



Optimization of Wastewater Treatment Process in Industry “A Case Study of Hattar Industrial Estate Haripur”

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Abstract

This study was conducted with the objectives to analyze Ghee Mill effluents, search out low cost wastewater treatment and make the water suitable for irrigation. For this purpose Ghee Mill effluents were analyzed for 19 physico-chemical parameters twice, before and after treatment and were compared with Pakistan National Environmental Quality Standards (Pak-NEQS). The analytical results revealed that Total Suspended Solids (TSS), Chemical Oxygen Demand (COD) and oil & grease were high. For identification of suitable treatment method, two different techniques were tested, coagulation and adsorption. The optimum dose of 35mg/L to 66 mg/L was identified as appropriate to remove suspended solids. For adsorption a column containing 0.2 mg/L was identified as suitable dose for removal of color and COD. The analytical results after treatments were complying with Pak-NEQS. Therefore, coagulation in combination with adsorption is herein recommended for treatment of Ghee Mill effluents.

Keywords: Adsorption; Coagulation; Cleaner Production; End of Pipe treatment; Ghee mills; Wastewater

Introduction

Cooking oil and vegetable Ghee industry is a large manufacturing sector of Pakistan. Around 115 units are producing vegetable ghee/cooking oil with an installed capacity of around 2.8 million tons. The actual production against this capacity is around 1.5-1.8 million tons [1]. This meets one third of the demand. Therefore, about one third is imported which is 5% of the total import. The present investment is of Rs 384 billion (\$ 4.5 billion). According to Mehdi et al. [2] (2009) annual increase in edible oil consumption is about 7.7 percent due to population growth and increase in per capita income. Edible oil is important food stuff but it has got negative impact on environment and need a careful eye.

Hattar Industrial Estate (HIE) is the largest industrial Estate of the Province Khyber

Pakhtunkhwa (KP), consists of more than 360 industrial units out of which 17 are edible oil and ghee industries [3]. The main problem in the Hattar Industrial Estate is wastewater and Ghee industries are the major source of wastewater in the study area [4]. Out of the total, only 10 units are functional and contributing to pollution load of the Hattar Industrial Estate. There are 2 industries present in Hattar Industrial Estate which have their own treatment plants while other industries, including edible oil industry have no treatment facilities [5].

The nearby surrounding population of Hattar Industrial Estate is dependent on ground water resources. Therefore, water monitoring and pollution control is a big requirement [6-7]. The industrial sector in the KPK began with a focus on

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consumer goods with later transition to the production of more sophisticated products. Presently, 25% of industrial units are in the food sector; with an equal share in textiles (Table 1).

Table 1. Major Industries of KP Industrial Estate and Wastewater contents.

S. No	Industries	Major effluents	No. of units
1	Food, beverages and tobacco	Starch, citric acid, sugar	392
2	Textile apparel and leather products	Mineral acid, fat, oil	384
3	Wood products	Zinc, Sugar, Sulphide	72
4	Chemicals, petroleum, oil, Plastics	Phenol mineral acid, phosphate, Hydrocarbon, lead paper	224
5	Mineral products	Citric acid, Starch, organic materials	198
6	Metals product	Heavy and Trace metals	164
7	others	Other pollutants	59
	Totals		1513

Source: Sarhad Development Authority, 2009

According to Saravanamoorthy and Ranjitha [8], the effluents of textile industry have high concentration of phosphorus, nitrogen, potassium and other organic matters, which could enhance the growth of leaves and yields. Similarly the effluents of food and beverages industry have high organic contents which could be suitable for soil fertility and crops yield [9]. Majority of industrial effluents have high concentration of COD, BOD Oil and grease, toxic and major elements. These elements have potential significant impacts on agriculture soil, aquatic biota, food chain with ultimate accumulation in human body and causing various diseases and disorders [10].

Majority of inorganic contaminants are not biodegradable and tend to accumulate in soil, water and ultimately enter to living organism, causing health related problems [11]. For the mitigation and prevention of these contaminants various technologies and treatment process are available such as coagulation, chemical precipitation,

solvent extraction, osmotic filtration, ultra filtration, Nano filtration, biological system, electrolytic process, reverse osmosis, photocatalytic degradation, adsorption, ion exchange methods [12]. Due to high cost in safe disposal of treatment plant wastes, majority of these methods for treating wastewater have not been applied widely [13].

