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Heavy Metal Pollution in River Kabul Affecting the Inhabitant Fish Population*

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Abstract.- Elevated levels of heavy metals in river water can be a good indicator of man-induced pollution in the vicinity. Concentrations of Cr, Ni, Pb, Cu and Zn were measured in water taken along a section of River Kabul receiving untreated city sewage and industrial effluents and compared with water from Warsak Dam being upstream and pristine. Warsak Dam water (sample A) had 0.009±0.01 mg/l chromium during winter (low Q) and 0.051±0.06 mg/l during summer (high Q), while it increased 1.97 fold during low Q and 6.86 during high Q for water sample from the river having received industrial effluents (Site E) and 17.11 fold during low Q and 8.23 fold during high Q for water sample downstream after having received city sewage and industrial effluents (Site F) from River Kabul. Zinc at Warsak Dam water was 0.046±0.03 mg/l during low Q and 0.087±0.0 mg/l during high Q, while it increased 8.04 fold during low Q and 4.71 fold during high Q in water sample E and 9.17 fold during low Q and 5.76 fold during high Q in water sample F. Copper at Warsak Dam water was 0.016±0.02 mg/l during low Q and 0.042±0.04 mg/l during high Q season, which increased 23.75 fold during low Q and 10.95 fold during high Q in water sample E and 25.81 fold during low Q and 11.38 fold during high Q in water sample F. Nickel in Warsak Dam water was 0.047±0.0 mg/l during low Q and 0.012±0.02 mg/l during high Q which remained unchanged during low Q at Sites E and F, and showed 1.28 fold increase at Site E and 4.75 fold increase at Site F at high Q. Similarly lead in Warsak dam water was 0.008±0.01 mg/l during low Q and 0.009±0.08 mg/l during high Q, which increased 5 fold during low Q and 8.89 fold during high Q in water sample E and 4.63 fold during low Q and 10.33 fold during high Q in water sample F. A remarkable increase in levels of all the investigated heavy metals confirms the presence of a high metal load in river water.

Key words: River Kabul, aquatic pollution, industrial effluents, city sewage, heavy metal contamination.

INTRODUCTION

River Kabul originates from the base of Unai Pass in the Paghman Mountains in Afghanistan. Flowing east along the northern side of Kohi-Safed Mountainous range 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 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. 1). The monthly discharge of the River Kabul when measured at Warsak Dam shows high seasonal variability. The average discharge at Warsak Dam is 20,500 cusecs with a low flow period from September to April and a high flow period from May to July. The significant variations in river flow are the result of seasonal rains, glacial and snowmelt. Below the dam the river is divided into three main channels Shah Alam, Naguman and Adezai and several canals originating from these channels irrigate Peshawar and Charsadda Districts. After flowing for 34 and 30 km, respectively, the Naguman and Shah Alam join again at Garhi Momin and are joined shortly by the Adezai. The Main River flows as a single channel downstream for many kilometers before joining River Indus at Kund (Attock).

Warsak Dam is situated on River Kabul at Warsak, between Khyber and Mohmand Agencies (Fig. 1). It is hydroelectric powers project, used both for irrigation and electricity production. 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 is

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without any fish ladder, therefore, is an obstacle for upstream migration of the fish population especially during 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.

Fig. 1. The River Kabul and its tributaries.

The city of Peshawar is close to the Shah Alam branch of River Kabul with a population of more than one million. Other large towns like Nowshera, Akora Khattak, Jehangira and a large number of villages are situated at the banks of River Kabul.

A survey in NWFP lists 348 large and small scales industries, of which about 80 industries and industrial units discharge their untreated effluents directly or indirectly into the River Kabul (Fig. 2) (IUCN, 1994).

Unluckily most of the above units are without effluent treatment facilities and the effluents from the above units end up in the River Kabul, either directly or indirectly through canals or nullahs. 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).

