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WATER QUALITY ASSESSMENT OF RIVER KABUL AT PESHAWAR, PAKISTAN: INDUSTRIAL AND URBAN WASTEWATER IMPACTS

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Untreated wastewater discharges may have significant short term and long term effects on the quality of a river system. Present study was undertaken to assess the present status of the water quality of River Kabul near Peshawar in Pakistan. Seven sites were sampled upstream and downstream in River Kabul in 2009. Samples were also taken from waste water channel (Budni Drain) that carries wastewater of Peshawar Industrial Estate as well as the domestic sewers to assess the pollution contribution of these sources to River Kabul. Physico-chemical and microbiological parameters of the samples were analyzed during the study, as well as possible sources of contamination were investigated. The study showed that the pollution level in river is rising from upstream (at city entrance) to downstream (at city exit) due to discharge of domestic waste water effluents, agricultural activities, and solid waste dumping directly into the river.

Keywords: River Kabul (Pakistan), water quality, industrial waste water, physico-chemical, microbial parameters, heavy metals.

Introduction

Water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions. A regular monitoring of water bodies with required number of parameters in relation to water quality not only prevents the outbreak of diseases but also help to mitigate occurrence of hazards [1]. Rivers are vital and vulnerable freshwater systems that are critical for the sustainability of all life. However, the declining quality of the waters in these systems threatens their sustainability. Rivers are waterways of strategic importance across the world, providing main water resources for domestic, industrial, and agricultural purposes [2]. Discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial wastes discharges, agricultural runoff and other sources, all of which may be untreated, can have both short term and long term significant effects on the quality of a river system [3]. It is a common practice for people living along the river catchments to discharge their domestic waste as well as human excreta into rivers [2, 4].

Rivers included in most recent studies are the Huluka and Alaltu Rivers of Ambo, Ethiopia [5], Juru River, Malaysia [6], Owo River, Lagos-Nigeria [7], Neponset Watershed, Massachusetts, US [8], Sabarmati River at Ahmedabad, India [9], Guksu River, Turkey [10], River Mahi, India [11]. Nansha River, Beijing Central Region China [12], Jiulong River, China [13], River Tame, Birmingham, UK [14], Weihe River, China [15], Chenab River, Pakistan [16]. Water quality of few rivers like Siran river [17], Chenab [18], Indus at Kotri [19], Neelam [20] and Lei [21] have been reported in Pakistan. Studies on the water quality of River Kabul of NWFP [22] under High River flow and Kabul at Noshera [23] has been conducted more than a decade ago. Results from these studies revealed that anthropogenic activities greatly deteriorated water quality in the downstream sections of the major rivers as a result of cumulative effects from upstream development and in small tributaries with inadequate wastewater treatment facilities.

The study area starts from Warsak dam up to 50 km downstream (Khyber Pakhtunkhawa Pakistan). The river receives wastewater from domestic sewers, storm water discharges, industrial wastes discharges and agricultural runoff covering an area of 1257 km^2 with a population of more than 3.6 million. Peshawar Industrial Estate (Hayatabad) is located on the Peshawar Jamrood Kabul Highway in the North West of Peshawar. According to Sarhad Development Authority, the "Hayatabad Industrial Estate" (HIE) housed 272 operational units. HIE spread over an area of 884 acres, can be divided into six main domains namely, Match, vegetable ghee/oil, pharmaceutical, marble, chemicals and woolen mills.

The quality of river was studied more than a decade ago in relation to industrial effluent load at Noshera which is 61 km downstream to Kabul at Warsak (Peshawar) [22]. With the rapid expansion of industrialization and population growth caused concerns over the water quality of the River Kabul. The whole region relies on the water supplied by the Kabul for its agriculture, domestic and industrial activities. Untreated wastewater discharges into freshwater bodies like River Kabul may affect the aquatic biota as well as dependent human communities indirectly. It is therefore imperative to assess the status of water quality of river and industrial waste water pollution.

