Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 3, p. 241-254, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Assessment of the impact of effluent disposal in river ravi at lahore on the water quality for irrigation and recreational purposes at upstream of Balloki Barrage, Pakistan

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Article published on September 12, 2014

Key words: River Ravi, six drains, irrigation use, recreational use , FAO and WWF guidelines.

Abstract

This paper focuses on the effluent impact on River Ravi received by it from the Lahore city at a number of locations upstream of Balloki Barrage located at 60 km downstream. The Qadirabad-Balloki link canal carries about 18,000 cusecs freshwater from the Chenab River into River Ravi at 5 km upstream of Balloki barrage, thus diluting it. River Ravi water quality was determined by sampling over a year including the periods of maximum, average and minimum river flows. Sampling was carried out at the six major drains near their disposal point and in River Ravi at Lahore Bridge (upstream boundary and control for this research), at Balloki barrage in main river channel and in Balloki-Sulemanki offtake link canal. The samples were analyzed for EC, SAR, RSC, TDS, anions (SO_4^-, Cl^-, CO_3^{-2}), cations (Ca^+, Mg^+, Na^-), and heavy metals (Fe, Cu, Cr, Ni) for irrigation purposes and DO, pH, EC,COD, BOD, TDS,SO_4^- and heavy metals (Fe, Cu, Cr, Ni) for recreational purposes. Samples coordinates were taken by Global Positioning System. The results were compared with FAO and WWF guidelines for Pakistan for irrigational use and with WWF guidelines for recreational use of water. Consequently, river water quality at the Balloki Barrage was acceptable during average and high flows and was deviating the standards during low flows.The dilution does not work during low flows and requires alternate solution to make the water quality acceptable. Also the drains being used for bathing and swimming for recreation is unsafe for such type of activities.

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Introduction

Pakistan is one of the world's most arid countries, with an average rainfall of 240 mm a year. The population and the economy are heavily dependent on the annual entry of water into the Indus river system (Indus, Jhelum, Chenab, Ravi, Beas, and Sutlej Rivers). About 180 billion cubic meters of water emanates from the neighboring countries and is mostly derived from snow-melt in the Himalayas (Briscoe and Qamar, 2008). River Indus and its tributaries supply 154 MAF of water annually: the westerns rivers contribute144.91 MAF of water while the eastern rivers bring 9.14MAF (MoE, 2005)

A large scale of uncontrolled pollution of water in Pakistan is due to the increasing quantity of the pesticides and fertilizers in runoff to meet the demands of increasing population and urban sprawl. Non functional and poorly working factories and industries drain their effluents in the river Ravi in the vicinity of Lahore and its surrounding areas (Briscoe and Qamar, 2008). In Pakistan per capita water availability is decreasing at an alarming rate. In 1951 per capita availability of water was 5300 m^3, which has now decreased to 850 m^3 in 2013 and is expected to decrease to 659 m^3 by 2025. The existing water resources are under threat due to untreated discharge of municipal and industrial wastes to rivers and other surface water reservoirs (MoE, 2005).

The Ravi River which has the smallest catchment of Pakistan's Rivers is 894 km long with a catchment area of 39,680 km^2. The municipal and industrial effluents are discharged in the River through 6 major drains at Lahore and its surroundings. In addition, untreated municipal effluents of Lahore city and Shahadra are disposed off into the River. The discharge of untreated municipal and industrial effluents has converted the River into a sludge carrier (Ayesha, 2001).

Most of the drains in the vicinity of the Ravi are producing Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) in quantities more than the allowable effluent standards. According to the latest report, by 2009, the Main City outfall on the Ravi is highly polluted by the untreated communal wastewater. According to the literature, Ravi is just like a wastewater carrier with high discharge variation of 270-81,000 ft^3/sec and approximately 750 ft^3/sec of untreated effluent is being added to the river. Pumping stations at "Shadbagh", "Chota Ravi","Main Outfall" and "Multan Road" are the main contributors to the river pollution. According to Water and Sewerage Authority (WASA) Lahore, the accumulative estimated discharge from these pumping stations is approximately 1650 cusecs (Ejaz *et al.*, 2011).

The pollution in River Ravi is the highest of all the rivers in Pakistan. Most waste water discharges in the river reach between Lahore and Balloki, a length of 62 km (Ahmad and Ali, 2000). The river presently receives 47% of the total municipal and industrial pollution load discharged into all rivers of Pakistan. In Lahore, six major wastewater drains that are Chota Ravi drain, Sagian drain, Gulshan-e-Ravi drain, Mian Mir drain, Babu Sabu drain and Kharak drain outfall into the river at downstream of Ravi Bridge (Sami, 2001).The wastewater from eastern and southern Lahore is carried by Hudiara drain that also drains its effluent into the river Ravi. The impact of this pollution and degradation of water quality greatly effects flora, fauna and also to human being through the food chain as the water of river Ravi has been used for irrigation since many years (Ali, 2003).

