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Influence of Polyelectrolytes on Sewage Water Treatment Using Inorganic Coagulants

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Sewage samples collected from municipal sewage farm, Coimbatore, was analysed for a period of 2 year. The sample contained high amounts of turbidity, total solids, suspended solids, BOD, COD and phosphates. For the treatment of this sewage water, gravitational settling and flocculation processes were tried. For flocculation, the inorganic polymers, alum, ferric chloride, mixed sulphate and poly aluminium chloride (PAC) were used. The optimum concentration of the coagulants for effective treatment of sewage was determined. The effect of addition of polyelectrolytes (anionic, cationic and nonionic) on the efficiency of the coagulants was studied. It was observed that polyelectrolytes amendment increased the flocculation efficiency of the coagulants thereby reduced the amount of coagulant required for the treatment and also the cost of sewage treatment.

INTRODUCTION

Sewerage of non - industrial towns consist mostly of domestic waste, such as dirty water from bathrooms, lavatories and kitchen. Industrial cities, like Coimbatore, receives apart from domestic wastewater, wastewater from various small and medium scale industries, like milk processing, dyeing and electroplating industries. As this city is located in a rain shadow area and water requirement for domestic and small scale industrial use is on the rise, an attempt was made to purify the wastewater by various physico - chemical methods. Physico - chemical methods are still highly used in wastewater treatment. Sedimentation, coagulation, flocculation and carbon adsorption are most attractive processes. Villiers *et al.* (1997) reported that the treatment of primary effluent by lime clarification and activated carbon treatment produces good quality of water with less cost to build, but more to operate than a conventional activated sludge plant. Since the carbon adsorption is a costlier method, low cost physico - chemical treatments are to be searched. Hence in the present study, the physico - chemical methods, plain settling and flocculation/coagulation were tried for the treatment of municipal sewage water. The effect of polyelectrolytes on the flocculants/coagulants efficiency was also studied.

MATERIAL AND METHOD

Wastewater

Sewage water samples were collected from Coimbatore municipal sewage farm for a period of 2 year.

Coagulants

Commercial grade alum, ferric chloride, ferric sulphate, mixed sulphate, poly aluminium chloride and lime used as flocculants were obtained from Southern Chemicals, Coimbatore. 10 % solution of the flocculants were prepared in distilled water and required volume was added to the sewage water for treatment.

Polyelectrolytes

Commercial grade polyelectrolytes (Richfloc) cationic, anionic and nonionic were obtained from Southern Chemicals, Coimbatore. Solution of 0.1 % of polyelectrolyte was prepared by dissolving 100 mg of the polyelectrolytes in 100 ml warm water with slow mixing and this stock solution was used for flocculation studies.

Water sampling method

The water samples were collected through glass sampling device. The whole assembly was lowered in to water to the depth of one foot and the cord of the lid was pulled and released only when displaced air bubbles ceased to come to the surface and the water was transferred in to pre - cleaned poly-

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Table 1. *Physicochemical characteristics of sewage wastewater (minimum and maximum values observed during the study period) in mg/L*

Parameter	Minimum	Maximum	SE	CD
pH	7.2	7.6	0.04	0.11
Turbidity, NTU	206	260	3.38	10.42
Total solids	1895	2513	64.97	170.62
Suspended solids	912	1393	11.79	31.69
BOD_5	550	785	5.97	16.07
COD	786	1236	42.07	131.81
Total alkalinity	90	160	5.47	14.70
Total hardness	210	388	11.66	31.34
Chloride	245	388	11.14	20.94
Sulphate	56	128	2.71	7.30
Total nitrogen	31.3	53.3	1.61	4.43
Phosphate	13.4	29.3	1.49	4.00
Sodium	267	420	14.01	37.66
Potassium	24.0	44.0	1.97	5.31
Calcium	105	190	5.65	15.19
Iron	3.80	9.00	0.14	0.37
Chromium	0.48	0.95	0.01	0.04
Nickel	0.43	0.94	0.02	0.06
Zinc	0.36	1.05	0.01	0.04
Lead	0.15	0.43	0.02	0.06
Cadimium	0.15	0.35	0.01	0.04

Note : The values are significant at 0.01 %

ethylene containers and stored at 4 °C. The samples thus collected for 12 hr with a time interval of 1 hr were mixed togethar for getting a composite sample. This composite sample was used for characterisation and treatment studies.

