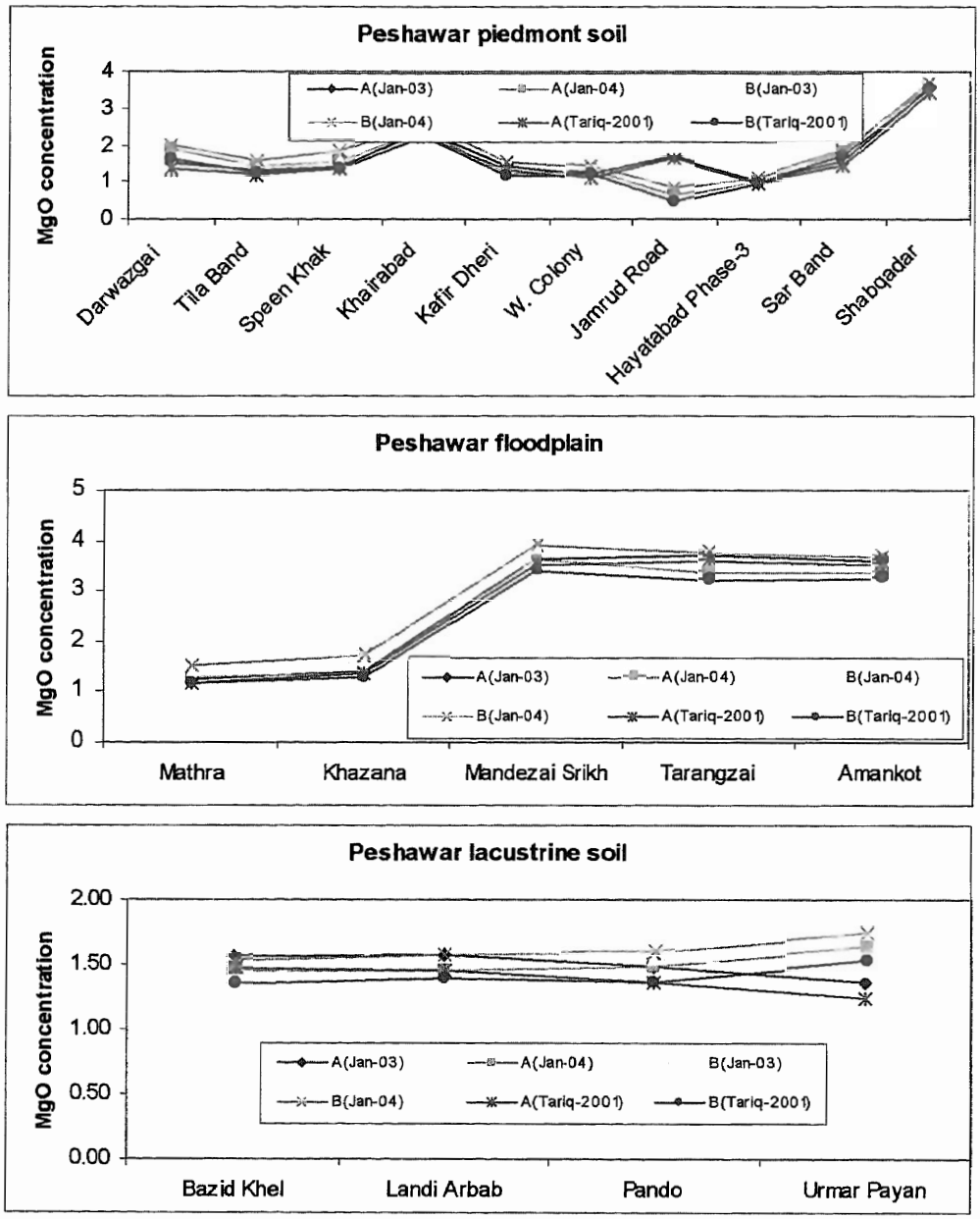


Fig. 4.7. Variation in concentration of MgO (wt%) in the soils of Peshawar basin during different times.

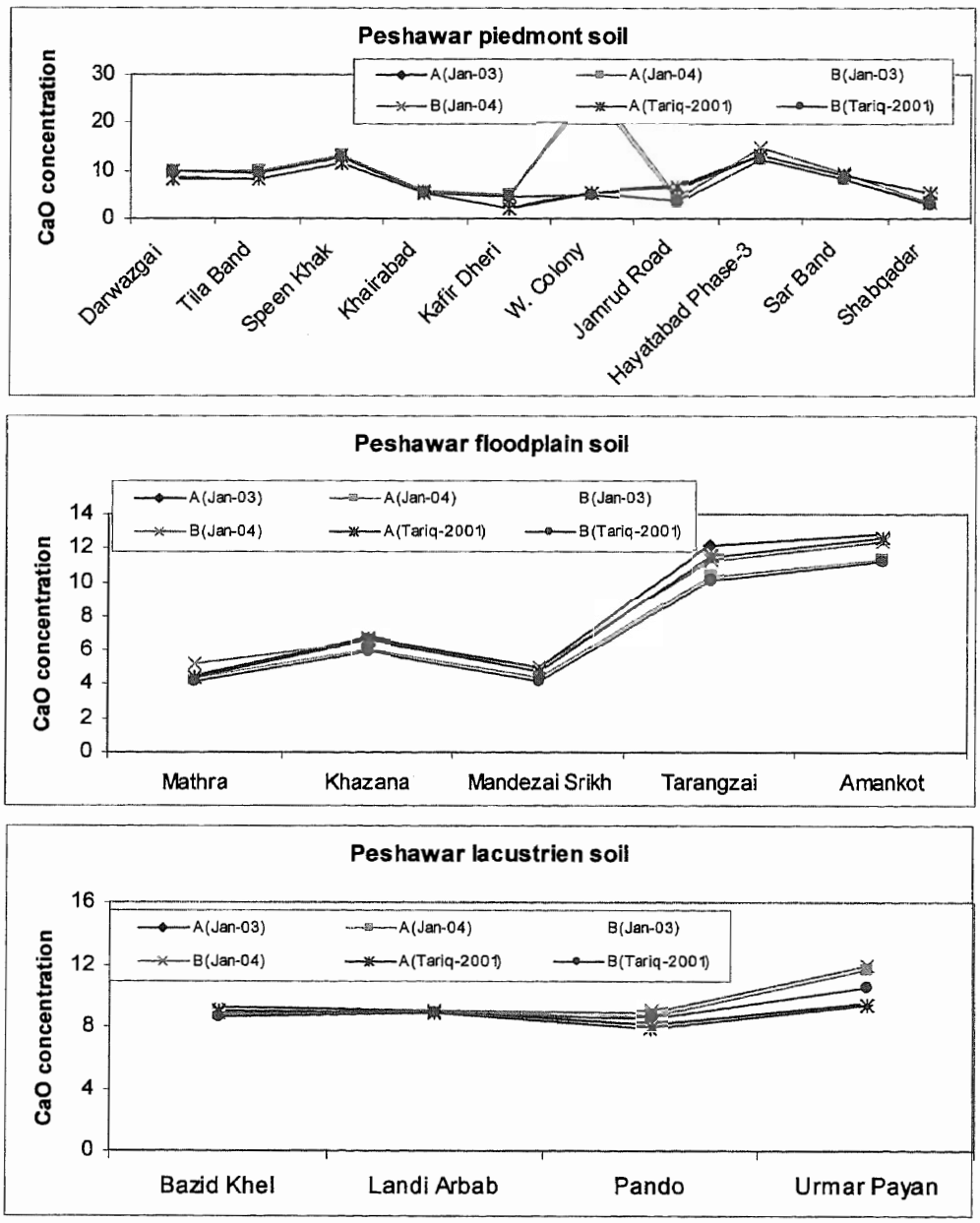


Fig. 4.8. Variation in concentration of CaO (wt%) in the soils of Peshawar basin during different times.

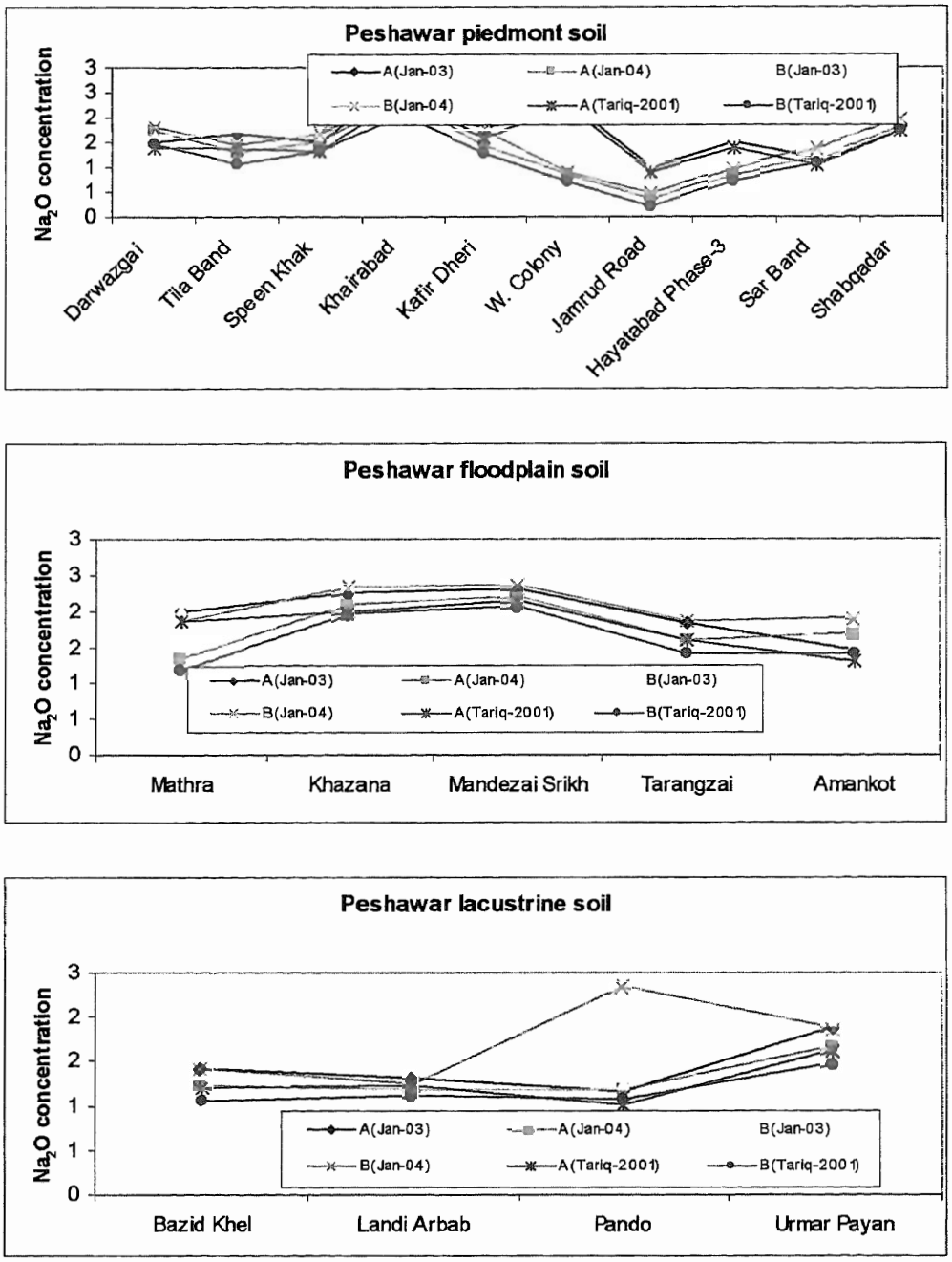


Fig. 4.9. Variation in concentration of Na_2O (wt%) in the soils of Peshawar basin during different times.

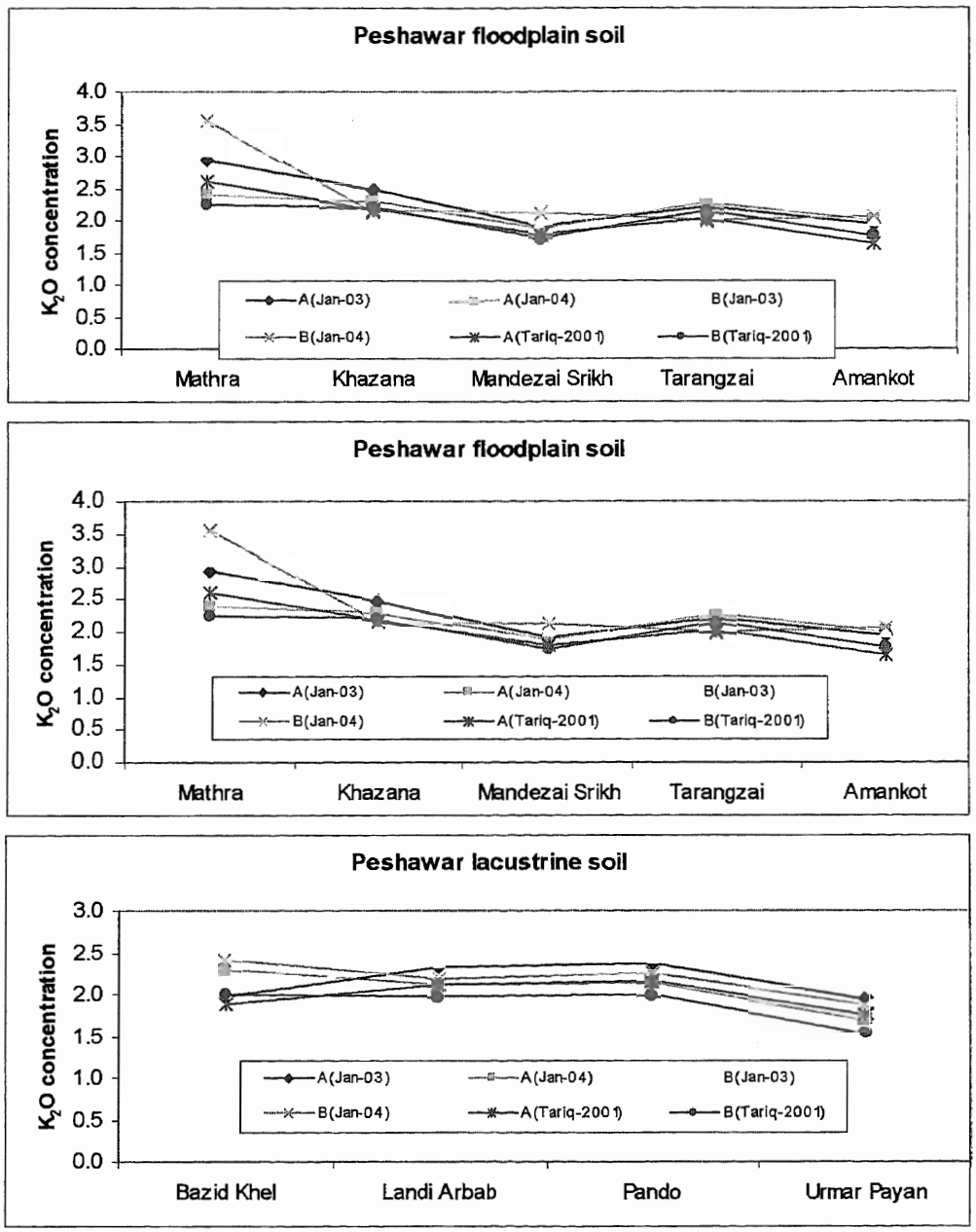


Fig. 4.10. Variation in concentration of K2O (wt%) in the soils of Peshawar basin during different times.