Balloki Barrage is located on River Ravi at about 60 km downstream of Lahore city (Fig. 1). The Barrage aims at diverting the part flow from the river for irrigation uses. Due to water shortages in the River in post-dam era, Q-B Link was constructed to supply about 600 m^3/sec water to River Ravi at about 5 km upstream of the Balloki Barrage (NESPAK, 1998). This water is diverted to B-S Link at Balloki Barrage at downstream. The B-S Link is a main source of freshwater for agriculture, animal watering and in

certain cases for domestic water uses for a population of more than 10 million and irrigates millions of hectares of land (NESPAK, 1998). At Balloki, the river water quality improves through augmentation of flow from the QB Link canal (Ahmad and Ali, 2000). Here the BOD values are low (2.3 - 3.9 mg/l), dissolved oxygen (DO) ranges from 6.2 to 8.2 mg/l, total dissolved solids (TDS) are between 98 and 225 mg/l and sodium absorption ratio (SAR) varies from 0.1 to 0.55 (Pearce *et al*, 1998). At this point, the river water meets the quality requirements for irrigation water. The high levels of faecal coliforms are, however, of concern for other water uses (Ahmad and Ali, 2000).

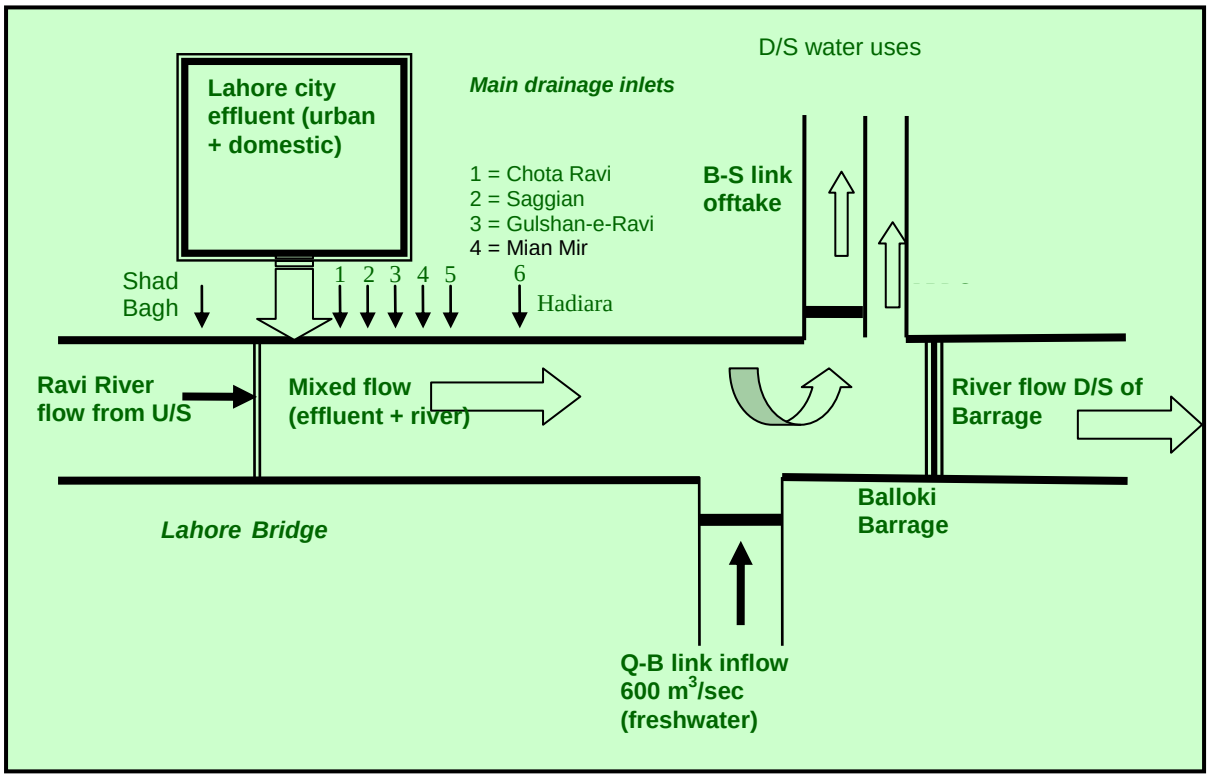

Fig. 1. Definition sketch of the study area (Sana and Muhammad, 2012).

The river reach from Lahore to the outfall of Q-B Link acts as drainage channel for effluent from the Lahore city during this period. The effluent is a major source of pollution of freshwater in the river (Pearce *et al*., 1998). However, the river water quality varies around the year depending on the quantity of freshwater flows and its dilution effect. The worst scenario is likely to occur during canal closure period, when canal inflows and outflows at Balloki barrage is zero or insignificant. During this time the effluent of Lahore can have detrimental effects, if any, on water quality. Therefore, the study was conducted during high flow, normal flow and low flow. Two canals off take from Balloki Barrage i.e. Sulemanki Link canal (B-S link) and Lower Bari Doab Canal (LBDC) , which serve lower Punjab areas of Sahiwal and Bahawalnagar for irrigation, animal watering and for domestic uses in certain locations. The continued discharge of industrial and domestic effluents may result in severe accumulation of the contaminants. This may affect the lives of human as well as animals around this river (Kumar and Krishna, 2011). Hence, there is an urgent need to treat the effluents before the final discharge. Being a first formal water withdrawal point at downstream of Lahore and main source of water services to downstream areas, it was imperative to assess the impacts of Lahore effluent on water quality at Balloki Barrage.

