MUNICIPAL WASTEWATER TREATMENT BY COAGULATION/ FLOCCULATION PROCESSES VIA OPTIMIZATION OF INOCULATION DOSE AND SETTLING TIME

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ABSTRACT

This study was conducted on municipal wastewater with an attempt to identify proper treatment measures. The drain under study was observed for three months. In total 45 samples were collected from five different sites at the rate of three samples per day (Morning, Afternoon and Evening). Each sample was a composite of three grab samples collected with four hours intervals. All Samples were analyzed for physico-chemical characteristics. On comparison with Pak NEQS it was observed that the municipal wastewater physicochemical quality was above the permissible limits. A series of coagulation/flocculation treatments were given by applying different doses of ferric chloride in combination of calcium hydroxide. Effective removals of pollutants were obtained by using ferric chloride and calcium hydroxide in ratio of 2:0.5 mL for settling time of 13 minutes. As treatment results, not only removed suspended solids (86%) but a tremendous decrease was observed in color, chemical oxygen demand (COD) and turbidity by 96%, 66% and 89%, respectively.

KEYWORDS: *Hayatabad, wastewater, coagulation/flocculation, treatment efficiency.*

INTRODUCTION

Water is the basic need of life and considered as a soul of the earth. It is use for different purposes such as drinking, washing, cooking, cleaning, and flushing toilets, washing, bathing, recreation, cooling, irrigation, transportation and industrial processes. Unfortunately less consideration have been given to the treatment, reuse and recycling of municipal and industrial wastewater in Pakistan due to lack of proper environmental budget. The direct untreated wastewater disposal has posed severe negative environmental effects on the quality of drinking water[1,2].

According to WHO report (1997), from water related disease about 40% death occurs in developing countries and 500 million diarrheal episodes occur each year in children under 5 years in Asia, Africa and Latin America[3]. Similarly, a study revealed that 5,000 children die per day due to water borne diseases and about 1.8 million children die from diarrhea each year in developing countries. This problem can be solved and prevented with the supply and availability of clean water. In the developing countries due to the lack of sanitation and clean water about 50 percent of people are suffering from health problems. The lack of clean water and sanitation in Pakistan is also the main problem and cause of child death[4].

It is obvious that water pollution is a matter of concern for every citizen around the globe. Understanding the source, interactions, and effects of the water pollutants is essential for controlling pollutants in an environmentally safe and economically acceptable manner[5]. Wastewaters that are collected from communities and municipalities can be finally returned to receiving water or land[6]. The direct use of untreated wastewater, even for crop irrigation is not recommended. In Pakistan, due to lack of knowledge, or water scarcity, most of the farmers in cities used municipal wastewater for irrigation. According to Lahore Development Authority (LDA) and Water and Sanitation Authority (WASA), more than eight million population of Lahore produces 400 million gallons wastewater per day[7].

Besides, municipal wastewater mostly produces unpleasant taste and odor. It needs great attention to overcome this problem. Different pathogenic organisms are also found which has negative impacts on the public health. To overcome on these problems the wastewater need physical, chemical and biological treatment. These treatment processes can be used to lower the level of COD, BOD, phosphorus, nitrogen, suspended solids and to remove bacteria. The physico-chemical treatments

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remove the color and odor, and also reduce the quantity of suspended solid, phosphate, and other harmful pollutants[8]. The colored wastewater is often objected to by the public on the assumption that color is a sign of pollution[9]. The odor of municipal wastewater is mostly produced by the presence of H_2S, CH_4 and urine[8].

Aeration can be perform for the purpose to add oxygen to water imparting freshness, explosion of CO_2, H_2S and other volatile substances causing taste and odor, and to precipitate impurities like iron and manganese in certain form[10].

