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Optimization of Electrooxidation Process for the Treatment of Acid Yellow 36 Using Graphite Electrode

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This study aimed to optimize electrooxidation process for the degradation of textile dye Acid Yellow 36 (AY 36) in waste water using graphite electrodes. The waste water was synthetically prepared and experiments were designed as the function of variables such as pH and electrolysis time. Graphite electrode was used for all the experiments and current density was fixed at 2.5 mAcm^2. Electrolyte (NaCl) concentration was kept at 0.1 M, after the electrooxidation process degradation efficiency of AY 36 were analyzed through analytical parameters such as colour and chemical oxygen demand (COD). The results confirmed that the electrooxidation process could efficiently remove colour and COD from the Acid Yellow 36 (AY 36) contaminated waste water.

Key words: Electrooxidation, Acid Yellow 36, Graphite electrode, COD, Colour removal.

Synthetic dyes are widely used in many industries, such as textile, cosmetic, printing, drug, and food processing (Zeng *et al.,* 2009). Synthetic dyes constitute one of the largest groups of organic compounds that represent an increasing environmental danger (Wang *et al.*, 2008). The world annual production of synthetic dyes is estimated at more than 80,000 tons, used mainly in food industries, cosmetics, paper mills and especially, in textile industries which constitute more than 70% of the total quantity produced. The intense use of synthetic dyes in these industries generates sources of considerable pollution to the environment. Indeed, 10 to 15% of the quantity of dyes used is rejected into the natural environment. These dyes represent a potential danger to both human and environment due to their toxicity (Maghri *et al.*, 2012). Decolouration of effluent is a well-known technical solution and therefore much research has been devoted to findout an effective treatment capable of solving this problem. Physical and chemical methods such as coagulation, electrocoagulation, flocculation, adsorption, Fenton's process, ozonation and combined processes have demonstrated to be effective (Choo *et al.*, 2008; Muthukumar *et al.*, 2007; Arslan Alaton and Seremet 2004; Perez *et al.*, 2002; Sevimli and Sarikaya 2002 and Walker and Weatherley, 2000). However, some of these methods present important drawbacks as sludge, high investment, elevated operational costs or pollution from residual compounds (Rodriguez *et al.*, 2009). As an alternative, electrochemical oxidation appears to be a promising method to solve the environmental problems caused by discharge of dye effluents. In this, graphite has been frequently used as an anode for the electrochemical degradation of textile waste water as it is relatively cheaper and gives satisfactory results (El Ashtoukhy *et al.*, 2012). Hence, this work investigates the decolourization of aqueous Acid Yellow 36 (AY 36) solution using graphite electrodes in the electrooxidation process. Experiments were conducted to investigate the influence of operational parameters on the efficiency of electrochemical oxidation process.

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Materials and Methods

Commercial dye AY36 was obtained from Atul Ltd., Gujarat (India) and used without further purification. Other chemicals used in the experiments were analytical grade. AY 36 solution at 1M was prepared using distilled water (Jie Ful *et al.,* 2010). The electrolyte (NaCl) concentration was fixed at 0.1 M. The pH of the reaction solution was adjusted using 1 mol L^{-1} H_2SO_4 and 1 mol L^{-1} NaOH (Papiae *et al.,* 2010). Figure 1 shows the experimental setup used for this study and Figure 2 shows molecular structure of Acid Yellow 36. The electrochemical reactor having the size of 7 cm × 7.1 cm made of glass to hold 500 ml of the sample was used. Two groups of alternating electrodes being cathodes and anodes (two plates of each group) were arranged vertically. The anode and cathodes were graphite sheets supplied by M/S Carbone Lorraine, India had a surface area of 100 cm^2. Distances between any paired anode and cathode were taken equal to 1 cm to minimize the ohmic losses. The anode and cathode were connected to a copper cable from the top of the graphite sheets and connected to the terminals of a direct current power supply, characterized by the ranges 0–30V/AC-DC/10A. All experiments were conducted at room temperature (Orathai Chavalparit and Maneerat Ongwandee 2009). The process efficiency was measured in terms of the following parameters: pH, colour removal, and Chemical Oxygen Demand (COD), which were measured by the procedure described in APHA (1995).