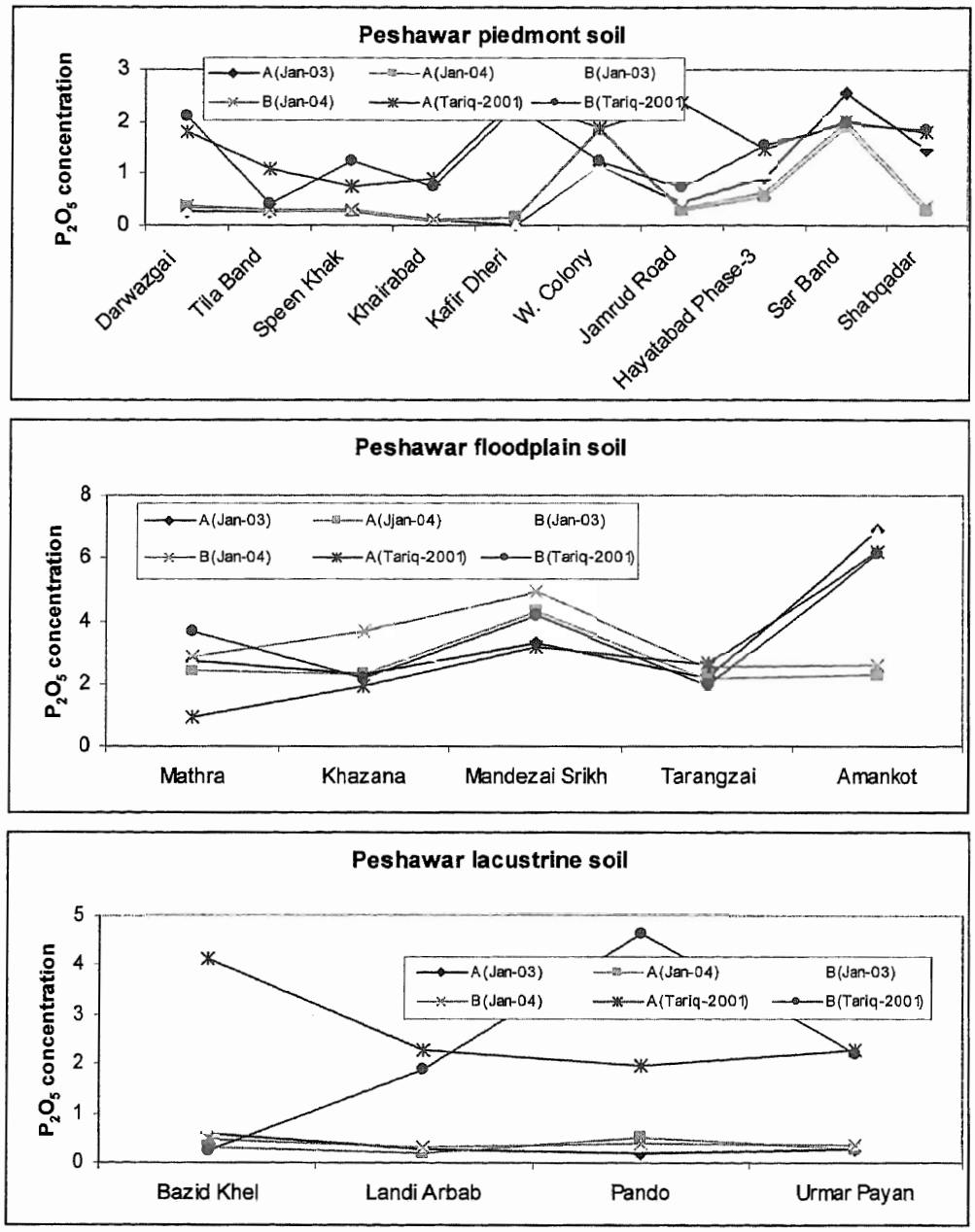


Fig. 4.11. Variation in concentration of P_2O_5 (wt%) in the soils of Peshawar basin during different times.

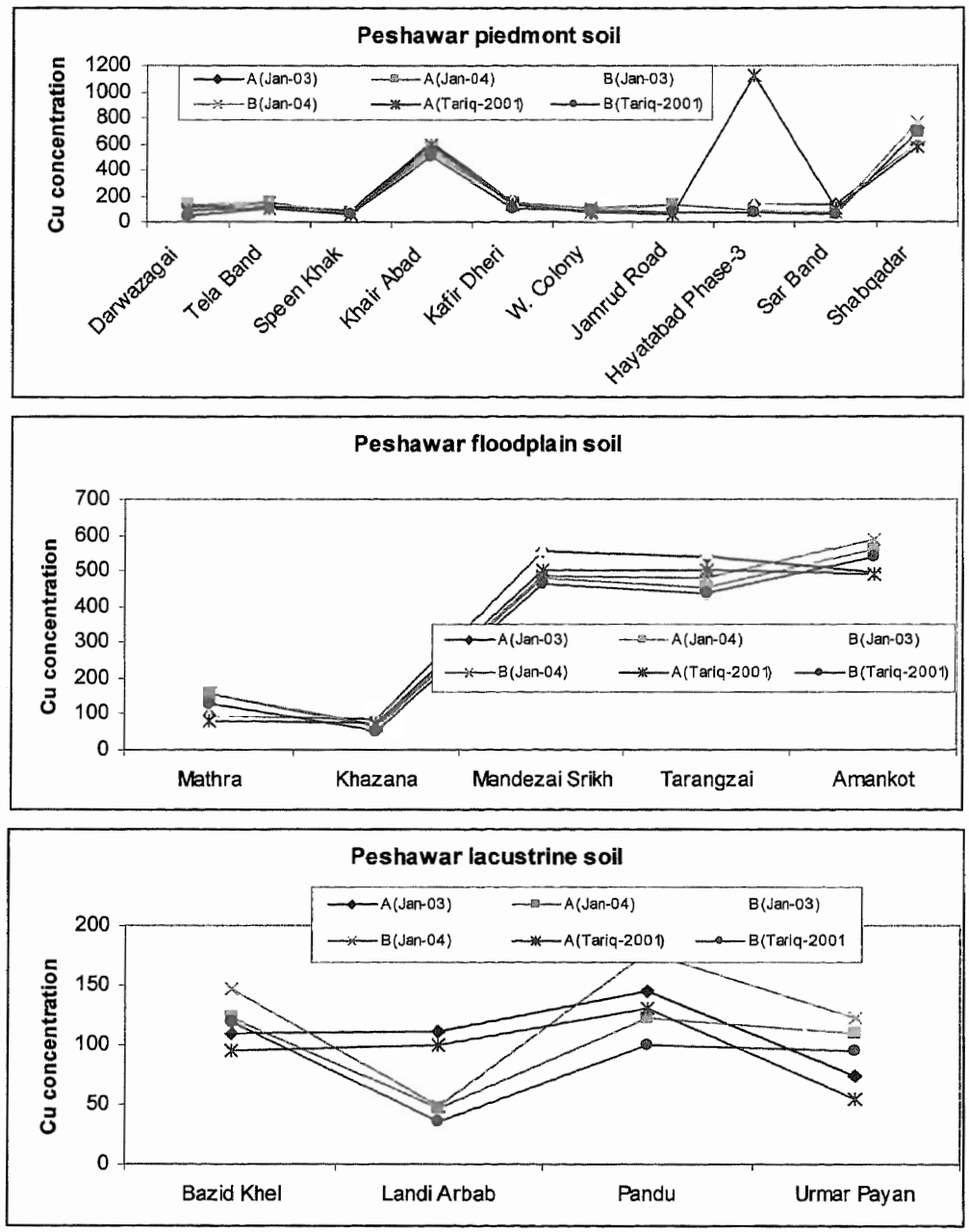


Fig. 4.12. Variation in concentration of Cu (ppm) in the soils of Peshawar basin during different times.

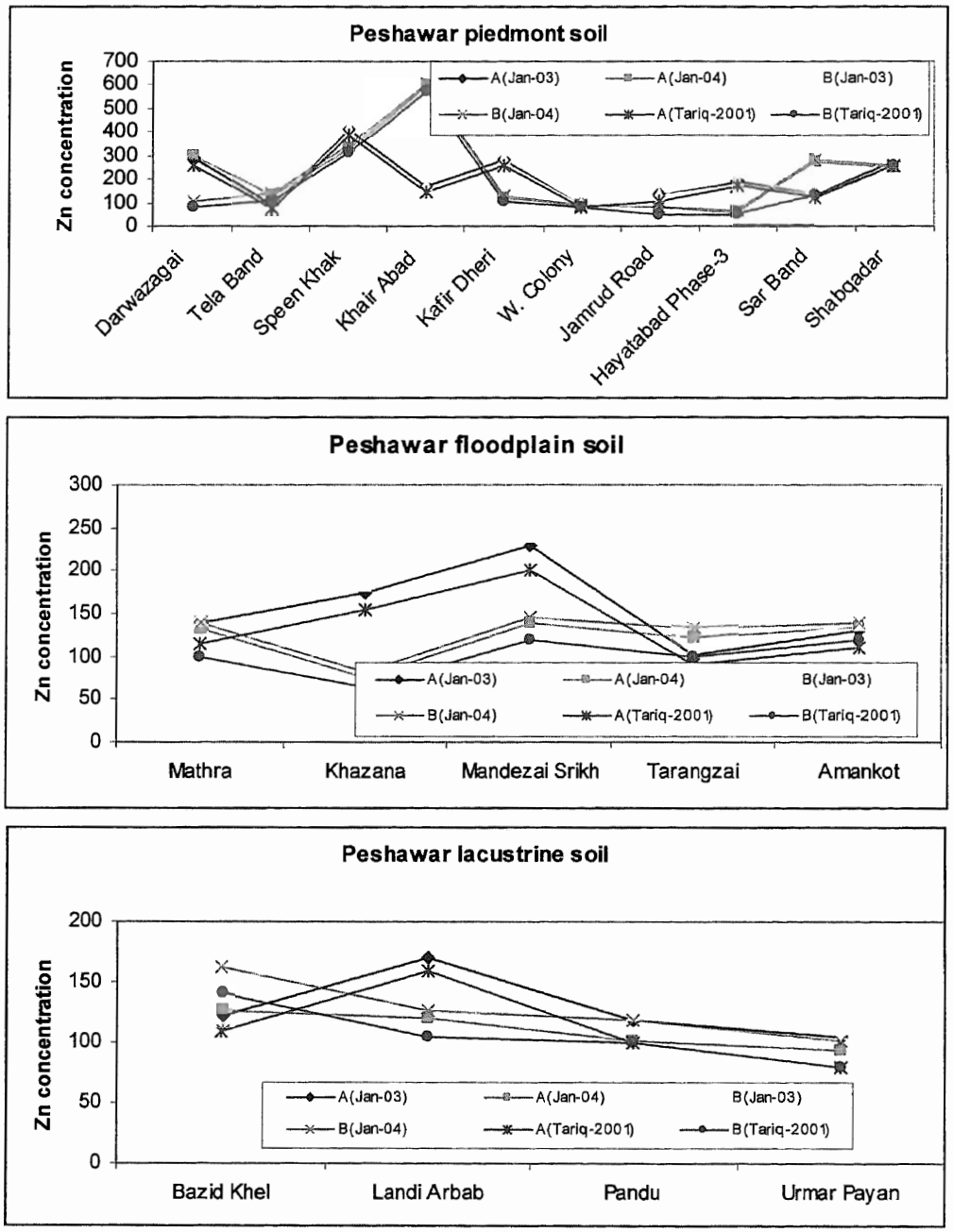


Fig. 4.13. Variation in concentration of Zn (ppm) in the soils of Peshawar basin during different times.

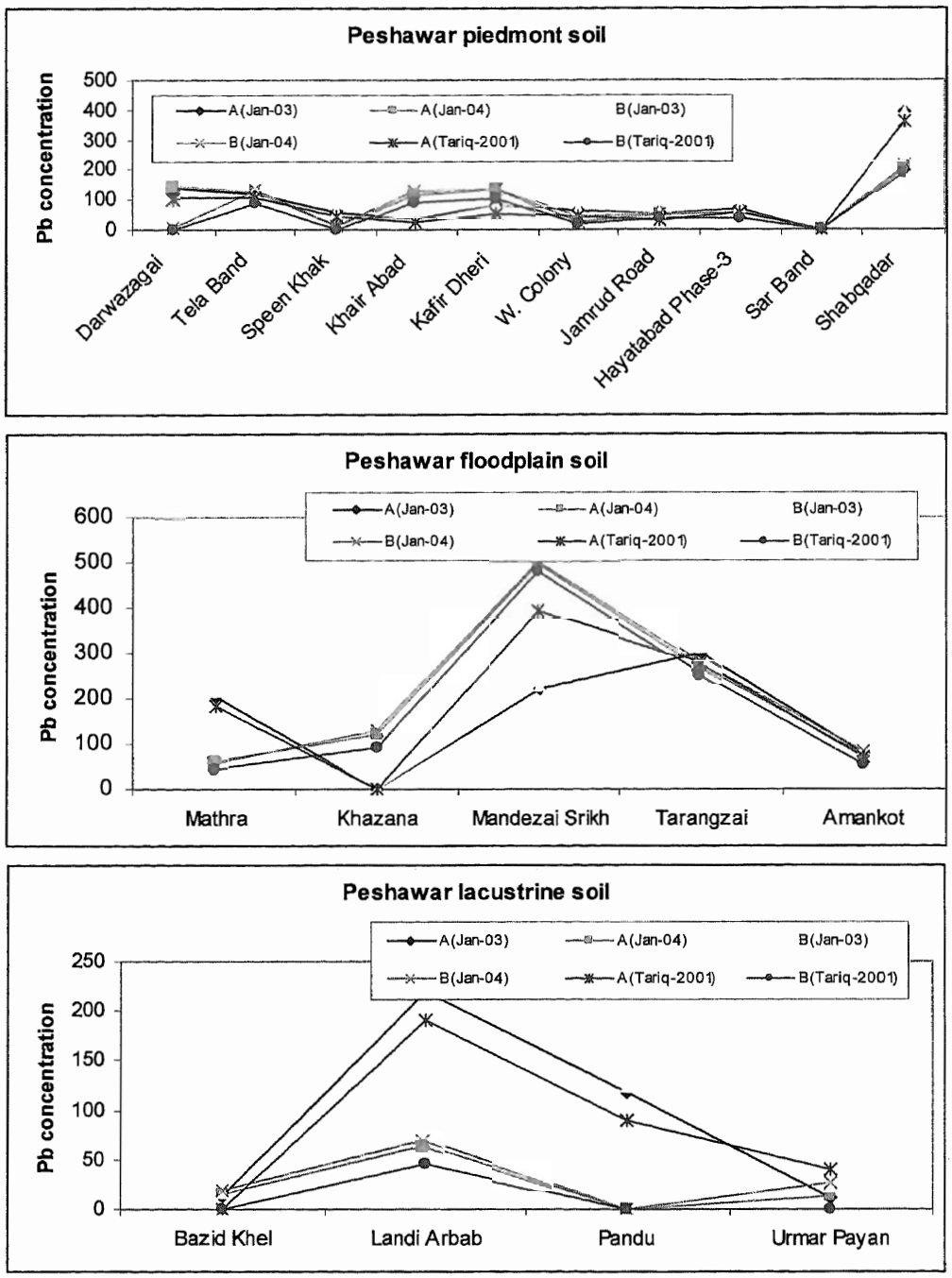


Fig. 4.14. Variation in concentration of Pb (ppm) in the soils of Peshawar basin during different times.

