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Treatment of dairy wastewater by inorganic coagulants: Parametric and disposal studies

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ABSTRACT

Present study reports treatment of simulated dairy wastewater (SDW) by inorganic coagulants such as poly aluminum chloride (PAC), ferrous sulphate ($FeSO_4$) and potash alum ($KAl(SO_4)_2 \cdot 12H_2O$). Batch coagulation experiments were conducted to evaluate the influence of initial pH (pH_i: 5–10) and coagulant dosage (m: 100–5000 mg/L) on chemical oxygen demand (COD) removal from SDW. Residual COD and system pH were observed as function of time. Optimum pH_i ($pH_{i,op}$) was found to be 8.0 for all the three coagulants. Optimum m (m_{op}) was found to be 300, 800 and 500 mg/L for PAC, $FeSO_4$ and $KAl(SO_4)_2 \cdot 12H_2O$, respectively, giving 69.2, 66.5 and 63.8% COD removal efficiency in 30 min. Heating values of the sludge generated by the coagulants PAC, $FeSO_4$ and $KAl(SO_4)_2 \cdot 12H_2O$ were found to be 20.7, 29.6 and 17.3 MJ/kg, respectively.

1. Introduction

Food processing industries cause serious environmental problems because of generation of strong wastewater characterized by high biological oxygen demand (BOD) and chemical oxygen demand (COD) (Orhon et al., 1993). Among the food industries, the dairy industry is the most polluting in terms of volume of effluent generated as well as in terms of its characteristics too, generating about 0.2–10 L of effluent per litre of processed milk (Vourch et al., 2008). The liquid waste in a dairy originates from several sources such as the receiving station, bottling plant, cheese plant, butter plant, and ice cream plant. The most significant organic materials in dairy wastewater are fat, lactose and proteins (mainly casein) (Gough et al., 2000).

Dairy wastewaters are treated using biological and physico-chemical methods. High energy requirement by aerobic biological treatment methods is the primary drawback of these processes (Wheatley, 1990), whereas, anaerobic treatment of dairy wastewater reflects very poor nutrient removal. Therefore, further treatment of anaerobically treated effluent is required. Among physico-chemical methods, coagulation–flocculation is used for removal of suspended and colloidal material from the dairy wastewater (Rossini et al., 1999; Al-Mutairi et al., 2004). Recently, Kushwaha et al. (2010) studied the adsorptive treatment of dairy wastewater by activated carbon and bagasse fly ash; Sengil and Ozacar (2006) studied the electrocoagulation (EC) treatment with iron electrode whereas Tchamango et al. (2010) used aluminum electrode for the same.

Only few studies are reported in open literature for the coagulation of dairy wastewater (Namasivayam and Ranganathan, 1992; Selmer-Olsen et al., 1996; Mukhopadhyay et al., 2003; Hamdani et al., 2004; Sarkar

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Table 1 – Parameters reported for the treatment of dairy wastewater by coagulation.

Waste Type	Coagulant	COD_i (mg/L)	%COD Removal	%BOD Removal	%TN Removal	%TP Removal	Reference
DI	Fe^{3+}/ Cr^{3+} sludge	2000	70 ± 5	68		70	Namasivayam and Ranganathan, 1992
	Ferric chloride		73	57		64	Namasivayam and Ranganathan, 1992
	Ferrous sulphate		61	57		79	Namasivayam and Ranganathan, 1992
DI	Chitosan	1160–2690	60			60	Selmer-Olsen et al., 1996
Whey	Chitosan	–		87			Mukhopadhyay et al., 2003
DI	Ferric chloride	6140			40		Hamdani et al., 2004
	Aluminum sulphate				40		Hamdani et al., 2004
	Calcium hydroxide				40	89	Hamdani et al., 2004
DI	Chitosan	1500–3000	57				Sarkar et al., 2006

DI = Dairy industry, COD_i = Initial COD, TP = Total phosphates.