Study area and monitoring sites. The study area is located in the Peshawar Division (Khyber Pakhtunkhawa Pakistan), starting from Warsak dam up to 50 km downstream to River Kabul. Sampling from industrial wastewater at (Budni Drain) before joining to Shah Alam River (one of the River Kabul branch after splitting into three) was also carried out. Other seven sampling stations were selected on main River Kabul and its three main branches after splitting, after joining branches and after the joining of Swat River to main River Kabul (Fig. 1).

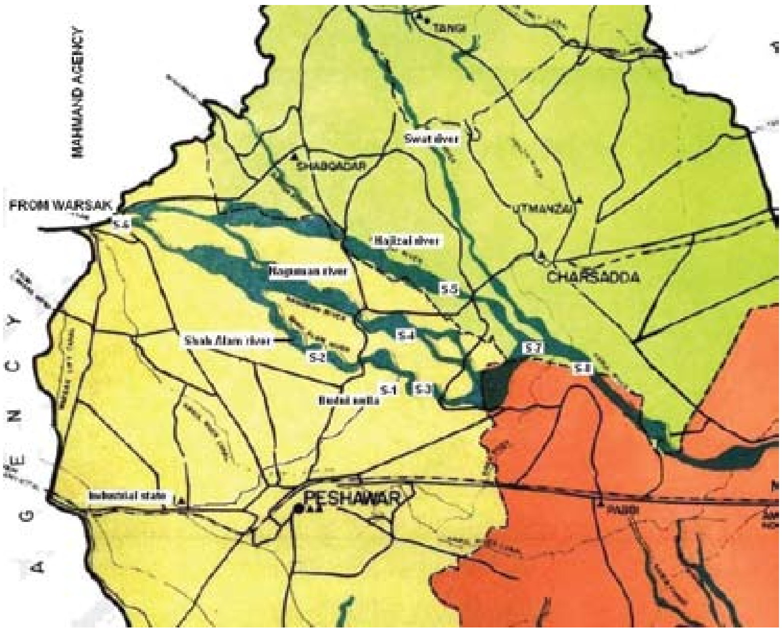

Fig. 1. Map of River Kabul showing sampling sites.

Water sampling and chemical analysis. Water samples were collected twice in winter spell (December, January) and summer spell (June, July) in 2009 from the allocated sampling sites (see Fig. 1). Water samples (1500 ml each) were collected manually at each site using acid-washed (10%, *v/v* HCl) into HDPE bottles. The pre-washed bottles were rinsed thrice with water samples on the site before sample collection.

Water samples were stored in a cooler box and transported to the laboratory. Chemical oxygen demand (COD) concentration was determined by analyzing the oxygen demand by using colorimetric method (Lovibond, Dortmund, Germany) [24]. Total suspended solids (TSS), Alkalinity (A_T), Cations and Anions, *E. coli* were determined using Standard methods for water and wastewater treatment [24]. The pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS) and temperature were measured on-site using DO/EC meter (Hanna, USA). Turbidity (Nephlometric turbidity unit; NTU) measurement was made by using turbidity meter (Lovibond, Dortmund, Germany). Sampling was always done in clear weather condition to prevent any abrupt changes in measurements, and to avoid unsteady conditions; sampling was not conducted after rainfall events. Sampling and measurements along each individual site were done continuously from upstream to downstream.

Results and discussion

The values of various physicochemical parameters at different sampling sites (S-1–S-8), and their average of all sampling sites along with the National Environmental Quality Standards (NEQS), National Standards for Drinking Water Quality Pakistan (NSDWQ-Pak), US and EU values for surface waters have been given in Table [25]. The rapid urbanization and industrial development has created severe pollution loads in inland surface water bodies in urban localities. Chemical quality assessment of such surface bodies may widely reect the pollution load and anthropogenic pressure on surface water systems. Water entering a river environment is derived mainly from three important sources; surface run-off, through flow and interflow and base flow or ground water flow [26]. All these sources have a direct influence on the net chemical composition of river waters. River water is generally a dilute aqueous solution whose chemical qualities are acquired from atmospheric, soil, and rock sources, the relative contributions of which is a function of climate modified by human activities both directly by effluent discharges and indirectly by agricultural activities, land-use/land-cover changes and pollutant discharges [27].