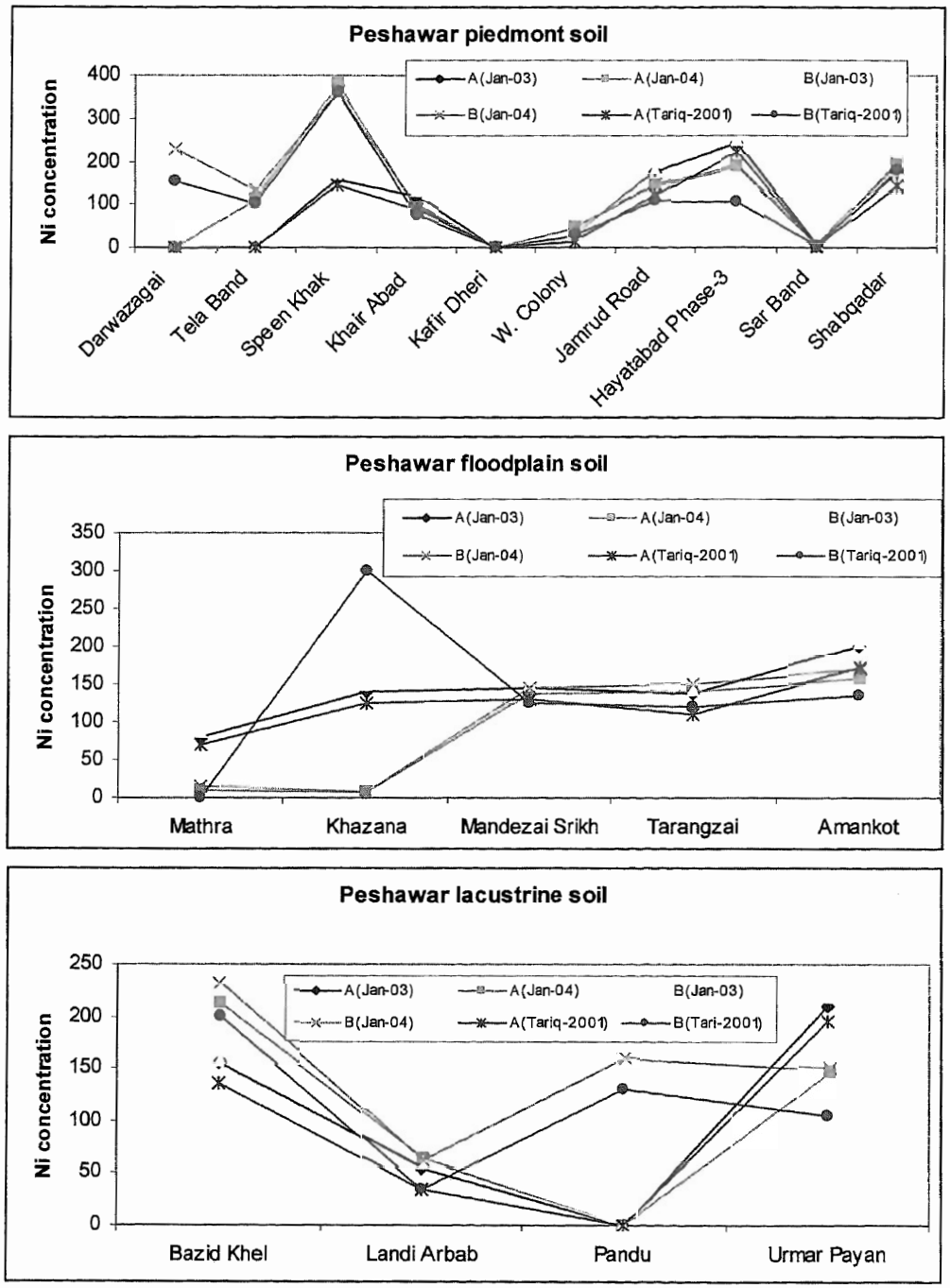


Fig. 4.15. Variation in concentration of Ni (ppm) in the soils of Peshawar basin during different times.

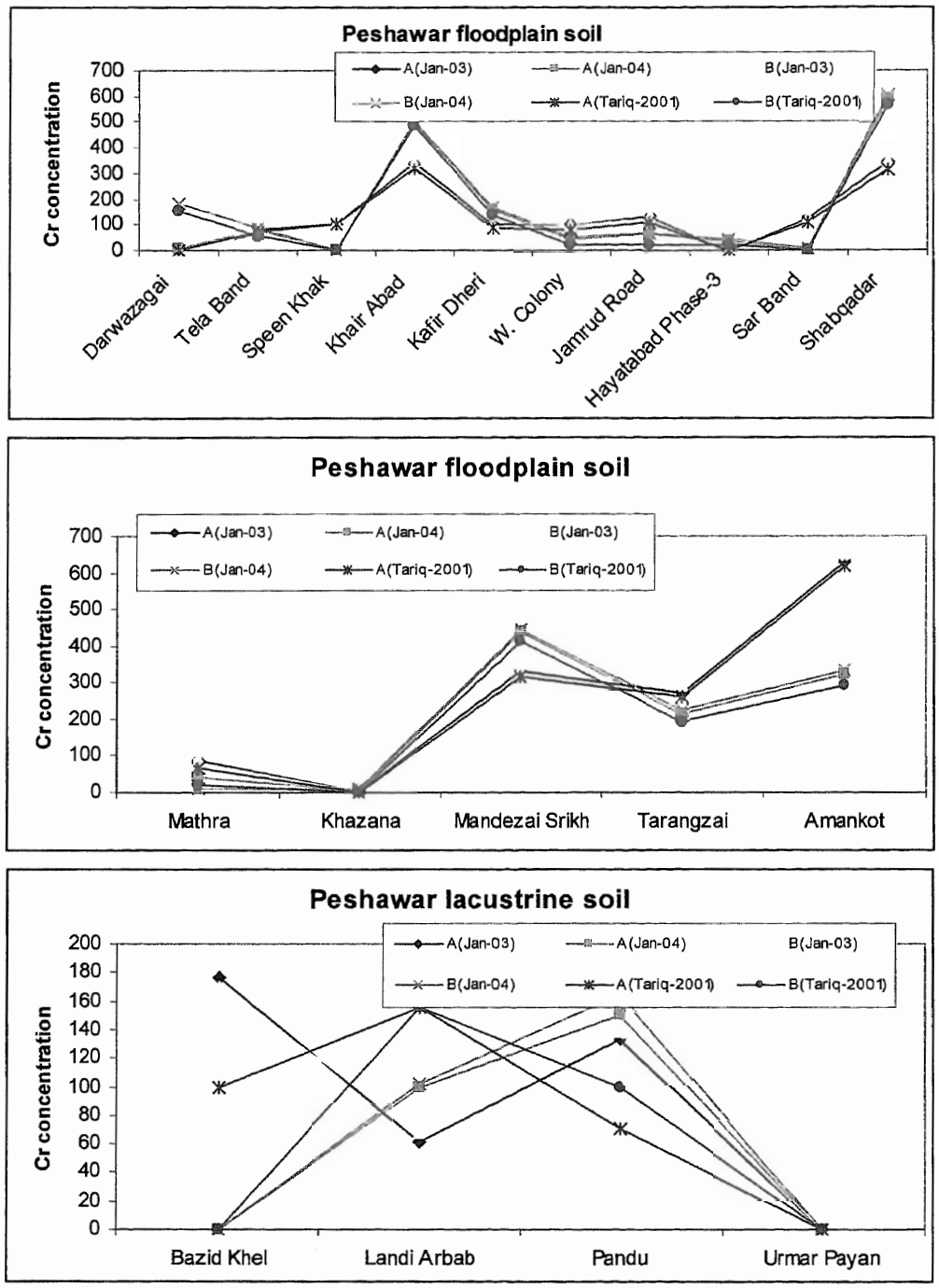


Fig. 4.16. Variation in concentration of Cr (ppm) in the soils of Peshawar basin during different times.

CHAPTER 5

AIR POLLUTION

Presence of excessive amounts of gases, liquids or solids present in the atmosphere is called air pollution. Generally air pollutants fall in two categories including primary and secondary air pollutants. Primary air pollutants are released directly into the air and they include oxides of sulphur, nitrogen, carbon, hydrocarbons and particulate matter. Secondary air pollutants are formed from other substances, which are released into the air e.g., ozone and smog. Natural as well as anthropogenic activities are responsible for the release of the harmful pollutants in the atmosphere. Natural activities include volcanoes, earthquakes and evaporation of isoprene (Hydrocarbons from plants) etc. The industrial, vehicular, agricultural, domestic and commercial activities attribute to the hazy air laden with harmful particles containing heavy metals, soot particles and hazardous gases. The negative impacts of the air pollution include reduced visibility, corrosion of materials, rubbers and monuments, lung diseases, respiratory problems, pneumonia and cardiovascular diseases. Heavy metals are released from various metal base industries, metal workshops, auto workshops, vehicles pesticides and insecticides (Khan et al., 1989). The heavy metals exceeding the permissible limits in the air, may pose threat to biosphere (ARC 1976; Motgomery, 1992; Barnowska, 1993).

The air pollution generally retards the growth of roadside plants by affecting photosynthesis and degrades chlorophyll contents and carbohydrate in plants (Hussain et al., 1994; Vora et al., 1986). It also contributes to the chemical decay of marble, limestone, dolomite, stone woks and concrete structure (Johnson, 1997). Detail studies on

the air pollutants have been conducted in developed countries with a long history of industrialization, extensive road, building and the use of leaded gasoline (Harrison, 1997; Kazeemi, 1989; Dong et al., 1984). However, very little work has been done in the developing countries and the data is very sparse in this regard in these countries.

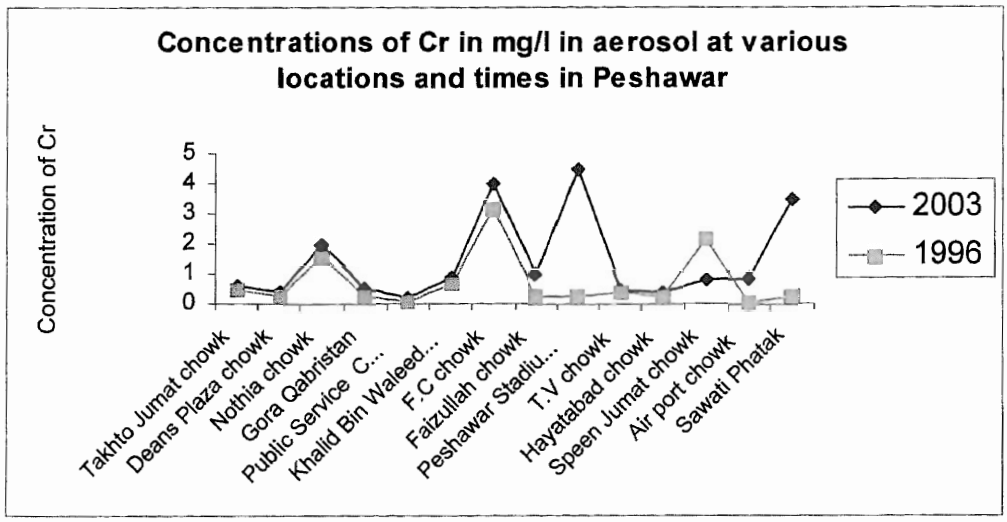
Due to widespread industrialization and enormous vehicular traffic in Peshawar there are possibilities of increase in the air pollution to great extent. The common sources of air pollutants could be the SO2, CO2, Nox, volatile organic compounds and suspended particulate matter such as heavy metals (Ahmad, 2005). Khan (1996) and Hamidullah et al. (1998) have conducted the heavy metal pollution studies in the sixteen traffic-congested areas of the Peshawar metropolitan city. They have pointed out certain areas of the city where some heavy metals are polluting the air to some extent.

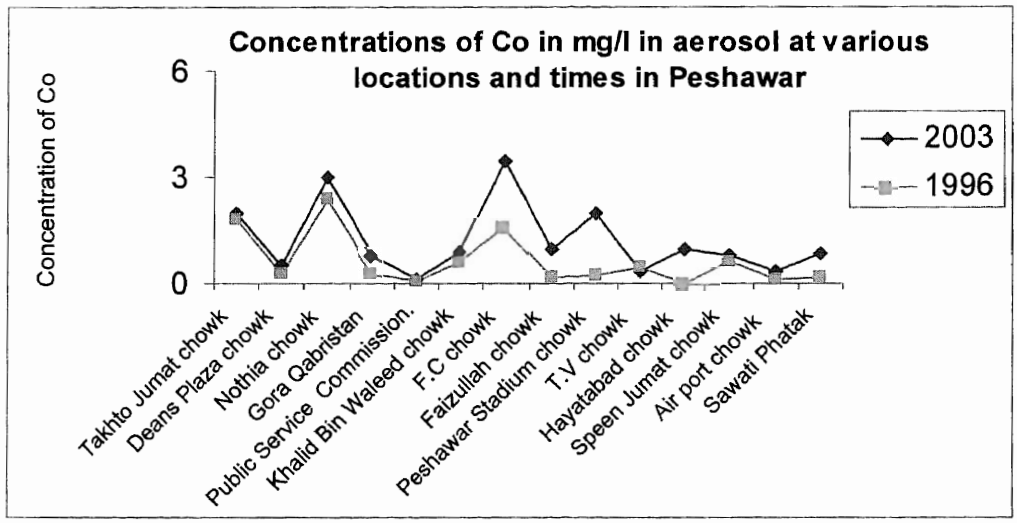
This study has therefore, been carried out to monitor the increase or decrease of the heavy metal pollution in the air of the Peshawar metropolitan city of the Peshawar basin with the passage of time. Aerosol / dust fall samples from 14 places, where from the dust fall samples were also collected by Khan during 1996 (Khan, 1996), have been collected at nose height level (~ 1.25 m) in open buckets filled with distilled water during summer of 2003 (see Appendix-1). The target areas include Takhto Jumat chowk, Deans plaza chowk, Nothia chowk, Gora Qabrishe, Public Service Commission, Khalid Bin Walid chowk, FC chowk, Faizullah chowk, Peshawar Stadium chowk, TV chowk, Hayatabad turn, Speen Jumat chowk, Air Port chowk and Swati Phatak. The data has been given in Table 5.1 and the results are graphically presented in Figure 5.1. It is clear

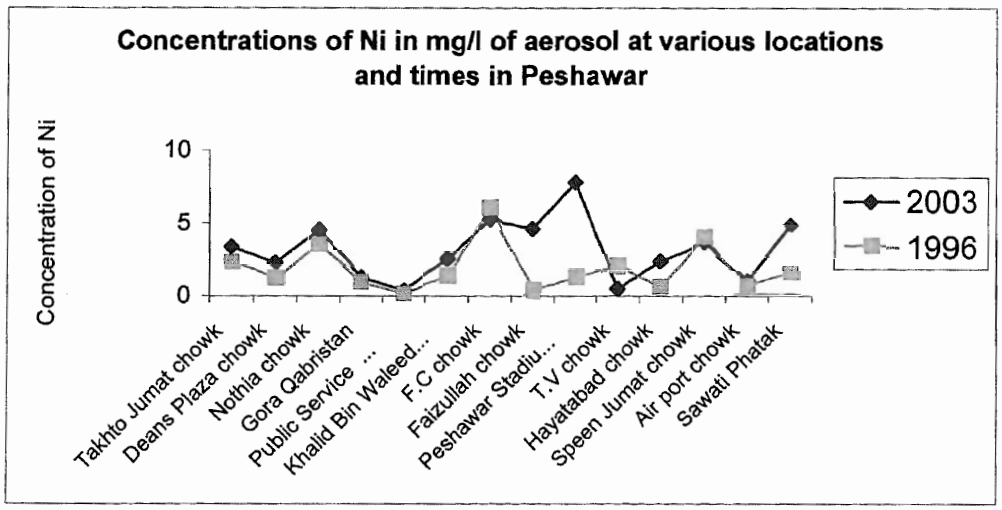
form the table that Cr is ranging from 0.20mg/l to 4.5mg/l, Co from 0.1mg/l to 3.45mg/l, Ni from 0.40mg/l to 7.83mg/l, Cu from 0.85mg/l to 10.50mg/l, Zn from 0.96mg/l to 18.20mg/l. Fe from 5.25mg/l to 68mg/l and Pb from 10.32mg/l to 90.20mg/l with an average amount of 1.44mg/l, 1.22mg/l, 3.17mg/l, 5.64mg/l, 10.24mg/l, 34.12mg/l and 34.00mg/l of Cr, Co, Ni, Cu, Fe and Pb respectively (Table 4.1). This shows that Cr is relatively high in few places such as Nothia chowk, FC chowk, Peshawar Satium chowk and Swati phatak; Co in Takhto Jumat chowk, Nothia chowk, FC chowk and Peshawar Stadium chowk. However, Ni, Cu, Zn, Fe and Pb show relatively high concentration (>2mg/l) in many areas of the Peshawar metropolitan (Table 5.1). The heavy metal aerosol / dust fall data has further been compared with the data collected by Khan in 1996 (Khan, 1996) from the same places in Figure 5.1. It is clear from this figure that there is a little increase in almost all the metals analyzed in the dust sample collected during this study. However, many fold increase in the Pb concentration in all the sampled areas has been noticed with the passage of time.

