PHYSICO-CHEMICAL MONITORING OF COMBINED INDUSTRIAL AND MUNICIPAL EFFLUENTS IN PAHARANG DRAIN, FAISALABAD

By

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Abstract
Paharang Drain, Faisalabad, starts near Chak Jhumra. During its long stretch of 84 Km, it traverses through dense industrial and population clusters, agriculture farms and fields before meandering into river Chenab. The main goal of this study was to characterize the combined industrial and municipal wastewater of Paharang Drain in terms of physico-chemical parameters. The objective was to determine the spatio-temporal variations in wastewater quality, and flow rates and evaluate its treatment options. For this purpose three sampling stations were selected along the first 29 Km of the drain and fourth sampling station was selected before the confluence of Paharang Drain into river Chenab. Parameters analyzed on-site included temperature, pH, total dissolved solids (TDS) and conductivity. All the collected samples were analyzed as per methods listed in the *Standard Methods* (APHA, 2005). The Paharang Drain was found significantly contaminated with pollutants such as total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides and oil and grease, their concentrations were significantly higher as compared to National Environmental Quality Standards (NEQS).

Keywords: *sampling stations, monitoring, wastewater, industrial, Textile industry, municipal, Paharang Drain*

Introduction
Most of the industrial effluents in Pakistan are disposed off untreated into natural water ways or artificial impoundments. Paharang Drain, Faisalabad, is a typical example of a man made channel receiving both industrial and municipal wastewater in raw form. It was originally excavated in 1973 to collect excess water from the water logged areas, but now it is being used as major carrier of industrial and domestic wastewaters to river Chenab. A vast majority of the large industries in Faisalabad discharge their untreated industrial effluents into Paharang Drain which is often diverted to irrigate food and fodder crops which directly become the source of contamination. According to Munir and Mukhtar (2002), Faisalabad is divided into two zones: Eastern Zone and Western Zone. The sewage generated in the Eastern Zone drains into Madduana Drain and Western Zone wastewater flows into the Paharang Drain. Open Paharang and Madduana Drains pose serious threat to the bank side residents as they are exposed to polluted industrial and domestic wastewater laden with toxic chemicals. Besides being source of odor and eye irritation due to prevailing anaerobic conditions, these drains are also contaminating groundwater which is evident from increased TDS levels in groundwater (Kahlown *et al*., 2006).

WASA, Faisalabad, Kahlown *et al*., (2006), and, Munir and Muktar (2002), conducted studies on Paharang Drain. But they only measured the flow one time and at only one point and also analyzed the wastewater in terms of few parameters. Due to work in pieces and sporadic data no comprehensive treatment strategy was developed. But our study was based four month sampling period and to generate a meaning full technical data that could be used as basis for designing a pilot scale wastewater treatment plant

Combined industrial and municipal effluents exhibit high COD, BOD, TSS, TDS, heavy metals, toxic chemicals and pathogenic microorganisms besides being source of odor and eye irritation. Such effluents make the soil infertile. According to Pak-NEQS for municipal and industrial

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effluents, COD and BOD_5 of wastewater should not exceed 150 mg/l and 80 mg/l respectively. But Water and Sanitation Agency (WASA), Faisalabad does not have enough resources to test and treat all of the wastewater so it has to dispose into surface impoundments or natural on land or in surface water channels without treatment. Therefore, characterization and treatment of such combined effluents is vital for any beneficial reuse.

Currently, textile industries in Faisalabad are discharging their untreated effluents either into the sewer system into open Paharang Drain. Pakistan Environmental Protection Act, 1997, requires that all industrial wastewater should be treated to comply with NEQS (PEPA, 1997) before discharged into the receiving water bodies.

Material and Methods

Study Area

Paharang Drain, Faisalabad, starts near Chak Jhumra. 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. Three sampling pointes were selected along the first 29 km of the drain. The fourth sampling station was selected before the confluence of Paharang Drain into river Chenab. A schematic of the sampling sites and inter-site distances are given in Table-1 and Figure-1.

