Effect of Time Intervals on Levels of Selected Heavy Metals in Surface and Ground Waters in Peshawar Basin

[1]SHAHIDA NASREEN ZAKIR, [2]IHSAN IHSANULLAH*,
[1]MUHAMMAD TAHIR SHAH AND [3]ZAFAR IQBAL

[1]Center of Excellence in Geology, University of Peshawar, Pakistan.
[2]Nuclear Institute for Food & Agriculture, Peshawar, Pakistan.
[3]Department of Pharmacy, University of Peshawar, Pakistan.

Summary: During the last two decades, the high rate of industrialization, unplanned urbanization and heavy load of transportation resulted in a drastic increase in water pollution within the Peshawar basin in general and in the Peshawar metropolis in particular. The present study is based on the monitoring of heavy metals such as iron (Fe), copper (Cu), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd) and cobalt (Co) in surface and ground waters of the Peshawar basins, one of the largest basin of Pakistan, during the years 2003 and 2004. In order to evaluate the increase of the levels of these metals with the passage of time, the data obtained are presented. The results are also compared with the previous studies and the permissible limits set by US-EPA and WHO. The concentration of tested elements in the waters of most of the areas of Peshawar basin are within the permissible limit, but in certain areas, the concentrations of Fe, Pb, Cr and Ni are too high and pose a threat to the health of the people. Both anthropogenic and geogenic sources could be responsible for this contamination. The anthropogenic sources include the waste from the industrial estates and many tannery industries in Peshawar city and the corrosion of underground pipes, while the geogenic sources include the sulfide seams and mafic and ultramafic rocks in the northwest and northeast of the Peshawar basin.

Introduction

Peshawar basin is an *intra*-mountain basin (>5500 km^2) situated at the southern margin of the Himalayas and northwest of the Indus plain in the North West Frontier Province (NWFP) of Pakistan. It is bounded by the mountain ranges of Khyber in the west and northwest, Attock Cherat in the south and Swat in the north and northeast while the Indus River borders its southeastern side where it is open for discharge of water. Peshawar, the capital city of NWFP, Nowshera, Charsadda and Mardan are the major cities of this basin. It is mainly irrigated by the Kabul and Swat rivers and their tributaries.

The Peshawar basin has quaternary flanglomerates along the margins of the basin while the central part of the basin is generally covered with fluvial micaceous sand, gravels and lacustrine deposits. On the basis of varying lithologies, the Quaternary sediments, covered soils and hosting aquifers of the Peshawar basin are classified as Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine sediments, soils and aquifers respectively. The principal source of water for domestic and agricultural use is the groundwater and

the rivers Kabul and Swat in the Peshawar basin. The groundwater mainly occurs in basin in three types of semi-confined aquifers with water table varying from 2 to 2.5m below surface. According to Tariq [1] *et al.* the piedmont aquifers are generally of fluvial lacustrine and floodplain origin and are considered to host good reservoirs of water. These are generally below 2.5 m and less affected by the surface water. However, the lacustrine and floodplain aquifers are generally present at shallow depth (< 2.5 m) and can, therefore, possibly be contaminated by the seepage of canals, rivers, streams and direct infiltration of rainfall [2].

Naturally, heavy metals occur in significant amount in rocks and soils ranging from 10.0 to 100 mg/l. However, the concentration of these metals in the surface and groundwater are usually well below the amount that would be predicted on the basis of solubility product consideration. There are many anthropogenic sources of these metals which include alloys, paints pigments, electroplating, batteries, automobile parts, coatings and electrical wiring. These metals are also released in industrial waste and

*To whom all correspondence should be addressed.

sewage sludges. These metals have little mobility in soil; therefore, their anthropogenic impact to surface and groundwater is small. Levels of metal contaminants were determined in vegetables grown around Peshawar using sewerage and canal water [3]. Characterization was also reported of selected metals in milk collected from animals fed on coastal areas of Kabul River in NWFP [4].

Iron (Fe) and copper (Cu) are essential elements if present in permissible amount, however, in case of higher concentrations in water, their toxicity can cause a number of health problems in the community. Iron and copper contamination in surface and groundwater can be contributed from both geogenic and anthropogenic sources. The anthropogenic sources can be held responsible for the major toxicity of these cations in the drinking water, if present in higher concentration than the permissible level. The Cu toxicity includes digestive disturbances (nausea, vomiting, hemorrhagic gastritis) and liver, spleen and kidney damage [5]. Iron concentration up to 300 mg/l (ppm) is the safe limit while the maximum permissible level of copper in the drinking water is 1000 µg/l [6].

Lead (Pb) contamination in drinking water can be caused due to percolation of water through the sulfide zone in areas having sulfide deposits or from anthropogenic sources like storage batteries, paints, ink, ceramics gasoline and automobile industries [7]. The US-Environmental Protection Agency considers this metal to be highly toxic and a major public health threat [6]. If it is present above 50 µg/l in the drinking water, it can cause damage to both adults and children, although in the children the effects tend to be greater (*i.e.,* mental retardation, kidney damage, delayed development, hypertension, weight loss neuromuscular disfunction and encephalopathy, carcinogenic renal tumors etc.) [8].

The primary natural source of nickel (Ni) in drinking water is leaching from ultramafic rocks and the soils derived from these rocks. The anthropogenic sources include production of electroplating, and production of high grade steel alloy, electronic components, automobiles, batteries, coins, jewellery, surgical implants, kitchen appliances, sinks and utensils [9]. No safe limit for Ni for drinking water is recommended [6]. It has numerous toxic effects such as its contact with skin may cause a dermatitis and its inhalation can cause lung cancer [10].

Chromium (Cr) is used in the leather tanning industry, the manufacturing of catalysts, pigment and paints, fungicides, the ceramics and glass industry, and in photography and for chrome alloy and chromium metal production, chrome plating and corrosion control [6]. Chromium, with in the recommended limit in drinking water, is essential in human nutrition to maintain the normal glucose metabolism. However, if higher than the recommend level, it causes a nephritis and glycosuria diseases. Similarly, the higher levels of Cr in chromite dust produces skin ulcers and nasal mucosum [11].

