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Pollution of Large, Subtropical Rivers-River Kabul, Khyber-Pakhtun Khwa Province, Pakistan) : Physico-Chemical Indicators

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Abstract.- Water quality in River Kabul was monitored to determine if indusatrial effluents and city sewage had a significant impact on it. Water samples were collected three times a year, two times in winter (low Q) and once during summer (high Q) for three years. Sampling was carried out along a section of River Kabul receiving untreated industrial effluents to assess the physico-chemical variables and was compared with upstream water from Warsak Dam being pristine. Factories discharge effluents having high organic pollutants load into the river which is evident from the high value (290.5, 280 mgO_2/l for low Q and 295.7, 281.7 mgO_2/l for high Q periods) of biological oxygen demand (BOD) in comparison with the National Environmental Quality Standard (NEQS) value of 80 mgO_2/l set for this variable. The river water downstream of entry of industrial wastewater had total suspended solids, biological oxygen demand, NH_3, Cl^- and SO_4^{2-} 17%, 8%, 58%, 42%, 17% and 148% higher than those in the upstream water during low Q (winter), whereas these variables were 6%, 100%, 286%, 25% and 132% higher than those in upstream water, respectively, during the high Q (summer) season. These raises concern over the long-term health of the River Kabul ecosystem.

Key Words: Industrial effluents, River Kabul, Warsak Dam.

INTRODUCTION

South Asia has an annual rainfall of over 4000-km3 and river flow of about 1880 km^3 and estimated groundwater resources of 1880-km^3. The South Asian Nations together have over 2800 km^3 of renewable freshwater resources (Gleick, 1998). This shows that there is no paucity of fresh-water in the Indian sub-continent. One of the problems in the region is the discrepancy in the distribution of these huge water resources.

Water pollution is a major environmental problem in South Asia. The explosion of the population living along the banks of the Ganges and Indus Rivers and their tributaries, combined with this region's rapid industrialization and urbanization, has placed a growing stress on the region's water resources in recent years. Water quality has been affected by a combination of factors including sewage and industrial wastes, agricultural run-off and salinisation intrusion. Pakistan, India and its neighbors industrialized rapidly following independence in 1947, often in an environment without significant regulation. Industrial growth quickly outstripped existing infrastructure, and the poverty of the regional governments has precluded the development of adequate sewerage containment and waste disposal facilities. As a result, many industrial wastes are discharged directly into the environment. River Kabul receives untreated effluents from a large number of large and small industries including 13 leather-processing units (IUCN, 1994). Similarly in the leather processing city of Kanpur, for example, 175 factories regularly dump large amounts of untreated heavy metals directly into the Ganges. Agricultural contamination is also a threat to the regions potable water supply. Agricultural use accounts for approximately ninety percent of the region's water use, and this proportion is growing. The spread of cities over former agricultural land and the increasing food demands of the region's growing population have required an intensification of agriculture on existing cropland and occasioned the spread of agriculture to more and more marginal areas. To meet agricultural needs, many rivers have been dammed and diverted, and significant proportions of the region have been canalized with irrigation ditches. The long-term

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consequences of this intensive agriculture for the watersheds are several. They include contamination of surface and groundwater supplies by agricultural chemicals, septic contamination from animal wastes, salinisation of rivers and aquifers.

Rivers play a key role in the lives of millions of people in South Asia. They provide fish, freshwater, fertile silt, transportation, recreation and many other essential functions. Rivers and their catchments-the life blood of the region are increasingly under threat from ill planned development schemes. Aquatic pollution in Pakistan is mainly due to industrial disposal, agricultural activities, poor sanitation and unhygienic practices by the general public. According to a report 30% percent of all reported cases of illness and 40% deaths in Pakistan are due to water borne diseases (Akhtar, 1981). Similarly about 40% adult and 60% infant deaths in Pakistan are related to water-borne diseases such as typhoid, diarrhea, infective hepatitis *etc*. It is reported that 25% of the overall deaths occur below the age 5, mainly due to gastroenteritis (Rump and Kirst, 1992; Laghari *et al*., 2000; Baloch *et al.,* 2001). About 55% of the population is deprived of safe water.

Study Area

River Kabul:Origin and course

River Kabul originates from Paghman Mountains in Afghanistan and flows for about 480 km before joining River Indus at Attock in Pakistan. It passes Kabul approximately 72 km from its source at its confluence with the Loger River (Gresswell and Huxley, 1965; Fazl-i-Hadi *et al*., 1988). The Kunar River formed by the joining of Chitral River and a branch from Nuristan joins the Kabul River near Jalalabad (Fig.1).

The River Kabul enters Pakistan at Shalman in the Khyber Agency. It then flows through the Khyber and Mohmand Agencies flanked by the Kohi-Safed Mountains until it reaches Warsak Dam (Fig.2). Inside Pakistan below Warsak Dam the River Kabul divides into three main branches, which rejoin after flowing for about 34 km. The river flows about 70 km in Pakistan. The depth wedth ratio is highly variable at different places and in different seasons. There is no exact data available, however in Pakistan the depth will vary from 6-10 feet and width vary from 100-300 feet approximately. The river carries the name mainly due to the political and historical background.

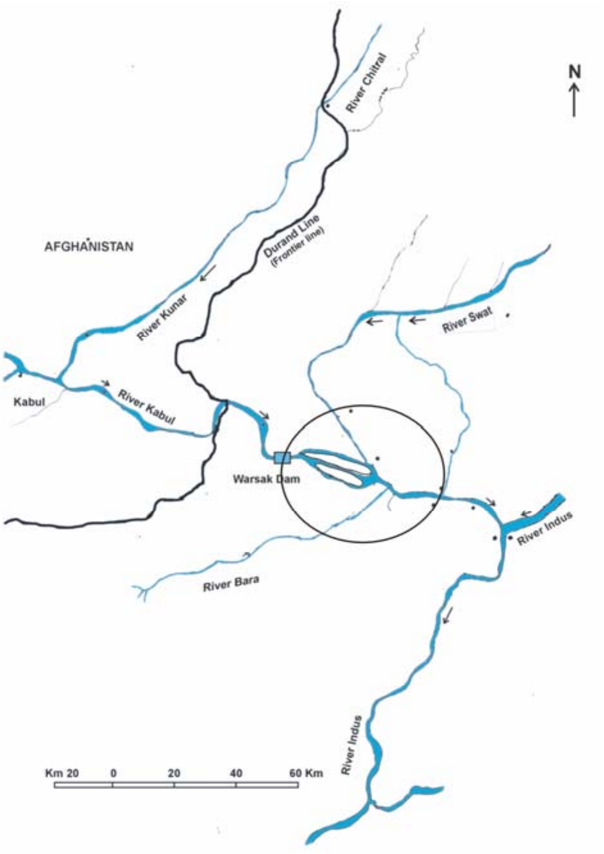

Fig. 1. A scheme of river Kabul system with fragment under study encircled.

