Physico-Chemical Characterization of Wastewater in Paharang Drain, Faisalabad

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Abstract

This research attempts to characterise wastewater in Paharang Drain, Faisalabad as it traverses through industrial clusters, human settlements and vast agricultural fields and receives all kinds of effluents. The aim was to study temporal and spatial variations in the drain water in terms of selected physico-chemical parameters and drain flow rates. The data so generated may be beneficial for designing a pilot scale wastewater treatment plant. Wastewater samples were collected at six different points along the active stretch of the drain. The drain was found significantly contaminated in terms of high concentrations of total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, oil and grease, as levels of these parameters were significantly higher than recommended by Pakistan National Environmental Quality Standards (NEQS). Results indicated that reuse of such wastewater for crop irrigation would not only adversely affect the soil fertility but also the crop yield and quality. Poor groundwater quality near drain demonstrated that infiltration of drain wastewater has already deteriorated the quality of the upper aquifer.

Keywords: Monitoring, wastewater, industrial, Textile industry, municipal, Paharang Drain

Introduction

Rapid industrialization and urbanization in developing countries though helps improving the lifestyle of the common populace yet it alters the quality of environment and creates ecological disturbances and associated problems for the community. Faisalabad is the third largest industrial city and textile heartland of Pakistan. In addition to thousands of small weaving units, over 279 full-scale textile units are operating in Faisalabad. The city is located at the center of the Punjab province. With population of approximately 2 million spread over 122 km^2, city's sewerage and drainage system is divided into Eastern and Western zones. Untreated as well as partially treated, effluents from industries and municipalities in the Eastern Zone are carried away by Paharang Drain which ends up into Chenab River, and wastewater from the Western Zone is carried away by Madduana Drain which delivers its loads to River Ravi. Average annual rainfall in Faisalabad is about 550 mm with temperatures extremes touching 2°C and 45°C. Ground water in Faisalabad generally has a high content of total dissolved solids (TDS), ranging from 350 mg/L near fresh water irrigation canals to over 3000 mg/L at distant locations and around wastewater carriers [WASA, 1993].

Paharang Drain in Faisalabad was originally excavated to collect excess water from the water logged areas in 1973 with an average width of 30 ft and length 84 km. Rapid population growth and unplanned industrialization, overstressed the decades old sewer system and Paharang Drain turned into a major carrier of municipal and industrial effluents. As such the drain poses a serious threat to the health of the bank-side residents by exposing them to highly polluted industrial and domestic wastewater [Munir and Mukhtar, 2002]. Water and Sanitation Agency (WASA), Faisalabad, has proposed several wastewater treatment options but so far only one 20 MGD facility of municipal wastewater is operational and provides oxidation ponds treatment. The estimated wastewater discharge in Faisalabad is 584 MGD [Ali, 2002].

Industrial wastewaters especially from textile units are heavily loaded with organic, inorganic and toxic pollutants. Out of various activities in textile industry, chemical processing alone contributes about 70% of water pollution [Subrata, 2000]. Treatment of such wastewaters of complex nature is a great technical and economical challenge. Due to the lack of enforcement of National Environment Quality Standards (NEQS) by EPA, most of the industries are not interested in treatment except for a few national and multinational enterprises under the requirements of ISO 14001 Certification. Any suggestion for pretreatment of industrial wastewater is weakened by the addition of untreated municipal wastewater by WASA into the drain. Despite the long stretch of the drain and active self-purification process throughout its length, the quality of water as discharged into the river is above NEQS. Occasionally, drain water is diverted for irrigation of fodder and vegetable crops. This adds to the calamity of already poorly nutritious vegetables which ultimately enters into the consumer's food chain.

Federal and Provincial EPAs have promulgated various regulatory instruments such as self monitoring and reporting tool (SMART) software to encourage rather enforce industries to treat their wastewater before disposal. National Environmental Quality Standards have been notified for wastewater, air and noise pollution control. Environmental Magistrates and Tribunals have been established to resolve pollution related matters, three levels

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Table-1: Sampling stations along with sampling distances

Station number	Station name	Distance from zero point (kms)
1	Near Supreme Fabrics, Chak Jhumra	13
2	Near Bawa Chak bridge (Before mixing of another tributary)	16
3	100 Meter down the mixing point of the main drain and its tributary)	16.2
4	After Bawa Chak municipal drain discharge into main drain	17.5
5	Before effluent from 20 MGD Plant joins main drain.	25
6	After the outfall from oxidation ponds	29

of offences and related penalties have been announced and communicated to the industry. Most industrialists are well aware of the national environmental policies and regulatory framework like the Pakistan Environmental Protection Act 1997 but country's poor economic conditions prevent strict enforcement.

This study aimed at investigating the on-going pollution of Paharang Drain in Faisalabad and generating technical data to design a pilot scale wastewater treatment plant to treat drain water to a re-use level of quality. The study is supported by a comprehensive literature survey and discusses the results of the water quality monitoring survey conducted in 7-8 months. Keeping in view the combined (municipal & industrial) nature of the drain water, results of representative municipal and textile effluents quality analysis have been added for clarity.