Material and methods

The River Ravi Bridge at Lahore was selected as upper boundary for monitoring of water quality.

Surplus flows from MR (Marala - Ravi) link at upstream of Lahore have dilution effect on the effluent from Shad Bagh drain at upstream of the Bridge also favors the selection of the bridge as upper boundary (Sana and Muhammad, 2012). Therefore, Ravi Bridge and Balloki Barrage are the upper and lower boundaries of the study reach of the river respectively. Rest of the sampling points are the major drains in between this reach (Fig. 1). Sampling of one canal from B-S (Balloki - Sulemanki) Link and LBDC (Lower Bari Doab Canal) indicated the water quality passing through these canals.

The frequency of sampling and defining the main parameters for analysis were selected according to the standards designed for the selected purposes. The water quality at upstream of Balloki Barrage was evaluated in the framework of irrigation and recreational water uses recommended by World Wide Fund for Nature (WWF) and Food and Agriculture Organization (FAO). The main quality parameters included parameters such as pH, DO, EC (Electrical Conductivity), RSC (Residual Sodium Carbonate), SAR, COD, BOD, TDS, TSS, carbonates, bicarbonates, heavy metals, salinity etc. The technique adopted for collecting water quality samples and instruments used for parameter estimation was according to Sana and Muhammad, 2012.Field observations at the time of sampling are given in table 1.

Table 1. Field Observations at the Time of Sampling.

Location		**Field notes**		
Sampling Points	**Grid Reference**	**8thAug (High Flow Season)**	**24th Nov (Normal Flow Season)**	**8th Jan (Low Flow Season and Canal 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. Grayish 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	Bad odor. People selling fruits and vegetables along the drain. Solid waste heaps present along the drain. Gated structures were closed	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

Location		Field notes		
Sampling Points	**Grid Reference**	**8thAug (High Flow Season)**	**24th Nov (Normal Flow Season)**	**8th Jan (Low Flow Season and Canal Closure Period)**
		to drain the floodwater.	and sewage flows under the gravity.	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 banks of 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 terms of physical parameters.

Results and discussion

Results of the investigations were interpreted and discussed in comparison with the recommended standards.

Irrigational use

For irrigational use of River Ravi waters, the results of the study were compared with FAO guidelines and irrigation water quality guidelines given by WWF, Pakistan (WWF, 2007).

High Flow Conditions (August)

Pakistan has an agriculture dependent economy. So in order to meet the domestic needs as well as to generate foreign exchange, there must be extensive and sustainable agriculture in the country. The lines of agriculture are primarily based upon the irrigation water availability and its quality. The availability must be adequate to meet the needs and the quality must be such that it must not produce crops that are hazardous for human health (Van der Hoek *et al.*, 1999) and must not cause water logging and salinity of soils. This is especially important because raw sewage water is also used in irrigation. So the guidelines given for irrigation water quality must be strictly followed.

Excessive rainfall leads to a huge amount of dilution in the fresh water bodies and wastewater drains. The sewage drains included in the study area also act as storm water drains during monsoon season and drains off the storm water with the help of electric pumps and gated structure built on them. In normal conditions, they drain the sewage under gravity flow.

During the flood season, the only problem with the control was the increased value of Electrical Conductivity (Fig 2) and Total Dissolve Solids (Fig 5) according to both FAO standards and WWF guidelines for irrigation water quality. The rest of the parameters including the heavy metals were well within the permissible limits of FAO as well as WWF standards. The drains that carry the sewage waste of Lahore in between the study reach showed an increased level of EC, TDS, cation and anions, chromium, iron and nickel. The worst conditions were found in Chotta Ravi, Saggian, Gulshan-e-Ravi and Mian Meer Drain. In Kharak Drain, only chromium exceeded the guidelines given by WWF in addition to EC and TDS. While in Hadiara Drain, pH and Nickel also exceeded the limits set by FAO and WWF guidelines (Table 2). Around the periphery of Lahore, most of the vegetables consumed by the masses of the city are grown along these drains and are fed by sewage water. Even within the city, plant nurseries and vegetable fields are fed by sewage water of these drains. Some heavy metals get adsorbed on the surface of vegetables especially the green vegetables.

Table 2. Results of Laboratory Testing of Drains for Irrigation Purposes.

