Environmental Geochemistry of Surface and Subsurface Water and Soil in Peshawar Basin, N.W.F.P., Pakistan

Dissertation submitted to the National Centre of Excellence in Geology, University of Peshawar in partial fulfillment of the requirement for the degree of Doctor of Philosophy

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Dedicated to my husband
Who left me in peace when
I was writing this thesis
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ABSTRACT

Peshawar Basin is situated at the southern foothills of Himalayas between the longitude 71° 15' and 72° 45'E and latitude 33° 45' and 34° 30' N in the North-West-Frontier Province (NWFP) of Pakistan. Major cities of the basin are Peshawar (capital), Mardan, Charsadda and Nowshera. The E-W flowing Kabul river and its tributaries irrigate the basin and join the Indus at the eastern exit. Peshawar Basin is surrounded by mountain ranges of Khyber in west and northwest, Attock-Cherat in south and Swat in the northeast. The basin is filled with Quaternary sediments ranging from Pleistocene to recent in age. These sediments overlie rocks of Paleozoic age. The Quaternary sediments of the Peshawar Basin are physiographically classified as Peshawar piedmont-sediments, Peshawar lacustrine sediments and Peshawar flood plain/stream channel sediments.

The sediments present in the foot hills of the mountains in the western (Khyber Range) and southern (Attock-Cherat Range) part of the Peshawar Basin are coarse deposits of sand and gravel. However, the sediments of the central part of the basin contain relatively large proportion of fine material and are characterized as the lacustrine sediments. On the basis of existing lithologies the aquifer of Peshawar Basin has been classified as Peshawar Piedmont aquifer and Peshawar Lacustrine aquifer. The Peshawar Piedmont aquifer has further been divided into Khyber mountain range piedmont aquifer, Attock-Cherat Range Piedmont aquifer and Lower Swat Range Piedmont-aquifer.

Fast growing urbanization and industrialization in and around the major cities is threatening the air as well as the surface and subsurface water systems of the Peshawar Basin. In the cities, air is consistently polluted by vehicular emanations, industrial effluents and metals-born dust, which ultimately make their way to surface
and underground water. This study is part of a large project concerning surface and groundwater and soil pollution of major and trace elements and heavy metals. The isotopic data of surface and groundwater of the Peshawar Basin has also been evaluated in order to identify the sources of pollution.

The hydro-physical and chemical parameters of the water of Peshawar Basin determined during the present study include pH, Temperature (T) electrical conductivity (Ec), total dissolved solid (TDS) calcium (Ca), magnesium (Mg), potassium (K), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co), lead (Pb) vanadium (V), bicarbonate (HCO₃), sulfate (SO₄) and chloride (Cl). Surface and groundwater of all the aquifers and rivers respectively have been classified as normal alkaline fresh water and alkaline earth fresh water with higher contents of alkalies. This suggest that the cations and anions have played an important role in categorizing the waters of the Peshawar Basin. On the basis of physical parameters (i.e., pH, T, Ec and TDS), the water of all the rivers and aquifers of Peshawar Basin can be generally classified as “fresh”, however, “Slightly saline” water is also present at various places. The groundwater of some areas have pH in acidic range and have high SO₄ contents suggesting the contamination through coal and sulfide seems having metal sulfides. These areas of unsuitable drinking water have been delineated during this study.

In order to establish the chemical contamination in the water of the various aquifers of Peshawar Basin, the above mentioned parameters have been compared among various aquifers and also with the permissible limits of US-EPA and WHO. Various cations (e.g., Cu, Na, K, and Fe) anions (e.g., SO₄, Cl, HCO₃) and trace elements (e.g., Cu, Pb, Zn, Ni, Cr, Co and Cd) in the drinking water of Peshawar are generally within the permissible limits set by US-EPA and WHO. However, Ca, Mg,
Na, K, Fe, Pb, Cr, SO₄, Cl, and HCO₃ at some places exceed the permissible limit. This could generally be attributed to the compositional changes in the lithology of the area. The oxygen isotopic characteristics of both surface and groundwaters of the Peshawar Basin have been determined. The three rivers, Kabul, Swat and Indus have distinct δ¹⁸O signature with Indus river being the most depleted, Swat river being the most enriched and Kabul river midway between the two. The oxygen isotopic data for the underground water system of the Peshawar Basin indicate that the aquifers in the Peshawar Basin are recharged both by rainwater and waters from the Kabul and Swat rivers. In this respect the Kabul river remains dominant over the Swat river. This data also indicate that the shallow waters in the basin are more contaminated than the deep water. This suggests that there are chances that any pollution in the surface water can very easily be transferred to the underground water. This study also indicate that the soils of Peshawar Basin have higher contents of few major elements such as MgO, CaO, Na₂O, K₂O and trace elements such as Cu, Pb, Cr and Ni when compared with the normal soil elsewhere in the world. This could possibly be correlated with the surrounding rocks (ultrabasic to acidic nature) of Peshawar Basin.

It is evident from this study that though the waters of the piedmont aquifers are safe both for agricultural and drinking purposes but still the special measures shall be taken to protect the underground water of the area from contamination if the industries are to be established in these areas of the Peshawar Basin in future. In this regard, some recommendations are also given at the end.
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<td></td>
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<tr>
<td>ACPATW</td>
<td>Attack-Chenab piedmont aquifer tube wells water</td>
<td></td>
</tr>
<tr>
<td>ACPALDW</td>
<td>Attack-Chenab piedmont aquifer dug wells water</td>
<td></td>
</tr>
<tr>
<td>ACPFS</td>
<td>Attack-Chenab piedmont soils</td>
<td></td>
</tr>
<tr>
<td>AERFWA</td>
<td>Alkaline Earth Fresh Water with high Contents of Alkalis</td>
<td></td>
</tr>
<tr>
<td>cm</td>
<td>centimeter</td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>Electric Conductivity</td>
<td></td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Impact Assessment</td>
<td></td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
<td></td>
</tr>
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<td>FIG</td>
<td>figure</td>
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<tr>
<td>ft</td>
<td>foot Feet</td>
<td></td>
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<tr>
<td>IUCN</td>
<td>The world conservation Union</td>
<td></td>
</tr>
<tr>
<td>IARC</td>
<td>International Academic Research Council</td>
<td></td>
</tr>
<tr>
<td>Km</td>
<td>kilometer</td>
<td></td>
</tr>
<tr>
<td>KIA</td>
<td>Kohistan Island Arc</td>
<td></td>
</tr>
<tr>
<td>KLIA</td>
<td>Kohistan and Ladakh Island Arc</td>
<td></td>
</tr>
<tr>
<td>KPATHW</td>
<td>Khyber piedmont aquifer tube wells water</td>
<td></td>
</tr>
<tr>
<td>KPADMW</td>
<td>Khyber piedmont aquifer dug wells water</td>
<td></td>
</tr>
<tr>
<td>MPS</td>
<td>Khyber piedmont soils</td>
<td></td>
</tr>
<tr>
<td>Mt</td>
<td>million cubic meters</td>
<td></td>
</tr>
<tr>
<td>Ma</td>
<td>million ago</td>
<td></td>
</tr>
<tr>
<td>mg/l</td>
<td>milligram per liter</td>
<td></td>
</tr>
<tr>
<td>µg/l</td>
<td>billion gram per liter</td>
<td></td>
</tr>
<tr>
<td>nS/cm</td>
<td>milli Siemens per centimeter</td>
<td></td>
</tr>
<tr>
<td>msl</td>
<td>meters above sea level</td>
<td></td>
</tr>
<tr>
<td>MCL</td>
<td>Maximum Contaminant Level</td>
<td></td>
</tr>
<tr>
<td>MBT</td>
<td>Main Boundary Thrust</td>
<td></td>
</tr>
<tr>
<td>MKT</td>
<td>Main Karakoram Thrust</td>
<td></td>
</tr>
<tr>
<td>MMT</td>
<td>Main Mantle Thrust</td>
<td></td>
</tr>
<tr>
<td>Myr</td>
<td>Million years</td>
<td></td>
</tr>
<tr>
<td>NAEFW</td>
<td>Normal Alkaline Earth Fresh Water</td>
<td></td>
</tr>
<tr>
<td>NAS</td>
<td>National Academy of Sciences</td>
<td></td>
</tr>
<tr>
<td>NIOS</td>
<td>National institute of occupational Safety and Health</td>
<td></td>
</tr>
<tr>
<td>NRCC</td>
<td>National Research Council of Canada</td>
<td></td>
</tr>
<tr>
<td>NWFP</td>
<td>North-West Frontier Province</td>
<td></td>
</tr>
<tr>
<td>NCIE</td>
<td>National Centre of Excellence</td>
<td></td>
</tr>
<tr>
<td>PHPD</td>
<td>Public Health Engineering Department</td>
<td></td>
</tr>
<tr>
<td>PFWATW</td>
<td>Peshawar floodplain/stream channel aquifer tube wells water</td>
<td></td>
</tr>
<tr>
<td>PFWATL</td>
<td>Peshawar lacustrine aquifer tube wells water</td>
<td></td>
</tr>
<tr>
<td>PFWADM</td>
<td>Peshawar floodplain/stream channel aquifer dug wells water</td>
<td></td>
</tr>
<tr>
<td>PFWALD</td>
<td>Peshawar lacustrine aquifer dug wells water</td>
<td></td>
</tr>
<tr>
<td>PFS</td>
<td>Peshawar Floodplain/stream Channel soils</td>
<td></td>
</tr>
<tr>
<td>PLS</td>
<td>Peshawar lacustrine soils</td>
<td></td>
</tr>
<tr>
<td>ppm</td>
<td>part per million</td>
<td></td>
</tr>
<tr>
<td>SCARP</td>
<td>Salinity Control and Reclamation Project</td>
<td></td>
</tr>
<tr>
<td>WAPDA</td>
<td>Water and Power Development Authority, Pakistan</td>
<td></td>
</tr>
<tr>
<td>US-EPA</td>
<td>US-Environmental Protection Agency</td>
<td></td>
</tr>
<tr>
<td>US-PSHS</td>
<td>US-Public Health Services</td>
<td></td>
</tr>
<tr>
<td>USDA</td>
<td>United State Department of Agricultural</td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
<td></td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
<td></td>
</tr>
<tr>
<td>SMOW</td>
<td>Standard Mean Ocean Water</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

The quality of water and soil are a vital concern for mankind since these directly linked with human health. Both surface and subsurface water are widely used in many fields by human beings and animals, while the soil provides nutrition to plants, especially edible one's, which are ultimately utilized by the human being and animals. Water and soil are also extensively used for agriculture purposes. Therefore, the quality of water and soil are of prime importance in the environmental circle. Water and soil of the Peshawar Basin, N.W.F.P. is never studied systematically. Isolated studies are available which a few NGO, Institution and individuals carry out. Important work in this regard is of Bondsehuh (1992). The present study deals with the environmental geochemistry of water and soil of Peshawar Basin.

1.1 PESHAWAR BASIN

Peshawar Basin is an intramountain basin situated at the southern margin of the Himalayas (Fig. 1.1) and northwest of the Indus Plain. It came into existence during the Plio-Pleistocene time due to the uplifting of the Attock-Cherat Range (Burbank & Tahirkheli, 1985). It lies between the longitude 71° 15' and 72° 45' east and latitudes 33° 45' and 34° 30' north and covers an area of about 8,000 km². It is surrounded by mountain ranges of Khyber in west and northwest, Attock-Cherat in south and Swat in northeast, while its southeastern side is bordered by the Indus river, and is open for discharge of water. The surface water of Swat and Indus rivers and their small tributaries and groundwater is widely used by the inhabitants of the basin.

The Khyber Mountains are the eastern limit of the Sulaiman Range (Kakar et al., 1971; Chaudhry et al., 1974a, b; 1976; Butt et al., 1980). The Attock-Cherat Range marks the southern margin of the basin and is dominated by the metasediments of Pre-Cambrian
to Devonian age. Further to the south it is thrust over by the folded strata of the Kala-Chitta Range (Tahirkhel, 1970; 1980).

The Lower Swat-Buner Schistose group and Swat Granite Gneisses bound the Peshawar Basin in northeast (Martin et al., 1962). These rocks are regarded to form the base of the stratigraphic sequence of the basin (Tahirkhel, 1979; 1982; Kazmi et al., 1984). The southern slope of these rocks cover the Malakand mountains and stretch eastward into lower Swat-Buner area. Mesozoic meta-sedimentary rocks with protoliths of late Paleozoic characterize these mountains. Mesozoic meta-sedimentary rocks include the Saidu garnet-bearing graphitic phyllite and marble and the late Paleozoic comprises the green schist and amphibolitic facies meta-basalts, pelitic and psammitic schist and calc-silicates (Martin et al., 1962; Jan & Tahirkhel, 1969; Jan et al., 1969; Rehman & Zeh, 1970; Chaudhry et al., 1974a; 1976).

1 Drainage

Four major rivers, Kabul, Swat, Bara and Indus and their tributaries, drain the Peshawar Basin. Kabul river is the most significant because it drains the major portion of the basin (i.e., from the west at Warsak to the east at Khairabad) and falls into the Indus at Khairabad. The Kabul river divides the basin into northern and southern parts. The Swat river drains the basin from the northwestern side near Munda Qila village up to the Charsadda town where it joins the Kabul river. The Bara River drains the southwestern part of the basin. Kalapurai river is the exception, which originates within the basin and drains a large area of northern side of the basin. It joins the Kabul river 5 km downstream of Nowalpora. There are several other small perennial streams locally called “khwars”. They originate from the surrounding mountain ridges. These streams feed water and sediments to the Kabul and the other rivers. Two types of drainage patterns are recognized in the basin i.e., dendritic and trellis. The dendritic patterns are present in the
northwestern and northeastern parts of the basin whereas the torrent patterns can be seen in the southeastern and southwestern parts (Fig. 1.2).

i  Climate

Diverse type of climate is present in the basin. The western part is semi-arid to sub-tropical and the eastern part is sub-humid to sub-tropical. The data from two meteorological stations located in Peshawar and Mardan show that the average rainfall in the basin is between 340 mm to 630 mm. The hottest months are June and July with an average daily maximum temperature of 46-48 °C and the coldest month is January with an average daily minimum temperature of 0.5 °C. The mean annual potential evaporation is approximately 1200 mm in Mardan and Nowshera, 1100 mm in Charsadda and 1300 mm in Peshawar (WAPDA & TNO, 1994).

ii  Population and Domestic water supply

According to the census of 1981, the population of the basin is about 4.8 million, including the four major towns, Nowshera, Mardan, Charsadda and Peshawar. The Peshawar Basin is the most urbanised part of the province, and nearly 50 percent of the population resides in these major towns. The domestic water supply in the area is largely served by groundwater. In the rural areas dug wells are mainly used for the domestic needs. Approximately 60% tube wells are supplying water to the major towns and villages in the study area. The exact locations of the water supply tube wells have not been inventoried, neither the data are available on the total amount of water that is pumped for domestic use. The per capita use of water for the urban population is 50 liters per day and for the rural population is 25 liter per day. The estimated total ground water withdrawal for domestic use reaches 24 millions cubic meter per year for the urban areas and 37 millions cubic meter per year for the rural areas (WAPDA & TNO, 1994).
iv Industrial water supply

Peshawar Basin is one of the industrialized areas in the N.W.F.P. About one hundred and eight industries are registered in this area and water is the basic need for these industries for washing and cooling. Exact figures are not available on the groundwater use by the industries. It is seen that the water consumption in the industrial sector is negligible when compared to the domestic and agricultural sector (WAPDA & TNO, 1994).

v Irrigation with surface water

The surface water irrigation depends on rivers and canals. The Joo Seik Canal is the main canal in the area and also many other canals are tapping the Kabul, Swat and Bara rivers. All these canals carry water during periods of high river discharge in summer. The perennial canals are carrying water from the rivers to control the water level. The lower Swat canal drains out from the left bank of Swat river at Mandi Qila in the northwest of the Basin. Its commanded area lies between Charasadda and Mardan town and is 54,200 ha. 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 into the Abazai and Machai branches. The former commands 28000 ha in the northwest of the basin and the latter commands 84,000 ha in the north and east.

The Warsak high level left bank canal off takes from the left bank of Kabul river just upstream of the Warsak Dam. It enters the basin through a 660 m long tunnel and its command area lies in Dobita between the Kabul and Swat rivers. The Warsak high level right bank canal off takes from the right bank of the Kabul river opposite the left bank canal and flows through a 5760 m long tunnel to the basin. At the end part of the tunnel the water is lifted 48 m to feed the left canal while the rest flows through the gravity
canal. The command area of 108,300 ha. is between the left canal and the Kabul river canal.

In the northeast of the Peshawar in the Pehur canal off takes from the right bank of the Indus river 8 km downstream of Tarbela Dam. Its command area is 17,670 ha lying on both sides of the canal. The private canals and Kheiras 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 Department operated about 106 tube wells within the Peshawar Basin. These tube wells were used for irrigation purposes. A number of dug wells also used for irrigation are found in Mardan and Charsadda areas. According to Roberts (1988) the total estimated area irrigated by groundwater is 31,200 ha during Rabi and Kharif crops (WAPDA & TNO, 1994).

1.2 AIMS AND OBJECTIVES

The Peshawar Basin has been studied on various aspects of geology, including tectonics, sedimentology, stratigraphy and geomorphology, but no such systematic studies have been carried out on the quality of water and soil. By considering their environmental impacts on the living organism of the basin.

The main purpose of the present research is to determine the anions, cations (including heavy metals) and oxygen isotopes in the surface, groundwater and soils of the Peshawar Basin for utilization in environmental and geochemical modeling as follow:

- Classification of waters of the basin on the basis of concentrations of various elements using standard classification schemes (e.g., Piper classification).
- Categorization and comparisons of the waters of the basin for their utilization in drinking, domestic and agriculture purposes.
• Identification of anomalous concentration of various anions and cations in waters and their relation to possible health hazards/negative environmental impacts in the basin.

• Identification of anomalous concentration of trace elements and heavy metals in waters of the basin and their relation to possible health hazards/negative environmental impacts in the basin.

• Classification of the soils of the basin and delineation of anomalous soils on the basis of their chemistry (anion, cation and heavy metals).

• Investigation of possible relationship between the anomalous waters, soils and other source material including the Paleozoic rocks and Quaternary deposits of the basin.

• In order to reach the best possible sources of chemical component, including both normal and anomalous concentration, it is highly needed to characterize the container in which these waters exist on the basis, other than chemical parameters. Therefore, one of the objectives of this study is to understand the stratigraphy of the basin and its surroundings and use it for establishing the aquifer characters (hydrogeology) of the basin.

1.3 METHODOLOGY

During the present study various promising areas of Peshawar Basin in regard to contamination/hazardous risks were selected for water and soil sampling. About 112 water sample (both for surface and subsurface) and 36 soil samples were collected during this study (Fig 1.3).

Field Investigations

Various parameters of water i.e., pH, alkalinity, electric conductivity, and temperature were carried out at the site. Water samples were collected from each site in a
cleaned polythene bottle and was acidified with 5\% HNO₃ for further analyses in the laboratory.

The soil samples were collected at two different depths or horizons (A= 0-15 cm & B= 15-45 cm) at various places. The soil samples were stored in polythene bags for further analyses in the laboratory.

The acidified water samples were treated directly for the determination of cations, anions and various major and trace elements by using electrothermal Atomic Absorption Spectrophotometer, UV/visible spectrophotometer and Hach Dr/200 spectrophotometer.

The soil samples were pulverized and dissolved by different acids. These samples were then analyzed for major and trace elements by using both flame and electrothermal Atomic Absorption Spectrophotometer and UV/visible spectrophotometer. All these analyses were carried out at the geochemistry laboratory of National Centre of Excellence (NCE) in Geology, University of Peshawar. The detail procedures are given in appendix B. The isotopic determination of water samples have been carried out at the Department of Geoscience; University of Arizona USA.
Figure 1.3 Location map of Water, Soil and Isotopes samples from Peshawar Basin
Figure 5.2 Map showing the Drainage Pattern of the Peshawar Basin.
PREVIOUS WORK


Tectonic framework of the Peshawar Basin evolved through the studies of Calkin et al. (1975), Tahirkhel (1970), Burbank (1962), Yeats and Hussain (1987) and Hussain et al. (1989). These authors believe that the subsequent erosion of the sediments occurred 0.6 Ma ago along the southern margin of the basin as a result of pressure ridges, folding, and faulting in the basin. They concluded that high angle faults probably extend deep into bedrock and cut through the Holocene sediments at places.

Allen (1964), Nazari (1973), Hameed et al. (1986), Khan (1987), WAPDA (1985; 1988; 1989 and Hussain et al. (1990) studied the Pleistocene sediments in the north-east of the Peshawar Basin and concluded that the sediments were deposited in a lacustrine environment. The extension of the lake sediments towards the northern part of the basin took place during the overflow inundation of the entire basin of lake sediments near Risalpur in the Peshawar Basin. They suggested that fracture fills extensive disturbance and the presence of infrequent pebble and cobbles dropstones, characterize the lacustrine sediments of the Quaternary age.

A number of workers contributed towards a better understanding of the Paleozoic tectonic and depositional history of the Peshawar Basin and surrounding areas. These include Coulson (1936), Martin et al. (1962), Davis and Ahmed (1963), Teichen and Stauffer (1965), Stauffer (1966), Ali and Anwar (1969), Latif (1970), Fuchs (1975),
Pouge and Hussain (1986), Hussain et al. (1991), Jafirkhani (1978), Suid et al. (1977),

According to Burbank (1983) the basin sediments formed approximately 2.4 to
1.6 Ma ago and probably derived from the volcanic complex of Dushi-e-Nawar in the
east-central Afghanistan. The studies also indicate that:

1. The sedimentation process was continued until early 0.6 Ma ago, when the uplift
   of the Attock-Cherat Range caused folding and exposure of the sediments.

2. The deposition of intermontane-basin sediments about 2.8 Ma ago over the
   folded and faulted Muree Formation of the Miocene age.

3. The deposition of more than 300 m thick sediments by alluvial fans progressing in
   the basin from the Attock-Cherat Range along the southern margin.

4. Erosion of the lower slope of these alluvial fans.

5. The production of the young geomorphic feature in the form of the piedmont
   plains in the basin.

Cornwell (1994) working on the history of catastrophic floods along Indus valley
and Pehawar Basin describes the lacustrine sediments indicating rhythmic flooding and
lake-related depositional processes. He also believes that the depositional sequence in the
basin is Quaternary sediments, rhythmites and Punjab erratic; all formed as a result of
catastrophic flooding along middle Indus valley followed by loess and other sediments as
the youngest ones (see also Cornwell & Hamidullah, 1992).
CHAPTER 3

STRATIGRAPHY AND HYDROGEOLOGY

2.1 REGIONAL GEOLOGY

The Peshawar Basin is an integral part of the Himalayan continental collision zone. In the northern Pakistan three principal tectonic blocks, the Karakoram plate, the Kohistan island arc and the Indo-Pakistan plate characterize the Himalayas. Two major crustal sutures (Fig. 2.1) separate these blocks, the northern suture or the Main Karakoram Thrust (MKT) and the southern suture or the Main Mantle Thrust (MMT). The Indo-Pakistan plate got separated from Gondwana land and migrated northwards during early to middle Cretaceous (Powell, 1979). The northern suture formed in response to the closing of the ocean between the Kohistan island arc and Asian plate in late Cretaceous (Coward et al., 1986). The collision between Kohistan island arc and Indo-Pakistan plate took place along the southern suture in Paleocene 55 Ms. (see Hamidullah & Omer, 1992 and many others). After the collision, the continued displacement of the Indo-Pakistan plate occurred, which resulted in crustal shortening and the rising of the mountains chains through thrust systems i.e., Main Boundary Thrust (MBT) within Indo-Pakistan Plate (Power & Conaghan, 1973). The Peshawar Basin constitutes an essential part of the area extending from MBT in the south to MMT in the north (Bartholm & Reynolds, 1984). The MBT and MMT are considered as tectonic boundaries of Peshawar Basin. The Attock-Cherai Range exposed to the south of the Peshawar Basin is folded into several south-verging anticlines and synclines. There are three major faults named as: Khairabat Thrust, Cherai Thrust, and Hissarabag Thrust dominating the structural style of the area (Fig. 2.2).

On the bases of thrust and faulted contacts between different lithologies in and around the basin, Yeats and Hussain (1987) have regarded it an ancient topography as
Figure 2.1 Regional tectonic map of North Pakistan showing the Peshawar Basin and Main Thrust blocks. (Coward et al., 1986).
representing valleys and ridges buried under the Quaternary strata. This is supported by
the existence of thrust faulted contact of the Nowmern reef complex with the underlying
Kinder Phyllite (Tahirkheli, 1979).

This indicates that the major tectonic processes involved in the development of
MMF and MBT have also played a role in the formation of Peshawar Basin. Zeitzler et al.
(1982) believes that since the area was uplifted about 22 to 15 Ma, the presence of cliffs
and windows in different parts of the basin are all surface expressions of a very long
period of erosion.

The Quaternary alluvial and aeolian unconsolidated sediments have covered
extensive area in the intermountain basin and the Indus Plain. Quaternary glacial and
fluvio-glacial deposits are confined to basins and gorges of the Himalayas and Trans-
Himalayan ranges.

The topography of the Peshawar Basin suggests that piedmont/alluvial fan
deposits, and loess deposits cover major part on the periphery of the basin while the
central limited part is occupied by lacustrine, fluvial, and stream channel deposits. These
deposits represent various types of depositional environment within the basin.

Burbank and Tahirkheli (1985) believe that deposition of these sediments started
about 2.8 Ma when the deformational processes in the Attock-Chenab ranges ended.
Subsequently, more than 300 meters of basin-filling sediments accumulated
unconformably over the folded and faulted Marree formation of Miocene age at a rate of
about 15 cm/1000 years. By around 2.5 Ma, the alluvial fans were derived from the
uplift of Attock-Chenab range, that eroded slowly into the Peshawar Basin at Dog Ismail
Khel (Burbank, 1985). At the same time the floodplain and floodplain deposits formed on
the western part of the basin near Garhi Chandan and in the surroundings. Subsequently
the braided river invaded the basin, represented by the downstream and fluvial deposits of
the alluvial fans, containing silts in coarse-grained gravel. These sediments are transitional in character between the overbank deposits of the Indus plains and the sediments of foreland-basin (Yeats & Hussain, 1987). Hubrank (1983) and Custrell (1994) reported that the Peshawar Basin inundated periodically by catastrophic floods, occurred in prehistoric times.

2.2 PALEOZOIC STRATIGRAPHY

The Paleozoic sequence of the Peshawar Basin is exposed in Khyber Mountains Range, Attock-Cherat Range, Nawabshah-Swabi hills and Lower Swat Range (Figs. 2.3-4). Geology and geomorphology of the Peshawar Basin and surrounding areas is discussed below and photographs of study sections are given in appendix – B).