The surface water pollution issue has been enlisted as one of the most serious problems in developing countries. Most of the rivers in the urban areas of the developing world are the end point of effluents discharged from the industries. In Pakistan, urban runoff and sewerage disposal in river catchments areas is the major problem of river water quality maintenance. The wastewater from urban runoff and industrial discharges contributes to water resources degradations, reduces agriculture production and affects public health.

Averages values of water quality parameters of the River Kabul along with standard limits of fresh water and wastewater by NSDWQ-Pak, USEPA and EU

	Fresh water Quality					Wastewater quality		
Parameters	NSDWQ Pak	EU drinking water standards	USA Irrigation water quality	Present study (Mean)	Previous study[22] (mean)	NEQS Pak	USEPA	Mean values
Temp (C)	–	–	–	18±0.5	25	–	–	20±0.1
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 8.4	7.5±0.1	7.6	6 – 9	6.5 – 8.5	7.6±0.05
EC (μs/cm)	–	2500	< 700	609±9	265	–	–	1151±121
DO (mg/L)	–	5.0	4.0 – 6.0	5.6±0.1	6.3	–	4.0 – 6.0	1.7±0.05
TSS (mg/L)	–	–	5	490±12	–	200	5	900±51
TDS (mg/L)	< 1000	–	< 450	577.8±15	–	3500	500	1753±56
Turbidity (NTU)	<5	–	–	47.7±5	–	–	–	117.6±6
COD (mg/L)	–	–	–	116±2	78	150	4	932±16
Alkalinity (mg/L)	< 500	–	–	140±4	92	–	–	230±12
Nitrate (mg/L)	50	50	–	10.3±0.5	1.26	–	0.1	28.5±2
Sulfate (mg/L)	–	250	–	126.7±9	31	600	250	570±12
Chloride (mg/L)	< 250	250	< 140	196.5±11	12	1000	250	675±10
Cr^{3+} (mg/L)	0.05	0.05	–	0.5±0.01	–	1	–	1.81±0.05

Cont.

Cu^{2+} (mg/L)	2	2	–	0.07±.0.01	–	1	–	0.5±0.05
Fe^{2+} (mg/L)	–	0.2	–	1.1±0.01	–	2	–	3.5±0.1
Ni^{2+} (mg/L)	0.02	–	–	0.2±0.01	–	1	–	1.5±0.05
Cd^{2+} (mg/L)	0.01	0.005	–	0.03±0.01	–	0.1	–	0.5±0.05
Pb^{2+} (mg/L)	0.05	0.01	–	0.52±0.01	–	0.5	–	1.3±0.1
E.Coli (CFU/100 mL)	Nil	Nil	–	1740±50	–	Nil	Nil	11x106±1000

The analysis results of study sites were given in Fig. 2 – 4. The pH is the indicator of acidic and alkaline condition of water status. NEQS suggest 6.5 – 8.5 range of pH for water for any purposes in that respect; the mean value indicated moderately alkaline water of river. The pH varied from 7.4 to 7.6 in various sampling sites, with maximum of 7.7 of site S-1, which is the pH of Budni nullah, which joins to Shah Alam branch of River Kabul (see Fig. 1). Higher pH could be attributed to bicarbonates and carbonate of calcium and magnesium in water which may be due to the geology of the region in which limestone is the most common.

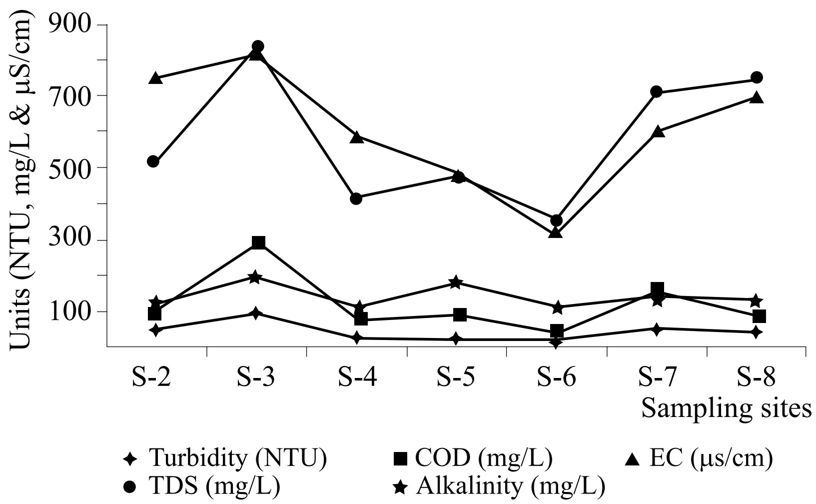

Fig. 2. Variation of Turbidity, COD, EC, TDS and Alkalinity of River Kabul for various sampling sites.