Warsak Dam

Warsak Dam is situated on River Kabul at Warsak, between Khyber and Mohmand Agencies (Fig. 2). It is hydroelectric powers project, used both for irrigation and electricity production. The dam construction was started in 1952 and completed in 1960 with the technical and financial assistance of the Canadian Government. The dam is 750 feet long and 235 feet high. Water reservoir is 26 miles long and 1000 feet wide with a storage capacity of 20,000-acre feet water. The dam has 240 MW (mega watt) electricity production capacity. Three canals for irrigation have been taken up. The dam is without any fish ladder, therefore, is an obstacle for upstream migration of the fish population especially during fish breeding season, which starts in spring and lasts till late summer. The reservoir inhabits almost the same fish population as is found in River Kabul and is used for commercial fishing as well.

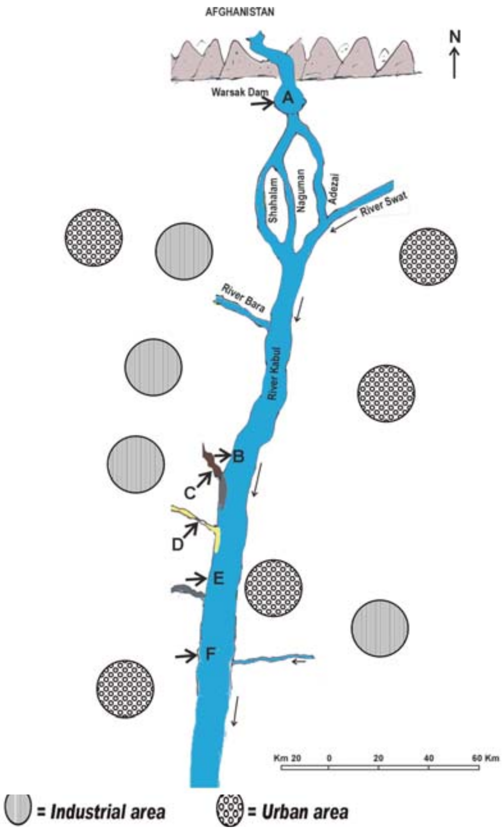

Fig. 2. Localization of sampling stations in main river: A (Warsak Dam) as control point and B, E, F and of waste effluents: C, D.

Geology

The River Kabul watershed is geologically complex. Most of the lower basin is underlain by the sedimentary limestone and shales that are common in the Indus Basin, while the headwaters of the main tributaries rise among very complicated sets of igneous and metamorphic rocks that result from the plate tectonics and mountain-building processes that are active around the edges of the sub-continent. There is some geomorphological evidence that the river channel through the hills along the Pakistan-Afghanistan border predates the uplift of the sedimentary rocks in this area.

Agriculture

The River Kabul is diverted into several canals for irrigation. This has improved agricultural yields but the original designs had inadequate drainage and has led to considerable water logging and salinization of soils. Water, which does return to the river often, contains agricultural chemicals.

Hydrology

The monthly discharge of the River Kabul when measured at Warsak Dam shows high seasonal variability. The average discharge at Warsak Dam is 20.5×$10^3 m^3 sec^{-1}$ with a low Q period from September to April and a high Q period from May to July (Fig. 3). The significant variations in river flow are the result of seasonal rains, glacial and snowmelt. The River Chitral, which joins River Kunar inside Afghanistan accounts for about half of the measured discharge. The whole area is very arid and rainfall influence is largely masked by glacial inputs. The tributaries in Afghanistan are also from areas of low rainfall. Below Warsak Dam the major tributary of the River Kabul before its confluence with the Indus River at Attock is the River Swat (Fig. 2).

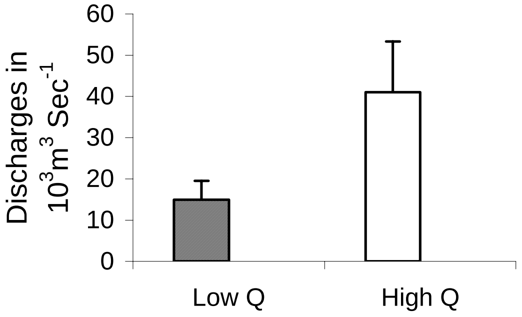

Fig. 3. Graph presenting the average discharges of River Kabul at Warsak Dam during winter – low Q and summer – high Q (1998 – 2002).

Vertebrate fauna of River Kabul

Among the vertebrate fauna, fish and turtles are found in the river. About fifty four fish species have been identified from River Kabul and its tributaries (Rafique, 2001) of which about thirty five are considered as common. Turtles are common along many parts of the river. No detailed data is available about turtles of the river.

The wetlands of the River Kabul provide wintering habitat to a variety of migratory bird species from Siberia such as cranes, waterfowls and waders. Migration is towards north in the spring and south in autumn (IUCN, 1994).

Uses of the River Kabul

The river water is mainly used for irrigation, effluent and waste disposal, watering live stock, fishing, recreation, transport, washing and bathing.

Fisheries in River Kabul

The entire River Kabul and its tributaries are used for commercial as well as sport fishing. Commercial fishing in River Kabul and its tributaries are the only source of living for thousands of poor families residing along its banks. Summer, because of fish abundance, is the best earning season for these fishermen.

During the course of this study, several unauthorized and highly undesirable methods of fishing like the use of electric current, explosives and insecticides were also observed.

Hunting

The river is used for sport hunting. The main hunting season starts from November when waterfowls start migration from Siberia to Pakistan and India for feeding, and lasts till April when emigration to Siberia for breeding along the Indus flyway is completed. Shooting waterfowls is a popular sport both for locals and visitors.

Recreation

Boating, hostelling, fishing and hunting are currently the main recreational uses of the river. Huts and river view restaurants are present along the riverbank. Fried fish is specialty of these huts and restaurants. The above uses and economic benefits demands that the river must remain in a "healthy" state.

Industry along River Kabul

About 80 different industries and industrial units including pharmaceutical, oil and ghee, textile, paper and sugar and soap industries and tanneries discharge their untreated effluents directly or indirectly into the River Kabul (Fig.2). These pollutants have not only deteriorated the river water but the sub-surface water of the area as well (Akif *et al*., 2002; Khan *et al*., 1999a).