2.2A Khyber Mountain Range

The Khyber Mountain Range lies in the west and northwest of Peshawar Basin (Figs. 2.3-4). The elevation of these mountains range from 310 to 840 meters above sea level. The topographic expression is marked by gentle and moderate escarpment slopes. In the vicinity of the basin, the paleo-stratigraphic sequence of Khyber Mountain Range comprises of non-sediments and low grade metamorphic rocks with minor intercalations (Shah et al., 1986). However, this sequence gradually changes into a succession of schist and limestone beds with abundant acid intrusive in the Mohmand and Umarghel territory in the northwest. Further north and northeast in the Duihar Agency, the exposed rocks are dominantly schistose, acid plutonic, volcanic and volcano-sedimentary (Chaudhry et al., 1976; Bud et al., 1980).

The foot-hills consists of alluvial fans composed of heterogeneous sediments, deposited by several perennial and non-perennial braided streams of ephemeral pattern that originated from the bordering mountains and flow towards the basin in west and northwest. Deep gullies have formed by these streams in the entire area. Within the
Figure 2.3 Correlation of Paleozoic stratigraphic sequence of the Peshawar Basin
escarpments, the alluvial deposits also form valley-sills in the lowlands. Main tributaries cross the moderately deep to the shallow valleys resulting into the terraces of 8 m to 34 m thick in the downstream ratio. In various places, Lenticular deposits of gravels, cobbles, sand and siltstone of fluvial origin are noticed, which are indicative of the entrenchments of the Kabul and Swat rivers in the area.

The climate of the Khyber area is semi-arid and characterized by sparse vegetation reflecting a short raining season. The annual precipitation is about 650 mm. The summer showers are torrential and of short duration and the winter showers are of low intensity and long duration originating from Mediterranean and Caspian seas. Therefore, the maximum recharge to groundwater is during winter. The higher elevation bordering mountain area get more shower than lower elevation plains. The temperature generally is variable during the year. During summer a maximum of 45 °C has been recorded, whereas below freezing conditions frequently occur during winter.

The Cambrian rocks have not been identified in the Paleozoic complex of the Khyber Mountain Range (Fig. 2.4).

i  Ordovician to Silurian

Landihotal Formation

The Landihotal Formation is exposed in the eastern part of the Khyber Agency near Afghan border. The type locality of the formation is the Landihotal village along Khyber Pass. It is a prominent and thick sequence, forms low rolling hills, escarpments and cliffs. The formation consists of dark greenish and dark grey slates, schist and phyllites, interbedded with fine-grained sandstone and siltstone at places. The beds of siltstone and sandstone exhibit sole marks, pillow structure and consolidate building. Lamination and praded building has also been reported from the sequence. Smollier (1966b) correlated the Landihotal Formation with the upper part of the Panipir Formation of Nowshera-Swabi.
area. The thickness of the formation is 1830 m and it has been assigned Ordovician to Silurian age (Shah et al., 1980).

ii. Devonian

Khyber Undifferentiated Carbonate Complex

The Khyber Undifferentiated Carbonate Complex has a faulted contact with the underlying Landikotal Formation. The formation extends from Ghundi Sar in the south to Shahid Mann in the north. It is highly deformed in the northern part and dissected by basic rocks. The formation consists of shales, quartzite, limestone and dolomite. The limestone beds are fossiliferous and contain brachiopods and crinoid remains. The Khyber Undifferentiated Carbonate Complex is correlated with Nowshera Formation and assigned an early Devonian age (Shah et al., 1980).

Shagai Limestone

The Shagai Limestone overlies the Landikotal Formation and the contact are marked by the thrust. The type locality is one km northeast of Shagai Fort (Stauffer, 1968a). The formation comprises of light grey, thinly laminated, nodular and weathered limestone. The nodules range in size from 4 to 6 cm showing serrate boundaries. The formation consists of black, partly brown, thin to medium-beded limestone with thick calcite veins. Limestone is unfossiliferous, locally dolomitic and highly fractured along the contact of Landikotal Formation. The reported thickness of the Shagai Limestone is 46 m. Shah et al., (1980) assigned Silurian to early Devonian age and correlated the formation with Inzari Formation (Attock-Chirat Range) and Nowshera Formation respectively.

Ali Masjid Formation

This formation extends over entire Khyber Agency (Stauffer, 1968b). The type locality is Ali Masjid village (Khyber Pass). It has a thrust fault upper contact with
overlain by quartzite and limestone at the type locality. From base to top it displays the grey quartzite and undifferentiated metasandstones, with highly fossiliferous beds containing brachiopods and corals in the west of the type locality indicating an upper to middle Devonian age. Shah (1977) correlated the Ali Masjid Formation with Miari Bandha Quartzite (Nowshera-Swabi) and Hiji Gak Formation across the border in Afghanistan.

### Carboniferous-Permian

#### Khyber Limestone

The Khyber Limestone conformably overlies the Ali Masjid Formation (Hayden, 1898; Griswold, 1852; Stansfeld, 1908). Its type locality is the Ali Masjid village (Khyber Pass). It consists of thick-bedded limestone, marbles and massive dolomite, locally with minor shale intercalations. In the middle part of the formation the limestone rich, sandy beds indicates a disconformity (Shah et al., 1980). The upper part of the formation is intruded by basic dykes and sills in the north and west of the type section. At Tarha Mola and Misri Khol, the Khyber Limestone is highly fossiliferous and intercalated with shale. Shah et al (1980) assigned a Permian age to the formation.

### 2.2B Attock-Cherat Range

The Attock Cherat Range lies in the south of the Peshawar Basin (Fig. 2.4). The general trend of the Attock-Cherat Range is east-west and it turns to the south-west and merges into Nizampur-Kotar mountains in Damat Adam Khol, a tribal territory, south of Peshawar. The elevation ranges from 318 m to 1020 m above sea level at Cherat and 1820 m to 1933 m above sea level at Jalata Sar. The relief is low around the Attock Range (Fig. 2.4). The rocks are covered by alluvial deposits near Karara hills and drop out in the west (Dag lamesh village), northeast (Khyber Mountains Range) and southern Hazara. The stratigraphic sequence is composed of Proterozoic and Paleozoic.
rocks (Stausser, 1968b; Tahirkheli, 1970). Thrust faults trending east-west are running along the northern and southern face of the range and yield imbricate type structure in the area. The rocks are composed of argillite, slate, phyllite, subordinate quartzite and limestone intruded by dolomite sills and dykes.

At the foot hills of the entire Attock-Cherat Range, the lowland area is filled with unconsolidated sediments, derived from the adjacent hill and hill slopes forming piedmont plains drained by several intermittent and seasonal torrential streams (Figs. 1.1-2). These streams ultimately join Kabul river in the north. These torrential streams carve deep gullies in the piedmont deposits and carry large quantity of sediments. Some of these khwara (streams) are very short lived and do not drain an extensive area. The climate is semi-arid with hot summer and cold winter. The temperature rises more than 45°C in summer and falls to almost zero°C in the winter. The annual precipitation estimated is 600 mm for the plain area and 850 mm for the mountains.

Cambrian

Dawotza Formation

The Dawotza Formation overlies the Procamian sequence in the area including Manki Formation, Shakhet Formation, Usb Khuituk Formation, Shekhali Formation and Dakhan Formation. It represents the lowest part of the Cambrian rocks in Attock-Cherat Range. It is exposed on the southern slopes of Attock-Cherat Range (Hussain et al., 1990). The upper contact is gradational with the overlying Husantang Formation while the lower contact is not exposed. The formation is represented by light grey to yellowish grey unfossiliferous dolomitic limestone that grades upward into grey-green and maroon shale. The maroon shale in the upper part contains worm burrows. The thickness of the formation is 34 m and it is correlated with Ambar Formation of Nowshera-Swabi area (Hussain et al., 1990).
ii Ordovician-Silurian

Hisartag Formation

The Hisartag Formation is overlain conformably by the Inzari Limestone and has a conformable gradational contact with underlying Darwaza Formation. The upper part of the formation displays thin bedded to massive, yellow to brown, grey and finely laminated limestone, while the lower part consists of dark grey to black argillite, light grey quartzite, sandstone with intercalated slaty shales and contain worm burrows (Hussain et al., 1989; 1990). The formation is 650 m thick. On the basis of lithology the Hisartag Formation is correlated with the early to middle Ordovician Miari Banda Quartzite of Nowshera-Swabi Area (Hussain et al., 1990).

iii Devonian

Inzari Limestone

The Inzari limestone is thin to thick bedded yellowish to greenish-grey, crystalline, unfossiliferous, and laminated (Hussain et al., 1990). Dolomite and argillites are common in the formation. Hussain et al. (1990) considered it as time equivalent with early Devonian Nowshera Formation.

2.3C Nowshera Swabi Hills

Nowshera hills are located on the right bank of Kabul river and extend from Nowshera to Jehangira. The southern margin is marked by Kabul river. The elevations of these hills are 1200 m above sea level at Sarang Kandra and in alluvial area ranges from 280 m to 394 m above sea level near Jehangira (Fig. 2.3).

The southern part is characterized by the high undulating deposits, traversed by gullies and khwers originated in the basin and draining into the Kabul river. Some of the isolated outcrops of bedrock are exposed in Nowshera and Swabi area in the Peshawar Basin. In the basin the rocks of the Nowshera Formation are regarded as ancient barrier
reef based on the fossils. The unconsolidated deposit in this area are comprised of 
lacustrine deposits with sandy intercalation and overlain with very young alluvial 
deposits. The flood plain deposits are mostly formed along the riverbank during high 
flood. These deposits consist of sand, silt and clay with clast material.

The Kabul river is the main river of the Nowshera-Swabi hills which controls the 
entire drainage system of the valley. A number of intermittent and seasonal hill torrents 
originated in the piedmont plain, joining Kabul river in the south. These torrents are 
carrying floodwater during raining season and produce deep gullies in the piedmont 
deposits. Some of these khwars receive spring water and flow downstream for some 
distance and gradually vanish in the streambed. The climate of the area is subtropical 
with hot summer and cold winter. The weather is variable and characterized by frequent 
showers and occasional gales. The temperature ranges widely and rises about 48 °C in the 
summer and drops below freezing point in winter. The annual precipitation is about 722 
mm while mountain area receives 1167 mm of rain per year. The stratigraphy of 
Nowshera area has been modified and revised on the basis of fauna and geology by 
Pourag and Hussain (1986) and Hussain et al. (1989).

i Cambrian

Ambar Formation

The contact of the Ambar Formation with the Misri Banda Quartzite is 
unconformable. The formation is mainly composed of brownish-grey dolomite with chert 
lenses and shale. The rocks exposed near Misri Banda and Mian Dheri 
illages along the Kabul river. The upper part is more massive and contains 
stromatolitic laminations. Dolomite pebbles of the Ambar Formation are present in 
the basal conglomerate of the Ordovician Misri Banda Quartzite. The formation is
about 425 m thick. On the basis of lithology it is correlated with the Abottabad Formation (Cambrian) of Hazara (Hussain et al., 1990; Fig. 2.3).

ii. Ordovician–Silurian

*Misri Banda Quartzite*

Misri Banda Quartzite of Early to Middle Ordovician overlies unconformably upon the Amber Formation of Cambrian (Staufer, 1966a; Pogue & Hussain, 1986; Hussain et al., 1988; 1990). It is predominantly composed of feldspathic quartzite with subordinate argillite. The rocks are grey to pink in colour, cross-laminated and contain worm burrows and ripple marks (Hussain et al., 1989; 1990). The upper part formation contains tapholite trace fossil “Crepidocystites”, of lower to middle Ordovician age. The base is locally formed by conglomerate composed of calcareous quartzite matrix. The formation is 175 m thick.

*Panjpir Formation*

The type locality of Panjpir Formation is Panjpir village in Mardan district. The contact of the Panjpir Formation is unconformable with the underlying Misri Banda Quartzite (Fig. 2.3; Pogue & Hussain, 1986; Hussain et al., 1989; 1990). The formation comprises of limestone and argillite. In the lower part of the formation, the limestone is highly fossiliferous and consists of crinoids, pelecypods, cephalopodes and luvianian conodonts (Hussain et al., 1990). In the upper part, nautiloid fragments have been found in the limestone. The crinoidal limestone at the top yields conodonts of late Silurian age (Talent & Mawson, 1979). The formation is about 1075 m thick. Pogue and Hussain (1986) have interpreted the age of formation as Middle Ordovician to late Silurian.
Devonian

Nowshera Formation

The Nowshera Formation conformably overlies the Pungipur Formation (Stauffer, 1968a; Pogue & Hussain, 1966; Hussain, et al., 1989; 1990). The type locality is 3.5 km north of Nowshera town. Pogue and Hussain (1966), defined the Nowshera Formation by including the lower fossiliferous limestone/dolomite unit (Nowshera Formation; Stauffer, 1968a), the middle unit of carbonate-cemented sandstone (Miri Bunda Quartzite, Stauffer, 1968a) and upper limestone/dolomite unit (Pir Sabak Formation; Shah, 1977). The marble exposed near Rasulpur area consists of rich fauna, characteristic of reef environment (Stauffer, 1968). Talent and Mawson (1979), assigned early Devonian to the formation on the basis of conodonts. Corals in the upper part (Pir Sabak Formation), indicate a (pre-late) Devonian age (Shah et al., 1970). The thickness of the Nowshera Formation is about 595 meters (Pogue and Hussain, 1986).

Carboniferous-Permian

Jafar Kando Formation

The Jafar Kando Formation overlies the Nowshera in the northeastern part of Nowshera Formation at Rustam area (Pogue & Hussain, 1986). The basal unconformity is marked by a discontinuous conglomerate bed. The formation consists of agglutines with subordinate limestone, quartzite and conglomerate. Pogue et al. (1992) reported conodonts of late Devonian to early Mississippian and late Pennsylvanian age in the formation. The age has been assigned as Carboniferous.

2.2D Lower Swat Range

The lower Swat Range is located on the northern margin of the Peshawar Basin (Fig. 2.4). The landscape composed of steep to gentle slopes. The elevation ranges between 716 m to 1625 m above sea level in the north and at the bedrock of the Swat
in the southwest of the area respectively. Rock exposures are good except in the
wider plains. The gentle slopes and flat plains of the area contain stream, river and wind
blown deposits of the recent age.

Structurally the lower Swat area is lying below an intercontinental tectonic suture,
the Main Mantle Thrust (MMT). In the northwest and southeast the major structure lies
with alternating anticlines comprise of granitic bodies and synclines with metamorphic
rocks. The older structures are related to the syntax of the northwest Himalayas. The
younger structures are present due to the northward underthrusting of the Indian shield
along MMT and southwards obduction of the Kohistan terrane (Shams et al., 1983). The
rocks have extensive exposure in the region.

The Swat river drains in entire Swat valley. A number of small streams are
originated from the hill slopes and discharge their water and sediments in the Swat river.
The climate of the area is subtropical with hot summers and cool winter. The weather is
variable and characterized by frequent showers and occasional gales. The temperature
rises about 41°C in the summer and draw below freezing point in the winter. The annual
precipitation is 856 mm while mountain area receives 1287 mm per year.

The stratigraphy of the lower Swat Range has been revised by various workers
since the reconnaissance work by Martin et al. (1962), Kazmi et al. (1984) subdivided the
lower Swat Range into; Swat granite gneisses, Manghaur schist, Alpurai schist, Saidu
schist, and the ladus melange group. According to revised stratigraphy, the Swat granite
invasions intruded into the Manghaur schist and both are unconformably over lain by the
Alpurai group.
Cambrian

Swat Granite gneisses

The Manglar schist of the lower Swat Range, metasedimentary sequence intruded by the Swat granite gneisses towards the south of the Main Mantle Thrust where latter form the basement rock. Martin et al. (1962) described these Swat granite gneisses as the Choga granite which are exposed east of the lower Alpurai village. The Loe Sar granite occurring in the south of Manglar, the Ilkan granite in south of Mingora (Rosenberg, 1985; Ahmad, 1988) and the tourmaline granite gneiss along the unconformity below the Alpurai group are all regarded as the Swat granite gneisses by Lawrence et al. (1989) and DiPietro (1990). Le Fort et al. (1980) correlate the Swat granite gneisses with the Manshera granites and gneisses of Hazara. Radiometric data ranging from Cambrian to lower Ordovician have been reported from other granitic gneisses in Lesser Himalayas, (Le Fort et al., 1983; Le Fort, 1986). The age assigned to this formation is late Cambrian (see Le Fort et al., 1980).

Devonian

Jobra Formation

The Jobra Formation unconformably lies on the Swat Granite Gneiss and unconformably overlies by Alpurai Group. In the Swat about 5 km southeast of Illume discontinuous lenses of cation-silicate bearing marble has been named Jobra Formation (DiPietro, 1990). On the basis of its stratigraphic position and cation-silicate mineralogy, it can be correlated with the Nowshera Formation. DiPietro (1990) assigned it a Palaeozoic age on the basis of its position between the Swat granite gneisses and the Alpurai group.
iii Carboniferous

**Marghzar Formation**

The Marghzar Formation unconformably overlies the Manglaue schist and Swat granite gneiss (c.f., Alpurai Schist of Kazmi et al., 1984, 1986). The Marghzar Formation is overlain by the calcareous schist of the Kashalu Formation followed by the Saidu Schist and Nikanai Ghar Formations. The Marghzar Formation consists of gneissose schist, amphibolite, hornblende schist, psammitic schist and phlogopite marble. The Kashalu Formation has yielded late Triassic (Carnian) conodonts (Pogue et al., 1992) and the sequence above the Marghzar Formation is Mesozoic in age (DiPietro, 1990; 1991). The formation is Carboniferous in age (Pogue et al., 1992).

iv Carboniferous- Permian

**Alpurai Group**

The Alpurai Group is exposed in the Swat area near Baroch (Pogue & Hassain, 1986). Kazmi et al. (1984) distinguished three different types of sediments in the lower Swat-Buner area, which are:

a) twice metamorphosed crystalline schist (Manglaur schist) probably of Precambrian age,

b) metamorphosed shelf sediments of probable Paleozoic age (Alpurai group), and
c) metamorphosed possible Indus flysch equivalents (Saidu member).

The Alpurai schist unit has been further subdivided by DiPietro and Lawrence (1997) into four distinct members.

a) the Marghzar member, occurs at the base and consist of a variable sequence of K-feldspar-bearing psammitic schist, phlogopite-bearing-calc-schist, garnetiferous pelitic schist, and quartz-hornblende.
b) the amphibolite horizon of Maria et al. (1962) occurring at the top of the Buvme member.

c) the Kachna member overlies the Marghuzar member and consists principally of
garnetiferous calc-schist, cale-phylabies and marble.

d) Graphitic phyllites, characteristic of the overlying Sainhu member. Also thick
sequence of marble and dolomitic marble characterize the stratigraphically
equivalent Mianri Ghar member of Ahmad et al. (1988).

Lawrence et al. (1985) reported a large overturned orthoclines nappé in the rocks
of the lower Swat Range. Rosenberg et al. (1985) suggested three different phases of
deformation in the rocks, south of the MMT. More recently, rocks of the lower Swat
have been found to have undergone multiple deformation with at least four periods of
folding (D Pietro & Lawrence, 1997). South east of the Swat River K-Ar dates
determined on biotites from the Loi Shilmaa and Silai Patti carbonatites yield 31 ± 2 Ma
(s. Bas et al., 1987). Further south Rb/Sr determinations on the Koga carbonatite in the
Ambeli complex yields the dates 297-315 Ma (s. Bas et al., 1987).

2.3 QUATERNARY STRATIGRAPHY

The major portion of the Peshawar Basin is covered with the Quaternary
sediments ranging from Pleistocene to Recent in age. These Quaternary sediments overly
unconformably the Pre-Cambrian rocks in basin and reflect the composition of deposits
of the eroded area. These sediments are present along the surrounding foothills as well
as in the central part of the basin and are characterized by horizontal repetitive graded
beds of the sand, silt, clay and gravel. These deposits are physiographically classified as
piedmont deposits, fluvial plain and stream channel, lacustrine/loess sediments by all the
previous workers (Allen, 1964; Ponge, 1980; Cumme, 1992; WAPDA & TNO, 1994; Fig. 2.5).
Figure 2.5  Map showing the Location of studied sections and Quaternary geology of the Peshawar Basin
The general stratigraphy of these basin fill sediments are mainly comprised of alternating sequence of buff to olive-grey clay and silt overlain with grey coarse to fine sand. At several localities the sand horizons are capped by thick horizon of pebbles, gravel and boulders. The lithology of these sediments represents the composition of the deposits of the catchment area within the Peshawar Basin.

Sedimentological features such as, laminations, cross bedding, ripple marks, occasional mudcracks and bioturbation as well as sediment filled fractures are common in the various stratigraphic sections. Burrow cast was also observed throughout the sections. The laminations and cross beddings occur throughout the sections in silty clay and clay to coarse sand horizons. Clay beds with buff to olive brown colour were observed at several horizon within the measured sections. These clay beds were horizontally continuous within the same exposures but correlation of these clay beds across different sections was not successful. These clay horizons thus represent either a local depositional phase from the nearby drainage basins or a disparate distribution of clay horizon, presenting the remnants of a pedogenic horizons throughout the Peshawar Basin (Cornwell, 1994).

Sediments-filled fractures were also observed within all the sections. Hanafy et al. (1986) interpreted these fractures as sedimentary dykes at Jelala.

These fractures are inhumate and usually wider near the top of the section. The origin of these fractures are unknown, however, they are indicating wide tectonic processor within the basin fill sediments. Fine-grained sediments exhibit burrow casts and bioturbation horizon in several sections. These bioturbated horizons distinguish the overlying and underlying sediments which is an evidence of increasing activity and present the characteristic periods of deposition. The high levels of bioturbation determined the depositional cycles (Cornwell, 1994).
Excellent exposures of thick sections of Quaternary sediments are present along the surrounding foothills as well as in the central part of the basin. As a part of this study, previously described as well as new sections were selected for detail study. These stratigraphic sections include, Warsak, Takala, Minki, Piran, Ziarat Kata Sahib, and Spin Khak. All the sections were measured, sampled and described on the basis of field features such as, color, lithology, bedforms, sedimentary structures and overall morphology of the deposit. Figure 2.5 outlines the location of these sections in the Peshawar Basin. Considering these data, stratigraphic correlation among the deposits from various localities has been carried out.

2.3A Peshawar Piedmont Sediments

The Peshawar piedmont deposits were observed along the margins of the Peshawar Basin in Khyber Range, Attock-Chera Range and Lower Swat Range (Fig. 2.5). These deposits are formed along the foothills, where the rivers and streams deposit their coarse material when entering the plains and form the coalescent alluvial fans. These alluvial fans are dissected by the hill torrents in the lower slopes of the mountains and form the piedmont. These deposits comprise of gravels, cobbles, sand and siltstone of fluvial origin and indicate the encroachment of the Kabul and Indus rivers in that area. These alluvial fan are overlaid by thick layers of loess which is well-sorted fine silt.

i  Warsak Section

Thick fluvial deposits of sediments (sand and gravel) are present on the foothill of the Khyber Mountain Range, exposed along the Warsak-Janrud road (Plate 1). Along the Warsak-Janrud road, the deposits are exposed in 4 x 6 kilometers area and can be easily studied.

The general stratigraphy of the section is characterized by the thick fluvial sequence (Fig. 2.6). The basal portion of the section mainly comprising bar of fine sand
Figure 2.6  Stratigraphic section of the sediments at the Warsak Road (West of Peshawar Basin)
Plate 1. Thick Quaternary fluvial sequence exposed along Warsak-Jamrud road. The thickness of the entire sequence is more than 150 m.
that shows low-angle cross stratification. The sandy sequence contains several palaeosol layers ranging in thickness from few to 10 centimeters. These bars occur in the planar beds, which are separated by several palaeosol horizons. The exposed sand in the section was semi-indurated but upon deeper penetration the sand became unconsolidated.

The palaeosol horizons are dominated by brown to red oxidized layers (mm scale) showing small scale nodular fabric and root cast. Occasionally the sediments display the stratigraphic feature i.e. cross to planar laminated beds, channel- bedding with burrows, ripple marks and graded bedding (Plate 2). Above the basal part, the sandy sequence is overlain by thick lodge forming conglomeratic beds. The conglomerates are normal to inversely graded, non-graded and composed of matrix supported to clast-supported, conglomerates. These conglomerates occur in 50 cm to >2 m thick beds. At many places these conglomerate are wavy and erosional. The clast are moderate to very well rounded, sorting is relatively good, shape vary from circular, ellipsoid, disc and spherical (Plate 3). The identified lithology at type locality includes, granite, quartzite, schist, gneiss, basic, ultra-basic and volcanic. This lithology is showing the encroachment of Swat and Kabul rivers in the area.

In the nearby exposure, approximately one meter from the specific measured section, about 1 m thick buff colour lake sediments are exposed (Plate 4). The basal portion of the lake sediments consists of horizontal beds of silt and clay with calcareous concretions, while the top dominated by coarse, clast-supported conglomerates. These conglomerates composed of predominantly igneous and metamorphic clast. The lithology of the conglomerates was markedly similar to igneous and metamorphic origin.

At all other localities in the Warsak area where these fluvial exposure reveal underlying sediments, the fluvial sediments lie unconformably on the alluvium consisting of silty-clays with some sand and gravel and sparse channel showing similar origin.
Plate 3 Close-up view of clast-supported conglomerate (site upper sequence), Warsak section. Note abundance of well rounded spherical to disc-shaped clasts representing a different of lithologies. Hammer scales is 28 cm in length.
Plate 4 Close-up view of the lake beds, characterized by thin to medium, Wavy to planar, rhythmic beds of fine sand to pebbly sand along warsak-Jainrud road.
At several localities within the Warsak section, the fluvial sediments are overlain and occasionally interbedded with yellowish brown alluvial-loess. In different places where the stratigraphic relation between the sediments are visible or in the areas where the topography had not been incised by the local stream, erosion these loess sediments were observed. These loess deposits produce a rolling hill landscape. Large boulders of Himalayan origin occurred sporadically on the loess sediments in the small valleys. These boulders are the result of recent floods whose sediments are eroded from the surface.

ii Ziarat Kaka Sahib Section

The thick fluvial sediments are exposed along an incised stream (valley) on the waning edge of an alluvial fan sequence about 12 km south-southeast of Nowshera on Nowshera-Ziarat Kaka Road near Wall village. This alluvial fan sequence progrades to the northward in the Peshawar Basin from the Attock-Cherat Range (Fig. 2.5). The fluvial sediments were deposited unconformably upon the late Pre-Cambric Manki Slate Formation at the locality. The flood deposits are overlain by alluvial fan sediments, which are mainly composed of limestone and Manki slate slabs.

Figure 2.7 illustrates the 20 m thick stratigraphic section measured at Ziarat Kaka Sahib. The basal part of the section comprise of clast supported conglomerate and silt and clays with lenses of coarse grain sand. The silt and clay are predominantly buff in colour. The sand is grey in colour, massively bedded and indurated into the fine grained sediment (Plate 5-6). This is due to the percolation of groundwater more readily through the coarser grained sands and the precipitation of calcite as a cement agent in these sediments. The contact between individual sandy beds and overlying silt and clay is relatively sharp. The fine lamination is present within this sandy horizon. In several isolated locations the fan clasts range in size from sand and gravel to boulders. The
Figure 2.7  Stratigraphic section of the sediments at the Zirat Kaka Salhe exposed south of Eshawar Basin.