Cadmium [Cd] occurs naturally in zinc, lead, copper and other ores which can act as sources to ground and surface waters. Major industrial releases of cadmium are due to waste streams and leaching of landfills and a variety of operations that involve cadmium or zinc. Cadmium can be released in drinking water from the corrosion of some galvanized plumbing and water main pipe material [12]. According to US-EPA [6] if people are exposed to cadmium for short periods of time, it can cause health hazards such as nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury convulsions, shocks and renal failure. Long term cadmium exposure can cause effects such as kidney, liver, bone and blood damage [13].

Cobalt (Co) is used in many alloys, in magnetic recording media, as catalyst for petroleum and chemical industries, as drying agents for paints and inks. Cobalt consumption is beneficial for humans being because it is a part of vitamin B_{12}, which is essential for human health [14]. Low levels of cobalt can cause nutritional diseases in animals, known as the Bush sickness in cattle and sheep. It may produce carcinogenic effects and also cause lung problems, vomiting and nausea, vision and heart ailments if it is taken in high quantity.

The maximum permissible levels (MCL) for tested metals in drinking water [6, 15] as recommended by United States-Environmental Protection Agency (US-EPA), World Health Organization (WHO) and Pakistan-Environmental Protection Agency (Pak-EPA) are shown in Table-1.

In order to assess the importance of vegetables cultivated on industrial wastewater in Greece, the daily intake of trace elements *via* vegetables were estimated. The intakes of Cr, Pb, Zn,

Table-1: The Maximum permissible levels (MCL) of tested metals for the drinking water.

Characteristics	MCL of US-EPA	MCL of WHO	MCL of Pak-EPA
		(μg/l)*	
Iron	300	300	300
Copper	1000	1000	1000
Lead	50	50	50
Nickel	20	-	-
Chromium	50	50	-
Cadmium	10	5	-
Cobalt	-	-	-

* μg/l = ppm

Co and Hg were highest in spring, whereas the intakes of As and Se were highest in winter [16]. Levels of heavy metals in sewage contaminated water were measured and its impact on underground water, soil and crop plants in Alluvial Soils of Northwestern India was also evaluated [17]. Although certain natural processes may cause some of the water pollution, however, human activity is the largest cause of our seas, rivers and lakes getting polluted [18]. We need to use water every day both in our industries as well as our homes. We get this water from groundwater sources, rivers, and lakes and after using it and often contaminating it, most of this water gets back into the rivers, lakes and oceans.

To determine the quality of the surface and groundwater of the Peshawar basin, the water samples collected from various localities have been analyzed for heavy metals.

Results and Discussion

The waste water from agricultural, industrial practices and households is referred to as sewage. If this is allowed to flow back in to water systems without being treated, it causes pollution, which results in harming both humans as well as animal life. Water also gets polluted when there is a runoff of rain water from industrial, agricultural and urban areas, which flows directly through storm water drains into water systems without any treatment.

Effort has been made to develop a data base of heavy metals of the Peshawar metropolis in order to gain information by obtaining more accurate and precise values to assess the impact of sewerage and effluent releases on man. In the literature, classical and chemical methods are described in early work on the determination of heavy metals while more recently physical and instrumental techniques have become available and have proved suitable for the analysis of these metals. Clearly the selection of a

method for the determination of heavy metals is mainly dependent on the concentration in the samples, the type and number of samples, the location of the samples, the availability and cost of facilities and the type of information required. Attention has been focused for this purpose on atomic absorption spectrophotometer (AAS), a powerful technique for metal analysis. Hence, with the advent of AAS as a highly sensitive method of detection of heavy metals, this has been investigated and successfully applied to analyze these metals.

The chemical study of both surface and groundwater of Peshawar Basin is aimed at several aspects on regional scale. These studies included regular monitoring of physico-chemical parameters of both surface and ground waters of the Peshawar basin in order to determine the extent of environmental degradation with the passage of time. This study is the second of its type after Tariq [1] in the Peshawar basin. Therefore, the water samples from the same localities were collected. The same heavy metals were also determined, so that enrichment or depletion of these essential/hazardous elements can be monitored with passage of time. Data for selected heavy metals in the surface and groundwater of the various aquifers of the Peshawar basin, collected during the months of January and June of 2003 and 2004, are graphically presented in Figs 1-6, along with the iron concentration reported earlier [1].

