STUDY ON THE PERFORMANCE OF WASTEWATER TREATMENT PLANT DESIGNED FOR INDUSTRIAL EFFLUENTS

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ABSTRACT

The present study was conducted to assess the performance of the treatment plant installed on the main effluent drain of Hayatabad Industrial Estate (HIE) for reducing pollution load. The objective of the study was to know about the pollution removal efficiency and suggest changes in the existent treatment plant, if required. For this purpose, samples were taken from the effluent, before and after it went through the treatment plant. It was found that the treatment was not sufficient to remove various physical and chemical parameters including Suspended solids (SS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Sulfide (S) in order to comply with Pakistan National Environmental Quality Standards (Pak-NEQS).The collected samples were then treated in the laboratory in order to identify and suggest suitable coagulant. For this purpose three different treatments .i.e. Lime, Alum and Alum+Lime were applied. The optimum doses identified were 25, 35 and 26:13 ml respectively. The settling time was 25, 35 and 20 minutes respectively for lime, alum and alum+lime. The results revealed that the combine treatment (Alum + Lime) effectively removed suspended load up to 90%, along with 82% BOD, and 80% COD respectively. Therefore, it was concluded that the installed small scale treatment plant is not enough in its present form and needs to be upgraded by adding a coagulation step.

Key Words: *Industrial effluents, wastewater treatment, Coagulation, TSS (total suspended solids), Biochemical Oxygen Demand, Chemical Oxygen Demand*

INTRODUCTION

Malfunctioning of a wastewater treatment plant can lead to various direct and indirect environmental problems[1]. Wastewater production and its treatment is the main problem for industries and the society as well. The operation and maintenance of wastewater treatment plants is highly problematic[2]. Annually 4432.35 million cubic meter of Industrial wastewater is produced in Pakistan. It has been estimated that only 1% of it is treated before its disposal[3]. In Lahore, it has been reported that 3% industries are using hazardous chemicals without taking preventive and curative measures. The same trend exists in other parts of the country. For instance, the two big industrial estates in Karachi .i.e. Korangi Industrial Trading Estate (KITE) and Sindh Industrial Trading Estate (SITE) are running without any wastewater treatment facility. These industrial discharges, pose a negative impact on river water quality by making it unfit and harmful for human use. In Kasur there is a treatment plant, currently operational, however it cannot handle large scale industrial effluent[4]. Due to that, the surface and ground water quality of the area is deteriorating day by day, which adversely affect ecology, human health and other flora and fauna[5]. Similar trend exists in the province of Khyber Pakhtunkhwa. At present, there are three wastewater treatment plants, especially designed for municipal wastewater but are not operational[6]. The present study is an attempt to collect information about the performance of the treatment plant, installed by Peshawar Development Authority (PDA) on the main drain of Hayatabad Industrial Estate. Treatment plant design for HIE also seems deficient. For this purpose the treatment plant was observed for one year. Wastewater

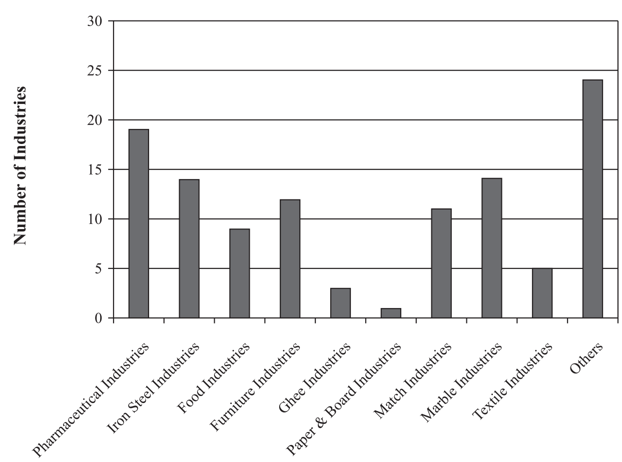

Figure 1: Present Industrial Composition of Hayatabad Industrial Estate

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samples were taken before and after it went through the treatment plant for evaluation and identification of suitable treatment procedure.

