Study on the factors affecting coagulation and flocculation in treatment of industrial effluents

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Abstract

The introduction of wastewater treatments increases the plant cost; therefor any attempt to improve their efficiency is valuable. The industrial liquid effluents are very difficult to generalize. Their characteristics not only vary with the type of the industry, but also from plant to plant producing same type of end products. Coagulation and flocculation can achieve the effective removal of suspended particles. Operating within the optimum parameters will reduce the cost of treatment and will increase the quality of the water. The objectives of the study were, to compare the effectiveness of different coagulants, to determine their optimum dosage, and the optimum pH.

In the present study "Jar Test" was used. Samples from Pulp and Paper, and Textile effluents were used. The following coagulants were used: ferric chloride, ferrous sulphate, aluminium sulphate, and combination of them. Aluminium sulphate was regarded as the best coagulant since it achieved 98% solids removal for pulp and paper effluent and 95% for textile effluent at pH=7. With the combination of aluminium sulphate and ferric chloride the turbidity of 1.83 NTU was achieved for pulp and paper effluent, compared with 74.5 NTU from the industry. For the textile effluent 6.01 NTU turbidity was achieved.

1 Introduction

The continued increase in water consumption for industrial and domestic use, stringent discharge standards, and high cost of wastewater treatment processes have prompted the research efforts to identify and improve the methods for wastewater treatment and water recycling. Large amount of water is used in pulp-papermaking and textile industries. These industries have total dependence upon enormous quantities of water. The suspended sediments play an important role in the biological and chemical dynamics of the aquatic environment. The textile waste effluents are one of the very difficult to treat because they are highly variable in composition [7]. Coagulation and flocculation play an important part in many liquid-solid separations and is widely used in wastewater treatment.

The polar, high molecular weight and hydrophobic compounds are best remove by coagulation and flocculation. Hydrophobic colloids are charged particles surrounded by a cloud of opposite and equally charged ions [8]. Near the border of the particle there is a charge-free space, called the sternlayer. On the interface between the strenlayer and the diffuse layer there is zeta potential, which is important for the stability of the colloids [6]. The destabilization of the colloidal system can be achieved by suppression of the zeta potential. Coagulation is the transformation of colloidal and dispersed particles into small flocs. The aggregation is controlled by a combination of hydrodynamic and surface-chemical interactions. In flocculation the destabilized suspended particles are agglomerated into large rapidly settling flocs [1]. The flocculation is caused by the random "Brownian" motion of the particles (perkinetic flocculation), the velocity gradient (orthokinetic flocculation) [11].

Most of the coagulants used are salts of iron or aluminium. When mixed with water a mutual exchange of groups is taking place, and the end product is hydroxides in the form of gelatinous precipitate [8]. The choice of the best coagulant for any particular water is determined by experiment. The operating factors as pH, different coagulants, amount of coagulant, mixing parameter are explored in this work to determine their respective effects on the efficiency of the coagulation and flocculation. The optimum operating range for each of those variables were experimentally determined. When the salt of the trivalent aluminium and iron cations are dissolved in water, the metal ion hydrates attaching six molecules of water and forms an aquametal ion. The form ion then can hydrolyze and form monomeric and polymeric ferric compounds [3].

2 Characteristics of wastewater effluents

The fibers used in the textile industry may be broadly classified into four groups: cotton, wool, regenerated and synthetics. The pollutants in the textile wastewater include natural impurities in the fibers used, and processing chemicals. The liquid waste comes from the following operations: slashing, scouring and desizing, bleaching, mercerizing, dyeing and finishing. The entire liquid effluent may include the following organic and inorganic substances: starch, carboxymethyl cellulose, sodium hydroxide, detergents, peroxides, hypochlorites, dyes and pigments, sodium gums, dextrins, waxes, sulphides, sulphates, etc. The combination of strong color and high dissolved solid content lead to high turbidity of the liquid effluent [2].

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Crude pulp and paper mill wastes, or insufficiently treated wastes cause very serious pollution problems, when discharged into the streams. Generally the pulp and paper mills wastes are characterized by strong color, high BOD, high amount of suspended solids and high COD/BOD ratio. The pulp and paper effluents contain resin acids, fatty acids, phenols, tannins, lignins, terpenes, etc [9].