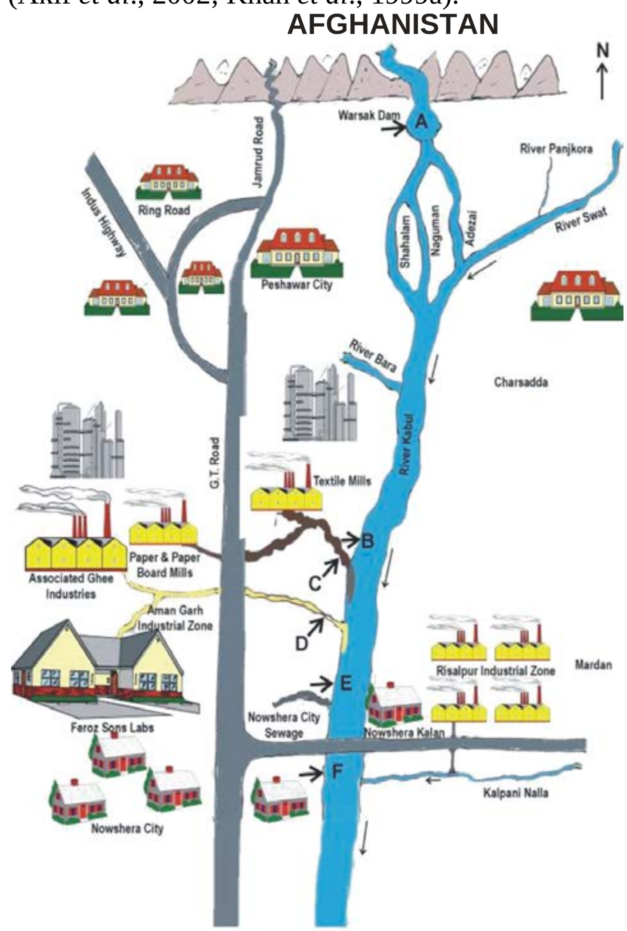

Fig. 2. Water sampling points at Warsak Dam (A) main river (B, E, F) and factories drains (C, D) along River Kabul.

Contamination of aquatic ecosystems by heavy metals has long been recognized as a serious pollution problem. Metals, released into surface water, tend to accumulate in the sediments through adsorption and precipitation processes.

Metals have the tendency to accumulate in various organs of the aquatic organisms, especially fish, which in turn may enter into the human metabolism through consumption causing serious health hazards (Puel *et al*., 1987; USEPA, 1991). Metals are non-biodegradable, and once they enter the aquatic environment, bioconcentration may occur in fish tissue and other aquatic organisms by means of metabolic and biosorption processes (Hodson, 1988; Carpene *et al*., 1990; Wicklund-Glynn, 1991).

To evaluate the quantity of metal pollution in River Kabul, water samples were taken from different parts of the main river and analyzed for heavy metal concentration. The heavy metal content of effluents have been compared with those of the National Environmental Quality Standards (NEQS) and those of downstream river water samples have been compared with control (Warsak Dam) water to ascertain the extent of heavy metal pollution in River Kabul.

MATERIALS AND METHODS

Sampling sites

To evaluate the quantity of metal pollution, water samples from the following points of the Main River, factory drains and Warsak Dam were collected as shown in Figure 2.

Water samples (A) were collected from Warsak Dam water reservoir constructed on River Kabul in 1960 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 and industrial population. This was considered as control sample.

Water samples B, E and F were collected from polluted part of the Main River at Industrial area Aman Garh, Nowshera, at sites B, E, and F. Site B is at the Main River upstream of the effluent discharge into the river, site E is at the Main River downstream of the effluent discharge and site F is at the Main River after city sewage flows into it.

Effluent samples were collected from factories' drains at Industrial Area Aman Garh, Nowshera at sites C and D. Site C receives effluents from Colony Textile Mills Limited and Sarhad Paper Industries Limited. Site D receives effluents from Ferozesons Pharmaceutical Laboratories and Associated Ghee Mills Limited.

Composite water samples from the sampling sites were collected in clean, marked, new plastic bottles, thoroughly washed with distilled water followed by washing with the sample water. Sampling was conducted three times a year. Water samples from Main River were collected 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.

Water samples for heavy metal estimations were collected in 1 litre plastic bottles and were preserved with 5 ml HNO_3 (55%) per litre to prevent metal adsorption on the inner surface of the container. All water samples were then stored at 4°C in refrigerator before analyses for heavy metals.