Description of the Installed Treatment Plant

Hayatabad Industrial Estate was established in 1963[7]. At that time the concept of Environmental protection or regulatory measures were not introduced in Pakistan. That is why, no treatment plant was planned. Later, in 2001, after the promulgation of Pakistan Environmental Protection Act 1997, the industrial estates were brought under self-monitoring scheme and were forced to comply with Pakistan National environmental quality standards (Pak-NEQS). For this purpose, a low cost treatment plant was being constructed on the main drain of industrial estate.

Total area of the industrial estate is 868 acres[8]. Total number of installed industrial units in HIE are 212, out of which 132 are operational and 80 are close units[9]. The industries in Hayatabad industrial area could be divided into 10 categories (Figure 1). Some industries such as pharmaceutical, match, furniture etc are not contributing to industrial effluent but industries like iron and steel, food, marble and paper recycling mill contributes a lot. Out of the total, the major contributors to the industrial effluents are paper and board followed by iron and steel, food, ghee, marble and a variety of other industries respectively (Figure 2).

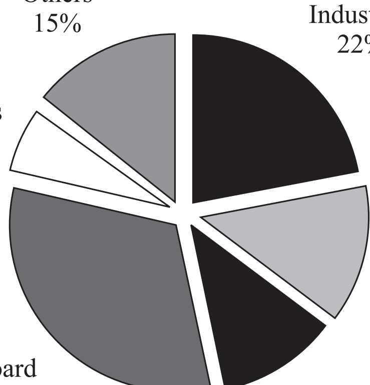

Figure 2: Percent Industrial Effluent Composition Contributed by Various Industries

The industrial effluents from HIE flows through the small drains and finally reaches the treatment plant. The treatment plant is based on physical practice only and no chemicals or biological treatment options are used here. The effluents after undergoing the sedimentation process are carried away through an underground drain (Figure 3).

METHODOLOGY

Sampling and Analysis

The present research study was carried out in two steps. The first step is comprised of the characterization of the wastewater samples to evaluate the performance of the installed treatment facility. For this purpose, wastewater samples were collected before and after treatment and examined according to the standard procedure. The examined parameters includes; Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biochemical Oxygen Demands (BOD), Chemical Oxygen Demands (COD) and Sulfide. The result of the first part presented a clear picture of performance of the installed low cost treatment facility.

In the second step, effluent samples were subjected to laboratory scale treatment like coagulation with Alum and alkalinity (calcium hydroxide) at different doses and adsorption by activated charcoal, in order to reduce suspended solids, BOD, COD and sulfides.

Physical Treatment

The focused parameters were TSS, BOD, COD and sulfide. One liter each wastewater samples were taken in different graduated cylinders (having 1000mL capacity). Each cylinder filled with wastewater sample was subjected to separate physical and chemical treatment. In physical treatment the samples were subjected to sedimentation without chemical/coagulant addition and observed for 24 hours time.

Chemical Treatment

In chemical treatment different doses of alum and alkalinity were used. Each treatment was initiated with minimum dose. The dose was increased gradually along with clear observation. The samples were stirred with