Characterisation of wastewater

The methods followed for preservation and analysis were according to standard methods of American Public Health Association (APHA, 1981). To study the effect of seetling time on removal of turbidity and COD by physical method, 1000 ml of sample was taken in a measuring cylinder and allowed to settle. The samples were collected at different time intervals and analysed for turbidity and COD. To study the effect of pH, to 1000 ml of sample various inorganic coagulant, namely lime, alum, ferric sulphate. ferric chloride, mixed sulphate (at a concentration of 300 mg/L) and poly aluminium chloride (PAC - 150 mg/L) were added at different pH levels. The samples were flash mixed for 1 min at 120 rpm followed by flocculation for 10 min at 15 rpm and allowed to settle for 30 min (Thakur *et al.*, 1977). After 30 min, turbidity was measured. To study the effect of various coagulants/flocculants on turbidity and COD removal, various concentrations of coagulants/flocculants were added to 1000 ml of samples and the samples were treated as stated before (Thakur *et al.*, 1977)

Table 2. *Effect of settling time on turbidity and COD removal by plain gravitational settling (physical method)*

Settling time, min	pH	Turbidty, NTU	COD, mg/L
0	7.3	280	960
15	7.3	230	870
30	7.3	215	805
45	7.3	201	775
60	7.3	190	758
75	7.3	180	736
90	7.3	178	720
105	7.3	175	718
120	7.3	175	718
180	7.3	175	718
Factor	**SE**	**CD**	**Significance%**
Turbidity	7.58	15.81	0.01%
COD	56.13	117.09	0.01%

Table 3. *Effect of pH on turbidity removal by different coagulants*

pH	Turbidity, NTU					
	Lime, 300 mg/L	Ferrice sulphate, 300 mg/L	Ferric chloride, 300 mg/L	Alum, 300 mg/L	Mixed sulphates, 300 mg/L	PAC, 150 mg/L
Control	220	220	220	220	220	220
6.5	159	163	21	31	24	16
7.0	147	155	20	24	18	16
7.5	129	138	24	20	17	18
8.0	88	80	32	25	23	21
8.5	64	50	45	30	34	30
Factor	**SE**	**CD**	**Significance (%)**			
Turbidity	1.29	3.39	0.01 %			