Results and Discussion

Effect of pH on colour removal

The pH of a solution strongly influences the process of electrooxidation; in fact, in acid media (<2) the main active species is Cl_2, in neutral media HClO is the active species and in alkaline media (>11) the active species is ClO^-. All the species have different oxidation potential. In order to study the effect of pH on degradation process and colour removal

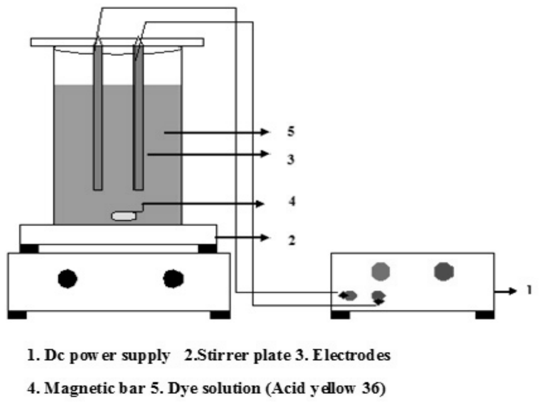

Fig. 1. Experimental setup used

of Acid Yellow 36, studies were conducted at different pH from 3 to 11 (3, 5, 7, 9 and11), under the conditions: sample (Acid Yellow 36) concentration was 1 M, current density of 2.5 mAcm^{-2}, electrolyte (NaCl) concentration of 0.1 M and treatment time of 60 min. The results obtained from this study is shown in Figure 3. At pH 3, the removal started at 5

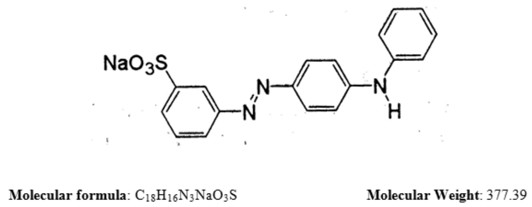

Fig. 2. Molecular structure of Acid Yellow 36

min and it did not achieve 100% removal at 60 min; whereas, at pH 11, the removal started only after 10 min and the 100% removal was obtained at 60 min. Since the oxidizing agents *viz*., HClO, OCl^-, H_2O_2, HO_2, O_2, OHÚ, generated during the electrochemical oxidation process are known to cause the breakage of chromophore or functional groups, the results of present study showed continuous discolouration.

Effect of time on colour removal

The effect of time on colour removal of Acid yellow 36 was explored when the current density was kept at 25mAcm^{-2}. Based on the above study, pH of the dye (Acid yellow) solution was adjusted to 3 and electrolyte (NaCl) concentration to 0.1M. The results

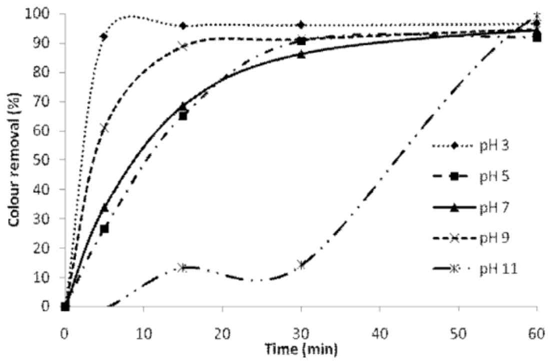

Fig. 3. Effect of pH on colour removal of Acid Yellow 36

are presented in Figure 4. From the results, it is apparent that the colour removal was complete at the treatment time of 60 min. The rate of decolouration was observed to be very fast,

