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Hudiara Drain - A Case of Trans-boundary Water Pollution Between India and Pakistan

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Abstract: The present study monitored the water quality of Hudiara drain using 72 water samples from three sampling points on a fortnightly basis and analysing for a range of water quality parameters. Large variations were found in almost all water quality indices with most of the lower values being observed during the monsoon season (July to September). Mean dissolved oxygen (DO) was below 1 mg L^{-1} at all sampling points. Mean biochemical oxygen demand (BOD, 104-115 mg L^{-1}) and chemical oxygen demand (COD, 255-276 mg L^{-1}) values exceeded the Pakistan National Environmental Quality Standards (NEQS) for industrial effluents. Although mean total dissolved solids (TDS) and metal concentrations (Cd, Cr, Cu, Li and Pb) of the drain's water were below the limits set for industrial effluents (NEQS), concentration of most of these indices (e.g. TDS, Cd and Cu) was above the acceptable limits of irrigation water. Between points, the TDS values were found lower at point 1 and the converse was the case for most of the metals at that point. *E. coli* were found above 200 MPN 100^{-1} ml at all sampling points. The daily contribution of pollution load of Hudiara Drain to the River Ravi in terms of TDS, BOD and COD was 354, 45, 111 tons respectively. Prolonged use of water of the Hudiara drain for irrigation may be harmful to soils due to high TDS. Similarly, long term use of the drain's water for irrigation may cause accumulation of Cd, Cu and Mn above the limits known to cause soil pollution. With an annual discharge of approximately 180 cusecs, Hudiara drain is one of the main causes of both chemical and biological contamination in the River Ravi. Poor water quality and stress on aquatic life in the River Ravi, especially during low flow may be largely attributed to Hudiara drain.

Key words: Wastewater, dissolved oxygen, biological oxygen demand, chemical oxygen demand, *E. coli,* metals

Introduction

The importance of technological advancement and industrial development has to be continued to serve the ever-increasing demand of human being. However, this development should not be at the cost of the degradation of natural resources. Like other developing countries, a quarter of a century ago industrial development started both in Pakistan and India. However, little attention was given to the problems associated with this development. This was primarily because organisations, for example environmental protection agencies, either did not exist in these countries or did not realize the importance of sustainable development. Only recently it has been realised that there is a significant threat to the environment from the effluent and toxic emissions of industries, from the vehicular emissions and chemical usage in agricultural sector.

Contamination of soils around industrial units or near mining activities is quite common. In contrast, air pollution does not respect boundaries and quite often toxics released in one country can be detected in neighbouring countries. Like soil contamination, water contamination is mainly confined to individual countries: however, there are examples of trans-boundary water pollution as well. One such example is Hudiara drain, which originates in Batala of Gurdaspure District, India and enters Pakistan near Laloo village. This drain is one of the main tributaries of River ravi. The total length of Hudiara drain is 98.6 and 44.2 km in Indian territory and 54.4 in Pakistan territory.

This drain was a storm water drain, however, dumping of industrial and domestic wastewater has turned it into a perennial drain. Its annual average discharge at its confluence with the Ravi is 178 cusecs. There are approximately 84 industries of different nature situated along Hudiara drain in Pakistan, which dump effluent into it. In addition, wastewater of some parts of Lahore city and of other small villages also enters this drain.

Water, which is of critical importance to life and environment, must be of certain standards. It would not support normal aquatic life if, for example, its dissolved oxygen (DO) content was below 4 mg L^{-1} or biochemical oxygen demand (BOD) was above 8 mg L^{-1} (Wedmemayer and Wood, 1974). Similarly, water used for irrigation purposes has to meet irrigation standards (Ayers and Wescot, 1989). A series of studies conducted by different researchers and organisations reported that the quality of Hudiara drain water had deteriorated over the time. For example, according to one study conducted in 1977 by the Institute of Public Health Engineering and Research (IPHER, 1977), the quality of Hudiara drain in terms of DO and BOD was acceptable; BOD and DO were in the ranges of 2-33 and 2-6 mg L^{-1}, respectively. However, ten years later (1987) a study conducted by Balfours Consulting Engineers found an almost four fold increase in BOD (120 mg L^{-1}) (BCE, 1987). Recently Ziai and Ahmad (1996) reported that BOD and DO of Hudiara drain varies from 162-177 and 1.5-1.8 mg L^{-1}, respectively.

