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Studies on Minimization of Pollutants from Sugar Industry Effluent by Using a Combination of Metal Coagulant and Polymer

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ABSTRACT

World is facing lot of health issues due to industrial wastewater pollution. Increasing population and industrialization are one of the main causes of water pollution. In general, industrial wastewater contains suspended, colloidal and dissolved impurities. Industrial effluent may be either excessively acidic or alkaline and may contain high concentration of coloured matter. In this study, coagulation-flocculation method has been used for minimization of contaminants from sugar industry effluent. Lime has been used in conjunction with poly diallyl dimethyl ammonium chloride (PDADMAC) for reduction of chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS) and turbidity. It could remove 97% turbidity, 92.8% TSS, 95.5% TDS and 90.5% COD from sugar industry wastewater. Scanning electron microscopy (SEM) studies were also performed to support the formation of flocs.

Keywords: Turbidity, Chemical oxygen demand, Total suspended solids, Total dissolved solids, Scanning electron microscopy.

INTRODUCTION

The wastewaters from different industries vary greatly in pollution strength. In general, industrial wastewater contains suspended, colloidal and dissolved solids. Industrial wastewater may be either excessively acidic or alkaline and may also contain high concentration of coloured matter. It is necessary to pre-treat the wastewater prior to its release in surface or ground water[1,2]. The types of waste present in industrial wastewater include total suspended solids (TSS), oil & grease, heavy metals, turbidity causing substances, soluble organic compounds, total dissolved solids (TDS), unwanted colour and pathogens[3,4].

Among all industries, sugar industries generate one of the most polluted water. India is largest sugar producing country globally that has vital role in India's economy. Sugar effluent is known to exhibit variable pH, high concentration of TSS, high temperature, high turbidity and high amount of COD and BOD values so there must be some treatment technology before final discharge to achieve the aesthetic and environmental standards[5,6]. This results in foul odour and production of H_2S gas leading to unsightly appearance. Further, suspended impurities block the drainages. If effluents are thrown directly in soil, it affects the plant growth and seed germination[7,8]. Some literature shows that sugar industry effluent adversely effects the germination of seeds[9]. The different sources of effluent discharge in the sugar industry are mill houses, process houses and boiler houses. Effluent generating from the mill house includes high quantities of TSS and oil & grease. Further, effluents coming out from process houses and boiler houses includes large quantities of turbidity, BOD and COD. Ultimately wastewater stored in the final effluent tank has large amounts of BOD, COD, TSS, turbidity and oil & grease. In this study, wastewater has been collected from final effluent tank.

Coagulation- flocculation is well established method enabling the removal of pollutants from different industrial effluent. It is one of the vital physico-chemical treatment steps in industrial wastewater utilized for reduction of TDS, COD, BOD, TSS[10-12]. Sugar industry effluent treatment method using ferrous sulphate, zinc sulphate, and lime has been reported extensively. But metal coagulants generate larger amount of sludge. So, utilization of polymer as a coagulant aid/ flocculants in conjunction with metal coagulant for removal of contaminants in wastewater has grown greatly. Advancements in research in terms of polymer chemistry have benefited greatly in minimizing pollution level of wastewater[13,14]. The objective of the present work is to reduce the pollutants level in sugar industry wastewater with the help of metal coagulant in conjunction with polymer namely poly diallyl dimethyl ammonium chloride (PDADMAC). PDADMAC is high charge density cationic polymer. As per literature, high charge density polymer is proven to be more successful as secondary coagulant in removal of pollutants from industrial wastewater[15-18].

METHODOLOGY

The sugar industry effluent was collected from Dhampur sugar mill, Dhampur, UP, India and preserved in refrigerator so that it can be used for longer time. After filtration, the physico-chemical properties of effluent have been determined. The physicochemical parameters such as pH, E.C, turbidity, TDS, and dissolved oxygen have been determined by standard methods by APHA[19]. The physico-chemical properties of sugar industry effluent have been tabulated in Table 1.