The discharge of industrial effluents in River Kabul have resulted in marked decline in whole fish population in general and Mahaseer, *Tor putitora* (Hamilton) in particular which has been reported to be very sensitive to oxygen depletion due to the effluent pollution (Khan *et al*., 1985). It has been reported that River Kabul water is no longer fit for drinking (Khan *et al.*, 1999a; IUCN, 1994), its major tasks these days are as carrier of domestic and industrial wastes, and to provide water for irrigation.

A study of river water quality comprising of physico-chemical parameters upstream and downstream to the effluents discharge is undertaken and compared with water samples from Warsak Dam (being pristine in the sense far away of the urban activities) to assess the pollution level during high Q-summer and low Q-winter discharges.

MATERIALS AND METHODS

Composite water samples A, B, C, D, E and F were collected from upstream to downstream of the river. Sample (A) was collected from Warsak Dam water reservoir, which is about 60 Km upstream of the polluted part of the River and can be called safe in the sense far away of the dense human population and industrial activities. This was considered as control sample. Water samples B, E, and F (Fig. 2) were collected from polluted part of the Main River at Industrial area Aman Garh, Nowshera. Sample B was taken downstream to control sample but upstream to the effluent discharge into the river, sample E was taken downstream of the effluent discharge and sample F was taken further downstream after city sewage flows into the river. Effluent samples C and D were collected from factory drains discharging into the river.

Sampling was carried out in 3 litre clean plastic bottles, three times a year, once in high-flow season in the months of June and July and two times a year in low-flow season in the months of February and December to highlight the effect of water volume on the quantity of water pollution. All water samples were then stored at 4°C in refrigerator before analyses for various physical and chemical parameters. Standard methods (APHA, 1985) were followed for the determination of various physical and chemical parameters in water samples.

Among the physical parameters, temperature and pH were measured on the spot. Ordinary centigrade thermometer was used for temperature measurement. Conductivity meter (Model HI 8033, Hanna Instruments, Italy) was used for measuring the electrical conductivity. For total suspended solids (TSS), water sample (100 ml) was filtered through the glass fibre filter paper and washed with three successive volumes of distilled water. The filter paper was dried for one hour at 105°C in an oven and weighed after cooling in a desiccator. The TSS were calculated and reported as mg/L. For total dissolved solids (TDS) one-hundred mililitre volume of a well-mixed water sample was filtered through a glass fibre filter paper and was added to a pre- weighed evaporating dish, evaporated to dryness on a water bath, and dried for one hour in an oven at 105°C. The dried mass was then weighed after cooling in a desiccators. The soluble salts were weighed, calculated and reported as mg/L.

Among the chemical variables biological oxygen demand was determined by the Azide (Alsterberg) method. Separate BOD bottles of 300 ml capacity were used for the determination of initial dissolved oxygen on the date of collection and final dissolved oxygen after five days incubation at 20°C. Dilution water was used wherever fraction of sample was taken. 1 ml of phosphate buffer pH 7.2 (8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g $Na_2HPO_4.7H_2O$ and 1.7 g NH_4Cl dissolved per litre of solution), 1 ml of $MgSO_4.7H_2O$ (22.5 g of $MgSO_4.7H_2O$ dissolved per litre), 1 ml of $CaCl_2$ (27.5 g of $CaCl_2$ dissolved per litre), and 1 ml of $FeCl_3 .6 H_2O$ (0.25 g of $FeCl_3 .6 H_2O$ dissolved per litre) solution were added to 1 litre well-aerated (oxygen saturated) distilled water for the preparation of dilution water. The dilution water along with sample was used for the determination of initial and final dissolved oxygen before and after 5 days incubation at 20°C. The dissolved oxygen was measured by titrimetric method. To 300 ml dilution water containing 1 ml sample water, 2 ml $MnSO_4.H_2O$ solution (364 g $MnSO_4.H_2O$ was dissolved in distilled water, filtered and diluted to 1 litre) and 2 ml alkaline iodide-sodium azide solution (500 g NaOH and 135 g NaI was dissolved in distilled water and diluted to 950 ml and cooled. Slowly, with stiring 10 g NaN_3 was dissolved in 40 ml distilled water. Both the solutions were combined and the total volume was made 1 litre by adding distilled water) were added to BOD bottles. The bottles were stoppered, mixed and left for few minutes to form precipitate. After the precipitate settled, 100 ml clear supernatant was separated in fresh bottle, to which 2 ml H_2SO_4 was added, mixed well and immediately titrated with 0.025 N Na_2SO_3 to pale yellow color. Blue color was formed after the addition of few drops of fresh starch indicator. The mixture was again titrated against 0.025 N Na_2SO_3 solution till disappearance of blue color.

The BOD was calculated as follows:

$$\text{BOD (mg O2/L)} = \frac{D_1 - D_2}{p}$$

Where D_1 is dissolved oxygen in samples before incubation (initial dissolved oxygen), D_2 is dissolved oxygen in samples after incubation for 5 days at 20°C (final dissolved oxygen), and p is the decimal fraction of sample used (v/300), where v is the volume (ml) of the sample taken and 300 ml is the total volume including dilution water used.

EDTA titrimetric method was used for the estimation of total hardness. Well-mixed water sample (25 ml) was diluted to 50 ml with distilled water in a flask. To this flask 2-4 ml buffer pH 10 (67.5 g NH_4Cl in 570 ml conc. NH_4OH and diluted to 1 litre), and 2 to 3 drops of Eriochrome Black-T [0.5 g sodium salt of 1-(1-hydroxy-2-naphthylazo)-5-nitro-2-naphthanol-4-sulfonic acid dye in 100 g triethanolamine] indicator were added and slowly titrated against 0.01 M EDTA with continuous stirring until the last reddish tinge color changed to bluish purple.

$$\begin{array}{l} \text{Total hardness (mg/L)=} \\ \text{Ca + Mg (as CaCO}_3\text{)} = \end{array} \frac{V \times M \times 100 \times 1000}{\text{Sample (mL)}}$$

Where V is volume of EDTA used, M is molarity of EDTA (0.01 M) and 100 is the molecular weight of $CaCO_3$.

Titrimetric method was used for the

estimation of total alkalinity. One drop of methyl orange indicator was added to 25 ml of sample and titrated against 0.02 N H_2SO_4 solution until color changed from red to pink/orange.

$$\text{Total alkalinity as } CaCO_3 \text{ (mg/L)} = \frac{N \times E \times 1000 \times V}{\text{Sample (mL)}}$$

where N is normality of H_2SO_4 (0.02 N), E is the equivalent weight of $CaCO_3$ (50), and V is the volume of H_2SO_4 (ml) used during titration.

