Low Cost Wastewater Treatment at Beverage Industry, Hattar Industrial Estate, Pakistan - A Case Study

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***Abstract*- The objective of this study was to investigate the potential for reducing freshwater consumption through recycling, low cost wastewater treatment and beneficial use of sludge of beverage industry at Hattar industrial estate (HIE), Haripur, Pakistan, under the concept of clean technology and water recycling. Samples were collected from end of pipe and analyzed for various physico-chemical parameters such as flow rate, temperature, conductivity, odor, chloride, sulfate, sodium and calcium which were found below the National Environmental Quality Standards (NEQs), while pH, color, turbidity, alkalinity, hardness, total dissolved solids (TDS), total suspended solids (TSS) and chemical oxygen demand (COD) were found above the NEQs level. The treatment techniques comprised of sedimentation, coagulation and adsorption, were designed for those parameters which were beyond the Pak-NEQs. The optimum doses of coagulants were 15, 25, 35, 45 and 55 ml/l with 5:1 ml alkalinity were identified and removed significant amount of pollution loads. After treatment, the achieved sludge was processed for identification of organic and inorganic contents in terms of their beneficial purposes. The treated water was used for Agriculture, municipal and in industry such as washing of carats, bottles and floor, cooling and other minor activities within the premises of industry.**

Keywords- Cleaner Production; Coagulation; Hattar Industrial Estate; Industrial Wastewater; Pollution Loads; Treatment

I. INTRODUCTION

In both developed and developing countries the industrial activities have caused huge amount of untreated wastewater to carelessly release into freshwater streams. In Gulf regions, 80% of industrial effluents were directly discharged into rivers through various media [1]. In the past rivers were the safe sites for waste disposal, especially industrial effluents in Nigeria and other developing countries [2, 3]. As there is an increase in industrial activities, the pollution stress was developed on the water bodies [4, 5], and resultant environmental and health problems rose in great extent [6]. In many African states, there is a rapid increase in population, urbanization and industrialization which has altered aquatic diversity due to discharge of pollutant to water bodies [7]. Tolba (1982) stated that presence of high organic pollutant in African water bodies due to extreme poverty, low water sanitation system with respect to developed countries [8].

The beverage industries were pin pointed as major consumers of water and became economic source in the world [9, 10]. But the industrial activities without adequate treatment facilities have led to discharge of wastewater into water bodies [11, 12]. The wastewater generation and management in beverages industries become a serious threat to freshwater bodies, aquatic biota and human health [13]. The continuous discharge of effluents into streams and rivers raises the level of trace and toxic metals, which have considerably adverse effect on fresh water bodies [14, 15].

In the last decade, Pakistan entered into industrial race and reported 70% increases per year. But due to lack of management plan, resources and poor enforcement authority cannot achieve their goals [15]. In Pakistan beverage industries play an important role in country economy, with an annual production of 23 liter/person/year [16].

Hattar industrial estate is comprised of a large number of industrial units and has a significant role in the country's economy. But this exposure of industrial estate has adverse impacts on the ecological system [17, 18]. The food and beverage have high demand for freshwater and as a result a huge amount of wastewater (contaminated with toxic and trace metals) generated and released to environment. No systematic work has been carried out on the wastewater of food and beverage industries in the light of clean technology. Therefore, the goal of this study was to assess the pollution loads on daily basis and their treatment in Hattar industrial estate Haripur, Pakistan.

II. METHODOLOGY

A. Field Survey

Field survey was conducted in summer season (2013) at Hattar Industrial Estate, Haripur, which is 51 km from Islamabad (Capital of Pakistan). The survey was conducted in terms of selection of samples sites, location of end-of-pipe and was to identify the source and extent of pollutants as shown in Fig. 1. To get one accurate and representative wastewater sample, a composite sample technique was followed with uniform two-hour interval from single point released by food and beverage industry HIE [19, 20].