Lithological Legend

- Cast Supported Conglomerat
- Finely laminated Sand
- Pebble bearing Silt and Clay
- Clay and Silt
Plate 5 Fluvial sediments exposed at Ziarat Kaka Sahib. (Ziarat Khawar). The basal part showing sandstone which is low-angle, cross laminated and moderately sorted.

Plate 6 Clast-supported conglomerate at Ziarat Section. Note abundance of spherical to disc-shaped clasts representing a variety of lithology. Hammer (28 cm) is for scale.
stream channel cuts were filled with buff colour silty clay and loess in the uppermost flood sediments. These channel cuts are filled with overlain alluvial fan sediments.

The silt and clay are massively bedded and exhibit spheroidal weathering. The calcite carbonate concretion occurs along with sporadic gravels and pebbles of igneous and metamorphic origin. Desio and Orombelli (1983) believe that these fragment represent ice-raifed debris which are brought by Indus river during glacial flood events.

At about 5 m above the base of the section a sand bed display thin lamination of fine to very fine sands which are capped by pebble bearing silt and clay. Capping the exposure in few places is a well indurated litharenite (cemented vary from fine sand to cobbles. Cross laminations and ripple marks are also observed in this horizon (Plate 5-6).

iii Manki Section

Fluvial deposits are exposed in the Manki khwar at Manki village about 7 km south of Nowshera. These exposures extend eastwards up to Piran village on Nowshera-Ziarat Kaka Sahib Road, and west ward upto Garhi Chandan, on Peshawar-Kohat Road. The alluvial fan sequence progrades to the north into the basin from the Attock-Cherat Range as observed in the Ziarat Kaka Sahib section. The sediments are unconformably overlie the Precambrian Manki slates. These fluvial sediments closely resemble the sedimentological character of flood sediments measured at Ziarat Kaka Sahib, Jalala and Firan.

A hundred meters thick stratigraphic section is measured at Manki village (Figs. 2.8 and Plate 7-8). The sequence is composed of alternating layers of silty sand, sand and gravels with thin interbeds of clay separated by several paleosol horizons. The sediments in the basal part of the section display a variety bedforms including planner beds, low-angle cross bed and horizontal laminations. The finely laminated sand and silt clays are streaked with rust in places and range between 5-70 cm in thickness. The fine grained
Figure 2.8 Stratigraphic section of the sediments at the Manki exposed south of Peshawar Basin.
Plate 7. Photograph showing fluvial Quaternary sequence exposed along Manki Nala. The sequence is composed of alternating layers of fine laminated sand, clay, silt and pebbles bearing silty clay with thin interbeds of clay separated by several paleosol horizons. The thickness of the sequence more than 100 m. The sediment display a variety of bedforms including, planar beds, low-angle cross beds and thin discontinuous lenses of limited lateral extent.
Plate 8. View of the Manki Nala outcrop shown in Plate 7. The dark gray layers in the photograph represent coarse-grained sediments and light brown layers show fine-grained clay interbeds.
silty clays exhibited bioturbation (Plate 8). In the upper part of the section, the fluvial sediments are predominantly granular to pebble size and contain grey, yellowish to greyish clast of sandstone, siltstone, slate and reddish fragments (Plate 9). The clasts are mainly composed of Manki slates and pebbles of igneous and metamorphic origin which are similar to other Piran and Ziarat Kaka Sahib localities. The individual clasts are ellipsoidal and subrounded to angular which display a size grading within the beds. The matrix consistute less than 5%, unconsolidated, yellowish to buff colour clay layers, which show low-angle cross bedding.

Further to southwest of the Manki village approximately 10 kilometers at Dag Ismail Khel village (the northern edge of the Attock-Cherat Rang), a thick exposure of alluvial fan is exposed. The section begins at the depositional contact of the folded and highly dissected Murree Formation with the over lain Peshawar Basin sediments (Plate 10). These alluvial fan sediments are covered by the colluvium about 120 to 200 m thick. These sediments occur throughout the Dag Ismail Khel area and closely resemble the sedimentological character of the fluvial sediments measured at Spin Khak, Warsak, Piran and Manki sections.

In general the sections exhibits thin to fine-grained siltas and abundant conglomerates while the basal part of the section is dominated by pale red and greyish yellow clay that displays thin, wavy and parallel laminations. The clay horizon preserve numerous burrows and minor organic debris. These alluvial sediments are about 50 m thick and covered by the thick colluvium.

iv Spin Khak Section

The Spin Khak section occurs along the southern boundary of the Peshawar Basin (the northern edge of the Attock-Cherat range) and extends to the village of Spin Khak, approximately 10 km southeast of the Nowshera. The thick fluvial sediments are
Plate 9. Close-up photographs of Manki Nala outcrop showing detailed lithology and bedforms. Note planar beds of predominantly clast-supported conglomerate with interbeds/lenses of clay and low angle cross bedded layers with irregular lower contact and layers within the conglomerate displaying grain size variations. Hammer length is 28 cm.
deposited by an alluvial fan prograding in the basin from the Attock-Cherat range along the southern margin of the Peshawar basin (Fig. 2.5). These fluvial sediments are characterized by the presence of fine-grained material, consisting of silt and clay overlying sand and gravels (Plate 11). The surface lithology indicates the deposition of predominantly coarser materials in the southwestern part of the basin.

A fifty meter thick fluvial sequence is exposed near Spin Khak village. The exposure is dominated by fluvial, deposits (Fig. 2.9). The basal part of the section displays thick finely laminated silty mud interbedded with thin clay beds of 3-15 cm (Plate 12). About 4 meter thick fine-to coarse-grained sand bed is associated with massive siltstone bearing calcareous concretion. At many levels within the coarser beds, the sediments are sandy, clayey with rare gravel clasts.

Within the escarpments the section terminates at the top, where it is capped by a limestone dominated conglomerates. The matrix supporting conglomerates is found to be subangular to subrounded and moderately sorted sandstone (Plate 13-14).

2.3B Peshawar Lacustrine Sediments

The entire central part of the basin is covered by lacustrine and loess deposits with buff coloured silt and clay. These lake sediments were deposited in the temporary lake, which was formed due to the blockage of drainage in the basin. This blockage of drainage system of pounding of the flows of Indus river was through the Attock-Cherat Range (Burbank, 1983 and Cornwell (1994). These authors interpreted these lake sediment products of catastrophic floods along middle Indus valley (Also see Cornwell & Hamidullah, 1992).

The loess deposits form thick sheets of wind blown material have been subjected to wind and water erosion. In several places these loess deposits are completely eroded exposing the underlying gravel beds. On the southeastern margin of the basin these
Figure 29  Stratigraphic section of the sediments at the Sph Khak exposed south west of Peshawar Basin.
Plate 12. Photo shows thick fluvial sequence, exposed at Spin Khak. The beds are characterized by the alternating layers of silt, sand and gravel with thick interbeds of clay. The sediments display the low-angle cross-bedded planar beds and thinner discontinuous lenses of later extension.
Plate 13. Closeup of course-grained sediments with fine-grained clay interbeds exposed along the Khwar near Spin Khak.

Plate 14. Closeup of matrix supported clasts at Spin Khak. Hammer (28 cm) is for scale.
lacustrine deposits cover an area of about 25 km extending from Manki road to Doa Khula-Khawar in the form of a narrow belt south of Nowshera. These extending from Manki road to Doa Khula-Khawar in the form of a narrow belt south of Nowshera. These sediments are also accumulated exposed in the south-west of Peshawar Basin, near Jalala and Shergarh in Mardan district and its surrounding area. At some places the loess sediments are present between the lacustrine layers. The silt and sand deposition in lacustrine and fluvial plain indicates an intervening dry period.

1 Jalala Section

An excellent thick exposures of lacustrine sediments are exposed in Jalala, 46 km north of the Nowshera city along Peshawar-Malakand highway. Other outcrops of these sediments are spread over in isolated patches in the entire Peshawar Basin (Fig. 2.5). These sediments were described by various workers (Allen, 1964; Hanzeef, et al., 1986 & Cornwell, 1994).

The lacustrine sediments exposed as horizontally deposited graded beds of sand, silt and clay are well exposed along the steep valley cut in the Kalpani drainage in the northern part of the Peshawar Basin (Plate 15-16). These graded sediment exposures are also observed along the streams and road cuts that are exposed just south of Jalala and Shergarh and approximately 2 km east of the Lund Khawar.

Allen (1964) described these sediments as the Shergarh lake sediments. These sediments represent more characteristics of the alternate layers that occur in several other distal locations within Peshawar Basin. At Jalala bridge the lacustrine sediments represent about 50 m thick sequence characterized by alternating thin- to medium-beds of silty clay and clay. A number of sedimentary structures including planar lamination, cross lamination, ripple marks, graded bedding, slump feature, channel beds and animal burrows are present throughout the sequence. The lacustrine sequence is capped by loess
Figure 2.10 Stratigraphic section of the sediments at the Jalala exposed North of Peshawar Basin.
Plate 15. Panoramic view of the lake sediments near Jalala bridge. Kulepani stream has dissected the lake sediments. Note Jalala village in the background.

Plate 16. Close-up of the lake sediments of Jalala village. Note horizontal layering and fracture fills within the sediments.
The olive grey sediments are horizontally continuous and rarely graded into each other, and separated by distinct grain size boundaries. The coarse-grained material, which is predominately fine- to medium- sand with rare silt, is producing a morphological feature due to weathering with the less resistant silt and clay beds. Rare gravel clasts are present in the coarse horizon of the entire section (Fig. 2.10). Plate 17 shows the horizontal sedimentary beds are intersected by vertical as well as inclined fracture fills. These are generally extending to a depth of more than three meters and a width ranging from 3 to 35 cm. However, most of these are wider in the uppermost parts.

Few prominent fracture fills suggest that they may extend laterally for several tens of meters. Almost all the fractures are filled with clay which have alternating been hardened due to compaction and by losing its moisture to the adjacent sandy beds on both sides. This clay is exposed in resistant forms on the surface. In rare cases the fracture fill also contain some granitic boulders and sand. These fracture fills have been formed due to the tectonism during deposition of sediments (see Hanesf, et al., 1986).

ii Piran Section

The Piran section is exposed along the southern margin of the Peshawar Basin (northern edge of the Attock-Cherat Range) and extends from the village Piran, approximately 10 km southeast of the Nowshera. According to Burbank (1983) these lake sediments were formed from catastrophic flood sediments that emanated from the Himalayas. Plate no. 18 shows the stacked nature of the Piran quaternary sediments along the banks of braided streams and is many galleys that exposes the waning edge of the alluvial fan sequence. The alluvial fan sequence progrades to the north into the Peshawar Basin from the Attock-Cherat Range.
Plate 17. Photograph showing bedforms within Jalila lake sediments. Note buff colour, unstratified loess deposits underlying predominantly sandy, silty, lake sediments. This sequence is overlain by an other loess deposits (not visible in the photo). The lake sequence is characterized by fracture fills that has a cross cutting relationship with the lake beds. Jacob's staff is 1.5 m long.
Plate 18. Photographic view of the lake sediments at Piran Khwar. The braided stream has dissected the lake sediments showing good exposures of sediments along the banks of stream. Buff coloured, unstratified loess deposits overlying predominately sand and silty lake sediments. Note photograph showing the contact of palaeozoic sequence with the lake sediments. The lower photo is a close up of the right side of the upper one.
The Piran quaternary sediments are deposited unconformably upon the late Pre-Cambrian Manki slate Formation in the area (Plate 19) and overlie alluvial fan sediments that are mainly comprised of the Manki slate clasts. These fan clasts range in size from sand and gravel to boulder. In several locations, channel cuts in the uppermost sediments were filled with buff colour silty clay sediments.

A 45-50 meter thick section was observed in broad shallow stream at Piran. Figure 2.11 illustrates the stratigraphic measured section. The exposure displays an alternating sequence of upward fining cycles (graded beds) of stream channel and flood plain that are 30-60 cm thick. The beds pinch and swell over the bedrock topography.

The basal part of the section consist of olive to olive-gray sands, lenses of coarse-grained sand and pebble bearing silt and clay. The sporadic rust staining are also observed throughout the section. Individual cycles commence with massive, medium-to fine-grained, poorly-sorted sandstone. These are overlain by flood plain deposits of compact, yellowish colour finely laminated silt clay and clay-supported conglomerates. The stream channel sediments at the type locality are angular to subrounded and poorly sorted. The predominant lithology is slate, sandstone and limestone. This sequence contain large scale low angle cross bedded fluvial channels at places. The stratigraphic contact is gradational within the sediment deposits. The entire sequence is capped by buff colour less deposits which has the angular unconformity with underlain sediments (Plate 19-20).

Burbank (1983) suggested the deposition of sediments occur in two distinct cycles at Piran area. The older cycle represents that the basin fill sediments are lying directly on the Manki slates bedrock and dips with 6-8° towards northwest. The younger cycle shows that these sediments are overlain with a thin veneer of Manki slate colluvial clasts.
Figure 2.11 Stratigraphic section of the sediments at the Piran exposed southeast of Peshawar Basin.
Plate 19. Paleozoic sequence of Manki slates are exposed at the base.
Note rock showing angular unconformity with lake sediments.
Plate 20. Photograph showing the relationships of the Paleozoic (Manki Formation) with the Peshawar Plain sediments. Note northward dipping Manki slates in the lower part of the photograph. Topographical irregular front view adjacent to the slates (in back view) is lake sediments of Peshawar Plain.
Plate 21
The limestone clay deposits are well exposed along the Farm Khwar.
less than one meter thick and dips with 2° towards northwest.

The younger cycle sediments are well exposed at the Praino khear observed during the traverse along the Piran village. These sediments are thinning out and become buried beneath colluvial sediments. Another exposure of similar sediments is exposed approximately 5 km down stream on the top of the colluvial sediments. These sediments are sedimentological different from the upstream sediments at the Piran locality.

iii Kheshki Section

A typical section of the lacustrine deposits is exposed in central part of the Peshawar Basin, west of Charasadda, north of the Kabul River near Kheshki village and about 10 km northwest of Nowshera. Kheshki section is predominantly composed of lacustrine sediments capped by loess deposits. Due to gully type weathering sandy beds have been exposed and now form sand cover. Cornwell (1994) believe that these sediments are lacustrine in nature and sand beds represent an old channel fill.

A fifty meter thick stratigraphic section was measured at Kheshki (Fig. 2.12). The general stratigraphy of the section shows buff colour clay and sand beds with thin laminations. This basal portion consists of stabilized sand dune overlain by the isolated buff colour clay beds, which are capped with alluvial fan sediments. The sediments show parallel lamination, graded and horizontal bedding. The silt and sand have variable amount of bioturbation and exhibit a few thin laminations.

The buff colour clays are overlain with fine to medium sand. Rare indurated clay beds, cross bedding and lamination are present. The sand is encountered in different horizons in the section. In several locations the sand is fine-to medium-grained and massively-bedded. The exposed sand on surface is semi indurated but upon deeper penetration, a few centimeters the sand becomes unconsolidated (Plate 22). In the east of
Khoshki village, a large sediments filled fracture (30 cm thick) occurs in these sands. This sediments-filled fracture terminate below the cross-bedded sand horizon. This feature characteristically representing an old channel fill, indicates the lacustrine nature of the sandbais.

Near the village of Kandar, south of the Risalpur along the Nowshera-Mardan road (Plate 23), the lacustrine sediments are exposed on the uplifted hills, which are composed of Nowshera Formation. About 10 meter of lacustrine sediments are exposed in the isolated exposures and also bordering the southern margin of the basin. These lacustrine sediments resemble the sediments observed at Jalala and Khoshki. These sediments are unconformably deposited on the rocks of Nowshera Formation of Paleozoic age. These rocks are mainly comprised of thin to massive-bededd limestone, dolomite, sandstone and quartzite.

2.3C Peshawar Floodplain Sediments

The floodplain sediments are present along the rivers in the central part of the basin. These deposits mainly cover the area along Kabul river extending from Nowshera to Khairabad. The deposits consist of sand with intercalation of clay sediments and spread out by river overflow during high floods. The area covered by the floodplain sediments is fairly flat with water table ranging from few meters near the river to about 1.5 meter near Khairabad. These sediments can be interpreted as alluvium/ floodplain sediments based on the grain size variations and the presence of few subrounded to rounded cobbles. The thick exposure of Quaternary sediments in a wide valley tangent to the Attock-Chenab Range south of Indus river, revealed the presence of late deposits.
Figure 2.12: Stratigraphic section of the sediments at Kuchki exposed in the center of Peshawar Basin.
Plate 22. Photograph showing rolling hill topography developed in sand. The remnant of loess deposit are clearly visible.

Plate 23. Photograph showing remnant outcrop of the lake sediments near Kandar village. The outcrop lies about 1 km south of Rishapur, along Nowshera-Mardan Road.
2.4 HYDROGEOLOGY

2.4A Aquifer condition in Peshawar Basin

An aquifer can be defined as the saturated permeable zone that can transmit significant quantities of water under ordinary hydraulic gradients. Therefore, sedimentary rocks could be the best aquifers. An aquitard is described as the less permeable bed that transmit water in significant quantities when viewed over large areas for long periods. Due to less permeability these aquitards are not playing any significant role for the completion of the production wells. Therefore, clay and shale could be the typical aquitard. Aquiclude is that alluvial area which does not transmit water at all. This strata is mainly composed of dense unfractured igneous or metamorphic rocks (Teweel & Cherry, 1979). The course material is the most permeable strata which not only stores water but also transmit water significantly, therefore, the course sediments, mainly gravel and sand provide best reservoir for groundwater.

Peshawar Basin predominantly consists of a thick sequence of alluvial sediments of Pleistocene age. Because of the coarseness of these sediments (i.e., gravel and sand) there could be the development of best aquifers in the Peshawar Basin.

Water and Power Development Authority (WAPDA) survey data was used to study the entire hydrogeology of the Peshawar Basin. Both surface and subsurface stratigraphy and lithology of borehole (tube wells) data are studied to determine the aquifer condition in the Peshawar basin. The locations of these boreholes from the entire basin are given in Figure 2.13. The information on subsurface geology is described in the first part of this chapter and is also available from lithological log of boreholes drilled by WAPDA (1988).

These data indicate that the fluvial sediments, mainly composed of coarse deposits of sand and gravel, vary in thickness from few meters to about 150 m. These
Figure 2.12  Fence diagram showing the subsurface lithology of

1. Viewline direction NS
2. Datum Plane Height = Mean Sea Level
3. Faults Contained not Continued

Legend:
- Clay
- Sand (with coarse gravel & clay)
- Sand (with coarse gravel & clay)
- Clay
- Gravel (with coarse gravel & clay)
- Gravel (with coarse gravel & clay)
Fluvial sediments present in the foot hills of the mountains in the western (Khyber Range) and southern (Attock-Cherat Range) part of the Peshawar Basin. The coarseness of these sediments increases from north to south of the basin.

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. This finer material characterized the lacustrine sediments.

2.4B Description of Boreholes

The lithological logs of boreholes (obtained from WAPDA office, Peshawar) were used to prepare the geological cross sections for the Peshawar Basin (Fig. 2.13). In this diagram the lithological logs of borehole at different localities from Peshawar Basin are plotted (only those boreholes are plotted which are studied for their physical, chemical and isotopic properties). These logs are ranging in depth from 5 m to 120 m, however, the total thickness of Quaternary sediments are not known because non of the borehole is penetrating the bedrock.

In the west of the basin, borehole No.19 and 13 at Kafir Dheri and Forest colon are having clay, gravel with sand, admixture types near the surface and gravel with subordinate clay and sand at the base.

Towards southwest of the basin, borehole No.32 and 40 at Aderai and Soanai respectively mainly consist of gravel, clay-sand, and gravel with alternate beds of clay and sand. The coarse sediments are dominant throughout these boreholes.

In south and southeast of the basin (Attock-Cherat Range), boreholes No. 84 at Dag Baad, No.69 at Manki Sharif and No.103 at Akora Khattak show gravel-clay-sand (admixture type), gravel with subordinate clay and sand, clay and gravel with subordinate sand; and thin layers of clay. The coarse sediments are generally encountered at the top.
and base while the middle part has compact sand and clay lenses. The Public Health Engineering Department (PHEC) also drilled a number of boreholes near Mungi Sharif, and Ziarat Kala Sahib. These boreholes depth are ranging from 55 m to 110 m.

In the middle part of the basin, borehole No. 90 at Pungi and No. 96 at Tangi (Chasaddi) show a fine sediments lithology. Clay and sand strata dominate the top and base of the borehole while strata below the sand is gravel with clay and sand (admixture type).

In the central part of the basin, lacustrine lacs sediments are ranging from few meters to about 15 m in thickness. The lithology at Risalpur mainly consists of thick clay and sand strata with minor gravel and clay. The borehole data further suggested that there could be the fluvial deposit present at depth.

Figure 2.13 shows 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). It may be assumed that the gravel strata and sand strata are hydraulically interconnected and form a large regional aquifer. 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 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 piezometric level of water above the land surface. As a consequence many boreholes are free flowing artesian in the western part of the basin (WAPDA & TNO, 1994).
In the northwestern part of the basin, aquifer mainly occurs below the depth of 46 m and mainly consists of sand with mixed gravel that indicates that these coarse sediments are the main aquifer in the basin. Fine-sand and sandstone beds of moderate hardness also occur below the depth of 6.6 m where the confined or semi-confined aquifers are usually found. The resistivity survey also indicates low resistivity values (below 6.6 m) due to the dominance of clay material. The borehole data further suggest that the aquifer in Peshawar Basin is generally present within the heterogeneous lithologies with a variable transmissibility over a wide range (WAPDA & TNO, 1994).

The depth of watertable along the Kabul River ranges between 1.5 m to 15 m. Watertable is shallow (5 m to 30 m deep) towards the center of the basin and relatively 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 12 m to 39 m.

In various localities (e.g., Spin Khak, Aza Khel Bala, Chapri and Dag Basud area), topographic elevations indicate the depth of watertable greater than 80 m. However, at Manki area the watertable level is shallow and in the vicinity of mountain it is about 40 m deep. At several localities the aquifer is recharged through lateral flow from fracture zones of surrounding rocks and infiltration of runoff through permeable stream beds. The streams (khwans) in the alluvial sediments are useful sources of recharge during heavy rains in the basin. No perennial stream as such has been observed in the south of the Peshawar Basin. In the central part of the basin the irrigation water losses are contributed to the groundwater recharge between Mardan and Kabul river (WAPDA & TNO, 1994).

Robbert (1988) suggested that 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). The subsurface in flow is however, negligible in the basin (WAPDA & TNO, 1994).

2.4C Classification of Aquifers in Peshawar Basin

There is no such borehole data available which can classify the various types of aquifers in the Peshawar Basin. However, on the basis of two main lithologies of the areas (i.e., piedmont and lacustrine deposits), various types of aquifers can be classified in this basin.

1. Peshawar Piedmont Aquifer

The Peshawar piedmont deposits characterize the piedmont aquifer. Such aquifers are mainly present at the marginal parts of the basin as following:

1. Khyber Mountain Range piedmont aquifer.
3. Lower Swat Range piedmont aquifer.

1. Khyber Mountain Range Piedmont Aquifer

Khyber Mountain Range is present in the west and northwest of Peshawar Basin. The piedmont aquifer of this range is generally composed of fluvial sediments of piedmont deposits in the form of alluvial fans. These sediments mainly consist of admixture type of gravel, sand and clay layers. Calcium carbonate concretions (irregular shape and very well sorted) are associated with fine to coarse-sand. These fluvial sediments form a vast unconfined aquifer which is intervened occasionally by thin clay layers.

2. Attock-Cherat Range Piedmont Aquifer

The Attock-Cherat Range is generally composed of Paleozoic rocks and is considered as the catchment area for Nowshera and surroundings. Piedmont deposits are
generally composed of alluvial sediments in the form of alluvial fans. The alluvial deposits are composed of clast material derived from the bordering hills except along the river and main streams (khwats) 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.

3. Lower Swat Range piedmont aquifer

The Lower Swat Range is present in the northern margin of the Peshawar Basin mainly composed of lower Swat Buner Schistose group. The alluvial deposit in this range form unconfined and confined aquifer. This aquifer system occurs towards northeast and central part of the basin. Locally these aquifer conditions prevail due to the presence of clay lenses. The unconfined aquifer of low permeability consists of silt, clay and sandy fine sand strata, while the confined aquifer of high permeability is generally composed of sand and gravel strata from a depth of 30 m to 150 m. These aquifers are often separated by thick clay strata of low permeability. Deep wells in this area also indicate the low permeability and shallow ground water of low capacity, however, these wells are used for only domestic purposes (WAPDA & TNO, 1994).

ii Peshawar Lacustrine Aquifer

Peshawar lacustrine aquifers classified on the basis of stratigraphic sequence in the Peshawar Basin is characterized by the lacustrine deposits that mainly occur in the central part of the Peshawar Basin in Nowshera, Mardan and Swabi areas (Fig. 2.5). The alluvial sediments of the central part of the basin contain relatively large proportion of fine material such as 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 rivers. The strata of the fine
material indicate semi-confined aquifer over most of the central part of the Peshawar Basin.

iii Peshawar Floodplain/Stream Channel aquifer:

The upper part of the aquifer along and the vicinities of the current and past courses of Kabul and Swat rivers, where these rivers have deposited their sediments are classified as Peshawar Floodplain/Stream Channel aquifer. This type of aquifer is local and relatively shallow in comparison to the lacustrine aquifer of the basin.
CHAPTER 3
WATER CHEMISTRY

3.1 General

Waters chemistry plays a vital role in interpretation of geological environment, source, direction, recharge, movement, climatic influence, presence of ore bodies and sources of concentration (both anthropogenic and natural) for groundwater. More importantly the determination of physical and chemical properties of water is essential for assessing the suitability of water for various uses like drinking, domestic, industrial and agricultural.

The chemical composition of surface and groundwaters depends on dissolution of salts and gas radicals, recharge and chemical composition of aquifers. The chemistry of groundwater changes with the depth as waters travel through the sediments of various aquifers in a basin. Most of the minerals are dissolved in groundwater as it percolates through rocks. In this way it is saturated with these minerals as dissolved solids. These dissolved minerals greatly effect the chemical nature of groundwater and surface waters. The groundwater normally contains more mineral constituents than surface water.

Groundwater is one of the principle sources of industrial, public and rural supplies in the Peshawar Basin. It is essential, either direct or indirect, to almost all activities, of human being. In addition to its use in household activities it is tremendously used for irrigation purposes. Broadly, the groundwater mainly occur in basin in various semi confined aquifers (see chapter 2) with water table varying from 2 to 2.5 m below surface. Five semi-confined aquifers i.e., Khyber piedmont, Attock-Chorat piedmont, Peshawar Floodplain, Peshawar lacustrine, and Swat piedmont, have already been described in the Peshawar Basin (chapter 2). These piedmont aquifers, generally of fluvial lacustrine and Floodplain origin, are considered to host good reserves of water. Here water table is
generally below 2.5 m, and is believed to be unaffected by applied irrigation. Water table in Peshawar lacustrine and floodplain aquifers is generally present at a depth of 2.5 m from land surface and is thus affected by the seepage of canals, rivers, streams and direct infiltration of rainfall in the Peshawar Basin. Various studies on regional scale have been carried out on the groundwater quality in the Peshawar Basin and surrounding area, (WAPDA & TNO 1994; WAPDA, 1983, 1986, 1984). These studies were confined only to consideration of total dissolved solids. However, Bundschuh (1992), IUCN (1994), Shahab (1995) and OPCV (1996-97) have studied the major and trace elements in the waters of certain parts of the basin.