Table 1: Physico-chemical properties of sugar industry wastewater

Sr. No	Parameters	Unit	Values
1	Odour	-	Objectionable
2	Colour	-	Dark pale yellow
3	Turbidity	NTU	127
4	pH	-	5.8
5	TDS	mg/L	1110
6	TSS (at 104±1°C)	mg/L	112
7	E.C	mho	2.3
8	COD	mg/L	510
9	Total hardness	mg/L	885

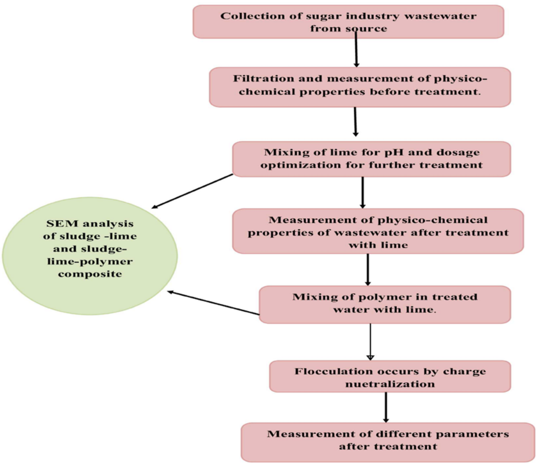
Optimization of pH with lime

A jar test apparatus (the Phipps and Bird six–paddle stirrer) along with illuminate base was selected for jar test with two lit square Plexiglas jars. All six jars were filled up with one lit of water and kept on each slot. Lime was added in all six jars at various dosages and agitated at 100 rpm for one minute. Further, the mixing speed was much reduced to 70 rpm for 8 min and then 50 rpm for another 8 minutes. After sedimentation for 30 min, the sample was taken from mid-depth of the jar, pH and other physico-chemical properties were determined. The pH of the water sample was found to be different at different dosages of lime as shown in Table 2. The main objective of this study was to investigate the coagulation efficiency of lime for sugar industry effluent and to determine optimum dosage of lime for further treatment of wastewater with polymer. The optimum dose of lime was chosen as 5 mg/L for further study.

The wastewater treated with 5 mg/L dosage of lime was further treated with PDADMAC. Polymer was taken in each jar at different doses and agitated at 100 rpm for one minute. Mixing speed was further reduced to 70 rpm for 10 min and then by 50 rpm for another 10 minutes. After sedimentation for 30 min, an aliquot of 10 mL sample from mid depth of the jar was collected. The residual turbidity, TSS, COD, colour and TDS were determined at different dosages. The effect of coagulant and coagulant aid was studied on the basis of percent reduction of turbidity, TSS, COD, BOD and oil & grease. The method of treatment of sugar industry effluent has been shown in Scheme 1.

Table 2: Effect of lime dosage on pH values of sugar water

Sr. No	Lime Dosage (mg/L)	pH Value
1	2	8.6
2	5	9.5
3	10	10.5
4	15	11.2
5	20	11.8



Scheme 1. Flow chart showing different steps adopted for the treatment of sugar Industry wastewater

Scanning Electron Microscopy (SEM) analysis

Using a Jeol (Japan) JSM 6510Lv SEM apparatus operating at a 15 kV accelerating voltage, materials were imaged using SEM. Using a typical SEM, a 1 cm to 5 μ area can be scanned with a 50–100 nm spatial resolution. In SEM, a concentrated beam of electrons interaction occurs with the specimen and creates images of the adsorbent's surface that reveal the sample's topography.

RESULTS AND DISCUSSION

Basic Characteristics of Effluent

The quality of sugar industry effluent was analyzed. It was having bad smell and was dark pale yellow in colour. Water pH was slightly acidic in nature. The high value of TSS, turbidity, TDS, COD and BOD values indicated that it was highly contaminated. Addition of coagulant and coagulation aid involves destabilization of particulate matter present in wastewater followed by collision of particle and flocs formation which results in sedimentation.

Effect of lime

Lime has been used here as an auxiliary coagulant. The optimum dose of lime was found to be as 5 mg/L. Lime has been chosen as a inorganic coagulant as it not only reduce pollutant level in wastewater but simultaneously it also helps in pH adjustment. So no other chemicals are required for pH adjustment for further study. The basic nature of lime affects pH values of treated water. At the dosage of 5 mg/L, the pH range is 9.5 which is best suited for further study. As per literature, at a higher pH value (more than 10), polymers are not found to work efficiently as high pH values diminish the flocs growth[21]. Zeta potential is also adversely affected by high pH value of wastewater. That's why dosage of 5 mg/L of lime has been chosen here.

Although the foul odour was still present in water, but lime was able to remove 48.00% turbidity, 38% TSS, 29% COD and 25% TDS from the wastewater. However, achieved values of turbidity, COD, TDS and TSS in coagulated wastewater with lime still exceeded the discharge limits; so, it was necessary to further treat the water with polymer in order to obtain the result within desired range.

Effect of polymer in sugar industry effluent

Lime was found to be promising coagulant in minimizing solids, and nutrient loads in sugar.

In order to further decrease the turbidity, COD, TDS and TSS in wastewater, PDADMAC worked efficiently as a coagulant aid. Result obtained during treatment studies exhibited the good efficiency of PDADMAC for reduction in turbidity and contaminants removal from sugar industry wastewater. There was an improvement in flocculation size when PDADMAC was exploited as a coagulant aid in conjunction with lime.