Based on the source, wastewater/effluent may be a potential source of metals (e.g. Cd, Cr, Cu, Li, Ni, Pb and Zn etc.) contamination (McLaren and Smith, 1996). Metals are non-biodegradable and can accumulate in organisms or in soils irrigated with such industrial effluent for extended periods (McGrath *et al.,* 1994). In addition, wastewater from human settlements might be a potential source of biological (bacteria, viruses and protozoa) contamination (Nebel and Wright, 1996).

Earlier research work on the Hudiara drain was mostly based on short-term studies with water samples taken either once or at irregular intervals for a short period of time. Similarly, metals as well as biological contamination were not taken into consideration. The main objective of the present study was to assess the extent of pollution of Hudiara drain at three different strategic points in Pakistan in a systemic way (fortnightly basis) for 12 month period. This would assess the pollution status of Hudiara drain at its entry point into Pakistan and its contribution in terms of total pollution load to River Ravi. Water quality monitored in terms of temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved solids oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), heavy metals (Cd, Cr, Cu, Li and Pb) and *E. coli.*

Materials and Methods

Project location and duration: Project location was 54.4 km stretch of Hudiara drain in side Pakistan from entry point (Pak-India border) to River Ravi. Water sampling collected on a fortnightly basis for one year from April 2000 to March 2001.

Sampling points: Based on the initial survey of Hudiara drain, three sampling points were selected for water sample collections (Fig. 1).

The first sampling point (point 1) was chosen near Pak-India border (Laloo village) to assess the quality of the drain's water at its entering point in Pakistan. The second sampling point (point 2) was near Multan road; downstream of Sattokatla drain. Sattokatla drain is one of the main tributaries of Hudiara Drain and receives some of the wastewater of the Metropolitan Corporation Lahore and some industries. This point was chosen to estimate the extent of pollution contributed by most of the industrial units and human settlements (e.g. Lahore city) along the drain in Pakistan. The third sampling point (point 3) was before drain confluence with the River Ravi, which assessed the contribution of pollution load that Hudiara drain contributes to the Ravi.

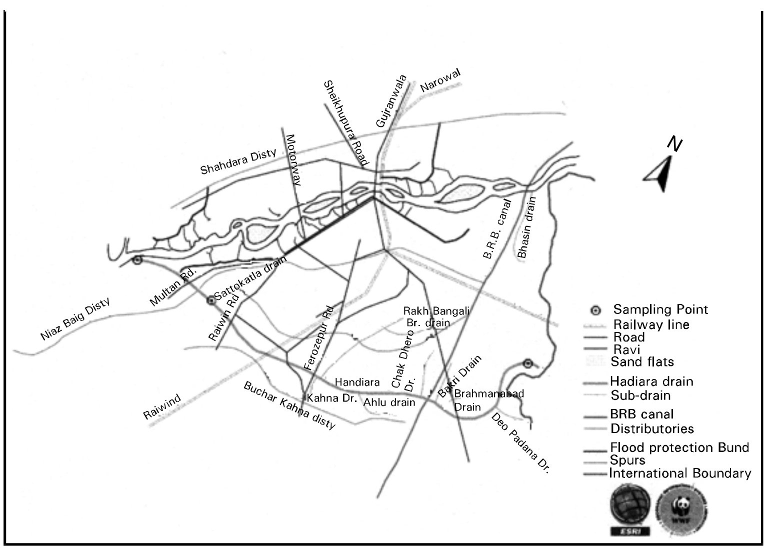

Fig. 1: Index plan of Hudiara drain in Pakistan territory (map is not according to scale)

Sampling procedure: Water samples from Hudiara drain were collected for 12 months (April 2000 to March 2001) on a fortnightly basis. At each sampling point, 24 water samples were collected over the whole monitoring period (12 months). The grab method was used for water sample collections. Each sample consists of 3-4 sub samples. Water samples were placed in labelled polythene containers, transported to the laboratory the same day and stored at appropriate temperature before measurement could be started. Temperature, pH, EC, TDS, DO and discharge were measured in the field. BOD, COD, metals (Cd, Cr, Cu, Li and Pb) and *E. coli* were measured in the laboratory.

Analytical measurements: Hydrolab Quanta (Hydrolab Corporation, version, 2000) was used for on the spot measurements of temperature, pH, EC, TDS and DO (Quanta, 2000). Discharges at all three points were measured by the float method. This method considers width and depth of the drain's water and the time taken by an object to float per unit distance.

