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# Composite wastewater treatment by aerated electrocoagulation and modified peroxi-coagulation processes

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## HIGHLIGHTS

- Electrochemical treatment of composite wastewater.
- Enhanced performance of electrocoagulation with external aeration.
- Superior performance of modified peroxi-coagulation process than aerated electrocoagulation process.
- Active chlorine generation is irrespective of process and pH.
- Hydroxyl radicals are superior oxidant responsible for pollutant removal.

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## ABSTRACT

Treatment of composite wastewater generating from the industrial estates is a great challenge. The present study examines the applicability of aerated electrocoagulation and modified peroxi-coagulation processes for removing color and COD from composite wastewater. Iron plates were used as anodes and cathodes in both electrochemical processes and experiments were carried out in a working volume of 2 L. Aeration enhanced the efficiency of electrocoagulation process significantly. More than 50% of COD and 60% of color were removed after 1 h of electrocoagulation process operated at pH 3 and applied voltage of 1 V. Efficiency of the modified peroxi-coagulation process was significantly higher than that of aerated electrocoagulation. COD and color removal efficiencies of the modified peroxi-coagulation process were found as 77.7% and 97%, respectively after 1 h of electrolysis operated at 1 V, solution pH 3 and 50 mM hydrogen peroxide addition. This improved efficiency of modified peroxi-coagulation compared to aerated electrocoagulation is mainly due to the attack of in-situ generated hydroxyl radicals.



## 1. Introduction

Small and medium-sized industries play a vital role in the economic growth and development of every country. It is reported that more than 300000 of small-scale industries are spread all over India and most of these industries are situated in 867 industrial estates (CPCB, 2005). It is estimated that small and medium scale industries are responsible for generating about 50% of industrial wastewater in India (Singh et al., 2008). Wastewater generated from these industries contains a variety of pollutants and should be treated before its discharge into natural waterbodies. Lack of operational space, technical manpower, scale of operation, budget etc. are the main challenges to operate individual wastewater treatment plant for each industrial units. To solve these problems and to protect our environment, Ministry of Environment and Forest, India introduced the concept of common effluent treatment plant (CETP) in 1984 (Pathe et al., 2004). The concept of CETP is to collect effluent generated from different industries and treat them at a common treatment system (Kapley et al., 2007). Effluent generated from each industry transported via tankers or pipeline to the equalization tank of CETPs. This system is similar to a municipal sewage treatment plant system where sewage generating from individual houses is treating in a common treatment plant. CETPs can be planned in such a way that there will be no issue of space in future expansion. Implementation of CETPs reduces the effluent treatment cost for individual industries significantly (Pophali and Dhodapkar, 2011; Singh et al., 2008). CETP eliminates several

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effluent discharge points and provide a better platform for the effective management of treated effluent and generated sludge.

CETPs can be divided into homogeneous and heterogeneous CETPs, based on the types of industries from which CETPs receiving the effluents. Homogenous CETPs receives effluents from a similar type of industries, while heterogeneous CETPs receive effluents from various types of industries such as textile, tanneries, pharmaceutical, chemical etc. Wastewater treatment in heterogeneous CETPs is quite difficult as compared to that in homogenous CETPs. The quantity and quality of wastewater receiving at heterogeneous CETPs are highly fluctuating than homogenous CETPs. Thus treatment of composite wastewater (mixed industrial wastewater) is a great challenge.

Central Pollution Control Board, India (CPCB, 2005) examined the performance of 78 CETPs operating in India and found that only 20 CETPs are meeting effluent discharge standards for the parameters pH, BOD, COD, and TSS. Only 5 CETPs out of 78 CETPs were meeting parameters including TDS (CPCB, 2005). This poor performance of CETPs is mainly due to the heterogeneous nature of wastewater. Most of the CETPs were designed by extrapolating sewage treatment plant design assumptions. Wastewater receives in STPs are homogeneous in nature, while the inlet wastewater characteristics of CETPs varies with the type of industries and industrial process. More often the industrial effluents contain toxic compounds which retard the performance of secondary treatment system (Roshini et al., 2017). Apart from all, most of the organic compounds present in industrial wastewater are non-biodegradable.