Parameters	FAO Standards	WWF Guidelines	Chota Ravi Drain			Saggian Drain			Gulshan-e-Ravi Drain		
			Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
pH	6.5-8.4	6.5-8.5	7.6	7.4	7.2	7.8	7.9	8.0	8.5	7.9	7.8
EC (dS/m)	0.7	1.5	1.3	1.0	1.0	1.2	0.9	0.9	1.2	0.8	0.8
SAR	16	8	2.1	1.9	2.0	2.7	1.6	1.9	1.8	1.5	1.4
RSC (me/l)	1.25	1.25	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
TSS (mg/l)	-	-	265	216	179	287	154	143	306	265	242
TDS (mg/l)	450	1000	978	758	739	878	658	639	870	617	602
Cl (me/l)	4	2.81	4	2.5	2.3	4.8	2.8	2.5	2.8	2.2	2.0
Ca (me/l)	0-20	-	7.1	5.9	3.9	7.9	5.9	2.9	9.9	5.9	5.0
Mg (me/l)	0-5	-	9.8	6.7	3.4	10	8.0	6.7	14	11	11
CO_3 (me/l)	0-0.1	-	7.1	4.1	3.1	6.6	4.4	4.1	3.8	3.2	2.9
HCO_3(me/l)	1.5	-	2.4	2.0	1.3	1.8	1.2	1.1	1.9	1.6	1.4
SO_4 (me/l)	0-20	-	0.5	0.3	0.03	0.4	0.3	0.3	0.4	0.3	0.3
Na (me/l)	3	-	8.3	6.6	3.7	8.1	4.4	4.1	6.4	4.6	4.1
Fe (mg/l)	5	5	0.6	1.8	2.0	0.8	0.9	1.7	0.3	1.0	1.3
Cr (mg/l)	0.1	0.01	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Cu (mg/l)	0.2	0.2	0.4	0.5	0.7	0.4	0.4	0.4	0.3	0.3	0.3
Ni (mg/l)	0.2	0.2	0.2	0.3	0.4	0.1	0.4	0.7	0.7	0.7	0.9

Table 2 (Contd.)

Parameter	FAO Standards	WWF Guidelines	Mian Mir Drain			Kharak Drain			Hadiara Drain		
			Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
pH	6.5-8.4	6.5-8.5	7.9	8.0	8.1	7.7	7.6	7.6	8.9	8.6	8.3
EC (dS/m)	0.7	1.5	1.1	0.8	0.8	1.1	0.7	0.7	1.9	1.2	1.1
SAR	16	8	3.0	2.8	2.9	2.4	2.2	2.3	1.7	1.4	1.4
RSC (me/l)	1.25	1.25	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
TSS (mg/l)	-	-	208	139	129	302	208	197	332	212	202
TDS (mg/l)	450	1000	838	602	591	831	502	494	1398	869	848
Cl (me/l)	4	2.81	2.8	2.2	2.0	2.8	2.2	2.1	9	6.5	6.1
Ca (me/l)	0-20	-	9.9	5.9	5.0	4.9	3.2	3.1	12	6.9	6.7
Mg (me/l)	0-5	-	14	11	11	10	7	6.5	15	9.5	8.8
CO_3 (me/l)	0-0.1	-	3.8	3.2	2.9	3.4	2.5	2.4	5.8	3.4	3.1
HCO_3 me/l)	1.5	-	2.7	2.4	2.4	2.7	2.4	2.4	2.5	1.6	1.4
SO_4 (me/l)	0-20	-	0.41	0.26	0.25	0.41	0.26	0.25	0.72	0.49	0.45
Na (me/l)	3	-	6.8	5.2	5.1	6.8	5.2	5.1	6.5	4.2	3.9
Fe (mg/l)	5	5	0.2	0.6	2.9	0.9	0.9	1.1	0.8	1.5	2.6
Cr (mg/l)	0.1	0.01	0.1	0.2	0.3	0.06	0.3	0.66	0.08	0.1	0.2
Cu (mg/l)	0.2	0.2	0.2	0.3	0.4	0.1	0.4	0.7	0.03	0.07	0.08
Ni (mg/l)	0.2	0.2	0.4	0.5	0.6	0.1	0.3	0.4	0.1	0.3	0.4

Table 3. Results of the Laboratory testing of Control and End Points of the Study for Irrigation Purpose.

Parameter	FAO Standards	WWF Guidelines	River Ravi at Lahore Bridge (Control)			River Ravi at Balloki Barrage (End point)			B-S Link at Balloki Barrage		
			Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
pH	6.5-8.4	6.5-8.5	7.7	7.5	7.2	8.2	8.2	7.8	8.2	8.0	7.8
EC (dS/m)	0.7	1.5	2.1	1.3	0.9	1.4	0.9	0.6	1.3	1.0	0.74
SAR	16	8	4.2	2.8	2.7	2.1	1.5	1.8	2.8	2.6	1.89
RSC (me/l)	1.25	1.25	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
TSS (mg/l)	-	-	580	304	106	337	208	196	369	212	154
TDS (mg/l)	450	1000	1551	975	690	996	689	474	955	740	528
Cl (me/l)	4	2.81	5.5	4	3.6	4	2.6	1.6	4	2.5	2.3
Ca (me/l)	0-20	-	6.7	4.9	4.9	13	7	3.8	7.1	5.9	3.99
Mg (me/l)	0-5	-	10	6.9	6	10	7.2	3.3	9.8	6.7	3.4
CO_3 (me/l)	0-0.1	-	3.3	2.5	1.4	5.8	3	1.4	7.1	4.1	3.1
HCO_3 me/l)	1.5	-	2.02	1.8	0.4	1.7	1.1	0.5	2.4	2.0	1.36
SO_4 (me/l)	0-20	-	3.34	3.0	2.8	0.5	0.3	0.2	0.5	0.3	0.04
Na (me/l)	3	-	12.3	7	6.3	7.4	5	3.5	8.3	6.6	3.7
Fe (mg/l)	5	5	0.54	0.7	3.2	0.7	1.4	3.2	0.2	0.6	2.94
Cr (mg/l)	0.1	0.01	0.08	0.1	0.1	0.04	0.06	0.08	0.03	0.05	0.09
Cu (mg/l)	0.2	0.2	0.3	0.3	0.3	0.04	0.05	0.07	0.04	0.05	0.07
Ni (mg/l)	0.2	0.2	0.01	0.08	0.15	0.02	0.03	0.05	0.02	0.04	0.05