Material and methods

Study Area

Paharang Drain, Faisalabad, starts near Chak Jhumrah. During its long stretch of 84 km, it traverses through dense industrial and population clusters, farms and agriculture fields before meandering into River Chenab. Most of the discharges into Paharang Drain are found within the first 29 km of its length. The rest of the drain stretch serves as storm water or agricultural return flow collector. Six sampling points were established along the first 29 km of the drain to study the temporal and spatial changes in the drain wastewater quality. A schematic of the sampling sites and inter-site distances are given in Table-1 and Figure.-1.

Reconnaissance and walkthrough surveys

A comprehensive foot survey was conducted to map the location of various bridges, main drains and outfalls into Paharang Drain. The objective was to identify critical points where sampling stations could be established for flow measurement and sample collection. It was also noticed during the walkthrough surveys that an enormous amount of drain water is used for fodder crop irrigation.

Sampling sites

Proper selection of sampling stations largely reduces the expenditure for quality monitoring program and magnifies its success. Since, most of the industrial and non-industrial outfalls discharged into Paharang Drain within the first 29 km of the drain, this active stretch was therefore divided into six sub-stretches of varying lengths depending upon the quantity as well as the type of the outfall between each sub-stretch. Ease of sample collection and availability of a regular structure for flow measurement were other considerations for selecting sampling sites.

Sample collection

A team of four graduate students helped collecting samples and measuring water flow. Proper personal protection gear was provided to each field worker. Sample collection and preservation protocol mentioned in the Standard Methods for Water & Wastewater Analysis (APHA, 2005) was strictly followed. Grab and duplicate samples were collected in pre-washed, 1L, amber glass bottles. Each bottle was rinsed with the drain water before sample collection. Each sample was properly sealed, preservatives added and secured in the ice box after collection. The samples were analyzed within 4 to 6 hours of the sample collection.

Analysis of parameters

Table-2 provides information about the selected physico-chemical variables studied in this project along with the equipment and method of analysis used. In general, the collected samples were analyzed as per methods listed in

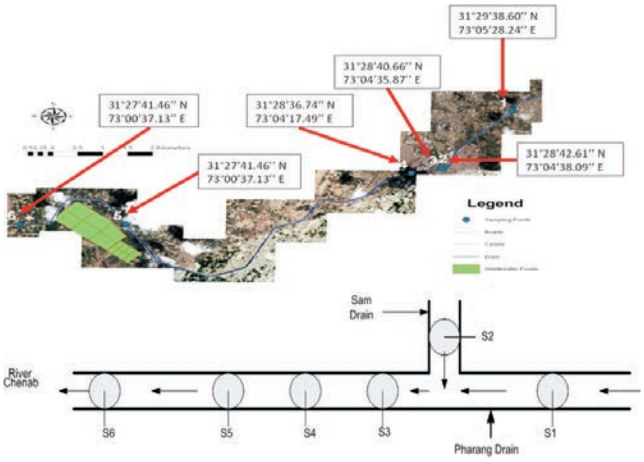

Fig. 1: Layout of sampling points along Paharang Drain

Table-2: Variable of interest, equipment and method used

Variable	Unit	Point of Analysis	Equipment Used	Method Used
Temperature	^oC	Field	pH Meter HACH sension 1	Laboratory Method
pH		Field	pH Meter HACH sension 1	Potentio-meteric Method
Color	Pt. Co. Units	Lab	Spectronic Genesys 5	Spectrophotometric method
Conductivity	mS/cm	Field	Conductivity meter	Potentio-meteric Method
Turbidity	NTU	Lab	HACH Turbidimeter 2100N	Nephelometric Method
TDS	mg/L	Field, Lab	Conductivity meter, Millipore filtration assembly and glass fiber filter type A-e Gellman Sciences	Total Dissolved Solids at 180^oC
TSS	mg/L	Lab	Millipore filtration assembly and glass fiber filter Type A-e Gellman Sciences	Total Suspended Solids Dried at 103-105^oC
SO_4	mg/L	Lab	UV visible spectrophotometer	Turbidimetric Method
Total-P	mg/L	Lab	UV visible spectrophotometer	Vanadomolybdophosphoric Acid Colorimetric
DO	mg/L	Lab	DO meter of model "Oxi 538"	Membrane Electrode Method
BOD_5	mg/L	Lab	DO meter of model "Oxi 538"	5-Day BOD Test
COD	mg/L	Lab	Digestion vessels, HACH COD Reactor, pipet, beaker,	Closed Reflux Titrimetric Method
TOC	mg/L	Lab	Analytickjena multi N/C 3100	High Temperature Combustion Method
TN	mg/L	Lab	Analytickjena multi N/C 3100	High Temperature Combustion Method
Chloride	mg/L	Lab	Erlenmeyer flask, Burette, Magnetic stirrer	Argentometric Method
Flow	MGD	Field	Current Meter – Model--	

the US-EPA and Standard Methods (US-EPA, 1998; APHA, 2005).

Results and discussion

Physico-chemical characterization of drain water at various stations along Paharang Drain was performed so that variations resulting from diverse inputs all along the active stretch of the drain could be examined. Since the drain has been divided into sub-stretches based upon sampling stations, discussion is oriented around sampling stations as well as variations in quality parameters at these stations. Table-3 provides the means and the standard deviations of various parameters as measured at each station along with National Environmental Quality Standards for comparison.