The geochemical study, described in this chapter, is aimed at several aspects of the groundwater and surface water in the Peshawar Basin on regional scale. These studies included major and trace elements chemistry of both surface and subsurface waters together with oxygen isotope studies of the waters, in order to determine the extent of environmental degradation.

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 & springs) were collected from Khyber piedmont aquifers (west and south-west in the basin), Attock-Cherat piedmont aquifers (south and south-east in the basin) and Peshawar floodplain and lacustrine aquifers of the central part of the basin, (cf. Fig. 2.5). At different locations the water samples were collected at the depth between 2.5 m to 120 m. The location of the surface and subsurface water samples are marked in Figure 1.3. In addition other water quality aspects including; pH, specific electrical conductance (EC), total dissolved solids (TDS), total organic substance, with special emphasis on heavy and trace elements, the classification of waters and the types of chemical reaction taking place
The cations and anions determined in natural waters from various aquifers of the basin, include calcium (Ca$^{++}$), magnesium (Mg$^{++}$), potassium (K$^{+}$), sodium (Na$^{+}$), bicarbonates (HCO$_3^-$), sulfate (SO$_4^{2-}$) and Chloride (Cl$^-$). Besides these other cations, usually present in small or in trace concentration, including, iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co), lead (Pb) and cadmium (Cd) were also determined. Concentration of mineral constituent in waters is essential for life and for the optimum health of all organisms. Their existence beyond the safe limit may result in toxicity of the hosting organism. Maximum Contaminant Level (MCL) of US Environmental Protection Agency (US, EPA, 1978) or that of the World Health Organization (WHO, 1975) for water quality, that satisfy the requirements of domestic, drinking and irrigation water are shown in appendix B (Table 3). (US, EPA or WHO will be mentioned where ever required).

3.2 WATER CLASSIFICATION

Piper (1944) suggested a scheme for the classification of groundwater. This scheme is widely used throughout the world for classifying various types of water. It uses four cations (Ca - Mg- Na- K) and three anions (HCO$_3^-$ - SO$_4^{2-}$ - Cl$^-$) under consideration for classification of water into various types. Chemical data of water samples from all the four aquifers (i.e., Khyber piedmont, Attock-Cheraat piedmont, Peshawar central lacustrine and Peshawar floodplain) from Peshawar Basin are plotted on Piper diagram. The ionic-ratios of both surface water and groundwater from various aquifers from the basin are plotted in Figures 3.1, 3.2, 3.3, 3.4, and 3.5.
Figure 3.1 shows the classification of groundwater from the Khyber piedmont aquifers. Four out of thirteen tube wells water samples fall in the subfield of b, [Hydrogen carbonate-sulfate (Na+K-Cl+SO₄ type)] of normal alkaline earth fresh water. On the other hand six tube wells and one dug well lie in the subfield d [Hydrogen carbonate (Ca+Mg-HCO₃ type)] and three tube wells and two dug wells fall in the subfield e [Sulfatic (Cl-SO₄ type)] of the alkaline earth freshwater with high content of alkalies (Fig. 3.1; Piper, 1944).

Majority of the subsurface water samples of Attock-Cherat piedmont aquifers occupy the subfields b and e [Hydrogen carbonate (Ca+Mg-HCO₃ type)] and [Sulfatic (Cl-SO₄ type)], respectively, of the alkaline earth freshwater with higher content of alkalies. Three water samples (one tube well and two dug wells) have the (hydrogen)-carbonate (Na+K-Cl+HCO₃ type) and sulfatic-chloride (Cl-SO₄ type) character (subfields f & g, respectively) of the alkaline freshwater (Fig. 3.2, Piper, 1944).

Twenty one subsurface water samples (thirteen tube wells and eight dug wells) from the Peshawar limestone aquifers lie in the subfield d [Hydrogen carbonate (Ca+Mg-HCO₃ type)] while seven such sample (five tube wells and two dug wells) lie in the subfield e, of sulfatic (Cl-SO₄ type) with high content of alkalic of alkaline earth fresh water. Five dug wells occupy the subfield f, [(hydrogen) carbonate (Ca+Mg-HCO₃+ Cl type)] and three tube wells and four dug wells occur in the subfield g, [Sulfatic-chloride (SO₄, Cl)] of the alkaline freshwater. One dug well water sample shows the [Hydrogen carbonate (Ca+Mg-HCO₃ type)] character (subfield a) of the normal alkaline earth freshwater type (Fig. 3.3; Piper, 1944).

Majority of groundwater samples (five tube wells & five dug wells) from the Peshawar floodplain aquifers mainly lies in the field d [Hydrogen carbonate (Ca+Mg-HCO₃ type)] of alkaline earth freshwater with high content of alkalies, One tube well and
two dug wells however, occupy subfield prevailing sulfatic (e) of alkaline earth freshwater with high content of alcalines. Five water samples (four tubewells and one dug well) lie in the fields f and g [hydrogenocarbonic (Ca+Mg-HCO₃ + Cl type) and sulfatic-Chloride (SO₄-CI type)] alkaline freshwater while one water sample (tube well) shows hydrogenocarbonic (Ca+Mg-HCO₃ + Cl type) characteristic (subfield a) of normal alkaline earth freshwater (Fig. 3.4; Piper, 1944).

Majority of the samples from Kabul river at, Warsak, Nowshera areas and Indus river at Attock KHurd indicate hydrogenocarbonatic (Ca+Mg-HCO₃ type) character (subfield a) of normal alkaline earth freshwater and hydrogenocarbonatic (subfield d) and sulfatic (subfield e) character of alkaline earth freshwater with higher contents of alcalines (Fig. 3.5; Piper, 1944). Therefore surface water of the basin are generally hydrogenocarbonatic and sulfatic types.

According to the piper diagram majority of the surface (rivers) and groundwater (tubewells & dug wells) from the Peshawar Basin are classified as normal alkaline freshwater and alkaline earth freshwater with higher contents of alcalines.
Figure 3.1 Classification of water from Khyber Piedmont aquifers.

Normal alkaline earth freshwater
a. Prevailing Hydrogen-carbonatic
b. Hydrogen-carbonatic-Sulfatic
c. Prevailing Sulfatic

Alkaline freshwater
f. Prevailing (hydrogen) Carbonatic
g. Sulfatic-Chloride

Alkaline earth freshwater with high contents of alkalis
d. Prevailing Hydrogen-carbonatic
e. Prevailing Sulfatic

- Thakwai well
- Dugwell
Figure 3.2 Classification of water from Attock-Cherat Piedmont aquifers.

- Normal alkaline-earth freshwater
  - a. Prevailing Hydrogencarbonate
  - b. Hydrogencarbonate-Sulfate
  - c. Prevailing Sulfate

- Alkaline freshwater
  - f. Prevailing (hydrogen) Carbonate
  - g. Sulfate-Chloride

- Alkaline earth freshwater with high contents of alkalis
  - d. Prevailing Hydrogencarbonate
  - e. Prevailing Sulfate

- Tubewell
- Dugwell
Figure 3.3 Classification of water from Lacustrine aquifers.

- Normal alkaline earth freshwater
- Alkaline earth freshwater with high contents of alkalis
  a. Prevailing Hydrogen carbonate
  b. Hydrogen carbonate-Sulfate
  c. Prevailing Sulfate
  d. Prevailing Hydrogen carbonate
  e. Prevailing Sulfate

- Alkaline freshwater
  f. Prevailing (hydrogen) Carbonate
  g. Sulfate-Chloride

- Tubewell
- Dugwell
Figure 3.4 Classification of water from floodplain aquifers.

Normal alkaline earth freshwater  Alkaline earth freshwater with high contents of alkalis
a. Prevailing Hydrogencarbonatic  d. Prevailing Hydrogencarbonatic
b. Hydrogencarbonatic-Sulfatic  e. Prevailing Sulfatic
c. Prevailing Sulfatic

Alkaline freshwater
f. Prevailing (hydrogen) Carbonatic  g. Sulfatic-Chloride
  • Tribewell  • Dugwell

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Figure 3.5  Classification of water from surface water (Rivers).

- Normal alkaline earth freshwater
- Alkaline earth freshwater with high contents of alkalis
- Prevailing Hydrogencarbonatic
- Hydrogencarbonatic-sulfatic
- Prevailing sulfate
- Alkaline freshwater
- Prevailing (hydrogen) Carbonatic
- Sulfatic-Chloride

- Rivers
3.3 PHYSICAL AND CHEMICAL PROPERTIES OF WATERS OF THE PESHAWAR BASIN

3.3A PHYSICAL PARAMETERS

i Temperature (T °C)

Temperatures of aquifers are affected by exposure of the wells to sunlight, depth of the water table, and the surrounding atmospheric pressure. To draw the water samples up from an aquifer without avoiding these factors is very difficult. This is the reason that temperature of groundwater is not a representative of the geothermal gradient of the aquifers. Groundwater is generally warmer than the air temperature during winters and cooler during summers. In general, the average temperature of groundwater in shallow zone of the phreatic aquifer approximates that of the mean annual temperature of the air. The surface water temperature are subjected to large fluctuations than groundwater temperature and the amount of total dissolved solids in the term affected by this phenomenon (Kranzckopf, 1979).

In Peshawar Basin, temperature ranges from 16.8 to 25 °C in Khyber piedmont aquifer and 19 to 25.4°C in Attock-Cheraq piedmont aquifer. In Peshawar lacustrine and Peshawar floodplain aquifers the temperature is ranging from 16 to 27 °C and 18 to 24.3 °C, respectively.

ii pH of waters

Natural waters generally contain dissolved carbon-dioxide gas and bicarbonate ions that form a buffered system with carbonic acid. Difference between field pH value and laboratory pH values are commonly as much as 0.5 or even greater in samples low in dissolved solids (Davis, 1966). It is generally believed that very high pH values, i.e., above 8.5 is usually associated with the carbonate and bicarbonate of sodium in waters.
Moderately low and very low pH value (4.0) is associated with free acids derived from oxidizing sulfide minerals (usually pyrite) in waters (Knappert, 1979).

Water samples show the greater variability of pH in waters of Peshawar Basin (appendix-B; table 1). The pH of underground waters from the Khyber piedmont aquifers range from 5.4 to 9.9 and from Attock-Cherat piedmont aquifers, range from 4.9 to 7.7. In the central part of the basin pH is ranging from 5.1 to 9.2. Peshawar lacustrine and 6.9 to 8.7 in Peshawar floodplain aquifers, respectively. This suggest that water of Peshawar Basin is ranging from acidic to alkaline (Fig. 3.6-7) and this variation is noticed even at the local scale. The groundwater (both tube wells and dug wells) of Aza Khel, Tail Band, University Town, Landi Arabab, Darwazgai, Mattani, Tekhal bala, Hazri Khani, Sorzai, Adzai exhibit the lowest pH value varying from 4.9 to 5.2. The water samples at Darwazgai (dug wells) from Attock-Cherat piedmont aquifer and from Zahirabad (dug wells) and Umer (tube wells) from Peshawar lacustrine aquifer indicate high concentration of SO4 (1287, 1297, 370 mg/l, respectively) with pH value of 4.96, 5.06, 5.06, respectively (appendix-A). Such a correlation can be attributed to the dissolution of pyrite, also shown by; high concentration of Cu (59, 55 µg/l) in these samples; pointing to a possible percolation through localized sulfide rich zone in these areas.

iii Total Dissolved Solids (TDS) and Electrical Conductivity (EC) of water

The amount of dissolved minerals in the fresh water represent the total dissolved solids (TDS) which are measured in milligram per liter (mg/l). A high dissolved solid content usually indicates that the water has passed through rocks composed of soluble minerals. Water is a potent solvent that can hold in solution most of the solids and gases found in the nature. Most of the dissolved solids in natural water consist of the same solutes, whether, in sea, river and lakes or in groundwater. The total dissolved solids are obtained by determining the capability of the fresh water to conduct an electric current.
Figure 3.6 Concentration of pH in tube wells from the aquifers of Peshawar Basin.

KPATW: Khyber piedmont Aquifer tube wells
PFATW: Peshawar Floodplain Stream Channel Aquifer tube wells
PLATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Chorai piedmont Aquifer tube wells

Figure 3.7 Concentration of pH in dug wells from the aquifers of Peshawar Basin.

KPADW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Chorai piedmont Aquifer dug wells
The electrical conductivity of fresh water is the conductance of a cubic centimeter of water at a temperature of 25°C, generally measured in millisiemens per centimeter (mS/cm). The electrical conductivity (EC) of the groundwater is usually quite low, so it is measured in millisiemens per centimeter (mS/cm). The electrical conductivity (EC) gives a general impression of the chemical behavior and chemical quality of waters. Conductivity shows remarkable 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 mS/cm, which may increase to 4 mS/cm, after storage for a few weeks (Jones and Buford, 1951).

The measured values of electrical conductivity of groundwater in Khyber piedmont aquifers generally range from 42 to 917 mS/cm and in Attock-Chorat piedmont aquifers from 53 to 780 mS/cm, both signifying fresh water when compared with US Public Health Service water quality limits (1985). In the Peshawar Leuvritine and Peshawar floodplains aquifers of the central part of the basin, except two sample (one each from each aquifer), all the rest are again classified as freshwater on the basis of US Public Health Service water quality limits (1985; Table 3.1).

The major cations in natural water are: Na⁺, K⁺, Ca²⁺, Mg²⁺, and major anions include Cl⁻, SO₄²⁻ and HCO₃⁻. Both Na⁺ and Cl⁻ are present in most of the waters. According to the US Public Health Service, the drinking water can be classified as fresh, slightly saline, moderately saline, and very saline and brine on the basis of their TDS. The limits are given in Table 3.1.

Several processes are responsible for the increase of dissolved solids 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 groundwaters
Table 3.1 Classification of water on the basis of Total Dissolved Solids.

<table>
<thead>
<tr>
<th>Total Dissolved Solids (TDS mg/l)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. less than 1,000</td>
<td>Fresh</td>
</tr>
<tr>
<td>2. 1,000 - 3,000</td>
<td>Slightly saline</td>
</tr>
<tr>
<td>3. 3,000 - 10,000</td>
<td>Moderately saline</td>
</tr>
<tr>
<td>4. 10,000 - 35,000</td>
<td>Very saline</td>
</tr>
<tr>
<td>5. More than 35,000</td>
<td>Brine</td>
</tr>
</tbody>
</table>


from various aquifers are also presented in appendix-A and shown graphically in Figures 3.8 and 3.9. The total dissolved solids determined in water samples of Peshawar Basin and its main rivers are shown in the appendix-A. Many of the samples of all the aquifers have total dissolved solids below the Maximum Contaminant levels (MCL) of US-EPA (<500). However, there are samples, which have TDS values higher than the MCL of US EPA (see appendix-B, Table 1) and some exceed the MCL of WHO (i.e., 1000; see appendix-B, Table 1 & 3). Examples are tube wells from Akbar pur (sample No STWP 66), Aman Kot (sample No STWP 99), dug wells from Wadpago (STWP 65) and Aman Kot (STWP 98). Among the rivers, Kabul river at Warasq Dam is carrying the highest TDS (525 mg/l) which is still very low than the MCL of US-EPA compared to Indus and Swat rivers (see appendix-B, Table 1 & 3), considering these data and comparisons with the MCL of US-EPA, WHO and Pak-EPA, expect a 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". The few samples of the Peshawar lacustrine and Peshawar floodplain aquifers in the central part of the basin can be classified as "slightly saline".
Figure 3.8 Concentration of TDS in tube wells from the aquifers of Peshawar Basin.

KPTW: Khyber piedmont Aquifer tube wells
PFATW: Peshawar Floodplain Stream Channel Aquifer tube wells
PLTW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.9 Concentration of TDS in dug wells from the aquifers of Peshawar Basin.

KPA DW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells
3.3B CHEMICAL PARAMETERS

CATIONS

i Calcium (Ca)

Calcium is an abundant constituent in the waters that is associated with calcite, dolomite and gypsum. Shale and other deposits usually contain calcium carbonate as cementing material. Gypsum and anhydrite occur as evaporites in sediments and are important sources of calcium in groundwater. Calcium is also present in the form of adsorbed ions on negatively charged minerals in the surface soil and rocks. The carbonates and calcium sulfate however, are soluble in most natural waters. 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 soil fractions (Driscoll, 1986; Balke, 1988).

Calcium concentrations of water from various location in different aquifers of the Peshawar Basin are given in appendix-B (Table 2) and are also plotted in Figures 3.10 and 3.11. 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, one sample from Danishabad in the Khyber piedmont aquifers shows calcium concentration (792 mg/l) above the permissible level (75 mg/l). Similarly a tube well sample from Akhapura lying in the Peshawar lacustrine aquifers also show higher Ca than allowed by the MCL of EPA (see Fig. 3.10). None of the dug wells in the basin indicate Ca content above the 75 mg/l permissible limit US.EPA (Fig. 3.11; appendix-B, Table 2). However on the basis of a local comparison with each other the dug well samples from Shaber Ghari (71.8 mg/l) and Zahirabad (73.8 mg/l) show relatively higher value. All the three rivers (i.e. Kabul, Indus and Swat) show calcium contents within the permissible limit.
Figure 3.10 Concentration of Ca in tube wells from the aquifers of Peshawar Basin.

KPATW: Khyber piedmont Aquifer tube wells
PFATW: Peshawar Floodplain/Stream Channel Aquifer tube wells
PLATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.11 Concentration of Ca in dug wells from the aquifers of Peshawar Basin.

KPADW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain/Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells

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ii Magnesium (Mg)

Magnesium is an important alkaline earth metal and is an essential element for plants and animals nutrition. In sedimentary rocks, magnesium occurs in magnetic and other carbonates, e.g., calcite and dolomite, while in igneous rocks it is found in higher concentration in mafic and ultramafic rocks. The concentration of magnesium in groundwater is relatively smaller than calcium, except where those waters have been in contact with dolomites or with magnesium-rich evaporites that release magnesium in high concentration (Betke, 1988). 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 (MCL, US-EPA, 1978).

Magnesium concentration at various location in the aquifers of Peshawar Basin are given in appendix-B (Table 2). These data are also plotted in Figures 3.12 and 3.13 for comparison. Most of the groundwater samples from Peshawar Basin are classified as normal with magnesium <50 mg/l, on the basis of MCL of US-EPA. Magnesium contents are however generally high in the dug wells as compared to tube wells in the basin.

High magnesium content of tube wells in Peshawar floodplain Stream Channel aquifer are noticed at Kokor (66 mg/l) and Bedha Bdr (48 mg/l). The former is above where as the latter is below but close to the permissible limit of 50 mg/l allowed by US-EPA. Similarly values above and below this limit are also noticed in tube wells of the Peshawar lacustrine aquifer at Gulshan Rahman Colony, Tehsil Gang, Gulbahar No.2, Hazara Khwani and Wadpara, all ranging from 49 to 52 mg/l (Fig. 3.12; appendix-B, Table 2) and located with in or around Peshawar city.

As stated above, among the dug wells and hand pump samples (i.e shallow aquifers) from the basin majority remains within the permissible limit, i.e. below
Figure 3.12 Concentration of Mg in tube wells from the aquifers of Peshawar Basin.

**Sample locations**

KPA TW: Khyber piedmont Aquifer tube wells
PFATW: Peshawar Floodplain/Stream Channel Aquifer tube wells
PLTW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.13 Concentration of Mg in dug wells from the aquifers of Peshawar Basin.

**Sample locations**

KPA DW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain/Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells
50 mg/l. However, several lie close to or above this limit in all the aquifers with some showing values as higher as 157 mg/l (Zahirabad; PLADW; Fig. 3.13). The higher magnesium concentration in all these dug wells and certain tube wells can be related to a number of reasons of local or most probably of regional significance, e.g., soil composition containing carbonates and other di-integrating ferromagnesium minerals with source in the surrounding Paleozoic rocks or underlying and hosting Quaternary geology described in chapter 2. Such possibilities of contamination will be discussed in detail in the Discussion chapter.

All the main rivers of Peshawar Basin have magnesium contents within the permissible limit (appendix-B, Table 2).

ii Sodium (Na)

Sodium in groundwater occurs in significant quantities (Driscoll, 1986). It is an important member of alkali metals. Sodium is primarily derived from feldspars in igneous rocks and its weathering products (clay minerals) in other sediments. Shale and clay often yield water with a relatively high sodium content. Sodium occurs at upper soil layers, and its concentration in groundwater increases through mixing with salty connate water from deep percolation of marine origin. According to Karanth, (1993), sodium in the groundwater is derived from the precipitation of sodium salts fertilizing in the soil of shallow water tract, particularly in arid and semi-arid region. However, sodium carbonate or sodium bi-carbonate compounds are also present in groundwater at the pH of 9 or more. The concentration of sodium and chloride increase as the total dissolved solids contents increase. In deep aquifers the sodium content is relatively high due to very low groundwater velocity as compared to the shallow aquifers (Driscoll, 1986). Concentration of sodium mainly depends upon the origin of waters. 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 alkali soil considered impaired for the agriculture uses. High concentration of sodium has serious impacts on human health. It can disrupt blood chemistry with serious consequences. An excessive intake of sodium may cause hypertension (see Cruze, 1984).

The sodium contents in the water samples of Peshawar Basin are shown in appendix-B (Table 2) and graphically presented in Figures 3.14 and 3.15. Most of the tube well samples from various parts of Peshawar Basin have sodium below the MCL of US EPA (<50 mg/l). However, samples from Kirthi Dhori, Rahjar, Tarangzi, Prang, Aman Kot, Aklar Pur, Pabbi, Irmot, Nowshera Cantt and Dag Band have value (46-182 mg/l) close to or above the permissible limits (50 mg/l) (Fig. 3.14). Waters at shallow depth (dug wells etc.) are also normally not richer in Na than allowed by the US-SPA, however, generally speaking, the number of samples showing higher Na than the allowed limit is higher at shallow levels (dug wells) than at deeper levels (tube wells) (Figs. 3.15; see also Fig. 3.14 & appendix-B; Table 2 for comparison). 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 environmental degradation impact of Warsak Dam. Several Scarp projects have been carried out around Charsadda, Mardan, Swabi and Water logging and salinity has declined around Peshawar, Charsadda, Mardan and Swabi in the past years but evidences of salts concentration on surface and at shallow depth still remains in the area (see Shahab Danishwar, 1997; Bunduchak, 1992).

The presence of caliche south of Nowshera and at several other localities and our data support such an interpretation.
Figure 3.14 Concentration of Na in tube wells from the aquifers of Peshawar Basin.

Samples Locations

KPATW: Khyber piedmont Aquifer tube wells
PFATW: Peshawar Floodplain/Stream Channel Aquifer tube wells
PLATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.15 Concentration of Na in dug wells from the aquifers of Peshawar Basin.

Sample Locations

KPADW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain/Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells

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All the major rivers of Peshawar Basin have Na within permissible limit. However, Kabul river has relatively higher sodium content as compared to Indus and Swat rivers (appendix-B; Table 2).

iv Potassium (K)

Potassium is more abundant in the rocks because of the presence of potassium feldspar, micas and clay minerals. It is less abundant in water due to its very low solubility as compared to the other cations. According to Goldich (1938), potassium is present in the groundwater due to decomposition of clay mineral. In groundwater, potassium salts normally ranges from 1-15 mg/l (US-EPA, 1978; WHO, 1975).

The concentration of potassium in water samples from various aquifers in the basin are given in appendix-B (Table 2) and Figs 3.16 and 3.17. These data and their plot classify all the table water from Peshawar Basin having potassium concentration below the MC (10 mg/l) of US-EPA.

Majority of the dug well sampler also behave similarly, however 15% of the data showed values above the MCL of US-EPA (Fig.3.17). Such water exist in all aquifers expect in Attock-Cherat piedmont aquifer. This behavior support our previous interpretation of salt transportation and concentration due to water logging and salinity which was more dominant in central, northern and western parts of the basin is the vicinity of Warsk Dam. All the major rivers show low (<1mg/l) potassium concentration.

v Iron (Fe) and Manganese (Mn)

Iron is more abundant in the sediments and rocks than manganese. Iron and manganese are crucial constituents of drinking water in regards to health-related hazard. These cations are usually present in minor concentration or in traces, in the waters and have a major significance regarding to water quality used for domestic and industrial purposes. Iron normally occurs in water as ferrous or ferric iron. US-EPA (1978),
Figure 3.16 Concentration of K in tube wells from the aquifers of Peshawar Basin.

KPATW: Khyber piedmont Aquifer tube wells
PFAW: Peshawar Floodplain/Stream Channel Aquifer tube wells
LATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Choa Piedmont Aquifer tube wells

Figure 3.17 Concentration of K in dug wells from the aquifers of Peshawar Basin.

KPADW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain/Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Choa Piedmont Aquifer dug wells
recommended the MCL of iron and manganese as 300 and 50 μg/L, appendix-B (Table 2); Figs 3.18 and 3.19 respectively. Except a tube well sample from Phase 2 Hyatabad (790 μg/L) and one from Jehangir (620 μg/L) showing values above the permissible limit of 300 μg/L, all other tube wells, dug wells, rivers and spring samples show Fe content well below the permissible limit. The exception at Hyatabad and Jehangir 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 (see Figs. 3.18, 3.19). The Mn data collected is below the detection limit of the instrument used (1 μg/L) and can not be considered reliable for comparison. On the basis of the iron concentration the surface and groundwater from Peshawar Basin can be classified as safe for drinking and agriculture uses.

ANIONS

vi Sulfate (SO₄²⁻):

Sulfate occurs in groundwater in the form of sulfides, sulfate and thiosulfate. Sulfate deposits are normally found in evaporite sediments (i.e., gypsum, anhydrite, and sodium sulfate). Calcium, magnesium and sodium sulfate salts are usually present in high concentration in the groundwater. This is due to the percolation of water traversing through sediments and dissolving salts. A part from these natural sources, sulfate could be present through the application of sulfatic soil conditions and sulfide minerals. Such minerals produce soluble sulfates through oxidation processes in the groundwater. Climate has also important affect 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 (Driscoll, 1986).
Figure 3.18 Concentration of Fe in tube wells from the aquifers of Peshawar Basin.

KPTW: Khyber piedmont Aquifer tube wells
PFLATW: Peshawar Floodplain Stream Channel Aquifer tube wells
PLATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Arooch-Chirra piedmont Aquifer tube wells

Figure 3.19 Concentration of Fe in dug wells from the aquifers of Peshawar Basin.