Procedure adopted for estimation of metals

Water sample (100 ml) in 250 ml volumetric flask was acidified with 5 ml of HNO_3 (55%) and evaporated on a hot plate to about 20 ml. 5 ml additional HNO_3 (55%), 10 ml perchloric acid (70%) and a few glass beads were added to prevent bumping. The mixture was evaporated until brown fumes change into dense white fumes of perchloric acid ($HClO_4$). The sample was removed at this stage from the hot plate, cooled to room temperature and diluted to 100 ml with distilled water in a 100 ml volumetric flask. The solutions were then aspirated into flame atomic absorption spectrophotometer (model AA-660X VI42) for determination of Cr, Zn, Ni, Cu and Pb under the following operating parameters. The flame used was air acetylene (A-AC).

Standard curves were prepared and the ODs obtained were calibrated against the standard curves to determine the concentration of metal present (APHA, 1985). All the reagents used during water analyses were of analytical grade.

Statistical analysis

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

Warsak Dam upstream water (Sample A=Control)

Tables I and II show heavy metal concentrations in water samples from Warsak Dam and other collection sites along the river during low and high Q. Warsak Dam water (sample A) had chromium content varying between 0.002 and 0.12 mg/l with 0.009±0.01 mg/l during low flow and

0.051±0.06 mg/l during high flow season (Table I, Fig. 3), zinc content varying between 0.011 and 0.091 mg/l with 0.046±0.03 mg/l during low flow and 0.087±0.0 mg/l during high flow season, copper content varying between 0.01 and 0.091 mg/l with mean value of 0.016±0.02 mg/l during low flow and 0.042±0.04 mg/l during high flow season, nickel content varying between 0.001 and 0.03 mg/l with mean value of 0.047±0.0 mg/l during low flow and 0.012±0.02 mg/l during high flow, and lead content varying between 0.002 and 0.150 mg/l with mean value of 0.008±0.01 mg/l during low flow and 0.009±0.08 mg/l during high flow season.

Table I.- Heavy metals contents of water sample A from Warsak Dam (control), water sample B from River Kabul upstream to the confluence point, effluent sample C from Textile and Paper Industries, effluent sample D from Ferozesons Laboratories and Associated Ghee Industries Limited, water sample E from River Kabul downstream to the confluence point and water sample F from River Kabul downstream of E, where city sewage joins the river during low flow (winter) and high flow (summer) during 1998-2002.

Parameters (mg/l)	Control A	River B	Effluent C	Effluent D	River E	River F
Low Q (low flow, winter)						
Cr^{3+}	0.009±0.01	0.06±0.01***	0.53±0.07***	0.03±0.02	0.101±0.1*	0.154±0.01***
Zn^{2+}	0.046±0.03	0.27±0.06***	0.33±0.23*	0.43±0.33*	0.37±0.04***	0.422±0.04***
Cu^{2+}	0.016±0.02	0.31±0.05***	0.08±0.02***	0.37±0.27**	0.38±0.05***	0.413±0.04***
Ni^{2+}	0.047 ±0.0	0.07±0.03**	0.02±0.01	1.35±0.33***	0.04±0.01***	0.044±0.01***
Pb^{2+}	0.008±0.01	0.02±0.01**	0.1±0.03***	0.02±0.02	0.04±0.06	0.037±0.05
High Q (high flow, summer)						
Cr^{3+}	0.051±0.06	0.26±0.01**	0.66±0.05***	0.03±0.02	0.35±0.02	0.42±0.08***
Zn^{2+}	0.087±0	0.36±0.05***	0.75±0.15**	0.59±0.21*	0.41±0.10**	0.501±0.02***
Cu^{2+}	0.042±0.04	0.34±0.04**	0.15±0.03*	0.62±0.08**	0.46±0.03***	0.478±0.02***
Ni^{2+}	0.012±0.02	0.08±0.02**	0.01±0.01	1.45±0.28***	0.06±0.01*	0.057±0.02*
Pb^{2+}	0.009±0.08	0.04±0.01	0.11±0.05	0.07±0.05	0.08±0.06	0.093±0.07

* Mean±SD ; Student's t test; *p<0.05, **p<0.01, ***p<0.001

** Abbreviations: chromium; Cr^{3+}, Zinc; Zn^{2+}, copper; Cu^{2+}, nickel; Ni^{2+}, lead; Pb^{2+}

National Environmental Quality Standards (NEQS) for municipal and liquid industrial effluents of Pakistan: Cr^{3+} 1.0 mg/L, Zn^{2+} 5 mg/L, Cu^{2+} 1.0 mg/L, Ni^{2+} 1.0 mg/ l , Pb^{2+} 0.5 mg/L.