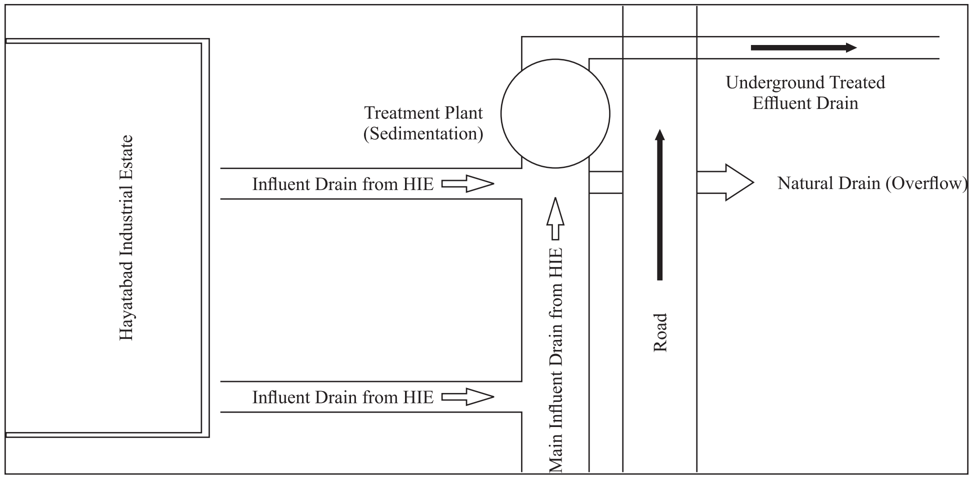

Figure 3: Present Treatment Plant

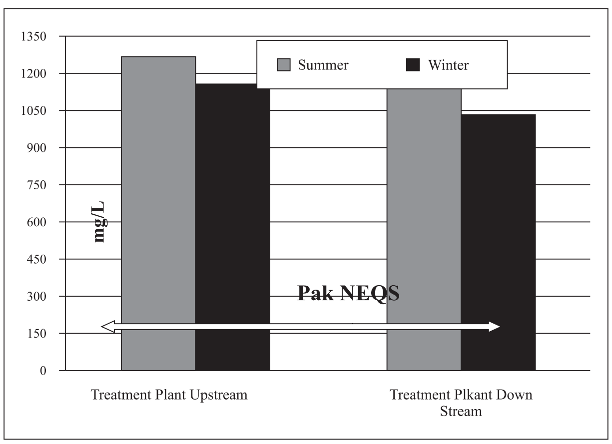

Figure 4: TSS values before and after treatment plant

uniform mixing speed. The pH, of the samples , was regularly checked and adjusted accordingly. After this process portion of the treated water was then taken and tested again in Laboratory for different parameters, so as to determine their values such as TSS, TDS, BOD, COD and Sulfide etc. The coagulation process was monitored and flocks development and sedimentation were focused.

RESULTS AND DISCUSSION

Physico-chemical analysis revealed that industrial effluent was high in TSS. In summer effluents, the average TSS value was found to be 1271 mg/L and 1155 mg/L, before and after treatment. While for winter effluents, this value is 1158.75 mg/L and 1034.5 mg/L respectively (Figure 4). In summer effluents, the average TDS content was found to be1955 mg/L and 1926.75 mg/L before and after treatment respectively. While for winter effluents the value is 1393.5 mg/L and 1372.25 mg/L, which was within the permissible limit, when compared with Pakistan National Environmental Quality Standards (Pak-NEQS) of 3500 mg/L. The average sulfide contents in summer were found to be 3.65mg/L and 3.43 mg/L, while during winter effluents, these values were 3.1 mg/L and 2.82 mg/L respectively. In summer effluents the average BOD value was found to be187 mg/L and 179.50 mg/L, while for winter effluents, the values are134.75 mg/L and 117.75 mg/L respectively. Chemical Oxygen Demand (COD) value was found to be 463.75 mg/L and 452 mg/L in summer, while for winter effluents the values are 398.25 mg/L and 374 mg/L.

Physical Treatment

Normally sedimentation is carried out to get rid of those settable suspended particles. In the speedy flow of water, the particles remain suspended but when the water speed decreases, the particle in suspension tends to settle down. But sometimes even with retention time, the colloidal particles in suspension do not settle due to identical charge on particles[10]. After physical treatment (sedimentation) the level of TSS decreased from 1271 to 1048mg/L in summer effluents and from 1158.75 to 1013.50 mg/L in winter effluents. However, it was found above the permissible limit of 150 mg/L as listed in Pak-NEQS. Similarly BOD, COD and sulfide were found above Pak NEQS (Table 1). The observed decrease in TSS was 17.55% and 12.54% for summer and winter respectively. This revealed that the behavior of suspended load remain almost the same in summer and winter. It was due to similar nature of suspended

Table 1: Average parameters values and decrease observed after Physical Treatment in the form of settling (mg/L)

Season	Parameters	Pak NEQS	Before Treatment	After Treatment	Total Decrease	Percent decrease
		A	B	C	D	($\frac{D}{B}$)*100
Summer	TSS	150	1271.00	1048.00	223.00	17.55
	BOD	80	187.00	178.75	8.25	4.41
	COD	150	463.75	439.25	24.50	5.28
	Sulfide	1	3.65	3.53	0.12	3.29
Winter	TSS	200	1158.75	1013.50	145.25	12.54
	BOD	80	134.75	131.25	3.50	2.60
	COD	150	398.25	390.75	7.50	1.88
	Sulfide	1	3.10	3.08	0.02	0.65