KPADW: Khyber piedmont Aquifer dug wells
PFAWD: Peshawar Floodplain Stream Channel Aquifer dug wells
MLDWA: Peshawar Lacustrine Aquifer dug wells
ACPADW: Arooch-Chirra piedmont Aquifer dug wells
Sulfate contents of water samples from Peshawar Basin are presented in appendix-B (Table 2) and compared with the MCL of US-EPA in Figures 3.20 and 3.21. It is clear from the data that majority of the tube wells and dug wells have sulfate within the permissible limit (<250 mg/l). Samples showing high concentration than the permissible limit are tube wells from Akbar para (368 mg/l), urmar (1287 mg/l) and Amin Kot (266 mg/l) and dug wells samples from Darwazgra (370 mg/l), Ghar-Chandan (433 mg/l) and Zahirabad (1287 mg/l). Such groundwater may represent contamination from gypsum and anhydrite sediments in the aquifers (Hussain et al., 1990). Or from sulfate bearing fertilizers widely used in the area. All the rivers and spring have sulfate contents within permissible limits.

vii Chloride (Cl)

Chloride is contributed to natural water from evaporites, salty connate water, marine waters and very little from igneous rocks material. Water containing high concentration of chloride along with sodium, indicates a marine origin. Some of the chloride may result from industrial activity. Abundant chloride contents in groundwater may indicate seepage from the sewage and human wastes. According to Davis (1966), chloride in the groundwater is mainly added from ancient seawater entrapped in sediments. According to the US-EPA (1978) the permissible limit of chloride for drinking water is 250 mg/l.

Except one sample from the Peshawar lacustrine aquifer at Akbarpara showing chloride content of 255 mg/l, all other tube wells samples from the basin stay within the permissible limit (<250 mg/l) of US-EPA. Similarly only 3 out of 40 dug well samples from the basin show chloride concentration above the permissible limit (Figs. 3.22 & 3.23). Three dug wells with high values are from Zahirbad (882 mg/l), Reji (452 mg/l) and Amin Kot (357 mg/l). These area show high contents of sodium and in addition
Figure 3.20 Concentration of SO₄ in tube wells from the aquifers of Peshawar Basin.

**Sample locations:**
- KPAW: Khyber piedmont Aquifer tube wells
- PFATW: Peshawar Floodplains Stream Channel Aquifer tube wells
- PLATW: Peshawar Lacustrine Aquifer tube wells
- ACPATW: Anjock-Churat piedmont Aquifer tube wells

Figure 3.21 Concentration of SO₄ in dug wells from the aquifers of Peshawar Basin.

**Sample locations:**
- KPADW: Khyber piedmont Aquifer dug wells
- PFADW: Peshawar Floodplains Stream Channel Aquifer dug wells
- PLADW: Peshawar Lacustrine Aquifer dug wells
- ACPADW: Anjock-Churat piedmont Aquifer dug wells

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Figure 3.22 Concentration of Chloride in tube wells from the aquifers of Peshawar Basin.

KPATW: Khyber piedmont Aquifer tube wells
PPATW: Peshawar Floodplain Stream Channel Aquifer tube wells
PLATW: Peshawar Lacustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.23 Concentration of Chloride in dug wells from the aquifers of Peshawar Basin.

KPADW: Khyber piedmont Aquifer dug wells
PFADW: Peshawar Floodplain Stream Channel Aquifer dug wells
PLDWA: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells
both these elements are relatively high both in tube wells and dug wells (see appendix-B; Table 2); Figs. 3.22, 3.23; see also Figs 3.14, 3.15). The percolation of water through localized salt seems suggested earlier may one of the reasons but as suggested before salinity transfer due to water logging may be a more acceptable reasons for salt concentration in localized zones. The chloride contents in all the major rivers of the basin are within permissible limit (4 mg/l to 40 mg/l) (appendix-B, Table 2).

viii Bicarbonate (HCO₃⁻)

Alkalinity of waters is mainly dependent on the concentration of bicarbonates. Most of bicarbonate ions in groundwater are derived from the carbon dioxide in the atmosphere, soil, and solution of carbonate rocks (Davis, 1966). The concentration of bicarbonate in rain water is less than 10 mg/l and the groundwater generally have more than 200 mg/l. Higher concentration occur where CO₂ is produced within aquifer. If pH is less than 4.5 it causes the conversion of bicarbonates to carbonic acid, pH between 4.5-8.2 forms bicarbonates, and if pH is over 8.2 then bicarbonates form carbonate (Davis, 1966). It is clear that there is a greater variation in the bicarbonate contents of the water of all the aquifers indicating variation in pH values (see appendix-B, Table 1, 2). Plots of pH against bicarbonate for water from different aquifers are shown in Figure 3.24. Data from lacustrine and fluvial plain aquifers show positive correlation where as majority of the data from phreatophyte aquifer show very limited range for pH values and thus no definite correlation can be established. The data however indicates that in general bicarbonates in these aquifers remain pH dependent. Majority of data obtained from tube wells/ bore holes and dug wells/ handpump, show bicarbonates within the range described by US-EPA i.e., 250 mg/l (appendix-B, Figs. 3.25 & 3.26). However many wells show values above this limit (Jamrud Road, Shabqadar, Matta Magal Khel, Shiekh Umer Baba, Dag Husud, University Town, Akbar Pura, Bashirabad, Shiggi, Moizari, Regi, Hazar)
a. Khyber piedmont Aquifer

\[
y = 13.66x + 0.162
\]
\[
R^2 = 0.0426
\]

b. Peshawar Floodplain/stream Channel Aquifer

\[
y = 27.427x + 19.752
\]
\[
R^2 = 0.1334
\]

c. Peshawar lacustrine Aquifers

\[
y = 5.8198x + 157.32
\]
\[
R^2 = 0.0039
\]

d. Attock-Cherat piedmont Aquifers

\[
y = -0.8333x + 133.66
\]
\[
R^2 = 0.004
\]

Figure 3.24 The correlation of pH vs HCO₃⁻ in groundwater (tube well & dug wells) from various aquifers of Peshawar Basin.
Figure 3.25 Concentration of HCO₃ in tube wells from the aquifers of Peshawar Basin.

KPTW: Khyber piedmont Aquifer tube wells
PFTW: Peshawar Floodplain Stream Channel Aquifer tube wells
PLATW: Peshawar Laccustrine Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

MCL of HCO₃ (250 mg/l) is drinking water

Sample locations

310
210
110
0

Figure 3.26 Concentration of HCO₃ in dug wells from the aquifers of Peshawar Basin.

KPAW: Khyber piedmont Aquifer dug wells
PfadW: Peshawar Floodplain/Stream Channel Aquifer dug wells
PLADW: Peshawar Laccustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells

MCL of HCO₃ (250 mg/l) is water

Sample locations

500
400
300
200
100
0
Kiwani, Wadragga, Zahirab, Urmar Payan, Shahz Ghari, Kukar, Mandezai-Srich. Kandi Hayat, Mathua and Tuchh Bheji). Similarly samples from Indus rivers at old Attock bridge, from Kabul river at Nowshera bridge and from all the springs show high levels of bicarbonates.

Several reasons including the composition of the host rock, the percolation of water system through high bicarbonate or low pH bearing sources, interaction of sewage with water system, contamination by industrial sources and agricultural wastes can be pointed out as the reasons for high bicarbonates. The variety of samples involved are tube wells, dug wells rivers and springs with different histories of exposures and contamination, if any, and with different sources and hosts. Therefore, a detailed study may be needed to be carried out to find out the reasons of anomalous bicarbonates in individual sources of the samples collected.

3.4 Chemical reaction in various aquifers

Concentrations of elements and the chemical changes in solutions mainly depend on the pH value, redox-potential and temperature. CO₂ is less soluble in hot water relative to cold water, therefore, the solubility of CaCO₃ in pure water decrease with the increase of temperature. (Kraskipf, 1979). In greater depth in the earth crust, the flow velocity decreases, as the dissolved solids increase with the increase of temperature and, therefore, the major soluble salts (except CaCO₃) are present at the depth of the aquifers. Water percolating through limestone (CaCO₃), dolomites (CaMgCO₃), magnesite (MgCO₃), anhydrite (CaSO₄), gypsum (CaSO₄.2H₂O) and rock salt or halite (NaCl) has greater chances of dissolving various cations and anions. Ca²⁺, Mg²⁺, Na⁺, Cl⁻, SO₄²⁻, HCO₃⁻, CO₃⁻ are the most abundant ion in groundwater. Therefore considering the correlation factor (R²) of these cations and anions, the main ionic pair Na-Cl has been identified in both tube wells and dug wells of various aquifers of basin (Table 3.2). This ionic pair
shows a linear positive trend indicating a positive correlation with $R^2 \equiv 1$. In Khyber piedmont aquifer Na-Cl and Na-SO$_4$ show linear trends indicating positive correlation with $R^2 \geq 0.9902$ and 0.6363, respectively (Figs. 3.27a & b). Mg-SO$_4$ shows a positive correlation with a relative high scatter and low $R^2 \equiv 0.2241$ (Table 3.2). Other cations and anions indicate no significant correlation in the tube wells. In dug wells of Khybor piedmont aquifer significant pairs are Na-Cl, $R^2 \equiv 1$; Na-SO$_4$, $R^2 = 0.991$; Mg-Cl, $R^2 = 0.954$; Mg-SO$_4$, $R^2 = 0.984$; Fe-Cl, $R^2 = 0.976$; Fe-SO$_4$, $R^2 = 0.942$; Mg-SO$_4$, $R^2 = 0.984$ (Fig. 3.27a & b; Table 3.2). High $R^2$ in dug wells shown by majority of pairs is certainly because of the limited number of samples (4 only).

In Peshawar floodplain aquifer the dominant ionic pair is Na-Cl both in tube wells ($R^2 = 0.9885$) and dug wells ($R^2 = 0.9995$) (Figs. 3.28a & b). Other significant pair, with $R^2 > 0.3$, is Na-SO$_4$ (Table 3.2). In the Peshawar lacustrine aquifer only Na-Cl has an $R^2 = 0.9977$ in tube wells and $R^2 = 0.9919$ in dug wells (Figs. 3.29a & b) and thus stand the most dominant pair. Ca-SO$_4$ in dug wells show an $R^2 = 0.402$ indicating some significance (Table 3.2). Other pair is least significant with $R^2 < 0.3$. Similarly in Attock-Cherat piedmont aquifers in addition the dominant ionic pair is Na-Cl both in tube wells and dug wells ($R^2 = 0.955, 0.9854$) respectively (Figs. 3.30a & b). Other pairs are Mg-SO$_4$, Fe-Cl, Ca-SO$_4$, Mg-Cl, and Na-SO$_4$ in dug wells and Ca-SO$_4$, Ca-HCO$_3$, Fe-Cl, and Mg-SO$_4$ in tube wells in decreasing order of significance (see Table 3.2).

It can be concluded from the cations and anions correlation that in all the aquifers Na and Cl has shown greater availability and correspondence with each other, but still remained within the range of normal water. The rest of the cations did not form strong pairs due to very low concentration and less solubility compared to the Na-Cl. The chemistry of the groundwater from Peshawar Basin shows that the cations and anions existing in these waters are from normal rather than enriched sources such as limestone.
Figure 3.27a-b The main ionic pairs in the tube wells (a) and dug wells (b) from Khyber piedmont aquifer.

Figure 3.28a-b The main ionic pairs in the tube wells (a) and dug wells (b) from Peshawar floodplain/stream channel aquifer.

Figure 3.29a-b The main ionic pairs in the tube wells (a) and dug wells (b) from Peshawar lacustrine aquifer.

Figure 3.30a-b The main ionic pairs in the tube wells (a) and dug wells (b) from Attock-Cherat piedmont aquifer.
salt seeps, gypsum and dolomite etc. Individual water samples indicating higher concentrations of certain elements can be attributed to the localized enrichment.

3.5 HEAVY METALS AND TRACE ELEMENTS

Heavy metals are defined as those elements having densities 5 times greater than water. Trace elements are defined as elements with concentrations < 0.001% in a given system (Goyer, 1986). Heavy metals such as copper (Cu), iron (Fe), lead (Pb), zinc (Zn), cadmium (Cd), chromium (Cr) and nickel (Ni) etc. generally occur in rocks, soils, plants, waters as well as in the human body in trace concentration and are therefore also called trace elements in these systems. Plants and human beings require certain elements (e.g., carbon, hydrogen, nitrogen, oxygen, sodium, magnesium, phosphorus, silicon, potassium, calcium and traces of chloride, manganese, iron, copper and zinc) in specific limits. Deficiency or excess of these in relation to limits set by WHO or US-EPA may result in diseases or toxicity (appendix-B, Table 3). There are certain elements like lead, cadmium, mercury, chromium and arsenic, which are not essential for the living organism, however if present in smaller quantities are considered to be toxic. Baranowska (1993) has discussed the heavy metal poisoning in human in relation to sex, age and place. Toxic effects of heavy metals on kidney in human body have also been reported by Berndt et al. (1993).

To determine the quality of water with respect to drinking and domestic purposes, the concentration of various heavy metals and trace elements are evaluated in various aquifers of Peshawar Basin. The data has been presented in appendix-B (Table 2).

i Copper (Cu)

Copper is a gastrointestinal-tract irritant, irritating the nerve endings in the stomach and initiating the vomiting reflex in the higher animals. A potentially hepatotoxicity of copper in people undergoing long term hemodialysis had been reported.
Copper metal slices or salts leave a sweetish, metallic taste, cause salivation, nausea, vomiting, gastric pain, hemorrhagic gastritis, diarrhea, cramps in the calves, and terminally, muscular rigor and prostration (Patty, 1962). Due to constant exposure to copper the liver, kidneys, and spleen may be injured and anemia may develop in human body, although chronic poisoning from copper is unknown (Patty, 1962).

The permissible limit of copper for drinking water in the United States is 1000 µg/l, which is based on taste consideration, rather than toxicity (US-EPA, 1976). The European standards for drinking water are about 0.05 mg/l at the pumping station and 3 mg/l after 16 hours of contact with plumbing.

Copper toxicity is causing particularly from the dissolution of copper in water pipes ending up to 0.01 mg/l. There are instances when drinking water could be contaminated by copper from industrial waste (Disnayake & Jayatilaka, 1989) in the world. Among the industrial sources, metallurgical processing (smelting) for copper, iron, steel production and coal combustion is among the major sources of copper contamination. The most widely used source of water soluble copper in agriculture is CuSO₄·H₂O, which contains 25.3% of copper (Lucascio, 1978). Copper compounds have been used for many years as fungicides and bactericides. The other source of copper contamination could be the percolation of water through sulfide zones. It is currently believed that most of the population obtains adequate amounts of copper from food, water and cooking utensils. Thus unlike iron, copper supplements are probably not necessary.

Copper concentration in the water samples from various aquifers of Peshawar Basin are given in Figures 3.31 and 3.32 (appendix-b, Table 2). In Khyber piedmont aquifer the concentration of copper varies from 0 to 59 µg/l. Similarly in Attock-Cherat piedmont aquifer it ranges from 0-17 µg/l, in Peshawar lacustrine it is 0-33 µg/l and in
Figure 3.31 Concentration of Cu in tube wells from the aquifers of Peshawar Basin.

PATW: Peshawar Floodplain Stream Channel Aquifer tube wells
KPATW: Khyber piedmont Aquifer tube wells
D PATW: Davaqir Aquifer tube wells
ACPATW: Attock-Cherat piedmont Aquifer tube wells

Figure 3.32 Concentration of Cu in dug wells from the aquifers of Peshawar Basin.

KPDW: Khyber piedmont Aquifer dug wells
PDADW: Peshawar Floodplain Stream Channel Aquifer dug wells
PLADW: Peshawar Lacustrine Aquifer dug wells
ACPADW: Attock-Cherat piedmont Aquifer dug wells

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Peshawar floodplain is 0-51 kg/ha. The river waters have negligible amount of copper (appendix-B, Table 2). It is clear that majority of the water samples show copper content below the Maximum Contaminant Level (1000 µg/l) of US-EPA (1978).

ii Cadmium (Cd)

Cadmium is present in traces in rocks, soils, waters, plants and other environmental matrices. The average concentration of cadmium in the earth crust is 0.15-0.20 mg/kg (Fleisher et al., 1974). Cadmium is a silver-white and ductile metal used as alloys, in auto industry, electroplating, in pigments, as stabilizers for polyvinyl plastics and in Ni-Cd batteries (Forstner, 1980). Cadmium 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. Chino and Mori (1982) determined cadmium concentration of domestic waste waters of some typical families. They found the cadmium concentration of waste waters from lavatory, kitchen, laundry, and both to be 38, 0.04, 0.6 and 0.5 µg/l respectively. The total amount of cadmium discharged with such domestic waste waters was calculated to be 126 µg/l day/person. Cadmium arising from phosphate fertilizers and sewage sludge may reach to man through the food chain (Fleisher et al., 1974). The US-EPA (1978) has set a standard of 10 µg/l for cadmium in drinking water for human body, while the WHO (1984) has considered a standard of 5 µg/l. Cadmium is a trace contaminant of phosphate fertilizers and is steadily builds in agriculture soils. Cadmium has several toxic effects in human body, it may also contribute to high blood pressure and heart and kidney diseases. Cadmium oxide fumes and dust are severe pulmonary irritants (Bennett, 1965; Levia, 1972; Fassett, 1975; Stokinger, 1981). According to National Institute of Occupational Safety and health, US (NIOSH, 1984), epidemiological evidence shows that excess of respiratory cancer deaths among the workers of cadmium production company are due to the potential carcinogenic
character of cadmium. Concentration of cadmium has been determined in waters of tube wells, dug wells and surface from various aquifers of the Peshawar Basin (appendix-B, Table 2). Cadmium concentration in all aquifers of the Peshawar Basin fall below the permissible limit of US-EPA(1978) and WHO (Figs. 3.33 and 3.34). Therefore, there is no drastic effect of this elements in relation to water contamination from the aquifers of the Peshawar Basin.

iii Chromium

Chromium is a steel-giny, lustrous, hard, brittle metal. Chromium is mainly used in metallurgical, refractory, leather and chemical industries (Langard, 1980). Chromium in metallurgical industry is used in making stainless steel and its chemicals are used for taining, catalysts, pigments, plating and wood preservatives. The other sources of chromium contamination originates from paper industries, chemicals, petrochemicals and fertilizers. The vehicular pollution also causes the release of chromium in the air (NRCC, 1976). Chromium causes a nephritis and glycosuria diseases. The chromite dust produces skin ulcers and nasal mucosum (Major, 1922). According to Bussi (1956) a syndrome, chromium enteropathy eternal injury caused by to Cr2O3. Chromium is essential in human nutrition to maintain the normal glucose metabolism. The WHO (1984) have set a 50 µg/I standard for drinking water.

Chromium concentration in tube wells and dug wells from Peshawar Basin are shown in Figures 3.35 and 3.36. Though majority of the samples is below the (50 µg/I) MCL of WHO. Few samples show higher values than allowed MCL among the tube well samples from Tarangzai and dug well sample from Takht Bhai may owe their high values due to high chromium-bearing sources rocks/soils because of occurrence in the vicinity of SkhoKot Quils, ultramafic complex (Ahmed, 1982, Noor Jehan & Haridullah, 1996). The higher values of chromium in the tube wells from Landi Arbab, Aza Khel Bala and
Figure 3.33 Concentration of Cd in tube wells from the aquifers of Peshawar Basin.

- KPATW: Khyber piedmont Aquifer tube wells
- PFATW: Peshawar Floodplain Stream Channel Aquifer tube wells
- PLATW: Peshawar Lacustrine Aquifer tube wells
- ACPTW: Attock-Chott piedmont Aquifer tube wells

Figure 3.34 Concentration of Cd in dug wells from the aquifers of Peshawar Basin.

- KPADW: Khyber piedmont Aquifer dug wells
- PPADW: Peshawar Floodplain Stream Channel Aquifer dug wells
- PLADW: Peshawar Lacustrine Aquifer dug wells
- ACPADW: Attock-Chott piedmont Aquifer dug wells
Urmari village and dug wells samples from Sorazai, Urmari Bala, Urmari Paya, Aza Khel Bala, Darazazi and Spin Khel can be attributed to the use of chromium in the machinery of the tube wells or to the same reason mentioned for samples from Takht Bahai and Tarangi, if the chromite bearing soil extend further south and east at deeper level in the basin. Higher chromium from the tube well at Tehsil Gang may have its origin from mixed sources of urban nature including construction work, metal businesses etc. (see Hamidullah et al. 1997 a, b). Rivers samples show normal chromium values, however, samples from old Attock bridge (53 µg/l), Sardaryab (168 µg/lo) and Shah Alam rivers (54 µg/l) show high values than the allowed limit of WHO. The high values at old Attock bridge may have mixed sources, however, the high value at Sardaryab and Shah Alam rivers must owe their origin to the leather industry on the river bank in this area.

iv Lead

Lead is found in galena and other minerals but its existence is rare in nature. Lead is used in storage batteries, paints, ink, ceramics and automobile radiator repair etc. In 1970, lead has been used in gasoline to prevent the knocking of engine in vehicles and thus it became the greatest source of lead contamination in air. Lead is a vital metal in industrial economy. The automobile and construction industries are the primary users of lead. About 60 percent is consumed in the automobile industries, batteries manufacturing and as a gasoline additive (Robinson, 1978).

Lead originates in waters from atmosphere, geological formation and plumbing fixtures (in the case of drinking water). Environmental contamination of lead in metropolitan area arises primarily from automobile emission and industries and sewage sludge (Sommers et al., 1976). Coal combustion and commercial fertilizers also emit Pb
into the atmosphere, which contains from traces to several mg/l of lead (Steenstrom & Vithas, 1974; Mortvedt & Giordano, 1977; Williams, 1977).

Georgians et al. (1955), has described lead as a potent and noxious metal. The absorption of lead or its inorganic compounds results in severe gastro-intestinal disturbances and anemia, neuromuscular disfunction and encephalopathy. The symptoms of lead poisoning or plumbism are often abrupt and cause weakness, weight loss, hypertension, lassitude and insomnia (Kehoe, 1972; NIOSH, 1972). Several studies present that certain lead compounds including lead acetoate and lead phosphate in excess to be carcinogenic for health but primarily produced renal tumors (NIOSH, 1972, IARC, 1976). Excessive exposure to lead during pregnancy has resulted in neurological disorders in infants (Angel, 1964).

The concentration of lead in drinking water from various aquifers of Peshawar Basin is given in appendix-3 (Table 2). Majority of the samples from all aquifers have Pb below the MCL of 50 μg/l of US-EPA (1978) and WHO (1984). Exceptions are tube wells from Saad, Mattani, Gharibaiad, Gul Bahar No.2 and dug wells from Chapi (see appendix- B, Table 2; Figs. 3.37 & 3.38). The high lead content may be related to local incision from the tube well machinery, grasing and welding processes of the machinery. High lead values have been noticed by Humidiullah et al (1997) in this area in air and water samples.

v Nickel (Ni)

Nickel is a silvery white metal and is resistant to corrosion and a good conductor of heat and electricity. It is insoluble in water and soluble in acids. Its solubility may control by sulfide (Richter & Thiel, 1980). Nickel used in the production of electroplating, high grade steel alloy, fabrication, electronic component and mainly present in a wide variety of commodities, such as automobiles, batteries, coins, jewelry,
Figure 3.37 Concentration of Pb in tube wells from the aquifers of Peshawar Basin.

Figure 3.38 Concentration of Pb in dug wells from the aquifers of Peshawar Basin.
surgical implants, kitchen appliance, sinks and utensils. As no limits of Ni for drinking water are recommenced by the US-EPA, it may appears to be relatively safe. However Clemente et al. (1980) reported its limit below 10 μg/l for mineral and deep spring water. Stamer et al. (1985) noticed that its contact with skin may cause a dermatitis disease and its inhalation can cause lung cancer. Nickel is considered less toxic to the aquatic life than several other metals, although its toxicity depends on pH, synergistic effects, and other factors. Nickel may enter the aquatic environment and then to soil through discharges from mine 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, rivers water samples from various aquifer of Peshawar Basin (appendix-B, Table 2). Majority of tube wells, dug wells, rivers and spring samples showing nickel content below the permissible limit or in trace (<1μ g/l). Except tube well samples from Danishabad (34 μ g/l), Sar Band (39 μg/l), Urmar village (47 μg/l), Hashim Kili (12 μ g/l) and dug well samples from Musha Ghar (20 μ g/l) and Urmar Payan (21μ g/l) showing values above the reported limited of nickel by Clemente et al. 1980. The exception of high nickel content in Danishabad, Sar Band, Urmar village, Hashim Kili and Urmar Payan seems to be composition of the hosting quaternary sediments or interaction of sewerage sludge with water system.

vi Cobalt (Co)

Cobalt is silvery white metal and is resistant to corrosion and to alkalis but is soluble in acids. Cobalt occurs as a sulfide in rock and ores bodies and commonly associated with sulfides of other metals, especially silver, nickel, lead, copper and iron. It is used in the production of magnetic alloys and high grade steel, drying agent in paints, varnishes, enamels, inks.
According to Adriano (1986), cobalt is the basic constituent of vitamin B₁₂ in all animals. Low level of cobalt can cause nutritional diseases in animal, known as the Bush sickness in cattle and sheep. About 0.07 mg/kg of cobalt is essential in nutrition to maintain the normal health of animals. From various reports it is clear that cobalt is relatively non-toxic to animal and human beings but may produce carcinogenic effects if it taken in high quantity.

The concentration of cobalt in all tube well, dug well, rivers and spring samples is generally below the detection level (< 1 μg/l) while one sample from a stream at Pir Baha (19 μg/l) shows high content of cobalt (appendix-B, Table 2). Due to very low concentration of cobalt in the drinking water of the basin, no drastic effect of these elements in relation to water contamination can be observed.

3.6 OXYGEN ISOTOPE

Oxygen is the most abundant chemical element in the earth crust which in combination with hydrogen to form water (H₂O). Oxygen occurs in three isotopic forms ¹⁶O, ¹⁷O and ¹⁸O with their abundance as 99.63%, 0.0375% and 0.1995%, respectively. The isotopic composition of oxygen is reported in terms of delta notation (δ¹⁸O) which is the ratio of ¹⁸O and ¹⁶O (¹⁸O/¹⁶O) relative to the standard known as SMOW (Standard Mean Ocean Water). δ¹⁸O is the per mil (‰) difference relative to SMOW and is expressed as:

\[ \delta^{18}O \text{(sample)} - \delta^{18}O \text{(SMOW)} \times 10^3 \]

Positive values of δ¹⁸O indicate an enrichment of a sample in ¹⁸O (heavy oxygen) compared to SMOW, while negative values intimate depletion of these isotopes in the sample relative to the standard. The δ¹⁸O value of enrichment or depletion is generally related to: the ratio of the quantity of oxygen in the exchangeable minerals to that in water, the temperature of exchange, and the initial isotopic composition of the
phases (Stepphurt, 1986). It is now understood that during the decondensation of water vapor, the liquid phase is enriched in $\delta^{18}O$ and, therefore, the first raindrop from the cloud has the isotopic composition of ocean water. This removal of $\delta^{18}O$ from the moist air mass causes enrichment of $\delta^{18}O$ in the remaining vapor phase. This is the reason that the $\delta^{18}O$ values of water vapors in the air become progressively more negative as the rain, snow or hail continue to fall from it (Faure, 1986). As the vapour get depleted in $\delta^{18}O$, the $\delta^{18}O$ values become progressively negative. So the isotopic fractionation during evaporation of water from ocean and subsequent condensation of vapour in clouds cause the depletion in $\delta^{18}O$. The $\delta^{18}O$ values of meteoric water (water from rain, snow, ice, river, lake and most low temperature ground water), therefore, range from -6 to -6.5‰ (Faure, 1986). This isotopic composition of oxygen in water can be determined on mass spectrometer by comparing its $^{18}O$/$^{16}O$ ratio at known temperature to that of a standard gas (CO$_2$), which is equilibrated with SMOW.

