Impact of Industrial Discharges on the Quality of Kabul River Water at Amangarh, Nowshera (Pakistan)

A. R. KHAN*, M. AKIF, MUMTAZ KHAN AND M. RIAZ
P. C. S. I. R Laboratories, Jamrud Road, Peshawar-25120, Pakistan

(Received 15h June, 1998, revised 5th January, 1999)

Summary: Samples of effluents from different industries at Amangarh, Nowshera and receiving Kabul River water were analysed for various parameters like; pH, D.O. suspended solids, electrical conductivity, alkalinity, hardness, COD, NO_2-N, NO_3-N, chlorides, sulphates, Na^+, K^+ etc. The results indicate localized pollution within half kilometer after the confluence point where the quality of the river water is being deteriorated. The data suggest that the river water in comparison to US rivers and Indus River at Kalabagh and at Tarbella Dam is more saline. Industrial effluents contribute towards increase in the salinity of river water. Presence of appreciable amount of oxygen demanding waste in effluents and in the downstream of the river create a suffocating environment to fish crop.

Introduction

Both, humans and industries have contributed significantly in spoiling the quality of water by adding different pollutants. Contaminated water is responsible for transmitting a wide variety of diseases and illnesses in humans. Tebbutt [1] quoted the WHO survey showing that 80% of all illnesses in developing countries are water-related. A quarter of children born in developing countries die before the age of 5, the majority of them from water-related diseases. Overall, about 30,000 people die from water-related diseases each day. At any one time there are likely to be 400 million people suffering from gastroenteritis, 200 million with schistosmiasis, 160 million with malaria and 30 million with onchoceriasis. All of these diseases can be water-related although other environmental factors may also be important.

Kabul River is mainly used for effluent and waste disposal, irrigation, fishing, recreation, watering livestock, transportation, washing and bathing. The villagers living on the banks of the river had been complaining about pollution in Kabul River. The complains were the result of the increasing obvious signs of pollution including periodic fish kills. Kabul River had also been blamed for skin diseases in humans and maladies in livestock. Some people had also complained of reduced crop yields in field irrigated with water polluted with industrial effluents [2]. A report [3] had indicated that the land irrigated with effluent had made the soil unproductive with no vegetation. Flora and fauna was found to be present in the effluent free areas while the same were totally absent in effluents suggesting the latter areas to be a "harsh environment."

*To whom all correspondence should be addressed.

Our industries are one of the main culprits in polluting our rivers by discharging their effluents directly without any prior treatment. Probably, that is the reason why Pakistan has been declared as "Polluter's Paradise" [4]. Industrial effluents containing a huge quantity of organic compounds contribute to enhancing the growth of different algae and the depletion of dissolved oxygen in the receiving water. This adversely affects the aquatic life by causing a suffocating environment and changes the characteristics of water rendering it unfit for various uses including the aesthetic values. If this contaminated water is consumed by humans or live-stock, serious consequences may arise. Crops irrigated frequently with such a water may produce harmful effects on the people consuming them for a longer time. Previously, incidences have occurred [5] where several buffallows have died and crops have dried in fields using a stream water containing effluents of Pak. China Fertilizer and Hazara Super phosphate located at Haripur Hazara.

Earlier, Tchobanoglous and Schroeder [6] have pointed out the different impurities present in industrial waters which include; materials that deteriorate taste, odour and colour, toxic substances (e.g. pesticide, herbicides, heavy metals etc.), biological growth stimulants and reactive materials that can cause scaling, corrosion or may reduce the dissolved oxygen level. Insoluble material, i.e. colloids which cause turbidity, similar sediments result in shoaling and filling of pipes and channels.

Previously, Larry [7], Kamin *et al.* [8] and Akif and Khattak [9] have studied the effects of industrial pollution on receiving water bodies. Khan *et al.* [10] have indicated that industries at Amangarh, Nowshera is adversely polluting the receiving water of Kabul River due to high oxygen demanding waste after the effluents of Khazana Sugar Mills. As, a continuous monitoring of the extent of pollution in a river is essential for quantification of any changes in its characteristics a comprehensive study during four seasons of a year was considered necessary at Amangarh Nowshera.