Direct Nesslerization method was used for the estimation of NH_3-N. Nessler's reagent (5 ml) was added to 100 ml of water sample in a flask, mixed well and after 30 minutes absorbance of the sample against blank was determined at 420 nm wavelength on a spectrophotometer. Standard curve was prepared by plotting absorbance against mg of NH_3-N. Blank was prepared by adding 5 ml Nessler's reagent to 100 ml distilled water. NH_3-N was determined by the following formula:

$$NH_3\text{-N (mg/L)} = \frac{\text{mg } NH_3\text{-N} \times 1000}{\text{Sample volume (mL)}}$$

mg NH_3-N was read from the calibration curve. Nessler's reagent was prepared by dissolving 34.9 g of KI in 100 ml of distilled water, 45.5 g of HgI_2 was added gradually and stirred until completely dissolved. In another flask 112 g of KOH was dissolved in 200 ml distilled water and cooled to room temperature. The two solutions were mixed and the total volume was made up to 1000 ml with distilled water. The mixture was allowed to stand for 2-3 days to settle down the precipitate before use. For preparation of standard curve the standard solution of NH_3 was diluted ten-fold to prepare a solution containing 0.01 mg NH_3/ml. Different quantities *viz.*, 2.0, 4.0, 6.0, 8.0 and 10.0 ml of this solution was transferred to a series of 100 ml volumetric flasks. A blank was also prepared by using distilled water. Solution in each flask was diluted to about 75 ml with distilled water and then 5.0 ml of Nessler's reagent was added to each flask, while swirling. After 30 minutes, absorbance of each solution was measured at 420 nm wavelength on a spectrophotometer against blank. The absorbance of each standard solution was plotted against the NH_3 concentration on a graph paper to prepare a standard curve.

Phenoldisulfonic acid method was used for the estimation of NO_3-N. Volume of silver sulfate (Ag_2SO_4) equal to the volume of 0.02N H_2SO_4 used for the estimation of total alkalinity was added to 100 ml of water sample, heated for a few minutes, neutralized to pH 7 and evaporated to dryness on water bath. The residue was mixed with 2 ml phenoldisulfonic acid, followed by 20 ml distilled water and 7 ml concentrated NH_4OH and waited until maximum yellow color was developed. Absorbance was read at 420 nm wavelength against the blank prepared from the same volume of distilled water, phenoldisulfonic acid and NH_4OH used for the sample. Nitrite concentration was estimated from the standard curve. For preparation of standard curve, 50 ml stock nitrate solution (100 mg/L) was placed in the boiling water bath until dryness. The residue was dissolved with 2 ml phenoldisulfonic acid reagent and diluted to 500 ml with distilled water to make a solution of 10 μg N/ml. Different quantities *viz.*, 0.1, 0.5, 0.7, 1.0, 1.5, 2.0, 3.5, 6.0, 10, 15 and 30 ml of the standard nitrate solution were taken in separate 100 ml flasks, to which 2 ml phenoldisulfonic acid and 7 ml concentrated NH_4OH was added. A blank was prepared from the same volumes of phenoldisulfonic acid and NH_4OH. Absorbances of standards were read against the blank at 420 nm wavelength. The calibration curve was prepared by plotting absorbance against the amount of NO_3-N. The corresponding value of the sample was read from the standard curve. The amount of nitrate-N was calculated as follows:

$$\text{Nitrate-N (mg/L)} = \frac{NO_3\text{-N (mg)} \times 1000}{\text{Sample volume (mL)}}$$

$$\text{Nitrate-N (mg/L)} \times 4.428 = NO^-_3 \text{ (mg/L)}$$

where 4.43 is the factor for the conversion of nitrogen (NO_3-N) into nitrate and is obtained by dividing the molecular weight of nitrate (62) by the atomic weight of nitrogen (14).

Argentometric method in which the water sample is titrated against standard $AgNO_3$ titrant was used for the estimation of chloride. A 25 ml well-mixed water sample was diluted to 50 ml with distilled water to which was added same volume of 0.02 N H_2SO_4 as used for the total alkalinity followed by 2 to 4 drops of potassium chromate (K_2CrO_4) indicator and titrated against 0.0141 N $AgNO_3$ solution until the color changed to a pinkish yellow. Amount of chloride present was calculated from the amount of silver nitrate used as a titrant.

1 ml $AgNO_3$ = 0.45 mg chloride.

$$Cl^- \text{ (mg/L)} = \frac{A \times 1000}{\text{Sample (mL)}}$$

where A is the volume of $AgNO_3$ used in titration.

EDTA titrimetric method was used for the estimation of sulfate. To 25 ml of sample the same volume of 0.02 N HCl solution was added that was equal to the volume of 0.02 N H_2SO_4 used for total alkalinity, followed by 5 ml 0.02 M $BaCl_2$ while boiling. The mixture was cooled to room temperature, to which was then added 1 ml 0.02 M $MgCl_2$ + 2 to 4 ml ammonia-ammonium chloride buffer pH 10 (67.5 g NH_4Cl in 570 ml conc. NH_4OH and diluted to 1 litre) and a few drops of Eriochrome Black-T (EBT) indicator and titrated against 0.01 M EDTA until color changed from red to violet blue. A blank containing only 25 ml distilled water instead of sample without adding HCl was also titrated against EDTA. The net EDTA volume (Z) was calculated as follows:

$$Z = B + H - A$$

where B is volume of EDTA used for blank, H is volume of EDTA used for total hardness, and A is volume of EDTA used for sample. The sulphate concentration was calculated by the following equation:

$$SO_4^{2-} \text{ (mg/L)} = \frac{Z \times M \times 96 \times 1000}{\text{Sample volume (mL)}}$$

where M is molarity of EDTA (0.01 M), and 96 is the molecular weight of SO_4^{2-}. Stannous chloride colorimetric method was used for the estimation of phosphate. In colored water samples, 1 drop of phenolphthalein indicator and a few drops of conc. H_2SO_4 solution was added to discharge the pink color. In routine analyses, 50 ml water sample was taken to which 2.0 ml ammonium molybdate solution and about 5 drops of stannous chloride solution were added. The color developed was measured after 10 minutes at 690 nm wavelength on spectrophotometer (Hitachi, Japan U2000) against blank made for this purpose using same reagents and distilled water instead of sample water. Calibration curve was prepared by plotting absorbance against mg PO_4^{3-}-P. The corresponding mg of P was read from the standard curve.

$$\text{mg P/L (x)} = \frac{\text{mg P (reading from std.curve)} \times 1000}{\text{Sample volume (mL)}}$$

The PO_4^{3-} concentration was found out by the following equation:

$$PO_4^{3-} \text{ (mg/L)} = \frac{95\text{g } PO_4^{3-} \times (x)}{31\text{g P}}$$

where (x) is mg P/L, 95 is the molecular weight of PO_4^{3-} and 31 is the atomic weight of P. A standard stock phosphate (500µg/ml) solution was prepared by dissolving 0.7164 g of anhydrous KH_2PO_4 in 1.0 litre of distilled water. This standard solution was diluted 10 times to make a concentration of 50 µg/ml of phosphate.