The sampling *Station#1* was located near Supreme Fabrics, a textile industry 13 km from starting point (hereinafter referred to as zero point) of the drain. The wet width of the drain at this point is approximately 24 feet. A dense cluster of industries and residences discharge their effluents prior to this station as illustrated in Fig.-1 and Table-1. Being the first receptor point of variable discharges, flow rate in the drain at this station was the lowest of all the subsequent stations. The mean value of drain flow was around 5.8 MGD as reported in Fig.-2. As evident from Table-3, pH of the drain water shows its alkaline nature yet within the NEQS. Mean BOD_5 was about 60 units higher than NEQS as reported in Table-3 and exhibited in Fig.-3. Most of the other variables were within or near the NEQS which indicates that drain water quality up to this point was not horrendous and, if not further degraded; natural processes would restore the water quality of the drain to a level within the NEQS.

Sampling *Station#2* was located on Sam Drain just before it met the main Paharang Drain near Bawa Chak Bridge as illustrated in Fig.-1 and Table-1. Once again, the outfalls prior to this point comprised the domestic and industrial effluents. Major industries in this area included Rasheed Textile Industry and Sidique Textile Industry along with several small sized industries. The wet width of the drain was about 14 meter. Flow rate at this station ranged between 12.76 and 30.44 MGD for six readings over a span of seven months as reported in Table-3 and exhibited in Fig.-2. The drain water was highly turbid (191.4 NTU), low in dissolved oxygen (0.5 mg/L) and high in COD (612 mg/L) as detailed in Table-3. Such water could not support any aquatic life which needed a minimum of 2-5 mg/L of oxygen and lower turbidity. Hanif *et al*. (2005), however, reported that average turbidity in industrial effluents in this area was around 75 NTU and COD of combined industrial effluents at various locations in Faisalabad ranged from 400 to 6000 mg/L. High COD levels imply toxic condition and presence of biologically resistant organic matter. This result was inconsistent with what was earlier reported by Yusuff and Sonibare (2004), where COD variations at various locations in wastewater drains varied from 1000 to 2500 mg/L. Almost all other water quality parameters except chlorides and sulfates were higher than NEQS and required extensive treatment before any beneficial reuse.

Sampling *Station#3* was located on the main Paharang Drain as illustrated in Fig.-1 and Table-1. The wet width of

Table-3: Physico-chemical analysis of wastewater samples collected from six stations along the Paharang Drain

S#	Parameter	NEQS	Unit	Type	Station#1	Station#2	Station#3	Station #4	Station#5	Station#6
1	Flow	---	MGD	Range	(3.09-16.8)	(12.76-30.4)	(19.09-68.05)	(29.8-84.75)	(68.1-170)	(70.3-179.9)
				Mean SD	5.8 5.5	20.2 6.7	31.8 18.5	45.1 20.3	102.2 31.1	111.1 36.4
2	Temperature	40	^oC	Range	(17.8-38.2)	(33.9-39.2)	(31.5-38.9)	(30.8-36.4)	(26.3-36.3)	(26.3-36.5)
				Mean SD	31 7	35.8 2.3	34.2 2.9	33.5 2.3	31.1 4	31.1 4
3	Conductivity	---	mS/cm	Range	(3.94-6.48)	(4.32-5.75)	(3.07-5.92)	(3.73-6.48)	(3.65-5.46)	(3.73-5.68)
				Mean SD	5.3 1.2	5.3 0.5	5.2 1.1	5.6 1	5.1 0.7	5.2 0.7
4	pH	6-10	---	Range	(8.18-8.9)	(7.7-9.8)	(8.44-9.8)	(8.68-9.85)	(8.11-8.9)	(8.21-8.93)
				Mean SD	8.6 0.3	8.9 0.8	9 0.5	9.3 0.5	8.4 0.3	8.5 0.3
5	Turbidity	---	NTU	Range	(12.8-93)	(119.7-400)	(131.65-330)	(81.3-227)	(57-127)	(72.3-130)
				Mean SD	37.4 30.5	191.4 107.4	202 70.4	152 49	87.2 26	88 21.2
6	Color	---	Pt-Co	Range	(250-4420)	(500-2300)	(510-2245)	(410-2050)	(260-1530)	(420-1850)
				Mean SD	1178 1596	1393 700)	973 641	1068 625	811.7 523	848.3 555
7	DO	---	mg/L	Range	(0.065-0.89)	(0.12-0.76)	(0.16-0.69)	(0.14-0.97)	(0.11-0.98)	(0.13-0.96)
				Mean SD	0.52 0.5	0.51 0.3	0.48 0.2	0.48 0.5	0.53 0.5	0.50 0.4
8	TDS	3500	mg/L	Range	(2040-3830)	(2270-2820)	(1872-2980)	(1934-3120)	(1920-2800)	(1926-2830)
				Mean SD	2910 727	2737 233	2705 414	2839 470	2597 334	2646 354
9	TSS	150	mg/L	Range	(40-132)	(187-468)	(332-430)	(292-430)	(210-318)	(178-332)
				Mean SD	94 47	324.3 123	380 29	351.3 56	255 38	270.3 55
10	TVSS	---	mg/L	Range	(14-74)	(100-243)	(150-216)	(94-227)	(78-1328)	(72-146)
				Mean SD	39 24.7	164 54.4	186 23.7	151 48	114 24.7	112 29.9
11	TS	---	mg/L	Range	(2172-4042)	(2460-4328)	(2460-4328)	(2364-4168)	(2184-3950)	(2224-3928)
				Mean SD	3164 809	3268 608	3152 458	3397 593	3046 561	3068 541
12	BOD	80	mg/L	Range	(74.5-320)	(247-390)	(238-386)	(184-398)	(175-332)	(189-390)
				Mean SD	141 91	318 60.9	307 63	273.5 82	227 54	252 78
13	COD	150	mg/L	Range	(337.9-608)	(521-625)	(416-647.7)	(352-511)	(352-499)	(380.4-549)
				Mean SD	420 158	612 73	569 98	497 95	405 78	458 65
14	TOC	---	mg/L	Range	(39-129)	(126-203)	(95-219)	(91.7-246)	(56.1-163)	(70.5-157)
				Mean SD	73 30	168 33	158 48	151 60	111 47	111 33
15	TN	---	mg/L	Range	(7.65-22.1)	(56.9-93)	(31.1-86)	(49.7-94)	(25.6-74)	(35.6-68.5)
				Mean SD	12.2 7	75.8 12	67.9 19	68.5 16	53.3 18	51.5 13
16	Sulphates	600	mg/L	Range	(130-720)	(300-480)	(260-500)	(320-550)	(320-550)	(290-550)
				Mean	485	428	424	455.3	418.3	450