Table 4. Results of Laboratory Testing of the Drains for Recreational Purposes.

Parameters	WWF Guidelines for Recreational Water	Chota Ravi Drain			Saggian Drain			Gulshan-e-Ravi Drain		
		Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
Temp (˚C)	The maximum water temperature change shall not exceed 3ºC relative to an upstream control point.	35	25.2	18.6	34.1	24.6	20.3	34	24.6	20.5
pH	6.5-8.5	7.6	7.49	7.24	7.8	7.93	8.01	7.9	8.06	8.18
EC (dS/m)	1.5	1.37	1.06	1.04	1.23	0.92	0.9	1.1	0.84	0.83
DO (mg/l)	>4	1.62	1.4	1.00	1.54	1.02	1.01	2.1	1.73	1.6
COD (mg/l)	-	302	488	528	302	410	418	275	328	342
BOD (mg/l)	8	111	135	201	132	182	185	101	123	133
TDS (mg/l)	1000	978	758	739	878	658	639	838	602	591
SO_4 (mg/l)	400	24.4	18.9	18.4	21.9	16.4	15.9	20	15	14.7
Fe (mg/l)	-	0.59	1.84	2.06	0.83	0.92	1.75	0.2	0.64	2.97
Cr (mg/l)	0.05	0.11	0.18	0.22	0.12	0.15	0.17	0.1	0.22	0.35
Cu (mg/l)	1.5	0.39	0.56	0.71	0.40	0.43	0.45	0.2	0.37	0.48
Ni (mg/l)	-	0.27	0.32	0.39	0.10	0.41	0.69	0.4	0.53	0.68

Table 4. (Contd.)

Parameters	WWF Guidelines for Recreational Water	Mian Meer Drain			Kharak Drain			Hudiara Drain		
		Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
Temp (˚C)	The maximum water temperature change shall not exceed 3ºC relative to an upstream control point.	33	24.6	18	31	24.6	17.2	37.9	23.3	21.7
pH	6.5-8.5	8.5	7.8	7.8	7.7	7.66	7.63	8.89	8.65	8.32
EC (dS/m)	1.5	1.2	0.86	0.8	1.1	0.70	0.69	1.97	1.22	1.19
DO (mg/l)	>4	1.1	0.93	0.7	1.8	1.4	1.38	1.81	1.08	0.8
COD (mg/l)	-	316	493	515	278	319	326	188	334	452
BOD (mg/l)	8	118	236	243	116	146	153	76.2	147	198
TDS (mg/l)	1000	870	617	602	831	502	494	1398	869	898
SO_4 (mg/l)	400	21.7	15.4	15	19	12.5	12.3	34.8	23.5	21.6
Fe (mg/l)	-	0.38	1.08	1.3	0.9	0.97	1.13	0.85	1.50	2.68
Cr (mg/l)	0.05	0.10	0.16	0.2	0.06	0.30	0.66	0.08	0.19	0.20
Cu (mg/l)	1.5	0.31	0.35	0.3	0.16	0.46	0.75	0.03	0.07	0.08
Ni (mg/l)	-	0.69	0.75	0.9	0.13	0.39	0.47	0.12	0.39	0.42

Table 5. Results of the Laboratory analysis of the water at Control and End Points of the Study for Recreational Purposes.