* All the units are expressed in mg/L

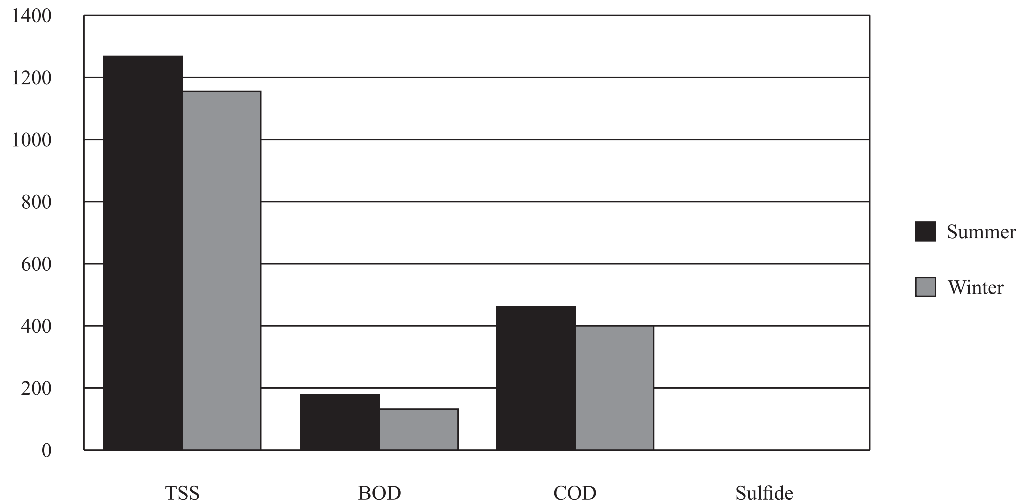

Figure 5: Showing change in physico-chemical parameters due to seasonal variation

solids in HIE effluents. Similarly the decrease in BOD, COD and Sulfide was also very less with a range of 4.41, 5.28 and 3.29% respectively in summer.

There was no significant difference observed in the values of summer and winter. . It was observed that there were no significant differences in the physico-chemical parameters due to its homogenous nature (Figure 5).

Lime Treatment

For lime treatment 1000 mg/L CaO solution was used. Analytical results of wastewater treatment with lime revealed that settling was started by adding 5 mL of CaO solution. By doing so, 254.2 mg/L of SS settled down. A regular increase in sedimentation was observed by increasing the dose of lime. After adding 25 ml lime solution no further change in sedimentation was observed (Figure 6). In this way, the same dose was used for remaining treatment.

After lime treatment it was observed that, more than 50% decrease was observed in SS, BOD, and COD (Table 2). Total suspended solids were decreased from 1271 to 509.50mg/L (59.91%) in summer and from 1158.75 to 440.25 mg/L (62.01%) in winter. BOD was reduced from 187.00 to 88.25mg/L (52.88%) in summer and from 134.75 to 75.75mg/L (43.78%) in winter. COD was decreased from 463.78 to 220 mg/L (52.56%) in summer and from 398.25 to 198.75mg/L (50.09%) in winter.

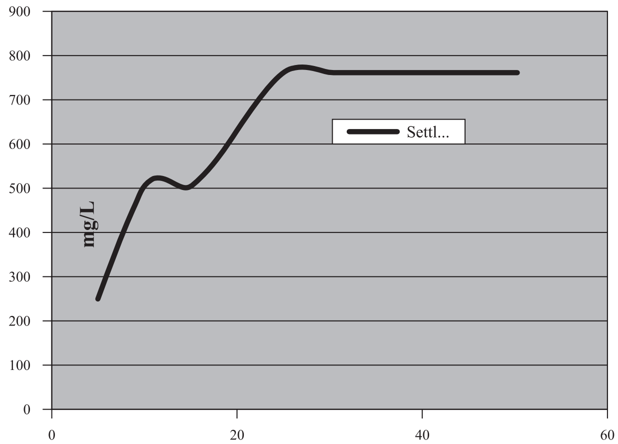

Figure 6: Settling of TSS after Lime treatment

Similarly, sulfide was decreased by 3.65 to 2.33 mg/L (36.16%) in summer and, 3.10 to 2.37mg/l (23.55%) in winter (Table 2).