Although the waste generated by different industries varies dramatically from one another in concentration range of pollutants. Its minimization is necessary through low-cost techniques, such as bio-remediation or chemical coagulation [14] [15]. The Coagulation and flocculation are popular techniques for industrial wastewater treatment. Several studies have been conducted on the evaluation of coagulation for its performance and optimization [16].

There are two approaches to mitigate the problem of pollution. One is end-of-pipe (EOP) treatment and other is cleaner production (CP). The aim of cleaner production is to explore mitigation measures of preventive nature. In this way some benefits are also expected in terms of saving in raw material, production and decrease in emission [17]. The basic elements of cleaner production are recycling, reuse and reduce. Beside this, there is variety of feature that helps in prevention of insufficient use of resources and avoidance of unnecessary generation of waste, and residues the operation costs, and save water [18][19].

In this study an attempt has been made to evaluate the wastewater quality from oil and Ghee industry and identify suitable methods of treatment. The Ghee Mill under study was deficient in the concept of cleaner production and treatment. Therefore, first the wastewater was characterized and subjected to end-of-pipe treatment with the objective to identify pollution load and proper cleaner production options.

Methodology

Sampling

Field survey was conducted for identification of pollution points and selection of samples sites. To collect a representative sample, four composite samples were collected randomly at

two hours interval. The effluents drain was kept under observation for six months and was sampled with 10 days interval. A total of 18 samples (@3 samples/month) were collected for analysis and treatment.

Laboratory work

The wastewater of Ghee Mill was characterized for 19 physical and chemical parameters. The physical parameters include pH, E. Conductivity was measured through elemental analyzer (InoLab99), Total Solids (TS), Total suspended solids (TSS), and Total dissolved solid (TDS) total Organic and Total Inorganic solids were measured through gravimetric method as suggested by Hammer [20]. The chemical parameters include Chemical oxygen demand (COD) which was measured through Open reflux method, while for the determination of Oil and Grease standard method was applied as suggested by Gupta [21]. For all sort of analysis, standard method of water and wastewater analysis were followed [16, 24]. While Cd, Cr, Pb, Ni, Co, Cu, Fe, Mn were determined through Atomic absorption Spectrophotometric method (PerkinElmer7000). Flame photometric analysis was also used for Na and K [22].

Coagulation

Coagulation tests were performed on simple jar-test as per procedure listed in Tatsi et al., [16]. The jar apparatus consists on three cylinders with 50 cm length of one litter capacity. The sample was shacked for one minute and then transferred to Jar Test apparatus. The 35 to 66.6 ml of coagulant with different doses of FeCl_3 , $\text{Al}(\text{SO}_4)_3$ (1000 ppm) were added to each jar and mixed rapidly for 2 minutes and slowly for 15 minutes.

Adsorption

For the removal of color, COD and other organic, Powder Activated Carbon (PAC) was used. One litter sample was passed through a thin column containing 0.2, 0.3, and 0.4 mg PAC. The experiment was repeated three times for each sample [23].

Quantification of pollution load

The pollution was quantified through following equation

$$\text{Load (Kg)} = \text{Concentration (mg/L)} * \text{flow rate (L/d)} / 10^6 \text{mg (1Kg)}$$

This formula shows the quantity of pollution released by industry per day as shown in Table 7.

Pollution removal performance in terms of percentage (Table 7) after treatment was calculated through following equation

$$\text{Percent Removal Efficiency} = (A - B/A) * 100$$

Results and Discussion

Analytical results of Ghee industry wastewater including, physical and chemical results before and after the treatment are given in tables and each parameter could be discussed in the detail as under, while the heavy metals are under permissible limit and could be excluded from discussion.