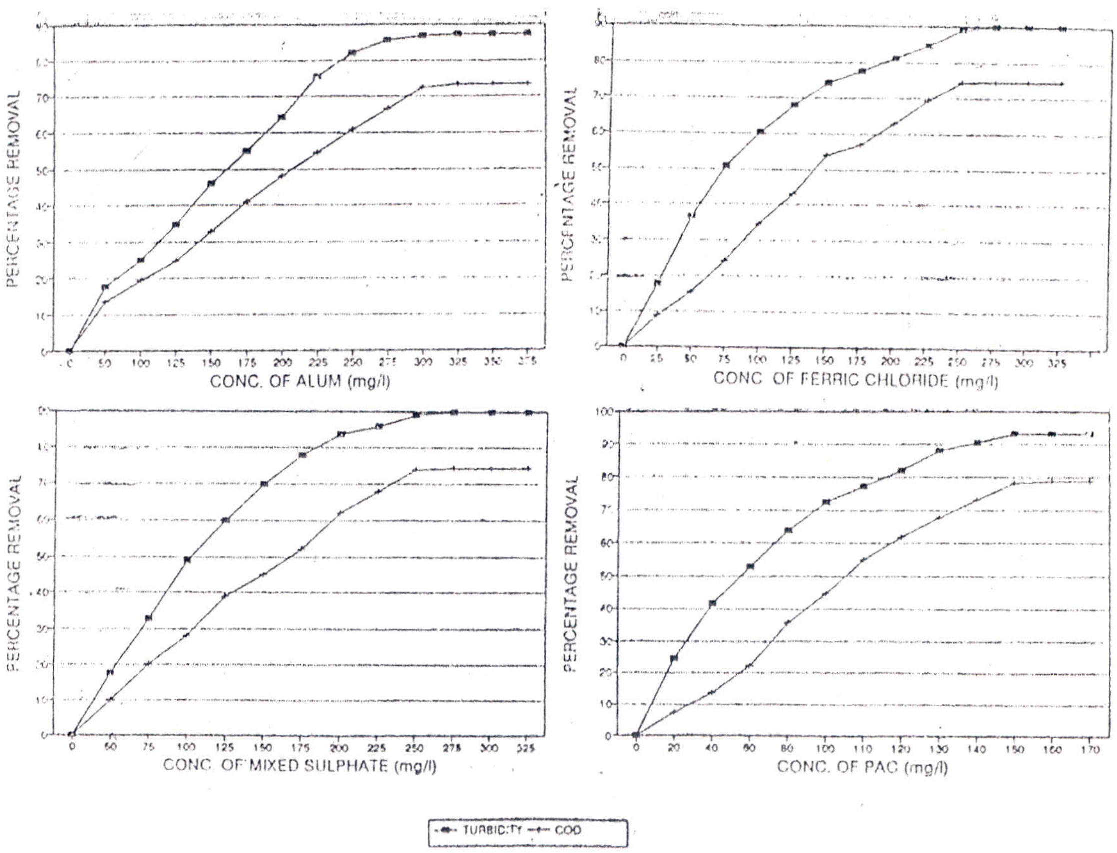

Figure 1. *Percent removal of turbidity and COD from sewage water by inorganic coagulants*

Table 4. *Statistical analysis of data present in figures 2 and 3*

Treatment	Factor						Significance %
	Turbidity		COD		Polymer/coagulant		
	SE	CD	SE	CD	SE	CD	
Cation	0.76	2.00	1.08	2.83	1.42	3.74	0.01
Anion	0.34	0.91	0.49	1.29	0.69	1.82	0.01
Nonion	0.36	0.95	0.51	1.34	0.77	2.02	0.01
Alum	5.13	13.43	6.28	16.45	11.47	30.04	0.01
$FeCl_3$	55.95	146.50	68.53	179.43	125.12	325.59	0.01
Mixed sulphates	32.97	86.34	40.39	105.75	73.74	193.07	0.01
PAC	4.61	12.08	5.65	14.80	10.32	27.20	0.01

and after 30 min, turbidity and COD were measured.

RESULT AND DISCUSSION

The sewage water collected from Coimbatore municipal sewage farm was analysed for a period of 2 year to assess the characteristics and seasonal variation. It has been observed from the results (Table 1) that most of the parameters indicate fluctuations; this might be due to variation in the discharge pattern of wastewater from various sources and seasonal changes. Normally, the fresh water sewage will be gray in colour with paint odour (Agrawal *et al.*, 1976). However, when the organic matters present in the sewage are partially digested by microbial activity, the sewage wastewater becomes black in colour with foul odour. It has been observed in the present study that in all the sampling periods, the sewage was black in colour with foul smell. Reduction of sulphur containing organic molecules in the presence of iron might lead to the formation of iron sulphides resulting in black colouration of the wastewater. The pH is an important factor in maintaining the bicarbonate and carbonate system and play an ipomrtant role in the formation of algal bloom (Palharya *et al.*, 1993).

Before flocculation : pH 7.3 ; Turbidity : 210 NTU ; COD : 937 mg/ml.