It is evident from Fig. 1 that the concentration of iron remains more or less the same in different times of the year and no significant change is noticed with the passage of time in the concentration of iron from the same localities. The iron concentration in almost all the samples, except two, from surface and ground water of the basin is below the permissible limit [6]. One sample from the tube-well of Hayatabad Phase-3 in the Khyber piedment aquifer and one sample from the bore hole well of Jehangira area in the Attock-Cherat piedment aquifer have high concentration (> 600 mg/l) of iron. This high concentration in the tube well water of Hayatabad Phas-3 and the bore hole well water of Jehangira seems to be local and related to rusting from the pumping facility. This interpretation is based on the sharp contrast of these high value data with the rest. On the basis of iron concentration the surface and groundwater from Peshawar basin can be classified as safe for drinking purposes.
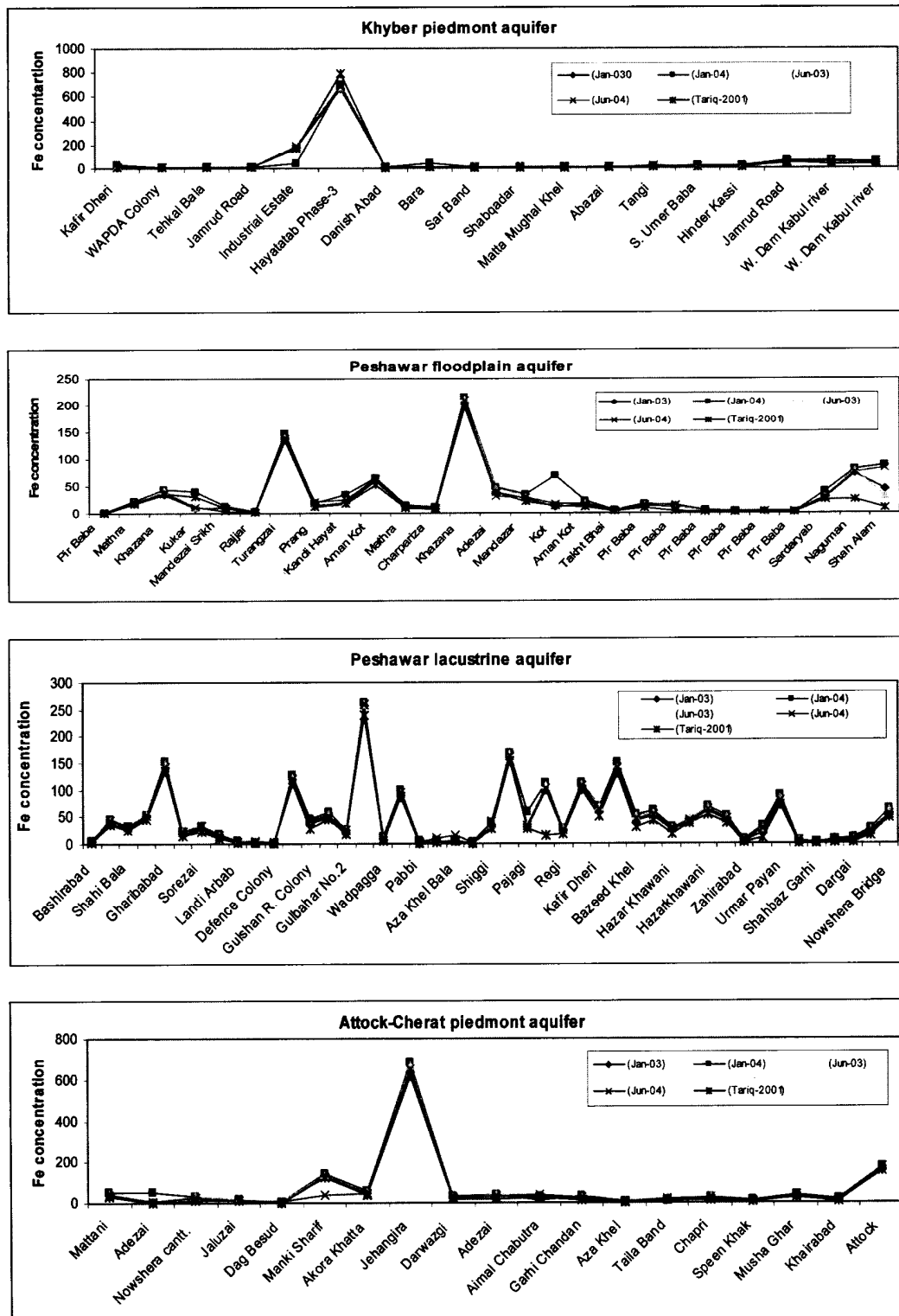
Fig. 1:   Variation in concentration of Fe (µg/l) in the surface and ground waters of Peshawar Basin
during different times.

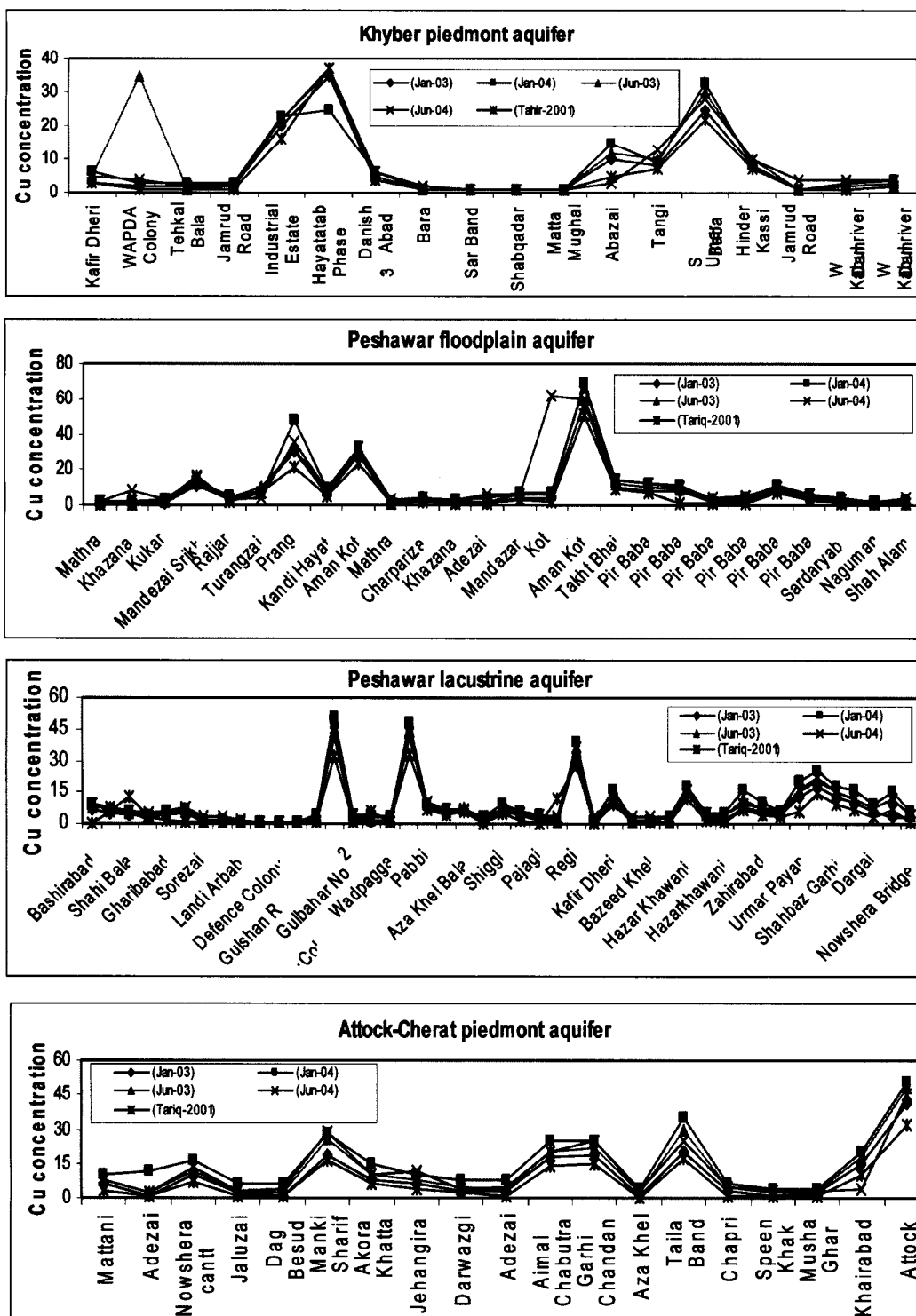Fig. 2:   Variation in concentration of Cu (μg/l) in surface and ground waters of Peshawar basin during different times.