Coagulation of untreated wastewater lead to sedimentation, the rate of which depends on quantity, mixing times and alkalinity. The process of coagulation removes 80 to 90% of the total suspended solid. Various studies revealed that up to 50-80% BOD[5] removal was also observed[6]. Usually, 60% of the suspended solids are settle able and can be settled by physical treatment (sedimentation) for remaining 40% chemical coagulants are used. In this way most of the settleable suspended solids (organic and inorganic) can be removed[8]. It has been observed that the process of coagulation shows an excellent removal of COD along with suspended solids and color[11,12]. Similarly, coagulation/flocculation treatment has been used to decrease color and turbidity and to remove pathogens. Likewise, coagulation/flocculation/precipitation processes have been intensively used for decolorizing wastewater. It is well established that coagulation/flocculation involves the chemicals addition to change the physical state of suspended and dissolved solids and facilitate their removal by sedimentation in water/wastewater treatment[13,14,15]. The chemical products as coagulants react with the suspended and colloidal particles to bind them together and thus allowing for their removal in the consequent treatment processes[16]. The mechanisms through which colloids and particles are removed include a combination of charge neutralisation, entrapment, adsorption and complexation with coagulant ions into insoluble masses[14,17].

The study aims to investigate the physicochemical characteristic of municipal wastewater of Hayat Abad and give treatment with specific dose of coagulants which are more effective in short time limit. This study is also an attempt to identify such dose of coagulant that not only removes suspended solids but also other pollutants such as Chemical Oxygen Demand (COD), color and turbidity. Hayatabad is situated approximately 15km, south-west of the main city (Peshawar) centre. Hayatabad lies between 33°99”335’ North latitude and 71°45”750’ East longitude. The study drain collect wastewater from 65448 acres of land with 50 thousands population[18,19,20,21].

METHODOLOGY

During winter season municipal wastewater samples

Table 1: Summary of parameters falls within permissible limits before treatment of municipal wastewater Hayatabad, Peshawar. Units: Conductivity µS/cm, TS mg/L, TDS mg/L

Parameters		Location 1 (Phase 7)	Location 2 (Phase 1)	Location 3 (Phase 7,5,4,1)	Location 4 (Phase 6,3,2)	Location 5 (Combine drain)
pH	Min	6.96	7.10	6.99	6.90	7.01
	Max	7.58	8.03	7.55	7.60	7.45
	Mean	7.32	7.46	7.33	7.28	7.203
Conductivity	Min	662.00	804.00	748.00	778.00	1003
	Max	1123.00	1254.00	1106.00	1212.00	1199
	Mean	854.08	1039.92	933.78	1015.22	1111.666
TS	Min	460.00	600.00	520.00	600.00	720
	Max	900.00	1180.00	1040.00	880.00	980
	Mean	626.67	781.67	697.78	700.00	820
TDS	Min	300.00	480.00	200.00	460.00	480
	Max	720.00	740.00	860.00	740.00	660
	Mean	521.67	621.67	488.89	568.89	586.666

(n = 45) in morning, afternoon and evening with specific time interval of 4 hours were collected in cleaned and washed plastic bottles of one and half liter from five points of municipal sewerage system of Hayatabad, Peshawar. Samples were analyzed for color, pH, conductivity, turbidity, TS, TDS, TSS, and COD before and after treatment. Samples were collected with 15 days interval for three consecutive months (September to November). Electrical Conductivity (EC) and pH were determined on the spot by using conductivity meter and pH meter respectively. Turbidity was measured by nephlometric method using turbidity meter. TS, TDS and TSS were measured through gravimetric methods while COD was measured by closed reflux method using HACH Company COD DR/3 spectrophotometer. Samples were refrigerated at 4^{o}C and were analyzed in the quick possible time[22,23,24].

For municipal wastewater treatment a series of jar test carried to determine a suitable dosage of coagulant (ferric chloride), based on the settling time. Different doses of ferric chloride in combination of calcium hydroxide were added and mixed into the municipal wastewater samples and were allowed to settle. The formation and settling capability of the flocs was observed carefully and time was noted (Table 4).

The effective dose of ferric chloride and calcium hydroxide was found in the ratio of 2 mL and 0.5 mL, respectively. During addition of coagulant the pH and conductivity of samples were also measured on the spot. Behind the selection of ferric chloride is its effectiveness over a high range of pH (4-11) unlike other coagulants i.e. alum. The flocs formed by ferric chloride have an excellent settling quality than that of alum because it is heavier[25].

RESULTS AND DISCUSSION

The average pH ranged from 7.20 to 7.46 against Pak-NEQS of 8-10 pH scale. For conductivity, no permissible limit has been defined. Conductivity (average) ranged from 854.08 µS/cm to 1111.666 µS/cm. The observed average values for total dissolved values ranged from 488.89 to 621.67 mg/L against Pak-NEQS 3600 mg/L. The values for TDS were within the permissible range. Parameters falls within permissible limits are summarized in Table 1.