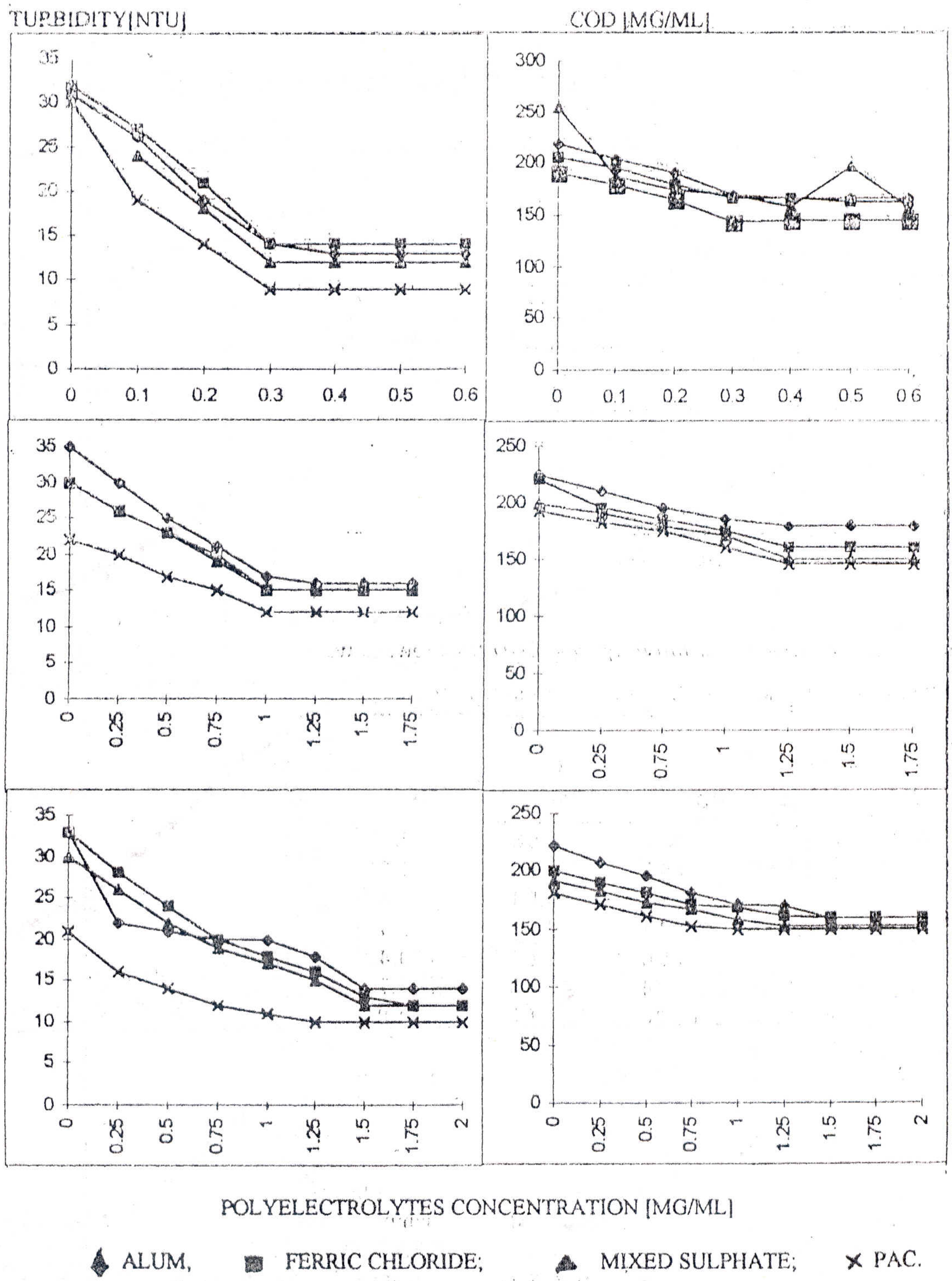

Figure 2. *Effect of polyelectrolytes concentration with fixed concentration of inorganic coagulants on turbidity and COD removal*

The pH of the water samples was observed to be almost neutral during the study period (pH 7.2 - 7.6). The pH variation was observed very slightly, however, it was within the tolerance limit for discharge of wastewater into receiving water system.

The amount of total solids, suspended solids, BOD

Before flocculation : pH 7.3 · Turbidity : 238 NTU, COD 1027 mg/ml.