For all other parameters, most of the standard analytical procedures (American Public Health Association, 1989) were adopted (APHA, 1989). For BOD (5-days), reduction in DO was measured over a five days period whereas for COD calorimetric method was used (USEPA, 1983). Metals (Cd, Cr, Cu, Li and Pb) were determined by atomic absorption spectrophotometry (Varian model 1275-A). *E. coli* was estimated by bacterial density based on the most probable number (MPN) (APHA, 1975).

Total pollution load (tons day^{-1}) in terms of TDS, BOD and COD was calculated from discharge data and corresponding values of these parameters for all three sampling points.

Results and Discussion

On each sampling occasion, water samples at all three points were collected on the same day and with an interval of 2-3 h. Furthermore, parameters for each sampling occasion were tested under similar laboratory condition. Therefore, the data obtained for three points is comparable and discussed together.

During the monitoring period, Hudiara drain water temperature varied between sampling points and for different sampling dates at each sample point. However, the average temperature for 12 months at all three sampling points was similar (approximately 27^{0}C) and ranged from 14–37^{0}C (Table 1). As expected, the lower values were observed in winter whereas the highest were in the summer.

Overall, the drain's water pH is alkaline with little variation between sampling points. For all three points, greater values of pH were noticed between the months of October to February, which may be attributed to lower water temperature during this period (Table 1). High temperature favours the breakdown of organic carbon by microorganisms, which produces organic acids; production of such acids lowers the water pH.

The average EC for 11 months (measurement of this parameter started a month latter than other parameters)

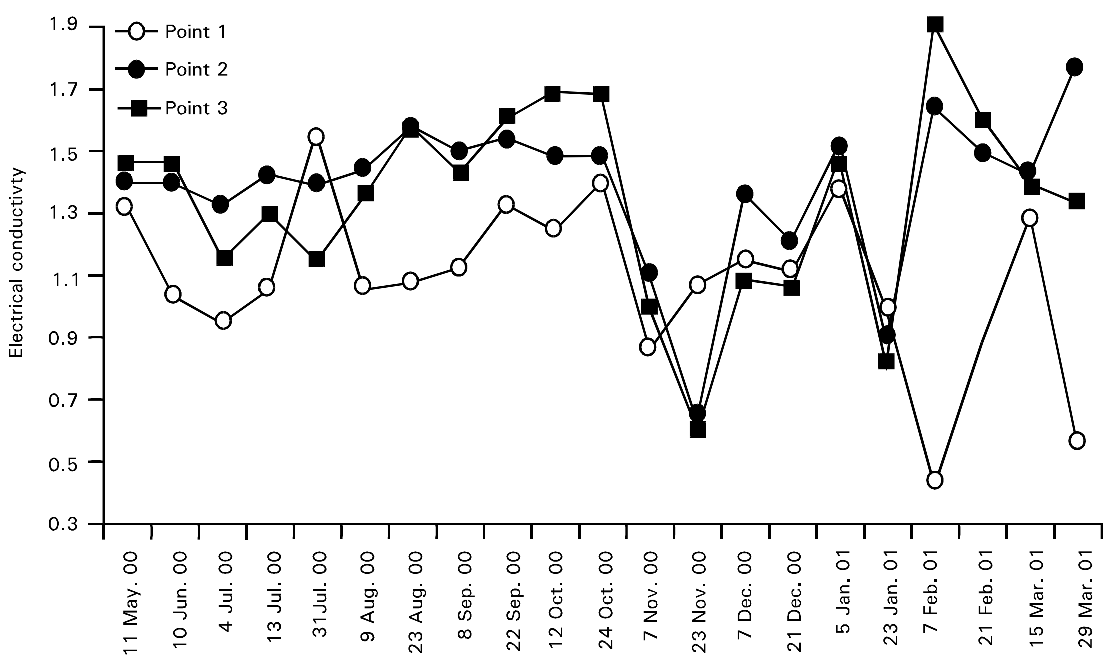

Fig. 2: Fortnightly measurement of electrical conductivity (µS cm^{-1}) of Hudiara drain's water at three sampling points