DO may be a potential indicator of river quality in assessing urban impacts on river ecosystem. DO of River Kabul ranged between 3.0 mg/L to 7.5 mg/L with mean of 5.6 mg/L. The maximum mean DO was found at S-8 (7.5), followed by S-6 (7.3) both points are the entry and exit of the river to region (see Fig. 1). This further indicated the turbulences and owrate of river water at different sites, which may be benecial for dissolved solid breakdown through self-pollution regulating mechanisms of fresh water system. A sharp decreasing trend was observed down stream at S-3, where Budni Drain meets upstream fresh water. The water quality in terms of DO content is always of primary importance because at the waste discharge points in river, the DO is required for aerobic oxidation of the wastes. Also, DO levels are important in the natural self-purication capacity of the river. A good level of DO in sampling sites of the river indicated a high re-aeration rate and rapid aerobic oxidation of biological substances. The difference among sampling sites for DO was of least significance in upstreams and probably it might be related directly to the turbulences and owrate of water in the river system, however in down streams (Shah Alam branch) lower DO values indicate the level of pollution due to anthropogenic activities.

COD is also an important parameter of water indicating the health scenario of freshwater bodies. COD is often used as a measurement of organic pollutants in natural and waste waters and to assess the strength of waste such as sewage and industrial effluent waters. COD varied from 75–282 mg/L with mean of 116 mg/L of the river (see Fig. 2). A trend of increasing COD level was observed at downstream sites (S-3 and S-7); however, it diluted to lower value at S-8 downstream, where Swat River joins the Kabul River. Higher COD at S-3 shows the pollution load caused by the mixing of sewage water, garbage dumping and industrial effluents without any pretreatment.

Conductivity of river water was not signicantly different among sampling sites except upstream at S-6 which is possibly dilution due to huge water reservoir of Warsak Dam. The values varying from 320 to 821 μs/cm with mean of 609 μs/cm (see Fig. 2). High conductivity at sites S-3 indicates the mixing of the industrial and sewerage waste in river water as this site is located downstream to S-1 whose conductivity was found to be 1151 μs/cm.

There is no significant variation observed in turbidity of River Kabul for different sampling sites (see Fig. 2). Turbidity varied from 18 to 99 NTU with mean of 45 NTU. It was higher possibly due to the mixing of domestic sewerage water and industrial efuents in river (at S-3). The increasing turbidity at downstream sites was due to the ow turbulences (at S-7) and further decreasing due to settling factors.

TDS and A_T further indicate the salinity and alkalinity behavior of river water. TDS and A_T content of river water was in the range of 350 – 830 mg/L and 115 – 195 mg/L with mean of 578 to 140 mg/L respectively. The maximum TDS and A_T was observed at S-3 sampling site indicating the mixing of pollutants in river from anthropogenic activities by well populated city such as the mixing of sewerage, clothes washing and garbage dumping, which are some common activities at the riverbank in this area. The overall increasing order of TDS was observed from upstream to downstream of the river (see Fig. 2). Higher TDS in water system increases the chemical and biological oxygen demand and ultimately depletes the dissolved oxygen level in water.

Anion concentrations of Cl^-, NO^{3-}, and SO_4^{2-} values are given in Fig. 3.