The source of water can be determined if we know the isotopic ratio of ($^{18}O$/$^{16}O$) of water. The combined H and O isotopic composition of water is now widely used world over to get information concerning both the source and history of water. The Oxygen isotopic composition of the waters from surface and groundwater of Peshawar Basin are evaluated in order to consider; a) to see anomalous concentration of $\delta^{18}O$ in water system and how they are propagated in the area, b) to see the effects of river waters on the groundwater of the area, c) to see whether the isotopic data can explain what portion of the rain fall recharges the ground water and d) to assess what isotopic similarities and differences exist among shallow (dug wells) and deep (tube wells) groundwater. Due to the lack of exact depth of tube wells and dug wells, the tube wells having depth of >25 m (greater than 90 ft) are considered as deep wells and the dug wells having depth of <25 m (less than 75 ft) are considered as shallow wells. Forty eight water samples from the dug
The various sources that replenish the sub-surface water system of Peshawar Basin are direct precipitation of Kabul and Swat rivers and it is appropriate to discuss the sources first. Hussain et al. (1991) determined an isotopic index of -5.0 ‰ for rainwater in Mardan area. They have also obtained a similar time consistent value for an underground water sample from a spot that he considered as being replenished only with rainwater. This sampling point they considered as representative of rain index. During the current study δ¹⁸O values above -6 ‰ with many closer to -5 ‰ and even further enriched ones have been obtained from various places in the basin including locations west of Peshawar along Jamrud road near Jamrud (-4.92 ‰), south of Peshawar along Kohat road at Sortmand (-4.54 ‰), at phase III, Hayatabad (-5.3 ‰), at Forest, colony of Peshawar University Campus (-5.11 ‰), as several other places (see Table 3.3). All these locations occur away from Kabul and Swat rivers and the only possible source of recharge is rain water. Unfortunately this study did not collect δ¹⁸O data from underground water on monthly or annual basis, however, these values closely correspond with the representative rain index of Hussain et al. (1991). River water in the basin and in Indus carry very distinct signatures of δ¹⁸O with pure Swat indicating a variation from...
Table 3.3  Oxygen isotope analyses of water samples from the tube wells and dug wells of Peshawar Basin.

**Khyber piedmont aquifer**

<table>
<thead>
<tr>
<th>S.#</th>
<th>Sample No</th>
<th>Location</th>
<th>δ¹⁸O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>STWP54</td>
<td>Wapada Colony</td>
<td>-10.60</td>
</tr>
<tr>
<td>2.</td>
<td>STWP90</td>
<td>Jamrud Road</td>
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**Dug wells (Shallow wells)**

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**Peshawar Floodplain aquifer**

**Tube wells (deep wells)**

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**Dug well (Shallow wells)**

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### Peshawar Lacustrine aquifer

#### Tube wells (deep wells)

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### Attock-Cheraff piedmont aquifer

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Figure 3.39 Contoured representations of $\delta^{18}O$ data for tube wells in Peshawar Basin
Contoured representations of $\delta^{18}$O data for dug wells in Peshawar Basin
-5.97 %/o in October, -8.48 %/o in March and -8.42 %/o in September, pure Kabul indicating a variation from -10.23 %/o in March to -12.85 %/o in August and pure Indus indicating variation from -12.03 %/o in February to -14.10 %/o in September (see Table 3.4; Fig. 3.41) Also samples collected down stream of the confluences carry the signature of the mixing rivers. The means of the time-based pure samples of each river and of their mixture are plotted in Figure 3.42. This diagram indicates a systematic depletion of δ¹⁸O from pure Swat through Swat + Kabul, pure Kabul, Kabul + Indus to pure Indus rivers. The highly depleted values in Indus river and enriched values in Swat river with Kabul river representing intermediate values are reflecting the following:

i) Water in Indus represents precipitation from clouds of very high altitude, more evapotranspiration in the upper and middle Indus valleys and less percent evaporation as compared to other rivers.

ii) Water in Swat represent precipitation from clouds of low altitude, a high degree of evaporation and relatively less evapotranspiration because the catchment area of Swat river is much smaller and closer to aquifer as compared to that of Indus.

iii) Kabul river originates in Chitral and flows along Kabul to Peshawar Basin and, therefore, clouds precipitating water in Kabul are from altitudes lower than those for Indus but higher than those for Swat river. Also upstream of Attock, Indus has the longest valley and largest catchment area while Swat has the shortest valley and smallest catchment area, whereas Kabul stands in between. Therefore, for Kabul river the chances of evaporation and evapotranspiration, both affecting the δ¹⁸O of water, stand in between those of the other two rivers as is shown by our current data.

iv) A monthly variation exists with Indus and Kabul rivers showing highly depleted values in August or September and relatively enriched values in February and

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Fig. 3.41 Comparison of the δ¹⁸O values of the various aquifers of Peshawar Basin.

1. Khyber piedmont aquifer
2. Attock-Cherat piedmont aquifer
3. Lacustrine aquifer
4. Floodplain aquifer

Fig. 3.42 Comparison of the average δ¹⁸O values of the various rivers of Peshawar Basin.

1. Indus river
2. Mixture of Indus & Kabul rivers
3. Kabul river
4. Mixture of Kabul & Swat rivers
5. Swat river
March. On the other hand, the Swat river shows extreme depletion of $\delta^{18}O$ both in March and September and relatively enrichment in October. The reasons for two negative anomalies in Swat river are the two rainy seasons in Swat valley. It may be born in mind that Swat valley is at a higher altitude than Peshawar valley and clouds here must be rendering precipitation with values depleted in $^{18}O$ compared with the later where a precipitation Index of $-5 \%o$ is accepted. Further, the depletions in Indus and Kabul rivers are most probably related more to melting of glaciers than the rainy season, because monsoon do not reach upper Indus valley and Chitralt areas from where Indus and Kabul originate.

The Oxygen isotope data of the underground water from Peshawar Basin indicate the following features (Table 3.3).

1) In the Khyber piedmont Aquifer, the tube well samples can be divided into three classes:

a) Samples from Jamrud road, Haysabbad, Phase III, Sar Bad showing values of $-4.92 \%o$, $-5.33 \%o$ and $-4.54 \%o$ respectively and can be classified as carrying no or the least signature of the river water (Mean Kabul river = $-11.4 \%o$, Mean Swat river = $-7.52 \%o$)

b) Samples from Shabqadar, Matta Maghul Khel, Abazai and a Tragi showing values of $-7.30 \%o$, $-7.43 \%o$, $-7.94 \%o$, and $-6.84 \%o$, respectively are similar to the values of Swat river and therefore, indicate contamination through river bed (Abazai) or irrigation canals.

c) Sample from Wapda colony of Warsak dam shows a value of $-10.60 \%o$.

This is a close correspondence with those of pure Kabul river indicating a high degree of contamination. This is also supported by the further
depleted value of -10.96 \(^{\circ}/_{\text{oo}}\) obtained from a dug well sample from Hinder Kassi in this area (see Table 3.3).

ii) In the Peshawar floodplain aquifer the tube well data indicate a similar variation from the least depleted water at Tarangzai (-5.15 \(^{\circ}/_{\text{oo}}\)) through tube wells carrying signatures of Swat river (Rajjar: -6.27 \(^{\circ}/_{\text{oo}}\), Praw: -8.29 \(^{\circ}/_{\text{oo}}\), Kandi hayat: -3.91 \(^{\circ}/_{\text{oo}}\)) to tube wells carrying signatures of Kabul river (Mathra: -9.10 \(^{\circ}/_{\text{oo}}\), Kultur: -10.34 \(^{\circ}/_{\text{oo}}\)). In this aquifer the least depleted samples are missing from among the dug wells which have values similar to both Swat and Kabul rivers and a more depleted average (-8.13 \(^{\circ}/_{\text{oo}}\)) than that of the tube wells (-7.88 \(^{\circ}/_{\text{oo}}\)) in this area.

iii) The tube wells of Peshawar lacustrine aquifer also indicate values between -5.11 \(^{\circ}/_{\text{oo}}\) and -7.80 \(^{\circ}/_{\text{oo}}\) which reflect rain water signatures and contamination. The least depleted values are from Forest colony (-5.11\(^{\circ}/_{\text{oo}}\), Sore zai (-5.91 \(^{\circ}/_{\text{oo}}\)) and Jehangirabad (-5.87 \(^{\circ}/_{\text{oo}}\)), location that can be accepted away from any major river. The relatively more depleted values in this part of the basin are from Shihi Dala (-6.94 \(^{\circ}/_{\text{oo}}\), Sadh Ber (-7.80 \(^{\circ}/_{\text{oo}}\)), University Town (-6.27 \(^{\circ}/_{\text{oo}}\), Akbarpur (-7.03 \(^{\circ}/_{\text{oo}}\), Pabbi (-7.69 \(^{\circ}/_{\text{oo}}\) and Aza Kisl Bala (-7.30 \(^{\circ}/_{\text{oo}}\)). These values are similar to those of Swat river but this river has no extensions in the areas from where these samples are collected. This indicates contamination from Kabul river but to lesser extent. The main channels of contamination from Kabul river in these areas in addition to Kabul river itself, are Budai canal and Warsak canals, north and south of Peshawar metropolis, respectively. These interpretations are confirmed by the \(^{81}O\) data obtained from the dug wells of Peshawar lacustrine aquifer with values ranging from the least depleted -5.7 \(^{\circ}/_{\text{oo}}\) at Zahirabad to the highly depleted one of -10.71 \(^{\circ}/_{\text{oo}}\) at Pajagai. The mean \(^{81}O\) of these dug well indicate extreme negative value (-8.85 \(^{\circ}/_{\text{oo}}\) when compared with that of the tube
wells (-6.66 °/oo) in this aquifer, further confirming recharge from the river water system.

iv) In the Attock Cheraot Piedmont Aquifer the tube wells show more depleted values than the dug wells with the former indicating an average of the -6.51 °/oo compared with -5.88 °/oo of the later. This featured is in contrast to the general trend observed in other aquifer. The reason for this overturn is the collection of tube well samples in relatively closer vicinity of Kabul river when compared to the dug wells, which are also mostly located at relatively higher elevations than the tube wells. In general the Attock Cheraot piedmont aquifer is the least depleted aquifer as far as δ18O values are concerned. This shows that mixing from river water is minimum in the part of the Peshawar Basin.

The δ18O data of the river systems of the Peshawar Basin and of the Indus-Kabul confluence together with the data from the underground water aquifer of the Peshawar Basin indicate that the altitude of the clouds rendering precipitation, the extent of the catchment area the amount of evaporation and the amount of evapotranspiration have drastically influenced the isotopic character of the three rivers systems with Indus showing highly depleted, Swat showing enriched and Kabul showing intermediate δ18O values. Such data for the underground water system of Peshawar Basin indicate that the aquifers in the basin are replenished both by rain water and waters from Kabul and Swat rivers. Recharge from rainwater is mainly confined to the piedmont areas of the basin whereas recharge from the Swat river occurs north of the Hajizai branch of Kabul river in the vicinity of the Swat river itself (Abazai) or close to its irrigation canals. Similarly recharge from Kabul river occur to its south mainly between Hajizai and Nagaman branches, between Nagaman and Shah Alam branches where the area represents the flood plain of Kabul river. Recharge from Kabul river also occurs south of Peshawar through
canals at Wazirah and in the villages along Peshawar-Islamabad Highway east of
Peshawar city. The data also indicates that shallow water in the basin are more
contaminated than the deep water. This study also confirms the results and interpretations
reported by Russain et al. (1983) obtained from similar data around Mardan.

Except certain locally high values most of the underground and surface water
samples from Peshawar Basin indicate elemental values (major and trace elements and
heavy metal concentrations) within the permissible limits (chapter 3) indicating that so
far no significant contamination from surface or an underground source has occurred.
The Oxygen isotopic data, however, indicate that if our rivers, turned polluted, their
impact will certainly reach to deep levels in aquifers, especially in the vicinities of rivers
and their irrigation canals emerging from these rivers.

The oxygen isotope data also shows that the Indus water has rendered no
signatures to the underground water of the Peshawar Basin.
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<td>Mass transfer coefficient</td>
<td>1° 1°</td>
<td>8° 9°</td>
</tr>
<tr>
<td>Emissivity</td>
<td>1° 1°</td>
<td>8° 9°</td>
</tr>
<tr>
<td>Porosity</td>
<td>1° 1°</td>
<td>8° 9°</td>
</tr>
</tbody>
</table>

Table 3.5: Comparison of average oxide scale values of various alloys and their effects.
CHAPTER 4

SOIL

4.1 General

Soil is an unconsolidated material that essentially supports plant growth and agricultural activities. Soil is usually differentiated into horizons of variable depth (soil profiles). According to soil scientists, soil is a solid earth material that has been 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. Climate, parent material, topography, time, plants and organic activities also play significant roles in the formation of soil (Mason, 1966). On the other hand, there are certain trace and major elements that are essential for the growth of plants kingdom i.e., Cu, Pb, Zn, Ni, Cr, and Co etc., and Ca, Mg, Fe, P, Ti etc.). These trace 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. The domestic and industrial sewage sludges produce 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. Wastewater is also one of the major sources of heavy metals supply to the soils. Fertilizer applications and other agriculture practices also attribute pollution to soil (Page, 1974, and Sommer, 1977). 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 contaminates subsurface water system, render the
land unsympathetic for living purposes and enter the food chain and may pose threats to human health (Brownlee, 1979).

Major, heavy and trace elements exist in surface, groundwater. These may pose a potential threat of entering into food chain indirectly through surface and groundwater in drinking and irrigation water, and directly through plant roots.

4.2 Soil Chemistry of Peshawar Basin

Soils of Peshawar Basin were evaluated at different locations in order to:

a) Identify the sources of contamination, which affect and control the chemical composition of water in various aquifers of the basin.

b) Establish relationship (if any) between the chemistry of soil and quality of water.

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

Different locations were selected for representative sampling from the basin for the determination of various major, minor, heavy and trace elements in the soil. These samples were collected from the cropland where from the groundwater sampling was done (Fig. 1.1). From each location two core samples of soil, at a depth of up to 20 cm and 20 to 45 cm were collected. The soil up to a depth of 20 cm has been named as “A” horizon and from 20-45 cm as “B” horizon in the text for the sake of distinction. The concentration of major element oxides (i.e., SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, K₂O, Na₂O, MnO, & P₂O₅ & Ig,less) heavy and trace elements, (i.e., Cu, Zn, Pb, Co, Ni, Cr, Ag) were determined by atomic absorption spectrophotometer and the results are given in appendix-D (table 4 and 5). In order to avoid confusion the soil samples have also been grouped, in similar way as for the water samples, into Khyber piedmont soil, Peshawa floodplain soil, Peshawar lacustrine soil and Attock-Cherai piedmont soil. The chemical characters of these soils of the Peshawar Basin are discussed below:

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4.2A Major Elements Oxide

The major element oxides analyses carried out in various soils from Peshawar Basin are presented in appendix-B (Table 4 and 5). The concentration of these major oxides is compared with the values recommended by various workers. The description of these oxides are discussed in detail as follows:

1 SiO₂

Rocks are classified on the basis of their silica content such as basic rocks containing 40-55 percent silica are derived from gabbros, basalt, limestone, and diabase, Intermediate rocks, with 55-65 percent silica e.g., granite, rhyolite, sandstone and gneiss. Acid rocks containing 65-75 percent silica, e.g., syenite, diorite, and andesite (Marbut, 1951). These rocks are also rich in iron calcium, magnesium and sodium. The level of silica (40.35 wt %) for the normal soils has been reported by United States Department of Agriculture (USDA; 1957). silica concentration in both horizon A and B, from Peshawar Basin soils are shown in Figure 4.1 and appendix -B (Table 4). Though majority of the soil samples plot above the USDA value of silica (40.35 wt %) in soils. They are below the value of silica for the average of 235 samples from the Mississippi delta sediments (Brownlew, 1979), indicating that the soils of Peshawar Basin may carry some signatures of delmian sediments. This is consistent with the history of the deposition of lake deposits in Peshawar Basin (Cornwell, 1992).

2 TiO₂

TiO₂ is one of the accessory minerals present as rutile in igneous rock and metamorphosed limestone. TiO₂ presents in traces in both horizons A and B from piedmont, floodplains, and lacustrine soils of Peshawar Basin. TiO₂ concentration in the soil samples at different locations in the basin is 0.03-0.97 wt % that is within the permissible limits of TiO₂ for normal soils (appendix B, Table 4) of USDA and those
Figure 4.1 Concentration of SiO₂ in soils samples at various location in Pothawar Basin.
iii. $\text{Al}_2\text{O}_3$

$\text{Al}_2\text{O}_3$ occurs in low to very high weathered rocks and minerals (e.g., orthoclase, albite, anorthite, muscovite, garnet, hornblende, biotite and tourmaline). Concentration of $\text{Al}_2\text{O}_3$ is high in sandy loam soil as compared other soils (Mohr, 1959). The value of $\text{Al}_2\text{O}_3$ (31.04 wt %) in normal soils has been reported by United States Department of Agriculture USDA (1957). $\text{Al}_2\text{O}_3$ concentration in soil samples from various locations in different soils from basin given in appendix-B (Table 4). Figure 4.2 values are below the limit described by USDA (1957; 31.04 wt %) and generally above the limit for the Mississippi River delta of Brownlew (1979).

iv. $\text{Fe}_2\text{O}_3$

Iron is fourth abundant element in the earth crust. It is one of the essential elements both for animals and plants. Iron occurs in trace and major concentration both in rocks and minerals. Iron rarely found in native form, however, rocks and minerals those contain amphiboles, pyroxenes, mica and olivine contain iron. USDA (1957) recommends the most common range of $\text{Fe}_2\text{O}_3$ (10.11 wt %) in normal soils. $\text{Fe}_2\text{O}_3$ content of soil samples from Peshawar Basin are presented in appendix-B (Table 4) and compared with the value of USDA (1957) in Figure 4.3. It is clear from the data that soil samples have $\text{Fe}_2\text{O}_3$ content below the permissible limit (10.11 wt %) of USDA (1957) and of the doleritic soil from Staffordshire, England (14.6%) and above the average of Mississippi River delta (3.5 wt %).

v. $\text{MnO}$

Manganese is an iron-gray relatively hard metal mainly associated with other manganese and iron oxides. It occurs in trace form both in rocks and minerals. Like other elements the scientist has not reported the international range for $\text{MnO}$ in normal soil.
Figure 4.2 Concentration of Al$_2$O$_3$ in soils samples at various location in Peshawar Basin.

Figure 4.3 Concentration of Fe$_2$O$_3$ in soils samples at various location in Peshawar Basin.
MnO concentration in the soil samples from Peshawar Basin presented in appendix B (Table 4) range from 0.03 to 0.11 wt%. These values correspond with those described by Conor and Shackle (1975) for the cultivated and non-cultivated soils from USA (see Brownlew, 1979).

vi MgO

Soils formed from mafic and ultramafic rocks are rich, whereas soil from magnetite, dolomite and other carbonates etc., are poorer in magnesium (discussed in Chapter 3). Magnesium is supplied from soil to plants in ionic and an exchangeable form through the surface clay and humus particles. USDA (1957) has recommended the value of 0.71 wt % MgO in normal soils. Though majority of soil samples from the basin shows values of MgO above this limit, however, they fall below the ranges described by Brownlew (1979); see Fig.4.4. Such data indicate the Mg sources rich in magnesium bearing minerals like, dolomite and mafic and ultramafic rocks. As mention earlier (Chapter 2) such sources are common in the surroundings and along the course of Indus, Kabul and Swat rivers. That are responsible for the deposition of Quaternary strata in the Basin (Chapter 2; Cornwell, 1992; Hamidullah & Cornwell, 1994).

vii CaO

Calcium is abundant element occurs as sodium and calcium silicate, calcium alumino-silicate, calcite and limestone in rocks and minerals. Similarly calcium is supplied to plants in ionic and an exchangeable form in humus particles and surfaces clay. USDA (1957) recommends CaO value (0.51 wt %) in normal soils. appendix B (Table 4) and Fig. 4.5 show calcium concentration in both horizon A and B at various locations from Peshawar Basin soils. These soil samples showing higher CaO concentration than the average limit (0.51 wt %) of USDA (1957) and those of Brownlew (1979). Calichi has been noticed in soils of the basin all over the places and its major
Figure 4.4 Concentration of MgO in soils samples at various location in Peshawar Basin.

Figure 4.5 Concentration of CaO in soils samples at various location in Peshawar Basin.
cause is water logging and salinity due to Warsak Dam. Calichi is mainly composed of CaCO₃. It is precipitated at higher levels due to rise and fall of water table. The modernly high concentration of CaO may therefore, attributed to the deposition of Calichi

viii Na₂O

Sodium occurs in soil as feldspars and other sediments. Sodium usually lies in upper soil layers. Na concentration increase in soil when it incorporated along with percolating water into surface and subsurface soil in agricultural fields and ground surface (see chapter 3). The allowed limit of Na₂O (0.24 wt %) in normal soils are recommended from US. Department of Agriculture (1957). Na₂O concentration in various soils of Peshawar Basin are though generally below (Fig. 4.6) the average of the Mississippi Delta (2.17 wt%), but drastically exceed the limits of the doloritic soils and that allowed by USDA (1957). Na concentration is very sensitive to human health and therefore we do not consider the Mississippi River delta values as good values. We rather stick to the lower value and consider the Peshawar Basin soil as having NaO above 183 wt% normal. High Na can be related to water logging and salinity (e.g. Kheshki area, Nishta, see Bundschuh, 1992) and to ion exchange reaction and Mg through water irrigation. ions replace the calcium and magnesium ions in a base-exchange reaction and forms alkali soils (see chapter 3).

ix K₂O

Potassium occurs in rocks and minerals as masevite and biotite. However, in soils it is derived from orthoclase and microcline. Similar to calcium and magnesium, potassium is supplied to plants in ionic and an exchangeable form and some of it is adsorbed on surface of clay and humus particles. One percent of the total potassium is present in exchangeable form and 1-5 percent in soil. USDA (1957) has recommended 0.81 wt% K₂O in normal soils. In Peshawar Basin majority of the soil samples show
Figure 4.6 Concentration of Na$_2$O in soils samples at various location in Peshawar Basin.
values above this limit (Fig. 4.7, though below the ranges of Brownless (1979). Like considering K₂O sensitive to human health we consider the USDA to average as and standard and classify the Peshawar Basin soils rich in K₂O for the same reasons give for Na₂O.

\[ x \text{ P}_2\text{O}_5 \]

Phosphorus is derived in soils from calcium phosphate, iron phosphate and aluminium phosphate and from decomposition of organic matter (Tamhane et al, 1964). Concentrations of P₂O₅ in majority of soils samples at different locations in Peshawar Basin (appendix –B, Table 4) are above the permissible range of USDA (0.42 wt %) for normal soil (Fig. 4.8). It is difficult to pinpoint a specific source for this richness in P₂O₅, however, the role of both organic (plants, bones) and inorganic (rocks) sources cannot be related out.

4.2B Heavy and Trace Elements

The concentration of heavy and trace elements including Cu, Zn, Pb, Co, Ni, Cr and Ag in two horizons (A & B) of soil from Peshawar Basin are given in appendix B (Table.5) The description of these metals at different location in basin soils are given here:

i Copper (Cu)

Copper ranks 26th among elements in crustal abundance occurs as native metal (Vinogradov, 1959). Copper occurs in nature as sulfides, sulfates, and sulfosalts, carbonates, and other compounds (Adriano, 1986). It is reddish in color and malleable. Electrical industry is one of the major users of copper in the production of electrical apparatus. The extensive use of copper and its occurrence in various types of industrial commodities, it contaminates the environment to a greater extent. Sources from which Cu derived to soil are copper fertilizers, fungicides and bactericides, and sewage sludge.
Figure 4.7 Concentration of $K_2O$ in soils samples at various location in Peshawar Basin.

Figure 4.8 Concentration of $P_2O_5$ in soils samples at various location in Peshawar Basin.
(Adriano, 1986). According to (Adriano, 1986) an average value of Cu in normal soils range from 20 to 40 ppm. Cu was reported for tropical Asian paddy soils a mean of 33 ppm of total Cu (Zborischnik & Zylin, 1978). Cu tends to accumulate within the top few centimeters of the soil profile (Kuo et al., 1983). Similarly in cropland it may accumulate in the surface from fungicide application and crop residues (Wright, et al., 1955). Copper in traces is essential for growth and well being of both animal and plants but its high concentration (more than 20 ppm) in crops and plant causes toxicity (NAS, 1977). The high content of copper may cause stunting, reduced growth, discolored root system and Chlorosis (Robson, & Reuter, 1981).

The values of Cu in soils from different location of the basin lie above the permissible ranges (Fig. 4.9). In addition soils from Shabqadar (575 & 695 ppm), Kafir Dheri (135 & 105 ppm), Nandezai Srieh (500 & 465 ppm), Taranzal (500 & 475 ppm), Aman Kot (485 & 540 ppm), Taila Band (100 & 110 ppm), Pando (130 to 100 ppm), and Khairabad (595 & 510 ppm), are richer in Cu and than the soils from other parts of the basin.

Copper in the soils of Peshawar Basin is in the range of 35 to 695 ppm. Therefore it exceed that of the normal agricultural soil (50 ppm; Gilbert, 1952) at various places (e.g., Shabqadar, Kafir Dheri, Jamrud, Surban, Tlaband, Khairabad, Pando, Baziakhel etc.) of Peshawar Basin. The soils of these areas may cause toxicity due to Cu (e.g., reduced growth and chlorosis) in the plants of the area (Robson & Reuter, 1981).

ii Zinc (Zn)

Zn is the 24th most abundant element in the earth’s crust (Vinogradov, 1959). Zinc content in the soils depends on the nature of the parent rocks, organic matter, texture and pH (Tull & McBee, 1994). Soils formed from basic rocks are enriched in Zn whereas soils from granites and gneisses are poorer (Browelow, 1979). Zn is commonly
Figure 4.9 Concentration of Cu in various soils at different location in Peshawar Basin.

Figure 4.10 Concentration of Zn in various soils at different location in Peshawar Basin.
associated with the sulfides of other metals, e.g., Cu, Pb, Cd and Fe. According to Swaine (1955), the value of zinc in normal soils ranges from 10-30 ppm. Bettencourt and Evans (1964) reported a mean content of Zn as 40 ppm for normal soils. However, National Research Council (1979) has recommended the Zn value 90 ppm for the world normal soil.

Figure 4.16 indicate that the concentration of zinc in the Peshawar Basin soils falls within the range (10-300 ppm) of normal soils given by Swaine (1955). In the basin soils the relatively higher value of Zn are observed at Speen Khuk (390 & 315 ppm), Khairabad (145 & 575 ppm) and the highest at Shabqadar (2550 ppm in horizon A).

