Treatment of Food Processing Industry Wastewater by a Coagulation/ Flocculation Process

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Abstract

Food processing industry wastewater poses pollution problems due to its high COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand). Moreover the characteristics of wastewater depict wide variation due to the variation in the type of products manufactured and also the different fruits, vegetables and raw materials used. Many preservatives, colour, salts, oil, sugar, gelatin etc are added as per the requirement of production of various products, this adds to the pollution load. Because of these problems, the load on conventional treatment unit which employ anaerobic and aerobic reactors for the treatment generally malfunctions. It is therefore preferable to provide primary physicochemical treatment, using different coagulant and coagulants aids thus reducing the organic load on secondary biological treatment. Keeping this in view commonly available coagulants like lime, alum, ferrous sulphate and ferric chloride and few different polyelectrolytes as a coagulant aid were studied. Being acidic in nature this wastewater was treated by two stage physicochemical treatment.

Results indicated that this wastewater is amenable to physicochemical treatment and can be applied either as pretreatment technology or as a final polishing treatment. Lime dose of 200mg/ L resulted in optimum COD/ BOD reductions of 53.59% and 57.19% respectively. Amount of sludge development was only 25 ml/L at this dose. Alum dosage resulted in very poor removals. This wastewater being highly protinous in nature alum combines with protein and forms dense fine flocs which do not settle easily. At the alum doses between 50 and 300mg/ L COD and BOD reductions varied between 16.81-29.97% and 22.81-38.81% respectively. While removals incase of Ferrous Sulphate and Ferric chloride were slightly better between the dosage of 50-175mg/L. But considering the cost of these two chemicals, lime was selected for further studies using different polyelectrolytes. Lime dose of 200mg/ L was found to be optimum. This optimum dose of Lime was kept constant and different anionic, cationic and nonionic polyelectrolytes were tried. Results showed that Magnafloc E-207 was best among the selected *polyelectrolytes. Results showed 0.3mg/L of Magnafloc E-207 in combination with 200mg/L of optimum dose of Lime were very effective with COD, BOD and SS reductions of 67.61%, 71.01% and 81.53% respectively. While other two polyelectrolytes depicted more or less similar results and reduction were comparatively lesser. Both nonionic (i.e. Zetag 7650) and Cationic (i.e. Oxyfloc FL-11) showed 0.4 mg/L of polyelectrolyte as optimum.This paper discusses in detail the behavior of coagulant and its combination with various polyelectrolytes.*

Key words: Food Processing, Coagulant, Polyelectrolyte, Cationic, Anionic, Nonionic.

Introduction

The Indian food processing industry is one of the largest in the world in terms of production, consumption, export and growth prospects. The food processing industry in India is a sunrise sector that has gained prominence in recent years. Increase industrialization with literacy and affluence has given a considerable push to the food processing industry growth. Mechanical life style and crave for comfort is pushing people towards ready to eat services. Yes it is very good for the progress of the industry but it also leads to the generation and consumption of water in tremendous volumes.

Wastewater generated from these industries depicts wide variation in strength and characteristics. Variation due to the amount of water usage, type of vegetable and fruits used, type of product and different additives like salt, sugar, gelatin, colurs, oil and preservatives added also leads to the pollution load in the wastewater but this wastewater is non toxic in nature because it comprises less hazardous compounds. Almost 50% of the water utilized in food processing industry is for washing and rinsing purposes. Water being the primary ingredient is widely used as a cleaning agent in food processing industry. This wastewater has been reported to be treated by aerobic and anaerobic biological techniques. But the biological system malfunctions due to fluctuating load and characteristics of wastewater which fluctuates widely. It is hence preferable to provide primary physicochemical treatment to this wastewater prior subjecting it to the biological treatment.

Physicochemical wastewater treatment is a frequently used technique in the area of wastewater treatment. Physicochemical wastewater treatment techniques are applied for the removal of heavy metals, oils and greases, suspended matter and emulgating organic substances, organic and inorganic components, difficult to decompose, non polar organic substances, toxic pollutants or high salt concentrations, phosphorus. The physicochemical wastewater treatment techniques are used as pretreatment, final treatment as well as specific treatment for wastewater reuse as process water. In Norway there are many food processing industries/ plants where wastewater is provided chemical treatment only[1].

Food industry wastewater treatment by physicochemical method using Zinc Sulphate, Ferrous Sulphate and Ferric chloride has been reported. Where the reduction in COD has been obtained 60% with alum dose of 200 mg/L [2].