In comparison with physical treatment, the application of lime (CaO) was good and decreased SS along with other parameters to some extent, but the final results were above the Pak- NEQS.

Alum Treatment

For alum treatment 1000mg/L stock solution of aluminum sulfate was used. Results of treatment with alum revealed that settling started by adding 5 mL of alum solution. A regular increase in sedimentation was observed by increasing the dose of alum. After adding 35 mL alum solution equivalent to 33.81mg/L, as aluminum sulfate, about 895.25 mg/L TSS settled but after that no further change was observed (Figure 7). In this way, the same dose identified as optimum dose. By applying this optimum dose (33.81mg/L), the TSS was decreased from 1271.00 to 375.75mg/L (70.43%) in summer and from 1158.75 to 240.00mg/L (79.28%) in winter. BOD was decreased from 187.00 to 53.75mg/L (71.25%) in summer and from 134.75 to 41mg/L (69.57%) in winter. COD was reduced from 463.75 to 132.75mg/L (71.37%) in summer and from 398.25 to 121.00mg/L (69.61%) in winter. Similarly, reduction in sulfides also occurred. In summer the decrease was from 3.65 to 2.30mg/L (36.98%) and from 3.10 to 1.66mg/L (46.45%) in winter (Table 3).

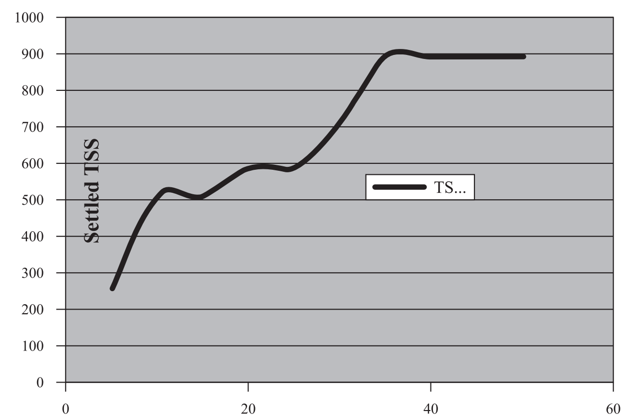

Figure 7: Settling of TSS after Alum treatment

Table 2: Average parameters values and decrease observed after Lime treatment (mg/L)

Seasons	Parameters*	Pak NEQS	Before Treat-ment	After Treat-ment	Total Decrease	Percent de-crease
		A	B	c	D	(d/b)/*100
Summer	TSS	200	1271.00	509.50	761.50	59.91
	BOD	80	187.00	88.25	98.75	52.81
	COD	150	463.75	220.00	243.75	52.56
	Sulfide	1	3.65	2.33	1.32	36.16
Winter	TSS	200	1158.75	440.25	718.50	62.01
	BOD	80	134.75	75.75	59.00	43.78
	COD	150	398.25	198.75	199.50	50.09
	Sulfide	1	3.10	2.37	0.73	23.55

* All the units are expressed in mg/L

Table 3: Average parameters values and decrease observed after Alum treatment (mg/L)

Seasons	Parameters*	Pak NEQS	Before Treatment	After Treatment	Total Decrease	Percent decrease
		A	B	c	D	(d/b)/*100
Summer	TSS	200	1271.00	375.75	895.25	70.43
	BOD	80	187.00	53.75	133.25	71.25
	COD	150	463.75	132.75	331.00	71.37
	Sulfide	1	3.65	2.30	1.35	36.98
Winter	TSS	200	1158.75	240.00	918.75	79.28
	BOD	80	134.75	41.00	93.75	69.57
	COD	150	398.25	121.00	277.25	69.61
	Sulfide	1	3.10	1.66	1.44	46.45

* All the units are expressed in mg/L

The alum treatment showed good effect on BOD and COD bringing it down to their respective limits but suspended load was still above the Pak NEQS.