				SD	226	65	86	78	76.3	100
17	Chloride	1000	mg/L	Range	(769.8-2710)	(779.8-1200)	(639.8-1280)	(819.8-1200)	(629.8-1080)	(690-980)
				Mean SD	1368 744	977 167	974 220	487 158.4	846 165	843 130
18	TP	---	mg/L	Range	(3-24)	(8.6-30)	(8.2-36)	(9.2-29)	(9.2-22)	(12.6-12)
				Mean SD	15.7 8	19.1 9	19.5 10.9	18.2 7.2	14.5 5.4	16.6 4.4
19	Oil and grease	10	mg/L	Range	(18.3-54)	(31.3-67)	(54.6-78)	(48-70)	(34-47.3)	(38-81)
				Mean SD	35 12.9	48 14.3	68 7.8	58 8.8	41 5.3	55 16.9

Note: Values based on mean of three replicates (dated: 03/07/08, 04/08/08, 30/08/08, 09/10/08, 05/11/08, and 17/11/08)
NEQS = National Environmental Quality Standards
SD= Standard Deviation

the drain at this station was about 13 feet. At this station the mean value of flow was found to be 31.8 MGD as mentioned in Table-3 and exhibited in Fig.-2. Water quality parameters such as pH, temperature, TDS, sulphate, chlorides were all within NEQS whereas BOD_5 and COD was somewhat two fold higher than NEQS as reported in Table-3. Another study conducted by Aslam *et al.* (2004) reported the values of BOD_5 and COD in textile effluent as fluctuating between 238-329 and 416-647.7 mg/L respectively as compared to current results of 238-329 and 416-647.7 mg/L respectively as illustrated in Fig. 3. Tufekci *et al.* (2007), however, showed a wider variation in BOD_5 and COD in textile effluents, i.e., between 280-1140 and 614-1960 mg/L, respectively. This difference may be due to different location and time of sampling. Another study by Khan *et al*. (2003) on Hudiara Drain, Lahore, Pakistan revealed that the values of BOD_5 and COD in combined industrial and municipal effluent were within the range 54-228 and 144-616 mg/L which was very consistent with results of this study as reported in Fig.-3. Similarly, mean value of TSS in Paharang Drain was 380 mg/L which was two fold higher than the NEQS as reported in Table-3 and illustrated in Fig.-4. All other variables except chlorides and sulfates were also higher than NEQS showing that such water should not be used for crop irrigation or any other secondary use directly as reported in Table-3.

Sampling Station#4 was located about 1.5 km downstream near Bawa Chak Bridge and near Bawa Chak pumping station. This station was included to observe the effect of freshly mixed textile effluents and the untreated domestic sewage from Bawa Chak pumping station into the drain as exhibited in Fig.-1. The wet width of the drain at *Station#4* was approximately 21 meter and depth was about 4 meter. At this station the drain flow ranged between 29.8 and 84.75 MGD with mean value of 45.1 MGD as reported in Table-3 and depicted in Fig.-2. Values of most of the water quality parameters at this station were within a similar range as that of *Station#3* except color that was found to be 1068 Pt-Co unit and several times higher than NEQS as detailed in Table-3. Conductivity and TSS were higher than NEQS as mentioned in Table-3 and exhibited in Fig.-4 and Fig.-8, respectively. According to Oke *et al*. (2006) such wastewater should not be discharged into the fresh stream, as it would encourage sludge formation within the stream, which will in turn encourage anaerobic reaction adversely affecting the self-purification phenomenon of the stream. This clearly showed that a comprehensive monitoring program is required before designing a facility for treatment of such combined effluents as found in Paharang Drain. Also, such hot water (34^{o}C) if diverted for irrigation would not only deteriorate soil characteristics but also the crops or vegetables grown. Using this water would be health hazardous for their consumers.