Parameters	WWF Guidelines for Recreational Water	River Ravi at Lahore Bridge (Control)			River Ravi at Balloki Barrage (End point)			B-S Link at Balloki Barrage		
		Aug	Nov	Jan	Aug	Nov	Jan	Aug	Nov	Jan
Temp (˚C)	The maximum water temperature change shall not exceed 3ºC relative to an upstream control point.	34	25	20	35.6	21	19	30	21.1	19
pH	6.5-8.5	7.75	7.5	7.2	8.2	8.2	7.8	8.2	8.02	7.8
EC (dS/m)	1.5	2.18	1.3	0.9	1.4	0.9	0.6	1.3	1.04	0.7
DO (mg/l)	>4	5.5	1.0	0.8	10.2	6.9	2.6	8.0	4.1	2.8
COD (mg/l)	-	44.1	186	420	21.8	23	65	12	19.2	62
BOD (mg/l)	8	14.5	71	191	7.12	7.5	20	2.9	4.67	21
TDS (mg/l)	1000	1551	975	690	996	689	474	955	740	528
SO_4 (mg/l)	400	160	146	137	25	16	9.9	24	18.5	1.7
Fe (mg/l)	-	0.53	0.7	3.2	0.77	1.4	3.2	0.2	0.62	2.9
Cr (mg/l)	0.05	0.08	0.1	0.1	0.04	0.06	0.08	0.03	0.05	0.08
Cu (mg/l)	1.5	0.33	0.34	0.3	0.04	0.05	0.07	0.04	0.05	0.07
Ni (mg/l)	-	0.01	0.08	0.1	0.02	0.03	0.05	0.02	0.04	0.05

Fig. 2. Comparison of Electrical Conductivity at nine sampling points during monsoon season for irrigation purpose.

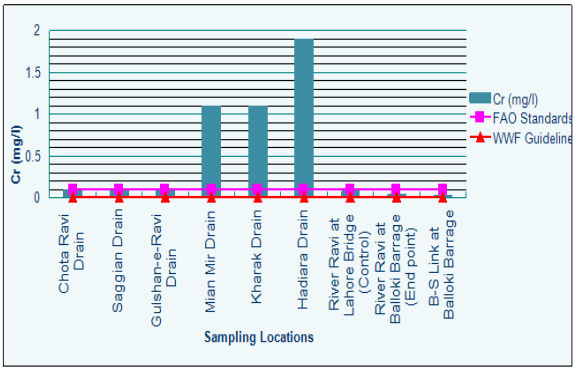

Fig. 3. Comparison of Chromium at nine sampling points during monsoon season for irrigation purpose.

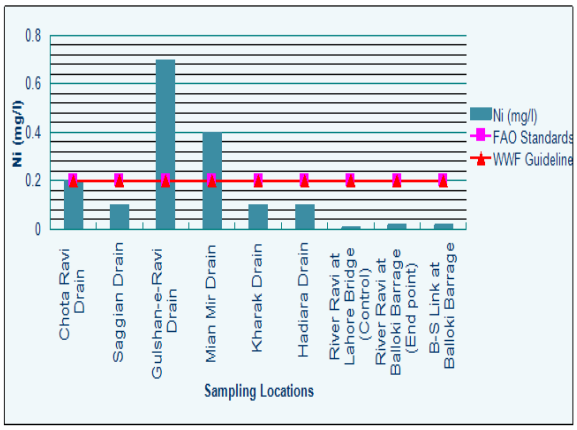

Fig. 4. Comparison of Nickel at nine sampling points during monsoon season for irrigation purpose.

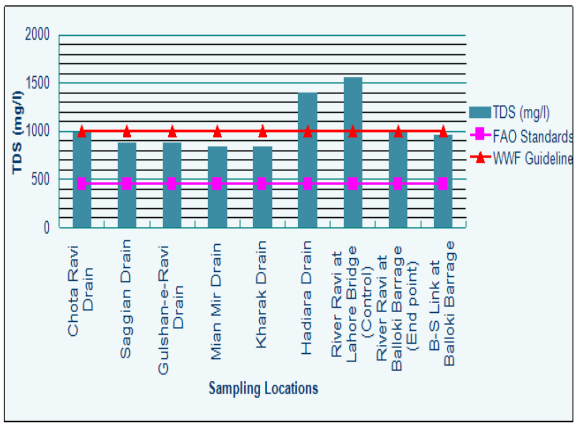

Fig. 5. Comparison of TDS at nine sampling points during high flow conditions for irrigation purpose.

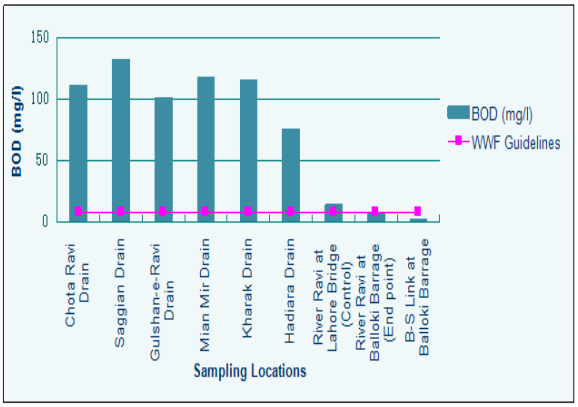

Fig. 6. Comparison of BOD at nine sampling points during monsoon season for recreational purpose.

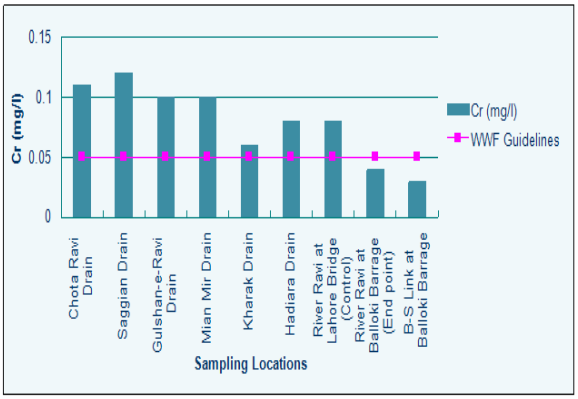

Fig. 7. Comparison of Chromium at nine sampling points during monsoon season for recreational purpose.