Wastewater Characteristics

The flow rates (155520 L/d) revealed, that there is release of large quantities of wastewater from Ghee industry and have a major role in increasing the amount of flow rate in the main drain of Hattar industrial estate. By comparing the results with Pakistan National Environmental Quality Standards (Pak-NEQS) [26], the physical parameters including temperature, TDS and pH were within the permissible limits with average value of 40 °C, 1760 mg/L and 8.3 respectively. Among the chemical parameters, chloride, sulfate sodium and potassium were within the permissible limit. Total suspended solid (TSS) of the effluents was about 10 time higher than Pak-NEQS (Table 2). The minimum, maximum and average value of TSS were 1050, 1900 and 1120 mg/L respectively. Chemical Parameters from pollution point of view were Total Organic Solids (TOS), Chemical Oxygen Demand (COD) and Oil & Grease were high when compared with Pak-NEQS (Table-2). Therefore treatment was given to identify exact pollution load.

Table 2. Physicochemical Characteristics of Ghee Mill before Treatment.

S. No	Parameters	Pak-NEQS	Min	Max	Average	units
1	Ph	6-9	8.3	11.3	8.3	-
2	E. Conductivity	-	2600	3505	3052.5	-
3	TDS	35000	1700	2350	1760	mg/l
4	TSS	150	1050	1900	1120	mg/l
5	TS	-	2880	4550	2880	mg/l
6	Alkalinity	-	330	520	?	mg/l
7	Total organic solid	-	1660	2970	1660	mg/l
8	Total inorganic solid	-	840	1280	1220	mg/l
9	Chloride	-	160	230	195	mg/l
10	Sodium	-	25	32	29	mg/l
11	Potassium	-	5	7	6	mg/l
12	COD	80	321	540	1220	mg/l
13	Oil and grease	10	370.6	600	489	mg/l

Treatment

Treatment process was designed for those parameters which were above the Pak-NEQS as given in Table 2. Treatment process consists of two process coagulation and adsorption [24]. In coagulation the wastewater samples were treated with ferric chloride and optimum dose of coagulant were found (Table 5) [25]. As ferric chloride imparts color to the wastewater sample, so the wastewater was treated with Powder Activated Carbon (PAC) to remove color and organic load as shown in Table 3. Each Jar shows efficient result by applying 0.2 mg PAC which is considered as optimum dose. Before the treatment process Total suspended solids (TSS), color, COD and Oil and grease were above the Pak-NEQS and after the treatment they were found below the Pak-NEQS.

Table 3. Physicochemical Characteristic of Ghee Mill after Treatment.

S/N	Parameters	Min	Max	Average
1	Color			White
2	pH	7.4	8.3	7.4
3	E. Conductivity	1445	2832	2138
4	TDS	950	1760	950
5	TSS	120	1120	120
6	TS	1070	2880	1070
7	Total organic solid	849	1660	849
8	Total inorganic solid	171	1220	171
9	COD	46.4	321	46.4
10	Oil and grease	00	489	00

Pollution load

Pollution load based on average values and flow rate ($155.5\text{m}^3/\text{day}$) shows that an average industry produces 174.2 Kg of suspended load daily. Most part is organic and contributing COD contents to freshwater (Table 4). This has got negative impacts of aquatic flora and fauna [22]. Therefore first suspended solids were targeted and treated.

In wastewater treatment, chemical coagulation is usually accomplished by addition of trivalent metallic salt such as FeCl_3 , $\text{Al}(\text{SO}_4)_3$. Therefore optimum dosages of coagulant were determine by performing series of experiments as also suggested by Manahan 1994 [27].

The test must be performed on water samples that is to be coagulated and must be repeated with different dosages [28].

A series of three glass cylinders with stirrers that hold at least 1 liter sample were arranged. The 66 mL coagulant was added to 1st jar and mixed rapidly for about 2 min, to ensure complete dispersion of the chemical and then mixed slowly for 15-20 min till flocs formation. The flocs were settled in 8 min and produced 1222 mg sludge. Similarly 50, 45, 40 and 35 ml

coagulants were added to each Jar and mixed rapidly for Two min for complete dispersion of chemical and then mixed slowly for 15 min till flocs were formed. The flocs were settled in 8, 9, 25, 10 and 6 minutes and produce 1222, 1100, 987, 1384, 1020, and 1175 mg sludge, respectively as given in table 6 [20, 25].

Table 4. Pollution load produced by Ghee Mill.