Sampling Station #5 lied near Chakera Pumping Station which discharged municipal wastewater to the oxidation ponds. This station was about 8.5 km down stream from *Station#4*. There are several municipal wastewater outfalls into main Paharang Drain between *Station#4* and *Station#5* as depicted in Fig.-1. At this station the flow rate reached to 102.2MGD (Table-3). Munir and Mukhtar (2002) and Kahlown *et al*. (2006) measured the flow of Paharang Drain as 68 and 74 MGD which clearly show that the flow has increased significantly since 2002. At this station all of wastewater quality variables were found in the lower concentration as compared to *Station #4* as reported in Table-3. This showed the effectiveness of natural self purification between sampling *Station#4* and *Station#5*. BOD_5 and COD were found to be 227 and 405 mg/L respectively which were about 2 times higher than permitted by NEQS as illustrated in Fig.-3. Another study conducted by Zaimoglu *et al.* (2006) on a similar drain in Turkey reported that the value of BOD_5 and COD was found within the range of 142-344 and 224-576 mg/L, respectively. The value of chloride was found in the range of 630-1080 mg/L as reported in Table-3 and illustrated in Fig.-6. High chloride contents are harmful for metallic pipes as well as for agricultural crops if such waste water is used for irrigation purposes (Nosheen *et al*., 2000).

Station#6 was located 2 km below the main outfall of the 20 MGD, municipal wastewater treatment plant (Oxidations Ponds System) at Chak Chakera. The wet width of the drain at *Station#6* was approximately 35 meter and depth about 4.5 meter as reflected by Table 1. The mean values of BOD_5 and COD were found to be 252 and 458 mg/L respectively as illustrated in Fig.-3. A similar study conducted by Kahlown *et al*. (2006) and sampled at the same point reported the BOD_5 and COD values as 384

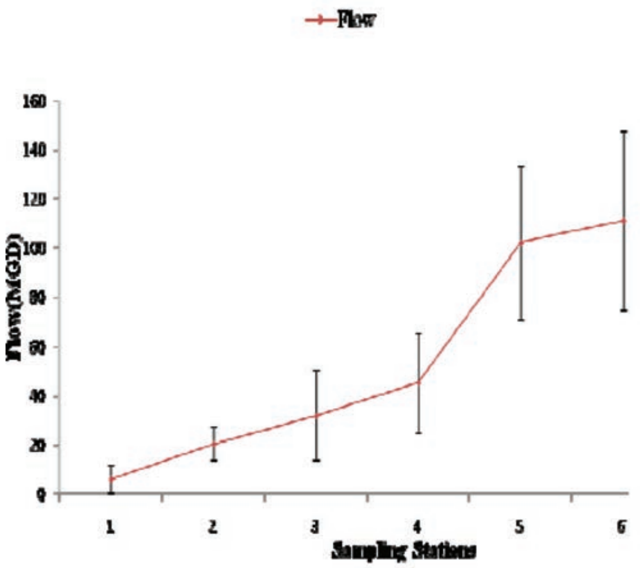

Fig. 2 Flow profile of Paharang Drain

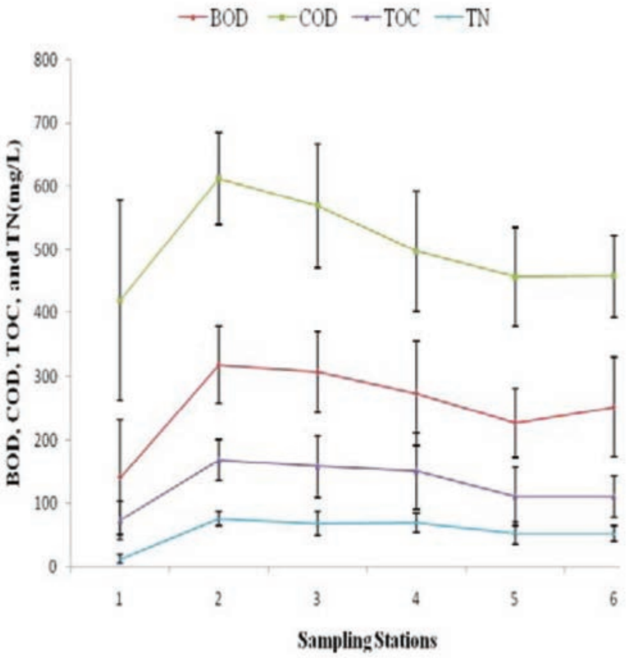

Fig. 3 BOD, COD, TOC and TN profiles at Station#1-6 of Paharang Drain

and 853 mg/L (Table-3) respectively. This difference in BOD_5 and COD values may be attributed mainly due to the following observations made during the sampling period to (a) the variable effectiveness of the wastewater treatment plant or (b) discharge of a relative by stronger organic waste by an industry or a group of industries, or (c) the difference in the sample collection time of the day as the drain water quality changes based upon the effluent batches released by industry.

A substantial rise in flow from the start of Paharang Drain to *Station #6* is illustrated in Fig.-2. Beyond *Station#6* and up to River Chenab, there is no major outfall into Paharang Drain which would impact the drain water quality or quantity, i.e., the self purification would continue to be effective until final disposal into the river. Fig. 3 shows the variations in various water quality parameters from *Station#1* to *Station#6* as we go along Paharang Drain and collect samples after fixed durations.