Table II.- Increase in heavy metal concentration at different sites along River Kabul with reference to water in Warsak Dam (control). The values given are change in concentration of various metals in different water samples with reference to control (Warsak Dam) and are shown as fold increase actual values of Warsak Dam.

Parameters (mg/l)	Control A		River B		Effluent C		Effluent D		River E		River F	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Cr^{3+}	0.009	0.05	6.66 fold	5.09	58.89	13.2	3.33	0.6	11.16	6.86	17.11	8.23
Zn^{2+}	0.046	0.087	5.87	4.14	7.17	8.62	9.35	6.78	8.04	4.71	9.17	5.76
Cu^{2+}	0.016	0.042	19.37	8.09	5	3.57	23.13	14.76	23.75	10.95	25.81	11.38
Ni^{2+}	0.047	0.012	1.49	6.66	0.42	0.83	28.72	120.83	-	5	-	4.75
Pb^{2+}	0.008	0.009	2.5	4.44	12.5	12.22	2.5	7.77	5	8.89	4.62	10.33

The concentration of heavy metals studied at Warsak Dam water were within the permissible limits laid down by the NEQS thus proving the Dam water safe for aquatic life including fish regarding heavy metals pollution.

River Kabul water (Water Sample B)

Water samples from river downstream to Warsak Dam and upstream to confluence point were analyzed for heavy metal content (Tables I, II).

Water sample B had chromium concentration ranging between 0.048-0.263 mg/l with 6.66 fold increase during low flow and 5.09 fold increase during high flow season, zinc concentration ranging between 0.172 and 0.4211 mg/l with 5.87 fold increase during low flow and 4.14 fold increase during high flow season, copper concentration ranging between 0.24 and 0.391 mg/l with 19.375 fold increase during low flow and 8.09 fold increase during high flow, nickel concentration ranging between 0.01 and 0.09 mg/l with 1.49 fold increase during low flow and 6.66 fold increase during high flow season. The lead concentration ranged between 0.02 and 0.04 mg/l with 2.5 fold increase during low flow and 4.44 fold increase during high flow season.

All the five metals *viz.*, Cr^{3+}, Zn^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+} in water sample B from River Kabul showed increasing tendency on comparison with water samples from Warsak Dam. However, all the heavy metals were below the NEQS recommended limits (Tables I-II; Fig. 3).

Effluents from Textile and Paper Industries (Water Sample C)

Sample C from Textile and Paper Industries had Cr concentration ranging between 0.41 and 0.71 mg/l, with 58.89 fold increase during low flow and 13.2 fold increase during high flow, zinc concentration ranging between 0.06 and 0.92 mg/l with 7.17 fold increase during low flow and 8.62 fold increase during high flow season, copper concentration ranging between 0.06 and 0.17 mg/l with 5.0 fold increase during low flow and 3.57 fold increase during high flow, Ni concentration ranged between 0.01 and 0.03 mg/l nickel with no significant deviation from the control. The lead concentration ranged between 0.045 and 0.15 mg/l with 12.5 fold increase during low flow and 12.22 fold increase during high flow season. Heavy metals in the effluent (water sample C) were below the NEQS recommended values. Chromium, Zn and Pb show increasing trend both in low and high flow as compared with that of site B. These values, though are less than NEQS recommended value of 1.0 mg/l, are still higher for productive rivers like River Kabul and could be harmful due to bioaccumulation quality of heavy metals. Cu and Ni concentrations however were reduced in this part of the river.

Effluents from Ferozesons Laboratories and Associated Ghee Industries Limited (Water Sample D)

The effluents (sample D) from Ferozesons Laboratories and Associated Ghee Industries Limited had Cr concentration ranging between 0.02 and 0.07 mg/l, with 3.33 fold increase during low flow and no change during high flow, zinc concentration ranged between 0.019 and 0.921 mg/l with 9.35 fold increase during low flow and 6.78 fold during high flow season, Cu concentration ranged between 0.019 and 0.71 mg/l with 23.125 fold increase during low flow and 14.76 fold increase during high flow season, nickel concentration ranged between 0.925 and 1.85 mg/l with 28.72 fold increase during low flow and 120.83 fold increase during high flow season. The lead concentration ranged between 0.01 and 0.12 mg/l with 2.5 fold increase during low flow and 7.77 fold increase during high flow season.