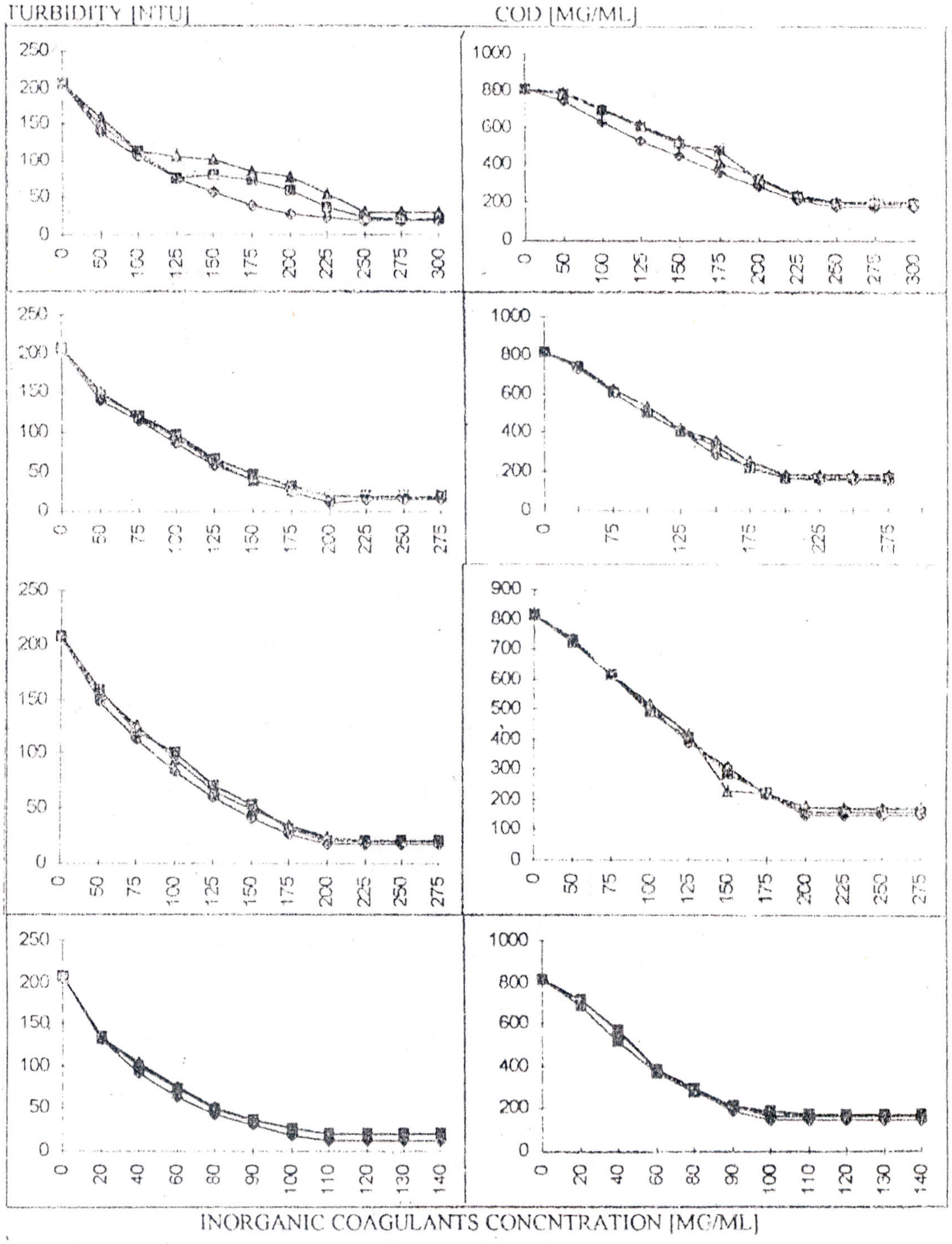

Figure 3. *Effect of inorganic coagulants concentration on turbidity and COD removal*

and COD was found to be higher in all the samples during summer season and slightly less during rainy and winter seasons. These parameters were observed to be higher than the tolerance limit for wastewaters discharged either into surface water or on to land. Higher suspended solids and turbidity will retard the penetration of light, disturb the dissolved oxygen balance and reduce the photosynthesis of aquatic system. The higher values of BOD and COD will lead to reduction in dissolved oxygen