Variations in BOD_5, COD, TOC and TN from *Station #1-6* are shown in Fig.-3. Concentrations of all these parameters sharply increase between *Station#1* and *Station#2* and than keep falling until *Station#5* beyond which these concentrations stabilize to their consistent levels as also reported in Table-3. Brief variations in the above mentioned variables after *Station#4* indicate that no major out fall exist in this area that would further deteriorate the drain water quality. In fact, small influents to the drain are balanced by the natural purification capacity of the drain and should this trend continued till the river, the drain water quality would further improve but may not reach to NEQS level where it could be reused for beneficial purposes as evident by a study conducted by Kahlown *et al*. (2006) which reported the BOD_5 and COD values of the Paharang Drain water before its entry into River Chenab ranged between 176 and 353mg/L, respectively.

Solids in any water would interfere with natural disinfection as they do not allow sunlight and provide refuge to the micro-organisms. Total solids (TS) and total dissolved solids (TDS) follow a gradual decrease in their concentrations as we go down the stream, whereas total suspended solids, increase gradually and then remain at certain level (Fig.-4 and Fig.-8) showing continuous agitation of drain water by various outfalls all the way from *Station #1-6*. It is likely that all, TSS, TDS and TDS would decrease beyond *Station #6* as there is no noticeable fall up to River Chenab as illustrated in Fig.-1. None of the past studies have reported solids level in the drain water before its fall into the river as per literature survey. This important aspect would be explored to understand the effect of the uninterrupted flow regime onto the drain water quality and the solids load being transferred from the drain to the river.

Fig.-5 above illustrates changes in total phosphorus (TP), pH and temperature of the Paharang Drain water between sampling *Station#1 and Station#6*. Rise in TP from *Station#1-3* is an indication of industrial and municipal inputs between these points as also reflected by Fig.-1. Slight increase in TP at *Station # 6* is a clear evidence of large in-flow of poorly treated sewage (Table-1). Temperature is quite high at the beginning but slowly smoothens down to 20 ^{o}C due to the effects of high ambient temperatures as reported in Table-3 and exhibited in Fig.-5. It is likely that adverse temperature effects will be dislodged far before the drain meets River Chenab. Placement of a pilot plant just after *Station#6* would not be affected by high temperature as the stream temperature touches the ambient temperature in this vicinity. A constant value of pH indicates that influents of acidic and

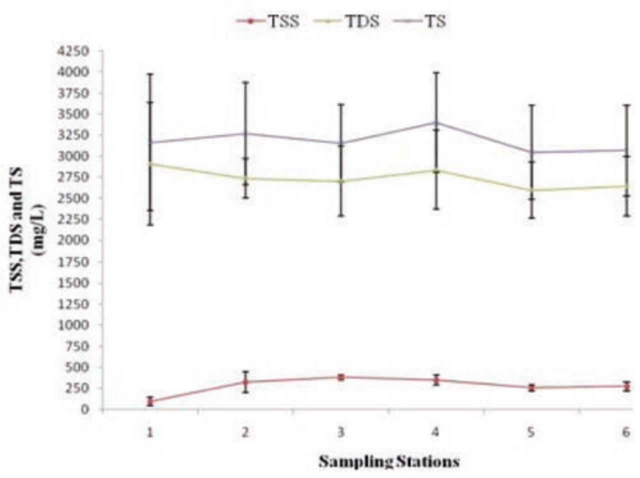

Fig. 4. TSS, TDS and TS profiles at Station#1-6 of Paharang Drain

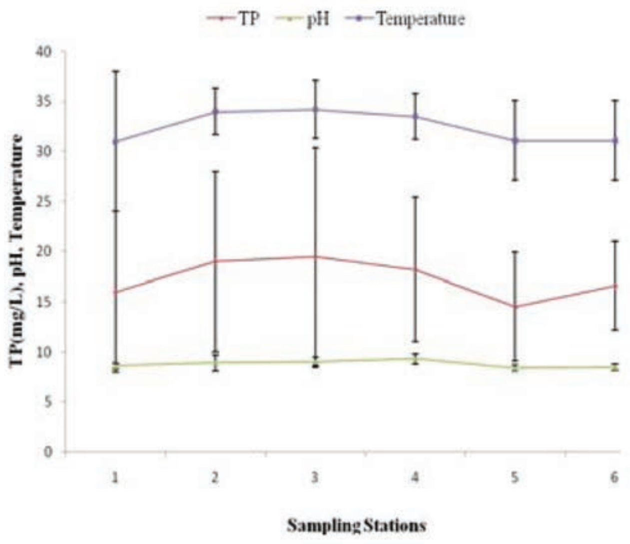

Fig. 5. TP, pH and Temperature profiles at Station#1-6 of Paharang Drain

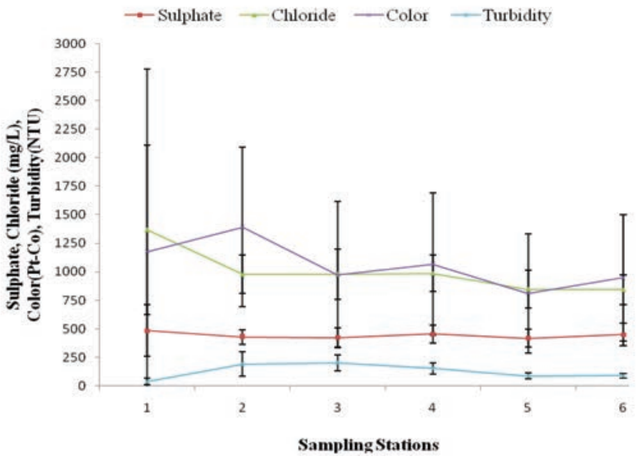

Fig. 6. Sulphate, chloride, color and turbidity profiles at Station#1-6 of Paharang Drain