Table-1: Sampling stations along with sampling distances

Station numbers	Station name	Distance from zero point (kms)
1	Near Supreme Fabrics, Chuck Jhumra	**13**
2	100 Meter down the mixing point of the main drain and its tributary (Sam Drain)	**16.2**
3	Before effluent from 20 MGD Plant joins main drain.	**25**
4	Before Confluence of Paharang Drain into River Chenab	**70**

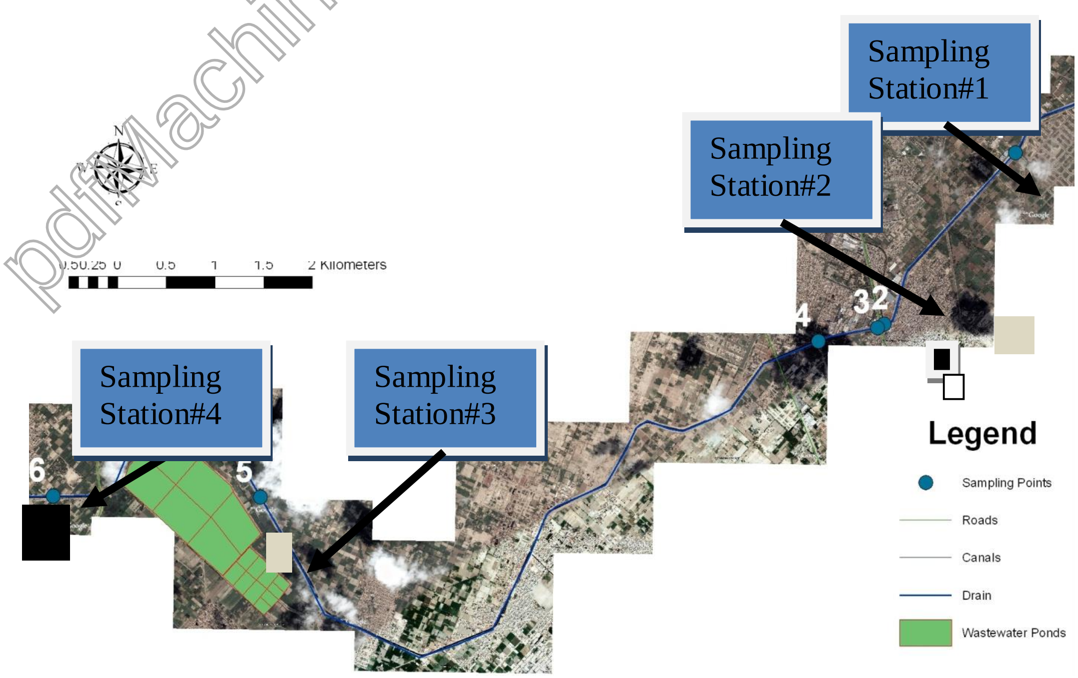

Figure 1: General layout of sampling points along the Paharang Drain

Sampling Plan

Proper sampling is one of the most important criteria of research work, so extreme care was exercised while collecting the samples. In order to find the characteristics of wastewater of Paharang Drain, the grab and composite samples were collected from all four stations of the Paharang Drain.

Sampling Procedure

Sampling for this study was carried out from January to April 2009. New plastic bottles of 1L capacity were used for sample collection. These bottles and caps were washed with detergent and then rinsed several times with tap water and distilled water and the cap was firmly placed in order to avoid any sort of contamination. Disposable gloves were used in order to protect from any possible health hazard associated with sampling. Then before sampling the bottles were rinsed with the sample water in order to homogenize the conditions and all samples were collected six inches below the water surface. Then the cap was placed on the bottles and was placed in icebox in order to avoid direct exposure to sunlight. Bottles preparation before samples collection is shown in Figure 2.