Electrochemical water and wastewater treatment methods have received great attention due to its simplicity, efficiency, lower operating cost compared to other treatment processes etc. (Brillas et al., 2009; Brillas and Martínez-Huitle, 2015; Martínez-Huitle et al., 2015; Nidheesh and Gandhimathi, 2012; Vasudevan and Oturan, 2014). Electrochemical treatment methods such as electrocoagulation (Shankar et al., 2014), electrochemical oxidation (Bhatnagar et al., 2014), anodic oxidation (Panizza and Cerisola, 2006), electro-Fenton process (Nidheesh and Gandhimathi, 2015; Roshini et al., 2017), peroxi-coagulation process (Nidheesh and Gandhimathi, 2014a), etc. are found very effective for the treatment of various industrial wastewater. Higher dissolved solid concentration present in the industrial wastewater is also helpful for the performance of electrochemical methods. The present study examines the performance of two electrochemical processes, namely aerated electrocoagulation process and modified peroxi-coagulation process for the treatment of composite wastewater. Efficiency of the processes was monitored in terms of color and COD removal.

## 2. Materials and methods

### 2.1. Chemicals

Sulphuric acid (98% pure), sodium hydroxide and hydrogen peroxide (30% pure) were purchased from Merck and used for the experiments without further purification or treatment. Deionized water was used for reagent preparation.

### 2.2. Composite wastewater

Composite wastewater was collected from the inlet point of a heterogeneous common effluent treatment plant situated in Gujarat, India. This composite wastewater contains effluents from various chemical industries, textile industries etc. Sufficient amount of wastewater was collected (without any filtration) in plastic containers and stored in the laboratory for experiments. Characteristics of wastewater were analyzed as per standard methods (APHA, 2012) and the results are given in Table 1.

### 2.3. Experimental setup and procedure

Rectangular tank constructed of acrylic sheet with dimensions 20 cm × 10 cm x 12 cm was used for the entire experiments. The working volume of 2 L was used for the experiments. Commercially available iron plates of size 5 cm × 8 cm x 1.2 mm were used as anode and cathode. Initially 2 L of industrial waste was poured into the reactor and the electrodes were dipped into the solution. A total of 5 cathodes and 5 anodes were arranged vertically and in parallel with a clear electrode spacing of 1 cm. Wet electrode area per electrode is kept constant at 25 $cm^2$. These electrodes were connected to a DC power supply (Jayam Electronics, India) in a monopolar manner. All the experiments were conducted by keeping applied voltage as constant. The solution was aerated using 2 numbers of aquatic aerator, purchased from the local market. Experiments were run in batch mode and samples of electrochemically treated wastewater were collected at the end of 5, 10, 15, 20, 30, 45 and 60 min. COD and color removal was considered as two main wastewater quality parameters to evaluate the performance of the electrochemical processes. COD of the samples were analyzed as per standard method using potassium dichromate as oxidant and in closed reflux method (APHA, 2012). Absorbance at 500 nm was measured using UV visible spectrophotometer (LT-290, Labtronics, India) and used for finding reduction in color. COD removal efficiency of the electrochemical process was expressed in percentage. Color removal was expressed as a ratio $C_t/C_0$, where $C_t$ is the absorbance of treated wastewater at time t and $C_0$ is the initial absorbance of wastewater. Preliminary experiments were carried out at without changing the solution pH. Further, effect of pH on the electrochemical process was carried out by changing the pH of industrial wastewater to the required level using 4 M sulphuric acid and 4 M sodium hydroxide. Prior to the experiments, electrode was cleaned using 2 M sulphuric acid followed by distilled water cleaning. This process removes rust and other impurities present on the electrodes surface.

## 3. Results and discussions

### 3.1. Composite wastewater treatment by aerated electrocoagulation

Electrocoagulation process is widely accepted electrochemical process in which pollutants are removed from the water medium by in-situ generated hydrolyzable metal cations (Anantha Singh and Ramesh, 2013; Nidheesh and Singh, 2017; Vasudevan and Oturan, 2014). This process is found highly effective for removing

**Table 1**
Characteristics of composite wastewater.

| No. | Parameter | Value |
|---|---|---|
| 1. | Solution pH | 7.7 |
| 2. | Electrical Conductivity | 18.26 mS $cm^{-1}$ |
| 3. | Total Dissolved Solids | 18920 mg $L^{-1}$ |
| 4. | Total Alkalinity | 2200 mg $L^{-1}$ as $CaCO_3$ |
| 5. | Total Hardness | 2000 mg $L^{-1}$ as $CaCO_3$ |
| 6. | Chloride | 9017.2 mg $L^{-1}$ |
| 7. | Nitrate | 26.1 mg $L^{-1}$ |
| 8. | Sulphate | 374.2 mg $L^{-1}$ |
| 9. | Potassium | 110.5 mg $L^{-1}$ |
| 10. | Sodium | 4499 mg $L^{-1}$ |
| 11. | Calcium | 1280 mg $L^{-1}$ |
| 12. | Magnesium | 720 mg $L^{-1}$ |
| 13. | Chemical Oxygen Demand | 1727 mg $L^{-1}$ |