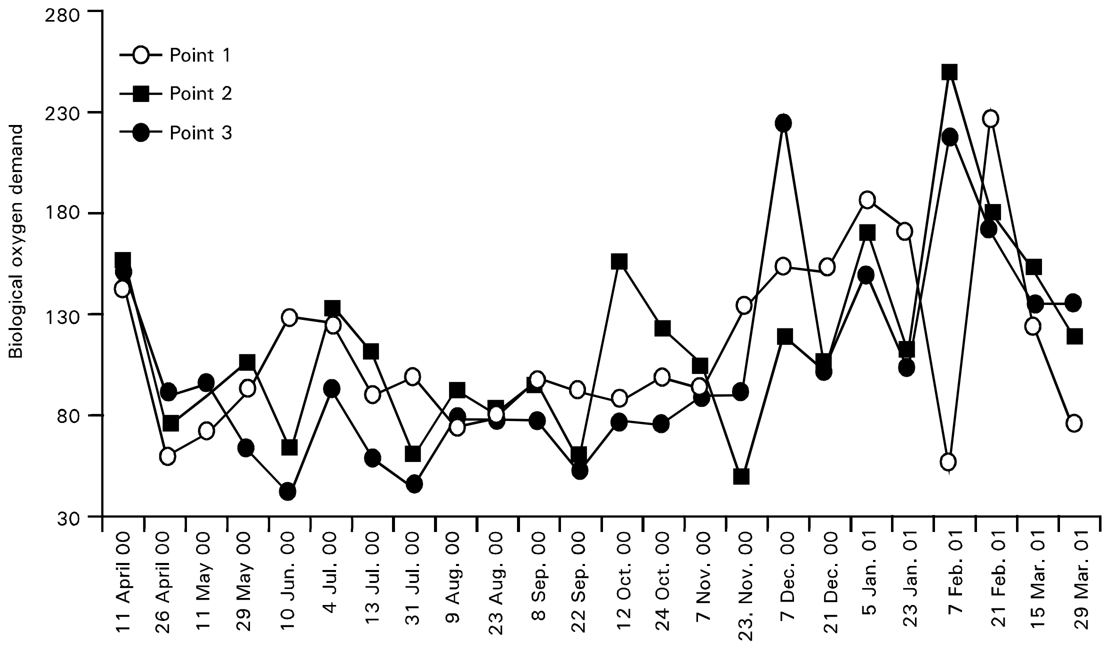

Fig. 3: Fortnightly measurement of 5-days biological oxygen demand (BOD, mg L^{-1}) of Hudiara drain's water at three sampling points

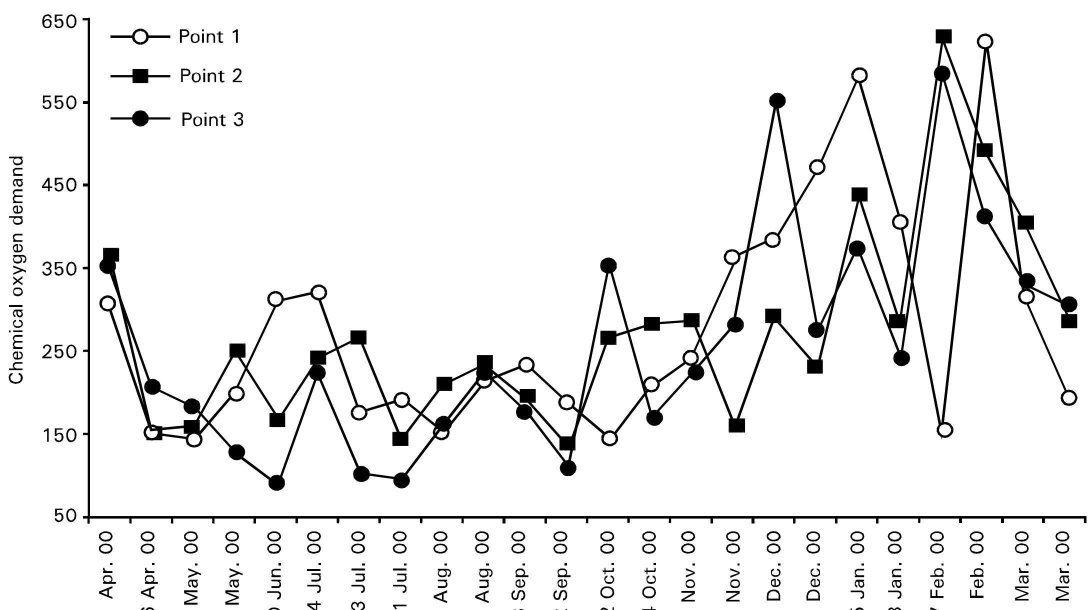

Fig. 4: Fortnightly measurement of chemical oxygen demand (COD, mg L^{-1}) of Hudiara drain's water at three sampling points