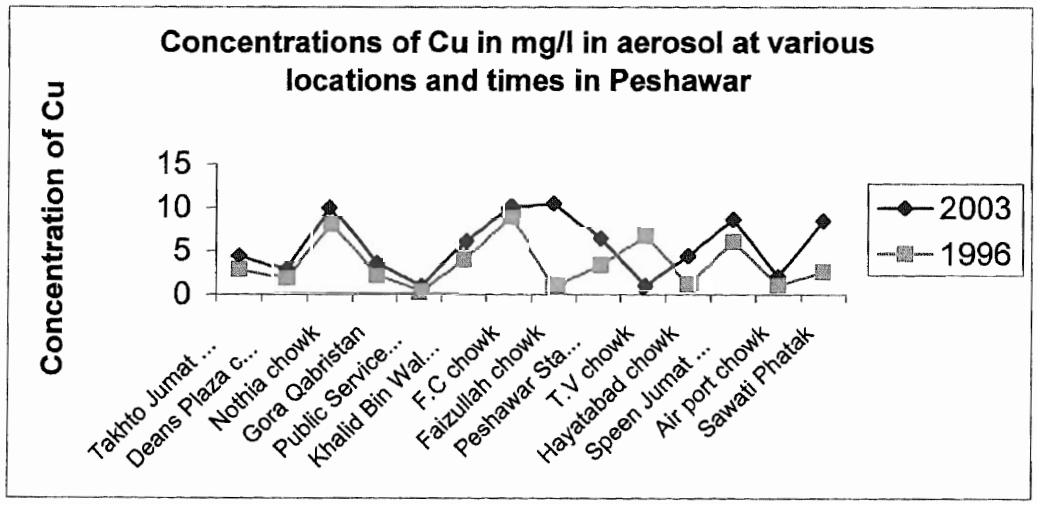
Table. 5.1. Concentration in mg/l of trace and heavy metals in the aerosol / dust fall in the various places of the Peshawar metropolitan.

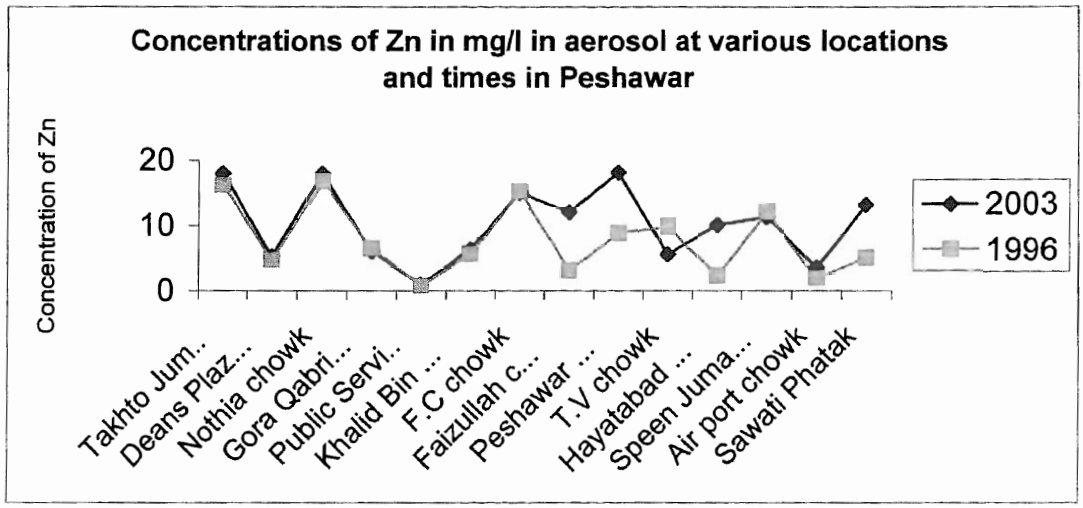
Locations	Cr	Co	Ni	Cu	Zn	Fe	Pb
Takhto Jumat chowk	0.62	2.00	3.40	4.46	18.00	42.00	32.00
Deans Plaza chowk	0.41	0.50	2.30	2.75	5.30	32.00	12.00
Nothia chowk	2.00	3.00	4.50	10.00	18.00	66.00	62.30
Gora Qabristan	0.56	0.80	1.30	3.50	6.00	22.00	22.12
Public Service Commission.	0.20	0.10	0.40	0.88	0.96	7.20	15.00
Khalid Bin Waleed chowk	0.90	0.90	2.50	6.00	6.32	35.00	17.00
F.C chowk	4.00	3.45	5.25	10.00	15.10	68.00	82.00
Faizullah chowk	0.98	0.98	4.62	10.50	12.00	45.00	26.00
Peshawar Stadium chowk	4.50	2.00	7.83	6.30	18.20	62.00	90.20
T.V chowk	0.45	0.35	0.50	0.85	5.60	5.25	10.32
Hayatabad chowk	0.40	0.95	2.40	4.45	9.98	17.22	16.20
Speen Jumat chowk	0.80	0.80	3.60	8.65	11.22	14.00	41.00
Air port chowk	0.90	0.35	0.93	2.10	3.45	13.00	18.72
Sawati Phatak	3.50	0.85	4.85	8.50	13.20	49.00	31.20

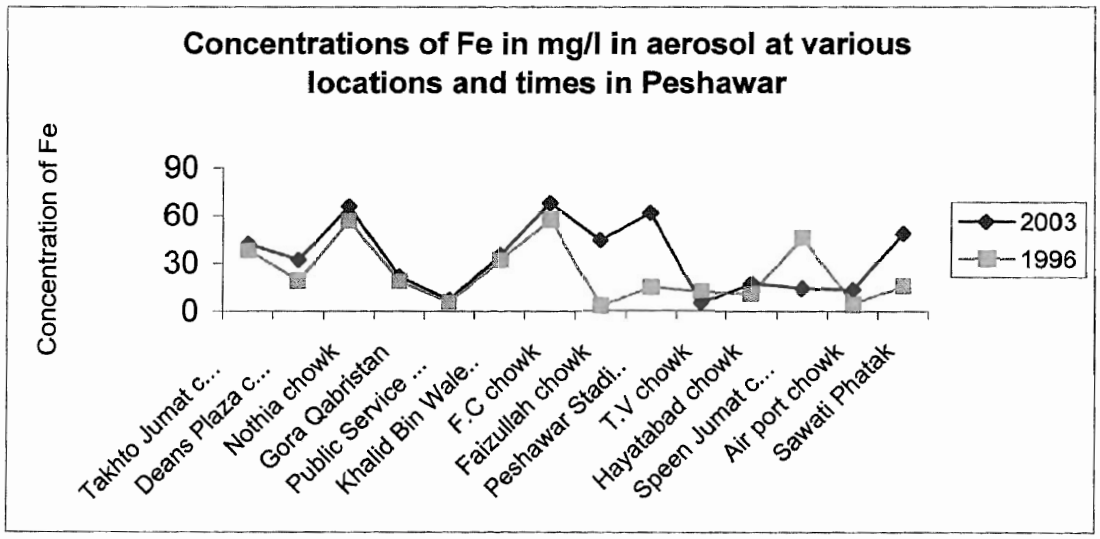

Concentrations of Cr in mg/l in aerosol at various locations and times in Peshawar
Concentration of Cr
5
4
3
2
1
0
2003
1996
Takhto Jumat chowk
Deans Plaza chowk
Nothia chowk
Gora Qabristan
Public Service C...
Khalid Bin Waleed...
F.C chowk
Faizullah chowk
Peshawar Stadiu...
T.V chowk
Hayatabad chowk
Speen Jumat chowk
Air port chowk
Sawati Phatak


Concentrations of Co in mg/l in aerosol at various locations and times in Peshawar
Concentration of Co
6
3
0
2003
1996
Takhto Jumat chowk
Deans Plaza chowk
Nothia chowk
Gora Qabristan
Public Service Commission.
Khalid Bin Waleed chowk
F.C chowk
Faizullah chowk
Peshawar Stadium chowk
T.V chowk
Hayatabad chowk
Speen Jumat chowk
Air port chowk
Sawati Phatak


Concentrations of Ni in mg/l of aerosol at various locations and times in Peshawar
Concentration of Ni
10
5
0
Takhto Jumat chowk
Deans Plaza chowk
Nothia chowk
Gora Qabristan
Public Service ...
Khalid Bin Waleed...
F.C chowk
Faizullah chowk
Peshawar Stadiu...
T.V chowk
Hayatabad chowk
Speen Jumat chowk
Air port chowk
Sawati Phatak
2003
1996


Concentrations of Cu in mg/l in aerosol at various locations and times in Peshawar
Concentration of Cu
15
10
5
0
Takhto Jumat ...
Deans Plaza c...
Nothia chowk
Gora Qabristan
Public Service...
Khalid Bin Wal...
F.C chowk
Faizullah chowk
Peshawar Sta...
T.V chowk
Hayatabad chowk
Speen Jumat ...
Air port chowk
Sawati Phatak
2003
1996


Concentrations of Zn in mg/l in aerosol at various locations and times in Peshawar
Concentration of Zn
20
10
0
Takhto Jum..
Deans Plaz...
Nothia chowk
Gora Qabri...
Public Servi..
Khalid Bin ...
F.C chowk
Faizullah c...
Peshawar ...
T.V chowk
Hayatabad ...
Speen Juma...
Air port chowk
Sawati Phatak
2003
1996


Concentrations of Fe in mg/l in aerosol at various locations and times in Peshawar
Concentration of Fe
90
60
30
0
Takhto Jumat c...
Deans Plaza c...
Nothia chowk
Gora Qabristan
Public Service ...
Khalid Bin Wale..
F.C chowk
Faizullah chowk
Peshawar Stadi..
T.V chowk
Hayatabad chowk
Speen Jumat c...
Air port chowk
Sawati Phatak
2003
1996

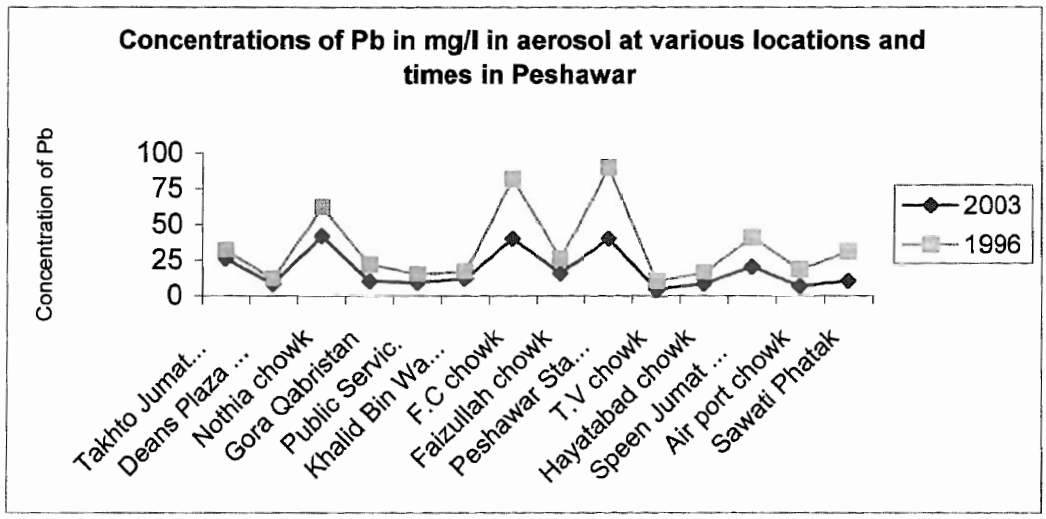


Fig. 5.1. The comparison of the heavy metals concentration of aerosol / dust fall samples of the present study and of Khan (1996).

CHAPTER 6

DISCUSSION

Peshawar basin is occupied by the major cities (i.e., Peshawar, Charsadda, Nowshera and Mardan) of NWFP and like other big cities of Pakistan the environment is being polluted ruthlessly and carelessly here too. The high rate of industrialization resulting into drastic and unplanned urbanization with heavy load of transportation together with a retarded rate of awareness/education in mainly poor masses have contributed to creating pollution of all sorts including those of air, water and soil (Hamidullah et al., 1997; 1998). Peshawar is one of the major metropolis of the country and provincial capital of the NWF>. Because of the fast human influx from the rest of the province to Peshawar and other cities such as Mardan and Nowshera of the Peshawar basin, the population in these cities has risen exponentially in the past two decades. According to 1999 census, Peshawar district had a population of 1650941 with a growth rate of 4.1. Industries have grown and vehicular traffic has highly overburdened the road system. Sewerage system is out dated and broken and, therefore, effecting the underground water system of the region.

The monitoring of surface and groundwater pollution within the Peshawar basin during two years time in January and June of 2003 and 2004 and comparing it with the earlier studies is the focus of this research. It is aimed at to understand the anomalous concentration and suitability of waters and soils of the basin on the basis of chemical constituents for related health hazards and agriculture purpose. Peshawar basin serves as a container for the various types of aquifers, the Quaternary sediments and the cover soils. These Quaternary sediments and the surrounding rocks of the Peshawar basin could be one of the possible sources of contamination in the water it contains or flows through it. Peshawar basin has adopted the shape of a basin because of the major Himalayan events. It has gone through tectonic, geologic, hydraulic and hydrogeologic changes mainly related with the Himalayan orogeny. It is surrounded by Khyber mountain ranges

in the west and northwest, Lower Swat range in north and northeast and Attock Cherat Range in the south. These mountain ranges along with the basement metasedimentary rocks have provided a firm foundation for the Quaternary deposits overlying these metasediments on one hand and also protected the quaternary sediments and the covered soil from erosion on the other hand. There is a major role of Kabul, Swat and Indus rivers in the deposition of the Quaternary sediments in the Peshawar basin. The presence of horizontally bedded, fining upward sequences of sand, silt, and clays through out the basin has previously been ascribed to Pleistocene lakes within the basin. However, the sedimentalogical properties suggest that the stacked sequences are more characteristics of deposits of periodic break-out flood deposits and not laucstrine deposits. The sediments of the basin show multiple episodes of flooding in the basin. In this regard there are many evidences of ice-dams and lakes in the Indus drainage system (Cornwell, 1992; Cornwell & Hamidullah, 1992; Hamidullah & Cornwell, 1994).

It is a hard fact that the Indus river has played a major role in the deposition of Quaternary sediments in the Peshawar basin but the role played by the Kabul and Swat rivers and their tributaries in the deposition of Quaternary sediments in the basin can not be ruled out. This is the season that the major input in the Quaternary deposits in from the Kohistan Island arc covering most of the mountainous region of the northern parts Pakistan. The multiple episodic flooding in the Indus river has deposited rhythmite sequences in the basin. Therefore, these sediments have very thick single large confined aquifer with the Paleozoic rocks at the base and the clay on the top acting as an aquiclude (Cornwell, 1992; Tariq, 2001). Various semi-confined aquifers, above this major confined aquifer in the middle part of the basin, have been defined in the Nowshera, Mardan and Peshawar areas. These aquifers are generally recharged by the Kabul and Swat rivers and their tributaries. These semi-confined aquifers generally known as piedmont, lacustrine and floodplain type aquifers depending on the nature of the sediments hosting these aquifers. The lacustrine and floodplain aquifers make small local aquifers of breached and artesian type (Hussain et al., 1991; Tariq, 2001). The lacustrine and flood plain aquifers at Jalala, Kheshki, Jehangira, Spin Khak and Swabi are composed of sand, silt, clay in the middle of the basin while the piedmont aquifers at

Warsak, Ziarat Kaka Sahib and Piran are generally consisting of clast supported conglomerates mainly in the marginal parts of the basin. These piedmont sediments in the surrounding of the Peshawar basin are considered as the major catchment areas of rain water for the aquifer. In many parts of these catchment areas no industry is present, accept in the western and southern portion of the Peshawar city. Therefore, there are less chances of anthropogenic contamination in the aquifer system of the basin. The middle part of the basin is having thick clay and silt which also play a major role in protecting the aquifer system of the basin from contamination to greater extent through anthropogenic sources. However, the contamination through banks of the rivers Kabul and Swat where the river beds cut deep through the aquifer can not be ruled out. The chemical characters of the waters and soils of the Peshawar basin are, therefore, evaluated in regard to their environmental pollution with the passage of time during this study.