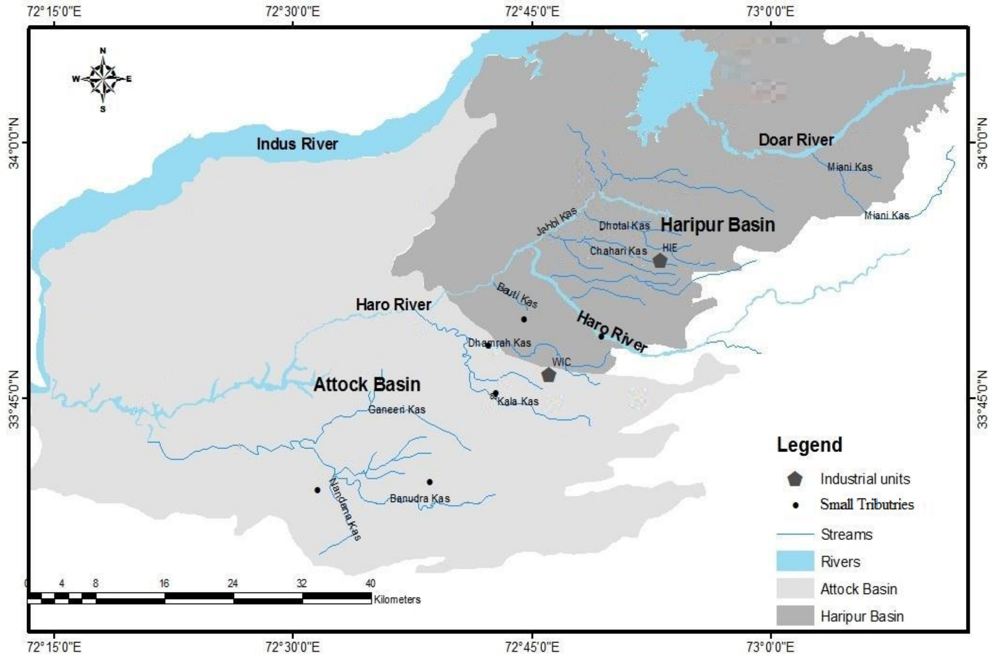

Fig. 1 Location map Hattar Industrial Estate, Haripur, Pakistan

B. Experimental Work

Physico-chemical parameters of whole and variously pre-treated industrial wastewater of beverage industry were analyzed for physical properties including color, odor, temperature, pH, electrical-conductivity, turbidity, total suspended solids (TSS), and chemical parameters including total dissolved solids (TDS), alkalinity, hardness, chemical oxygen demand, chloride, phosphate, sulfate, sodium and calcium. For all sorts of analysis (Table 1), a well-established standard procedure of water and wastewater analysis was followed [21, 22]. The flow rates were measured through mid-section method [23].

TABLE 1 PHYSICOCHEMICAL CHARACTERISTIC OF BEVERAGE INDUSTRY BEFORE TREATMENT

S No	Parameter	Unit	Result	NEQS	Analytical Methods
1	Temperature	^0C	42	40	Thermometer
2	Flow rate	m^3/d	15.27		Manual
3	Color	---	Dark yellow		Visual
4	Odor	TON	6.00		Quantitative
5	pH	---	8.9	6-9	Digital pH meter
6	Conductivity	µS/cm	4374		Conductivity meter
7	Turbidity	NTU	50		Instrumentation
8	Alkalinity	mg/L	812		Titration
9	Hardness	mg/L	1037		Titration
10	Chloride	mg/L	558	1000	Titration
12	Sodium	mg/L	120		Flame photometer
13	Sulfate	mg/L	190	600	Spectrophotometer
14	Calcium	mg/L	140		Titration
15	Chemical oxygen demand	mg/L	346	150	Reflux titration
16	Total suspended solids	mg/L	783	150	Gravimetric
17	Total dissolved solids	mg/L	3756	3500	Gravimetric
18	Dissolved organic	mg/L	2509	--	Gravimetric
19	Dissolved inorganic	mg/L	1247	--	Gravimetric

The treatment process is generally consisted of sedimentation coagulation and adsorption practices, using optimum dose and detention time. In sedimentation practice the wastewater was kept for one hour and 24 hours for settling of suspended solids in a natural way, but their removing capacity was 05 and 11 %, which was not efficient for industrial activity. For removing all sorts of wastes, coagulation technique was applied. In coagulation practice a series of five glass container with stirrers that hold at least 1000 ml sample were used. To each container coagulant Aluminum sulphate ($Al_2 (SO_4)_3 6H_2O$) were added with specific ratios [24] as given in Table 2.

TABLE 2 COAGULANT DOSES ADDED TO THE SAMPLE

S. N	Coagulant use per 1000 ml sample	Alkalinity Added (ml)	Coagulant concentration (mg/l)	Solids produced (mg/l)	Settling Time (Minutes)
1	15	3	14.7	2056	32
2	25	5	24.4	1811	26
3	35	7	33.8	1978	25
4	45	9	43	2026	22
6	55	11	52	2142	20

A coagulant of 15 ml (1000 ppm) with 5:1 ml alkalinity was added to 1st jar and mixed rapidly for 2 minutes and then mixed slowly for 15 minutes till the flocs formation. The flocs were settled in appropriate time as shown in Table 2.

After coagulation the sample was passed through adsorbent (charcoal). About 0.2 mg charcoal was added to sample. These charcoals were again settled through natural way, which was removed through sludge. The main purpose of this technique was to remove color, order and reduce the dissolved organic species in the wastewater.