Student's 't' test was applied for comparison of the data of control with the test samples. Values of P less than 0.05 were considered significant.

RESULTS

The results for various physico-chemical variables are presented in Figures 4 and 5. Figures shows significant increase in different variables in water samples E and F downstream to the confluence of effluents drains and city sewage to the river.

Figure 4 shows an increase in water temperature downstream the river after the effluent discharge. The effluent sample C had temperature value 47.3±1.75°C for low Q and 52.2±2°C for high Q periods. Both these values are higher than the NEQS recommended value of 40°C. Downstream river samples E and F showed a significant increase during high Q in water temperature in comparison with control sample A from Warsak Dam.

The effluents pH did not exceed the NEQS limits (Fig. 4). But in comparison with upstream samples A and B an increasing tendency was observed in the downstream samples E and F. For sample F during high Q the increase was highly significant.

Electrical conductivity showed an increasing tendency after the effluent joins the river. Electrical conductivity (EC) of water sample A (control) was 240.8±28.60 µ S/cm for low Q and 172±7.21 µS/cm for high Q. Effluent samples C and D were with higher EC values, sample C had a mean value of 736.3±26.87 µS/cm for low Q and 751.3±40.22 µS/cm for high Q, sample D had a mean value of 823.7±31.94 µS/cm for low Q and 1116.7±104.083 µS/cm for high Q. Downstream river water samples E and F have higher EC values showing a highly significant increase during low Q as compared to control sample A, for sample E it was with a mean value of 430.6±14.02 µS/cm for low Q and for sample F it was with mean value of 425.8±13.57 µS/cm for low Q. Effluent sample D is with high total suspended solids for both low and high Q periods, therefore this parameter increases in the downstream samples E and F. Sample F shows a significant increase for this parameter during high Q as compared to control sample A. Total suspended solids (TSS) for sample A were 421.8±80.39 mg/l for low Q and 630±60.83 mg/l for high Q, for effluent sample D TSS had a mean value of 1242.5±52.38 mg/l for low Q and 1166.7±152.75 mg/l for high Q. For downstream sample E this parameter had mean value of 454.7±55.77 mg/l for low Q and 861.7±164.39 mg/l for high Q while sample F had mean value of 467.7±55.56 mg/l for low Q and 863±31.09 mg/l for high Q.

Similarly, total dissolved solids showed a significant increase in downstream river water samples E and F during low Q period in comparison with control sample A. The increase may probably be again because of effluent D with high TSS. Water sample A had total dissolved solids (TDS) 1086±424.62 mg/l for low Q and 185±131.43 mg/l for high Q. Effluent sample D had value of 982±32.39 mg/l for low Q and 1038±103.29 mg/l for high Q, downstream river sample E had mean value of 559.7±96.59 mg/l for low Q and 543.3±82.61 mg/l for high Q and sample F had value of 581.7±93.31 mg/l for low Q and 312.3±37.5 mg/l for high Q.

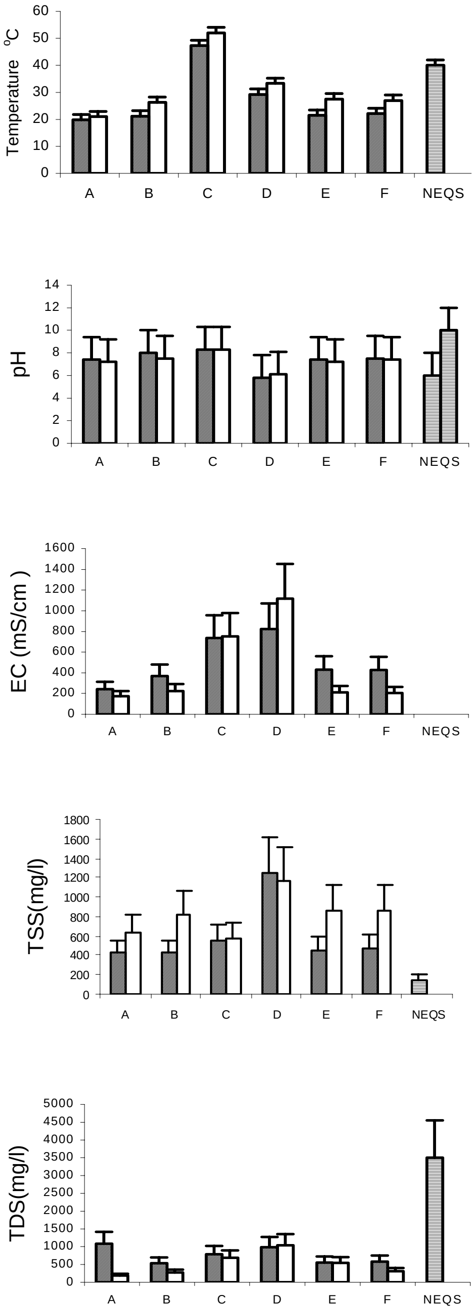

Fig. 4. Average (1998-2002, n = 6) values of selected physical parameters of River Kabul (Fig. 3) for: low (winter) and high (summer) discharge; A – F main river CD – waste effluents, thick bar on the left = standard value according to NEQS.

From amongst the chemical parameters BOD showed a highly significant increase in both the downstream river water samples E and F in comparison with control sample A both during low and high Q periods. This indicates the depletion of oxygen in the downstream river water. Again the increase may be because of effluent samples C and D with high BOD whose values much increase than the value (80 mgO_2/l) recommended by the NEQS for this variable. The water sample A from Warsak Dam had BOD of 0.72±0.12 mgO_2/l during low Q and 0.5±0.1 mgO_2/l during high Q. Effluent sample C had 290.5±11.81 mgO_2/l for low Q and 295.67±6.66 mgO_2/l for high Q while effluent sample D had a mean value of 280±23.84 mgO_2/l for low Q and 281.67±28.31 mgO_2/l for high Q. Downstream river samples E had value of 5.6±0.29 mgO_2/l for low Q and 4.03±0.35 mgO_2/l for high Q while sample F had value of 6.5± 0.53 mgO_2/l for low Q and value of 5.33±0.49 mgO_2/l for high Q.