Results and discussion

Tables 1 and 2 show the data for samples collected during autumn and winter seasons. The results indicate a high COD values, low DO and high nitrite-nitrogen concentration in the effluent

Table 1. Analysis of effluents and receiving water during *autumn*

	Collection points (Locations)					
	1	2	3	4	5	6
Appearance	Greyish	Milky	Black	Brown	Light brown	Clear
Odour	Nil	Pungent	Unpleasant	Unpleasant	Nil	Nil
pH	8.14	7.46	8.20	7.98	7.99	7.97
Temp. °C	24.0±1	24.0±1	29.0±1	28.0±1	20.0±1	20.0±1
DO (mg O_2/l)	8.6	5.2	1.2	6.1	9.1	8.8
E. Cond. (m S)	0.44	1.20	2.16	2.80	0.34	0.32
COD (mg O_2/l)	8.2	244.9	2510.2	775.5	122.5	28.6
NO_2-N (μg/l)	38.3	13.3	1570.0	36.7	82.5	41.6
NO_3-N (mg/l)	0.09	1.03	0.15	0.13	0.30	0.29
TDS (mg/l)	306.0	1026.0	2450.0	1946.0	271.0	208.0
Total Hardness as $CaCO_3$ (mg/l)	177.4	473.1	251.4	462.4	182.8	166.7
OH^- alk. (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
CO_3^{-2} alk. (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
HCO_3^- alk. (mg/l)	290.0	217.5	687.5	290.0	142.50	130.0
Cl^- (mg/l)	17.9	202.9	279.7	601.4	21.0	14.9
SO_4^{-2} (mg/l)	56.9	22.8	231.2	133.9	132.7	64.4
Na^+ (mg/l)	22.0	25.0	395.0	400.0	21.00	12.8
K^+ (mg/l)	4.8	2.4	216.0	39.3	3.0	3.0
Ca^{+2} (mg/l)	96.8	384.4	115.6	285.0	104.8	91.4
Mg^{+2} (mg/l)	69.8	88.7	134.4	138.5	78.0	72.6

alk. = *alkalinity as* as $CaCO_3$

* *Collection points:*

1. Upstream sample.
2. Effluents of paper and Board Mills (Main drain under G. T. Road)
3. Main drain just above the confluence point.
4. Black liquor from Paper Mills.
5. 300 meters downstream from the confluence point.
6. 1 km downstream from the confluence point.

Table 2. Analysis of effluents and receiving water during *winter*

	*Collection points (Locations)**						
	1	2	3	4	5	6	7
Appearance	Clear	Clear	Dark brown	Dark brown	Brown	Clear	Clear
Odour	Nil	Irritating	Pungent	Pungent	Nil	Nil	Smelly
pH	8.09	7.11	7.49	7.12	7.35	7.70	7.40
Temp. °C	12.0±1	12.0±1	16.0±1	18.0±1	12.0±1	12.0±1	30.0±1
DO (mg O_2/l)	10.3	3.7	0.2	4.3	10.1	10.3	1.5
E. Cond. (m S)	0.36	0.80	3.40	3.80	0.45	0.37	1.81
COD (mg O_2/l)	3.6	78.4	1963.9	763.7	80.0	4.4	36.4
NO_2-N (μg/l)	97.5	44.0	245.0	5300.0	300.6	122.5	48.3
NO_3-N (mg/l)	0.99	1.60	0.35	0.23	0.77	1.51	0.14
TDS (mg/l)	305.7	669.5	2822.4	3192.0	379.7	307.4	1522.1
Total Hardness as $CaCO_3$ (mg/l)	258.0	631.8	213.2	292.2	265.9	171.1	273.8
OH^- alk.(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CO_3^{-2} alk.(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
HCO_3^- alk.(mg/l)	125.0	148.8	353.8	221.3	170.0	130.0	235.0
Cl^- (mg/l)	21.7	29.7	367.5	442.4	28.5	19.8	227.7
SO_4^{-2} (mg/l)	226.4	623.4	197.1	270.4	197.1	127.9	157.2
Na^+ (mg/l)	19.3	37.0	510.0	710.0	29.5	15.0	175.0
K^+ (mg/l)	3.0	4.0	33.8	34.0	4.5	3.0	2.5
Ca^{+2} (mg/l)	75.1	172.9	68.3	72.8	41.0	79.6	99.0
Mg^{+2} (mg/l)	182.9	458.9	145.0	219.4	224.9	91.5	174.8

alk. = *alkalinity as* as $CaCO_3$

* *Collection points*:

1. Upstream sample.
2. Effluents of paper and Board Mills (Main drain under G. T. Road)
3. Main drain just above the confluence point.
4. Black liquor from Paper Mills.
5. 300 meters downstream from the confluence point.
6. 1 km downstream from the confluence point.
7. Drain carrying effluents from the pharmaceutical industries

samples. Similarly, the concentrations of anions Cl^- and SO_4^{-2} and cations Na^+, K^+, Ca^{+2} and Mg^{+2} are high in the effluent samples. These results further suggest that the concentration of these analytes fall as the dilution takes place away from the confluence point. Furthermore, no significant change can be observed in the pH and nitrate-nitrogen in the samples. Comparing the results contained in Table 1 and 2 it is apparent that the overall pollution caused as a result of the effluents dumping appears to be comparatively high in the autumn compared to the winter season. This could be due to the seasonal variations in the flow of water in the river. Kabul river is at the lowest flow during autumn and winter, as evident from Figure 1 and at its highest flow during the summer and rainy seasons [11].

The dissolved oxygen level has a direct relationship to the amount of oxidisable material present in a sample. COD, therefore, is an indication of pollution. Figure 2 indicates the same trend suggesting that the extent of pollution is reduced considerably beyond 1/2 km from the confluence point. This is due to the higher dilution factor during the spring season when the river is at a higher flow. The flow doubles from 8000 cusecs in March to 16000 cusecs in April and reaches upto

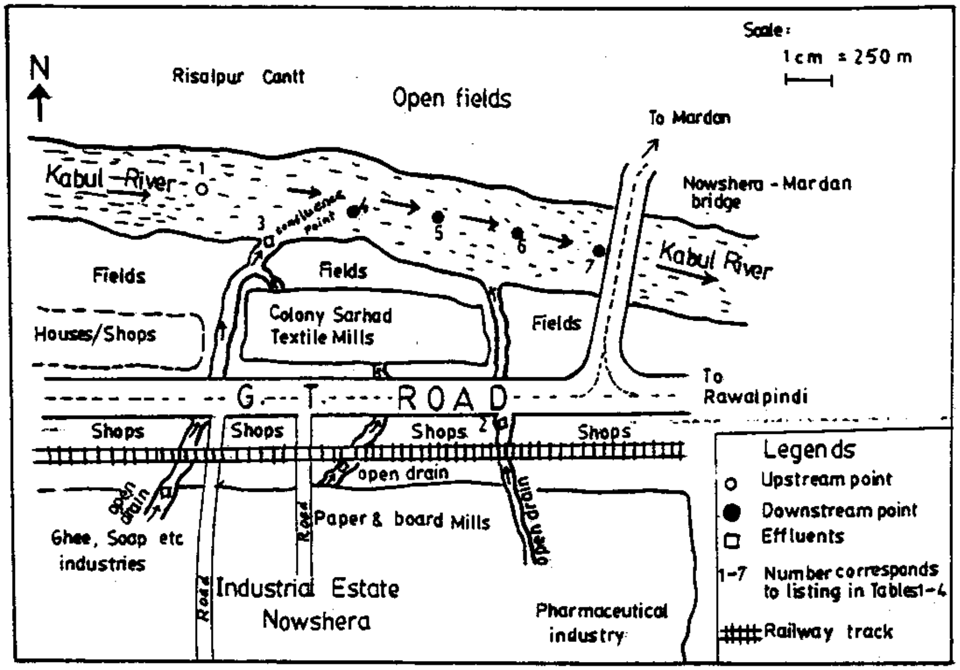

Fig. 1: Variation in water flow in Kabul River.
X-Axis ; Month
Y-Axis ; Discharge in cusecs (x 1000)

45000 cusecs in May (Figure 1). Comparing the data in Table 4 with the data contained in Tables 1-3, clearly demonstrates that because of the high flow and higher dilution factor during summer, as shown in Figure 1, all the values in Table 4 are quite low showing a pollution of the lowest level.