The hydrochemical data on the basis of cations (Mg, Ca, Na and K) and anions (SO_4, CO_3, HCO_3 and Cl) have categorized the aquifer system of the Peshawar basin as of generally alkaline earth fresh water with high contents of alkalies and also having a small in put of alkaline freshwater in certain areas. There is a greater variability in the pH of the waters of the Peshawar basin. It is ranging from acidic (pH = 4.5) to alkaline (pH = 10.1) in the various aquifers of the basin. No any significant change in the pH of the waters of the Peshawar basin has been noticed with the passage of time from 2001 to 2004. The groundwater obtained from dug wells and tube wells in many areas of the absin such as Tehkal Bala, Jamrud road, Adezai, Surezai, Jehangirabad, Ladi Arbab, Dabgari, Shuba, Hazar Khawani, Wadpaga, Urmer, Zahirabad, Mattani, Adezai, Dag Besud, Aza Khel, Taila Band, Chapri, Speen Khak and Musha Gharh and having low pH and are, therefore, considered hazardous. These waters have the capability of containing mineral acids which readily dissolve the metals and are becoming toxic in nature. These waters have the corrosion effect and are, therefore, more dangerous for the underground pipes used for drinking water purposes in the various municipalities of the Peshawar basin. This suggests that the water in these areas have contact with the localized seams of gypsum, sulfides and coals within the Quaternary sediments. The waters of the these

areas should be further evaluated in detail and necessary measures should be taken to make it drinkable for domestic use.

The electrical conductance (EC) and the total dissolved solids (TDS) of the waters (both surface and groundwater) of the Peshawar basin are generally within the permissible limit of US-EPA. However, certain areas such as S. Umar Bab, Kukar, Kandi Hayat, Aman Kot, Charpariza, Akbarpura, Pabbi, Mulazai, Regi, Shahi Bala, Wadpagga and Azakhel Bala are having both EC and TDS above the permissible limit (Chapter 3). This suggests that these waters have the capability to dissolve various minerals and salts. These waters are classified as slightly saline water but generally the surface and groundwater of the basin is considered as fresh water as far as the electrical conductance and total dissolved solids are concerned. These observations are in consistence with classification based on the cations and anions of these waters. Both EC and TDS exhibit no significant change with the passage of time which indicate the stability in both surface and groundwater condition of the basin. In the areas, where the groundwater is having high EC and TDS, there the chances of corrosion of underground steel and iron pipes used for the supply of drinking water seems to be very high (Driscoll, 1986). The anions (i.e, SO_4, Cl, HCO_3) in the drinking water of the Peshawar basin are generally within the permissible limit of US-EPA. However, there are certain areas where the drinking water of the dug wells and tube wells have high concentration of the anions especially SO_4 and HCO_3. These include Aman Kot, Akbar Pura, Urmar village, Zahirabad, Darwazgai, Ghari Chandan, Hazar Khawarri, Shiggi, Regi, Pawaka Shahbaz Ghari and Dag Basud (Chapter 3). The variation in the concentration of anions in the waters of the Peshawar basin suggest that there is no significant change in these anions with the passage of time (i.e., from 2001 to 2004). The high concentration of these anions seems to be a localized phenomenon where the groundwater percolates through the limestone, dolomite, gypsum and seams of sulfides, salts and coals within the Quaternary sediments.

The light element cations (i.e., Ca, Mg, Na and K) in the waters of the Peshawar basin are generally within the permissible limit of the US-EPA. Certain dug wells and tube wells from Kot and Shahbaz Ghari have high Ca, from Phandu, Wadpagga, Adezai,

Aimal Chabutra, Ghari Chandan, Zahirabad and Urmar have high Mg and Na and from Surezai, Phandu, Hazar Khawani and Wadpagga have high K contents (Chapter 3). The drinking water of these areas have alarming concentration of the afore-mentioned cations which can cause numerous health hazards in the inhabitants of the area. Proper monitoring of the drinking water and remedial measures are needed to be taken on urgent basis. The surface water in the rivers, streams and springs have the concentration of these light element cations within the safe limit. It is observed during this study that there is no significant change in the concentration of these cations with the passage of time from 2001 to 2004. The high concentrations of these light element cations in the above mentioned areas are correlating with the high concentrations of anions and further confirm the localized contact of the waters of the basin with limestone, dolomite, gypsum, sulfides, salts and coal seams within the Quaternary sediments.

The heavy and trace elements (i.e., Fe, Cu, Pb, Cr, Ni, Cd, Co) in the surface and ground waters of the Peshawar basin are generally within the permissible limit of the US-EPA. However, there certain areas where the drinking water has alarming concentration of Cr, Pb, Fe and Ni. Cr is exceeding the permissible limit in Tarangzai, Takht Bhai, Landi Arbab, Gunj, Urmar, Aza Khel Bala, Surezai, Darwazgai and Speen Khak; Fe in Hayatabad Phase 3 and Jehangira; Pb in Gulbahar No.2, Mattani and Chapri while Ni in Danishabad, Bara, Urmar, Shahbaz Ghari and Musha Ghari (Chapter 3). Cu, Cd and Co are found within the permissible limit. The contamination of Cr, Fe, Pb and Ni in the drinking water of the Peshawar basin is a localized phenomenon. Both anthropogenic and geogenic sources could be responsible for this contamination. The anthropogenic sources include the waste from the industrial Estates and many tannery industries in the Peshawar city and the corrosion of underground pipes. The geogenic sources include the sulfide seams and the mafic and ultramafic rocks in the northwest and northeast of the Peshawar basin. Among the surface water the Kabul river is having concentration of Pb and Cr above the permissible limit. This can be attributed to the waste from tannery industries and many other industrial which is falling ultimately in the Kabul river through Budni canal which is carrying the sewerage water of the city. The behavior of heavy and trace elements in the drinking water of the Peshawar basin is constant with the passage of time.

Therefore, no significant change in the concentration of these elements has been observed from 2001 to 2004.

The soils of the Peshawar basin have been classified in to 1) Peshawar piedmont soil, 2) Peshawar floodplain soil and 3) Peshawar lacustrine soil. The chemical composition of these soils from the agricultural land has been evaluated in regard to the normal agricultural soil for their possible effects on the ecosystem of the region. Among the major and minor oxides SiO_2, TiO_2 and Fe_2O_3 in majority of the soils of the basin are within the permissible limit for normal agricultural soil (Chapter 4). However, Al_2O_3, CaO, Na_2O and K_2O in majority of the soils are exceeding the limit for normal agricultural soil. This enrichment can be attributed to the geogenic sources such as the weathering of limestone, dolomite, mafic and ultramfic rocks and K-bearing clays occurring in the surrounding mountains of the basin. The water logging and salinity is another cause of enrichment of Al, Na, Ca and Mg in these areas. This study further suggest that no significant change in the concentration of the major and minor oxides has been noticed with increase or decrease of depth and also with the passage of time from 2001-2004.

The trace and heavy metals data of the soils of the Peshawar basin presented in Chapter 4 suggest that there is variable concentration of these metals in the horizon A and B and also in the soils of different localities. However, no significant change in the concentration of these metals occurs with the passage of time, from 2001 to 2004, in the studied soils. By comparing the three types of soils of the basin among each other and also with the normal agricultural soils elsewhere in the world, it has been noted that the Peshawar floodplain soils have relatively high concentration of Cu, Pb, Ni and Cr, while Zn is relatively high in the Peshawar piedmont soil. The data further suggest that almost all the studied heavy and trace elements, except Co, exceed that of normal agricultural soil. The agricultural lands of Shabqadar, Khairabad, Mandzai, Sirk, Taranzai, Amankot, Kafir Dheri, Darwazgai, Speen Khak, Khazana and Basid Khel areas of the Peshawar basin have toxic level concentration of the studied heavy and trace metals and need further detailed investigation for their environmental impact on the ecosystem of the

region. The high concentration of these elements in the soils of the basin can be attributed to the weathering and erosion of the sulfides, and mafic and ultramafic rocks in the surrounding mountainous regions with greater input from the northern regions of the Peshawar basin.

It evident from the chemical data in chapter 3, that the drinking waters of dug wells (shallow water) of the Peshawar basin are generally enriched in cations, anions and heavy and trace metals as compared to the tube wells (deep water). This can be caused by many factors including both anthropogenic and geogenic. However, by considering the ground realities this enrichment in the shallow level can be attributed to 1) the rapid rise and fall of the water table, 2) lithological changes in the sediments and 3) the incorporation of pollutants from the surface. The water logging and salinity in the various parts of the Peshawar basin has been reported after the construction of the warsak dam (Bundschuh, 1991). This could have transferred the various types of dissolved cations and anions from the deeper level to the upper level and their precipitation near surface and may have caused enrichment in the drinking water of shallow level. It has also been noticed that the various cations and heavy and trace elements are also enriched in the soils of Peshawar basin. There could be another possibility that these elements may have been incorporated into the groundwater from these soils. The enrichment of the soils of Peshawar basin in various elements as compared to the normal agricultural soils can be explained by understanding the depositional history of the Quarternary sediments along with the covered soils of the basin. It has already been mentioned that multi-episodes of catastrophic flooding along the Indus river are the main cause of the various depositional events in the basin. The river Indus brought the eroded load of sediments of the Kohistan island arc and Indus suture zone where the huge bodies of the mafic and ultramafic complexes (i.e. Chilas and Jijal complexs) and also the massive base metal sulfides (i.e., Besham massive sulfides) are exposed (Jan et al., 1984; Khan et al., 1989; Jan & Kazmi., 1997; Shah, 1991; 1997). These sediments were deposited within the Peshawar basin during flooding and damming of the water in the basin in the past. The Kabul and Swat rivers also have their role in the deposition of these sediments with input from the similar terrains. In certain areas of the basin, these sediments and the cover soils may also have

input from the rocks of the Dargai mafic-ultramafic complex or Skhakot-Qilla ophiolete complex exposed in the northern parts of the Peshawar basin (Ahmad, 1984; Hussain et al., 1984). The major minerals (i.e., olivine, pyroxene, amphibole, chromite etc) of these mafic and ultramafic complexes have high contents of Mg, Cr and Ni. Similarly the massive sulfides are having base metal sulfide minerals (i.e., pyrite, chalcopyrite, sphalerite, galena etc.) which are having high contents of Fe, Cu, Zn and Pb. Therefore, the enrichment of Mg, Fe, Ni, Cr, Cu and Pb in the soils and waters of the Peshawar basin can be explained according to this phenomenon. The occurrence of granites, limestone, dolomite, gypsum, halites, coal and graphites in the surrounding and at the basement of the basin may have also caused enrichment of Ca, Mg, Na, K, SO4, HCO_3 and Cl in the basin. The localized concentration of all the above mentioned cations and anions in the upper level may have been caused by the fluctuation in the water table due to climate changes and water logging and salinity problems in the certain parts of the aquifer (see Driscoll 1986; Tariq 2001).

Oxygen isotopic studies of the surface and groundwater of the Peshawar basin suggest that the aquifers in the basin are generally replenished both by rain water and water from Kabul and Swat rivers (Tariq, 2001). This suggests that the contamination in these rivers may have direct effect on the underground water, especially the shallow water (dug wells). As major portion of the aquifer system of the basin has various cations and anions within permissible limit, it is indicative of the fact that no significant contamination from the surface source has occurred so far. This clearly indicates that if the rivers and adjacent streams and canals of the basin got polluted due to anthropogenic sources in future, there are greater chances of pollution in the major aquifers, even at deeper level, especially in the vicinity of these rivers. Like other metropolitan cities of the world, Peshawar also has most of the environmental problems. The air, water and soil pollutions in Peshawar city and cantonment areas have already been reported in previous studies (Hamidullah et al., 1997; 1998). These studies indicate that the air and sewerage system of the Peshawar metropolis is highly polluted by the heavy metals and are mainly drained in the Budni canal which ultimately falls in the Kabul river. If the disposal of municipal and industrial waste is continuously falling in the Kabul and Swat rivers,

which are irrigating most of the basin, there are greater chances that in future with the establishment of industrial zones, as proposed, in the premises of Peshawar, Swat and Nowshera, the aquifer system of the basin would be polluted to a greater extent.

The air pollution in the traffic- congested areas of the major cities of Lahore, Rawalpindi and Islamabad have been assessed combindly by the Environmental Protection Agency of Pakistan (EPA) and Japan International Corporation Agency (JKA). This study suggests that the average suspended particulate matters in these cities have increased many times higher then WHO guidelines and the Japanese standards (Ahmad, 2005). According to Ahmad (2005), the air pollution in two major cities of Karachi and Lahore is estimated to be 20 times higher than the World Health Organization (WHO) guidelines and is rising very rapidly. The major cities of Peshawar basin (i.e., Peshawar, Maradn and Nowshera) are also facing the same problem of air pollution, as there is greater influx of the vehicles in these cities for last several years. The increase in the vehicular emission is causing increase in the air-pollution-related-diseases (Khan et al., 1989). This includes affects on breathing and respiration, cause lung damage, which may be fatal in most cases. The inhabitants of these cities may also suffering from hear and lung disease are especially at risk. The ambient air quality in the metropolitan city of Peshawar has been highly affected by the vehicular emission from old and poorly maintained heavy duty vehicles that contribute to high ambient concentration of fine particulates.

The trace and heavy metal concentration of the dust samples have been compared with the crustal abundance in Table 6.1 The enrichment factor, which is the enrichment of the element in airborne compared to that of Earth crust, has also been calculated and given in Table 6.1. It is clear from this table that all the metals i.e., Cr, Co, Ni, Cu, Zn and Fe, except Pb, have enrichment factor much lower than one. These are, therefore, considered as soil derived. However, Pb has enrichment factor of 2.62, which suggests that there must be some anthropogenic source for this enrichment. In this regard, the contamination of Pb through vehicular emanation cannot be ruled out. Pb is of special interest among the heavy metals present in the urban atmosphere as it is a toxic

contaminant. Vehicular emission is, however, considered as the single largest source of environmental lead pollution in most urban areas. Needleman et al. (1990) have correlated the low dose of Pb exposure in childhood with later problems in adolescence including an increased school dropout rate and other social behavioral problems. The Pb toxicity though of little amount has been observed in the aerosol / dust fall of the Peshawar metropolitan during this study but it has been noticed that there has been increase in all the heavy metal in air with the passage of time. Pb is, however, having many fold increase in this regard. This indicates that the vehicular emission could be the main source of Pb pollution in the air of Peshawar metropolitan. Special measures should be taken to reduce the vehicular emission to save our future generation form the air-borne diseases. This can be done by using the green fuel like CNG in all the vehicles, contents reduction in gasoline, abandoning of the use of old vehicles and the vehicles should be routinely checked for their safe vehicular emission. This will be right move towards the protection of environment and clean air to the public in the major cities of the Peshawar basin, especially Peshawar.

In order to minimize the future environmental problems regarding drinking water and soils of the Peshawar basin following measures are recommended on priority basis:

- Both surface and groundwater must be regularly monitored physico-chemically. This should include monitoring of rivers and their tributaries, canals, sewerage drains, sewerage pipes from industrial and residential areas.
- The air pollution in the major cities of the Peshawar basin should be monitored regularly and strict measures should be taken to reduce the pollution.
- The inhabitants of these areas should be educated regarding the water, soil and air pollution and their impacts on the ecosystem of the region.
- Environmental laws already formulated for disposal of domestic waste and industrial effluents should be forcefully implemented so that groundwater aquifers should be kept free of contaminants.

- The drinking water of tube wells and dug wells of certain areas of the Peshawar basin having high concentration of hazardous elements / radicals must be studied in detail. The water of these areas should be used after proper treatment.
- To control taste and odour problems, the best approach is the water shed supervision, use of insecticides, aeration, destratification of reservoirs, filteration and good management of the distribution system.
- The industrial effluents should be subjected to pre treatment before being disposed to any segment of the environment.
- Industrialists should encourage ISO certification to safe guard the environment from being polluted.
- The soil samples must be monitored regularly to check for the trace elements.
- Further study needs to be initiated for determining the concentration of the trace elements in vegetables, fruit and cereals.
- Mass awareness programmes regarding pollution must be encouraged both on print as well as electronic media.
- Health monitoring cells must be established in the small villages of the Peshawar basin.
- Not only top down but bottom up approach engaging locals in safeguarding the environment must be encouraged and adopted. As the soils of certain areas of Peshawar basin are rich in certain heavy metals, the impact of these metals are needed to be studied in plants and animals on urgent basis.
- Detail studies are needed to investigate the polluted dug wells and tube wells individually in order to find the precise source of this pollution.
- Detailed environmental impact assessment studies must be made mandatory prior to the installation of any new small and large industry that may be considered a potential source of the surface or underground pollution.