Four parameters exceeded the permissible limit of Pak-NEQS. These include color, turbidity, total suspended solids and COD as given in Table 2. Before treatment the average color, turbidity, suspended solids and COD results were 56.67 - 66.67 Pt-Co, 44.25 to 78.33 NTU, 105 mg/L-233.33 mg/L, and 51.66 mg/L - 261.11 mg/L) respectively. To bring down the concentrations of these

Table 2: Summary of parameters that crossing the permissible limits before treatment of municipal wastewater Hayatabad, Peshawar.

Parameters		Location 1 (Phase 7)	Location 2 (Phase 1)	Location 3 (Phase 7,5,4,1)	Location 4 (Phase 6,3,2)	Location 5 (Combine drain)
Color	Min	32.00	53.00	50.00	48.00	65.00
	Max	78.00	78.00	80.00	75.00	68.00
	Mean	56.67	64.50	65.67	59.67	66.67
Turbidity	Min	30.00	38.00	40.00	35.00	70
	Max	66.00	85.00	90.00	75.00	85
	Mean	44.25	62.17	72.56	57.33	78.333
TSS	Min	40.00	80.00	80.00	60	100
	Max	280.00	460.00	400.00	240	360
	Mean	105.00	160.00	208.89	131.1111	233.333
COD	Min	40	240	240	242	240
	Max	65	270	280	285	260
	Mean	51.666	252.583	256.666	261.111	250

parameters to safe permissible limit required a proper treatment for the purpose to make possible the reuse of high volume of wastewater that goes in vain. Here in this study to reduce the harmful effects of municipal wastewater coagulation/flocculation treatment is adopted which showed an effective removal of color, turbidity, TSS and COD.

Color ranged from 56.67 to 66.67 Pt-Co before treatment as summarized in Fig. 1. The results show that the values for colors at all locations are almost similar. High color (dark/brown) was observed at the combine drain of the municipal wastewater of Hayatabad. The average apparent color after treatment ranged from 2.22 Pt-Co to 2.83 Pt-Co (Table 5) which indicated 95.58% to 96.27% removal efficiency. Initially yellow color[26] appeared by adding ferric chloride dosage but after some time due to the floc settling operation all the suspended solids settled at the bottom and the water become colorless.

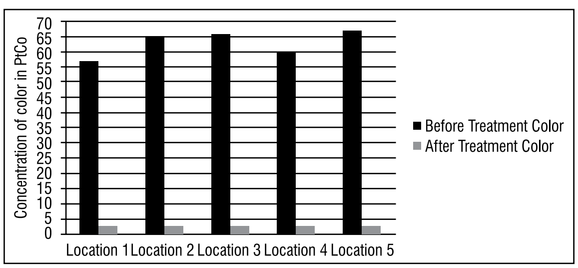

Figure 1: Color of municipal wastewater before and after treatment

High value of turbidity is observed at disposal point of effluent (location 5) before treatment while low value at location 1 as less populated area. After treatment results shows that turbidity range from 6 to 9.22 NTU (Table 5). Treatment by coagulation process shows an excellent removal efficiency of turbidity. From 86.44% to 88.51% of turbidity removal is obtained in the present study. According to rosenblum et al.[27] 90 % turbidity removal was obtained by using ferric chloride for treatment.

Higher concentration of TSS is observed at location 5 while low at location 1. Figure 3 show that only at location 1 and location 4 the concentration of TSS is within permissible limit of Pak NEQS (150 mg/L) before treatment and at locations 2, 3 and 5 is crossing the permissible limit. Treatment by addition of specific dose of ferric chloride with alkalinity determined 62.71%

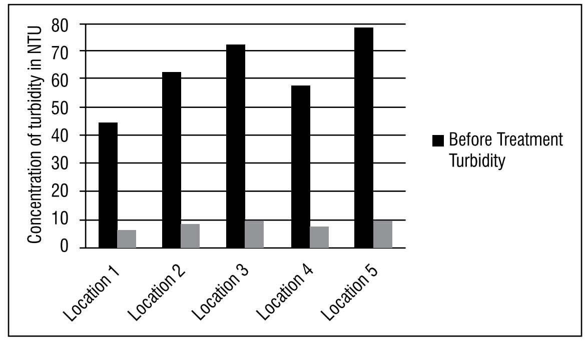

Figure 2: Turbidity of municipal wastewater before and after treatment

to 85.71% removal of TSS. High efficiency removal of TSS has been achieved using a specific dose of ferric chloride and calcium hydroxide in ratio of 2:0.5 mL for municipal wastewater treatment.