Characteristics of effluents

The effluent samples collected periodically during the year had pH values 7.49-8.50, and temperature 20-40 °C all of which are within the threshold limits as per USA, WHO [12] and National Environment Quality Standards (NEQS) [13] for the industrial effluents. The changes in the values of the above analytes are due to discharges from different processes at the time of sample collection. The DO level varied from 0.2 to 1.1 mg/l in most of the samples which is lower than the limits and can cause a localized hazard to aquatic life which needs at least 5 mg O_2/l [14,15] for its survival. However, one sample in the autumn collection (Table 1) has high D.O. (6.1 mg/l). This is due to the fact that at the time of sample collection, only the pulp wash was flowing in the drain. COD ranged from 778.8 to 2510.2 mg O_2/l which is also quite high, the permissible limit being 150 mg/l [13]. TDS varied between 2450 and 3192 mg/l which are well within the limits as the threshold value is 3500 mg/l according to NEQS [13] for effluents and wastewater. Alkalinity values were also below the objectionable level, except for the summer collection (Table 4) which had 330 mg/l hydroxide alkalinity. This can cause a localized hazard to aquatic life. Sulphate concentration was within limits in most of the samples, except winter collection (Table 2) which contained 623.4 mg SO_4/l. Some of the effluent samples showed a very high nitrite concentration (5300 µg/l in Table 2). In river water there is a possibility that it might have resulted from the biological reduction of nitrate indicating the recent pollution [1] due to bacterial activity. This statement is substantiated with the fact that here the sewage of Nowshera is being discharged into the Kabul River. 2 km downstream of the Nowshera Mardan bridge, the number of feacal coliforms was 2400000/100 ml which is the highest count ever found between Warsak and Khairabad [10] indicating the presence of substantial number of bacteria at this location.

Table 3. Analysis of effluents and receiving water during *spring*

	Collection points (Locations)*					
	1	2	3	4	5	6
Appearance	clear	Black	Brown	Greyish	Clear	Clear
Odour	Nil	Unpleasant	Smelly	Nil	Nil	Nil
pH	8.2	8.32	8.22	8.24	8.20	8.35
Temp. °C	12.0±1	27.0±1	14.0±1	12.0±1	12.0±1	12.0±1
DO (mg O_2/l)	12.0	0.5	5.0	10.0	10.5	11.5
E. Cond. (m S)	0.24	1.35	1.23	0.27	0.25	0.27
COD (mg O_2/l)	7.1	778.8	142.7	89.2	49.5	27.2
NO_2-N (μg/l)	10.0	352.0	144.0	58.0	23.0	18.0
NO_3-N (mg/l)	0.22	0.28	0.24	0.20	0.20	0.22
TDS (mg/l)	187.6	1120.0	1008.0	211.0	208.0	212.0
Total Hardness as $CaCO_3$ (mg/l)	180.6	193.6	188.2	188.0	184.0	184.0
OH^- alk.(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
CO_3^{-2} alk.(mg/l)	Nil	20.0	Nil	Nil	Nil	14.0
HCO_3^- alk.(mg/l)	120.5	205.0	155.0	150.4	144.0	127.5
Cl^- (mg/l)	11.3	343.1	105.3	55.0	15.0	14.7
SO_4^{-2} (mg/l)	30.5	227.0	90.4	50.0	42.0	38.0
Na^+ (mg/l)	6.1	220.0	92.4	64.4	10.6	10.8
K^+ (mg/l)	1.2	14.5	13.6	8.5	3.3	1.6
Ca^{+2} (mg/l)	67.0	75.4	70.2	72.0	69.0	68.8
Mg^{+2} (mg/l)	113.6	118.1	118.0	116.0	115.0	115.2

alk. = *alkalinity as* as $CaCO_3$

* *Collection points*:

1. Upstream sample.
2. Effluents of paper and Board Mills (Main drain under G. T. Road)
3. 100 meters downstream from confluence point.
4. 500 meters downstream from confluence point.
5. 1 km downstream from the confluence point.
6. 2 km downstream from the confluence point.

Characteristics of river water

The receiving water samples from the Kabul River collected over the year showed a pH range of 7.11-8.74 which follows an irregular pattern due to the different nature of effluents being discharged. The reason for the higher pH (8.74) of the receiving water of the Kabul River, though less polluted (Table 4), compared to all the downstream samples is not known to which no explanation is given. However, the pH values are well within the limits of not only drinking water but is in accordance with the NEQS [13] as well. There was no appreciable change in the values of the upstream samples and the sample collected about 1.5 km downstream. Similarly the temperature rise as a result of hot effluent discharges was also localized. Tables 1-4 also indicate that the temperature of upstream samples and that of the samples collected 1.5 km downstream showed no change, the same pattern was followed by dissolved oxygen as well. The data in Figure 2 indicate the localized pollution in the downstream water within half kilometre from confluence point. More adverse condition can occur when the river is at low flow. Although the TDS content near the confluence point was very high, it fell to almost the upstream level. This was partly due to the very high dilution factor and partly due to coagulation of solids in the effluents caused by filter alum coming from filter alum plant through another drain which contained

