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Impact of Water Quality on Aquatic Life in River Ravi, Pakistan

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ABSTRACT

This study assessed the water quality at the outfall of six drains in River Ravi at Lahore, Bridge and Balloki Barrage and B-S Link canal to check suitability of water for propagation of fish and aquatic life. The water quality parameters like pH, EC, DO, COD, BOD, TDS, SO_4 and heavy metals (Fe, Cu, Cr, Ni) were analysed at the outfall of six drains and three other locations on the river in 62 km stretch. The sampling period includes wet and dry weather seasons and canal closure periods. The study reach included the effect of urban and industrial effluents from the six drains and dilution effect of flow augmentation through Q-B Link canal. The results showed that the river water quality was not suitable for aquatic life during dry weather and canal closure period when compared with U.S.EPA standards for fish and aquatic life. The DO, BOD and heavy metals were not within the safe limits. Augmentation of about 600 m^3sec^{-1} discharge through B-Q Link helps to improve the water quality of the Balloki Barrage pond. However, during canal closure period the situation aggravates as this additional freshwater is not available during December and January. The river water quality at Lahore remained unsafe for aquatic life. The wet weather helps to flush out and slightly improve the water quality during July and August. Nevertheless, the storm water also brings heavy pollutant load from the city to the river. The study concluded that the disposal of untreated drainage effluent to the river remains as a major threat to its water quality and consequently the aquatic life.

INTRODUCTION

Rivers are major source of freshwater for human consumption and propagation of fish and aquatic life. Increase in population and economic growth and indiscriminately dumping of untreated effluents into the rivers have adversely affected their water quality and rivers' services to lives. Upper Mississippi River Conservation Committee identified the water quality as a key issue for over two million people who depend for water on rivers (Sullivan et al. 2002). However, the situation in the developing countries is worsening. WWF (2007) included the Indus River among the top 10 rivers at risk. Pakistan's water availability per capita have reduced from 53,000 m^3 in 1951 to 12000 m^3 in 1985 (PCRWR 1985), 1299 m^3 in 1996, 1100 m^3 in 2007 (WWF 2007) and 1000 m^3 in 2010 (Authors' estimate based on population data by Planning and Development Division, Government of Pakistan). The projections show that the per capita water availability in Pakistan will further reduce to about 877 m^3 by 2020. Declined water quality further reduces the freshwater availability and implicates health hazards. PCRWR (2006) based on 200 samples from 12 major cities in Pakistan showed contamination in 80% samples, whereas the contamination was found to be 100% in samples taken from Lahore. According to the Planning Commission of Pakistan, around 40% deaths occur due to the use of polluted drinking water in Pakistan. Direct disposal of untreated toxic waste into nearby drains and ultimately to the rivers, contributes major pollution load to the water bodies (Nazir 1993). Furthermore, one out of ten children died due to waterborne disease before reaching the age of one year. Ravi River is one of the major tributaries of the Indus River. It passes by Lahore, a city of about 10 million people. The city's domestic and urban effluent is directly or indirectly disposed off into the River Ravi, and thus is a major source of river water quality degradation (Chang et al. 1997). Disposal of untreated industrial waste from the Lahore Industrial State and other nearby industries is also a major source of the river pollution (Ullah et al. 2009, Fordyce et al. 2007). Punjab Environment Protection Department reported a daily effluent disposal of about 800,000 cubic meters into the Ravi River from 1120 industrial units in Lahore. As a result of this wastewater combined with reduced flows in the River, the fish population in Ravi River is almost at the verge of extinction. Untreated effluent disposal and reduced river flows in post-dam era have significantly reduced the dilution process of River Ravi at Lahore and has seriously affected the river water quality. The pollution in River Ravi is the highest of all the rivers in Pakistan. Most wastewater discharges in the river reach between Lahore and Balloki, a length of 62 km (Ahmad & Ali 2000). The river presently receives 47% of the total municipal and industrial pollution load discharged into all rivers of Pakistan. The polluted water is also used for irrigation in peri-urban areas, which adversely affects flora and

fauna and human population through food chain (Ali 2003). However, its impacts on river water at 62 km downstream at Balloki Barrage pond, a major water diversion point, were not investigated (Nazir 1993). Being a first formal water withdrawal point at downstream of Lahore and main source of water services to downstream areas, it is imperative to assess the impacts of Lahore effluent on water quality at Balloki Barrage. This paper has assessed the river water quality and its consequences to aquatic life.