Sr. No.	Parameters	Average Value mg/L	Amount in Kg/day Produce at flow rate of 155520 L/d
1	TDS	1760	273.8
2	TSS	1120	174.1
3	Total organic solid	2880	447.8
4	Total inorganic solid	1220	189.7
5	COD	1220	49.9
6	Oil and grease	489	76.0

Table 5. Chemical coagulants and their Doses.

Sr. No.	mL of Coagulant Added to 1000 mL sample	Coagulant concentration	Mix Sludge produce mg/L	Settling time (minutes)
1	66.6	62.4	1222	8
2	50	48	1100	9
3	45	43.1	987	25
4	40	38.5	1384	10
5	35	33.8	1020	6

Table 6. Difference between Physico Chemical parameters before and after treatment.

S No	Parameters	Before treatment	After treatment	Average	Difference after treatment	Units	Removal %
2	Color	Light yellow	white	--	100%		100
3	pH	8.3	7.4	7.85	0.9		10.8
4	E. Conductivity	3052.5	2138	2595	914	μs/cm	30.1
5	TDS	1760	950	1355	810	mg/L	46
6	TSS	1120	120	620	1000	mg/L	89.3
7	TS	2880	1070	1975	1810	mg/L	62.8
8	Total organic solid	1660	849	1254.5	811	mg/L	48.9
9	Total inorganic solid	1220	171	695.5	1049	mg/L	85.9
10	COD	321	46.4	183.7	274.6	mg/L	85.5
11	Oil and grease	489	0	489	489	mg/L	100

The best result of the optimum dose of chemicals is 40 and 35mL, which produce high amount of sludge in minimum time as shown in Table 5.

Comparison Before and after treatment

Before treatment majority of parameters such as COD, TSS, TDS, Total organic, inorganic and oil and grease are above their respective permissible limits. In treatment practices these parameters were reduced up to below the Pak-NEQs (Fig 1 & Table 6). The percent removal achieved of these parameters such as COD 86%, TSS 89%, TDS 46%, Total organic 50%, Total inorganic 86 % and oil and grease 100 % was satisfactory as given in Fig.1.

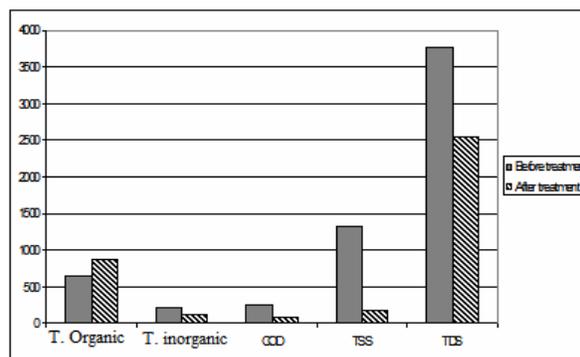


Figure 1. Graph showing comparison of before and after treatment

Pollution load recovered

The Ghee industry released a huge amount of wastewater with high amount of pollution load at a flow rate of 155.5 m³/day, it shows that before

treatment industry produces 174 kg of suspended load, and after treatment the suspended load is reduced to 18.6 kg. Most part is organic and inorganic as shown in (Table 7).

Table 7. Amount released by Ghee Mill after treatment.

S No	Parameters	Before treatment Average Value mg/L	Amount in Kg/day Produce at Flow rate of 155520 L/d	After treatment Average Value mg/L	Amount in Kg/day Produce at flow rate of 155520 L/d	Difference In amount removing in treatment process
1	TDS	1760	273.8	950	147.7	126
2	TSS	1120	174.1	120	18.6	156
3	Total organic solid	2880	447.8	849	132	315
4	Total inorganic solid	1220	189.7	171	26.5	162
5	COD	321	49.9	46.4	7.2	42.7
6	Oil and grease	489	76.0	00		489

Conclusion

The combine effect of coagulation and adsorption was quite effective for Ghee Mill effluent.

Ferric chloride is one of the coagulants, which not only help to remove suspended load but also reduce COD level. Other parameters which are reduced during coagulation and adsorption include alkalinity, pH, TS, TSS, TDS, Sodium, potassium, oil and Grease, and phosphates. Besides, minor changes were observed in sulfates, E. Conductivity and Hardness level. Therefore, coagulation along with adsorption is recommended for the effluent of Ghee Mill.

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