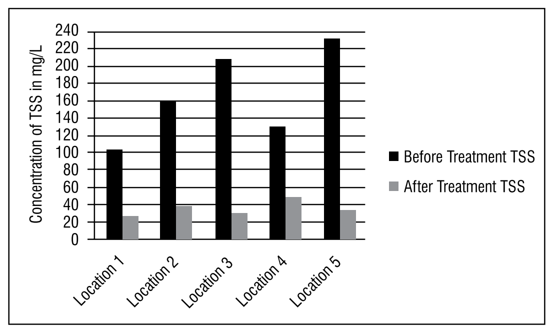

Figure 3: TSS of municipal wastewater before and after treatment

Figure 4 shows that the concentration of COD exceeded the permissible limit of Pak NEQS (150 mg/L) except at location 1 before treatment while after treatment average value of COD ranged from 19.25 mg/L to 93.33 mg/L (Table 5). Figure 4 also shows that the concentration of COD after treatment falls within permissible limit of Pak NEQS (150 mg/L) at all locations. By the process of coagulation/flocculation from 62.66% to 66.23% COD removal is ensured.

TREATMENT OF MUNICIPAL WASTEWATER

FLOW RATE

The flow of municipal wastewater at disposal point was measured three times per day which is mentioned in Table 3; as the minimum, maximum and average flow of domestic wastewater. Discharge flow rate is an

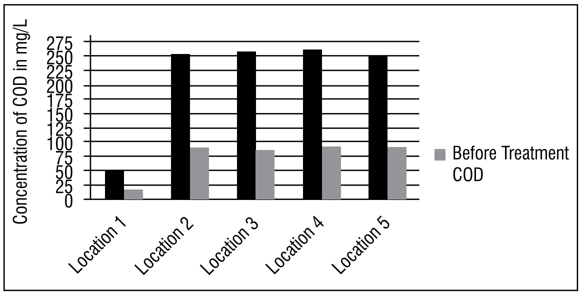

Figure 4: COD of municipal wastewater before and after treatment

important parameter, which helps in determining the total pollution load and needs consideration during the selection and designing of treatment plant. The flow rate of municipal wastewater was measured by the following procedure. Two points A and B were located at the bank of nalla which show the length of the nalla , now a plastic ball lay at the point A in effluents on reaching to the point B, time recorded by stop watch. The depth of the nala was measured at different locations between A and B and means were calculated, the width of the stream was also measured. Now the length (L), depth (D) and width (W) values multiplied among themselves and divided by time which shows the flow of domestic effluents. Flow rate of the municipal waste water of Hayatabad is given in the Table 3. Table 3 also shows the pollution load of COD and total suspended solids in kg/day. About 12158.59 kg/day COD and 9508.10 kg/day total suspended solids produced by the municipal wastewater effluent of Hayatabad.

COAGULATION DOSES

Table 4. shows the treatment doses of ferric chloride in combination with calcium hydroxide for the treatment of municipal wastewater. Five doses were used in this process to check their capability of settling quality and time required for the sludge settling in a jar test series. The outstanding performance for the settling quality in minimum time was observed by using the first dose of the below Table 4. Therefore dose number first was applied to all of the municipal wastewater samples collected from different sites of Hayatabad.

Table 3: Total pollution load (Kg) produced per day

Time	Min m3/s	Max m3/s	Average	Pollution load (COD)		Pollution load (TSS)	
				Average COD values (mg/L)	(Kg/day	Average TSS (mg/L)	kg/day
Morning	0.566	0.570	0.568	214.41	10522.21	167.67	8228.44
Afternoon	0.737	0.740	0.738		13671.47		10691.18
Evening	0.662	0.665	0.663		12282.09		9604.67
Average					12158.59		9508.10

Pollution Load: Kg/Day = (Con*Q*1000*86400)/1000000

Con. Concentration in mg/L

Q= Quantity of flow (m3/sec)