MATERIALS AND METHODS

River Ravi is 805 km long with a catchment area of 40,297 km^2. It originates in Himalayas, traverses its upper 80 km in India and lower 725 km in Pakistan. The major structures on the river are Thein Dam and Madhopur Headworks in India and Balloki and Sidhnai Barrages in Pakistan. Construction of Thein dam and flow diversion at Madhopur in India has drastically reduced the river flows. The river flows drop to almost zero in winter and may rise as high as 17,000 $m^3 sec^{-1}$ during monsoon floods in summer. The average annual flow of 8,634 million m^3 from 1922-1961 has reduced to about 1813 million m^3 in as of 2001 estimates (Adel 2001).

Balloki Barrage is located at about 62 km downstream of Lahore in Pakistan. An inter-river Q-B Link canal augments the river flows of 600 m^3/sec just upstream of Balloki Barrage (Ahmad 1990). The Q-B Link canal supplies water during a period from October to June (Nazir 1993). However, these flows at Balloki Barrage are diverted to the two canals, the main source of irrigation supplies to about 1.5 million ha and a source of livelihood of about 10 million people, leaves the downstream river channel almost dry (Ahmad 1990). Schematic layout of the River Ravi and inter-river canals is shown in Fig. 1.

During low flows in winter, the river channel between Lahore and the outfall of Q-B Link at upstream of Balloki Barrage virtually acts as effluent drain. Six main drains carry the urban and industrial effluents to River Ravi at Lahore (Fig. 2). These include Chota Ravi drain, Sagian drain, Gulshan-e-Ravi drain, Mian Mir drain, Babu Sabu drain and Kharak drain all outfall into the river at downstream of Ravi Bridge (Sami 2001). Hadiara drain also joins the river at downstream of Lahore. On the average total effluent of 11 m^3/sec is discharged against a dry weather flow of about 11.3 m^3/sec, which gets a dilution ratio of 1:1 at source (Ahmad & Ali 2000). This effluent is a major source of River Ravi pollution (Pearce et al. 1998). Due to dilution effect, the flows from the Q-B Link canal temporarily improve the water quality in the barrage pond (Ahmad & Ali 2000). Three main scenarios were developed for river water quality analysis that includes (i) wet weather flows, (ii) dry weather flows, and (iii) canal closure period without flow augmentation. Generally, July to September is rainfall and wet weather flow season and December to January is canal closure period. Dry weather flows prevail during remaining period of the year. Water samples were collected, processed and analysed for various parameters of water quality.

This study considered the Ravi Bridge as upstream and the Balloki Barrage as downstream boundary in the study. River discharge is measured at these two structures. The sampling locations include the Lahore Bridge, Balloki Barrage and B-S Link canal and six drainage inlets in urban and peri-urban areas (Fig. 2). Locations of sampling were noted in UTM by using Global Positioning System (GPS; *etrex vista* by GARMIN). Discharge data of the river and the canals were collected from Irrigation and Power Department, Punjab for the sampling dates. Discharge of the drains was estimated from velocity-area method. Main quality parameters were defined and sampling frequency was determined. It followed the water quality sampling and analysis in the Laboratory of the Punjab University during 2006 and 2007. Samples results were plotted, trends were analysed and results were interpreted. United State Environment Protection Agency (U.S.EPA) standards were used for comparison purposes. The main quality parameters included pH, electrical conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS) and heavy metals including iron, chromium, copper and nickel. Samples were collected during wet weather and dry weather flows and during canal closure periods, when freshwater flows in river becomes almost zero. Stable and straight reaches to minimize the flow turbulences were selected. The velocity by float method and the cross-section area was measured by average widths and depths at sampling locations. Location and time of sampling and field observations are given in Table 1. The results were compared with the WWF guidelines for propagation of fish and aquatic life (WWF 2007). Being a time lag of about 15 hours between upstream and downstream boundaries, the samples at the two sites were taken with this time lag.