Under food processing industry, Palm oil refining wastewater has been successfully treated by physicochemical treatment using chitosan, alum and PAC and reported [3]. Physicochemical and combined biological treatment has been successfully applied to a food processing industry wastewater for reuse quality[4]. Coagulation is one of the physicochemical methods most widely used in water treatment for purification of urban and industrial wastewater. The process is effective for removal of particles, suspended solids and also organic matters[5]. Many salts of iron, aluminium and lime have been widely used [6]. A natural coagulant Chitosan used as a coagulant to treat the wastewater from milk processing plant has been reported [7].

The wastewater of the food industry generally contains leavenings, carbohydrates inorganic and organic salts, oil, sugar, starch, detergents, cleaning products and high concentration of proteins. These constituents generally exerts load on biological process hence a primary treatment by way of physicochemical treatment is needed to reduce the organic load on secondary treatment.

Food processing industry includes varied type of food products processing which includes fruit, vegetable, oil industries, dairy, meat, fish, shrimp, Canning and jam processing. Food processing can be divided in to four major sectors: i.e. meat, poultry and sea food, fruit and vegetable, Dairy and beverage.

Being very complex wastewater many different treatment methods have been used for the treatment of food processing wastewater. Membrane technologies/ membrane filtration is a process used to separate dissolved salts and fine particles from the wastewater [8, 9 and 10]. But it is a very cost intensive process. It is seen that generally conventional coagulants like salts of iron, aluminium and lime have been used widely but addition of different polyelectrolyte have not been reported. Considering all the facts, it was envisaged to treat food processing industry wastewater by conventional coagulants like lime, alum, ferrous sulphate and ferric chloride. But efforts were also made to increase the removal efficiency of these coagulants by using minimum quantity of some polyelectrolyte's to achieve good quality effluent. Polyelectrolytes of anionic, cationic and nonionic in nature were tried and results have been discussed in detail.

Experimental

For the characterization of food processing effluent composite samples were collected and characterized. The samples were analysed according to the procedures given in standard methods [11].

The experiments were carried out using jar test apparatus. Six beakers of 1 litre capacity were used in which one litre neutralized effluent was taken for detail studies. Coagulant stock solutions were prepared and used for the complete set of each test.

While using jar test apparatus, initially the samples were flash mixed for one minute at high rpm of 100 and later at 40 RPM for half an hour. After half an hour of mixing, the samples were settled for half an hour. Supernatant liquid was drawn and subjected to various parameters and sludge volume settled was noted.

Results and Discussion

The food processing wastewater shows large variation in BOD/COD, total solids and suspended solids, oil and grease, starch, sugar, colour, preservatives, total nitrogen, total phosphates, chloride and sodium etc. This is due to the different additives used for different food products. Wastewater depicted COD/BOD and SS of 11220 mg/l, 6860 mg/L and 2210 mg/L respectively. Table 1 depicts the actual wastewater characteristics and the neutralized wastewater which was used for the experiments.

Table 1: Characterization of Food Processing Industry Wastewater.

Parameters	**Raw Wastewater**	**Neutralized wastewater**
pH	4.12- 4.28	6.9 - 7.1
Colour (Visual)	Creamish White	Black Gray
Total Acidity/Alkalinity as $CaCO_3$	980	410
Total Suspended Solids	2210	1310
Total Dissolved Solids	1620	1580
Total Solids	3830	2890
Chemical Oxygen Demand (COD)	11220	6020
Biological Oxygen Demand (BOD, 5day - 20°C)	6860	4050
Sulfide as (S^{-2})	264	212
Sulphates as (SO_4^{-2})	280	250
Total Phosphates as (PO_4^{-2})	3.2	3.0
Total Nitrogen as N	16.4	15.8
Oil and Grease	110	56
Sodium as Na^+	82	78
Potassium as K^+	27	24
Chloride	182	176
Heavy Metals		
Iron	12.63	12.52
Copper	0.468	0.450
Manganese	0.444	0.438
Nickel	0.126	0.122
Zinc	0.620	0.608
Chromium	0.026	0.024
Lead	0.468	0.459
Cadmium	Nil	Nil

***All values are expressed in mg/L except pH and colour**

A study on the effectiveness of lime alum, ferric chloride and ferrous sulphate individually and also with addition of polyelectrolyte were carried out. Lime being the most cost effective chemical was tried first with food processing wastewater. As the wastewater pH was around 4.2 the pH was adjusted to 7.0 before the start of the experiments. A lime dose of 2.2 mg/L was required to neutralize the combined wastewater from initial pH of 4.2. The neutralized wastewater was further subjected to chemical treatment (second stage) using different conventional coagulants.