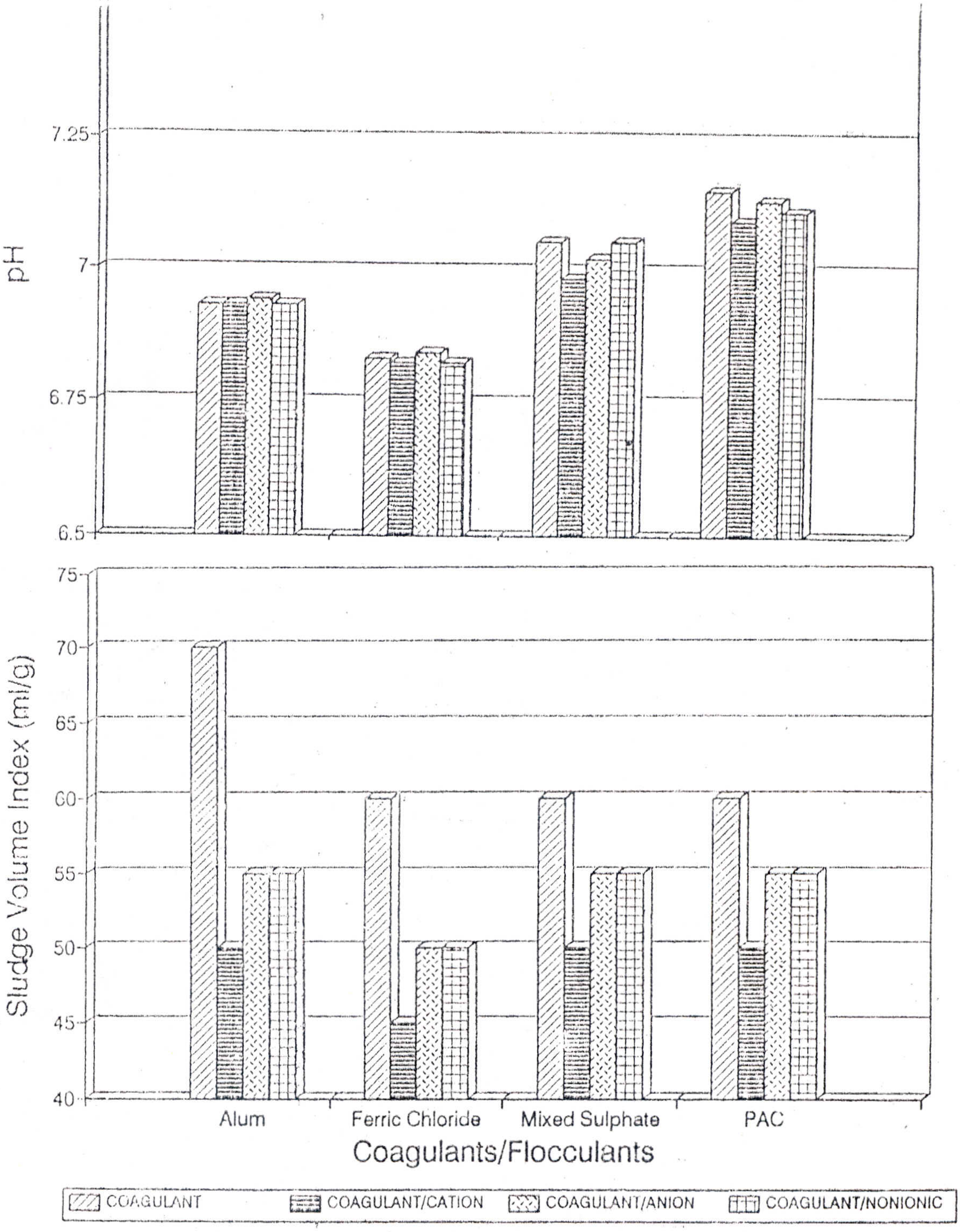

Figure 4. *Change in pH and sludge volume index of sewage water due to inorganic coagulants plus polyelectrolytes treatment*

content in aquatic system. The chemical parameters, such as total alkalinity, hardness, chloride, sulphate, phosphate, total nitrogen, sodium, potassium and calcium were analysed. Except phosphate, all others are within the tolerance limits. The concentration of heavy metals, such as nickel, zinc and cadmium were within the tolerance limit whereas iron, chromium and lead exceeded the limit The higher concentrations of the heavy metal in the sewage water is mainly due to the discharge of waste materials from electroplating, textile manufacturing and leather processing units along with do-