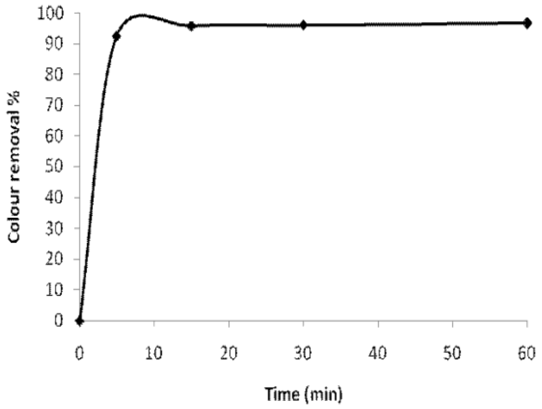

Fig. 4. Effect of colour removal on treatment time of Acid Yellow 36

particularly in the initial stages within 5 min. and 90% colour removal was reached within 30 min. Decolouration (100%) was complete at 60 min confirming that increased colour removal was obtained by increasing treatment time. The results proved that the electrochemical oxidation process

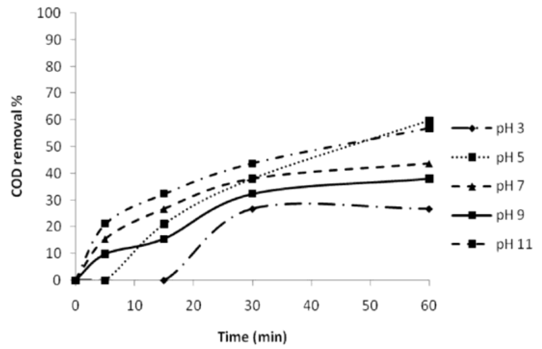

Fig. 5. Effect of initial pH on COD removal of Acid Yellow 36

was very effective to remove colour from Acid Yellow 36 within an hour.

Effect of pH on COD removal

The effect of pH on COD removal of Acid Yellow 36 by electrooxidation method using graphite electrodes was analyzed by varying the pH between

3 and 11. The experiment was carried out with the dye sample concentration of 1M (Acid Yellow), electrolyte concentration of 0.1M, by applying the current density of 2.5mA/cm^2 and treatment time of 60 min. The observed results are presented in Figure 5. The reaction is less in alkaline solution due to OH^- instability and considerably more in acidic solution due to formation of HOCl ion, which is more favorable for conducting reactions involving Cl_2. The results obtained shows 60% COD removal could be achieved at pH 5.

Effect of time on COD removal

Even though the colour was removed completely within an hour, the COD removal was only 60%. In

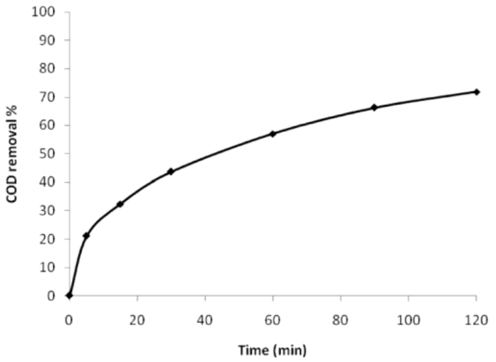

Fig. 6. Effect of COD removal at pH 5 of Acid Yellow 36

order to increase the COD removal, the treatment time was increased from 0 to 120 min, indicating that AY 36 removal was directly proportional to time. However, it is interesting to observe that at the high initial concentration and at the beginning of the electrolysis, the COD decreased linearly with the specific charge and under such conditions the oxidation of AY36 was controlled by the rate at which electrons were delivered at the anode. This indicates that the electrolysis was performed at a current below the limiting one. The observed results are presented in Figure 6. Obviously the maximum COD removal (92%) was obtained at 120 min of process at pH 5 which shows that the increasing treatment time does influence the removal of COD.

Conclusion

This study demonstrates that electrooxidation of acid dye AY 36 using a batch reactor with graphite electrodes in the presence of sodium chloride as an electrolyte. The effect of operating variables such as pH and treatment time was optimized. The optimum conditions were found to be pH 5, with the concentration of NaCl at 0.1M. The optimized electrolysis time was 60 min and the current density at 2.5 mA cm-$^{-2}$. When comparing alkaline (9.0) and neutral pH (7), acidic pH (5) required less time for complete decolourization. The electrolysis time and concentration of electrolyte indicated significant effect. The highest colour and COD removal was achieved at 92% and 62%, within 30 to 120 min at pH 5. These results proved that anodic oxidation with graphite electrode constitutes an excellent method for the treatment of effluents contaminated with AY 36.

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