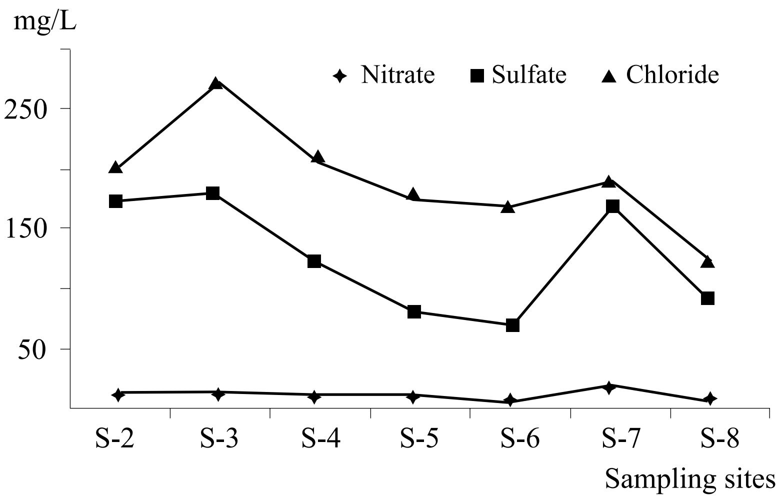

Fig. 3. Variation of anions of River Kabul for various sampling sites.

The values of these ions in River Kabul water is not exceeding the guideline values of NSDWQ and EU drinking water standards, however the chloride contents in water is higher than the US irrigation water guideline value (see Table). The detection of higher concentration of chloride in freshwater suggests the presence of pollutants. Nevertheless, chloride concentration at different sampling site did not exhibit a clear trend with respect to point or non-point pollution sites. Anions content of Cl^-, NO^{3-}, and SO_4^{2-} varied from 120 – 270, 8 – 13.2 and 70 – 180 mg/L with mean of 196.5 mg/L, 10.3 and 126 mg/L respectively (see Fig. 4). An ion concentration values in S-1 exceeds the limit of USA wastewater effluent, however under the acceptable values of NEQS-Pak.

Heavy metals are known to have serious health implications including carcinogenesis induced tumor promotion [28]. The growing consciousness about the health risks associated with environmental chemicals has brought a major shift in global concern towards prevention of heavy metal accumulation in soil, water and vegetables. Atmospherically driven heavy metals have been shown to significantly contaminate soil and vegetables causing a serious risk to human health when plant based foodstuffs are consumed [29]. Dietary intake of trace elements depends also on irrigational water use. There may not always be a strong relationship between the concentrations of trace elements in soil and plants, but there always exists a strong relationship between their concentrations in irrigational water and plants [30].

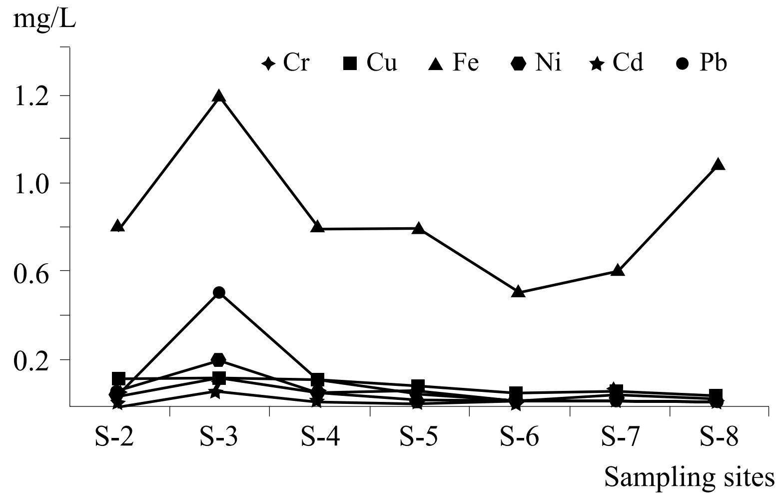

Fig. 4. Variation of heavy metals of River Kabul for various sampling sites.

Thus, the deposition of heavy metals in water bodies can doubly increase the human intake through food chain as well as through drinking water. Most of the surface discharge sources contaminate soil and water bodies especially the industrial waste water without pretreatment which carries large amount of heavy metal.

The concentration values of Fe [Fe(II)+Fe(III)], Ni(II), Pb(II) was found to be higher than the NSDWQ and EU drinking water guidelines (see Table), where as Cr [Cr(III)+Cr(VI], Cu(II) and Cd(II) are present under the standard limits. The values of Fe, Ni, Pb varies from 0.5 – 1.4, 0.01 – 0.2, and 0.01 – 0.5 mg/L respectively (see Fig. 4). Most of the heavy metal pollution is caused by the mixing of Industrial wastewater; however geology of the regions is also contributing in this load.