It is clear from Fig. 2 that there is no significant change in the concentration of copper in the various aquifers of the Peshawar basin with the passage of time. However, very little increase in the amount of copper has been observed in certain samples that could be attributed to the instrumental error. The copper concentration in the aquifers of Khyber piedmont, Peshawar floodplain, Peshawar lacustrine and Attock Cherat piedmont ranges from 1 to 36, 1 to 69, 1 to 48 and 1 to 35 mg/l, respectively. The data show that both surface and groundwater of various aquifers of Peshawar basin have copper concentrations within the permissible limit [6] and pose no environmental threat as for as the copper concentration in the waters of the Peshawar basin is concerned.

There is no significant increase or decrease of Pb concentration in the waters of all the aquifers of the Peshawar basin with the passage of time from 2001 to 2004 as shown in Fig. 3. The Pb concentration ranges from 1 to 43 µg/l, from 1 to 48, from 1 to 71 and from 1 to 155 µg/l in the aquifers of Khyber piedmont, Peshawar floodplain, Peshawar lacustrine and Attock-Cherat piedmont, respectively. All the water samples, except few, have Pb concentration within the permissible limit. However two samples from the tube well of the Gulbahar No.2 (up to 71 µg/l) from Peshawar lacustrine aquifer and the two from Mattani (up to 155 µg/l) and Chapri (up to 58 µg/l) from Attock-Cherat piedmont aquifers have Pb contents up to hazardous level and need to be further investigated. The contamination seem to be local either from the pipes etc. The surface water of the basin through having Pb concentration within the permissible limit but near Nowshera and Khairabad the Pb concentration in the Kabul river increase multifold and also the Pb contents of Indus water show elevated concentration. This indicates that the water of Kabul is receiving effluents from the industries and other waste of the Peshawar city.

Fig. 4 shows that there is no significant change of Ni concentration in the various aquifers of Peshawar basin with the passage of time. The majority of tube wells, dug wells, rivers and spring samples show nickel contents below the permissible limit (<12 µg/l). Some of the tube wells and dug wells have high concentration of Ni. These include the tube wells from Danishabad, Bara, Urmer village and the dug wells from Shahbaz Ghari and Musha Ghari. The surface water of the Peshawar basin has

Ni concentration within the safe limit. The high concentration of Ni in some of the samples could be local either due to pipes or sewerage waste or may be due to leaching of mafic and ultramafic phases in the Quaternary sediments.

There is no significant variation in the chromium concentration with the passage of time in the various aquifers of the Peshawar basin as clearly seen from Fig. 5. Most of the samples of drinking waters of the various aquifers of the basin are below the permissible limit of 50 µg/l. Chromium varies from 1 to 30 µg/l, 1 to 179 µg/l, 1 to 155 µg/l, and 1 to 96 µg/l in the Khyber piedmont aquifer, Peshawar flood plain aquifer, Peshawar lacustrine aquifer and Attock-Cherat piedmont aquifer respectively. All the water samples of the Khyber piedmont aquifer have chromium concentrations within the permissible limit. In the Peshawar floodplain aquifer the water samples of the tube wells of Turangzai and Takht Bhai have high concentration (up to 84µg/l) of chromium. In the Peshawar lacustrine aquifer, water samples of the tube wells of Landi Arbab, Tehsil Gunj, Urmar village and Aza Khel Bala and those of dug wells from Surezai, Urmar Bala, Urmar Payan and Azakhel Bala have chromium concentrations above the permissible limits. In the Attock-Cherat piedmont aquifer the water samples of the dug wells from Darwazgai and Speen Khak have chromium above the permissible limit. The high concentration of Cr in tube wells and dug wells indicate localized sources of enrichment of chromium in these waters that have not the effected the various aquifers in large scale. This contamination needs to be further investigated as the water of these areas could be hazardous for the inhabitants. The surface water generally has chromium below the permissible limit. However, the Kabul river at two localities *i.e.*, Sardaryab and Shah Alam have very high concentration (up to 179 µg/l) of Cr. One stream water at Pir Bala also has Cr above the permissible limit. The high concentration of Cr in the Kabul river and the stream water at the above mentioned localities is due to the effluents added to the river and stream water from the municipality waste and leather industry. The high concentration of Cr in the river Kabul and other streams could be hazardous for the aqutic life and also cause contamination in the Khyber piedmont aquifer.