The use of PDADMAC as a coagulant aid in flocculation process and residual turbidity drops to 4 NTU. PDADMAC is polymer with high cationic charge and molecular weight. Molecular weight and charge density play an important role in charge neutralization. Higher the molecular weight and charge density, more effective is the charge neutralization. Performance of PDADMAC polymer was recorded for turbidity removal. The residual turbidity along with dosage of polymer has been in shown in Fig. 1(a). PDADMAC has been able to remove 97% turbidity at polymer dosage of 10 mg/L from sugar wastewater.

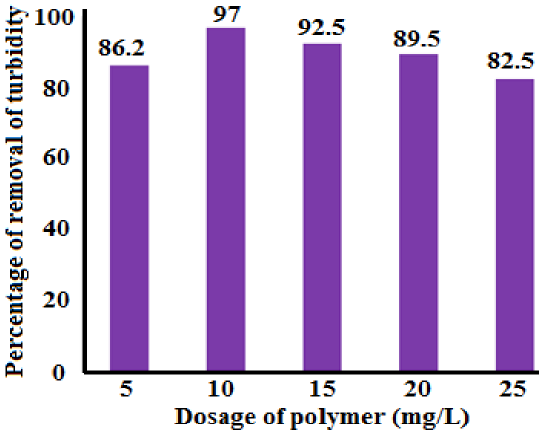


Fig. 1(a). Removal percentage of turbidity at different doses of PDADMAC

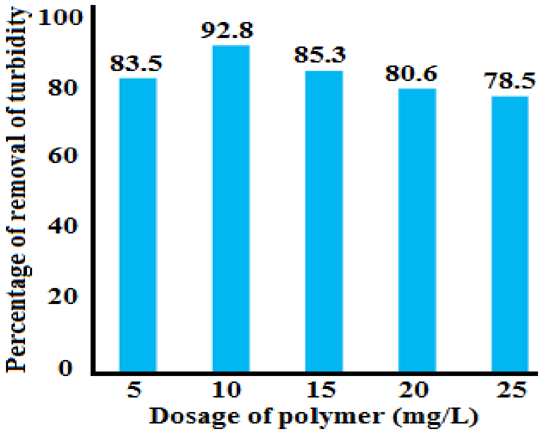


Fig. 1(b). Removal percentage of TSS at different doses of PDADMAC

To remove the TSS, it generally requires a polymer which should have good coagulating and flocculating capabilities. PDADMAC could show significant effects as a flocculant in removal of TSS. Maximum efficiency for the removal of TSS was found at the dosage of 10 mg/L. However, Fig. 1(b) shows the percent removal of TSS at different doses of PDADMAC.

The result shows that charge density is significant parameter in the removal of TSS and turbidity. Suspended and colloidal particles are negatively charged, so on addition of cationic polymer, charge neutralization occurs[20]. The colloids and suspended particles agglomerate due to force of attraction between them and results into charge neutralization.