Table: 4. Analysis of effluents and receiving water during *summer*

	Collection points (Locations)*						
	1	2	3	4	5	6	7
Appearance	Clear	Dark brown	Dark brown	Greyish	Greyish	Clear	Clear
Odour	Nil	Unpleasant	Unpleasant	Nil	Nil	Nil	Nil
pH	8.74	8.50	8.18	7.44	7.50	7.80	7.57
Temp. °C	26.0±1	40.0±1	16.0±1	18.0±1	12.0±1	12.0±1	30.0±1
DO (mg O_2/l)	8.5	0.8	1.1	3.0	6.7	7.4	8.9
E. Cond. (m S)	0.18	2.55	2.57	0.20	0.20	0.14	1.18
COD (mg O_2/l)	5.4	1875.0	1543.0	230.0	49.5	17.3	9.5
NO_2-N (μg/l)	-	-	-	-	-	-	-
NO_3-N (mg/l)	-	-	-	-	-	-	-
TDS (mg/l)	210.0	2752.0	2764.0	252.0	230.0	228.0	200.0
Total Hardness as $CaCO_3$ (mg/l)	81.3	150.0	225.0	93.8	93.8	87.5	108.4
OH^- alk.(mg/l)	31.5	330.0	Nil	Nil	Nil	Nil	Nil
CO_3^{-2} alk.(mg/l)	37.2	330.0	Nil	Nil	Nil	Nil	Nil
HCO_3^- alk.(mg/l)	101.5	Nil	220.0	187.0	203.5	170.5	176.0
Cl^- (mg/l)	12.5	225.0	535.0	150.0	17.5	10.0	12.5
SO_4^{-2} (mg/l)	126.9	227.0	185.8	183.8	164.1	173.4	108.4
Na^+ (mg/l)	4.9	5.4	83.5	9.8	5.0	5.0	0.8
K^+ (mg/l)	0.4	107.5	112.8	3.0	0.5	4.1	1.8
Ca^{+2} (mg/l)	26.0	52.0	85.0	33.0	30.0	29.1	40.2
Mg^{+2} (mg/l)	55.3	98.0	60.8	140.0	63.8	58.5	38.2

alk. = *alkalinity as* as $CaCO_3$

* *Collection points*:

1. Upstream sample.
2. Effluents of paper and Board Mills (Main drain under G. T. Road).
3. Confluence point.
4. 500 meters downstream from confluence point.
5. 1 km downstream from the confluence point.
6. 1.5 km downstream from the confluence point.
7. 2 km downstream from the confluence point.

about 2 % aluminum sulphate (unpublished data). Another possible explanation could be due to the biodegradation of the organic matter during its downstream course, precipitation of some solids due to higher pH of river water and adsorption of charged solids on the particulate matter. However, literature suggests [16] that the TDS range encompassed in Tables 1-4 for river water falls in the category below the saline level.

The COD values ranged between 4.4-230.0 mg O_2/l in all the samples whereas the upstream samples had values of 3.6-8.2 mg O_2/l. These values also indicate a localized pollution within a half kilometer from the confluence point. Sulphate concentrations are well within the limits, ranging from 64.4-197.1 mg/l. A small increase in the sulphate content in the samples near the new bridge is due to the sulphate containing sewage from different areas.

Both sodium and potassium are present in low concentrations. Very high concentrations of nitrite-nitrogen near the confluence point indicate recent pollution, as pointed out earlier [1]. However, nitrite-nitrogen level falls during the downstream course of river. According to the WHO and USA [12] drinking water standards, even trace amount of nitrite is