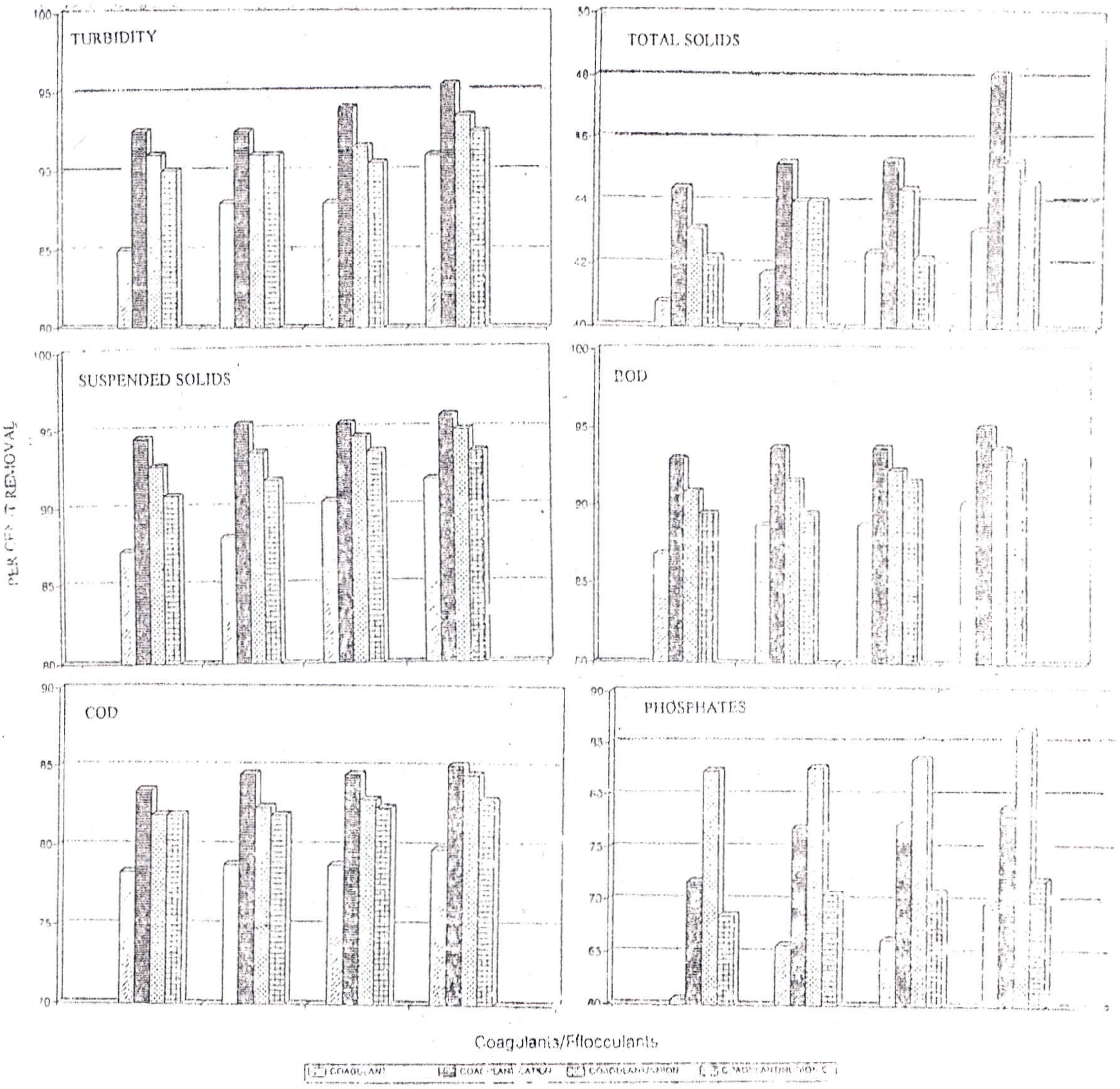

Figure 5. *Percent removal of pollutants from sewage water by inorganic coagulants plus polyelectrolytes treatment*

mestic wastewater.

Plain sedimentation method is used to remove settleable solids from wastewater. The removal efficiency depends upon the particle size, density and viscosity of the wastewater. The wastewater is allowed to settle for different time intervals. It was observed (Table 2) that the optimum time to remove turbidity (36.4 %) and COD (25 %) was 90 min. Chem (1993) also reported that in a plain sedimentation tank, the removal of suspended solids was always less than 50 % while COD was only 23 - 43 %. Since plain sedimentation alone is not sufficient for sewage treatment, the raw rewage wastewater was further treated with different coagulants/flocculants. The effectiveness of pH and coagulant/flocculant dosage either alone or in combination was tried to reduce the pollution load.

From the results (Table 3) it was observed that alum, ferric chloride, mixed sulphate and PAC are effective in the ph range of 6.5 - 7.5. But lime and ferric sulphate were effective only at higher alkaline condition (pH $>$ 8.0). The application of lime and ferric sulphate for sewage treatment was not tried since it required pH adjustment. Alum and ferric chloride are commonly used for treatment of wastewater containing organic matters. Licsko (1993) reported that alum and ferric chloride were used to treat organic containing wastewater in the pH range of 5.7 - 7.5, Hence alum and ferric chloride were used for the sewage treatment.