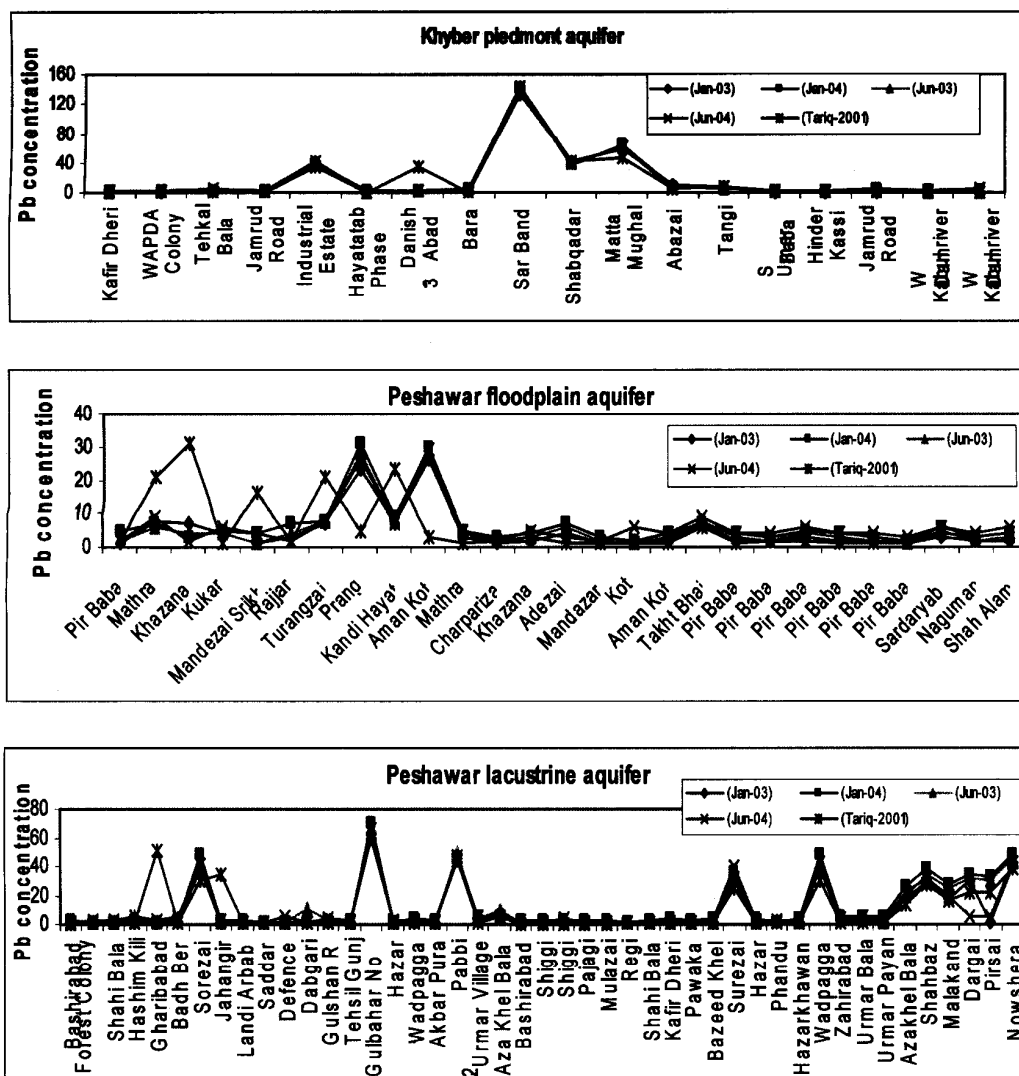Fig. 6 reveals that no significant change in the Cd concentration has been noticed with the

Fig. 3:   Variation in concentration of Pb (μg/l) in the surface and ground waters of Peshawar basin
during different times.

passage of time. The Cd concentrations in both surface and ground water of all the aquifers of the Peshawar are within the permissible limit and have no health hazards related to cadmium can be expected in the region.

It is noticed that all the samples have Co contents below the detection limit (>1μg/l), therefore, the Co concentration has not been reported. Due to very low concentration of cobalt in the surface and

ground water of the basin, no drastic health related hazards of Co could be observed in the ecosystem of the basin.