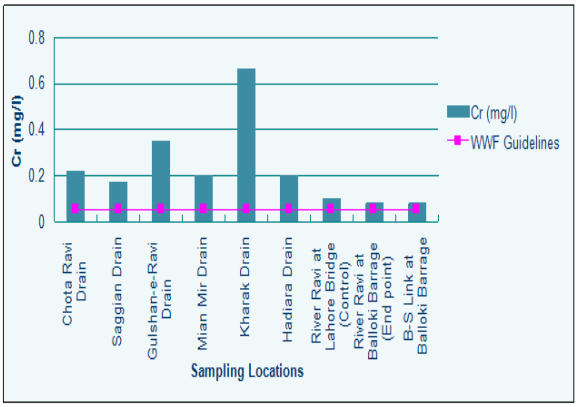

Fig. 8. Comparison Chromium at nine sampling points during reduced flow conditions for recreational purpose.

Chromium is not generally recognized as essential growth element. Conservative limits are recommended due to lack of knowledge on its toxicity to plants (Qayyum and Sabir, 1975). Copper is toxic to a number of plants at 0.1 to 1.0 mg/l in irrigation waters (FAO, 1985). Iron in irrigation water can contribute to soil acidification and loss of availability of some essential elements like phosphorous and molybdenum (Qayyum and Sabir, 1975). Nickel is toxic to a number of plants at 0.5 mg/l to 1.0 mg/l. It has a reduced toxicity at neutral or alkaline pH (FAO, 1985).

Normal Flow Season (November)

During the normal flow conditions, when storm water effect is subdued, there was a decrease in the EC, TDS, cations and anions but they were still exceeding the safe limit of either FAO standard or WWF guidelines or both. Also there was an overall increase in the heavy metal concentration due to decreased dilution effects.

River Ravi at Lahore Bridge during the normal flow conditions showed a change of color from reddish brown to blackish brown. Electrical conductivity and TDS decreased as compared to the high flow season but they were still exceeding the limits of FAO standards. Cations and anions showed the same behavior. Among the heavy metals, chromium exceeded both the FAO and the WWF standards. Concentration of copper also increased. Only nickel remained within the limits of both the standards. Among the drains, all the drains except Hudiara drain showed the same behavior. EC, TDS, cations and anions decreased but still exceeded the standards and copper, chromium and nickel increased in concentrations. In Hudiara Drain, chloride and pH were still higher. Copper, chromium and nickel were within the FAO range but were exceeding the WWF limits. At both the end points i.e. B-S Link Canal and Balloki Barrage, same pattern was followed as that of the drains. EC and TDS decreased as compared to the high flow period along with the decrease in cations and anions. Among heavy metals, only chromium

exceeded the WWF standards for irrigation at both the points.

Low flow season (January)

During the low flow season, when all the fresh water canals were closed for the bi-yearly silt cleanup purpose, the water quality of the study area was found to be most deteriorated for irrigation purpose.

The condition of the River Ravi at Lahore Bridge during this period was appalling. The water flowing through the Ravi was completely sewage water with heaps of tones of solid waste in the watercourse and a very nasty and bad odor of decomposing organic waste in the air. At the control there was a further decrease in EC, TDS, cations and anions but this decrease was not enough to bring the values within the permissible limit of FAO. Among the heavy metals, copper and chromium exceeded the FAO as well as WWF limits. Copper is known to be toxic to plants if present in irrigation water. Same was the situation with the drains with the decrease in EC and TDS and an increase in the concentration of heavy metals. But these changes in the drains were not too much as compared to the variations in the results between high flow to low flow period. This is due to the fact that that canal closure had no effect on the drains. In fact the drains had the most effect on the quality of River and Canal during this period.

As the water flowing through the B-S Link Canal and Balloki Barrage was mostly the sewage water of the drains, so it had all the characteristics of the drain water. EC, TDS, cations and anions followed the same pattern of decrease, while among heavy metals; only chromium exceeded the WWF guidelines at both the points. According to the results obtained from the study, the quality of water flowing through these points was better than that of control. Also, though there was a change in the color of the water and also a bad odor in the air but it was milder than the control and there were no heaps of solid waste in the watercourse.

On an overall basis, as compared to the water quality of the control, the water quality at the end points was much better during all the seasons. After the control, six major sewage drains fall into River Ravi and their effect on the end points of the study reach i.e. B-S Link Canal and River Ravi at Balloki Barrage was especially incorporated during the low or reduced flow conditions. The major problem with the River Ravi waters at the control as well as at end points, according to irrigation point of view, was the exceeding values of electrical conductivity . More the amount of cations and anions in the irrigation water, more will be its EC. This is an important parameter because it increases the salinity of irrigation water and leads to the addition in the stock of saline lands.