Amongst the heavy metals nickel exceeded the NEQS recommended limit of 1.0 mg/l with a mean value of 1.35±0.33 mg/l for winter and 1.45±0.28 mg/l for summer (Tables I, II; Figs. 3-4). Rest of the metals was below the NEQS recommended limits. The effluent sample D had more Cu and nickel as compared with effluent C, which is richer in Cr and Pb.

Polluted River Kabul water from Site 1 receiving effluents (Water Sample E)

Water samples downstream to the confluence point were analyzed for heavy metals parameters to quantify the extent of pollution (Tables I-II, Fig. 3). Water sample E from River Kabul had Cr concentration ranging between 0.01 and 0.31 mg/l with 11.16 fold more Cr during low flow and 6.86 fold more Cr during high flow, zinc concentration ranging between 0.029-0.49 mg/l with 8.04 fold more Zn during low flow and 4.71 fold more Zn during high flow, copper concentration ranging between 0.32 and 0.49 mg/l with 23.75 fold increase during low flow and 10.95 fold increase during high flow, nickel concentration ranging between 0.021 and 0.071 mg/l with no change during low flow and 5 fold increase during high flow. The lead content ranged between 0.006 and 0.121 mg/l with 5 fold increase during low flow and 8.89 fold increase during high flow season.

The water at Site E is twice as much polluted with heavy metals, as it was in water at Site B.