Lime dose varied between 50-300 mg/L and experiments were carried out. At lime dose of 200 mg/L pH of the wastewater increased to 7.8 with COD/BOD and SS reductions of 53.6%, 57.2% and 61.1% respectively. When the lime dose was increased to 250 mg/l, COD, BOD and SS removals increased by 2-4% only which was very marginal increase. When lime dose was further increased to 300 mg/L the removal improved by few percents only. It is very clear that after 200 mg/L dose of lime the COD/ BOD/ SS reductions were only marginal and 200 mg/L seems optimum as indicated in Table 2.

Table 2: Physicochemical Treatability of Combined Wastewater from Food Processing Industry Using Coagulant: Lime.

Sr. No.	***Parameters***	**Raw Wastewater**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				50	**100**	**150**	**200**	**250**	**300**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	7.0	7.4	7.8	8.0	8.5
2.	Suspended Solids (SS)	2210	1310	838	768	670	510	464	378
3.	% Removal of SS	--		36	41.37	48.85	61.1	64.58	71.5
4.	Bio-Chemical Oxygen Demand	6860	4050	2664	2430	2186	1734	1556	1394
5.	% Removal of BOD	--		34.22	40.00	46.00	57.19	61.58	65.58
6.	Chemical Oxygen Demand	11220	6020	4094	3696	3318	2794	2648	2440
7.	% Removal of COD	--		31.99	38.60	44.88	53.59	56.00	59.47
8.	Vol. of Sludge (ml)			10	16	20	25	38	40

Alum dosages tried were in the range of 50-300 mg/L as indicated in Table 3. At a dosage of 250 mg/l, suspended solids removal of 58.53%, COD of 27.81% and BOD of 35.21% were achieved. Beyond this dosage only marginal improvement was observed. Alum can be used only for initial removal of suspended solids as it is not economical at higher doses. Prior subjecting the wastewater to biological treatment a minimum dose of 150 mg/L of alum will be beneficial with a reduction of 40% suspended solids thus reducing the organic load on the secondary biological treatment. Wherever the wastewater warrants only SS removal as a primary treatment, alum dose of 150 mg/L can be advocated. Individually alum addition did not result in efficient COD and BOD removals. Considering the cost factor, coagulant ferrous sulphate and ferric chloride were used in the lower range of 50-175 mg/l.

Table 3: Physicochemical Treatability of Wastewater from Food Processing Industry Using Coagulant: Alum

Sr. No.	***Parameters***	**Raw Waste water**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				50	**100**	**150**	**200**	**250**	**300**
1.	pH	4.12-4.28	6.9 - 7.1	6.9	6.9	6.8	6.7	6.6	6.5
2.	Suspended Solids (SS)	2210	1310	878	820	778	724	648	596
3.	% Removal of SS	--		32.98	37.4	40.61	44.73	50.53	54.50
4.	Bio-Chemical Oxygen Demand	6860	4050	3126	3078	2988	2852	2624	2478
5.	% Removal of BOD	--		22.81	24.00	26.22	29.58	35.21	38.81
6.	Chemical Oxygen Demand	11220	6020	5008	4876	4756	4600	4346	4216
7.	% Removal of COD	--		16.81	19.00	21.00	23.59	27.81	29.97
8.	Vol. of Sludge (ml)			35	48	52	58	66	72

At maximum dosage of 175 mg/L ferrous sulphate gave 72.52% SS removal 58.22% of BOD removal and 52.99% of COD removal (Table 4). Sludge production was marginally lesser in volume compared to Alum. Moreover at highest dosage of ferrous sulphate, it imparted dark colour to the effluent. While at minimum dose of 50 mg/L SS removal was around 48.7% but COD and BOD reductions were 32.59% and 30% respectively. While considering overall efficiency, a dose of 125 mg/L of FeSO4 seems optimum, because COD/BOD/SS removals were around 46.21%, 51.21% and 65.65% respectively.