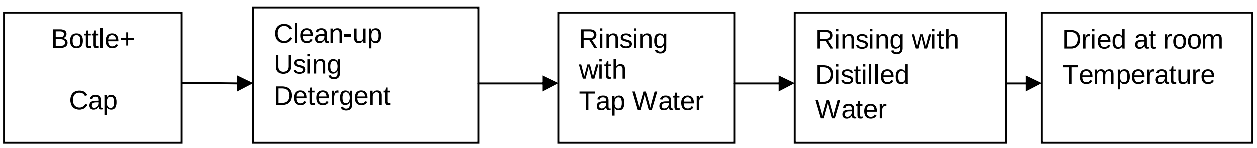

Figure 2: Bottle preparation for sample collection

Field Analysis

Samples for pH, TDS, conductivity and temperature were analyzed on site.

Parameters Analyzed in Laboratory

Table -2 provides information about the physical and chemical variables explored in this study along with the equipment and method of analysis used. In general, the collected samples were analyzed as per methods listed in the *Standard Methods* (APHA, 2005).

Table -2: Methods used for various parameter analyzed in this study

Variable	Units	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
Conductivity	mS/cm	Field	Conductivity Meter	Potentio-meteric Method
Turbidity	NTU	Lab	HACH Turbidiometer 2100N	Nephelometric Method
TDS	mg/L	Field, Lab	Conductivity Meter, Millipore Filtration Assembly and Glass Fiber Filter Fype 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^{-2}	mg/L	Lab	UV Visible Spectrophotometer	Turbidimetric Method
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
Chloride	mg/L	Lab	Erlenmeyer Flask, Burette, Magnetic Stirrer	Argentometric Method
Flow	MGD	Field	Current Meter – Model--	

Results and Discussion

The wet width of the drain at *Station#1* is approximately 24 feet. A dense cluster of industries and residences discharge their effluents prior to this station. Being the first receptor point of variable discharges, flow rate at this point was the lowest of all subsequent stations. The flow was found with mean value of 0.14 m^3/sec (Table-3). Value of pH of the drain water at this point shows its alkaline nature yet within the NEQS limits. BOD_5 and COD are one times higher than NEQS. Most of the other parameters excluding COD were within or near the NEQS values which indicate that water pollution up to this point was not horrendous and, if not further degraded; natural self purification processes would restore the water quality of the drain to a level within the NEQS.

Table -3. Physico-chemical characterization of Paharang Drain wastewater

S.No.	Parameters	Station1	Station 2	Station 3	Station 4	NEQS
1	Flow(m^3/sec)	0.14	0.85	3.04	3.3	---
2	Temperature (^oC)	25.4	29.7	25	21.1	40
3	Conductivity(mS/cm)	6	5.5	5.2	4.52	---
4	pH	8.8	9.2	8.3	7.9	6-9
5	Turbidity(NTU)	25.4	178.5	102.1	78.3	---
7	DO(mg/L)	0.6	0.5	0.8	1.01	---
8	TDS (mg/L)	3191.5	2984	2633.8	2292.7	3500
9	TSS (mg/L)	135	321	231.5	172.7	150
12	BOD(mg/L)	170.5	255.3	225.3	162.9	80
13	COD(mg/L)	339.6	496.1	436.9	308.8	150
16	Sulphates(mg/L)	567	494	383.3	332.7	600
17	Chloride(mg/L)	1060.9	1045.9	851.7	684.8	1000
19	oil and grease(mg/L)	21	40.3	32	26.1	10

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The wet width of the Paharang Drain at *Station#2* was approximately 17 feet. The mean flow rate at this was found to be 0.85 m^3/sec (Table-3). Other parameters such as pH, temperature, TDS, sulphate, chlorides were found to be within or near NEQS values. BOD_5 and COD were however, about two to three times higher than the NEQS values (Table-3). A study conducted by Aslam *et al.,* (2004) reported that average BOD_5 and COD concentration in textile effluents in Faisalabad was within the range of 238-329 and 416-647.7 mg/L compared to our results of 162-255mg/L (BOD_5) and 308-496 mg/L (COD) respectively. However, a similar study conducted by Tufekci *et al.,* (2007) in Turkey (Istanbul) showed much wider range of BOD_5 and COD in textile effluents as 280-1140 and 614-1960 mg/L respectively. This difference may be due to difference in point and time of sample collected. Also pure industrial effluent sampled by Tufekci *et al.,* (2007) was expected to exhibits higher COD and BOD_5. The study conducted by Khan *et al.,* (2003) on a drain (Hudiara Drain, Lahore) reported that the value of BOD_5 and COD in combined industrial and municipal effluent were found to be within the range 54-228 and 144-616 mg/L which is very close to our results. Mean value of TSS at *Station#2* was found to be higher than all other stations, 321mg/L which was about two fold higher than the NEQS. All other parameters except sulfates were higher than NEQS showing that such water should not be used any other secondary use directly.