RESULTS AND DISCUSSION

Wet weather: The results in Table 2 show the pH within the permissible limits. The EC was about 45% higher at upstream boundary and it was within the safe limits at the downstream boundary. A safe limit of the EC at the downstream boundary could be linked to the dilution effect of the freshwater inflow by the Q-B Link canal. The dissolved oxygen (DO) was higher than the minimum requirement at both the locations; however, it was almost double at the downstream boundary, which can again be linked with the freshwater injection. The BOD was 1.8 times higher at upstream boundary but it was within the safe limits at the downstream boundary.

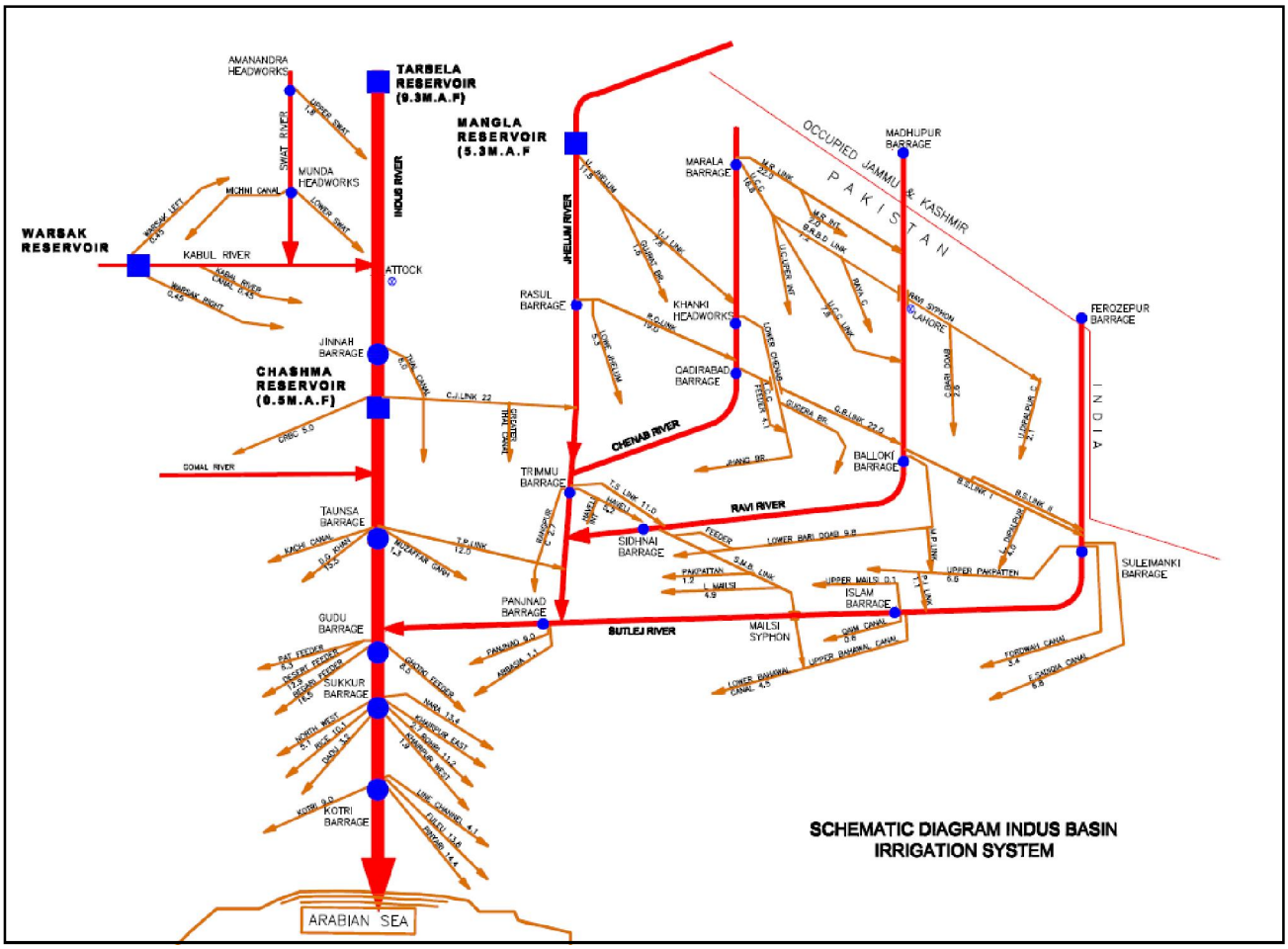

Fig. 1: Schematic representation of Indus basin system including River Ravi.

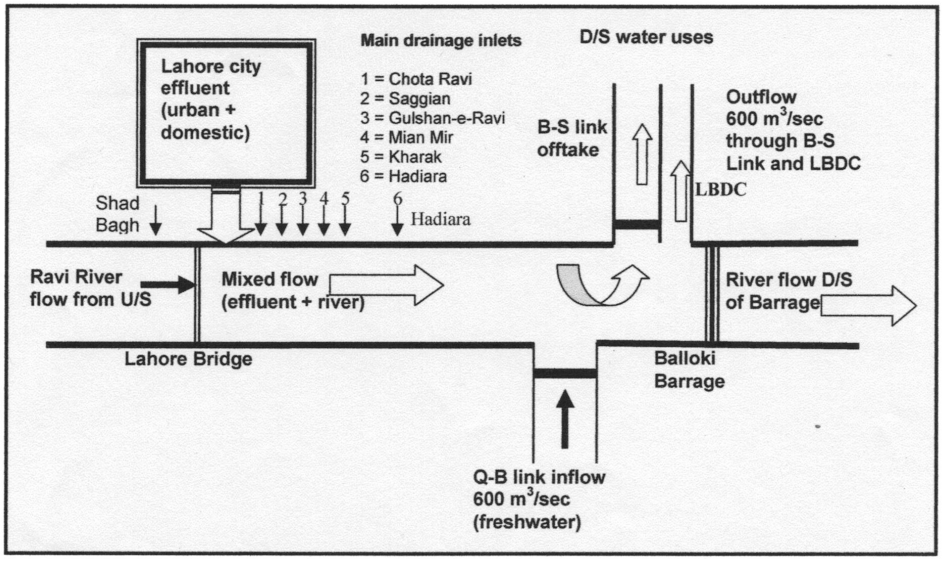

Fig. 2: The study reach of River Ravi.

Table 1: Sampling location, time of sampling and field notes.