Since villages are consumed by towns, towns are rapidly getting converted into cities and cities into big cities or metros. Considering the fact that the present human population is already six billion, the expanding frontiers of urban habitats invite concern. Twenty-one action points were
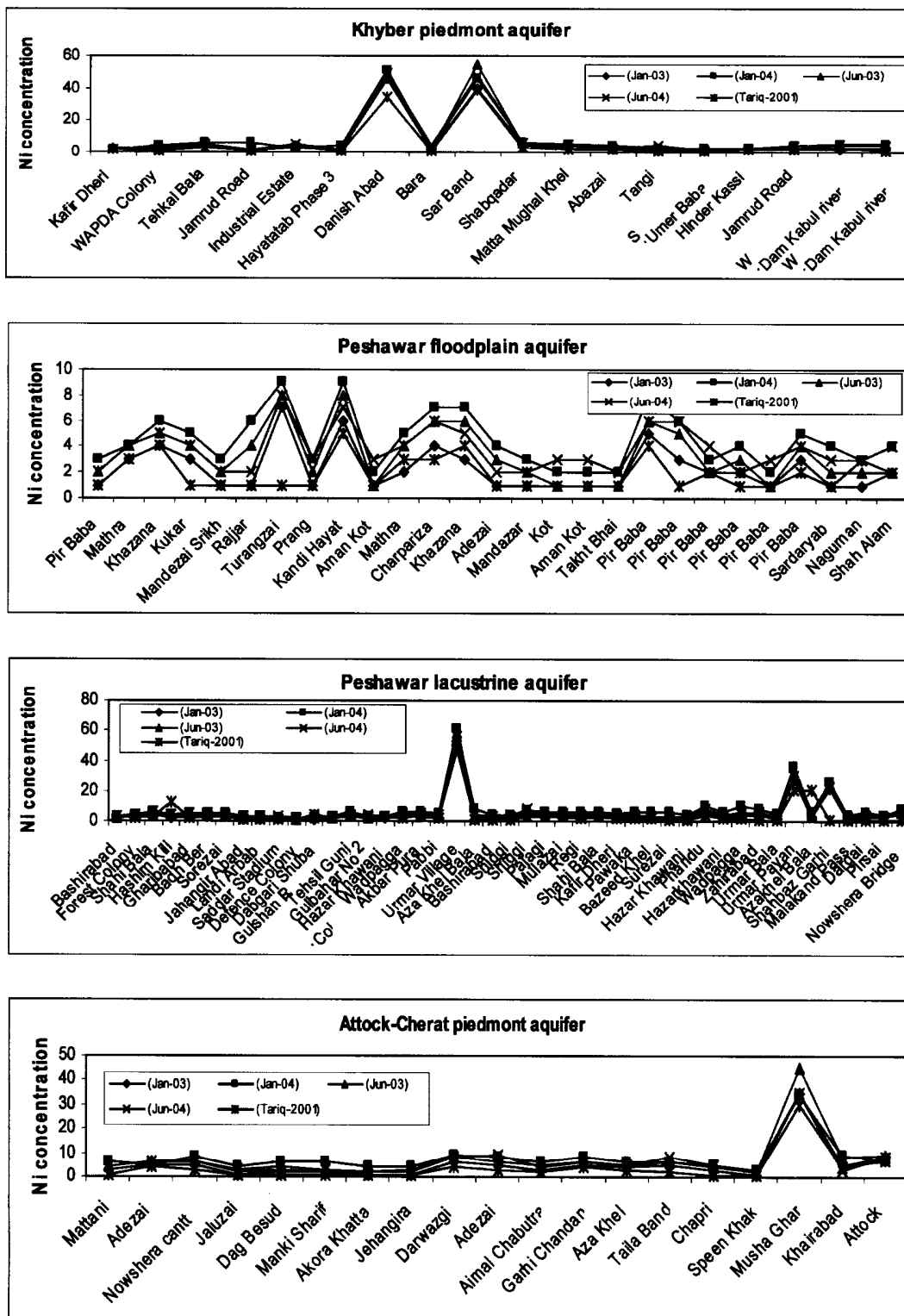
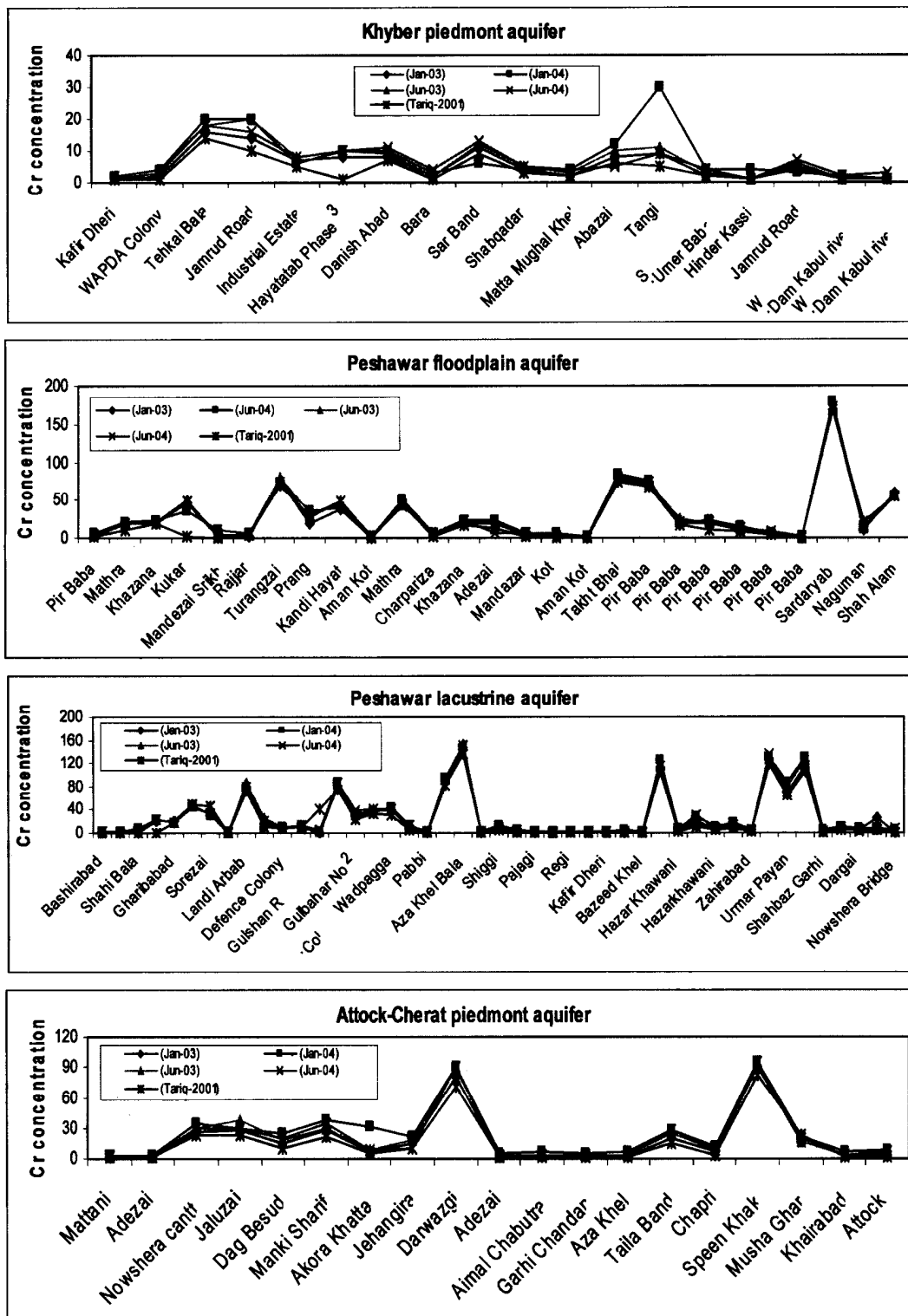Fig. 4:   Variation in concentration of Ni (μg/l) in the surface and ground waters of Peshawar basin during different times.