et al., 2006). Table 1 shows the comparison of the work carried out by these researchers. Hamdani et al. (2004) observed only 40% organic matter and nitrogen content removal from dairy wastewater by coagulation–decantation with ferric chloride ($FeCl_3 \cdot 6H_2O$), aluminum sulphate ($Al_2(SO_4)_3 \cdot 18H_2O$) and $Ca(OH)_2$. However, this treatment considerably reduced the suspended matter (94%) and total phosphorus (89%) with $Ca(OH)_2$. Sarkar et al. (2006) employed coagulation by chitosan followed by adsorption with powdered activated carbon as pre-treatment steps before treating the dairy wastewater by membrane separation method and found 57% reduction in COD at 10–50 mg/L chitosan dosage. A look into the literature shows that there is no description regarding the variation of COD removal efficiencies with change in *pH*. Moreover, these studies don't give information about settleability of the mixture of liquid-solid suspensions (slurry) and disposal aspects of the sludge generated during coagulation. These aspects are very important from industrial and designing point of view.

In the present study, the suitability of three commonly used inorganic coagulants namely poly aluminum chloride (PAC), ferrous sulphate ($FeSO_4$) and potash alum ($KAl(SO_4)_2 \cdot 12H_2O$) were investigated for the treatment of simulated dairy wastewater (SDW) in terms of their COD removal efficiency. Other parameters such as total nitrogen (TN), turbidity and total solids (TS) were also calculated for the treated effluent at optimum initial *pH* ($pH_{i,op}$) of SDW and optimum dosage (m_{op}) of the coagulants. Settleability of the slurry from the coagulation of SDW was also quantified by calculating sludge volume index (SVI). The sludge generated was also analysed for the possibility of its disposal using oxidation in air atmosphere.

2. Materials and methods

2.1. Wastewater

In order to make wastewater of constant composition throughout the experiments, 4 g of milk powder (Amulya brand, manufactured by Banaskantha District Cooperative Milk producer's Union Ltd., Palanpur, Uttarakhand, India) was dissolved in 1 L of distilled water to generate SDW. Several investigators used the same method for making SDW (Ramasamy et al., 2004; Balannec et al., 2005; Leal et al., 2006; Kushwaha et al., 2010). The characteristics of the SDW used in the present study are presented in Table 2. It was prepared freshly whenever required and the concentration was maintained uniform throughout the study.

2.2. Chemicals and analytical measurements

All the chemicals used in the study were of analytical reagent (AR) grade. PAC was obtained from Grasim Industries Ltd., Nagda, Madhya Pradesh, India; $FeSO_4$ was procured from Ranbaxy India Ltd. SAS Nagar, Punjab, India; and $KAl(SO_4)_2 \cdot 12H_2O$ was obtained from Sarabhai M chemicals, Baroda, India. COD was measured using digestion unit (DRB 200, HACH, USA) and double beam UV visible spectrophotometer (HACH, DR 5000, USA). Turbidity meter supplied by Aqualytic, Germany, was used to measure turbidity. The chloride content was determined by standard titrimetric Volhard method. Total nitrogen (TN) was determined using standard Kjeldahl method.

Energy dispersive X-ray (EDX) (SEM, QUANTA, Model 200 FEG, USA) was used to study the distribution of the elements in the sludge generated by the coagulation of SDW. For the

Table 2 – Characteristics of SDW and effluents treated by various coagulants.

Parameters	Value Range			
		Treated SDW		
	SDW	PAC	$FeSO_4$	$KAl(SO_4)_2 \cdot 12H_2O$
pH	6.3–6.8	5.4	4.7	4.5
COD (mg/L)	3900	1200	1305	1410
Total solids (mg/L)	3090	1930	2160	1970
Turbidity (NTU)	1744	1.6	0.8	1.0
Conductivity (μs/cm)	220	500	749	525
Chloride (mg/L)	31	46.94	19.9	22.96
Total N (mg/L)	113.18	8.7	8.27	9.29