Station#3 was located near Chakara pumping station before the stabilization ponds based municipal wastewater treatment plant in Faisalabad. At this station the flow was 3.04 m^3/sec much higher than *Station#2* (Table-3). Munir and Mukhtar (2002) and (Kahlown *et al*., 2006) measured the flow of Paharang Drain as 2.97 m^3/sec and 3.24 m^3/sec which clearly showed that flow increases from year to year. Before this point most of the channel#3 wastewater is diverted for irrigation. The mean value of TDS of the drain wastewater at this point was found to be 2634 mg/L which was far above TDS requirements of irrigation waters as per standard set by Punjab Irrigation Department (1000-1800) (Sial *et al*., 2005). At this station (Table-3) most of the parameters were found to be in lower concentration as compared *Station #2*. This shows the effectiveness of natural self purification and dilution by sewage between sampling *Station#2* and *Station #3*. BOD_5 and COD at *Station#3* were found to be 225 and 437 mg/L respectively which were about three folds higher than the permissible limits (80 mg/L (BOD_5) and 150 mg/L (COD)). 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 142-344 and 224-576 mg/L respectively. The value of Chloride was 843 mg/L. High chloride contents are harmful for agricultural crops if such wastewater is used for irrigation purposes (Nosheen *et al*., 2000).

The wet width of the drain at *Station#4* was approximately 50 feet and depth was about 4.5 feet (Table-3). The mean values of BOD_5 and COD were 163 and 309mg/L respectively. At this station the flow was 3.3m^3/sec (Table-3). Near river Chenab farmers were directly pumping wastewater from drain for irrigation. Considering drain water quality in terms of TDS and EC, its use for long-term irrigation should be discouraged. Farmers may be informed about the risks associated with the use of drain water for both irrigation and water buffalo bathing. Based on DO content Paharang Drain wastewater at discharging point does not support aquatic life and can be considered dead water body. The desirable DO of water ranges from 2-4 mg/l, to support aquatic life. Continuous discharge of Paharang Drain containing toxic substances into the river is putting the integrity of river Chenab at risk. Consequently the surface water of river is facing the menace of environmental degradation.

A substantial rise in flow from the start of the Paharang Drain to *Station #4* is illustrated in Figure 3. Beyond *Station#4* and up to river Chenab, there is no major outfall into the Paharang Drain. Therefore, average input of Paharang Drain to river Chenab would remain as 3.3m^3/sec.