In case of ferric chloride removals were much lower than ferrous sulphate. Reductions of COD, BOD and SS were 35.02%, 40.0% and 64.12% respectively at the dose of 125 mg/L (Table 5). At higher doses of 175 mg/L removals showed increasing trend but the removals were marginal but colour of the effluent was dark and aesthetically not suitable. In both ferrous sulphate and ferric chloride removals obtained were optimal at 125 mg/L dose. Ferric chloride also followed the same trend as that of ferrous sulphate. Ferric chloride also imparted colour to the treated effluent. Colour of the effluent was yellow and it went on intensifying as the dose increased. Sludge production in case of ferric chloride was marginally higher than the ferrous sulphate. Treatment using ferrous sulphate and ferric chloride is not very congenial to this wastewater considering the cost, colour and addition of iron content to the effluent.

Table 4: Physicochemical Treatability of Wastewater from Food Processing Industry Using Coagulant: Ferrous Sulphate.

Sr. No.	***Parameters***	**Raw Waste water**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				50	**75**	**100**	**125**	**150**	**175**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	6.9	6.8	6.7	6.6	6.5
2.	Suspended Solids (SS)	2210	1310	672	624	576	450	406	360
3.	% Removal of SS	--		48.70	52.37	56.00	65.65	69.00	72.52
4.	Bio-Chemical Oxygen Demand	6860	4050	2730	2552	2324	1976	1822	1692
5.	% Removal of BOD	--		32.59	36.99	42.62	51.21	55.00	58.22
6.	Chemical Oxygen Demand	11220	6020	4214	3982	3708	26363	3034	2830
7.	% Removal of COD	--		30.00	33.85	38.41	46.21	49.60	52.99
8.	Vol. of Sludge (ml)			25	30	38	44	49	55

Table 5: Physicochemical Treatability of Wastewater from Food Processing Industry Using Coagulant: Ferric Chloride.

Sr. No.	***Parameters***	**Raw Waste water**	**Neutralized Waste water**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				50	**75**	**100**	**125**	**150**	**175**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	6.9	6.8	6.7	6.6	6.5
2.	Suspended Solids (SS)	2210	1310	684	628	554	470	418	378
3.	% Removal of SS	--		47.79	52.10	57.71	64.12	68.10	71.15
4.	Bio-Chemical Oxygen Demand	6860	4050	3006	2892	2738	2430	2292	2242
5.	% Removal of BOD	--		25.78	28.59	32.40	40.00	43.41	44.64
6.	Chemical Oxygen Demand	11220	6020	4720	4508	4322	3912	3696	3516
7.	% Removal of COD	--		21.59	25.12	28.21	35.02	38.60	41.59
8.	Vol. of Sludge (ml)			30	34	40	48	56	58

Recently more stress is being given to the use of certain synthetic polyelectrolyte due to its enhancing removal qualities in terms of COD, BOD and SS of the wastewater having high turbidity.

With a view to reduce the cost and amount of chemical requirement, few polyelectrolytes were tried. Effluent wastewater from constant dose of lime was selected for further studies using polyelectrolyte. Lime treated wastewater was used considering low cost of the lime. A total three different types of polyelectrolytes, viz; anionic, non-ionic and cationic were studied.

Table 6: Physicochemical Treatability of Wastewater from Food Processing Industry Using Constant Dose of Lime 200 mg/L + Anionic-Synthetic Polyelectrolyte (Magnafloc - E-207).

Sr. No.	***Parameters***	**Raw Wastewater**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	6.8	6.7	6.6	6.5	6.4
2.	Suspended Solids (SS)	2210	1310	358	312	242	220	188	178
3.	% Removal of SS	--	--	72.67	76.80	81.53	83.21	85.65	86.4
4.	Bio-Chemical Oxygen Demand	6860	4050	1620	1458	1174	1054	932	900
5.	% Removal of BOD	--	--	60.00	64.00	71.01	73.98	76.99	77.20
6.	Chemical Oxygen Demand	11220	6020	2648	2408	1950	1782	1614	1598
7.	% Removal of COD	--	--	56.0	60.00	67.61	70.40	73.2	73.45
8.	Vol. of Sludge (ml)			24	26	30	35	40	45

Optimum lime dose of 200 mg/L as constant dose with different doses of polyelectrolyte of 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 mg/L were tried as it is indicated in the table 6. Results show that a constant lime dose of 200 mg/L and 0.3 mg/L polyelectrolyte Magnafloc E-207 gave efficient results. In this combination SS, COD and BOD removals were quite appreciable and were 81.53%, 67.61% and 71.01% respectively and sludge production was around 33 ml/L. Moreover this sludge quality may not pose much problem and can be used for the reclamation of soil.