The coli-form bacteria count (*E. coli*) in the river water is also alarmingly high and is a potential threat to humans' population in vicinity of the river which uses its water. Fig. 5 shows that up stream sampling site of S-6 are less polluted with an average of 650 CFU/100 mL. The most polluted site was found to be the S-3 due to S-1 waste water mixing downstream. Kabul River also shows the bacterial pollution, even after joining of Swat River downstream at S-8 which also shows the level of bacterial pollution in Swat River. The *E. coli* values of river varied from 551 – 5230 with mean of 1740 CFU/100 mL.

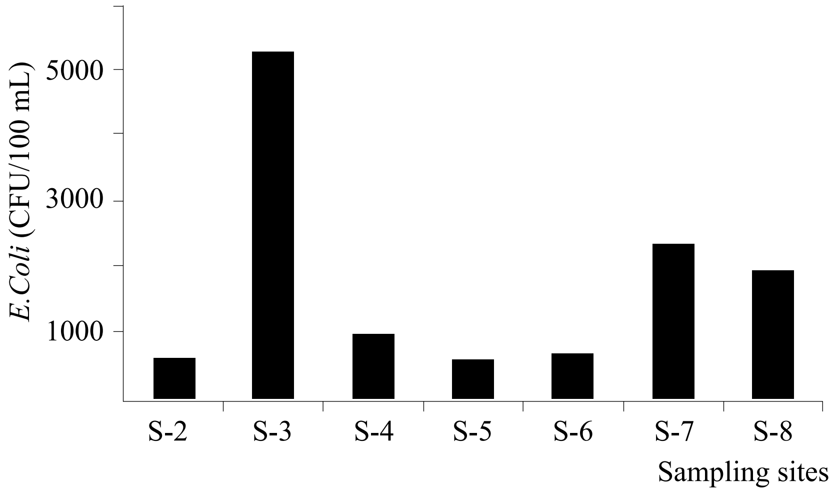

Fig. 5. Variation of E. Coli of River Kabul for various sampling sites.

Upon the comparison of NSDWQ, EU and US standards that no colonies should be found in 100 ml of sample (see Fig. 5). Variation of *E. coli* of River Kabul for various sampling sites. This contamination is caused by discharge of domestic waste water directly into the river without any treatment, open defecation by people, runoff from agricultural land into river as animal manure is used in the fields as fertilizers.

Conclusions

The water quality of the River Kabul is deteriorating due to several factors; most noteworthy is the anthropogenic activities like, agriculture, industry, domestic use of water and discharge in to the river without any pretreatment. Most of the parametric values show increasing trend during last decade. Increased anion concentration, high EC, COD, *E. coli* and low DO over the period of time suggesting that the agriculture water runoff, industrial and domestic wastewater was being mixing in River Kabul. The following recommendations have been proposed.

– To increase the availability and conservation of water, the water used in industries of HIE for cooling and other purposes may be reused.

– Recycling of waste and bi-product recovery practices should be encouraged to save the resources.

– Pollution control measures may be immediately adopted in HIE Peshawar e.g. wastewater treatment facilities may be installed in the industrial area, other than the old outdated previously installed. Each industry should have primary treatment including screening, sedimentation and neutralization on the premises of the factory to decrease the load of suspended materials and minimize the extent of pollution load and reduce biological oxygen demand, prior to their discharge into the receiving water bodies.

– Agricultural runoff, use of pesticides and fertilizer should be controlled through awareness and education in the down stream project area.

– In HIE industries may be categorized in term of wastewater disposal. The wastewater of these industries may be collected and treated/disposed at one place to help in abatement of pollution. For example marble factories waste water/effluents could be collected at one place and separate treatment could be caries out.

– Integrated approach for effective solid waste management needs to be adopted to stop pollutants entrance into surface and ground water sources present in the project area. It should be obligation of all the relevant agencies to regularly test the industrial effluents either through their own or other certified well-known laboratories of repute in the country.

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