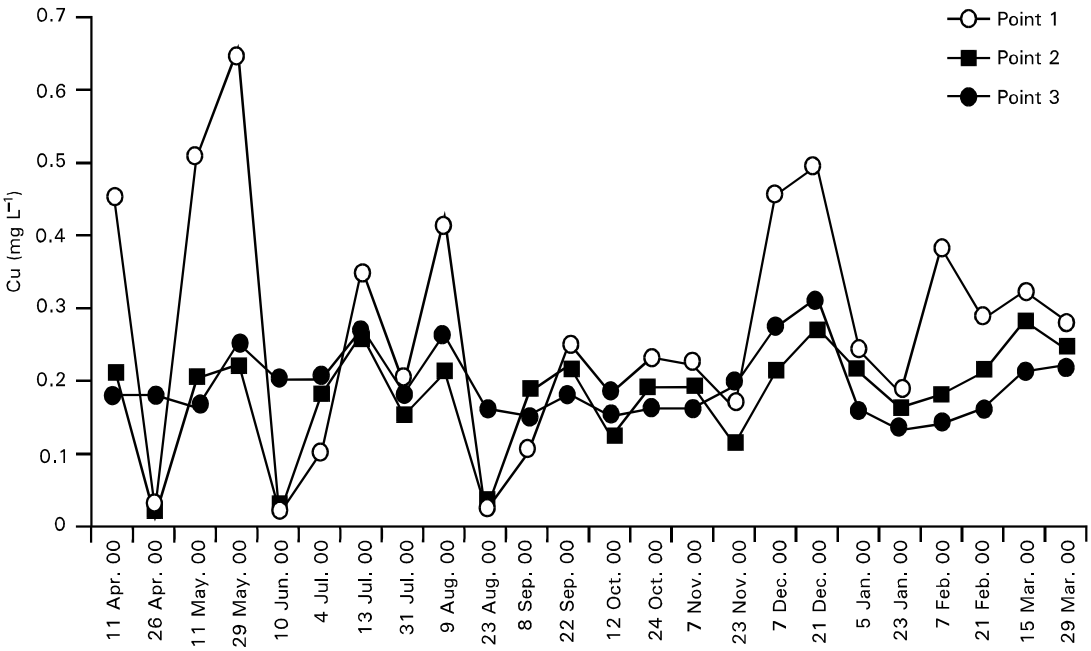

Fig. 5: Fortnightly measurement of Cu concentration (mg L^{-1}) in Hudiara drain's water at three sampling points

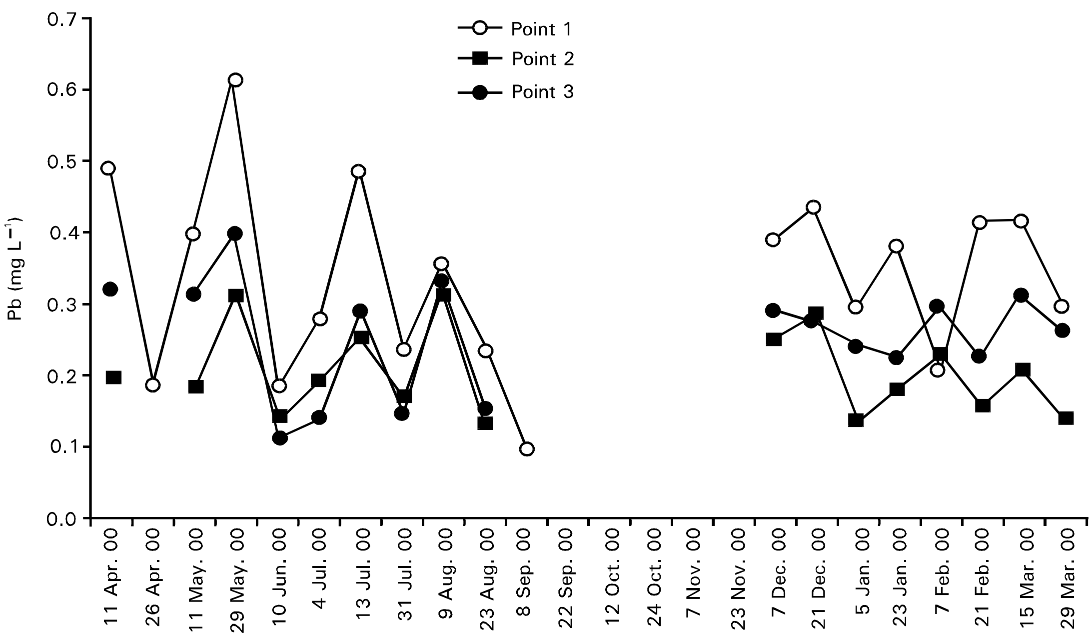

Fig. 6: Fortnightly measurement of Pb concentration (mg L^{-1}) in Hudiara drain's water at three sampling points