III. RESULTS AND DISCUSSION

A. Before Treatment

The detailed average results of wastewater before treatment were given in Table 1. Flow rate helps in designing an engineering system for treatment and recycling chambers. The treatment plant consists of three chambers i.e. sedimentation tank, coagulation chamber and storage tank. First the wastewater comes to sedimentation tank continuously three days for settling of grits and other heavy debris. This tank has a capacity of 80 m^3, while the water volume was 45.81 m^3. Then the wastewaters were transferred to coagulation chamber, for treatment (coagulation and adsorption). The coagulation chamber has a capacity of 60 m^3. After treatment the water passed to storage tank, having a capacity of 120 m^3 (Fig. 1). The treated water was stored for three days and can be used for various purposes.

The flow rate of industrial wastewater was found 15.27 m^3/day, which clearly affect the flow rate of main drain Jari Kass Nallah, Hattar Industrial Estate. The color and odor of the whole samples were determined and found dark yellow and pungent (6 TON) respectively, which has bad effect on freshwater asthesity. Temperature of the sample was found 42˚C and changed with the number of plants during operational activity. The average pH and conductivity of the samples were 8.9 and 4.37 mS/cm. Turbidity and SS of the wastewater were acquired 50 NTU and 783 mg/l, and found beyond the NEQS (5 NTU and 150 mg/l) respectively. TDS were analyzed and found 3756 with organic species 2509 and inorganic 1247 mg/l. The obtained concentration of alkalinity, hardness, chloride, sulfate, calcium and sodium were 812, 1037, 558, 190, 140 and 200 mg/l respectively, which can greatly contribute pollution loads to freshwater. Chemical oxygen demand (COD) was analyzed and obtained 346 mg/l, and found above the permissible limit (150 mg/l).

B. Treatment

The treatment system is composed of a number of unit operation and design for those parameters which were above the permissible limits [25]. The treatment consists of three major process, i.e. sedimentation, coagulation and adsorption. In coagulation the wastewater treated with chemical coagulant alum sulphate (1000 ppm) solution as given in Table 2.

A number of experiments were performed to identify optimum dosages of coagulants to remove maximum amount of pollutants loads in low cost and short time [26, 27].

In treatment practices different doses of coagulant were tried on Jar apparatus holding at least 1000 ml sample. In these experiments the best optimum dosage (as shown in Table 2) was identified to remove maximum quantity of pollution loads with minimum concentration. By adding 14.7 mg/l coagulants with 5:1 ml alkalinity to 1st Jar and produced 2.05 gm solids within respective time 32 minutes. Similarly coagulant dose of 24.4, 33.8, 43 and 52 mg/l was applied with detention time of 26, 25, 22 and 20 minutes, and produced 1811, 1978, 2026, and 2142 mg sludge respectively (Table 2).

C. After Treatment

The treatment can bring a desire changes in the physico-chemical parameters of food and beverages industry wastewater as shown in Table 3 and Fig. 2. In treatment color and pungent were removed and make for reuse in industry and agriculture practices. The pH and turbidity of the wastewater were reduced up to permissible level. The obtained results after treatment of alkalinity, hardness, chloride, sulfate and calcium are 198, 220, 770,130 and 45.7 mg/l respectively, while the concentration of chloride was increased but still under the concept of NEQs. For those parameters which were beyond the permissible level such as COD, SS and TDS, their acquire results are 43.5, 120 and 1743 mg/l respectively. Under the well-established treatment concept the industrial wastewater makes potable for the minor activity inside the industry and agriculture uses.

Before treatment some of the parameters were beyond their permissible limits, while in treatment all the parameters came to permissible limits as suggested by Pak-NEQs. The most common parameters such as color, turbidity, alkalinity and hardness, COD, TSS and TDS have high concentration. During the treatment operation these parameters can be reduced up to great extent, such as color was removed up to 100%, while turbidity 97 %, alkalinity 78 %, hardness 79 %, COD 87 %, TSS 86 % and TDS 68% were removed. In these pollutants the major portion is organic contents as shown in Table 3.