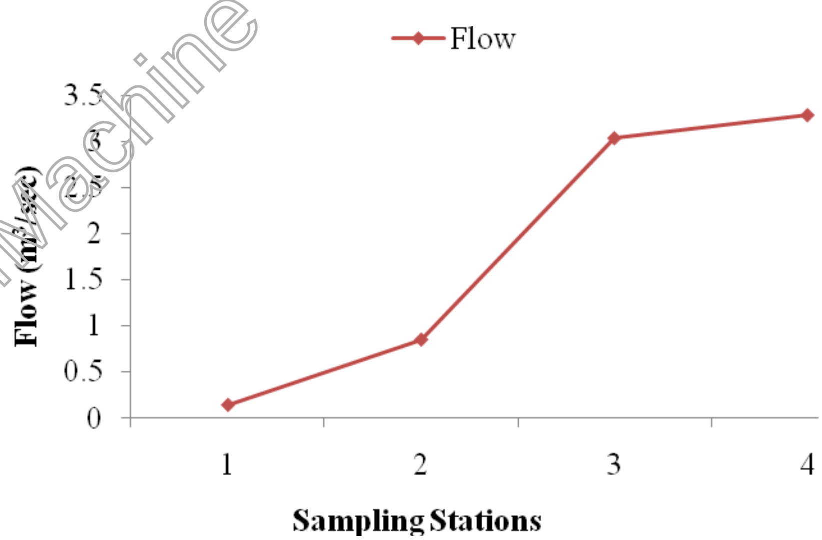

Figure 3: Flow profiles of the Paharang Drain

Variations in BOD_5, and COD from *Station#1-4* are shown in Figure 4. Concentrations of these parameters increased gradually up to *Station#2* indicating a continuous influx of industrial and municipal wastewaters. Fractional changes in the above mentioned parameters after *Station#2* indicated that no major out fall existed in this area that would further deteriorate the drain water quality. It was highly likely that, small influents to the drain were balanced by the self 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 a level where it could safely be diverted for beneficial usage. (Kahlown *et al*.,2006) reported that the BOD_5 and COD values of the Paharang Drain water before its entry into the river Chenab were 176 and 353 mg/L respectively, as compared to 80 and 150 mg/L required by NEQS.

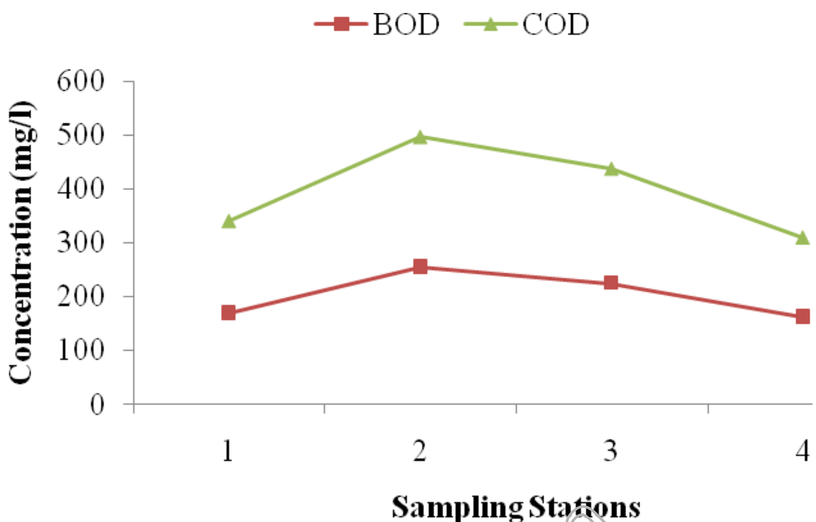

Figure 4: BOD and COD profiles of the Paharang Drain

Dissolved oxygen (DO) is essential for the survival of aquatic plants and animals**.** Minimum dissolved oxygen concentration has to be at least 5 mg/L for maintaining aquatic life healthy condition and dissolve oxygen concentration less than 5 mg/L are indicative of pollution (Kamal *et al*., 2007). Variation in value of DO is shown in Figure 5. The value of DO was found to very low from *Station#1-2* due to high pollution load of industrial and municipals effluents. Only few unit increases in DO was found from *Station#3* to *Station#4* due natural self purification and dilution by domestic wastewater.