Total hardness and total alkalinity both showed a highly significant increase in the downstream river samples E and F in comparison with control sample A both during low Q and high Q periods. Effluents were also rich for these variables (Fig. 4). The total hardness as $CaCO_3$ had a value of 160.8±4.71 mg/l for low Q and 80.7±2.08 mg/l for high Q for sample A. Downstream sample E had a value of 175.2±9.26 mg/l for low Q and 96.0±1.00 mg/l for high Q and sample F had mean value of 182.8±10.67 mg/l for low Q and value of 98±1.00 mg/l for high Q. This water sample A had total alkalinity of 73.2±12.19 mg/l for low Q and 58.67±8.10 mg/l for high Q. Downstream sample E had alkalinity of 199.7±45.49 mg/l for low Q and 101.6±2.89 mg/l for high Q and sample F had 204.8±4.71 mg/l for low Q and 105.3±4.51 mg/l for high Q.

For NH_3 and NO_3^- the increase in downstream samples E and F was highly significant in comparison with the control sample A during low Q period, while NH_3 again showed a highly significant increase during high Q period. Ammonia in water sample A was 0.0018±0 mg/l during low Q and 0.01±0.01 mg/l during high Q. Downstream sample E had 0.51±0.13 mg/l during low Q and 0.27±0.08 mg/l during high Q and F had ammonia with mean value of 0.81±0.10 mg/l during low Q and 0.36±0.06 mg/l during high Q. Nitrate concentration in sample A was 1.07±0.24 mg/l for low Q and 0.66±0.43 mg/l for high Q. Downstream river water sample E had nitrate with a mean value of 1.898±0.11 mg/l for low Q and 1.08±0.06 mg/l for high Q and for sample F it was 1.98±0.03 mg/l for low Q and 1.04±0.10 mg/l for high Q.

Similarly Cl^-, SO_4^{2-} and PO_4^{3-} showed highly significant increase in downstream river samples E and F when compared with control sample A both for low and high Q periods. Chloride concentration in sample A was 5.67±0.58 mg/l during high Q and 7±0.63 mg/l during low Q season. Downstream sample E had value of 23.7±3.02 mg/l during low Q and 17.23±2.04 mg/l during high Q season and F had value of 24.73±2.70 mg/l during low Q and value of 18.13±1.40 mg/l during high Q.

Sulphate content in sample A was 23.8±4.88 mg/l for low Q and 16.6±5.51 mg/l for high Q. Downstream sample E had 177.5±19.60 mg/l for low Q and 75.7±4.4 mg/l for high Q period and sample F had 220.5±36.2 mg/l for low Q and 182.3±4.7 mg/l for high Q.

Phosphate content in sample A was 0.07 mg/l for low Q and 0.08 mg/l during high Q season. Downstream sample E had 0.23±0.04 mg/l for low Q and 0.03±0.01 mg/l for high Q season and sample F had 0.234±0.04 mg/l for low Q and 0.04±0.01 mg/l for high Q.

After the discharge of the industrial effluents, the characteristics of river water at E changed drastically showing the following increase during low Q in various parameters on comparison with the upstream sample B. The EC (17%), TSS (8%), TDS (5%), BOD (58%), total hardness (6%), total alkalinity (14.5%), NH_3 (42%), NO_3^- (4%), Cl^- (17%), SO_4^{2-} (148%) and PO_4^{3-} (4.5%) were higher in concentration while during high Q the increase was: TSS (6%), TDS (98%), BOD (100%), total hardness (3%), total alkalinity (9%), NH_3 (286%), NO_3^- (4%), Cl^- (25%), SO_4^{2-} (132%).

The river water sample F on comparison with river water at site B had more EC (16%), TSS (11%), TDS (9%), BOD (83%), total hardness (10%), total alkalinity (17%), NH_3^+ (125%), NO_3^- (9%), Cl^- (22%), SO_4^{2-} (208%) and PO_4^{3-} (6%) for low Q and TSS (6%), TDS (14%), BOD (167%), total hardness (5%), total alkalinity (13%), NH_3

(414%), Cl^- (31%), SO_4^{2-} (458%) and PO_4^{3-} (33%) for high Q.

DISCUSSION

Among the physical parameters, downstream samples E and F, shows a significant increase in water temperature (Fig. 4) as compared to water sample A, especially during high Q. This increase could partially be because of effluent sample C for having an average of about 50°C effluent temperature exceeding the NEQS limit of 40°C and partially due to climatic change. All water bodies are subject to daily and seasonal variations in temperature. Natural variation in temperature is directly and indirectly dependent on prevailing weather conditions. Direct changes in water temperature result from changes in ambient air temperatures, while indirect changes may result from the inflow of water of a different temperature. Temperature is the most important physical variable affecting the metabolic rate of fish and is therefore one of the most important water quality attributes in aquaculture (Crawshaw, 1979).

The pH of the river in all the sampling points exhibited no drastic change. The pH of natural water ranges from less than 4 and greater than 12, but usually falls between 6 - 9. The tolerance range of most freshwater fish falls between pH 6-9, provided other criteria, particularly ammonia concentration, are optimal. Toxic effects of pH above and below this range generally arise from disturbances in internal ion homeostasis (South African Water Quality Guidelines, 1996). In our studies pH in all the river water samples felled between 6-9. This correlates with the pH of the other large rivers of south Asia. Subramanian (2004) reported pH value of 7.6 for River Indus, 7.7 for River Ganges, 7.6 for River Cauvery, 7.9 for River Tapti, 8.2 for River Narmada, 7.7 for River Mahandi and average value of 7.8 for all South Asian Rivers. Muhammad *et al.* (1998) have reported a pH 6.7 for River Swat at Mingora, Pakistan.

Electrical conductivity increased significantly in both the downstream samples E and F in comparison with control sample A. This can be correlated to the effluent samples C and D with high electrical conductivities. Total suspended solids and total dissolved solids in downstream samples E and F again showed an increasing tendency. This increase was highly significant for TDS both during low Q and high Q. TDS mean value for sample E was 559.7 mg/l for low Q and 543.3 for high Q, while for sample F this value was 581.7 for low Q and 312.3 for high Q. This shows that River Kabul is with high TDS as compared to the other rivers of South Asia. Subramanian (2004) reported TDS value of 173 mg/l for Indus, 39 for Kerala, 241 for Ganges, 107 for Brahamputa, 224 for Mahandi, 272 for Cauvery and 159 for combined Indian Rivers. Muhammad *et al*. (1998) have reported a TSS value of 175 mg/l for River Swat at Mingora, Pakistan.

TSS values at all the sampling sites of the river including dam exceeded the NEQS value of 150 mg/l for this parameter. This can be correlated to high flooding during high Q due to snowmelt on the peaks of the surrounding hills, both in Pakistan and Afghanistan and monsoon rains during summer months, excessive deforestation, weathering, soil errossion, mining and other anthropogenic activities along the banks of the river. TSS or turbidity is the amount of inorganic and organic solids suspended in the water. The impact of TSS on the suitability of water for aquaculture depends upon the physical presence of particles in the water and the degree to which it attenuates sunlight.