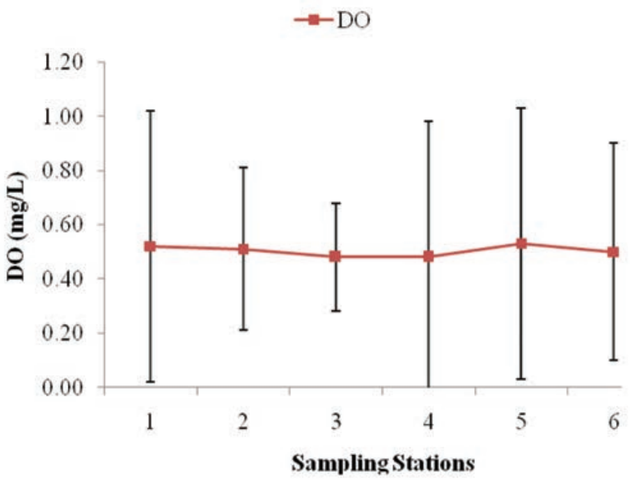

Fig. 7. DO profile at Station#1-6 of Paharang Drain

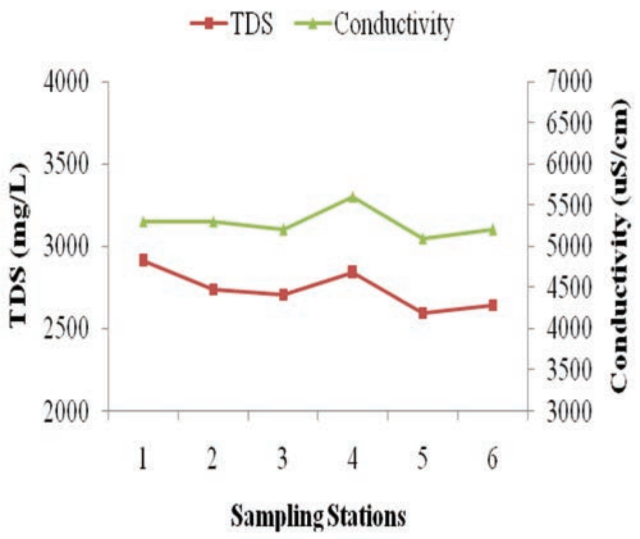

Fig. 8. TDS & Conductivity relationship Paharang Drain

alkaline nature are effectively neutralizing each other. Such a limited variation in pH is good for a biological wastewater treatment plant (Fig.-5).

Referring to Fig.-6 and Table-3, color shows a downward trend between *Station #1 and Station#5* and a slight increase at *Station #6*. This indicates that number and volumes of textile inflows reduces as one goes downstream from *Station#1to 6* and natural mixing of various effluents help in reducing color. Same is true for chlorides as most of the chlorides are discharged by the textile industry and the number of textile industry reduces as we go down to sampling *Station#6* (Fig.-6).

Consistent sulphate concentration demonstrates that chemical reactions between the textile and municipal effluents are balancing sulphate contents (Fig.-6 and Table-3). As reported in Table-3 and illustrated in Fig.-6, turbidity is affected by the turbulence caused by new outfalls as the stream flows. Its rise from 37.4 NTU to 152 NTU with significant decrease to 87 NTU clearly shows that most of the turbidity is due to suspended particles which settle during the undisturbed flows and rise after every new flow. This is a typical characteristic of stream quality behavior. Similarly, it is quite likely that turbidity would further reduce before drains' entry into River Chenab.

Dissolved oxygen (DO) is essential for the survival of aquatic plants and animals**.** Minimum dissolved oxygen concentration of 2 mg/L is required for maintaining aerobic conditions whereas dissolve oxygen concentration less than 5 mg/L are indicative of pollution (Kamal *et al*., 2007). Fluctuation in DO values is reported in Table-3 and illustrated in Fig.-7. The value of DO was found to be significantly low from *Station#1-6* due to high pollution load of industrial and municipal effluents as reported in Table-3. Similarly 0.02 mg/L increase in DO was observed from *Station#3* to *Station#5* due to natural self purification and dilution by domestic wastewater. Fig.-8 revealed direct relationship between TDS and conductivity. From *Station#1* to *Station#6* the TDS values increase with increase in conductivity as reported in Table-3. The electrical conductivity of wastewater is directly related to the TDS based on the assumption that TDS in the water consist mainly of ionic constituents that conduct electricity (Atekwana *et al*., 2004).