3 Materials and methods

3.1 Apparatus

A jar test apparatus was used in order to determine the effectiveness of various coagulants. It consists of a set of six beakers, which can be stirred simultaneously at specified speed. This makes it possible to simultaneously determine the effect of six different dosage of coagulant, as well as the effect of six different values of pH. The turbidity meter was used to measure the turbidity. It consists of nephelometer with a light source for illuminating the sample and one or more photoelectric detectors with a readout device. The turbidity is expressed in NTU (nephelometric turbidity units).

3.2 Experimental procedure

For optimal coagulation and flocculation it is important that aggregates of certain size, strength and density are formed. These properties are largely determined by coagulant type, dose, pH and mixing intensity [4, 5]. In order to determine the optimum pH, first the initial dosage of coagulant was determined using 200 ml of sample. The coagulant was added in small increments. After each addition, a 1-minute rapid mix (250 rpm), followed by a 15-minutes slow mix (20-rpm) was carried out. This continued until a visible floc had been formed. In order to determine the optimum pH the sample of 1000 ml was placed in each of the beakers and the initial dosage of coagulant was added. The pH was adjusted at 4.0, 5.0, 6.0, 7.0, 8.0 and 9.0. Rapid mix (250 rpm) for 1 minute, followed by 15 minutes mix at slow speed (20 rpm) was carried out. The samples were allowed to stand for 30 minutes and then turbidity was determined. The optimum dosage of coagulants was determined by keeping the optimum pH constant and varying the dosage of coagulant.

The wastewater effluents from Sappi Fine Papers and Alitex Textile were investigated. The Sappi Fine Papers produces coated paper from sugar cane bagasse. The Alitex Textile produces cotton textile. The initial turbidity of the effluent was 229.4 NTU at pH 6.8 from Sappi Fine Papers, and 226.6 NTU at pH 7.1 from Alitex Textile respectively. The particles were in all sizes from those in true suspension to colloidal range. Three different coagulants, namely, aluminium sulphate, ferric sulphate, ferric chloride and combination of them were used.

4 Results and discussion

4.1 Pulp and paper effluent

The initial turbidity of the wastewater was 229.4 NTU and pH was 6.8. The optimum pH was determined by using the three coagulants and the combination of the two best ones. The appearances of the flocculated solids and supernatants were quite different for each of the three coagulants used. The addition of ferric chloride resulted in fine grey-brown floc, which tended to form quite slowly. The supernatant was light brown in colour. Ferrous sulphate led to light brown flocs, which settled readily, and the supernatant was a clear yellow. Aluminium sulphate resulted in an almost clear supernatant and fine dark brown flocs, which settled very quickly. The initial dosage of the coagulants was found to be for ferric chloride 7.01 mg, ferrous sulphate 8.93 mg, and for aluminum sulphate 6.54 mg. The respective initial dosages were used in order to determine the optimum pH for each coagulant. The turbidity and the % solid removal were determined at different values of pH ranging from 3 to 10. The optimum pH was determined by plotting the pH Vs turbidity. The results are shown in fig. 1.

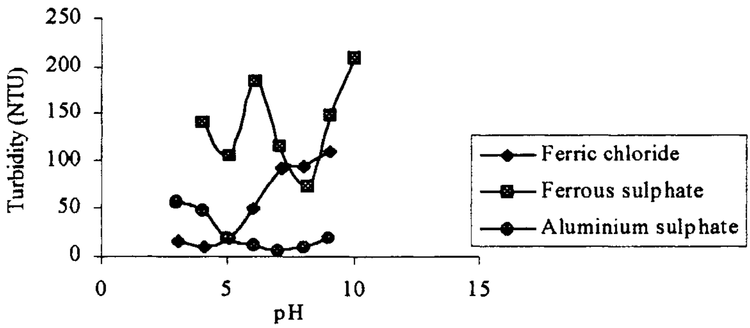

Figure 1: Optimum pH- pulp and paper effluent

The optimum pH determined were 4.12, 8.15, and 7 for ferric chloride, ferrous sulphate and aluminium sulphate respectively. At the optimum pH the turbidity obtained was 9.99 NTU for ferric chloride, 74 NTU for ferrous sulphate and 5.15 NTU using aluminium sulphate. The effect of pH was extremely important.