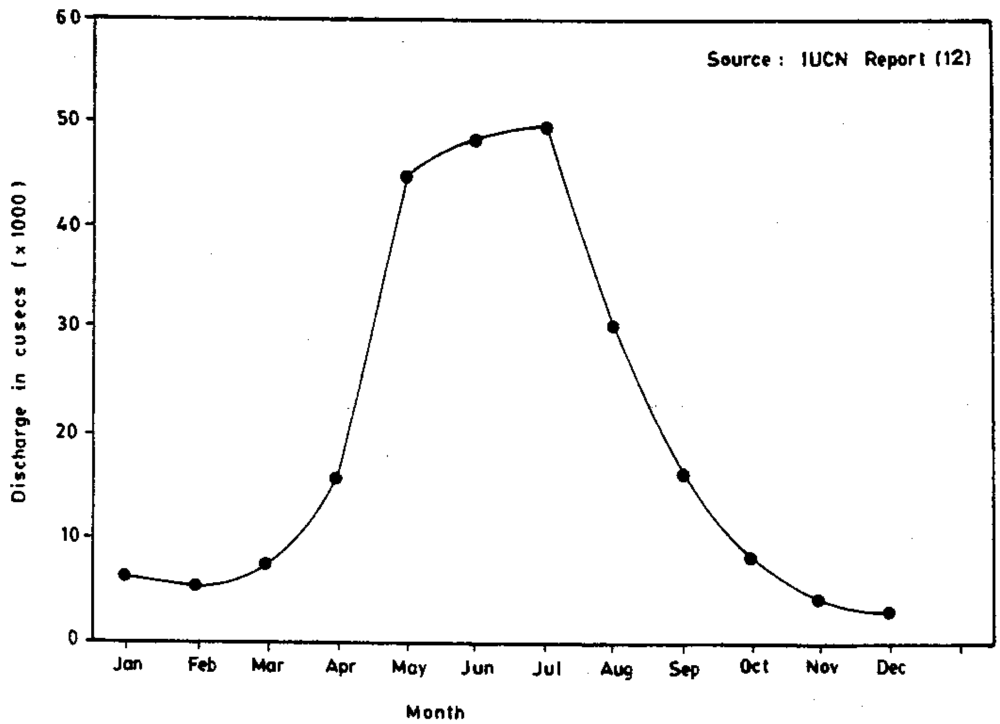

Fig. 2: COD and DO levels from confluence point at high flow condition.
X-Axis; Distance (Km)
Y-Axis:
i) DO (mg O_2/l
ii) COD (mg O_2/l
COD:
DO:

Table: 5. **Comparison of major constituents of Kabul River with Indus River and US rivers**

Constituent	Range (mg/l)			
		Indus River at		
	Kabul River* (*This study*)	Tarbella Dam [20]#	Kalabagh [21]#	US rivers** [22]
Total Dissolved Solids	200 - 379	104 - 211	125	72 - 400
Bicarbonate (HCO_3^-)	130 - 290	46 - 80	36	40 - 180
Sulphate (SO_4^{--})	57 - 226	15 - 49	57	11 - 90
Chloride (Cl^-)	10 - 150	7 - 10	14	3 - 70
Calcium (Ca^{++})	26 - 105	21 - 32	68	15 - 52
Magnesium (Mg^{++})	55 - 225	4 - 10	47	4 - 14
Sodium & Potassium	3 - 34	2 - 7	1 - 4	6 - 85

* River water samples taken before and after the confluence point excluding the main effluent samples.
** 90 % of total US stream flow [22].
# Values rounded to the nearest figure

objectionable in potable water. The presence of 18.0-300.6 μg NO_2-N/l in the river water samples render it unfit for human consumption [17, 18]. The nitrate concentrations were amazingly low (0.22-1.51 mg/l), decreasing in the downstream samples with the exception of winter sampling (Table 2) where it shows an opposite trend. No cause could be attributed to it.

Comparing some main constituents of the Kabul River (Table 5) to that of the published data for the Indus River at Tarbella Dam [19] and comparatively recent data at the proposed Kalabagh Dam site [20] and with the US rivers [21], it is apparent that the Kabul River is getting polluted. The presence of high concentrations of salts in the Kabul River, compared to the reported data [21], shows the continued dumping of different chemicals in it which is something that can not be ignored. Black liquor from Adamjee Paper and Board Mills is the main pollution source, damaging not only the quality of river water but also the aesthetic values of the river. Black liquor contains high concentrations of lignosulphonates which are detrimental to fish crops [14]. This liquor can be brought in use as a dispersant [22] in the cement manufacturing industries.

Experimental

Analysis

All the reagents were of analytical grade and were thus used without further purification. Standard methods [23] were employed for all the analyses. pH, temperature, dissolved oxygen (DO) and electrical conductivity of the samples were measured on the spot. A DO meter (model OXI 57, Germany) and a conductivity meter (model HI 8033, Hanna Instruments, Italy) were used for the measurement of DO and electrical conductivity respectively. A flame photometer, (model 19/FH 500, Gallenkamp, England) was used for the measurements for sodium and potassium. The open reflux method was used for the determination of COD. Spectrophotometric methods were used for measuring nitrite and nitrate concentration [23].