Recreational use

To discuss the use of River Ravi waters for recreational purpose, the results of the study were compared with the National Surface Water Classification Criteria proposed by WWF Pakistan (WWF, 2007). Waters for this class are intended to be primary contact recreation such as bathing, swimming, skin divining etc. The suitability of River Ravi waters at Lahore Bridge and Balloki Barrage for recreation purpose is discussed on the basis of seasonal variations. In a developing country like Pakistan, water quality problems are the main causes of a large number of diseases prevailing in the society. This is due to the fact that most of the people do not have access to clean and safe water for recreation purpose, either for swimming or bathing. During the field visits, a large number of people, especially the children were observed to be swimming, bathing and playing in the drains. Hence due to these circumstances, the drains were also considered as recreation spots for masses in this study, therefore the water quality of drains is also evaluated according to the standards drafted by WWF Pakistan (WWF, 2007).

High flow season (August)

During the monsoon period, maximum dilution was observed, that reduced the concentration of most of

the chemical and biological contaminants for the time being. The River Ravi at Lahore Bridge that was taken as control was found to have higher EC and correspondingly higher amount of TDS, higher BOD and increased chromium level as compared to the standards drafted by WWF, Pakistan for recreational use of water (WWF, 2007).

Similarly, Chota Ravi, Sagian, Gulshan-e-Ravi, Kharak and Hudiara Drain had decreased DO, BOD and Chromium concentration even during the monsoon period. Mian Meer Drain also showed increased level of copper in addition to the above mentioned parameters. So these sewage drains are in no case suitable for recreation purpose.

River Ravi water quality during maximum dilution period was perfectly well within the standards drafted by WWF, Pakistan for recreational purposes both at Balloki Barrage and B-S Link Canal from where the water serves a vast downstream area.

Normal flow season (November)

This is the period in which there is normal discharge in river and drains and there is no or minimized effect of storm water or rainwater. The DO at control decreased deviating a lot from the proposed standards and simultaneously increasing the BOD. The TDS decreased to an acceptable level due to minimized effect of flooding that brings with it a lot of dissolved solids. Also there was an increase in the concentration of chromium due to reduced storm water effect. Similar trend was observed in the results of all of the drains. Thus they become more hazardous to be used for recreational purpose during this season. At B-S Link Canal and Balloki Barrage, all parameters were well within permissible limits except that there was a very slight increase in the chromium concentration in B-S Link Canal and at Balloki Barrage.

Low flow season (January)

During the canal closure period, there was a further decrease in the value of DO and it fell to an alarmingly low level of less than 1 mg/l. This increased the BOD of the water at control point to a very high value of 191 mg/l. Also there was an increase in the concentration of chromium as compared to the normal flow period. Same was the case with the sewage drains carrying the waste of the city of Lahore into the River Ravi. During this canal closure period, the water flowing through the River Ravi in Lahore-Balloki reach comprises of drains effluent only. There is no entry of fresh water to dilute the wastewater effects. All the six drains within the study reach showed a slight decrease in the DO and slight increase in BOD and chromium concentration as compared to the normal flow conditions. These variations were little as compared to the variation in the results of high flow and normal flow situations. This is due to the fact that canal closure period affects only the waters in rivers and canals and not in the drains. The water quality results of the final point of the study reach i.e. Balloki Barrage and B-S Link Canal unveiled a further increase in the concentration of chromium. Only those parameters exceeded the safe values proposed by WWF Pakistan at the end point that deviated at the control and in the drains.

Conclusions

On the basis of the results and their discussion the outcome of the study are as follows:

1. Increased flow during monsoon season provides sufficient flushing effect on the system but it also has the potential to introduce stored pollutants that would otherwise have remained in place. In particular, there is potential for disturbed soil sediments to bring with them adsorbed pollutants such as biocides. However the dilution effect is such that these pollutants are not significant.

2. Water quality of the tail reach was better than the water quality at the control and water quality of B-S Link Canal was better than the water quality of River Ravi at Balloki Barrage during all the sampling durations for all the designated uses.

3. Water quality criterion for irrigation purposes was also met at the control as well as tail reach during the high and normal flow conditions in term of SAR, RSC and heavy metals. Only TDS exceeded the irrigation standards. However irrigation water quality of drains did not meet the required criterion in any sampling duration especially in terms of heavy metals and TDS.

4. Use of sewage water from the drains for growing of vegetables and fruits around the periphery of the city should be modified by mixing it with fresh water in some proportion to minimize the deleterious effects of raw sewage.

5. In case of paddy rice fields, zinc should be added to the soils before flooding it with water high in bicarbonates as bicarbonates remove zinc from the soil that is an essential micronutrient for the rice field.

6. People must be provided with better and cheap recreation facilities to strictly prohibit the use of drains for recreation purpose.

7. There is also a need to look at other options than wastewater treatment, to minimize the negative impacts of untreated wastewater irrigation, and come up with more realistic alternatives for wastewater treatment under the given set of social and economic conditions.

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