Conclusions

It is evident from the results obtained that the drain water, in its existing condition, cannot be utilized for any beneficial purpose. It cannot support aquatic life and is an evident source of odor and eye irritation due to prevailing anaerobic conditions. Following specific conclusions may, however, be drawn from the study:

(i) Most of the physico-chemical parameters of the Paharang Drain wastewater are higher than Pakistan National Environmental Quality Standards.

(ii) Wastewater quality deteriorates within the close proximity of industrial discharges and starts improving as the gap between the inlets increases. Self purification capacity of the drain was proportional to the gap between various stations outfalls. The longer the gap, more effective is the self-purification.

(iii) Biological treatment of drain water at Sampling Station#6 might be cost effective as quality remains relatively consistent throughout the larger part of Paharang Drain beyond this point.

Based on the findings of study the following measures should be taken by the government and the private sector:

(i) Prime importance should be given to the treatment of industrial effluent before it is allowed to be disposed off into any waterway. The enforcement of environmental regulations and NEQS should be more serious and strict.

(ii) Regulatory agencies must not approve any development application of the industrial nature until a wastewater treatment plant is proposed along with the application.

(iii) Education and awareness of the industry managers and municipal administration should help reduce drain pollution to a significant level. Common people should be educated about the harmful effects of the drain on their health.

(iv) The current practice of Paharang Drain water for irrigation of agriculture fields should be banned since it is harmful for the consumers utilizing those vegetables and crops.

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References

1. G. Hilson, " Defining cleaner production and pollution prevention in the mining context", Mineral Engineering, Vol. 16, No. 4, 2003, pp 305-321.
2. Ali N., "Economic and Institutional Issues of Wastewater Use in Faisalabad, Pakistan.", IWMI-Pakistan, 2002.
3. APHA, "Standard Methods for the Examination of Water and Wastewater", American Public Health Association (APHA), Washington, 2005.
4. Aslam M. M, Baig. A. M, Hassan. I, Malik. M. and Saeed. H., "Textile Wastewater Characterization and Reduction of its COD and BOD by Oxidation", Electronic Journal of Environmental, Agricultural and Food Chemistry. ISSN: 1579-4377, 2004, 804-811.
5. Atekwana. A. E, Atekwana. A. E, Rowe. S. R, Werkema. D. D. and Legall. S. F., "The Relationship of total dissolved solids measurements to bulk electrical conductivity in an aquifer contaminated with hydrocarbon"' Journal of Applied Geophysics. 56(2004),2004, 281-294.

6. Hanif. M. A, Nadeem. R. R, Rashid.U and Zafar. M. N., "Assessing Pollution Levels in Effluents of Industries in City Zone of Faisalabad, Pakistan", Journal of Applied Sciences. 5(10),2005,1713-1717.
7. Kahlown. A. M, Ashraf. M, Hussain. M, Salam. A. H and Bhatti. Z. A., "Impact Assessment of Sewerage and Industrial Effluents on Water Resources, Soil, Crops and Human Health in Faisalabad", ISBN -978-969-8469-17-7,2006.
8. Kamal. D, Khan. N. A. and Ahamed. F. "Study on the Physico-chemical Properties of Water of Mouri River, Khulna, Bangladesh", Pakistan Journal of Biological Sciences. 10(5) 710-717,2007.
9. Khan. M, Khan. N. H. and Aslam. H., "Hudiara Drain-A Case of Terns- Boundary Water Pollution between India and Pakistan", Pakistan Journal of Biological Sciences. Vol 6(2): 167-175, 2003.
10. Munir, S. and Mukhtar, M., "Assessment of Wastewater Production and Reuse in the Peri-Urban Areas of Faisalabad, Pakistan", IWMI-Pakistan, 2002.
11. Nosheen, S., Nawaz, H., and Rehman, U. K., "Physico- Chemical Characterizations of Effluents of Local Textile Industries of Faisalabad – Pakistan. International Journal of Agricultural and Biology", 2(3): 232-233,2000.
12. Oke, A. I., Okuofu, A. C., and Otun, A. J., "A Statistical Classification of Textile Wastewaters in Northern Nigeria. Journal of Applied Sciences Research", 2(4): 209-216,2006.
13. Subrata, D., "Textile Effluent Treatment –A Solution to the Environmental Pollution", (Unpublished data), 2000.
14. Tufekci, N., Sivri, N., and Toroz, I., "Pollutants of Textile Industry Wastewater and Assessment of its Discharge Limits by Water Quality Standards", Turkish Journal of Fisheries and Aquatic Sciences, 7: 97-103, 2007.
15. US-EPA., "Methods for the Chemical Analysis of Water and Wastes", Washington DC: Office of Technology Transfer, US-EPA-625/6-74-003, 1978.
16. WASA., "Faisalabad Environmental Infrastructure Master Plan", Faisalabad Pakistan, 1993.
17. Yusuff, R. O. and Sonibare, J. A., "Characterization of Textile Industries Effluents in Kaduna, Nigeria and Pollution Implications", Global Nest: the Int, J: 6(3):212-221, 2004.
18. Zaimolgu. Z, Sucu. Y. M., Davutluoglu. I. O, Hazir. I, and Yuceer. Ahmet., "Pollutant Monitoring of a Drainage Canal Receiving Industrial and Agricultural Wastewater Incukurova Plain", Journal of Biological Sciences 6(4): 646-650, 2006.