Alum + Lime Treatment

For combine alum and lime treatment, 1000mg/L aluminum sulfate solution and 1000mg/L CaO solution were used. Results of treatment with alum and lime revealed that settling started slowly by adding 2 mL alum solution equivalent to 1.99 mg/L aluminum sulfate and 1mL lime solution equivalent to 1mg/L as CaO after mixing. By doing so, 252.5 mg/L of TSS was settled. A regular increase in sedimentation was observed by increasing the dose of alum and lime. After adding 26 ml alum solution equivalent to 25.34 mg/L as aluminum sulfate and 13 ml lime solution equivalent to 12.83 mg/L as CaO, 1136.25 mg/L of TSS settled and after that no further change was observed (Figure 8). In this way, the same dose combination was used for remaining treatment see (Table 4).

Apart from TSS, BOD, COD and sulfides were also decreased. The value for TSS was decreased from 1271.00 to 134.75mg/L (78.79%) in summer and from 1158.75 to 142.50mg/L (87.70%) in winter. In summer, BOD was decreased from 187.00 to 41.50mg/L (77.80%) and in winter the decrease from134.75 to 30.75mg/L (77.17%). COD was decreased from 463.75 to 120.50mg/L (74.01%) in summer and from 398.25 to 94.25mg/L (76.33%) in winter. Similarly reduction in sulfides also occurred. In summer the sulfides were decreased from 3.65 to 1.50mg/L (58.90%) and in winter the decrease was from 3.10 to 1.10mg/L (64.56%) (Table 4).

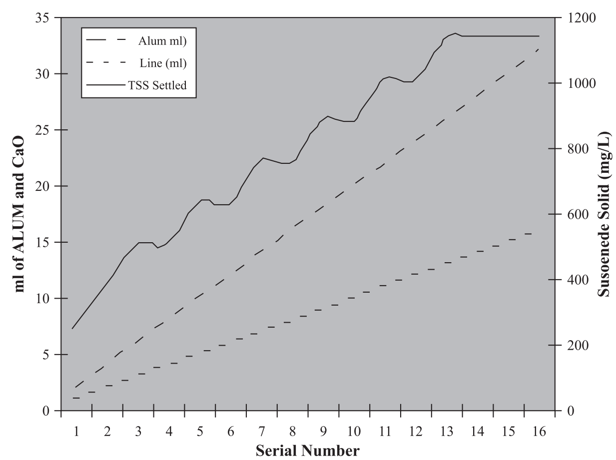

Figure 8: Settling of TSS after combine treatment of Alum and Lime

The combine treatment of alum + CaO was found a good combination and has produced tremendous result by bringing the suspended load below Pak-NEQS. In the same way, it showed good effect on BOD and COD reduction but only the sulfide was slightly above the Pak NEQS limit.

Alkalinity is of great significance as the coagulants like alum requires a little alkalinity to drive the hydrolysis reactions which permits the coagulants to function properly and helps in flock formation. In low alkalinity water addition of supplemental alkalinity is essential as it defines the way how chemicals will react with wastewater

Table 4: Average parameters values and decrease observed after Alum+ Lime treatment

Seasons	Parameters*	Pak NEQS	Before Treatment	After Treatment	Total Decrease	Percent decrease
		A	B	c	D	(d/b)/*100
Summer	TSS	200	1271.00	134.75	1136.25	89.39
	BOD	80	187.00	41.50	145.50	77.80
	COD	150	463.75	120.50	343.25	74.01
	Sulfide	1	3.65	1.50	2.15	58.90
Winter	TSS	200	1158.75	142.50	1016.25	87.70
	BOD	80	134.75	30.75	104.00	77.17
	COD	150	398.25	94.25	304.00	76.33
	Sulfide	1	3.10	1.10	2.00	64.51

* All the units are expressed in mg/L

Table 5: Settling behavior after combine treatment of Alum and Lime

S.NO	Coagulant (ml)	Alkalinity (ml)	pH	EC	Settling time	Percentage Settling
1	**2**	**1**	**6.92**	**1054**	**80**	**20**
2	4	2	6.87	1073	75	30
3	6	3	6.83	1087	70	40
4	8	4	6.97	1104	65	40
5	10	5	7.02	1116	60	50
6	12	6	7.13	1155	55	50
7	14	7	7.24	1173	50	60
8	16	8	7.28	1154	45	60
9	18	9	7.31	1148	40	70
10	20	10	7.42	1132	35	70
11	22	11	7.36	1144	30	80
12	24	12	7.29	1150	25	80
13	26	13	7.21	1157	20	90
14	28	14	7.19	1163	15	90
15	30	15	7.14	1174	10	90
16	32	16	7.21	1172	5	90

during treatment[11]. High alkalinity water can take large amount of acid without any considerable change in pH whereas water with low alkalinity can experience a fall in pH with a slight addition of acid[12].