Location		Field notes		
Sampling Points	Grid Reference	8th Aug. (High Flow Season)	24th Nov. (Normal Flow Season)	8th Jan. (Low Flow Season and Cannal Closure Period)
River at Lahore Bridge (Control)	43 R 0433338. UTM 497114	Recreational spot for the season. Beautiful view and clean water. Large number of masses was boating	Deteriorated scene. Greyish water with bad odor in air. Few people still boating. Dumped solid waste on the bank of the river	Hazardous view. Very reduced and black water. Highly pungent, irritating and unbearable odor. No masses were there. Heaps of dumped solid waste in the river was clearly visible.
Drain 1: Chota Ravi	43 R 0432494. UTM 3494054	3 km from Ravi Bridge. Collects drainage from Bhatti, Androon Lahore and Yadgar. Operational pump installed to drain flood water. High flow in the Drain.	Drainage pump was shut down. Sewage water flows under gravity flow. Highly irritating odor. Children playing along the banks of the drain.	Solid waste heaps dumped along and into the drain that reduces and blocks the flow of sewage. Highly irritating odor. People living around complained of deteriorating health conditions due to poor maintenance of drain.
Drain 2: Saggian Drain	43 R 0431816. UTM 3493249	2 km from Chota Ravi. Construction work in progress along the drain. High flow. No drainage pump. A nursery adjacent to drain is irrigated by drain water.	Construction work still in progress. Very little solid waste along the bank of drain. Slightly bad odor.	Construction work completed. No dumping of solid waste. Slightly bad odor. Well-flourished nursery adjacent to the drain fed by drain water.
Drain 3: Gulshan-e-Ravi Drain	43 R 0430896. UTM 3490821	3 km from Sagian drain. The drain passes through a densely populated area. There are gated weir structures on the sampling point of the drain that were open to drain the floodwater.	Bad odor. People selling fruits and vegetables along the drain. Solid waste heaps present along the drain. Gated structures were closed and sewage flows under the gravity.	Bad odor. More number of vendors along the bank and added amount of solid waste to the heaps as compared to previous visit. Solid waste dumped into the drain as well. Gated structures closed.
Drain 4: Mian Meer Drain	43 R 0430445. UTM 3489479	2 km from Gulshan-e-Ravi drain. It is a much wider drain as compared to the rest. The area is heavily populated and all the time full of heavy traffic. Small shops are there along the drain.	Irritating odor. At the time of sampling, cement was being unloaded along the drain from the trucks. Solid waste dumped into the drain was clearly visible.	Very bad odor. Some children and adults were bathing in the drain.
Drain 5: Kharak Drain	43 R 0430882. UTM 3486307	Some 2 kms from the Gulshan-e-Ravi drain is the Kharak Drain. Drain passes through the heavily populated area of Allama Iqbal Town. Gated structures were at the drain to control the flow of water.	Decreased flow due to absence of storm water flow. Vendors selling fruit and vegetables along the banksof the drains and were spraying the water of the drain to keep the fruits and vegetables fresh.	A very irritating odor. A worker was removing the solid waste thrown into the drain by the locals to ease the flow of water.
Drain 6: Hadiara Drain	43 R 0419759. UTM 3474132	Some 20 kms from Kharak Drain along the Multan Road is Hudiara Drain. It originates in India enters Pakistan and falls into River Ravi. During the monsoon it also acts as storm water drain. It is away from any heavily populated area. Access to obtain the water sample was not easy.	Reduced flow. No noticeable bad odor in the atmosphere due to openness o the area. Solid waste blocking the flow of water consisted of dead animals, and packing materials of electronic and other heavy machinery equipments etc.	Situation was found to be same as during normal flow conditions.
River Ravi at Head Balloki	43 R 0391214 UTM 3455013	38 kms from Hudiara Drain are situated Balloki Headworks, the end-point of the study from where the water of River Ravi is distributed to far off areas. The gates were partially open to control the flow of water downstream the Balloki Barrage.	A famous recreation point. People were enjoying along the River viewing the Headworks and tasting the freshly catched fish of Ravi. Aesthetic view was very pleasant.	Deteriorated conditions. Very reduced flow with blackish water. No visible heaps of solid waste. But a very irritating odor in the atmosphere. No tourists were there at sight.
BS Link canal at Head Balloki	43 R 0391593 UTM 3454558	B-S Link Canal emanates from the Balloki Headworks along with LBDC and serves the lower areas of Punjab. Gates of the Canal were partially open to control the downstream flow of water.	A very pleasant aesthetic view. No. odor. People were picnicking and enjoying along the canal. Flowing water was of perfectly good quality in terms of physical characteristics.	A very deteriorated view. An irritating odor was creating nuisance in the environment. Very reduced flow with deteriorated water quality in term of physical parameters.