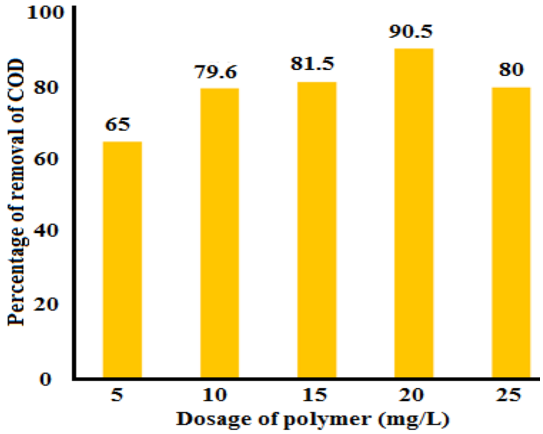


Fig. 2(a). Removal percentage of COD at different doses of PDADMAC

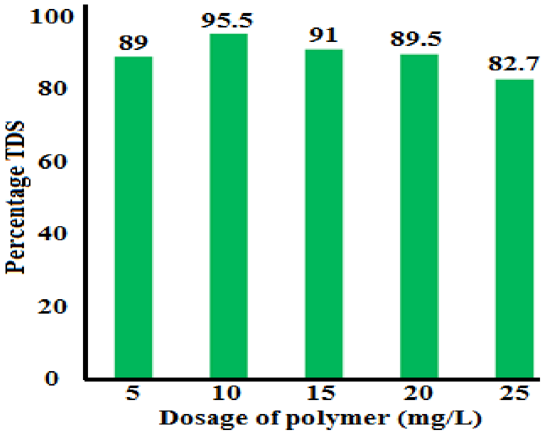


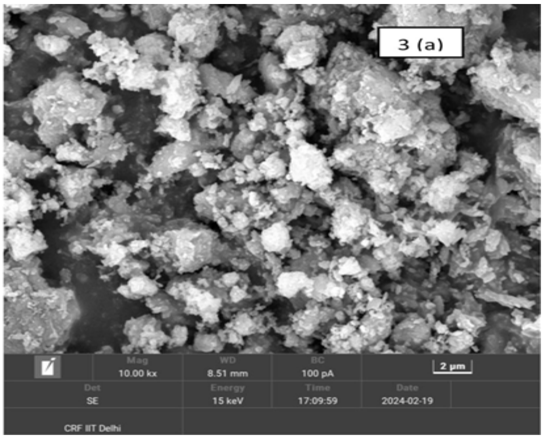
Fig. 2(b). Removal percentage of TDS at different doses of PDADMAC

Maximum removal efficiency of COD with PDADMAC was found to be 90.5% at 20 mg/L dosage as shown in Fig. 2(a). It can be seen from the result that initial load of COD increased the dosage of PDADMAC. It may be because higher dosage of polymer is required to remove the heavy chemical load. Result obtained in the lab studies showed that PDADMAC produces appreciable reduction in TDS; the best dosage of PDADMAC was 10 mg/L in removal of TDS as shown in Figure 2(b).

After jar test, the pH value of treated water got changed by about ± 0.1. The use of PDADMAC as a coagulant aid in flocculation process dropped the impurities below the standard level. So, on the basis of present study, it can be concluded that PDAMAC is efficient polymer in removal of turbidity and other contaminants from sugar industry wastewater. There was an improvement in flocculation size when PDADMAC was used as a coagulant aid in conjunction with lime as compared to lime alone. The pH of the solution was a critical factor in flocculation process. It has been concluded from current study that PDADMAC in conjunction with lime is very effective in the pH range of 9.5. The colour and odour has also been completely eliminated in sugar waste by the use of PDADMAC polymer.

Scanning electron microscopy (SEM) analysis

SEM studies of sludge along with lime and sludge along with lime in conjunction with PDADMAC has been analyzed. In order to explore the affect of metal coagulant only on sludge was analyzed at 10KX (Fig. 3a) magnification scale. Similarly, sludge with lime in conjunction with PDADMAC was studied at same magnification scale of 10KX (Fig. 3(b)). Fig. 3(a) shows that the particles are smaller in size and unevenly arranged at the surface. These unadjusted spaces could be observed on its surface without any uniform consistency. However, the micrograph in Fig. 3(b) shows the strong bond among sludge, lime and polymer. It confirms the formation of smooth and denser floc during the process. In addition, the adsorption and charge neutralization converts the destabilized particles into larger aggregates and flocs.



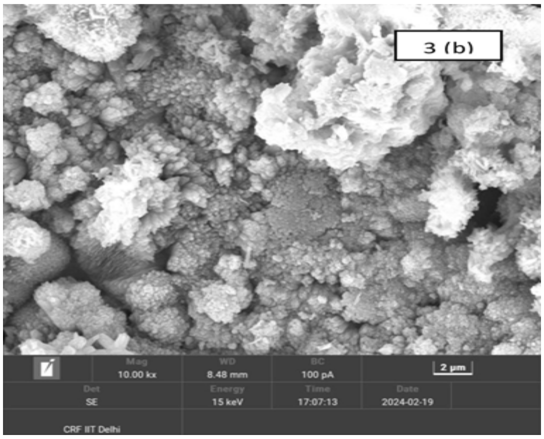


Fig. 3(a). Scanning electron micrographs of sludge-lime; 3(b). Scanning electron micrographs of sludge-lime-polymer composite

CONCLUSION

PDADMAC in combination with lime can be successfully used for treatment of wastewater from sugar industry. Performance of PDADMAC and lime is pH dependent. The experiment results showed that lime has efficiently worked as an auxiliary coagulant and not only helped to get the best pH range for the use of polymer but also decreased the organic load of sugar industry effluent. The results further indicated that polymer in combination with lime removed 97% turbidity, 92.8% TSS and 95.5% TDS, and 90.5% COD. Overall results indicate that it is an efficient approach for reducing pollutants level in sugar industry wastewater. SEM analysis confirmed that treatment with lime and polymer form dense flocs by charge neutralization technique and helps in purification of water.

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Conflict of interest

The author declare that we have no conflict of interest.

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