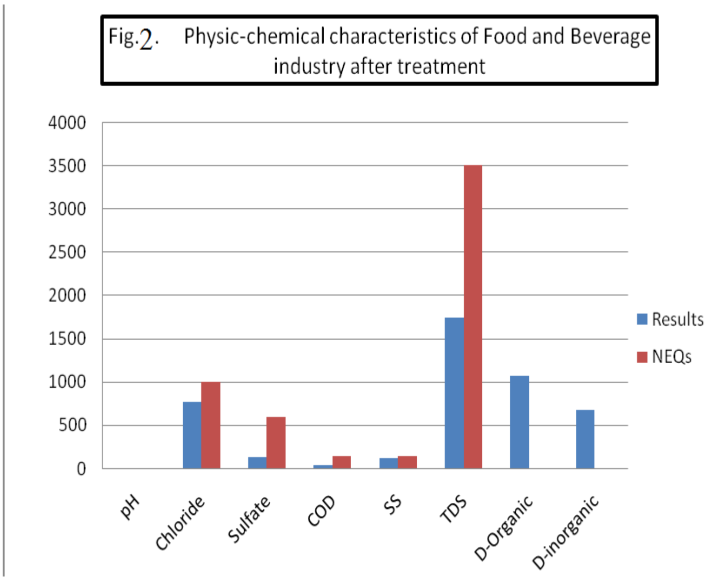

Fig. 2 Physico-chemical characteristics of beverage industry after treatment and comply with Pak-NEQs

TABLE 3 DIFFERENCES BETWEEN PHYSICO-CHEMICAL PARAMETER BEFORE AND AFTER TREATMENT

S No	Parameter	Before treatment	After treatment	Difference mg/l	Removal %	Units	NEQs
1	Color	Dark yellow	Colorless		100	- -	Not detected in 100 ml
2	Odor	6	2	4	67	TON	Not detected in 100 ml
3	pH	8.9	6.7	2.2	24.7	- -	6-9
4	E- conductivity	4374	2812	1562	38	µS/cm	--
5	Turbidity	50	20	30	60	NTU	5
6	Alkalinity	812	198	614	75.6	mg/l	200-400
7	Hardness	1037	220	817	79	mg/l	200-300
8	Chloride	558	770	212		mg/l	1000
10	Sodium	120	3.5	11.5	97	mg/l	--
11	Sulfate	190	130	60	32	mg/l	600
12	Calcium	140	45.7	94.3	67	mg/l	--
13	COD	346	43.5	302.5	87	mg/l	150
14	TSS	783	120	663	85	mg/l	150
15	TDS	3756	1743	2050	54	mg/l	3500
16	Dissolve Organic	2509	1068	1291	57	mg/l	--
17	Dissolve Inorganic	1247	675	572	46	mg/l	--

D. Pollution Load

Beverage industry released a huge amount of wastewater with high quantity of pollution loads at a flow rate 15.27 m^3/d. Before treatment the beverage industry produced 11 kg of suspended loads per day, while in treatment the suspended load was reduced up to 1.8 kg/d. Most part is organic and inorganic. The other contents such as TDS (including dissolved organic and inorganic) and COD also contribute to pollution to freshwater as shown in Table 4. This has got negative impacts of aquatic flora and fauna [28, 29].

TABLE 4 POLLUTION LOAD PRODUCED BY BEVERAGE INDUSTRY BEFORE AND AFTER TREATMENT

S/N	Parameters	Before treatment mg/l	Before treatment amount in kg/day at a flow rate of 15.27 m_3/d	After treatment mg/l	After treatment amount in kg/day at a flow rate of 15.27 m_3/d
1	TSS	783	11	120	1.8
2	TDS	3756	57	1743	26
3	Total organic solid	2509	38	1068	16
4	Total inorganic solid	1247	19	675	10
5	COD	346	5	43.5	0.7

IV. CONCLUSION

The wastewater and effluents flushing from beverages industries can contribute to a significant pollution loads to river Haro through Jari Kass Nallah. The physical treatment is not efficient i.e. 5 and 11% remove the total solid. But the chemical treatment (coagulation and adsorption) can reduce the significant amount of pollution loads up to maximum extent; such 54 % reduction occurred in TDS, 57% in dissolved organic, 46% dissolved inorganic, 85% TSS and 87% in COD. Similarly comparative reduction was also observed in other parameters as given in Table 3. It is suggested to treat the food and beverage industrial wastewater so as to reduce the stress on the freshwater resources and pay annual incentives to government. The treated water can be recommended to use for the variety of purposes such as cleaning, washing of carats and bottles. It can also be used for urban and municipal activities, households, recreational parks, cooling of power and industrial machineries, forestry and pastures and fire fighting purposes. Besides, this treated water is vital for the wetland, groundwater recharge, reduction of water scarcity and risk management option.

ACKNOWLEDGEMENT

The authors would like to thank Prof. & Dr. Noor Jehan, Department of Environmental Sciences University of Peshawar for his keen interest and encouragement. The authors are grateful to Dr. Seema Anjum Khattack NCE in Geology, University of Peshawar for his continuous support during this study. The assistance rendered by Department of Environmental Sciences and NCE in Geology, University of Peshawar staff is thankfully acknowledged.

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