Table 2: Results of samples analysis in comparison with WWF guidelines for aquatic life.

Parameters	WWF Limits	River Ravi at Lahore Bridge (U/S boundary)			River Ravi at Balloki Barrage (D/S boundary)			B-S Link Canal		
		Wet weather	Dry weather	Closure period	Wet weather	Dry weather	Closure period	Wet weather	Dry weather	Closure period
Temp. (°C)	± 3°C*	34	25.5	20.5	35.6	21.1	19.6	30.5	21.1	19.6
pH	6.5-8.5	7.75	7.5	7.22	8.2	8.2	7.8	8.2	8.02	7.8
EC (dS/m)	1.5	2.18	1.37	0.971	1.402	0.970	0.667	1.34	1.04	0.743
DO (mg/L)	>5	5.5	1.09	0.791	10.2	6.95	2.64	8.02	4.1	2.89
COD (mg/L)	-	44.16	186	420	21.8	23.2	65.6	12.5	19.28	62.8
BOD (mg/L)	8	14.5	71.8	191.4	7.12	7.59	20.3	2.9	4.67	21.9
TDS (mg/L)	1000	1551	975	690	996	689	474	955	740	528
SO_4 (mg/L)	400	160.7	146.7	137	25	16.2	9.9	24.7	18.5	1.75
Fe (mg/L)	0.3	0.537	0.731	3.208	0.77	1.393	3.2	0.284	0.625	2.940
Cr (mg/L)	0.05	0.085	0.123	0.164	0.04	0.06	0.085	0.037	0.056	0.088
Cu (mg/L)	0.007	0.337	0.345	0.374	0.04	0.052	0.073	0.039	0.051	0.075
Ni (mg/L)	0.05	0.01	0.08	0.15	0.02	0.037	0.055	0.025	0.04	0.056

*The maximum water temperature change shall not exceed 3°C relative to an upstream control point.

Total dissolved solids (TDS) were almost 50% higher than the permissible limit at upstream boundary and within the permissible limits at the downstream boundary. Among the heavy metals, iron and copper were higher than the permissible limits at both the boundaries. Chromium was higher at the upstream boundary when the nickel was within the permissible limits at both the locations.

Overall, the results showed that the water quality parameters deviated about 50 to 80% from the safe limits at the upstream boundary, while they maintained within the safe limits at downstream boundary. The higher value of EC, TDS, BOD and heavy metals at the upstream boundary showed that water quality of River Ravi at Lahore Bridge was deteriorated even during the wet weather when there was maximum dilution due to rainfall and storm water inflows in the river. It indicates implications to the aquatic life and fish propagation in the river near Lahore. However, waters of Balloki Barrage and B-S Link Canal were quite safe for propagation of fish and aquatic life during wet weather.

Dry weather: During dry weather flow, the EC and TDS were within the safe limits at both the upstream and downstream boundaries. The DO was lower than the minimum at Balloki Barrage requirements that is also enforced by about 9 times higher BOD at this location. However, it was within the safe limits at downstream boundary. Heavy metals were out of safe limit both at the upstream and downstream boundaries. Higher value of heavy metals during dry weather could be linked to the low river flows. However, slightly better situation at downstream boundary can be linked to additional inflows from the Q-B Link canal that may have diluted the degree of pollution. During the dry weather, when the monsoon effects faded the overall situation of River Ravi at all the three locations was more deteriorated as compared to the wet weather.