Among the chemical parameters BOD again increased significantly in the downstream samples E and F in comparison with sample A. The increase in the downstream samples is attributed to the discharge of industrial effluents and city sewage. The effluents samples C and D had BOD higher than the recommended value of 80 mgO_2/l by the NEQS both for low and high Q. Effluents C had BOD with mean value of 290.5 mgO_2/l for low Q and 295.67 mgO_2/l for high Q, similarly effluents D had BOD mean value of 280 mgO_2/l for low Q and 281.67 mgO_2/l for high Q. This means that effluents are discharging high organic load into the river, which raised this variable in the downstream samples. BOD has an inverse relationship with the dissolved oxygen (Bian *et al*., 1992). Fish kept at low DO concentrations show reduced fecundity and reduced egg and sperm viability. Gametogenesis is also impaired (South African Water Quality Guidelines, 1996). This shows that the water quality of the river at these sampling points is under stress for sustainable fisheries. Subramanian (2004) has reported 280 mgO_2/l BOD in domestic wastewater entering coastal waters at Mumbai. Khan *et al.* (1999) have reported an exceptionally high level of BOD of 200-225 mgO_2/l for Liyari River Pakistan. Many reports of different water pollution boards in India (Environmental Statistics, 1999) and Pakistan (Karns, 1977, IUCN 1994, Khan *et al*. 1999a,b) that BOD values are in excess of permissible levels for drinking water at practicall all locations in the sub-continent. Tariq *et al.*, (1996) have reported BOD in excess of 50 mgO_2/l for Indus at Karachi and Shahid (2000) has reported above 40 mgO_2/l for rivers in Bangladesh. Muhammad *et al*. (1998) have reported BOD value of 0.13 mgO_2/l for River Swat at Mingora, Pakistan.

Total hardness and alkalinity in the downstream samples E and F increased significantly both for low and high Q in comparison with the control sample. The increase could logically be attributed to effluent discharge. City sewage could also have its role in increase in both the variables in sample F. Total hardness for downstream sample C was 175.2 for low Q and 96 mg/l for high Q while for sample D the value was 182.8 mg/l for low Q and 98 mg/l for low Q. Muhammad *et al*. (1998) have reported total hardness of 21.6 mg/l for River Swat at Mingora, Pakistan. This shows that River Kabul water is harder in comparison with River Swat.

The total alkalinity in sample E enhanced to mean value of 199.7 for low Q and 101.6 mg/l for high Q, while that of sample F to 204.8 for low Q and 105.3 mg/l for high Q in comparison with control sample (73.2 for low Q and 58.6 for high Q). Comparison shows that this variable has different trends in different rivers of the region. Subramanian (2004) reported total alkalinity as 12 mg/l for Kerala Rivers, 135 for Cauvery, 274 for Gomti, 178 for Krishna, 105 for Godavari, 122 for Mahanadi, 225 for Narmada 150 for Tapti, 64 for Indus, 56 for Brahamputra and 128 for Ganges. Muhammad *et al.* (1998) have reported total alkalinity of 1.32 mg/l for River Swat at Mingora, Pakistan.

NH_3 exhibited a significant increase in both the downstream samples both for low and high Q discharges showing the deterioration of water quality downstream. It increased 42% in sample E and 125% in sample F. Ammonia is extremely toxic to fish and should be present ideally below 0.2 mg/l for better fish growth (Chapman, 1992). Both the downstream samples have values higher than 0.2 mg/l. Sample E had NH_3 mean value of 0.51 for low Q and 0.27 mg/l for high Q and sample F had 0.81 and 0.36 mg/l for low and high Q respectively. Khan *et al.* (1999) has reported high amount (10.2 mg/l) ammonia in Lyari River flowing to coastal area in Karachi, Pakistan. Muhammad *et al*. (1998) have reported ammonia value of 0.002 mg/l for River Swat at Mingora, Pakistan.

Effluent sample D (Fig. 5) discharges high quantity of chlorides both during low and high Q flow into the river. It is 238.67 mg/l for low Q and 260.3 mg/l for high Q. This discharge has caused a significant increase in downstream samples E and F both during low and high Q periods when compared to the upstream sample A which has 7 mg/l Cl^-. Sample E has mean value of 23.7 mg/l for low Q and 17.23 mg/l for high Q. South Asian rivers in comparison with River Kabul presents different trends at these sampling sites, some have low while others have high quantities than it. Subramanian (2004) has reported 7 mg/l Cl^- for Kerala Rivers India, 9 mg/l for Gomti, 17 for Godavari, 5 for Indus, 11 for Brahamputra and 10 for Ganges. All the above rivers show Cl^- values less than the study area at River Kabul. While Subramanian (2004) has reported 20 mg/l Cl^- for Cauvery, 38 for Krishna River, 23 for Mahandi River, 20 for Narmada River and 65 mg/l for Tapti River. The above South Asian rivers show more quantity for this variable.

Like other chemical variables SO_4^{2-} also showed a highly significant increase in downstream samples E and F. Sample E showed 148% increase for low Q and 132% for high Q while F showed 208% increase for low Q and 458% for high Q discharges. The increase could be attributed to effluent sample E that has a high volume of this variable as is clear from the Figure 5. Subramanian (2004) has reported 4 mg/l SO_4^{2-} for Kerala Rivers, 13 for Cauvery River, 15 for Gomti River, 49 for Krishna River, 8 for Godavari River, 3 for Mahandi River, 5 for Narmada River, 1 for Tapti River, 23 for Indus River, 4 for Brahamputra River and 11 mg/l for River Ganges. River Kabul has 177.5 mg/l