Correlation analysis for Alum+ Lime treatment shows positive relation among the alum and lime doses. Alum and lime doses affect the values of pH, EC positively, which affect the settling time simultaneously (Table 5 & 6).

Proposed Treatment Plant

In the proposed plant, a coagulation step has been added followed by sedimentation. The main underground effluent carrying drain was left unchanged. A temporary

Table 6: Correlation between coagulant dose with alkalinity, pH, EC and settling time

Correlations	Coagulant	Alkalinity	pH	EC	Settling time
Coagulant	**1**				
Alkalinity	1	1			
pH	0.68881867	0.6888187	1		
EC	0.835134666	0.8351347	0.743789		
Settling time	-1	-1	-0.68882	-0.83513	1

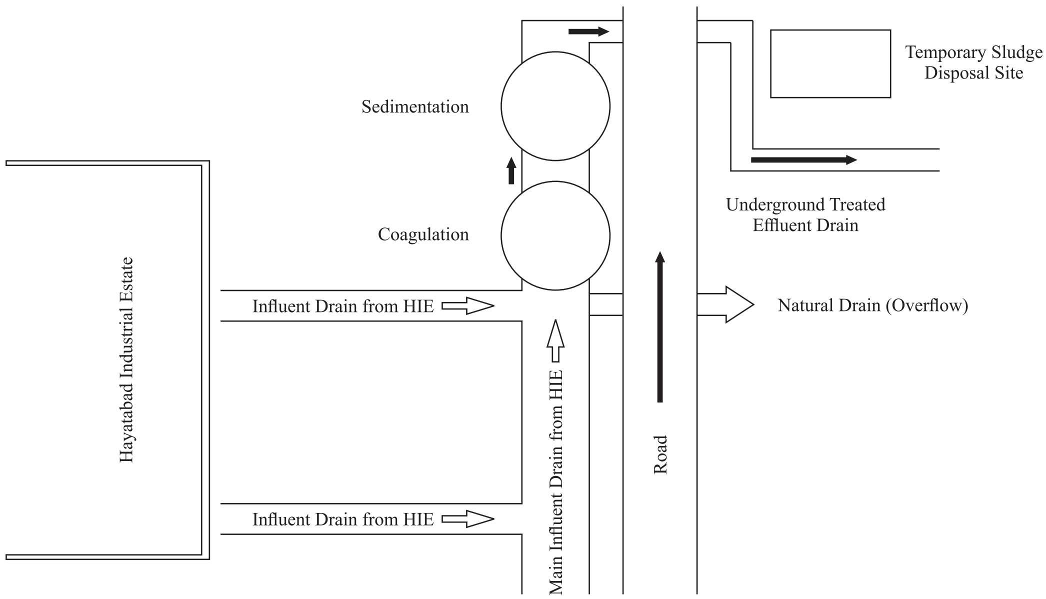

Figure 9: Proposed Treatment Plant

sludge disposal site has also been added so that sludge recovered can be disposed off for a short time (Figure 9).

CONCLUSION

This study concludes that the idea of establishing small scale, low cost treatment plant was a good attempt. The overall efficiency of the existing small scale treatment plant in Hayatabad is not satisfactory. Analytical work revealed that effluents leaving the treatment plant showed high values of TSS, BOD, COD and Sulfide exceeding the permissible levels of Pak NEQS. The efficiency of small scale plant can be enhanced if we add the process of coagulation. Among various testing, the combined dose of alum and lime showed good results in removal of TSS, TDS, BOD, COD and Sulphide. Keeping in view the overall discussion, it is suggested that the present small scale treatment plant should be re-designed for adding the step of coagulation.

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