- The municipal and industrial waste should not be allowed to percolate through the sediments of the Peshawar floodplain and also not to be allowed to mix with the waters of rivers and canals of the basin.
- Mining, mineral and metal-based industries, businesses and installations must be monitored on regular basis for relevant pollutions.
- Ground water, surface water and soil samples monitoring should be carried out according to the procedures prescribed for environmental auditing.
- Communal water supply should be properly fenced and protected from contamination from human and animal sources.
- The role of the environmental protection agencies must be strengthened.
- A briefing on the contents of this report must be submitted to the Government for a cleanup action of the polluted river Kabul as well as its tributaries.
- Rural participatory approach must be adopted to raise awareness among the locals to combat pollution at the grass root level.

Table 6.1. Enrichment Factors of the heavy metals of aerosol relative to crustal abundance in the Peshawar metropolitan.

Heavy metals	Average Aerosol concentration in mg/l	Crustal abundance in mg/l	Enrichment Factors
Cr	1.44	100	0.014
Co	1.22	25	0.049
Ni	3.17	75	0.042
Cu	5.64	55	0.103
Zn	10.24	70	0.146
Fe	34.12	5000	0.007
Pb	34.00	13	2.615

CONCLUSION

Peshawar Basin, covering an area of about 5500 km^2, is situated at the southern margin of the Himalayas. It is surrounded by Khyber mountain ranges in the North East and Attock Cherat ranges in the south and bounded by Indus River in the South West. Physiographical units consist of piedmont plain in the south west part, flood plain between the Kabul and swat river, loess plain in the central part of the plain and four important rivers i.e. Kabul river, Swat river, Bara river and Kalapani Nala. On the basis of varying lithologies, the quaternary sediments, covered soils and hosting aquifers of the Peshawar basin are classified as Peshawar piedmont, Peshawar flood plain and Peshawar lacustrine sediments, soils and aquifers.

High rate of industrialization, heavy load of transportation and lack of awareness on the part of the people, has contributed to the high levels of pollution in the surface water, ground water and soils of Peshawar basin. The natural as well as anthropogenic activities played vital role in high concentration of catains, anions and metals in Peshawar aquifers. The water samples at Darwazgai (dug wells) from Attock-Cherat piedmont aquifer and from Zahirabad (dug wells) and Umer village (tube wells) from Peshawar lacustrine aquifer indicate high concentration of SO_4. The Electrical Conductivity in the tube wells of Urmar Bala, Mulazai, Regi, Shahi Bala, Wadpagga and Azakhel Bala areas of the basin exceed the MCL (200-400 m S/cm).

The dug well of S. Umar Baba from Khyber piedmont aquifer, the tube well of Aman Kot from the Peshawar floodsplain aquifer, the tube wells of Akber Pura, Umar

village and dug well of Zahirabad from the Peshawar lacustrine aquifer and the dug wells of Darwargai and Ghari Chandan from the Attock-Cherat piedment aquifer have high concentration of SO^{-2}_4. One tube well of the Aman Kot from the Peshawar flood plain aquifer and one tube well of Akbar Pura and two dug wells of the Regi and Zahirabad from the Peshawar lacustrine aquifer have the concentration of chloride above the permissible limit. Some of the tube wells and dug wells in the Khyber piedmont aquifer (i.e., from Jamrud Road, Shabqadar, Matta Mughal Khel, Abazai and S. Umer Baba), in the Peshawar floodplain aquifer (i.e., from Kukar, Mandezai Srikh, Kandi Hayat, Mathra and Takht Bhai), in the Peshawar lacustrine aquifer (i.e., from Akbar Pura, Bashirabad, Shiggi, Regi, Pawaka, Hazar Khawani, Wadpagga, Zahirabad, Urmar Bala and Shahbaz Ghari) and in Attock-Cherat piedmont aquifer (i.e., from Dag Besud) have high concentration (> 250 mg/l) of bicarbonate.

The Ca content in the dug well samples of Kot in Peshawar floodplain aquifer and Shahbaz Ghari in the Peshawar lacustrine aquifer exceed the permissible limit. Most of the dug wells of the basin have Mg content within the permissible limit. However, dug wells of S. Umar Bala, in the Khyber piedmont aquifer, Shagai, Pajagi, Surezai, Phander, Wadpagga, Zahirabad and Urmar Bala in the Peshawar floodplain aquifer and Darwazgai, Adezai, Aimal Chabutra and Ghari Chandan in the Attock-Cherat piedmont aquifer have Mg contents above the permissible limit. The water samples of tube wells from Kafir Dheri in the Khyber piedmont aquifer, Rajjar, Turangzai, Prang and Aman Kot in the Peshawar floodplain aquifer, Akbar Pura, Pabbi, Urmar village in the Peshawar lacustrine aquifer and Dag Basud in the Attock-Cherat piedmont aquifer have Na concentration. Almost all the water samples, except from few dug wells, have K

concentration within the permissible limit. Few dug wells of the Peshawar lacustrine aquifer (i.e., the dug wells from Surazai, Phandu, Hazar Khawani and Wadpagga) contain alarming amount of Potassium (>20 mg/l). One sample from the tube well of Hayatabad Phase-3 in the Khyber piedment aquifer and one sample from the bore hole well of Jehangira area in the Attock-Cherat piedment aquifer have high concentration (> 600 mg/l). The data show that both surface and groundwater of various aquifer of Peshawar basin have copper concentration within the permissible limit. Two samples from the tube well of the Gulbahar No.2 (up to 71 μg/l) from Peshawar lacustrine aquifer and the two from Mattani (up to 155 μg/l) and Chapri (up to 58 μg/l) from Attock-Cherat piedmont aquifers have Pb contents up to hazardous level. The surface water of the basin though having Pb concentration within the permissible limit but near Nowshera and Khairabad the Pb concentration in the Kabul river increases multifold and also the Pb contents of Indus water show elevated concentration. Majority of tube wells, dug wells, rivers and spring samples have nickel contents below the permissible limit (<12μg/l). All the water samples of the Khyber piedmont aquifer contain chromium concentration within the permissible limit. In the Peshawar floodplain aquifer the water samples of the tube wells of Turangzai and Takht Bhai have high concentration (up to 84μg/l) of chromium. The Cd and Co concentration in both surface and ground water of all the aquifers of the Peshawar is within the permissible limit.

SiO_2 concentration of the soils of Peshawar basin is within the range of normal soil and are, therefore, considered safe for agricultural use. Majority of the soils samples of the Peshawar basin have Al_2O_3, high concentration of therefore, need precautionary

measure for agricultural use. The soils from Peshawar piedmont and Peshawar floodplain have relatively high concentration of iron. Majority of the samples have MnO concentration within the range of normal soil. However, MnO in the soils of Warsak colony, Kafer Dheri, Mathra, Landi Arbab and Phando are exceeding that of normal soil. This suggests that the soils of Peshawar basin are generally safe for agriculture use as far as the Mn concentration is concerned. The soils of Peshawar piedmont and Peshawar flood plain are relatively enriched in MgO as compared to that of Peshawar lacustrine. However, the MgO contents of all the soils of the basin exceed that of the normal agricultural soil. Almost all the soils of the Peshawar basin are very high in CaO contents as compared to that of the normal agricultural soil, especially the soils of the Peshawar piedmont has very high concentration in CaO. All the soils of Peshawar piedmont, Peshawar flood plain and Peshawar lacustrine of the Peshawar basin have high concentration as compared to that of the normal soil for agriculture the K_2O contents in almost all the samples of the soils from Peshawar basin exceed the normal limits. Almost all the samples of soils of the Peshawar basin have high concentration of P_2O_5. The Cu concentration in the soils of certain areas such as Khairabad, Shabqadar, Mandezai Srikh, Tarangzai and Amankot is on the higher side. The Peshawar piedment soils are rich in Zn concentration including Spean Khak, Khairabad, Kafirderi and Mandizai Srikh. Pb is found in manifold high concentration in Landi Arbad, Shabqadar, Mathra, Mandezai Srikh and Taurangzai. Ni is abundant in Spean Khak, Hayatabad Phase 3. and Dargai Cr concentration is also very high is Mandezai Srikh, Tarangzai and Amankot. The air quality of Peshawar metropolis has deteriorated with the passage of time and the concentration of Cr, Cu, Ni, co, Zn, Fe and Pb has reached to an alarming level posing

threat to the biosphere. In fact the pollution level has increased with every passing single day and it is high time for sensitizing the communities, Government and non-government origination to promote sustainable earth society.

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APPENDIX-1

METHODOLOGY

WATER ANALYSES

Collection of water samples

To avoid any possibility of contamination the polythene bottles used for the collection of water samples were treated with 5% HCl, or HNO_3 and then rinsed with double deionzed water.

In the study area two bottles of water were filled. The water of one bottle was analyzed for the determination of alkalinity, temperature, pH, and electrical conductivity, SO_4, Cl at the site. The second bottle was acidified with drops of nitric acid (HNO_3) to a pH below 5.0 to minimize perception and adsorption on wall of bottles. These polythene bottles of water samples were capped tightly and kept for further analyses of cations, anions and heavy metals in the geochemistry laboratory of national center of Excellence (NEC) in Geology, University of Peshawar.

DETERMINATION OF PHYSICAL PARAMETERS:

Temperature

The temperature of groundwater is fairly constant during the year at most places and is considerably lower than the air temperature during the summer. There are two principle factors that affect the groundwater temperature; a seasonal variations and the heat received from the sun, b. the movement of heat from the earth's interior. The temperature of water in stream and shallow lakes is approximately the same when the air

temperature is above 32° F as the daily mean air temperature. The rates at which various chemical process occur in water depend upon water temperature, with warm water, generally causing reactions to go faster.

To determine the temperature of surface and ground water the "Hach One combination pH electrodes model (44200)" was used. This instrument is fitted with a temperature senior who measures temperature, by immersing an electrode bulb into the water sample. This sensor in compatible with the pH meter and gives very accurate readings.

pH

Hach pH meter determined the pH of water samples. pH meter was standardized with buffer solution (solution whose pH tends to remain constant when small amount of acid or base added) of pH 4,0, 7.0, 8.0 and 12.0. The electrode bulb of the pH meter was subsequently immersed into the buffer solution for proper calibration. Then immersed into the water sample and reading was directly noted from the meter. For accurate result the standardization of the pH meter was checked by the buffer solution after the run of few samples.

Electrical Conductivity:

Cole pamer's (model 148-55) was used for the determination of electrical conductivity of water samples. The instrument was first calibrated with a standard KCl solution, having conductivity value of 1.45 mS/cm at 25° C.

Alkalinity:

Alkalinity of water is its acid neutralizing capacity. Alkalinity of surface and ground water is a function of carbonate, bicarbonate and hydroxide contents. To

determine the alkalinity of water samples, a special device of Hatch Digital Titration was used which is filled with concentrated titrants in compact containers called cartridges. Each cartiridge replaces about one quarter of standard titrant. A main drives crew in the Digital Titrator control is a plunger that forces the titration solution from a titration cartridge in a regulated flow. The titration body is constructed of precision-moulded, heavy duty chemical and impact resistant acetyl plastic. Accuracy is rated at + 1% or better. Titration solution are packed in disposable polythene plastic containers with Teflon solutions are packed in disposable polythene plastic containers with Teflon closures to cover the cartridge tips. Each contains approximately 13ml of titration solution. Most of the solutions are controlled to +0.5 N by comparing with normality and tolerance listed on the label provided. Solution concentrations are designed for titration of 10-40 turns (100-400 digits) of the delivery knob.

To start the procedure a known sample volume and sulfuric acids (H_2SO_4) Titration Cartridge corresponding to the expected alkalinity concentration as mg/l calcium carbonate was selected from the table.

Multiplier	**Sample Volume as $CaCO_3$**	**Titration in (ml)**	**Cartridge N:H_2SO_4**	**Catalog Digit No**
	10-40	100	1.600	14388-01
0.1	40-160	25	1.600	14388-01
0.4	100-400	100	1.600	14389-01
1.0	200-800	50	1.600	14389-01
2.1	500-2000	20	1.600	14389-01
5.1	1000-4000	10	1.600	14389-01

A clean delivery tube was then inserted into the titration cartridge. The delivery knob was turned slowly and gradually to eject a few drops of titrant, the counter was then repose to zero. The selected volume of water sample was measured with the help of graduated cylinder and transferred into 250ml with demonized water. The

phenolphthalein Indicator Powder Pillow was added to the water sample and swirled to mix. The sample solution titrated to a colourless end until the colour turned pink. By immersing the delivery tube tip into the solution it was then titrated with sulfuric acid to get colourless end. The digital reading was recorded as P-Alkalinity. In case of not obtaining pink colour with the addition of phenolphthalein, the bromocresol green methyl red indicator powder pillow was added to the solution. The titration was continued with a sulfuric acid to a light greenish blue-gray end. The number of digits were recorded and total alkalinity was calculated as:

Total ml required x digital multiplier = mg/l as $CaCO_3$ total (Tor M) alkalinity.

Chloride (Cl)

Chloride is one of the major inorganic anions in the natural and wastewater. To determine the concentration of chloride in water sample "mercuric Nitrate Method" was used by digital titration. Representative sample of maximum volume of 100 ml was taken in a clean, chemically resistant plastic bottle. The purpose of chloride titration with mercuric nitrate, Hg $(NO_3)_2$ is to form soluble, slightly dissociated mercuric chloride. Taking a sample volume and 0.0141 N Hg $(NO_3)_2$ cartridge corresponding to the expected chloride concentration. A clean and uncontaminated delivery tube is attached to the titration body. Known volume (100ml) was transferred to 250ml volumetric flask, and was diluted to 100ml with demonised water. Contents of one Diphenylcarbazone Powder Pillow, provided with instrument were added to the flash. The titration of mercuric nitrate was employed in such a way that the delivery tube was immersed into the solution and flash was swirled while titration with mercuric nitrate. The titration was continued until pale yellow colour was changed to light pink (the end point) the reading was recorded and the result were calculated.

Sulfate (SO_4)

Sulfate $(SO_4)^2$ concentration in potable and waste water was determined by "Turbidimetric Method" (Rossum and Villaruz, 1961 by using mass spectrophotometer. Sulfate in $(SO_4)^2$ is precipitated in an acetic acid medium with barium chloride (BaCl), so as to from barium sulfate ($BaSO_4$) crystal of uniform size. Light absorbency is wavelength dial to 450nm. The water sample 25ml was transferred into a cell, added the contents of one sulfa Ver 4 sulfate Reagent Powder Pillow tot he sample cell (the blank) filled with 25ml of deionized water was placed into the cell holder. By zeroing the photometer the display screen gave the reading of blank cell i.e, the concentration of sulfate 0.0 mg/l $(SO_4)^2$. After five minutes, the timer stopped and placed the prepared sample into cell holder; the result in mg/l was noted.

DETERMINATION OF LIGHT ELEMENTS

Determination of Ca and Mg

The Ca and Mg in both the certified water standards and the studied water samples were determined on Perkin Elmer atomic absorption spectrophotometric by directly aspirating the water samples. Wherever the concentration was high the samples were diluted accordingly.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Element	Ca	Mg
Mode	Absorption	Absorption
Wavelength	422 nm	285.2nm
slit width	0.4nm	0.4nm

Air flow	5l/min	5 l/min
Fuel flow	5 l/min	To best flame
Burner height	10mm	10mm

1. Stock solution of 1000 ppm for Ca & Mg: 2.497g $CaCO_3$ and 3.057g $MgCO_3$ were dissolved in 1N HCl and was diluted to one liter with deionized water in a 1000 ml volumetric flask.

2: Stock solution of 100 ppm for Ca & Mg: 10 ml of 1000 ppm stock solution was taken in 100 ml volumetric flask and was made upto the mark with deionized water.