was generally lower at point 1 (1.077 µS cm^{-1}) compared with points 2 and 3 which were 1.351 and 1.347 µS cm^{-1}, respectively (Table 1). Fortnightly variations in EC (Fig. 2) depicted that for the larger part of the study period (12 months) lower values were found at point 1. For other two points (2 and 3), almost similar values were observed. From May to October 2000, variations between EC remained more or less similar. A sharp decrease at all sampling points was noticed in November 2000, which recovered with a gradual increase over time (Fig. 2).

As in the case of EC, mean value of TDS for 12 months period at point 1 (712 mg L^{-1}) was found lower than the other two points (892 and 850 mg L^{-1}, respectively). These data therefore support the positive relationship which exists between EC and TDS. The 12 months fortnightly variations for TDS are almost similar to EC (Fig. 2) over this period (graphic details not shown).

DO, BOD and COD are inter-related and are often used as indicators of organic materials and other chemical contamination in the water. DO was found consistently lower (less than 1 mg L^{-1}) at all sampling points except on two occasions which were 4.6 mg L^{-1} at point 1 and 1.2 mg L^{-1} at point 3 (Table 2).

During the one-year monitoring period (12 months) lower values for both parameters were mostly observed during May to November 2000 (Figs. 3 and 4). Although average values for 12 months for BOD and COD at all three sampling points were similar (Table 2), almost 50% of individual values of BOD at point 3 were found lower than point 1 and 2 (Fig. 3). In contrast, at point 1 compared with point 2 and 3, most of the individual values of BOD (with few exceptions) were found to be higher (Fig. 4).

The average total pollution load for 12 months in terms of TDS was the highest (354 tons day^{-1}) at point 3 and lowest at point 2 (277 tons day^{-1}) (Table 3). Similarly, lower values of total pollution load in terms of BOD (36 tons day^{-1}) and COD (87 tons day^{-1}) were noticed at point 2. However, unlike TDS, greater values of total loads of BOD (51 tons day^{-1}) and COD (126 tons day^{-1}) were observed at point 1.

Pollution in Hudiara drain water occurs due to inflow of industrial and municipal wastewater. Biological contamination, which mainly occurs due to dumping of municipal sewage, was measured at all three sampling points. *E. coli* which indicate biological contamination (Nebel and Wright, 1996) were found greater than 200 MPN (most probable number) per 100 ml at all three sampling points over the whole monitoring period (data not shown).

Most of the metal concentrations measured over the 12 months period showed greater variations between different sampling occasions (Table 3). For example, Cd at point 1 ranged from 0.001 to 0.21 mg L^{-1}. Similarly, at points 2 and 3 it varied between 0 and 0.27 mg L^{-1} and 0 and 0.25 mg L^{-1}, respectively. The only exception was Cr, which was consistently lower than 0.1 mg L^{-1} at all sampling points for the whole monitoring period. Unlike other metals, average values of Cu (0.27 mg L^{-1}) and Pb (0.3 mg L^{-1}) at point 1 were found greater (around 50%) than the average values of these metals at points 2 and 3 (Table 3, Figs. 5 and 6). Copper concentration changed little at point 2 during the whole monitoring period, however, for other points (1 and 3) greater variations were observed (Fig. 5). In case of Cd, Li and Pb concentrations at all sampling points varied but without showing any particular trend. Concentrations of Pb at all 3 points were unexpectedly negligible (not detected) between September to December 2000, whereas lower concentrations were expected to be during July to September 2000 due to dilution of heavy rainfall during this period (Fig. 6). In case of Li, average concentrations at all points were similar; ranging from 0.34 to 0.38 mg L^{-1}.