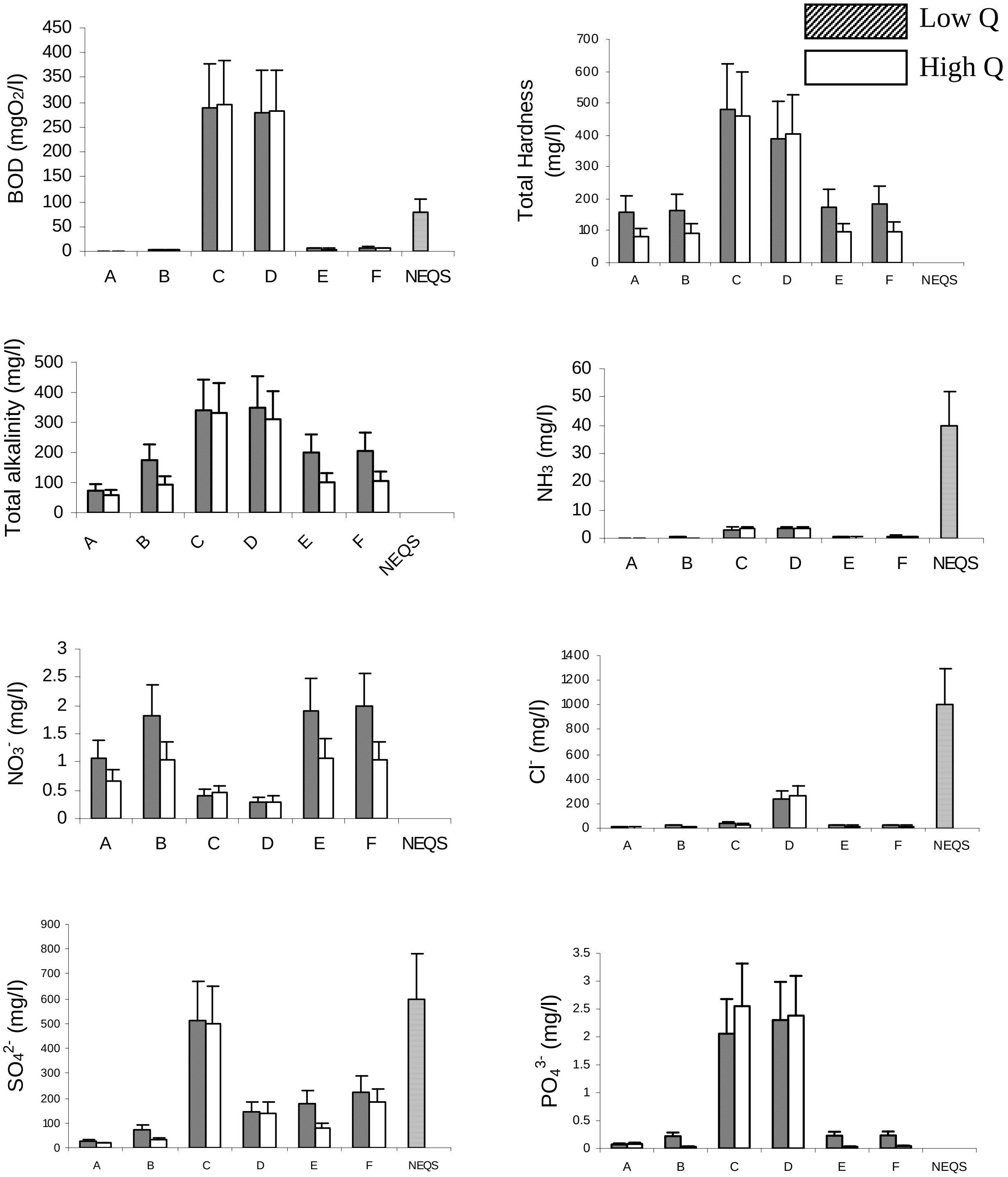

Fig. 5. Average (1998-2002, n = 6) values of selected chemical parameters of River Kabul (Fig. 2) for: low (winter) and high (summer) discharge; A – F main river CD – waste effluents, thick bar on the left = standard value according to NEQS.

and 75.67 mg/l SO_4^{2-} both for low and high Q discharges for downstream sample E and 220.5 mg/l and 182.3 mg/l SO_4^{2-} both for low and high Q discharges for downstream sample F. This shows that River Kabul has high sulphate load as compared to other rivers in the South Asian region which is matter of concern. Most probably River Kabul may be the source of this variable in River Indus being downstream. Effluent sample C (Figure 4) might be the source of SO_4^{2-} which discharge high load of this variable into the river.

High concentrations of dissolved phosphate may lead to osmotic stress, as is the case with high nitrate concentrations (South African Water Quality Guidelines, 1996). The dissolved phosphorous in many types of water bodies in the entire South Asian region is primarily governed by excess fertilizer run-off from agricultural fields and major water bodies in India are over-saturated with respect to Ca-phosphate (Subramanian, 2000; Datta and Subramanian, 1997; Tariq *et al*., 1996). Downstream samples E and F shows a significant increase for phosphate in comparison with the control sample A. Phosphate for sample E is 0.23 ppm and 0.03 ppm for low and high Q discharges while for sample F this variable has value of 0.234 ppm and 0.04 ppm for low and high Q discharges. Sample F showed 33% increase for phosphate for high Q In comparison with other South Asian rivers River Kabul has less phosphate load. Subramanian (2004) reported 50 ppb phosphate for River Cauvery, 12 ppb for River Tapti, 3 ppb for River Narmada, 2 ppb for River Mahandi, 68 ppb for River Godavari, 25 ppb for River Krishna, 27 ppb for River Ganges 22 ppb for River Brahamputra, 49 ppb for Indus and 67 ppb for Himalayan Rivers.

The pollutants enter under-ground water, with the discharge of industrial effluents on the surface; as a result a significant increase in the concentration of contaminants takes place under the vicinity of leaching bed (Lamb, 1985; Baloch *et al*., 2001). Contaminated water not only is a threat for aquatic organisms including fish but also is also responsible for transmitting a wide variety of diseases in humans. Tebbutt (1983) quoted the WHO survey stating that about 80% of all the diseases in the developing countries are water-related. Overall, about 30,000 people die from water-related diseases each day. At a time about 400 million people are suffering from gastroenteritis, 200 million with schistosmiasis, 160 million with malaria and 30 million with onchoceriasis worldwide. All of these diseases can be water-related although other environmental factors may be also important.

CONCLUSIONS

From the findings of this study it is concluded that industries discharging their effluents into the River Kabul causes sub lethal organic pollution. These effluents load is definitely polluting the river ecosystem and especially during long 8 month low Q period, when the water volume squeezes could be more harmful and will be adversely affecting the river productivity. The downstream river water is not fit for drinking by human and livestock and also for irrigation. This implicates that the river is endangered but is not biologically dead. This study confirms that the river has become polluted downstream and that there is localized pollution in vicinity of Nowshera. This pollution plug might be preventing the fish from their natural phenomenon of migration to and from the mighty River Indus, which have definitely played a role in reduction in whole fish population in general and *Tor putitora* in particular, which is considered as clean water lover and breeds in very clear waters. Moreover, this pollution will be more lethal to eggs and juveniles as compared to adults, and there is the sure danger of a definite loss of fish seed and grown up fish population.

It is also concluded that in comparison with other rivers in the South Asian region, River Kabul has:

1. High sulphate and TDS loads.
2. Less phosphate and BOD loads.
3. Different trends for alkalinity and chloride.
4. Almost same trend for pH.

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