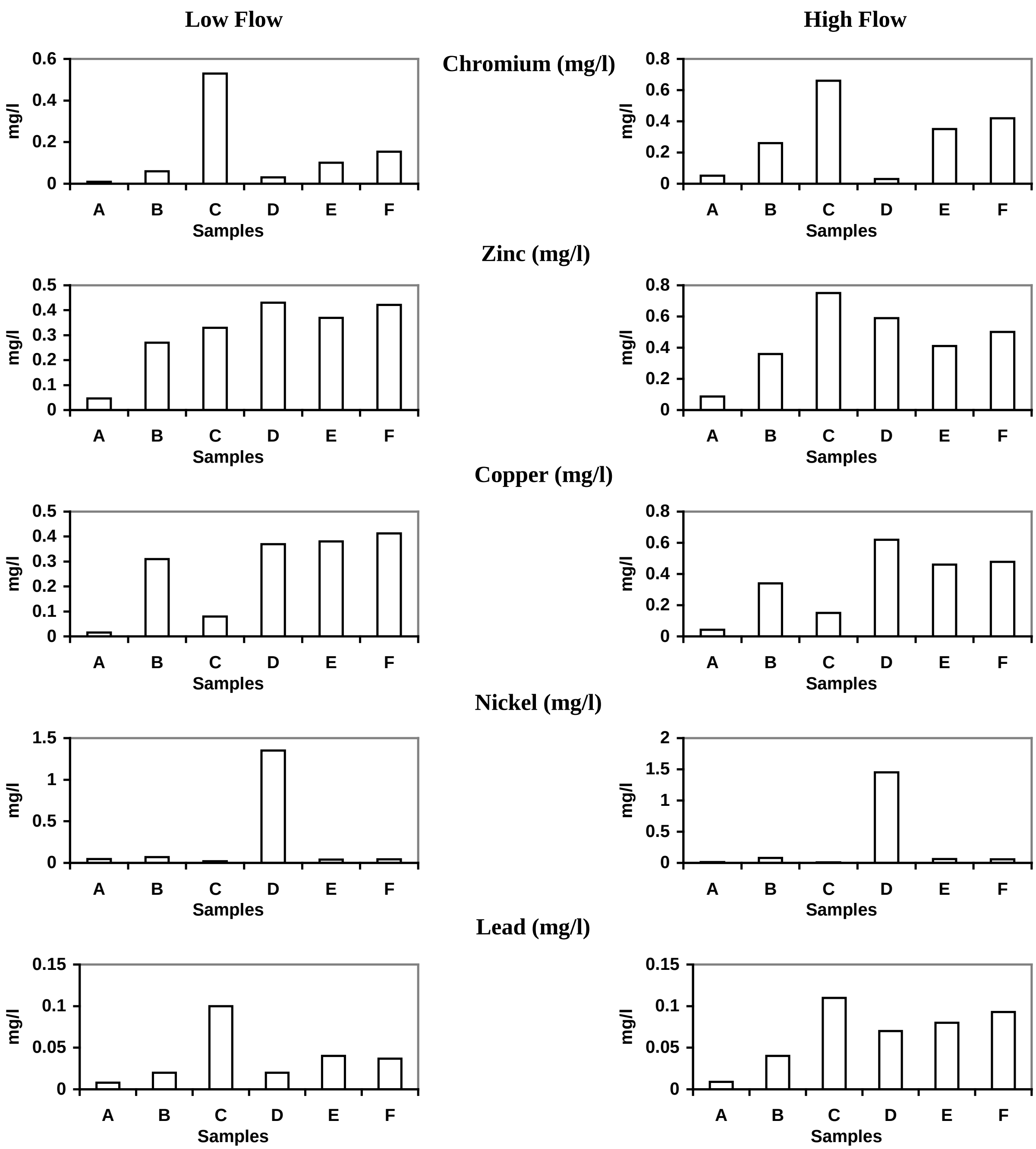

Fig. 3. Comparative heavy metals concentration of nickel and lead in water samples from Warsak Dam, River Kabul and effluents during low and high flows.
A, Warsak Dam water sample; B, upstream river water sample; C, Effluent 1 from Textile and Paper Industries; D,

Effluent 2 from Ferozesons Laboratories and Associated Ghee Industries Limited; E, River water sample downstream to the confluence point; F, River water sample downstream to sample E and to the point where city sewage joins the river.

Polluted River Kabul water from Site 2 receiving city sewage (Water sample F)

In water sample F chromium concentration ranged between 0.068 and 0.64 mg/l, with 17.11 fold increase during low flow and 8.23 fold increase during high flow (Tables I, II; Figs. 3-4), zinc concentration ranged betwenn 0.35 and 0.52 mg/l with 9.17 fold increase during low flow and 5.76 fold increase during high flow, copper concentration ranged between 0.38 and 0.49 mg/l with 25.81 fold increase during low flow and 11.38 fold increase during high flow, nickel concentration ranged between 0.04 and 0.074 mg/l with no effect during low flow and 4.75 fold increase during high flow season. The lead concentration ranged between 0.006 and 0.141 mg/l with 4.62 fold increase during low flow and 10.33 fold increase during high flow season.

The heavy metals at this site showed higher concentrations when compared with those of Warsak Dam and upstream water samples indicating the increasing heavy metal pollution in downstream waters (Tables I-II, Figs. 3-4). Though the heavy metals recorded at this point are below the NEQS maximum values but still are alarming due to their bioaccumulation capability especially during low flow period when water volume shrinks.

DISCUSSION

On comparison with the NEQS recommended values for effluent, all the samples studied contained heavy metal concentrations within the permissible limits laid down by the NEQS, highlighting the suitability of the Warsak Dam water for aquatic life including fish. Warsak Dam has been built in the tribal areas, far away from the industrial activities and human population.

On downstream journey from Warsak Dam the river passes through a number of villages and the city of Peshawar, therefore city sewage and effluents from many factories and mills and other installations in the vicinity of River Kabul and its tributaries mentioned earlier also joins the river. Moreover, dirty water of River Bara (IUCN, 1994) also joins the river on the way downstream; therefore it is obvious that the water quality of the river would deteriorate downstream. The water sampling point B was 55 km downstream from Warsak Dam and half a km upstream from the confluence point at Aman Garh Industrial Area Nowshera. All the five metals; Cr^{3+}, Zn^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+} at this site showed increasing tendency on comparison with samples from Warsak Dam. However, all the five metals had values below those recommended by NEQS.

The industrial effluent samples I were below the NEQS. All the heavy metal concentrations were less than NEQS recommended value of 1.0 mg/l but is still high for aquatic life. Akif *et al.* (2002) have reported 0.07, 0.50, 0.07 and 0.01 values for copper, chromium, lead and nickel, respectively. Thus it is clear that the effluents are not discharging high concentrations of heavy metals into the river, but this less quantity could be considered harmful for two reasons: firstly because of prolonged and continuous discharge and secondly because of bioaccumulation quality of heavy metals in life and bottom sediments.