Table 4: Optimum doses and settling time efficiency of coagulants used for the treatment of municipal wastewater

S.No	$FeCl_3.6H_2O$ mL	$Ca(OH)_2$ Alkalinity mL	pH	Conductivity µS/cm	Settling time(min)	Settling Quality
1	2	0.5	7.06	1082	13	Outstanding
2	1.5	-	7.08	1069	15	Excellent
3	1	1	7.13	1052	15	Very Good
4	0.5	0.5	7.15	1064	15.53	Good
5	2	1	7.05	1070	14	Good

For the municipal wastewater treatment and softening operation ferric chloride as coagulant with calcium hydroxide was used which showed good efficiency in the removal of color, turbidity, TSS, COD etc. It was

Table 5: Physicochemical Characteristics of Hayatabad Municipal Waste Water after Treatment. Units: Color PtCo, Turbidity NTU, Conductivity µS/cm, TS mg/l, TDS mg/L, TSS mg/L and COD mg/L.

Parameters		Location 1 (Phase 7)	Location 2 (Phase 1)	Location 3 (Phase 7,5,4,1)	Location 4 (Phase 6,3,2)	Location 5 Combine drain
pH	Min	6.95	7.3	7.25	7.25	7.32
	Max	8.03	7.99	8.06	8.15	7.42
	Avg	7.555	7.599	7.697	7.527	7.386
Conductivity	Min	688	931	735	809	1000
	Max	1046	1132	1006	1167	1194
	Avg	814.583	1010.833	929.666	977.444	1111.333
Color	Min	2	2	2	2	2
	Max	4	5	4	3	4
	Avg	2.5	2.833	2.666	2.222	2.666
Turbidity	Min	4	5	7	5	5
	Max	8	12	12	11	12
	Avg	6	8	9.222	7.111	9
TS	Min	440	540	480	540	500
	Max	700	800	580	740	600
	Avg	543.333	636.666	520	606.666	553.333
TDS	Min	400	500	440	500	480
	Max	680	760	540	700	560
	Avg	516.666	598.333	488.888	557.777	520
TSS	Min	0	0	20	20	20
	Max	80	60	60	80	40
	Avg	26.666	38.333	31.111	48.888	33.333
COD	Min	10	78	80	65	80
	Max	25	110	100	110	110
	Avg	19.25	91.916	86.666	92.555	93.333

observed too that treatment with ferric chloride developed a yellow color when added to the municipal wastewater but later the color settled with sludge. It should be kept in mind that for removing and discharge of the upper clear layer of the treated water is need a careful method such that the yellow color sludge don't mix with treated water, otherwise the disturbance of settled sludge and particles again pollute the treated wastewater aesthetically and deteriorate the quality of treated water.

Table 5. shows after treatment results of physicochemical characteristics of municipal waste water of Hayatabad. By the process of coagulation all the parameters fall within permissible limits of Pak-NEQS. The treatment shows an excellent efficiency in the removal of color, turbidity, suspended solids and COD which were exceeding against the permissible limits of Pak-NEQS before treatment.

CONCLUSION

The municipal wastewater of Hayatabad was analyzed for color, turbidity, pH, electrical conductivity, TS, TDS, TSS, and COD. By comparing the results with NEQS show that color, turbidity, TSS, and COD were above the permissible limits. Coagulation/flocculation treatment with Ferric chloride was given to the municipal wastewater which produces flocs, for the turbidity (flocs) settling Calcium Hydroxide was found very effective therefore Calcium Hydroxide was used with the combination of Ferric chloride. The effective specific dose of ferric chloride and calcium hydroxide was applied in the ratio of 2 mL and 0.5 mL respectively for optimum settling time of 13 minutes. The treatment efficiency indicates very good removals of an average apparent color (95.58% to 96.27%), turbidity (86.44% to 88.51%), TSS (62.71% to 85.71%), and COD (62.66% to 66.23%). The physico-chemical treatment of municipal wastewater should be adopted to bring the municipal wastewater aesthetically acceptable and also reduced the concentration of turbidity, conductivity, TDS, TSS, COD etc. The treated wastewater can be uses for washing of vehicles, floor, flushing of toilets and recreation to save the fresh water. The sludge and suspended loaded formed during the treatment has need to recover, reuse or land fill properly by beneficial way.

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