As regards water pollution, in 1993 the Government of Pakistan approved National Environmental Quality Standards (NEQS) for municipal and liquid industrial effluents which were revised and enacted in 1999 (Table 4) (PEPA, 1999). Mean temperature, pH and TDS of Hudiara drain's water meet these standards which are devised for industrial effluents (PEPA, 1999) whereas average values of BOD and COD are above these limits (Table 5). As mentioned above, Hudiara drain is a storm water drain and dilution due to different sources occurs all along its length. Rainfall for example when occurs, significantly dilute drain's water and this can be noticed from the fact that few values of BOD especially during the months of July to September were as low as 50 mg L^{-1} (Fig. 3).

Overall, despite dilution of the drain's water due to various sources, average BOD and COD values exceed NEQS limits for effluents. It is important to note that Hudiara drain is a surface water body, but its BOD and COD values still exceed the limits devised for industrial effluents. This indicates that Hudiara drain is a wastewater carrier rather than a storm water drain. It can also be safely assumed that industries along Hudiara drain and Lahore Metropolitan Corporation do not follow the national guidelines while disposing of wastewater into Hudiara drain. Similarly, greater values of BOD and COD at point 1 (near Pak-India border) indicate that relevant authorities in India do not follow guidelines for safe disposal of industrial and domestic wastewater, which results in trans-boundary water pollution.

The desirable DO of water ranges from 4-6 mg L^{-1}, support aquatic life for example fish. However, in case of Hudiara drain it was found below 1 mg L^{-1} (average value) throughout the monitoring period (12 months). Dilution due to rainfall during monsoon season sometimes brought down BOD level below NEQS (80 mg L^{-1}) but DO did not improve except only once in February 2001 at point 1 (4.62 mg L^{-1}) for which the corresponding BOD value was 54 mg L^{-1}.

As mentioned above, approximately 84 industrial units are situated along Hudiara drain (55 km stretch) in Pakistan and all of them dump their effluents into the drain without prior proper treatment. However, results of this study indicate that effluents generated by these units are low in

Table 1: Physicochemical properties of Hudiara drain's water at three different sampling points measured over a 12 months period on fortnightly basis

	Point 1		Point 2		Point 3	
Parameters	Range	Average*	Range	Average*	Range	Average*
Temperature (^{0}C)	14-37	27	15-35	26	15-33	26
pH	6.9-9.2	7.9	6.9-9.4	7.9	7.0-9.5	7.8
EC (µS cm^{-1})	0.415-1.548	1.077	0.597-1.890	1.351	0.625-1.772	1.347
TDS (mg L^{-1})	210-1350	712	430-1340	892	450-1160	850

*Average of 24 values EC = Electrical conductivity TDS= Total dissolved solids

Table 2: Dissolved oxygen (DO), biological oxygen demand (BOD, 5-days) and chemical oxygen demand (COD) of Hudiara drain's water at three different sampling points measured over a 12 months period on fortnightly basis

	Point 1		Point 2		Point 3	
Parameters	Range	Average*	Range	Average*	Range	Average*
DO (mg L^{-1})	0.2-4.63	0.62	0.3-0.6	0.43	0.28-1.2	0.51
BOD (mg L^{-1})	54-228	113	48-250	115	42-225	104
COD mg L^{-1})	144-616	276	136-488	271	91-580	255

*Average of 24 values

Table 3: Total pollution load (tons day^{-1}) in terms of total dissolved solids (TDS), biological oxygen demand (BOD, 5-days) and chemical oxygen demand (COD) of Hudiara drain's water at three different sampling points measured over a 12 months period on fortnightly basis

	Point 1		Point 2		Point 3	
Parameters	Range	Average*	Range	Average*	Range	Average*
TDS	143-812	302	145-448	277	132-557	354
BOD	14-113	51	15-71	36	12-117	45
COD	32-307	126	38-164	87	27-320	111

Table 4: Metal contents (mg L^{-1}) of Hudiara drain's water at three different sampling points measured over a 12 months period on fortnightly basis

	Point 1		Point 2		Point 3	
Metal (mg L^{-1})	Range	Average*	Range	Average*	Range	Average*
Cd	0.001-0.210	0.037	0-0.270	0.037	0-0.250	0.042
Cr	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cu	0.018-0.650	0.270	0.13-0.31	0.19	0.016-0.280	0.180
Li	0.22-0.82	0.38	0.16-1.30	0.38	0.16-1.20	0.34
Pb	0-0.70	0.30	0-0.35	0.16	0-0.45	0.20

*Average of 24 values

Table 5: National environmental quality standards of municipal and liquid industrial effluents (mg L^{-1}), unless otherwise defined)