The zinc value for agriculture soil generally varies from 5-162 ppm with an average of 54 ppm (Frank et al., 1976). The soils of the Peshawar Basin generally has zinc contents within the limit as specified for the agricultural soil. However, the soils of Mandzaibirk, Pir Baba, Shabqadar, Sarband, Spinkhak and Khairabad have about 2 to 3 fold high concentration of zinc. This can cause the zinc toxicity in the plants of the area (Jones, 1972).

iii Lead (Pb)

Lead is one of the most abundant heavy metal in the earth crust. Pb content in normal soil is <1.0 ppm where as it occurs up to 10 % in ore materials (Waldron, 1980). The average content of Pb in the earth crust varies from 13 to 16 ppm (Swaine, 1978; NRCC, 1973). According to Swaine (1978), Pb value in coal is ranging from .6 to 60 ppm, in sewage sludge from 1832 to 7627 ppm, in municipal water 3.7 to 6.2 ppm and in soil from 20 to 200 ppm. The non-contaminated Spanish soil contains 42 ppm Pb and that of United States soils contain 18 ppm Pb (Nriagu, 1978). Value greater than 110 ppm is considered anomalous by Davies (1983) and Swaine, (1955). The major sources of Pb in normal soils are automobile emissions, industrial and sewage sludge. Lead is a cumulative poison in human and is not considered essential to plants and animals. The
high concentration of Pb in the soils may also indicate the organic matter accumulation on the surface or plant dry matter recycling (Mitchell, 1971; Butler, 1954; Bradley, et al., 1978). In the polluted areas of Japan the Pb concentration vary from 400 to 500 ppm in soil found to be toxic to the plants (Chiino, 1981).

Except at Ser Band area where Pb content is less than 5 ppm Pb concentration in various soils from Peshawar Basin exceeds the average value of lead in normal soils given by Swaine (1978) and NARCC (1973) (appendix B Table 5).

The lead contents of the agricultural soil varies widely; for example the agricultural soil of Ontario, Canada has a range of 1 to 888 ppm with an average of 46 ppm (Frank et al, 1976) while that of the normal agricultural soil of Canada is ranging from 1 to 12 ppm (Warren et al; 1969). In this regard the soils of the Peshawar Basin are within the range as specified for the agricultural soils (Fig. 4.11). Therefore, no Pb toxicity can be observed in the plant kingdom of the area.

iv Nickel

Nickel is ranked 23rd among the elements in the crustal abundance (Lauria, et al. 1972). Ni content of the soils depends on the nature of parent rocks and organic material. The different values for total Ni in normal soils reported in literature by different scientists are 40 ppm by Vinogradov (1959), and 7.8-9.5 ppm by Anderson (1977) for normal Swedish soils. Recently Berrow and Reaves (1984) reported a value of 25 ppm while an average value of 22 ppm Ni was reported for Tropical Paddy soils by Domingo and Kyuma (1983).

Majority of the soil samples from Peshawar Basin show Ni concentration above the permissible limit given by the above workers (Fig.4.12; appendix B, Table 5). Though the Cr content of the soils of Peshawar Basin do not cross the limits of 4000 ppm and 5.23 % of Proctor (1971) and Nas (1974), respectively, but they do cross the limits of
Figure 4.11 Concentration of Pb in various soils at different location in Peshawar Basin.

Figure 4.12 Concentration of Ni in various soils at different location in Peshawar Basin.
11-78 ppm described for both cultivated and uncultivated soils of the United States (Connor & Schacklette, 1975). The source of this high Cr in the Peshawar Basin soils may be cromilies of the Dargai ultramafic complex and the Indus sand (Ahmad, 1971; Hamidullah & Jan 1986; Jan, 1969).

The nickel and chromium concentrations in the agricultural soil vary widely, depending on nature of the parent material. The soils derived from the ultramafic rocks have extremely high concentration of Ni (up to 3000 ppm) and Cr (up to 4000 ppm) (see Proctor 1971). The soils derived from other sources generally have relatively low concentration of Ni (up to 30 ppm) and Cr (up to 125 ppm) (see Albert & Pinta, 1977 and Morley, 1975 respectively). Soils of the Peshawar Basin must have contribution from the SQUG and local leather industry. Both Ni and Cr at many places in the Peshawar Basin is higher as compared to that of normal agricultural soil. The toxicity of these elements in the plant kingdom of the area cannot be, therefore, ruled out.

v Chromium (Cr)

Chromium ranks 21st among the elements in crustal abundance (Vinogradov, 1959). It occurs in soil, water, air and biological matter. Cr content in soil have been reported from trace to as high as 5.23 % (NAS, 1974). The parent material determines the concentration of Cr in soils. Soils derived from igneous rocks especially ultramafic ones can be expected to contain Cr as high as 4000 ppm (see Cannon, 1963; Proctor, 1971). Lukashev and Petukhova (1975) and Shakuri (1978) reported that Cr exists up to about 11 ppm in marl, sandstone and eolian deposits. Connor et al. (1957) reported that chromium accumulate from trace to 2.5 ppm and four times high in horizon B relative to A in the soil profile. However, some of soil profiles accumulate Cr within the top few centimeters of the soil profile (Kuo et al., 1983). Cr is not beneficial for plant but it is essential for animal in small amount. It is toxic and has carcinogenic effects in animal, if present in

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high quantity (Adián, 1986). Cr can be concentrated in the environment from the sources like, inorganic chemicals, petrochemicals, fertilizers, petroleum refining, steel work, aircraft plating, cement, asbestos product, textile mills, leather tanning, finishing and power plants and paper industries (NRCC, 1976). From all these sources Cr can reach the soil profile and may contaminate the agricultural land.

Cr values from Peshawar Basin fall within the recommended international value given in Fig. 4.13. It clearly shows that the values of Cr in Peshawar Basin are well in the range accepted for normal soils elsewhere.

vi Cobalt (Co)

The crustal abundance of cobalt have been reported as 20 ppm (Bowen, 1979), 23 ppm (Vinogradove, 1959), 20 to 23 ppm (Mitchell, 1945) and 27 ppm (Carr & Turkian, 1961). The soils derived from ultra basic rocks are usually enriched in Co (Underwood, 1977), whereas soils derived from acid igneous rocks, sandstone, limestone are depleted in Co with value <20 ppm. Young (1979) recommended the cobalt concentration in soil range from 0.2 ppm in Co scarce areas to 1000 ppm in mineralized areas.

The concentrations of cobalt in all soil samples from Peshawar Basin shown in Figure 4.14 and appendix B (Table 5) are below the detection limit of our instrument these data lay within the normal limit.

vii Silver

Silver ranks 66th among elements in crustal abundance and is present at about 0.07 ppm level (Krauskopf, 1979). Smith and Carnes (1977) reported the value of Ag in normal soil from <0.1 to about 1 ppm, while in mineralized soils Shacklette and Hoerger (1984) cited the average value of Ag range 0.7 to 2-5 ppm for high organic

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A mean of 2 ppm total Ag was reported for some Scottish soils (Mitchell, 1944).

Ag is a brilliant white, very ductile and malleable metal, occurs as an argentite and born silver in rocks and in ores bodies. It commonly associated with one of other metals, especially Pb, Pb-Zn, Cu, Ag, and Cu-Ni. Silver is used in silver alloys, silverware, jewelry, etc. In the form of Ag NO₃ it is used for photography, dental alloys and in making high capacity Ag-Zn and Ag-Cd batteries, mirror production. Silver iodide used as a nucleating agent for weather modification. Silver does not mix in soil easily and therefore it is considered harmless in the environment. Silver found in the soil samples at different location from Peshawar Basin is below the detection limit of our instrument (2 ppm) and within the range of normal soils (appendix-B, Table 5).
Figure 4.13 Concentration of Cr in various soils at different location in Peshawar Basin.

Figure 4.14 Concentration of Co in various soils at different location in Peshawar Basin.
CHAPTER 5

DISCUSSION

General Geological profile of a region is the foundation for all other profiles including agricultural forestry, geographic and geomorphic, demographic, hydrologic, hydrogeologic, etc. Environmental profile is the combinatory or outcome of all these profiles. Geological profile is itself the outcome of numerous geological and tectonic activities in a region. The separation of the Gondwanaland from the main African continent, its northwards motion that narrowed the Tethys and the Himalayan orogeny comprising of the creation of the Kohistan and Ladakh Island Arc (KLIA), the collision along MKT at 125 Ma and a collision along MMT at 55 Ma, the rise of the Himalayas, the wedging of Nanga Parbat bifurcating the KLIA into two portions and the still continuing tectonics (Nanga Parbat is still uplifting) are all geological and tectonic processes that lead to the development of very unique geological profile of our region, i.e., the Indo-Pakistan subcontinent. In Pakistan from north towards south the geological and geographic terrains comprise of the Tethyan Himalayas, Higher Himalayas, Lesser Himalayas, Sub-Himalayas and the plains of Punjab and Sindh where as in Baluchistan Kirthar Range, Raskoh Range and Makran range etc occur. These subdivisions have rendered the geomorphology of this country varying from sea level to those of more than 8000 meters (K2: 8611m; Nanga Parbat:8126 m, Tirich Mir: 7690 m), climate variation varying from arid and semi arid through 0 to 48°C, and a tremendous number of natural resources including minerals, Alpine glaciers, surface and underground water, soils, forests agriculture and many others occur in this region. Pakistan as part of this region is therefore, very unique for having highly versatile geological profiles rendering versatile characters to all other profiles, and for that reason to the environmental profiles. The existence of various resources has made Pakistan the locus for the development of human
civilization, especially in areas where agricultural land is available and water resources are plentiful. Such loci, though mainly include the plains of Punjab and Sindh where prehistoric (Harapa & Mohanjodaro) and historic civilizations existed, areas within Himalaya ranges including the upper and middle Indus valleys, as the valleys of Swat and Dir, and the Basin of Peshawar, and Kohat and similar geographic locations in Baluchistan have also hosted the growth of civilizations whereas these civilizations existed they have both enjoyed and suffered from the unique set up of the Himalayan region. Utilization of plentiful natural resources including those of water, versatility in climate, agriculture, the availability of natural sites for dam water and agricultural soil remained the positive faces of our environmental profile. On the other hand the accessibility problems in high altitude areas, the harshness of climate in the Higher Himalayan regions in the north and in the deserted areas of Sind, the yearly floods the catastrophic floods and their related devastations and diseases etc. are the negative faces of our environmental profile. In this modern era, additional growth of industrial sector is again playing both positive and negatives roles in building the environmental profiles of this region.

Surface and groundwater pollution in Peshawar Basin is the focus of this study to understand the anomalous concentration and suitability of water and soil on the basis of chemical constituents for related health hazards and agriculture purpose. It is highly desirable to understand the characters of the container containing that water and soil. Peshawar Basin serves as a container for the water under investigation and the rocks of the Peshawar Basin could be one of the possible sources of pollution to the water it contains or flows through it. Therefore stratigraphic characters and tectonic histories of Peshawar Basin have been described in chapter 1. These and other studies indicate that Peshawar Basin has developed mainly due tectonic, geologic, hydraulic and hydrogeologic process associated with Himalayan orography and, its subsequent
phenomena. The Himalayan orogeny moved the Indo-Pakistan plate towards north and caused its subduction underneath the Kohistan and Ladakh Island arcs in Pakistan. This movement and subduction was not a simple northerly journey of the plate but include collisions along MMT (55 Ma) and MKT (125 Ma), crustal thickening, the syntaxes of the Nanga Parbat resulting into the division of KLIA into two arcs, the growth of Hazara-Kashmir syntaxes, and also the development of basins like Peshawar Basin. Peshawar Basin has adopted the shape of a basin because of the above tectonic activities. It is surrounded by Khyber Mountain Ranges in the west and northwest, Lower Swat Ranges in north and northeast, Nowshera-Swabi Hills in east and southeast and Attock Cherat Range in south (Fig.2.1) leaving only one small outlet for surface water at southeastern extremity where Kabul river falls into Indus. The surrounding mountain ranges together with the base of the basin are metasediments of Paleozoic age which have provided a firm foundation for the quaternary deposits overlying these metasediments. The shape of the basin provides a protection from erosion for these quaternary deposits and their covering soils. As Kabul and Swat rivers flow across Peshawar Basin, one would naturally expect that the quaternary deposits of the basin must be the outcome of the depositional processes of these rivers. However, a recent study by Cornwell (1992), Cornwell and Hamidullah (1992), and Hamidullah and Cornwell (1994) have shown that the major part of the quaternary deposits have been deposited by the catastrophic floods which got generated due to breaching of glacial dams along upper and middle Indus valley and, therefore, these deposits carry the mineralogical characters of rocks of the Kohistan Island arc. This does not deny the role played by the Kabul and Swat rivers and, therefore, the sharing of sediments from the surrounding mountains also play roles in the growth of the quaternary deposits of the basin, however, these studies do register a major role of the KIA as source. The Indus river as the medium of transportation from which
the Quaternary deposits of the Peshawar Basin were grown. The deposits of the Quaternary deposits by large multiply episodic catastrophic floods in the basin also indicate that each flood deposited continuous layers of sediments throughout the basin at different time. Therefore, the Quaternary deposits are not only very thick (Cornwell, 1992) single large confined aquifer with the Paleozoic rocks acting as an aquitard at the base and the clay on the top as an aquiclude. In the entire middle part of the basin and above this major aquifer lie main semi confined aquifers in Mardan, Nowshera and Swabi areas and a smaller Peshawar floodplain aquifer confined to the eastern and north-western part of the basin where Swat river and the various branches of Kabul river flow currently or have been flowing in the past. Surrounding the middle part are the various piedmont type aquifer of Attock-Chera, Khyber (including parts of Mohmand agency in the northwest) and lower Swat rangaus. The hscustrine and floodplain aquifers in various combination of sediment type and their thickness make small local aquifers of peach and artesian type (see chapter 2, see also Hussain et al., 1991).

The Paleozoic and Quaternary stratigraphy and hydrogeology and hydrology of the Peshawar Basin are, therefore, described in detail in chapters 2 and 3 in order to understand the composition of the container that may be a possible source of pollution to the surface and underground water of the basin. Oxygen isotopes discriminate signatures for rain water, surface water and underground water and therefore $^{18}O/^{16}O$ ratio were determined for all the water samples in this study. Any possible mixing of surface and underground water could be recognized from the $^{18}O/^{16}O$ ratio and if there is any pollution due to mixing of such waters, it could be also identified.

Peshawar Basin is not only remained a stage for natural environmental processes but also remains the center of hundreds of anthropogenic activities that could have greater impact on the natural environment both in long and short terms. Highly versatile
industry in various industrial estates, city centers as well as in the country side together with hundreds of thousands of mobile vehicles ranging on the considerably thick network of roads in the basin are the most plausible sources of pollution to the surface and ground water. As the geology and tectonics indicate that Peshawar Basin has adopted the shape of a basin due to peculiar geological processes, the stratigraphy of the area indicates that above the hard Paleozoic basement acting as an aquitard for the aquifer system mainly composed of very thick Quaternary deposits mainly composed of sand, or pebbly sand, silt and clay in the middle of the basin (lacustrine aquifer at Jalala, Kheshki, Jehniger, Spin Khak, Swabi and a similar sequence but with clast supported conglomerate as an important component in the piedmont type aquifer i.e., Warsak, Ziarat Kaka Sahib, Piran sections). The surrounding piedmont areas, therefore, are the major catchment area of rain water for the aquifer. In this area no significant industry exist and, therefore, no anthropogenic source of pollution is expected except south of Peshawar city. On the other hand as the middle of the basin is covered mainly with fine clay that may protect the aquifer from surface pollutants except along the banks of river Kabul and Swat where riverbed cut deep through the aquifer.

The water chemistry with respect to Piper (1944) classification indicates that except the prevailing sulphatic type of NAFFW, all other types of water do exist in Peshawar Basin. However majority of the samples both from tube wells and dug wells of the basin concentrate mainly in the fields of prevailing hydrogeo-carbonatic and prevailing sulphatic of the alkaline earth Fresh water with high content of alkalies. The surface behave more or less similarly but are mainly confined to the prevailing Hydrogen carbonate types of both Normal alkaline Earth Fresh water and Alkaline Earth Fresh water with high contents of alkalies (AEFWHA). The occurrence of certain samples in the AEFWHA is consistent with K and Na above the allowed limit of EPA in many
samples from all types of aquifers (Figs. 3.14-17). The alkalinity and the content of sulphate and cadmium are less at Wazir, Kabul and Swat rivers and in Indus river as compared to the samples of surface water at Sardariab, Shah Alam, and at Khairabad where as Kabul river shows less SO$_4$ +Cl at Nowshera (upstream samples from Indus river). This generally high content of sulfur and chlorine as well as of alkalis in the surface water, with the exception at Nowshera, indicate that Na, K, S and Cl in the surface water of Kabul river have incorporates locally from industrial or soil sources (possible Khazana Sugar Mill, Shah Alam river, Nowshera and Jehangira Industrial areas and Khair Abad).

Both surface and groundwater of the Peshawar Basin are generally characterized by normal alkaline earth fresh water with high content of alkalis (Chapter 3). This suggest that the cations especially Na, K, Ca and Mg and the anion especially Cl, SO$_4$ and HCO$_3$ have played an important role in categorizing the waters (both surface and subsurface) of the Peshawar Basin.

The electrical conductance of water of the Peshawar Basin in various aquifers has reached to about 1670 $\mu$S/cm (see chapter 3). This suggests that the water of the basin has dissolved various minerals and salts. As a result the total dissolved solids (TDS) in these waters exceeded 1000 mg/l which is the maximum contaminant level (MCL) set by US-EPA (1978) and WHO (1986) for drinking water. In this respect the drinking water of Akbarpur, Amankot, and Wadpaga areas of the Peshawar Basin are considered unsuitable for domestic use. On the basis of TDS values the water of these areas can also be considered as slightly saline (US-PHS, 1965). Due to the high electrical conductance of the waters of the aforesaid areas, there are greater chances that underground steel and iron pipes of water and sewerage may have less durability due to the high corrosive effect and potential for electrochemical action of the water of these areas (Driscoll, 1986).
There is a wide range of pH value of the tube wells of Peshawar Basin varying from as low as 4.8 (acidic) at Takhtal Bala to as high as 9.9 (alkaline) at Jamrud Industrial estate. As this value is temperature dependent, no correlation could be established between the pH and alkalinity determined from chemical analyses. Such a wide variation in the pH values of the dug wells of the basin was not noticed (Fig. 3.7). The acid waters are generally considered as hazardous for the metals because these water contain the free-mineral acids from mine water, volcanic gases, contamination from industrial source or leaching from the sulfide rich zones within the crust. The drinking waters of Aza Khol, Tailband, University Town, Landi Arbab, Durbazgai, Mahewal, Tehkalbala, Hazar Khani, Zahirabad, Sonaizai and Adzai of the Peshawar Basin are more acidic (<5.5) in nature (see chapter 3). Many of these waters also have high concentration of SO₄ (reaching up to 1297 mg/l). This suggests that the waters in these areas may have been percolated through coal and sulfide seems having metal sulfides (e.g., pyrite). The oxidation of these sulfide minerals might have decreased the pH of the waters of various places within the Peshawar Basin. The waters in these areas may have corrosion or dissolution capacity for metals and, therefore, proper measures shall be taken for its storing and further supply for domestic and even industrial purposes.

The cations Ca, Mg, Na, K, and Fe, anions (SO₄²⁻, Cl⁻, HCO₃⁻) in the drinking waters of Peshawar Basin are generally within the permissible limits set by the US-EPA (1975). However, there are certain places where the concentration of both cations, anions and trace elements exceeds the permissible limits (see chapter 3). Also there is a greater contrast in the Mg concentration in the waters of tube wells and dug wells of the basin. Generally the dug wells have high concentration of cations, anions and trace elements when compare with tube wells (see chapter 3).
This phenomenon may be correlated to (a) the dissolution of these elements in water at deep levels and their precipitation at higher level due to rise and fall of water table, respectively, (b) variation in the composition of the host rocks or (c) incorporation of pollutants from surface. Previous studies indicate a history of water logging and salinity in Peshawar Basin due to the construction of Warsak Dam (Bundschuh 1991). This phenomenon may have played a role in the transfer of cations to higher levels. On the other hand this study indicate high value of SiO₂, MgO, CaO, Na₂O, K₂O and P₂O₅, Cu, Co, Ni in the soils of Peshawar Basin when compared with the normal soil composition of the world. The high concentration of Mg, Na, K and HCO₃ in the dug wells and also in certain tube well can be related to their incorporation from the soils rich in these elements. Why the soils are richer than the normal soils of the world in these elements is another question to be answered. As mentioned earlier, quaternary deposits in Peshawar Basin including the top soil covers are mainly brought by Indus that flow through the mafic and ultramafic rocks of the Kohistan Island arc, and MMT zones. The major minerals of these rocks and of the Peshawar Basin are pyroxenes, olivine, amphibole and garnets that are rich in Mg and, Ni and, therefore, the high content of Mg and Ni in the soils of Peshawar Basin may point to a source in these minerals. Cu and Pb are also higher than the normal range of soil and may be attributed to the same factor, i.e., a source in Kohistan (Besham and Chital Pb-Zn deposits; Cu in volcanics of KIA). The Cr content of the soils in Peshawar Basin is within the allowed range of USDA, however, this range for Cr is very wide (5-1000 ppm) as compared to that of Ni (20-30 ppm) described by the same agency for the normal soils. It is difficult to understand such a huge difference between the acceptable ranges of Ni and Cr, as both are heavy metals with more or less similar sources in rocks and similarly hazardous to human health. The Cr content of the soil of the Peshawar Basin may be, therefore, regarded higher than normal (see chapter 4) and a potential source of contamination for plants and under
ground water. Here we can postulate that the higher content of certain cations (Mg, K, Na) and anions (HCO$_3^-$) in number of dug wells of the basin have potential sources at lower levels in the aquifer (e.g., dolomite, limestone, gypsum, sylvinite, calcite, halite, chromite, and other mafic and ultramafic rock) and at upper level in the soil and the fluctuation of water table due to seasonal phenomena and water logging and salinity problem in the area may have acted as the agents (see Driscoll, 1986) of concentrating cations, anions and trace elements in certain parts of the aquifer. In this regard the drinking water of the dug wells of Umar village, Akbarpura, Zahirabad, Amankot, Sheikh Umar Baba, Regi, Wadapaga etc. are need to be considered for remedial measures. This study also indicates that except the plains mentioned above, the Peshawar Basin aquifer water is generally clean both for agricultural and drinking purposes. It also indicates that the water of the lower major aquifer is much cleaner than the water of the upper part. However, previous studies of soil and air pollution in Peshawar city and Peshawar cantonment areas have shown that tremendous sources of heavy metals occur in metropolitan areas which have already polluted the sewerage system of the city and the Budni Canal as well as Shah Alam branch of Kabul river.

Heavy metals may take their time to enter the aquifer directly through clay and silt beds. Therefore, in a type of sedimentological environment, existing in Peshawar Basin where fine clay and silt exist at various depths in the aquifer, heavy metals can be filtered at these horizons (see Hamidullah et al 1997; Hamidullah et al. 1998). However, the isotopic data indicate that replenishment of the aquifer occurs from Kabul and Swat river along their beds and irrigation canals (e.g., Budni canal, Chapter 3) and any contamination of the surface water is bound to ultimately reach the under ground water system. Therefore this is highly recommended that dug wells and tube wells especially in Peshawar flood plain aquifer, the river water and the waters of the irrigation canals must be thoroughly monitored.
for heavy metals and other pollutions. As the soils of Peshawar Basin also indicate high 
contents of certain elements, the systematic of these elements with respect to their mobility 
may also monitored from time to time.

The current study also indicates that underground waters of the piedmont aquifers, 
where industry still does not exist, are safe both for agricultural and drinking purposes. Any 
industrial installation in these areas and for that matter in all other parts of the basin must be 

carried out with thorough EIA studies in order to protect our underground water resources 
from contamination.
CHAPTER 6
CONCLUSIONS

On the basis of the data obtained and described in previous chapters, the following conclusions are drawn:

1. The quaternary alluvial deposits of the Peshawar Basin serve as a major storage system for the groundwater. Precipitation, Kabul river and Swat river are the major sources for replenishing these aquifers.

2. A single major confined aquifer extending over the whole basin is overlain by small semi confined aquifers with piedmont, lacustrine, floodplain type of sediments. The small aquifers are named as Khyber piedmont aquifer, Peshawar floodplain aquifer, Peshawar lacustrine aquifer, Attock-Cherat range piedmont aquifer and Lower Swat piedmont aquifer. Artesian and recharged aquifers also exist in the basin.

3. Both surface and groundwaters of the Peshawar Basin are characterized generally as normal alkaline each fresh water with high contents of alkalies.

4. In general both the surface and groundwaters of the basin contain cations, anions and trace and/ or heavy metals within the permissible limits recommended by various international agencies for drinking, domestic and agricultural uses.

5. Locally at several places both one or several major cations or anions in the surface and groundwater exceed the internationally accepted limits. A few localities that contain several cations and anions above the permissible limit are Zahirabad, Aman Kot, Akbarpura, Garhi Chandan, Umar, Wadpagra and Sheikh Umar Bóa. On the basis of electrical conductivity (Ecs) and total dissolved solids (TDS) the water of these areas, especially of Akbarpura, Amankot and Wadpagra are considered unsuitable for domestic uses.
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6. The groundwater of Peshawar Basin at Azakhel, Tella Bond, University Town, Landi Arbab, Darwazgai, Mulazai, Tehkal Bala, Hazar Kiwani, Zahirabad, Sorezai and Alezai are acidic (pH: <5.5) in nature with high concentration of SO₄ indicating percolation through coal and sulphide bearing strata.

7. The trace elements and heavy metals in the groundwater of the Peshawar Basin generally fall within the permissible limit of US-EPA (1978). Chromium is an exception at certain places including Tarangazi, Landi Arbab, Tehsil Gang, Azakhel Bala & Payan, Tukht Bhai, Sorezai, Urmar and Spin Khak and may have a source in the soils on top, in the sediments from Skhakot Qila ultramafic complex or in the local industry. Pb is also high at Sahband, Gharibabad, Gul Bahar No.2 and Matani with similar possible sources.

8. On the basis of SiO₂, Al₂O₃ and Fe₂O₃ the soils of the Peshawar Basin stand normal. However, MgO, CaO, Na₂O, K₂O and P₂O₅ of these soils are higher than the normal limits for soil set by the US-Department of Agriculture. Similarly heavy metal including Cu, Pb, Ni and Cr are high in this soil when compared with international limits. The reason for the high concentrations of CaO, Na₂O, K₂O are water logging and salinity and for high MgO, Cu, Ni and Cr, the availability of source material in the nearby Skhakot Qila ultramafic complex. The high concentration of P₂O₅ may also be the availability of high P₂O₅ bearing rocks just north of the basin at Solei-Patai. The source of Pb in soils at certain locations may be both source rocks and industrial.

9. The oxygen isotope data indicate that the three rivers of the region including Indus, Kabul and Swat have distinct δ¹⁸O signature with Indus river being the most depleted, Swat river being the most enriched and Kabul river midway between the two, with respect to δ¹⁸O when compared with δ¹⁸O.
The oxygen isotope data indicate that the sediment aquifers surrounding the basin are recharged solely with rainwater whereas the main central part of the aquifer in the basin is recharged both with rainwater as well as with surface waters from Kabul and Swat rivers. Kabul remains dominant over Swat in this respect.