Fig. 5: Variation in concentration of Cr (µg/l) in the surface and ground waters of Peshawar basin during different times.
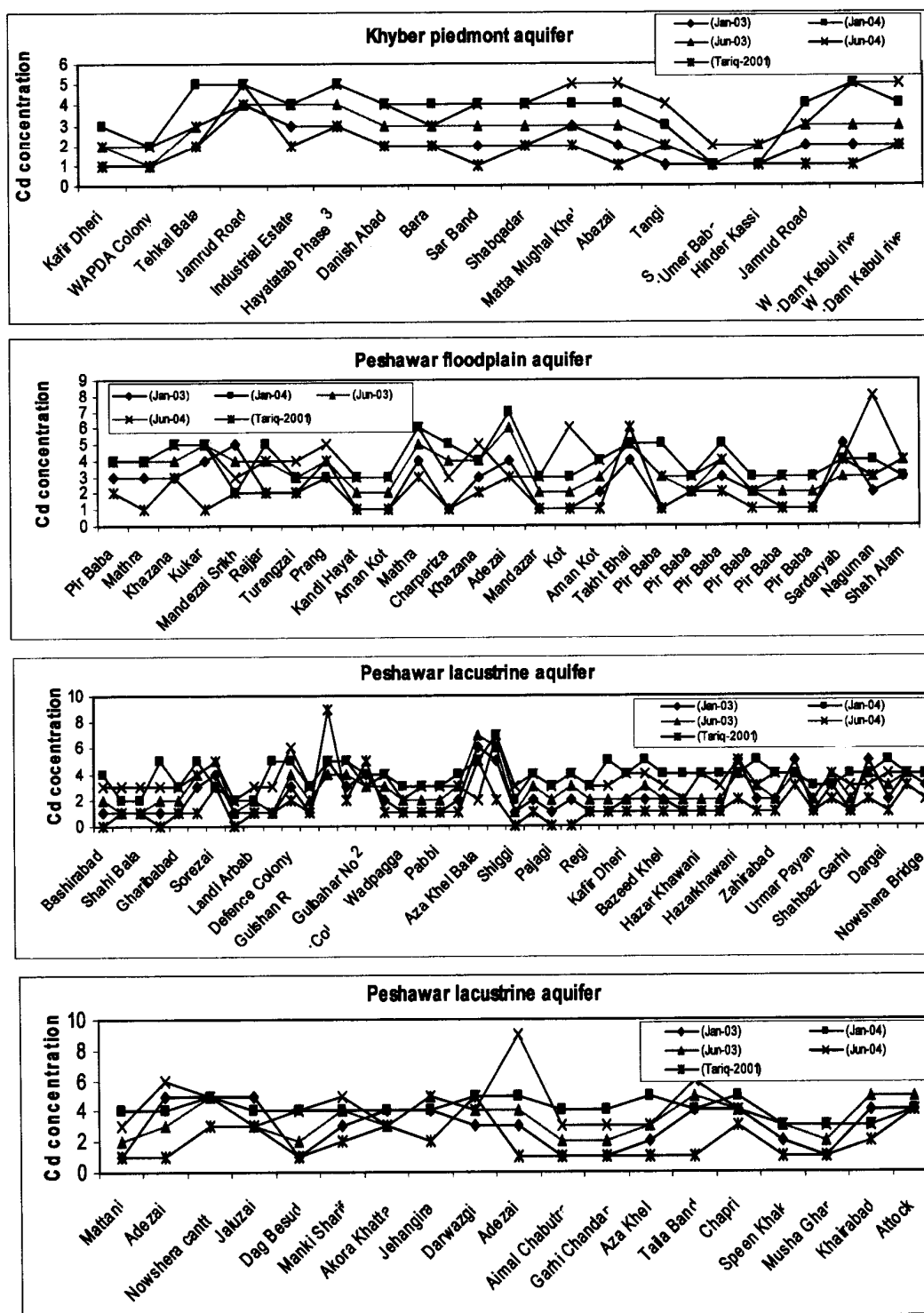
Fig. 6:   Variation in concentration of Cd (µg/l) in the surface and ground waters of Peshawar basin during different times.

suggested to put fifty selected big cities on a path to greener, healthier environments for the current residents and to approximately one million people that migrate globally to cities each week [19]. The present and earlier studies [1] suggest that the aquifers in the basin are generally replenished both by rain water and water from Kabul and Swat rivers. This suggests that the contamination in these rivers may have direct effect on the underground water; especially the shallow water (dug wells). Like other metropolitan cities of the world, Peshawar also has most of the environmental problems.

Experimental

Collection of Water Samples

To avoid possibility of contamination the empty polyethylene bottles used for the collection of water samples were treated with 5% HCl, or HNO₃ and then rinsed with double deionzed water. Fifty three water samples from deep aquifers (*i.e.,* tube wells), forty two from shallow aquifers (*i.e.,* dug wells) and nineteen from surface water (*i.e.,* river, stream and springs) were collected from Peshawar piedmonts and Peshawar floodplain and lacustrine aquifers of the basin in the polyethylene bottles. The locations of these samples are marked in Fig. 7.

Preparation of Samples

The containers were acidified with drops of nitric acid (HNO₃) to a pH below 5.0 to minimize precipitation and adsorption on wall of bottles. These polythene bottles of water samples were capped tightly and kept for further analyses of heavy metals in the geochemistry laboratory of National Center of Excellence (NEC) in Geology, University of Peshawar.

Instrumentation

Perkin Elmer Atomic Absorption Spectrophotometer (AAS), installed at National Center of Excellence (NEC) in Geology, University of Peshawar was used for the analysis of heavy metals.

Determinations of Heavy Metals

Selected heavy metals *i.e.,* iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co), lead (Pb) and cadmium (Cd) were determined in the water samples using Atomic Absorption Spectrophotometer. At NEC in Geology, University of Peshawar and cross checked in PCSIR Laboratories, Peshawar and Department of Environmental Sciences, University of Peshawar.

Solutions and Procedures used for Calibration

Iron (Fe)

1. Stock solution of 1000 ppm for Fe: 1 gram of pure iron metal was dissolved in minimum amount of HCl and was made to the volume with deionized water in one litre volumetric flask.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of iron were determined.

Copper (Cu)