Conclusions

These studies conclude that the localized pollution in Kabul River has not yet posed a very serious threat to the environment. However, this can not be under estimated, especially when there is an endless and continued activity of pollutant dumping in the river. Kabul River water contains higher concentrations of salts compared to the Indus River and rivers in USA. Therefore, further deterioration will damage the quality of water irreversibly. The presence of nitrite in the water indicates bacterial activity which renders it unfit for human consumption. Black liquor from Adamjee Paper and Board Mills which is a main source of pollution can be beneficially used as a fluidizer in cement industry. A recovery plant must be installed in the Paper/Board Mills for this purpose. This will greatly reduce the pollution due to black liquor. Alternatively, proper treatment measures must be developed for industrial effluents and adopted for the abatement of pollution in the Kabul River.

References

1. T. H. Y. Tebbutt, "Principles of water quality control", *3rd. ed.* Pergaman Press Oxford, pp. 42 (1983).
2. S. A. Khan, and M. Khan *J. Chem. Soc. Pak.* 19(3), 205 (1997).
3. M. H. Bokhari and S. A. Malik, Final Technical Report-Project No. P-BZU/Envir (29), Institute of pure and applied biology, Bahauddin Zakariya University Multan (1994-97).
4. S. S. Shamsi, *Engg. Horizon,* pp. 23, (Oct. 1992).
5. A. R. Khan and M. Akif, *Technical report,* PCSIR Labs. Peshawar, (Dec. 1994).
6. G. Tchobanoglous, and E. D. Schroeder, "Water quality-characteristics, modeling, modification", Addison-Wasley Publishing Company, California, pp. 203-204 (1985).
7. K. J. Larry, Terminal Report No. DP/PAK/76/009/A/01/37 Govt. of N.W.F.P. (Pakistan), pp. 6-37 (1977).
8. K. Kamin, M. Akif, M. A. Khattak, and R. A. Shah, *J. Engg. Appl. Sciences,* 4, 111 (1985).
9. M. Akif, and M. A. Khattak, *J. Anal. Env. Chem.*, *1*, 101 (1991).
10. A. R. Khan, M. Akif, Surraya Wadud and Kamin Khan, *J. Chem. Soc. Pak.* (in press).
11. IUCN Report, "Pollution and the Kabul River - an analysis and the action plan", IUCN Pakistan Programme - SPCS Unit, Planning, Environmental and Development Department,

Civil Secretariat, Peshawar - Pakistan, pp. 5-7 (1994).

12. In: "Industrial waste pollution", Govt. of Pakistan, Environment and Urban Affairs Division, Islamabad Report (June 1983).
13. The gazette of Pakistan, Notification SRO No. 742(1)/93, Pakistan Environmental Protection Agency, Environment and Urban Affair Division, Islamabad, pp. 1367-1372 (1993).
14. D. Barnes, P. J. Bliss, B. W. Gould and H. R. "Water and wastewater engineering systems", Vallentine, Longman Scientific & Technical System, England, pp. 135, (1986).
15. H. S. Peavy, D. R. Rowe and G. Tchobanoglous, "Environmental engineering", McGraw Hill Book Company, New York, pp. 55 (1986).
16. H. A. Swensen and H. L. Baldwin, "A premier on water quality", US Geological Survey, Govt. Printing Office, Washington, D. C., (1965).
17. A. A. Siddiqui, *Pak. A. F. Med. J.* XXXII-15, 59 (1980).
18. W.H.O. "Nitrite and nitrate", World Health Organization, Environmental Health Criteria No. 5, WHO, Geneva, pp. 1-7, (1978).
19. M. Akif and M. A. Khattak, *J. Env. Anal. Chem.* 1, 101 (1991).
20. M. I. Malik and S. Hussain, M. Sc. thesis, Deptt. of Environmental Planning and Management, University of Peshawar (1992).
21. J. C. Lamb, "Water quality and its control", John Wiley & Sons, New York, pp. 131 (1985).
22. M. A. Khattak, "A process for the manufacturing of cement slurry using spent sulphide liquor as a dispersant", Govt. of Pakistan, Patent No. 124111 (1974).
23. A.P.H.A. "Standard methods for the examination of water and wastewater" American Public Health Association (APHA), New York, 16th. ed., (1985).