Increasing concentration of alum, ferric chloride

Table 5. *Statistical analysis of data presented in figures 4 and 5, in mg/L*

Factor	SE	CD	Significance (%)
pH	0.02	0.05	0.01
Turbidity, NTU	6.42	20.09	0.01
Total solids	18.13	49.48	0.01
Suspended solids	15.57	42.49	0.01
BOD	12.75	34.80	0.01
COD	26.11	71.25	0.01
Phosphate, gm/L	0.87	2.39	0.01
Sludge volume, ml/L	2.32	6.35	0.01

mixed sulphate and PAC increased the removal of turbidity and COD. Each coagulants have different optimum concentration at which removal of turbidity and COD was measured (Figure 1.). For alum the optimum dosage was 300 mg/L and % removal of turbidity and COD are 82.3 and 64.6, respectively. For ferric chloride the optimum concentration was 250 mg/L and % removal of turbidity and COD were 85.2 and 71.2, respectively. In the case of mixed sulphates treatment, the optimum concentration was 250 mg/L and the % removal of turbidity and COD were 87.4 and 74.2, respectively. For PAC the optimum concentration was 150 mg/L and % removal of turbidity and COD were 90.6 and 77.0, respectively (Figure 1). While comparing individual inorganic coagulants, PAC was found to be more effective and only a low concentration was required to remove turbidity and COD. The efficiency of ferric chloride and mixed sulphate were more or less equal; alum was less effective and required higher dosage (300 mg/L) than other coagulants.

In the next trial, along with inorganic coagulants, polyelectrolytes were used for sewage treatment. Polyelectrolytes/organic polymers increase the size of the floc which will result in reduction of both settling time and coagulant dosage. The polyelectrolytes used as a coagulant aids the coagulation process basically in 2 steps; a. neturalization of the charge on the colloids and b. agglomeration of smaller particles in to bigger particles known as flocculation. Various polyelectrolytes, such as cationic, anionic and nonionic polymers have been used in different concentration with the effective concentration of alum (300 mg/L), ferric chloride (250 mg/L), mixed sulphates (250 mg/L) and PAC (150 mg/L). Maximum reduction in turbidity and COD was observee at 0.30 mg/L of cationic, 1.0 mg/L of anionic and 1.5 mg/L of non ionic polymer. The results showed that cationic polymer is more effective in removal of turbidity and COD than other polyelectrolytes (Figure 2).

After fixing the optimum dosage of polyelectrolytes a test was carried out to find out the optimum concentration of inorganic chemical coagulants. When combined with polymers the addition of polyelectrolytes has increased the removal of turbidity and COD at minimum coagulant concentration (Figure 3). The optimum concentration of alum, ferric chloride, mixed sulphates and PAC were 250, 200, 200 and 110 mg/L, respecrively with fixed concentration of 0.3 mg/L of cationic, 1.0 mg/L of anionic and 1.5 mg/L of non - ionic polymer. Chen *et al.* (1993) have reported that 30 mg/L of polyaluminium chloride has removed 70 % of suspended solids from the wastewater. If polyelectrolyte is added (about 1.0 mg/L), the dosage of PAC can be reeuced to around 50 % to maintain sollder removal efficiency at the same level. Among the various treatments PAC with combination of cationic polymer is more effective in reducing the turbidity and COD to the permissible limit.

In the final treatment, chemical coagulants either alone or in combination with organic polymers were used. Comparing the individual coagulants and their combinations with polymers (Figures 4 and 5), the order of efficiency was PAC > mixed sulphates > chloride > alum for removal of pollutants. The final pH values in all the treatment were within the limits. So, pH adjustment was not required after treatment. Even though the individual inorganic coagulants showed an effective % removal of pollutant, the addition of polyelectrolytes enhanced the efficiency and decreased the treatment cost. Among the polyelectrolytes used in this study, catonic polymer is more effective in the removal of solids, BOD, COD, whereas, anionic polymer is more effective in removing phosphates with the combination of different inorganic coagulants. The dosages required to treat sewage water in the present study were high when compared to other reports (Thakur *et al.*, 1977; Wey *et al.*, 1991). This may be due to higher pollution load and presence of complexing substances, such as fulvic acid, humic acid and other organic substances in the municipal sewage. Fetting and Ratnaveera (1993), Rebhum and Lurie (1993) reported that additional coagulant dosage would be need for efficient coagulation for the removal of humus from the wastewater. When the concentration of spiked fulvic acid in the clay suspension was increased by 3 mg/L (as TOC), the alum dosage would be raised to 5.3 times to destabilize the suspension and if fulvic acid concentration was increased to 7 mg/L (as TOC) the alum dosage has to de increased 10.2 times to cause destabilization (Rebhum and Lurie, 1993). Hence additional coagulant dosages were used in the present study for effective treatment of Coimbator municipal sewage water. Sewage water treated in the present study could be recommended for reuse in industries where less quality is raquired, for in house purposes and as diluent to reduce the toxicity of wastes before discharging into receiving water bodies.

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