The oxygen isotope data indicate that any pollution in the surface water can be easily transferred to the groundwater system through the water percolating from river to the aquifer.
CHAPTER 7

RECOMMENDATIONS

On the basis of the present study carried out and conclusion drawn the following recommendations (management & technical) are made:

Management:

1. Tube well and dug well waters with high concentration of elements/radicals must be treated prior to use for agriculture or at least domestic uses. Waters from Zahirabad, Amankot, Regi, Akbarpura, Darwazai, Garhi Chandhan, Umar, Azakhel, Washpaga, Sheik Umar Baba, Surezoom, Pandu, Hindi Kassi and Kukar areas must especially be treated for the removal of elements found in high concentration in these wells.

2. Both surface and groundwater must be thoroughly monitored physio-chemically. Rivers must be monitored at, above and below the junctions of their tributaries, canals, sewrage drains, sewrage pipes from industrial and residential areas.
   i. Public awareness regarding water and soil pollution must be carried out as part of environmental education program in NWFP.

4. Strict environmental laws are needed to be implemented.

5. Laws should be formulated for disposal of domestic waste and industrial effluents; and strictly exercised to keep the groundwater aquifer free of contaminants.

Technical

1. Because the soils of Peshawar Basin are rich in certain heavy metals, the impact of these metals are needed to be studied in plants and animals in order to see any adverse effects of these soils.
2. Detailed studies are needed to investigate the polluted dug wells and tube wells individually in order to find the precise sources of this pollution.

3. Detailed environmental impact assessment studies must be made a requirement prior to the installation of any new small and large industry that may be considered a potential source of the surface or underground pollution.

4. Mining, mineral and Metal based industries, businesses and installations must be monitored on regular basis for relevant pollutions.

5. This study must be based as a basis for further studies.
REFERENCES


178


Coulson, A. L., 1940. The mineral resources of NWFP, India Geol. Surv. vol. 75: 55.


Marbut C. F., 1951. Soils: Their Genesis and classification (volume of lectures delivered in 1928) Published by Soil Science Society of America.


National Research Council of Canada (NRCC), 1976. Lead in the Canadian environment, Ottawa, Canada. 176.


187


Shuhao, D. K., 1997. High Fluoride Contents and its source of contamination in drinking water of bKheeshi (District Nowshera) and Narangi (District Szabo) areas of N.W.F.P., Pakistan. Colloquiumon Geology and Human Life: 44.


Waagen, W., 1884, Section along the Indus from the Peshawar valley to the Salt Range. Geol. Surv. Of Indir Rec., vol. 17: 118-123.


APPENDIX – A
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FIELD METHODOLOGY

General

In order to avoid reduce the chances of contamination and other chemical changes various parameters such as pH, alkalinity, electric conductivity, and temperature are determined at the site where from the water samples have been collected. The instrumental determination of these parameters is discussed in detail as follows.

Collection of Water Samples

The natural water is never pure, it always contain at least small amount of dissolved gases and solids. The process of drawing the sample up from the aquifers makes variation in the chemistry of water. The chemical analysis of water sample from both surface and groundwater are an integral part of hydrogeological study. Therefore, care must be mandatory during the collection of the water samples.

To avoid any possibility of contamination the polythene bottles used for the collection of water samples were treated with 5% HCl or HNO₃ and then rinsed with double deionized 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, electrical conductivity, SO₄, Cl at the site. The second bottle was acidified with drops of nitric acid (HNO₃) 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 Centre of Excellence (NEC) in Geology, University of Peshawar.
Collection of Soil Samples

Representative samples of soil were collected from the selected location. Three samples were up to a depth of 45 cm by hand auger. The sample has been divided into two horizons “A” and “B”. Horizon “A” represents the core sample surface to a depth of 20 cm and horizon “B” represents a core sample from a depth of 20-45 cm. The collected samples were properly labelled and transferred to polythene bags that were further placed into canvas bags. The colour, texture and loose fragments of these samples were noted at the site.

Determination of Various 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 effect 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 processes 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 electrode model (44200)” was used. This instrument is fitted with a temperature sensor who measures temperature, by immersing an electrode bulb into the water sample. This sensor is compatible with the pH meter and gives very accurate readings.
pH

Hach pH meter determined the pH of water samples. pH meter was standardised 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 standardisation of the pH meter was checked by the buffer solution after the run of few samples.

Electrical Conductivity:

Cole-Palmer’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 neutralising 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 Hach Digital Titrator was used which is filled with concentrated titrants in compact containers called cartridges. Each cartridge replaces about one quarter of standard titrant. A main drive screw 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 solutions are packed in disposable polythene plastic containers with Teflon closures to cover the cartridge tips. Each contains approximately 13 ml 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 (H₂SO₄) Titration Cartridge corresponding to the expected alkalinity concentration as mg/l calcium carbonate was selected from the table

<table>
<thead>
<tr>
<th>Sample Volume as CaCO₃ Multiplier</th>
<th>Titrated in (ml)</th>
<th>Cartridge N: H₂SO₄</th>
<th>Catalog No</th>
<th>Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 40</td>
<td>100</td>
<td>1.600</td>
<td>14388-01</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>40 - 160</td>
<td>25</td>
<td>1.600</td>
<td>14388-01</td>
</tr>
<tr>
<td>0.4</td>
<td>100 - 400</td>
<td>100</td>
<td>1.600</td>
<td>14389-01</td>
</tr>
<tr>
<td>1.0</td>
<td>200 - 800</td>
<td>50</td>
<td>1.600</td>
<td>14389-01</td>
</tr>
<tr>
<td>2.1</td>
<td>500 - 2000</td>
<td>20</td>
<td>1.600</td>
<td>14389-01</td>
</tr>
<tr>
<td>5.1</td>
<td>1000 - 4000</td>
<td>10</td>
<td>1.600</td>
<td>14389-01</td>
</tr>
</tbody>
</table>

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 250 ml with deionized 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 the sulfuric acid to a light greenish blue-grey 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 (Titre) 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, \( \text{Hg(NO}_3\text{)}_2 \) 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 from the table given in the instruction manual processes titration of chloride concentration. A clean and uncontaminated delivery tube is attached to the titration body. Known volume (100 ml) was transferred to 250 ml volumetric flask, and was diluted to 100 ml with demineralized water. Contents of one Diphenylecarbazone Powder Pillow, provided with instrument were added to the flask. The titration of mercuric nitrate was employed in such a way that the delivery tube was immersed into the solution and flask 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 results were calculated.

**Sulfate \((\text{SO}_4)^2\)**

Sulfate \((\text{SO}_4)^2\) concentration in possible and waste water was determined by "Turbidimetric Method" (Rossum and Villaruz, 1961) by using mass spectrophotometer. Sulfate ion \((\text{SO}_4)\) is precipitated in an acetic acid medium with barium chloride (BaCl\(_2\)), so as to form barium sulfate \((\text{BaSO}_4)\) crystal of uniform size. Light absorbency and the sulfate concentration was determined by comparison of the reading with a standard curve. The procedure for the photometer follows as, centred the stored programme for sulfate powder pillows, adjusted the wavelength dial to 450 nm. The water sample of 25 ml was
transferred into a cell, added the contents of one sulfa Ver 4 sulfa Reagent Powder Pillow to the sample cell (the blank) filled with 25 ml 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 sulfa 0.0 μg/l (SO₄)²⁻. After five minutes, the timer stopped and placed the prepared sample into cell holder, the result in μg/l was noted.

Laboratory Methods

Chemical analyses of Water and Soil

The major, minor and trace elements in water and soil have been determined in the geochemistry laboratory of NCE in Geology University of Peshawar by using sophisticated instruments, such as Atomic Absorption Spectrophotometer (AAS) and UV/visible spectrophotometer. The accuracy of the results of geochemical investigations depends on the accuracy of the contents of elements determined in the standard and provision of the instruments. The details of the instrumental techniques for the methods of determination of various majors and trace elements in water and soil samples are given below:

Preparation of Solutions and Standards

1. Water solution

The acidified water samples collected during field are filtered through whatman filter No. 42 and stored for further analyses.

2. Preparation of Soil Solutions

The soil samples were collected from the study area in polythene bags. These air-dried samples were pulverized to 200-mesh size in a Tungsten Carbide Ring mill. To minimize the possibility of contamination each time the motor was cleaned and dried after every run. The powder of each sample was collected in contaminated free glass
bottles that were dried over night at 110°C in oven. From the dried powder the solutions were prepared.

3. Standard Solutions

Standard stock solution of 1000 ppm for the entire major, minor and trace elements were prepared first and then the working standards were prepared according to the need of instrumental setting.

To determine the concentration of Cu in water samples the standard stock solution of Cu was prepared. A weighted quantity of 1.30 g of analytical grade (100% pure) electrolytic Cu wire was dissolved in concentrated HNO₃, gently until complete dissolution of the Cu and was diluted to 1000 ml with double deionized water in volumetric flask. This contained 1000 ppm of Cu. The machine has been calibrated by setting the following conditions and the water samples were aspirated one by one in a batch of 40 each. The international standards were used as reference material.

1000 ppm of lead (Pb) standard stock solution was prepared by taking a 0.1599 g of lead nitrate, [Pb(NO₃)₂] of analytical grade dissolved in approximately 200 ml double of deionized water. 10 ml of concentrated HNO₃ was added and was diluted to 1000 ml with deionized water in volumetric flask. This solution contained 1000 ppm of Pb.

The standard stock solution for Ni was prepare by dissolving 1.273 g of nickel oxide of analytical grade in a minimum volume of 10% v/v HCl. Solution was diluted with double deionized water in 1000 ml volumetric flask. The solution contained 1000 ppm of nickel.

To prepare standard stock solution of chromium, 2.828 g anhydrous potassium dichromate (K₂Cr₂O₇) was dissolved in 200 ml of double deionized water and added 1.5 ml of conc. HNO₃ and was diluted to 1000 ml in a volumetric flask with double deionized water. This standard stock solution contained 1000 mg/l of chromium. The standard stock
solution of cadmium was prepared by dissolving 1000 g cadmium metal in a minimum volume of (141) HCl. It was transferred to volumetric flask of 1000 ml and diluted to 1000 ml with double deionized water.

To prepare standard solution of cobalt, 1.407 g of cobalt oxide (CoO) was dissolved in hot conc. HCl and diluted to 1000 ml with double deionized water. This contained 1000 mg/l of cobalt.

Standard solution of iron was prepared by dissolving 3.115 g, Moir Salt Fe (NH₄)₂SO₄ in deionized water and diluted to 1000 ml with double deionized water. Volumetric flask into the mark of. This standard stock solution contained 1000 mg/l of Fe and stocked into a polythene bottle for further treatment.

A. HF and HClO₄ Method for Sample digestion:

To determination the CaO, MgO, Fe₂O₃, Na₂O, K₂O and P₂O₅, the solution prepared from HF and HClO₄ method. A weight quantity of 0.5 g of soil sample was taken in platinum crucible and moistened with few drops of deionized water, to avoid the powder blowing away in draughts and effervescence. Then platinum crucible was placed in the fume cupboard. 10 ml of Hydrofluoric acid (HF) was added by ploy measure cylinder and after 20 minutes also added 4.0 ml 60% of perchloric acid. The crucible was then placed on sand bath, after an hour 2.0 ml of perchloric acid was further added and continued heating on sand bath until a past was obtained. The crucible was allowed to cool for a while. Some deionized water and 4 ml of perchloric acid was added to it. The content of crucible was thoroughly washed with deionized water into a beaker. The beaker was warmed and when a clear solution was obtained. It was transferred to a 250 ml volumetric flask and diluted with deionized water up to the mark. In case of any turbidity in the solution further treatment was made with HCl until clear solution was obtained. 5-10 ml of HCl was added to the beaker having the prepared solution and then
it was heated to completely remove the chlorine (as fumes). After this procedure the precipitate was dissolved and a clear solution was obtained. This solution was diluted with deionized water in a volumetric flask and made up to 250 ml and transferred into a contaminant free polythene bottle to avoid the possibility of adsorption on the walls of container.

3. HF AND HNO₃ Method for the Sample digestion

The solution was prepared by the method of HF and HNO₃ for the determination of trace elements (e.g., Cu, Ni, Cr, Co, etc.) in soil samples. 0.5 g of soil samples was taken in Teflon beaker and 5 ml of hydrofluoric acid was added to it. After 15 minute 15 ml of HNO₃ was added to it and was again heated on hot plate at a temp of 70 °C till completely dried. 50 ml 2N HCl was added to the beaker. The beaker was heated on low flame for a short time until the residue was almost dissolved. The sample solutions were then stored in contaminant free test tube and properly capped. This solution was then aspirated in A. Absorption for the determination of various trace elements.

C. NaOH Fusion Method for Sample digestion

Solution was prepared for determination of Si and Al. A solution of NaOH was prepared by dissolving 30g of NaOH in deionized water and diluted to 100 ml in volumetric flask. This solution was stored in polythene bottle ¼ ml of NaOH solution was taken in a series of 10 clean nickel crucibles. These crucibles were evaporated to dryness on hot plate. Accurately weight 0.5 g of sample was taken in each crucible. Each crucible was covered with lid and was heated on low flame for 2-3 minutes heating. The crucible was then heated to dull redness for exactly 5 minutes on the burner. After five minutes heating the crucible was removed from burner and was swirled while hot and was allowed to cool. The content of each crucible was washed in separate 1000 ml plastic beaker. Both crucible and lid were washed in their respective beaker. The solution of
each beaker was diluted to 500 ml and 10 ml of conc. HCl was added to solution in beaker. The solution was stirred for a while and kept for half an hour until complete dissolution occurred. Each solution was then transferred to 1000 ml volumetric flask and was made to volume with deionized water.

The concentration of unknown soil sample was determined relative to that of certified rock standard were used for calibration the UV/VIS spectrophotometer. The solution was kept in polythene bottles for determination of SiO₂ and Al₂O₃.

1. Atomic Absorption Spectrophotometer Technique

Two types of atomic absorption techniques were used for the detection of various elements in water and soil samples. Pye Unicam flame atomic absorption and flameless electrothermal atomic absorption (Perking Elmer 3300 model) equipped with HGA-600 graphite furnace and As-60 Auto-sampler were used for the determination of major, minor and trace elements. The flame atomic absorption technique was used for the determination of Na, K, Cu, and Mg in water only and also for Cu, Pb, Ni, Cd, Cr and Co in addition to Na, K, Cu and Mg in soil. However, Cu, Pb, Ni, Co, Cr, Fe etc. in water by using the graphite furnace atomic absorption. Si, Al, Ti and P have been determined by using Pye Unicarz, UV/ visible spectrophotometer.

i Determination of Trace elements in Water Samples

The detail of each metal as determined by the flameless atomic absorption is given below:

Copper (Cu)

From the stock solution, of Cu the working standard solutions of 25, 50, 100 and 200 μg/l were prepared.
Lead (Pb)

From this stock solution-working standard of the 25, 50 and 100 µg/l were prepared. The graphite furnace was calibrated by these standards under the following instrumental condition.

Nickel (Ni)

Working standard solution of 50, 100 and 200 µg/l were prepared from the standard stock solution. The graphite furnace was standardized with these standard solutions, by using the following instrument condition.

Chromium (Cr)

The standard solution of 25, 50, 100, and 200 µg/l were prepared from the standard stock solution. The instrument was standardized by using these standards under the following instrumental conditions.

Cadmium (Cd)

From the standard stock solution, the working standard solution of 25, 50 and 100 µg/l were prepared. The instrument was standardized by using these standards under the following instrumental conditions.

Cobalt (Co)

The working standard solution 25, 50, 100, and 200 µg/l was prepared from 1000 mg/l stock solution. The instrument was standardized by these standards under the following instrumental conditions.

Iron (Fe)

The working standard of 25, 50, 100 and 200 µg/l of Fe were prepared from the 1000 mg/l standard stock solution. The instrument was standardized by these standards under the following instrumental conditions.
Determination of Cations

To determine the major cation in water samples were directly run. The cation concentrations in the water were noted in mg/l (ppm). The soil samples were treated with the acids and the solution were prepared for the determination of both major and trace elements. The detail of preparation of soil solution is discussed as follow.

Water Dissolved Soil Solution

5.0 g of each soil sample was weigh in to a series of volumetric flasks of 100 ml. Approximately 50-60 ml of deionized water was added to it and each flask was shaken on automatic flask shaker for an hour. The constituents of flask were filtered when almost dissolved material of soil sample was dissolved in water it was filtered through Whatman # 42 filter papers in 100 ml flask. The filtration was then diluted with deionized water up to mark. Using atomic absorption spectrophotometer used these solution for the determination of water soluble constituent in soil samples.

Determination of Elements by A. Absorption

Calcium (Ca) and Magnesium (Mg)

To determine the concentration of Ca in ppm the standard solution of Ca and Mg was prepared by dissolved 2.479 g of CaCO₃ and 4.952 g of MgCO₃ in 100 ml of deionized water. The 10 ml Conc. HCl was added and then solution was made to volume in 1000 ml volumetric flask to complete solution. This solution contained 1000 ppm of Ca and Mg. The working standards (0.1, 2, 4 & 8 ppm) were prepared from 1000 ppm standard stock solution.

For the determination of Ca and Mg concentrations, atomic absorption was switched on, installed Cato’s lamp for Ca and Mg, set the wavelength of 422.7 nm for Ca and 285.2 nm for Mg. After preliminary adjustment of the instrument, the working
standard solutions were run for the calibration of the instrument. Then the concentration of Ca and Mg was determined simultaneously in water and soil samples.

Sodium (Na) and Potassium (K)

1000 ppm standard solution for Na and K was prepared by dissolving 2.542 g of sodium chloride (NaCl) and 1.91g KCl in deionized water and the volume was made upto 1000 ml in a volumetric flask. The stock solution contained 1000 ppm of Na and K. From this stock solution working standard solution of Na and K of 12.4 and 8 ppm were prepared. Settings, wavelength of 589.0 nm for Na and 766.49 nm properly adjusted the instrument for K. The Na and K were determined by using emission mode of the instrument.

Iron (Fe)

To determine the iron in the sample of soil the standard solution were prepared 3.911g of Mn Br salt. Fe (N₃(NH₄)₂) was dissolved with deionized water in a volumetric flask of 1000 ml and made the volume upto the mark. This standard stock solution contained 1000 ppm of Fe. From this stock solution the working standards of 1, 2, 4, and 8 ppm of Fe were prepared. After the calibration of standard solution on atomic absorption the solution of soil samples were run to determine the concentration of iron in ppm.

Cobalt (Co)

To prepare the 1000 ppm standard solution of cobalt, 1.487g of cobalt oxide (Co₂O₃) was dissolved of hot conc. HCl, when it was cooled the solution was diluted to a volume of 1000 ml in a volumetric flask. The required solution was preserved in a polythene bottle for further treatment. This stock solution contained 1000 ppm of Co, from this stock solution working standard solution of 1, 2, 4, and 8 ppm were prepared for analytical use. Cobalt was determined by fixing Co hollow cathode lamp and wavelength of 240.72 nm on the instrument.
Chromium (Cr)

To prepare a standard solution of chromium, 2.828 g of anhydrous potassium dichromate was dissolved with 200 ml of deionized water contain 1.5 ml of conc. HCl and was diluted to 1000 ml in a volumetric flask. Form this solution working solution of 1, 2, 4, and 8 ppm prepared. These standard solutions were utilized for the calibration of instruments and later on the solution of soil and rock were analyzed on Atomic Absorption to determine the concentration of Chromium in ppm.

Copper (Cu)

To determine the concentration of copper in soil sample solution, standard solution of Cu was prepared by dissolving 1.00g of metal copper in (1:1) HNO₃ and was diluted with deionized water in a volumetric flask of 1000 ml. The required standard stock solution of 1, 2, 4 and 8 ppm were prepared to calibrate the instrument. After proper calibration of the instrument, solutions of soil samples were aspirated into the atomic absorption for the determination of copper concentration in ppm.

Lead (Pb)

To determine the concentration of Pb in soil sample standard solution of lead were prepared by dissolving 1.598 g of lead nitrate in 200 ml of deionized water containing 1.5 ml of concentrate at HNO₃. This was diluted with deionized water in a volumetric flask of 1000 ml. The acquired solution contained 1000 ppm of Pb. From this solution working solution of 1, 2, 4, and 8 ppm were prepared. These standard solutions were run for the calibration of atomic absorption. The concentration of Pb was determined in soil in ppm.

Nickel (Ni)

The standard solution of Nickel was prepared by dissolving 1.273 of Nickel oxide in a minimum volume of 10% V/V JCL and diluted it with deionized water in a
volumetric flask of 1000 ml. The acquired solution contained 1000 ppm of Ni. Later on from this stock solution working standards of 1, 2, 4 and 8 ppm were prepared for the calibration of instrument. The concentrations of Ni in soil samples were determined by atomic Absorption.

**Zinc (Zn)**

The concentration of zinc was determined by atomic absorption in which standard solution were prepared for the calibration of instrument. Zinc metal (1.08 g) was dissolved in 20 ml (1: 1) HCl and was diluted to 1000 ml in a volumetric flask with deionized water. This solution contained 1000 ppm of nickel in it. From this stock solution the standard solution of 1, 2, 4, and 8 ppm were prepared for calibration of atomic absorption. Later on the samples of soil solution were treated to determine the concentration of Ni in ppm.

**v Determination of Elements by Uv/Vis Spectrophotometer**

Silica, aluminium, phosphorous, titanium has been determined by using the Pye Unicam 400 UV/ VIS spectrophotometer

4. **Preparation of Solution for UV/VIS Spectrophotometer**

Silica (SiO₂)

Silica was determined by colorimetric method or ammonium molybdate method of Shapiro and Brammock (1962). In this method, molybdate reacts with silica to form yellow silicomolybdate. Phosphomolybdate however may also give yellow colour but, adding tartaric acid solution can decompose it. The yellow silicomolybdate can be reduced to molybdate blue by adding 1-amine-2- naphthol-4-sulphonic acid. So ammonium molybdate solution, tartaric acid solution and reducing solution were prepared as reagent for silica determination. Then measured a quantity of 10 ml sample solution (prepared by NaOH Fusion solution) was taken in a volumetric flask of 100 ml,
dissolved it with 5 ml of deionized water. 2 ml of the ammonium molybdate solution was added, swirled to mix and sat aside for ten minutes. 4 ml of the tartaric acid solution was added followed by the addition of 1 ml of reducing solution that gives blue colour to it. The volume was made up to the mark by deionized water. The instrument was set at a wavelength of 650 nm and the concentration of unknown soil sample was determined relative to that of certified rock standard.

**Phosphorus (P₂O₅)**

The concentration of phosphorus was determined by the Spectrophotometer method. In this vanadomolybdate reagent solution was used and diluted nitric acid as a colouring reagent as suggested by Kinston and Melon (1944). For the preparation of vanadomolybdate reagent solution, dissolved 20 g of crushed ammonium molybdate in water and pour gradually into 140 ml of concentrated nitric acid. Added 1 g of ammonium vanadate, stirred it well until solution is complete and then it was diluted with water up to the mark of 1000 ml. In dilute orthophosphate solution ammonium molybdate reacts under acid condition to form a heteropoly acid and molydophosphoric acid. In the presence of vanadium yellow colour molybdovanado-phosphoric acid is formed. The intensity of yellow colour is proportional to the phosphorus concentration that was determined by spectrometer.

**Titanium (Ti)**

Titanium was determined by using hydrogen peroxide in order to develop the yellow colour of Ti. To prepare the colouring reagent for Ti, 50 ml of 50% H₂SO₄, 25% orthophosphoric acid and 30% hydrogen peroxide were added in a volumetric flask of 506 ml. And was diluted to the mark 10 ml of sample solution was taken in 25 ml of volumetric flask and 10 ml of reagent was added to it and mark to the volume. The
optical density of yellow colour was noted by spectrophotometer that was proportional to the amount of Ti in sample.

Alumina (Al₂O₃)

Riley and Boltz (1956) method was used for the determination of alumina. In this method 5 ml of rock sample solutions (obtained by fusion of NaOH) was taken in 100 ml of separating funnel. Deionized water 5 ml and 10 ml of complexing reagent solution (obtained by dissolving 1g of hydroxylamine hydrochloride, 3.6 g of sodium acetate trihydrate and 0.4 g of beryllium sulphate in 50 ml of deionized water, 0.04 g of 2,2 dipyrindyl dissolved in 20 ml of 0.2 NHCl (both the solutions were then mixed and make it 100 ml) was added to it. 20 ml of 8-hydroxy-quinoline regent solution (obtained by dissolving 1.25 g of 8-hydroxyquinoline in 250 ml of chloroform) was also added to separating funnel. Afterward the separating funnel was shaken for 5-8 minutes on automatic shaker. Organic layer was then collected in 25 ml of volumetric flask, then the separating funnel was washed thrice with chloroform and these washing impure with chloroform was also added to the flask and the volume was made with chloroform.

The Al₂O₃ was determined in the required solution by 400 UV/VIS Spectrophotometer at a wavelength of 380 nm. While in water samples Al₂O₃ was determined by crichrome cyanide R method as devised by Shull and Guitart (1967).

According to this method, 5 ml of water sample was taken in 50 ml of volumetric flask. One ml of ascorbic acid, 10 ml of buffer reagent (136g of sodium acetate dissolved in deionized water mixed with 40 ml 1 N acetic acid and diluted to 1000 ml), 5 ml of working dye regent (100 mg crichrome cyanine R dissolved in 50 ml deionized water) were added. The flask was made to the mark and was allowed for 5-8 minutes. Afer this Alumina concentration was determined by spectrophotometer.
APPENDIX – B
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<td>7</td>
<td>1-2</td>
<td>73</td>
<td>50</td>
<td>0.00</td>
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Table 4: Major Dises in % in the Sols of Reserves Basin

Kuiper Planetoid seed
<table>
<thead>
<tr>
<th>Table 5: Trace Element in ppm in the Soil of Resheware Basin</th>
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</thead>
<tbody>
<tr>
<td>Element</td>
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<tr>
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</tr>
<tr>
<td>Si</td>
</tr>
<tr>
<td>Al</td>
</tr>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Mg</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>P</td>
</tr>
<tr>
<td>Na</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>Cl</td>
</tr>
<tr>
<td>Mn</td>
</tr>
<tr>
<td>Zn</td>
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<tr>
<td>Cu</td>
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<tr>
<td>Pb</td>
</tr>
<tr>
<td>Ni</td>
</tr>
<tr>
<td>Co</td>
</tr>
<tr>
<td>Cr</td>
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<tr>
<td>V</td>
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<tr>
<td>Ti</td>
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<tr>
<td>Rb</td>
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<tr>
<td>Sr</td>
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<tr>
<td>Cs</td>
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<tr>
<td>Ba</td>
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<tr>
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<tr>
<td>Ce</td>
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<tr>
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<tr>
<td>Eu</td>
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<tr>
<td>Gd</td>
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<tr>
<td>Tb</td>
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<tr>
<td>Dy</td>
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<tr>
<td>Ho</td>
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<tr>
<td>Er</td>
</tr>
<tr>
<td>Tm</td>
</tr>
<tr>
<td>Yb</td>
</tr>
<tr>
<td>Lu</td>
</tr>
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</table>

Note: ppm stands for parts per million.