Further studies using 200 mg/L lime + addition of non-ionic polyelectrolyte Zetag-7650 was tried. Addition of 0.3 mg/L of zetag showed SS/COD/BOD removals of 72.37%, 58.0% and 64.0% respectively as optimum. Further increasing the polyelectrolyte dose to 0.4 mg/L increased the COD, BOD and SS removals by 3.0% excess. It is very clear that just to get marginal improvement it is not worth to increase the polyelectrolyte dose, because it may increase the cost. Hence it is clear that 0.3 mg/L polyelectrolyte dose to 200 mg/L lime is the optimal combination (Table 7).

Table 7: Physicochemical Treatability of Wastewater from Food Processing Industry Using Constant Dose of Lime 200 mg/L + Nonionic -Synthetic Polyelectrolyte (Zetag –7650).

Sr. No.	***Parameters***	**Raw Wastewater**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	6.9	6.8	6.7	6.6	6.5
2.	Suspended Solids (SS)	2210	1310	482	456	362	324	288	256
3.	% Removal of SS	--	--	63.20	65.20	72.37	75.27	78.02	80.46
4.	Bio-Chemical Oxygen Demand	6860	4050	1685	1620	1458	1320	1216	1110
5.	% Removal of BOD	--	--	58.4	60.00	64.00	67.4	69.98	72.59
6.	Chemical Oxygen Demand	11220	6020	2745	2639	2528	2300	2126	1974
7.	% Removal of COD	--	--	54.4	56.2	58.00	61.79	64.68	67.21
8.	Vol. of Sludge (ml)	--	--	28	32	36	40	44	49

Table 8: Physicochemical Treatability of Wastewater from Food Processing Industry Using Constant Dose of Lime 300 mg/L + Cationic -Synthetic Polyelectrolyte (Oxyfloc -FL-11).

Sr. No.	***Parameters***	**Raw Wastewater**	**Neutralized Wastewater**	**Effluent Concentration and Coagulant Doses (mg/L)**					
				0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**
1.	pH	4.12- 4.28	6.9 - 7.1	6.9	6.9	6.8	6.7	6.6	6.5
2.	Suspended Solids (SS)	2210	1310	542	518	465	394	334	298
3.	% Removal of SS	--	--	58.63	50.46	64.50	69.92	74.50	77.25
4.	Bio-Chemical Oxygen Demand	6860	4050	1766	1685	1612	1390	1280	1216
5.	% Removal of BOD	--	--	56.4	58.4	60.2	65.68	68.40	69.9
6.	Chemical Oxygen Demand	11220	6020	2758	2697	2624	2334	2180	2024
7.	% Removal of COD	--	--	54.2	56.2	56.42	61.23	63.79	66.38
8.	Vol. of Sludge (ml)	--	--	32	34	36	40	44	48

Keeping lime dose constant at 200 mg/L different doses of cationic polyelectrolyte oxyfloc-FL-11 was initiated. From the results it is seen that 0.4 mg/L of cationic polyelectrolyte to 200 mg/L of lime seems optimal with SS, COD and BOD removals of 69.92%, 61.23% and 65.68% respectively (Table 8). But among the polyelectrolytes, magnafloc E207 was found to be marginally superior compared to other non-ionic and cationic polyelectrolytes. In general all the three polyelectrolytes behaved very efficiently and removals were more than 60% in all the cases. Based on the easy availability any one of the three polyelectrolytes can be applied/ used. Individually all the three electrolytes were more or less showed the same trend of removals. Physico-chemical studies carried out indicate that the food processing industry wastewater is amenable to this treatment. It may be applied as a primary treatment before subjecting the wastewater to secondary biological treatment. This treatment will help in efficient working of biological system by reducing the organic load.

Conclusions

From the studies it can be concluded that the food processing wastewater is easily amenable to physico-chemical treatment. The results obtained show that all the coagulants used individually or in combination with polyelectrolyte can remove moderate to high degree of chemical oxygen demand, biochemical oxygen demand and suspended solids from the food processing wastewater. Lime individually also acts as an efficient coagulant and moreover it is very cost effective. Addition 0.3 mg/L of anionic polyelectrolyte magnafloc to 200 mg/L of lime resulted in good SS, COD and BOD removals. Among the polyelectrolytes studed magnafloc-E-207 gave the best removals of pollutants.

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