1. Standard stock solution of 1000 ppm: 1 g of copper metal was dissolved in 30 ml of (1:1) HNO₃ and was made to the volume of one litre with deionized water.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophoto-eter was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200
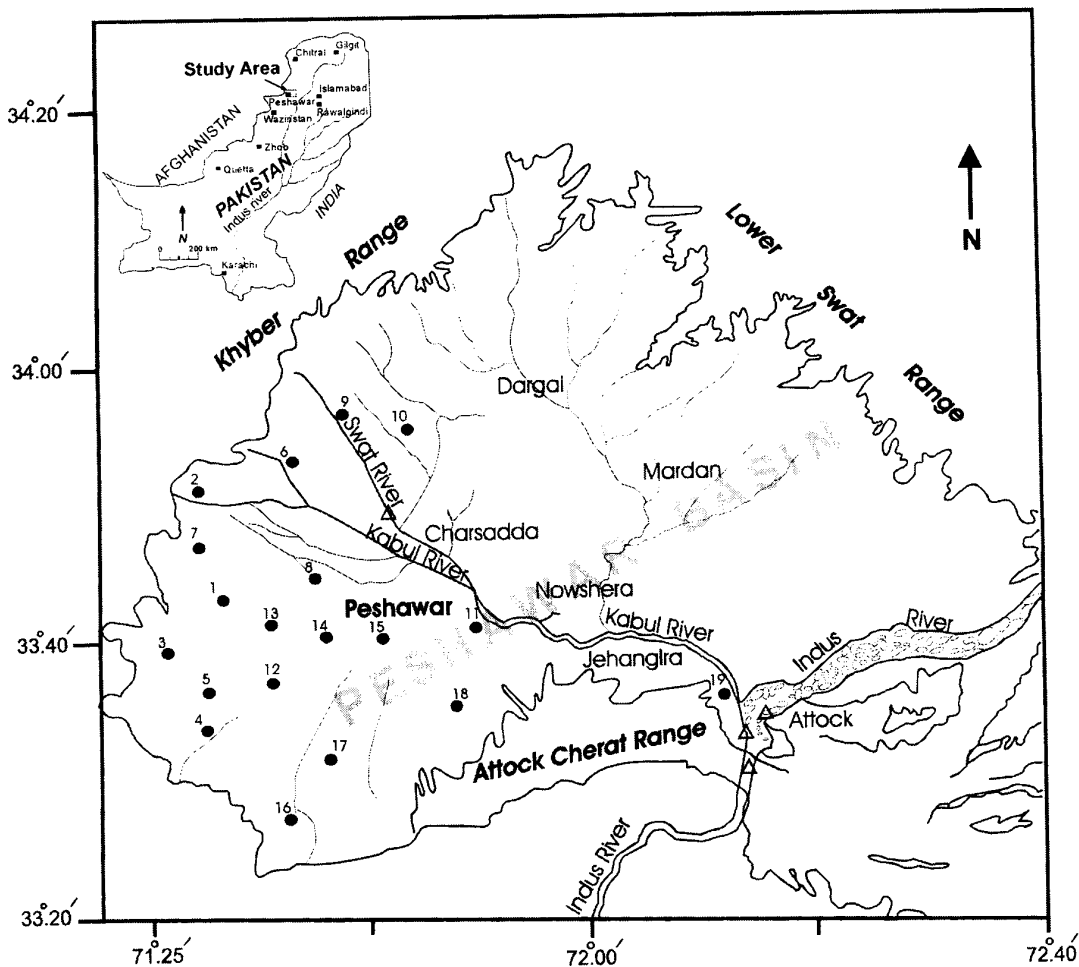
Fig. 7:   Location map of the surface and ground waters samples of the Peshawar basin.

ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of copper were determined.

Lead (Pb)

1.   Standard stock solution of 1000 ppm: 1.598 g of lead nitrate Pb (NO₃)₂ was dissolved in 1% HNO₃ and was diluted to 1 litre with deionized water.

2.   Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric

flask and made to the mark with deionized water.

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

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

samples were run on the atomic absorption and the concentrations of lead were determined.

Nickle (Ni)

1. Standard stock solution of 1000 ppm: 1g of Ni metal was dissolved in a minimum volume of (1:1) HNO_3 and was diluted to 1 litre with deionized water.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of nickle were determined.

Chromium (Cr)

1. Standard stock solution of 1000 ppm: 3.735g of K_2CrO_4 was dissolved in deionized water and diluted to one litre with deionized water.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water

samples were run on the atomic absorption and the concentrations of chromium were determined.

Cadmium (Cd)

1. Standard stock solution of 1000 ppm: 2.03 g of cadmium chloride ($CdCl_2-2\frac{1}{2}H_2O$) was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the cadmium working standard solutions of 25, 50, 100 and 200 ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of lead were determined.

Cobalt (Co)

1. Standard stock solution of 1000 ppm: 1.0 g of cobalt metal was dissolved in 30 ml of (1:1) HCl and was diluted to one litre with deionized water.
2. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
3. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
4. Procedure: The atomic absorption spectrophotometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water

samples were run on the atomic absorption and the concentrations of cobalt were determined.

Recommendations

In order to minimize the future environmental problems regarding drinking water the following measures are recommended on priority basis:

- Both surface and groundwater must be regularly monitored physico-chemically. This should include monitoring of rivers and their tributaries, canals, sewerage drains, sewerage pipes from industrial and residential areas.
- The inhabitants of these areas should be educated regarding water pollution and its impact on the ecosystem of the region.
- Environmental laws already formulated for disposal of domestic waste and industrial effluents should be forcefully implemented so that groundwater aquifers should be kept free of contaminants.
- The drinking water of tube wells and dug wells of certain areas having high concentration of hazardous elements and their speciation must be studied in detail. The water of these areas should be used after proper treatment.
- To control taste and odour problems, the best approach is the watershed supervision, use of insecticides, aeration, destratification of reservoirs, filtration and good management of the distribution system.
- The industrial effluents should be subjected to pre treatment before being disposed to the environment.
- Industrialists should encourage ISO certification to safeguard the environment from being polluted.
- Further study needs to be initiated for determining the concentration of the trace elements in vegetables, fruit and cereals.
- Mass awareness programmes regarding pollution must be encouraged both on print as well as electronic media.
- Health monitoring cells must be established in the small villages of the Peshawar basin.
- Detailed studies are needed to investigate the polluted dug wells and tube wells individually in order to find the precise source of this pollution.
- Detailed environmental impact assessment

studies must be made mandatory prior to the installation of any new small and large industry that may be considered a potential source of the surface or underground pollution.

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

Conclusion

Apart from clean drinking water, we also need to keep the waters in the oceans, rivers and lakes unpolluted because otherwise it harms the very planet we survive in. With human populations increasing rapidly it has resulted in us polluting all the water resources of our planet, so much that precious and unique organisms and ecosystems are being harmed and are even reaching extinction at an alarming rate. As a case study, the present study was conducted. It indicates that the sewerage system of the Peshawar metropolis is highly polluted by the heavy metals and is mainly drained in the Budni canal, which ultimately falls in the Kabul River. If the disposal of municipal and industrial waste is continuously falling in the Kabul and Swat rivers, which are irrigating most of the basin, there are greater chances that in future with the establishment of industrial zones, as proposed, in Peshawar, Swat and Nowshera, the aquifer system of the basin would be polluted to a greater extent. Similar results could

be drawn from all big cities lying around the Indus and other rivers of Pakistan.

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