Parameters	Into inland water	Into sewage treatment	Into sea
Temperature (^{0}C)	=< 3*	=< 3*	=< 3*
pH	6-9	6-9	6-9
Total dissolved solids	3500	3500	3500
BOD (5-days)	80	250	80**
COD	150	400	400
Cd***	0.1	0.1	0.1
Cr***	1.0	1.0	1.0
Cu***	1.0	1.0	1.0
Pb***	0.5	0.5	0.5

*The effluent should not increase temperature of the receiving water body more than 3^{0}C at the edge of the zone where mixing occurs.
** the value for industry is 200 mg L^{-1}
*** the total metals discharge should not exceed 2 mg L^{-1}

general metal contents. This can further be supported by the fact that most of these units produce textiles and related goods and may not be using metal salts as raw materials. High and continuous incidence of *E. coli* in the drain's water supports the continuous inflow of municipal wastewater into Hudiara drain.

Wastewater generated by the human settlements or industrial units is a good source of plant nutrients especially nitrogen and phosphorus (Chaussod *et al.*, 1985). Furthermore, farmers consider the drain's water as a reliable and cheap source of irrigation water. Approximately 120 pumps are installed all along the drain in Pakistan territory and farmers frequently use drain's water for irrigation. The lower values of total pollution load (tons day^{-1}) in terms of TDS and BOD at point 2 may be attributed to the lower discharge at this point due to uplifting of drain's water for irrigation.

TDS of drain's water at all sampling points are above 700 mg L^{-1} (average) with 1350 mg L^{-1} the highest individual value. Considering this parameter, drain's water can be used for irrigation but only on soils with good drainage. Most of the soils along the drain have already developed salinity and water-logging problems which continued irrigation with this water will further worsen.

The average values of most metal concentrations of the drain's water are within the limits considered safe for irrigation water, except Cu, which was 0.27 mg L^{-1} at point 1. The safe limit for Cu is 0.2 mg L^{-1} (Ayers and Wescot, 1989). Continuous irrigating of soils with metal contaminated effluents lead to elevated concentrations of available metals (Neilsen *et al.*, 1997) that may affect soil micro-organisms and their activities (Giller *et al.*, 1998; Khan and Scullion, 2000). However, nitrogen and phosphorus associated with wastewater may promote plant growth (Neilsen *et al.*, 1997) and dilute metal concentrations in plant tissues (Luo and Christie, 1998). This property of wastewater sometimes misleads the researcher to misinterpret the results in terms of plant yield and metal uptake by plants and also encourages farmers to continue wastewater irrigation without considering long-term risks to soil and human being.

As regard biological contamination, the present study found that the drain's water is polluted with infectious organisms at all sampling points. There is a strong possibility that irrigation with this water might contaminate food crops especially vegetables produced on these soils. Similarly, bathing of children and water buffaloes in the drain's water, which is noticed as a regular practice during summer may be another potential source of biological contamination.

As mentioned before, Hudiara drain is one of the tributaries of River Ravi and is believed to be contributing around 13-15% to the total pollution load of this river (Ziai, 1996). The present study observed that the daily contribution of Hudiara drain to the Ravi in terms of TDS (352 tons day^{-1}), BOD (45 tons day^{-1}) and COD (111 tons day^{-1}) is substantial. Although dilution occurs but during low flow times, Hudiara along with other similar drains which are tributaries of River Ravi may affect Ravi water quality significantly. According to one report (NCS, 1991) pollution in the Ravi has badly affected the fish and other aquatic life and it has been estimated that annual production of fish has been decreased by about 5,000 tons.

Hudiara is a surface water body, but some of its pollutants even exceed the limits devised for industrial effluents. Water quality of Hudiara drain at all sampling points indicated that both Pakistan and India use this drain for dumping of untreated industrial and domestic wastewater. Based on DO content Hudiara drain's water does not support aquatic life and can be safely considered dead water body. Considering drain water quality in terms of TDS, Cu content and *E. coli,* its use for long-term irrigation may be discouraged. Farmers may be informed about the risks associated with the use of drain water for both irrigation and water buffalo bathing.

Strict enforcement of the NEQS will be required to stop industrial units discharging untreated wastewater into the Hudiara drain. Similarly, the 1:10 dilution should be observed before dumping effluent into any water body. The Indian government should also be required to honour the bilateral Indus Water Treaty signed between India and Pakistan in 1960. According to its Article 4, Section 10, each party declares its intention to prevent, as far as possible, undue pollution of the waters of the Rivers.

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