Closure period: During canal closure period, the DO was one-sixth to one-half of the permissible limits and correspondingly an alarming increase of in BOD (3 to 24 times of the safe limit) at all the locations. Almost all the parameters were out of safe water quality limit during canal closure period except for TDS, which were lower than the prescribed limit. Therefore, closure period is not suitable for propagation of fish and aquatic life. The increase in the heavy metal concentration and decrease in the DO is particularly dangerous for the survival of fish and aquatic life. Even if the fish do survive in these conditions; it does not remain fit for human consumption due to the bioaccumulation of heavy metals. Thus, during the canal closure period, river water quality in B-S Link canal and Balloki Barrage are not suitable for fish propagation.

Better water quality at Balloki Barrage as compared to the Lahore Bridge was mainly due to dilution of pollutants during transmission of flow in 62 km length and an inflow of 600 m^3sec^{-1} at immediate upstream of Balloki Barrage. This phenomenon follows the general scientific principles of pollutant dilution during transmission. Due to inflow of concentrated untreated pollutants at six locations, the river water quality at Lahore does not meet the requirement of EPA guidelines and is not suitable for propagation of fish and other aquatic life. However, inflow from Q-B Link canal at upstream of Balloki Barrage is vital and provides a breathing space for aquatic life at Balloki Barrage and offtaking canals. The canal closure period in December and January is the most critical period for the propagation of aquatic life at Balloki Barrage and at the appurtenant canals. It may also be critical to consider a minimum environmental flow during canal closure period. Due to the decrease in dilution effects during dry weather, there was a noted increase

in the concentration of heavy metals i.e., iron, chromium and copper exceeding the WWF standards at all the three locations, while nickel only exceeded the WWF standards at Lahore Bridge. The increase in the heavy metal concentration at the three locations renders the waters of River Ravi between Lahore-Balloki reach dangerous for the propagation of fish and aquatic life. During wet and dry weathers, the DO values over 4 mg/L at the downstream end was due to freshwater dilution, biodegradation and aeration during flows transmission as compared to the upstream boundary. The seasonal and temporal variations in DO and BOD concentrations are linked to the variations in flow and water temperature. Metals can become 'locked up' in bottom sediments, where they can remain for many years. However, the lower pH level in water can cause an increase in metal solubility and the metal particles become more mobile increasing the toxicity level in water. The primary effect of dissolved oxygen in water is on oxidation-reduction reaction, involving iron, manganese, copper and compounds that contain nitrogen and sulphur (WHO 1984). Dissolved oxygen may tend to fall with flow residence time (WHO 1984), but these changes are normally indicative of corrosion processes. It is also possible that microbial respiration of organic material, especially in sediments and deposits, without a marked increase in the concentration of iron in the water (Ridgway 1979). Conversely, water containing high levels of iron as a result of corrosion may show little depletion of dissolved oxygen content.

In general, the concentration of metals in invertebrates is inversely related to their body mass. In fish, the embryonic and larval stages are usually the most sensitive to pollutants. The chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium. Higher concentration of chromium in the river water makes the fish dangerous for human consumption. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains.

CONCLUSIONS

1. Direct disposal of untreated urban and industrial effluents in River Ravi at Lahore causes serious water quality problems and is a threat for propagation of fish and aquatic life.
2. Treatment of drainage effluent before its disposal into the river or augmentation through freshwater flows to dilute the effect of untreated effluent during critical dry weather and canal closure period is needed for sustainability of the river aquatic life.
3. Flushing effect of wet weather flows reasonably improves the water quality for a period of about 2-3 months a year. However, the storm water has also a tendency to induce high pollution to the system.
4. Q-B Link Canal inflows play a critical role in improving the water quality and aquatic life at Balloki Barrage.
5. Canal closure is the most critical period for the aquatic life at Balloki. Largely, the Barrage pond receives sewage water during this period.
6. Low DO at the two boundaries is an indication of the higher organic loads, widespread sewage pollution and declining fish population in the canal and river waters. Protection of river water quality is needed to avoid further extinction of fish species, decline in fish productivity and contamination of fish population.

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