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The next to be determined was the optimum dosage of each coagulant. The optimum pH for each coagulant was kept constant and the dosage was varied. The results are shown in fig.2.

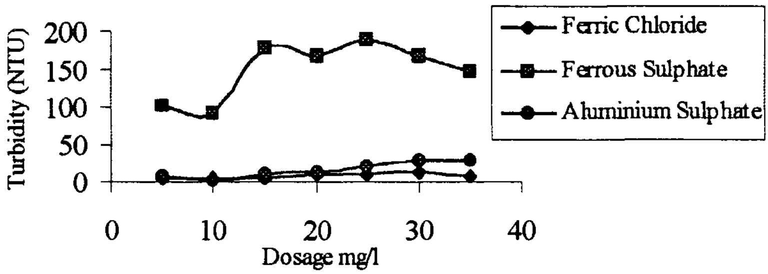

Figure 2: Optimum dosage - pulp and paper effluent

The optimum dosage was found to be almost the same for each of the coagulants 10 mg/l. In order to determine the effect of the combination of coagulants on the process of coagulation and flocculation, the two best coagulants, namely aluminium sulphate and ferric chloride were used. Thereafter a percentage of each coagulant was added together and the experimental procedure was carried out. The results are shown in table 1.

Table1: Combination of the best two coagulants.

	Aluminium sulphate mg/l	Ferric chloride mg/l	Turbidity (NTU)	% Solids removal
1	4.0	2.0	1.83	99.20
2	3.5	3.0	2.74	98.80
3	3.0	4.0	1.89	99.17
4	2.5	5.0	2.73	98.80
5	2.0	6.0	1.98	99.13
6	1.5	7.0	2.62	96.00

The comparison between the coagulants is shown in fig.3. The best coagulant was aluminium sulphate. It achieved a final turbidity of 3.17 NTU at pH 7. With the ferric chloride turbidity of 4.55 NTU was obtained at pH 4.12. The turbidity obtained using ferrous sulphate was 90.8 NTU at pH 8.15. The best results were obtained by the combination of aluminum sulphate and ferric chloride. The turbidity of 1.83 was achieved, compared with 74.5 NTU from the industry.

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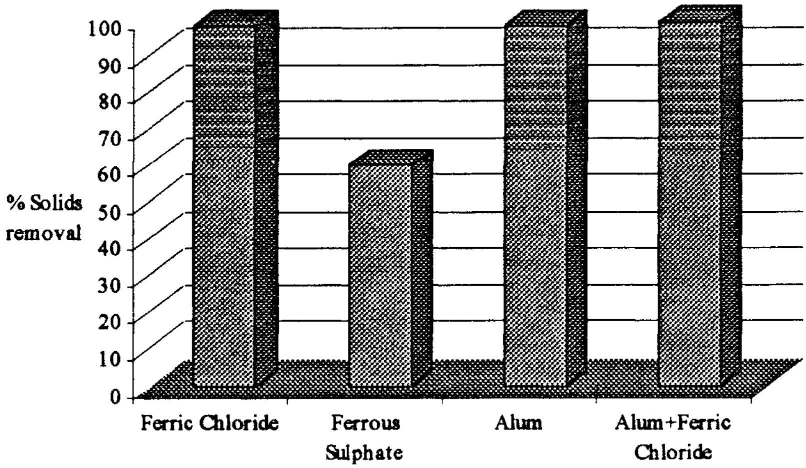

Figure 3. Comparison between the coagulants

4.2 Textile effluent

The sample was initially dark maroon in colour. The initial turbidity was 226.6 NTU and pH 7.1. The addition of ferric chloride resulted in gelatinous purple flocs, which are formed and settled relatively slow. The supernatant was light orange in colour. Ferrous sulphate coagulation form dark brown flocs, which settled very quickly, and the supernatant was light purple in colour. With the aluminium sulphate the resulted supernatant was clear and formed reddish-black flocs. The initial dosage of each of the coagulants was determine to be 15.46 mg, 18.95 mg, and 13.25 mg for ferric chloride, ferrous sulphate and aluminium sulphate respectively. Series of experiments were carried out in order to determine the optimum pH for each coagulant. The turbidity and pH readings were recorded by using turbidimeter and pH-meter. The optimum pH was determined by plotting the pH Vs turbidity. The results are shown in fig. 4.