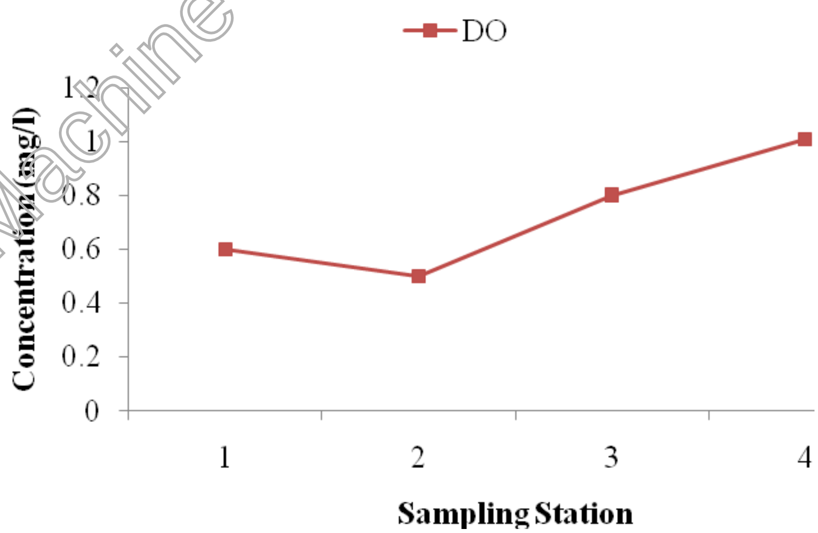

Figure 5: DO profile of the Paharang Drain wastewater

Chlorides (Figure 6) showed a downwards trend from *Station#1* to *Station#4* as most of the chlorides were discharged by the textile industry and the number of textile industry reduced as we went down to sampling *Station#4.* Similar was trend in shown in case of sulphate.

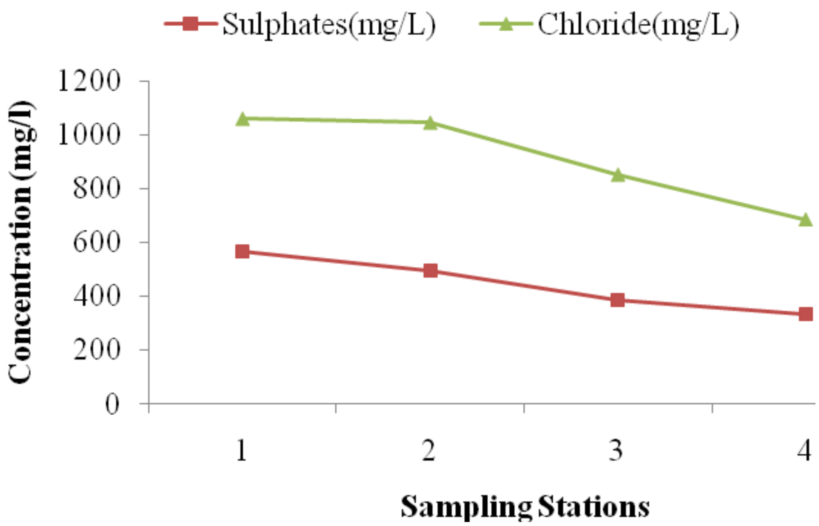

Figure 6: Sulphates and Chloride profile of the Paharang Drain wastewater

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.

To be specific following conclusions can be drawn from the study:

(i) A substantial rise in flow from the start of Paharang Drain *Station#1* to *Station #4* (0.14 to 3.3m^3/sec). Beyond *Station #3*and to river Chenab, there is no major outfall into the Paharang Drain and water quality improves due to natural process.

(ii) Most of the physico-chemical parameters of the Paharang Drain wastewater are 2-3 times higher than NEQS. Such waters are not only unfit for secondary human use such as swimming or irrigation but also a serious threat to ground and surface water resources. As Faisalabad is an agricultural and canal irrigated area, it is possible that wastewater might have entered in the food chain. It is urgently required to take necessary actions to properly treat wastewater prior to its use for irrigation or its discharge to river Chenab.

(iii) Wastewater quality deteriorate between sampling *Station#1* and *Station#2* and improved after *Station#2* to *Station#4*

(iv) Self purification capacity of the drain is proportional to the gap between the outfalls. The longer the gap, more effective is the self-purification. Due to self-purification the reduction in the value of BOD_5 and COD was found to be decreased *to* the end point of the Paharang Drain.

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 pour in Paharang Drain. The environmental laws and their implementation should be dealt more seriously and responsibly.

(ii) The practice of usage of Paharang Drain water for irrigation of fields should be immediately stopped as it is harmful for the consumers of those vegetables and crops.

(iii) Besides that, livestock should not be taken to the drain for bathing and drinking, it could become a potential source of toxic chemical and heavy metals through their milk.

(iv) Pumping of groundwater near drain for drinking purposes must be avoided

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