3: Lanthanum 5% Solution: 58.64g of La_2O_3 was dissolved in 200 ml deionized water to which 150 ml 60 % $HClO_4$ was added. It was heated until complete dissolution. The solution was then filtered through ordinary filter paper into 1000 ml volumetric flask and the volume was made upto the mark with deionized water.

4. Working Standards: 1, 2, 4 and 8 ppm of working standards for Ca and Mg were prepared by taking 0.5, 1, 2 and 4 ml of 100 ppm stock solution in a series of 50 ml volumetric flasks. To these flasks 10 ml lanthanum solution was added and the volume was made upto the mark with deionized water.

5. Dilution of Samples: 5 ml (depending upon the expected concentration of Ca & Mg) of the water samples of both certified water standards and the studied water samples were taken in a series of 50 ml volumetric flasks. 10 ml of lanthanum solution was added to each flask and the volume was made to the mark.

Procedure: Atomic absorption spectrophotometer was set according to the above mentioned conditions for Ca and Mg separately. The cathode lamp for both Ca and Mg were turn ON to warm up for at least 10 minutes. The instrument was then calibrated and standardized with the working standards of 2 and 4 ppm. All the working standards were

run as unknown and their actual concentration was verified. For further accuracy the certified water standards were run as unknown and the results were compared. After making sure that the results of the certified standards were within the confidence limit, the studied water samples were run on the atomic absorption and the concentrations of Ca and Mg were noted for each sample.

Determination of $Na_2O + K_2O$

Both Na_2O and K_2O were determined by atomic absorption spectrophotometer

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument Conditions:

Element	Na	K
Mode	Emission	Emission
Wavelength	589 nm	766 nm
Slit width	0.2 nm	0.4 nm
Air flow	5 l/min	5 l/min
Fuel flow	1 l/min	1 l/min
Burner height	20 mm	20 mm

1. Stock solution of 1000 ppm for Na & K: 3.087 g moisture free Na_2SO_4 and 2.228g moisture free K_2SO_4 were dissolved in deionized water and the volume was made to 1000 ml in a volumetric flask. The solution was stored in a polythene bottle.

2. Stock solution of 100 ppm Na & K: 10 ml of 1000 ppm stock solution was taken in a 100 ml flask and diluted to mark with deionized water.

3. Working Standards: 1, 2, 4 and 8 ppm working standards were prepared by taking 1, 2, 4, and 8 ml from 100 ppm stock solution in 100 ml volumetric flasks and was diluted up to the mark with
deionized water.

4. Diluted samples: All the samples as well as certified rock standards were diluted to 20 times.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned instrumental conditions in order to get the maximum absorbance. The instrument was set on emission mode and a conical burner head was used. In this case no cathode lamp was required. The instrument was calibrated and standardized by working standards of 4 and 8 ppm and then the working standards were also run as unknown in order to verify the standardization of the instrument. The diluted certified water standards were then run and the results were compared to know the accuracy of the method. The water samples were sprayed one by one through the flame and the concentration of Na and K was noted in each sample.

DETERMINATIONS OF TRACE & HEAVY METALS IN WATER

Determination of Iron (Fe)

The iron contents were determined by the graphite furnace atomic absorption spectrophotometer by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrumental conditions

Mode	Absorption
Wavelength	248.3 nm
Slit width	0.2 nm
Tube/site	Pyro/Platform
Matrix modifier	0.05mg $(NO_3)_2$
Pretreatment T °C	1400
Atomization T °C	2400

1. Stock solution of 1000 ppm for Fe: I gram of pure iron metal was dissolved in minimum amount of HCl and was made to the volume with deionized water in one litre volumetric flask.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of iron were determined.

Determination of Nickle (Ni)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wavelength	232.0 nm
Slit width	0.2 nm
Tube/site	Pyro/Platform
Matrix modifier	0.05mg (NO3)2
Pretreatment T °C	1400
Atomization T °C	2500

1: Standard stock solution of 1000 ppm: 1g of Ni metal was dissolved in a minimum volume of(1:1) HNO_3 and was diluted to 1 litre with deionized water.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of nickle were determined.

Determination of Chromium (Cr)

Atomic Absorption method

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	Absorption
Wavelength	357.9 nm
Slit width	0.7 nm
Tube/site	Pyro/Platform
Matrix modifier	0.05mg $(NO_3)_2$
Pretreatment T °C	1600
Atomization T °C	2500

1: Standard stock solution of 1000 ppm: 3.735g of K_2CrO_4 was dissolved in deionized water and diluted to one litre with deionized water.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of chromium were determined.

Determination of Cobalt (Co):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wavelength	340.7 nm
Slit width	0.2 nm
Tube/site	Pyro/Platform
Matrix modifier	0.05mg $(NO_3)_2$
Pretreatment T °C	1400
Atomization T °C	2500

1: Standard stock solution of 1000 ppm: 1.0 g of cobalt metal was dissolved in 30 ml of (1:1) HCl and was diluted to one litre with deionized water.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of cobalt were determined.

Determination of Copper (Cu)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	Absorption
Wavelength	324.8 nm
Slit width	0.7 nm
Tube/site	Pyro/Platform
Matrix modifier	Nil
Pretreatment T °C	1200
Atomization T °C	2300

1. Standard stock solution of 1000 ppm: 1 g of copper metal was dissolved in 30 ml of (1:1) HNO_3 and was made to the volume of one litre with deionized water.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of copper were determined.

Determination of Lead (Pb):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wavelength	324.8 nm
Slit width	0.7 nm
Tube/site	Pyro/Platform
Matrix modifier	0.2 mg $NH_4H_2PO_4$
Pretreatment T °C	1200
Atomization T °C	2300

1. **Standard stock solution of 1000 ppm:** 1.598 g of lead nitrate Pb $(NO_3)_2$ was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.

2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of lead were determined.

SOIL ANALYSES

Collection of soil samples

Representative samples of soil were collected from the selected location. The samples have been divided into two horizons "A" and "B". Horizon "A" represents the core sample surface to a depth of 20cm and horizon "B" represents a core sample from a depth of 20-40 cm. The collected samples were properly labeled and transferred to polythene bags that were further placed into canvas bags. The color, texture and loose fragments of these samples were noted at the site.

Crushing of soil samples

Various types of soils collected during field from the study area were air dried and selected portion of the soil samples were pulverized in a tungsten carbide ball mill to 200 mesh size. A portion of individual sample was collected after proper quartering and coning. During this whole process greater care was practiced to avoid contamination. The powdered samples were stored in the air tight glass bottles. These bottles, after removing the lids, were kept in the oven at 110 °C for two hours in order to remove the moisture.

Preparation of stock solutions

The moisture free powders of the soil samples as well as the world known rock standards were converted in to stock solutions of known volume by different methods. These stock solutions were used for the determination of major, minor and trace and heavy elements by classical and instrumental methods.

Three different types of stock solutions were prepared by the following methods:

Stock Solution A

HF and $HClO_4$ digestion method: 0.5g of powdered soil sample was accurately weighed in a Teflon beaker and was moist with few drops of deionized water. Then 10 ml of concentrated (49%) HF and 4 ml of concentrated(70%) $HClO_4$ was added to it. The sample was heated on a sand bath at low temperature until a small portion is evaporated. The beaker was then removed from the sand bath and was cooled for few minutes. Then 2 ml of $HClO_4$ was added and was again kept on sand bath until dry paste was obtained. The beaker was then removed from the sand bath and 4 ml of $HClO_4$ and a few mls of deionized water was added to it. The contents of the beaker was then transferred to 250 ml beaker. The beaker was well washed in to the beaker until no particle is left in the crucible. If there was some precipitation or turbidity observed in the solution, this solution was then heated for a while until clear solution was obtained. In certain cases still there was the persistence of precipitation in the solution. In that case the precipitation was dissolved by the addition of about 2 ml of Hydrochloric acid and heated the solution to boiling. The final solution was made to 250 ml in the volumetric flask with deionized water. All the samples were treated by the same procedure for the preparation of solution A.

Stock Solution B

Sodium hydroxide fusion method: 30 g of NaOH pellets were dissolved in 100 ml deionized water and stored in a polythene bottle. 5 ml aliquots of NaOH solution was added to a series of already cleaned nickle crucibles. The crucibles were kept on hot plate at approximately 100 C^{O} for complete dryness. These were then cooled in a desiccator. Accurately weighed 0.05g of soil samples and certified rock standards were added to separate crucibles. One crucible was used for the preparation of blank. The crucibles were covered with lids and each crucible was heated to dull redness over a gas burner for a period of 5 minutes. The crucibles were swirled while hot. Deionized water (5-10ml) was added to each crucible. The contents of each crucible were washed into different 600 ml polythene beakers which already contained 400 ml of deionized water and 10 ml of concentrated HCl.

In most cases clear solution was obtained at this stage. However, in few cases the solution was not clear. This type of solution was then warmed until the clear solution was obtained. The resulting solution was transferred to one litre volumetric flask and was made to the volume with deionized water and stored in polythene bottles for the determination of silica and alumina.

Stock Solution C

HF + equa rigia digestion method: Accurately weighed 1.0g of finely powdered soil sample was taken in a 100 ml teflon beaker. 5ml of HF was added to it and was kept on hot plate at a temperature of approximately 75 C^{O}. After 10 minutes, about 15 ml of equa rigia was added and the heating was continued until complete dryness. 2N HCl was added to the residue and was heated until the maximum dissolution of residue. The residue was filtered by using 2N HCl and the final volume was made to 25 ml and was stored in polythene bottle. This solution was then used for trace elements determination using atomic absorption spectrophotometer.

DETERMINATION OF MAJOR AND MINOR OXIDES

Determination of SiO_2

Spectrophotometric method

The method by Jeffery (1987) was adopted. In this method the silica in the stock solution B was determined by reducing the yellow color of silico molybdate to blue color.

Instrument: SP8-400 PYE UNICAM UV/VIS spectrophotometer.

Reagents

1. Ammonium molybdate solution: 7.5g of ammonium molybdate was dissolved in 70 ml deionized water by adding 20 ml of 9 N H_2SO_4. The solution was made to the volume of 100 ml and was stored in a polythene bottle.

2. Tartaric acid solution: 25g of the tartaric acid was dissolved in deionized water and was diluted to 250 ml with deionized water.

3. Reducing solution: 0.7g of sodium sulfite Na_2SO_3, 0.15g of 1-amino-2-naphthol-4-suphonic acid and 9g of sodium metabisulfite (Na_2 S_2O_5) was dissolved in 100 ml of deionized water. The solution was kept in a cool and dark place and was prepared freshly as this solution deteriorate after few days.

Procedure: 10 ml of stock solution B of each of the soil sample, each rock standards and a blank was taken in a series of 100 ml volumetric flasks. About 50 ml of deionized water was added to each flask. 2 ml of ammonium molybdate solution was added to each flask and was swirled to mix well. After exactly 10 minutes, 4 ml of tartaric acid solution was added to each flask and again swirled and mixed well. At the end 1 ml of reducing solution was added to these flasks and each flask was diluted to 100 ml with deionized water. All these solutions were set aside for at least 30 minutes. Blue color solution was obtained at the end. The silica was then determined on the spectrophotometer at a wavelength of 650nm relative to the reference rock standards.

Determination of Al_2 O_3

Spectrophotometric Method

Instrument: SP8-400 PYE UNICAM UV/Visible spectrophotometer

Reagents

1. 8-hydroxyquinoline solution: 1.25g of the 8-hydroxyquinoline was dissolved in 250 ml of pure grade of chloroform and was stored in a refrigerator.

2. Complexing reagent: 1g of hydroxylamine hydrochloride ($HONH_2HCl$), 3.6g of sodium acetate trihydrate and 0.4g of berillium sulphate tetrahydrate were dissolved in 50 ml of deionized water. 0.04g of 2,2 dipyridyl was also dissolved in 20 ml of 0.2N HCl. Both the solutions were then mixed and diluted upto 100 ml with deionized water.

Procedure: 5 ml of from each stock solution B of soil samples, 3 known standards and a reagent blank were taken into a series of 100 ml separatory funnels. 5 ml of deionized water and 10 ml of complexing reagent solution were added to these funnels and mixed well. After few minutes 20 ml of 8-hydroxyquinoline solution was added to each funnel. These solutions were then shaked for about 8 minutes by an automated flask shaker. The organic layers obtained at the bottom of these solutions in the seperatory funnels were then separated into 25 ml volumetric flasks by washing the funnels with chloroform for several times. The final volume of 25 ml for each sample was made with chloroform. The yellow color extracts obtained through this process were suitable for spetrophotometric determination. The Al_2O_3 was determined at wavelength of 381 nm relative to the reference rock standards.

Determination of total iron as Fe_2O_3

The total iron as Fe_2O_3 in the studied soil samples was determined by atomic absorption spectrophotometer by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Reagents

1. 8-hydroxyquinoline solution: 1.25g of the 8-hydroxyquinoline was dissolved in 250 ml of pure grade of chloroform and was stored in a refrigerator.

2. Complexing reagent: 1g of hydroxylamine hydrochloride ($HONH_2HCl$), 3.6g of sodium acetate trihydrate and 0.4g of berillium sulphate tetrahydrate were dissolved in 50 ml of deionized water. 0.04g of 2,2 dipyridyl was also dissolved in 20 ml of 0.2N HCl. Both the solutions were then mixed and diluted upto 100 ml with deionized water.

Procedure: 5 ml of from each stock solution B of soil samples, 3 known standards and a reagent blank were taken into a series of 100 ml separatory funnels. 5 ml of deionized water and 10 ml of complexing reagent solution were added to these funnels and mixed well. After few minutes 20 ml of 8-hydroxyquinoline solution was added to each funnel. These solutions were then shaked for about 8 minutes by an automated flask shaker. The organic layers obtained at the bottom of these solutions in the seperatory funnels were then separated into 25 ml volumetric flasks by washing the funnels with chloroform for several times. The final volume of 25 ml for each sample was made with chloroform. The yellow color extracts obtained through this process were suitable for spetrophotometric determination. The Al_2O_3 was determined at wavelength of 381 nm relative to the reference rock standards.

Determination of total iron as Fe_2O_3

The total iron as Fe_2O_3 in the studied soil samples was determined by atomic absorption spectrophotometer by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrumental conditions

Mode	Absorption
Wavelength	248.3 nm
Slit width	0.2 nm
Air flow	5litre/minute
Fuel flow	1litre/minute
Burner height	10 mm

1. Stock solution of 1000 ppm for Fe: I gram of pure iron metal was dissolved in minimum amount of HCl and was made to the volume with deionized water in one litre volumetric flask.

2. Stock solution of 100 ppm: 10 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.

3: Working standard solutions: 1, 2, 4 and 8 ppm working standard solutions were prepared by taking 1, 2, 4 and 8 ml from the 100 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 4 and 8 ppm. The working standards 1, 2, 4 & 8 ppm were then run as unknown. After verification of accuracy, the stock solution A of both certified rock standards and samples were run on the machine. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the rest of the sample solutions were run on the atomic absorption and the results of iron as Fe_2O_3 were determined.

Determination of MnO

MnO in the studied soil samples was determined by atomic absorption by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wave length	279.5nm
Slit width	0.2nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10mm

1:Stock solution of 1000 ppm for Mn: 4.058g of $MnSO_4.4H_2O$ was dissolved in 20 ml of 1N H_2SO_4. It was then transferred to 1000 ml volumetric flask and was made upto the mark with deionized water.

2: Stock solution of 100 ppm: 10 ml of 1000 ppm stock solution was taken in 100ml volumetric flask and was made upto the volume with deionized water.

3: Working standards: 1, 2, 4 and 8 ppm working standards of Mn were prepared by taking 1 2, 4 and 8 ml of 100 ppm stock solution in a 100ml volumetric flask and was made to volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions and the cathode lamp for Mn was warmed up for 10 minutes. After warming up of the cathode lamp the instrument was calibrated and standardized with the

working standards. The solution A of the certified rock standards were then run to check the accuracy of the method. After making sure that the atomic absorption is calibrated properly, solution A of the unknown rock samples were sprayed into the flame and the concentration was noted for every samples. The wt% of MnO was then calculated.