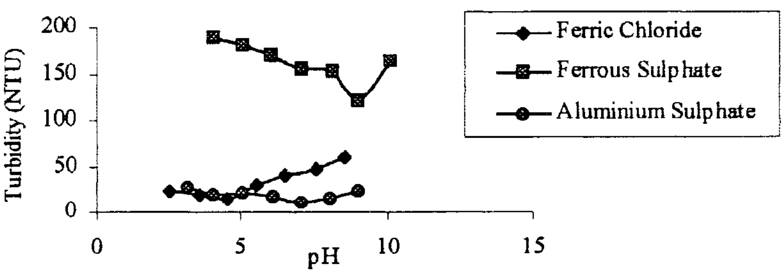

Figure 4: Optimum pH- textile effluent

The point with the lowest turbidity gives the value of the optimum pH.
The optimum pH determined were 4.5, 9.01, and 7.06 for ferric chloride, ferrous sulphate and aluminium sulphate respectively. At the optimum pH the turbidity obtained was 15.02 NTU for ferric chloride, 122 NTU for ferrous sulphate and 11.01 NTU using aluminium sulphate. The optimum dosage of each coagulant was determined. The turbidity Vs dosage of each coagulant was plotted as it is shown in fig.5.

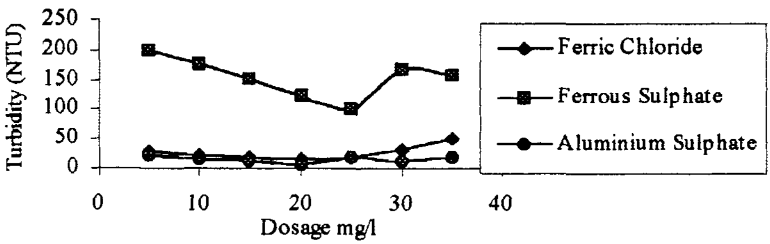

Figure 5: Optimum dosage- textile effluent

The optimum dosage was found to be 20 mg/l, 25 mg/l, and 20 mg/l for ferric chloride, ferrous sulphate, and aluminium sulphate respectively. Again the best results were obtained by using aluminium sulphate. The turbidity was 6.13 NTU, compared with 15.6 NTU for ferric chloride and 101.7 NTU for ferrous sulphate. The results from the combination of aluminium sulphate and ferric chloride are shown in Table 2. With the combination of aluminium sulphate and ferric chloride the turbidity of 6.01 NTU was obtained.

Table2: Combination of the best two coagulants.

	Aluminium sulphate mg/l	Ferric chloride mg/l	Turbidity (NTU)	% Solids removal
1	7.0	3.0	17.19	92.
2	9.0	6.0	10.27	96.
3	11.0	9.0	11.23	95.
4	13.0	12.0	6.01	97.
5	15.0	15.0	7.19	97.
6	17.0	18.0	12.75	94.

5 Conclusion

From the results obtained it can be concluded that the pH plays important role in the process of coagulation and flocculation. Aluminium sulphate was the best coagulant for both, pulp and paper and textile effluents. With the aluminium sulphate 98 and 97% removal of the solids were achieved for pulp and paper and textile effluent. The other advantage of this coagulant is that the optimum pH was about 7, so there is not need to adjust the pH of the water. Ferric chloride was found to be also effective at a pH range of 3 and 5. In order to achieve the max removal adjustment of the pH of the water is required. The aluminium sulphate is more expensive that the ferric chloride. The combination of the two coagulants could lead to the reduction in the cost of the wastewater treatment, and in the same time obtaining better removal of the solids.

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