Among heavy metals nickel was above the NEQS recommended value (1.0 mg/l) in effluent sample D. Nickel mean value for winter was 1.35 mg/l while for summer it was 1.450 mg/l was high than (1.0 mg/l) recommended by NEQS.

Anthropogenic activities (*i.e.* mining, electroplating and steel plant operations) can result in Ni discharge in water and air (Galvin, 1996). In aquatic ecosystems dissolved Ni concentrations are generally between 0.005 and 0.010 $mg.l^{-1}$ (Galvin, 1996).

Rest of the metals had values below the NEQS recommended values. Although the metals discharged are not alarming, but due to its continuous discharge and bioaccumulation this less discharge even can prove dangerous.

Comparing the data with the control (Warsak Dam) it is clear that a considerable increase in pollution have occurred. All the metals have increased (Table II), showing the signs of increased localized pollution in the river, most probably due to effluents discharge.

Chromium level showed high increase because of various chromium industries present in the vicinity of River Kabul. Acceptable standards for maintenance of fisheries and aquatic life for chromium are less than 0.002 to 0.02 mg/l (IUCN, 1994). All the recorded values for chromium at this station (except 0.01 mg/l) crossed the maximum limits for fish sustenance. In a previous study by IUCN (1994) high values of chromium in the river had been reported.

Natural waters may receive Cr from anthropogenic sources such as industrial effluents derived from the production of corrosion inhibitors and pigments (Galvin, 1996), which then becomes a pollutant of aquatic ecosystems and thus harmful to aquatic organisms (Srivastava *et al*., 1979).

Seafoods contain 0-0.44 (mg/kg) chromium, while river water has been reported to contain 1- 10 μg/litre (Baeter, 1956) however this is dependent upon the nature of the source of river water and other supplies. Urban supplies can be higher, with upto 80 μg/litre in some cases (Reilly, 1980). However, the average level for community water supplies in the USA has been estimated to be 2.3 μg/litre (Reilly, 1980). In seawater, most reports have indicated copper concentrations from 1-5 μg/1 (Piscator, 1979). In American rivers concentrations ranging from 0.83 to 105μg/1 have been reported (Durum *et al*., 1971).

Similarly zinc concentration compared to a standard of less than 0.03 mg/l for the maintenance of aquatic life and fisheries is considerably high (IUCN, 1994). Likewise all the recorded values of Zn are higher than the required values. Anthropogenic activity (ranging fron mining to industry) can result in greatly increased levels of Zn in the environment as well as people who utilize this environment for food, recreation and potable water.

Lead enters the aquatic environment through erosion and leaching from soil, lead-dust fallout, combustion of gasoline, municipal and industrial waste discharges, runoff of fall out deposits from streets and other surfaces aswell as precipitation (DWAF, 1996).

An increase in all the heavy metals was also observed at Site F. Chromium increased (1611%) from 0.009 mg/l to 0.154 mg/l during low flow and from 0.051 mg/l to 0.42 mg/l for high flow (723%). Zinc increased 817% for low flow and 475% during high flow. Copper increased 248% for low flow and for high flow 1038%. Nickel increased 6% for low flow and 375% during high flow, while lead increased 362% for low flow and 933% for high flow.

The heavy metals showed different trends in different seasons. It had shown increase and decrease both in low flow and high flow. During high flow as upheavals of sediments occur due to strong water currents, therefore the settled material might be mixing with water and enhancing metal concentration (IUCN, 1994).

Comparing metal concentrations to control, again a drastic increase occurred in concentrations of most of the heavy metals both during low flow and high flow sampling. Similarly a further increase in metal level, as compared to sample E, is also clear. As this sample was collected from the portion of the river where city sewage also joins the river a little upstream, most probably this city sewage may be further increasing the heavy metals concentration. Heavy metals are of high concern because of their accumulation by the organisms in water (Coetzee *et al*., 2002). It has been suggested that aquatic organisms are capable of bioaccumulating metals nearly 100 times the concentration of metals in the water.

CONCLUSION

The data confirms the existence of sublethal heavy metals load in the river, which automatically is affecting the growth of the inhabitant fish population and in turn productivity of the river. Moreover, as the heavy metals can pass to the human population in food chain, it is an emerging health problem too. A general biomonitoring program is necessary to be launched.

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