Determination of CaO and MgO

The CaO and MgO in both the certified rock standards and the studied soil samples were determined atomic absorption spectrophotometric method by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Element	Ca	Mg
Mode	Absorption	Absorption
Wavelength	422 nm	285.2nm
slit width	0.4nm	.0.4nm
Air flow	5l/min	5 l/min
Fuel flow	5 l/min	To best flame
Burner height	10mm	10mm

1. Stock solution of 1000 ppm for Ca & Mg: 2.497g $CaCO_3$ and 3.057g $MgCO_3$ were dissolved in 1N HCl and was diluted to one litre with deionized water in a 1000 ml volumetric flask.

2: Stock solution of 100 ppm for Ca & Mg: 10 ml of 1000 PPM stock solution was taken in 100 ml volumetric flask and was made upto the mark with deionized water.

3: Lanthanum 5% Solution: 58.64g of La_2O_3 was dissolved in 200 ml deionized water to which 150 ml 60 % $HClO_4$ was added. It was heated until complete dissolution. The solution was then filtered through ordinary filter paper into 1000 ml volumetric flask and the volume was made upto the mark with deionized water.

4. Working Standards: 1, 2, 4 and 8 ppm of working standards for Ca and Mg were prepared by taking 0.5, 1, 2 and 4 ml of 100 ppm stock solution in a series of 50 ml volumetric flasks. To these flasks 10 ml lanthanum solution was added and the volume was made upto the mark with deionized water.

5. Dilution of Samples: 5 ml (depending upon the expected concentration of Ca & Mg) of the stock solution A of both certified rock standards and the studied rock samples were taken in a series of 50 ml volumetric flasks. 10 ml of lanthanum solution was added to each flask and the volume was made to the mark.

Procedure: Atomic absorption spectrophotometer was set according to the above mentioned conditions for Ca and Mg separately. The cathode lamp for both Ca and Mg were turn ON to warm up for at least 10 minutes. The instrument was then calibrated and standardized with the working standards of 2 and 4 ppm. All the working standards were run as unknown and their actual concentration was verified. For further accuracy the certified rock standards were run as unknown and the results were compared. After making sure that the results of the certified standards were within the confidence limit, the studied rock sample solutions (in diluted form) were run on the atomic absorption and the concentrations of Ca and Mg were noted for each sample. The wt% of CaO and MgO in each sample was then calculated.

Determination of $Na_2O + K_2O$

Both Na_2O and K_2O were determined by atomic absorption spectrophotometer by using the stock solution A.

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument Conditions:

Element	Na	K
Mode	Emission	Emission
Wavelength	589 nm	766 nm
Slit width	0.2 nm	0.4 nm
Air flow	5 l/min	5 l/min
Fuel flow	1 l/min	1 l/min
Burner height	20 mm	20 mm

1. Stock solution of 1000 PPM for Na & K: 3.087 g moisture free Na_2SO_4 and 2.228g moisture free K_2SO_4 were dissolved in deionized water and the volume was made to 1000 ml in a volumetric flask. The solution was stored in a polythene bottle.

2. Stock solution of 100 PPM Na & K: 10 ml of 1000 PPM stock solution was taken in a 100 ml flask and diluted to mark with deionized water.

3. Working Standards: 1, 2, 4 and 8 ppm working standards were prepared by taking 1, 2, 4, and 8 ml from 100 PPm stock solution in 100 ml volumetric flasks and was diluted up to the mark with
deionized water.

4. Diluted samples: All the samples as well as certified rock standards were diluted to 20 times.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned instrumental conditions in order to get the maximum absorbance. The

instrument was set on emission mode and a conical burner head was used. In this case no cathode lamp was required. The instrument was calibrated and standardized by working standards of 4 and 8 ppm and then the working standards were also run as unknown in order to verify the standardization of the instrument. The diluted certified rock standards were then run and the results were compared to know the accuracy of the method. The diluted solutions of rock sample were sprayed one by one through the flame and the concentration of Na and K was noted in each sample. The wt% of Na_2O and K_2O were then calculated.

Determination of TiO_2

TiO_2 in the studied samples was determined by spectrophotometric method by using the stock solution A.

Instrument: SP8-400 PYE UNICAM UV/VIS spectrophotometer

Procedure: 10 ml of stock solution A of the rock samples and at least two certified rock standards were taken in 50 ml volumetric flask. Few drops of H_3PO_4 and 2 ml of H_2O_2 were added to each flask. The solution in each flask was made to volume with 10 % H_2SO_4 solution. A blank sample was also prepared by the same method. These solutions were then shaked and mixed well and were ready for analysis. The spectrophotometer was turn ON and set to warm up for 30 minutes. The wave length optimization was done on the certified rock standards. A maximum peak was noticed at 445 nm. The instrument was set on a wavelength of 445 nm and was zeroed with the blank. The certified rock standards were run on the instrument and the results were calculated and compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the rock sample solutions were then run as unknown. The optical density of each sample was noted and the wt% of TiO_2 for each sample was then calculated.

Determination of P_2O_5:

P_2O_5 in the studied samples was determined by spectrophotometric method by using the stock solution A.

Instrument: SP8-400 PYE UNICAM UV/VIS spectrophotometer.

Reagents:

1: Ammonium meta vanadate solution: 0.25g ammonium meta vanadate (NH_4VO_3) was dissolved in 120 ml of 33% HNO_3.

2. Ammonium molybdate solution: 10 g of ammonium molybdate was dissolved in 80 ml of deionized water.

Both the solutions were mixed and stored in polythene bottle.This mixture is used as vanadate molybdate reagent.

Procedure: 10 ml of stock solution A of rock samples and at least two certified standards were taken in series of 50 ml volumetric flasks. To each flask 2 ml of vanadate molybdate reagent was added. The volume was made to the mark with deionized water. The solutions were shaked and were run on spectrophatometer as under: The spectrophotometer was turn ON and set to warm up for 30 minutes. The wave length optimization was done on the certified rock standards. A maximum peak was noticed at 372 nm. The instrument was set at 372 nm and was zeroed with the blank. The certified rock standards were run on the instrument and the results were calculated and compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the rock sample solutions were then run as unknown. The optical density of each sample was noted and the wt% of P_2O_5 for each sample was then calculated.

Determination of Ignition Loss:

Gravimetric method:

Sample of known weight were taken in already weighed porcelain crucibles. These crucibles along with the samples were kept in a furnace at 1000 ^{O}C for 3 hours. Then cooled in a desiccators and weighed out after 15 minutes. The difference in weight was noted and the amount of ignition loss (in percent) was calculated for each sample.

DETERMINATIONS OF TRACE & HEAVY METALS IN SOILS

Determination of Copper (Cu)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	Absorption
Wave length	325.8nm
Slit width	0.4nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10 mm

1. **Standard stock solution of 1000 ppm:** 1 g of copper metal was dissolved in 30 ml of (1:1) HNO_3 and was made to the volume of one litre with deionized water.
2. **Standard stock solution of 100 ppm:** 10 ml of 1000 ppm standard stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4, and 8 ml from 100 ppm standard stock solution into a series of 100 ml volumetric flasks and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Cu cathode lamp was turned ON and let it to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instru ment was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample stock solutions C were then aspired into the flame and the Co concentration of each sample was noted. The Co contents in ppm were calculated.

Determination of Lead (Pb):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	absorption
Wavelength	217 nm
Slit width	0.4 nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10 mm

1. **Standard stock solution of 1000 ppm:** 1.598 g of lead nitrate $Pb(NO_3)_2$ was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.

2. Standard stock solution of 100 ppm: 10 ml of 1000 ppm standard stock solution was taken in 100 ml volumetric flask and was made to the volume with deionized water.

3. Working standard solutions: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4 and 8 ml of 100 ppm stock solution in a series of 100 ml volumetric flask and volume was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Pb cathode lamp was turned ON and allowed to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample stock solutions C were then aspired into the flame and the Pb concentration of each sample was noted. The Pb contents in ppm were calculated.

Determination of Nickle (Ni)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wavelength	232nm
Slit width	0.2nm
Fuel flow	1 l/min
Air flow	5 l/min

Burner height 10 mm

1: Standard stock solution of 1000 ppm: 1g of Ni metal was dissolved in a minimum volume of(1:1) HNO_3 and was diluted to 1 litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml from 1000 ppm stock standard solution was transferred into a 100 ml volumetric flask and was made to the mark with deionized water.

3: Working standards: 0.5, 1, 2, 4 ppm standard solution were prepare by taking 0.5, 1, 2 and 4 ml from 100 ppm standard solution into a series of 100 ml volumetric flask and was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Ni cathode lamp was turned ON and allowed to warm up for 10 minutes. After warming up of cathode lamp, the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 2 and 4 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution of certified standards was run and the results were compared with the certified values. After making sure that the result of the certified standards were within the confidence limit, the sample's stock solutions C were then aspired into the flame and the Ni concentration of each sample was noted. The Ni contents in ppm were calculated according.

Determination of Chromium (Cr)

Atomic Absorption method

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	absorbence
Wave length	357.9nm
Slit width	0.2nm
Fuel flow	4.5 l/min
Air flow	5.0 l/min
Burner height	10 mm

1: Standard stock solution of 1000 ppm: 3.735g of K_2CrO_4 was dissolved in deionized water and diluted to one litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml of 1000ppm standard stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards
were prepared by taking 0.5, 1, 2, 4 and 8 ml from the standard stock solution of 100 ppm in a 100ml volumetric flask and was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Cr cathode lamp was turned ON and let it to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample's stock solutions C were then aspired into the flame and the Cr concentration of each sample was noted. The Cr contents in ppm were calculated.

Determination of Cobalt (Co):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wave length	240.7 nm
Slit width	0.4 nm
Fuel flow	1.2 l/min
Air flow	5 l/min
Burner height	10 mm

1: Standard stock solution of 1000 ppm: 1.0 g of cobalt metal was dissolved in 30 ml of (1:1) HCl and was diluted to one litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml of 1000 ppm stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4 and 8 ml from 100 ppm standard stock solution in a series of 100 ml volumetric flasks and made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Co cathode lamp was turned ON and let it to warm for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the

confidence limit, the sample stock solutions C were then aspired into the flame and the Co concentration of each sample was noted. The Co contents in ppm were calculated.

AEROSOL / DUST ANALYSES

Collection of dust samples

The dust samples were collected in the plastic pans (30 cm diameter) from various traffic-congested areas of the Peshawar metropolitan. These include, Takhto Jumat Chowk, Deans Plaza chowk, Nothia chowk, Gora Qabristan, Public Service Commission, Khalid Bin Waleed chowk, F.C chowk, Faizullah chowk, Peshawar Stadium chowk, T.V. chowk, Hayatabad chowk, Speen Jumat chowk, Air port chowk and Sawati Phatak. The plastic pans containing double deionized water were hanged at a level of about 1.25m (nose level) from the ground with some support for about 48 hours. The dust / aerosol was collected during this time in these pans. The samples were then filtered through filter paper (whatman) and residues were dried in oven at 110^{0} and the contents of the dust were collected bottle from the filter paper and were pulverized in the mortar further processing.

Preparation of sample stock solution

HF + equa rigia digestion method: Accurately weighed 0.5g of finely powdered dust sample was taken in a 100 ml teflon beaker. 5ml of HF was added to it and was kept on hot plate at a temperature of approximately 75 C^{O}. After 10 minutes, about 15 ml of equa rigia was added and the heating was continued until complete dryness. 2N HCl was added to the residue and was heated until the maximum dissolution of residue. The residue was filtered by using 2N HCl and the final volume was made to 25 ml and was stored in polythene

bottle. This solution was then used for trace elements determination using atomic absorption spectrophotometer.

DETERMINATIONS OF TRACE & HEAVY METALS IN AEROSOL / DUST

Determination of Copper (Cu)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	Absorption
Wave length	325.8nm
Slit width	0.4nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10 mm

1. Standard stock solution of 1000 ppm: 1 g of copper metal was dissolved in 30 ml of (1:1) HNO_3 and was made to the volume of one litre with deionized water.

2. Standard stock solution of 100 ppm: 10 ml of 1000 ppm standard stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4, and 8 ml from 100 ppm standard stock solution into a series of 100 ml volumetric flasks and made to the volume with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Cu cathode lamp was turned ON and let it to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instru-

ment was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample stock solutions were then aspired into the flame and the Co concentration of each sample was noted. The Co contents in ppm were calculated.

Determination of Lead (Pb):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	absorption
Wavelength	217 nm
Slit width	0.4 nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10 mm

1. **Standard stock solution of 1000 ppm:** 1.598 g of lead nitrate $Pb(NO_3)_2$ was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.

2. **Standard stock solution of 100 ppm:** 10 ml of 1000 ppm standard stock solution was taken in 100 ml volumetric flask and was made to the volume with deionized water.

3. Working standard solutions: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4 and 8 ml of 100 ppm stock solution in a series of 100 ml volumetric flask and volume was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Pb cathode lamp was turned ON and allowed to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample stock solutions were then aspired into the flame and the Pb concentration of each sample was noted. The Pb contents in ppm were calculated.

Determination of Nickle (Ni)

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wavelength	232nm
Slit width	0.2nm
Fuel flow	1 l/min
Air flow	5 l/min
Burner height	10 mm

1: Standard stock solution of 1000 ppm: 1g of Ni metal was dissolved in a minimum volume of(1:1) HNO_3 and was diluted to 1 litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml from 1000 ppm stock standard solution was transferred into a 100 ml volumetric flask and was made to the mark with deionized water.

3: Working standards: 0.5, 1, 2, 4 ppm standard solution were prepare by taking 0.5, 1, 2 and 4 ml from 100 ppm standard solution into a series of 100 ml volumetric flask and was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Ni cathode lamp was turned ON and allowed to warm up for 10 minutes. After warming up of cathode lamp, the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 2 and 4 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution of certified standards was run and the results were compared with the certified values. After making sure that the result of the certified standards were within the confidence limit, the sample's stock solutions were then aspired into the flame and the Ni concentration of each sample was noted. The Ni contents in ppm were calculated according.

Determination of Chromium (Cr)

Atomic Absorption method

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions

Mode	absorbence
Wave length	357.9nm
Slit width	0.2nm
Fuel flow	4.5 l/min
Air flow	5.0 l/min

Burner height	10 mm

1: Standard stock solution of 1000 ppm: 3.735g of K_2CrO_4 was dissolved in deionized water and diluted to one litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml of 1000ppm standard stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards
were prepared by taking 0.5, 1, 2, 4 and 8 ml from the standard stock solution of 100 ppm in a 100ml volumetric flask and was made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Cr cathode lamp was turned ON and let it to warm up for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution C of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample's stock solutions were then aspired into the flame and the Cr concentration of each sample was noted. The Cr contents in ppm were calculated.

Determination of Cobalt (Co):

Instrument: Perkin Elmer Atomic Absorption Spectrophotometer

Instrument conditions:

Mode	Absorption
Wave length	240.7 nm

Slit width	0.4 nm
Fuel flow	1.2 l/min
Air flow	5 l/min
Burner height	10 mm

1: Standard stock solution of 1000 ppm: 1.0 g of cobalt metal was dissolved in 30 ml of (1:1) HCl and was diluted to one litre with deionized water.

2. Standard stock solution of 100 ppm: 10ml of 1000 ppm stock solution was taken in 100 ml volumetric flask and was made to the mark with deionized water.

3. Working standards: 0.5, 1, 2, 4 and 8 ppm of working standards were prepared by taking 0.5, 1, 2, 4 and 8 ml from 100 ppm standard stock solution in a series of 100 ml volumetric flasks and made to the mark with deionized water.

Procedure: The atomic absorption spectrophotometer was set according to the above mentioned conditions. Co cathode lamp was turned ON and let it to warm for 10 minutes. After warming up of cathode lamp the air acetylene flame was ignited. The instrument was calibrated and standardized with working standards of 4 and 8 ppm. All the working standards were then run as unknown to verify the standardization. Stock solution of certified standards were run through the instrument and the results were compared with the certified values. After making sure that the results of the certified standards were within the confidence limit, the sample stock solutions were then aspired into the flame and the Co concentration of each sample was noted. The Co contents in ppm were calculated.