

Degradation of Rhodamine B Dye Solution by Photoelectrocoagulation Treatment Techniques

K. VIJAYAKUMAR¹, S. GEETHA¹ and M. GOVINDARAJ^{2,*}

¹Department of Chemistry, M. Kumarasamy College of Engineering (Autonomous), Karur-639113, India

²Department of Chemistry, Thanthai Hans Roever College, Perambalur-621212, India

*Corresponding author: Tel: +91 4324 272155; E-mail: mgrajchemist@gmail.com

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Photoelectrocoagulation treatment of aqueous solution containing, rhodamine B has been studied. Three different supporting electrolytes such as NaCl, NaNO₃ and Na₂SO₄ were used for electrolysis. Only NaCl was found to be effective for the removal of colour from rhodamine B dye. Effects of the process variables such as pH, applied current density, electrode material, supporting electrolytes types, different concentration of electrolyte and treatment time were explored in order to find the best conditions for the degradation of rhodamine B. The complete degradation was obtained in 35 min of operating time for Fe electrode at optimum conditions such as initial pH 7.0, supporting electrolyte of 0.05 M NaCl and applied current density of 10 mA/cm² and treatment time of 35 min. Sludge characterization was analyzed by FT-IR spectra and the morphology of sludge was characterized by SEM were discussed. The SEM image confirmed the characteristics of phases, which are amorphous or poorly crystalline in nature.

Keywords: Photoelectrocoagulation, Rhodamine B, Combined aluminum, Iron electrodes, Colour removal.

INTRODUCTION

Water contamination by colours is one of the real issues confronting around the world. Effluents from ventures like material, paper and mash, cowhide, plastics and nourishment contain various types of engineered colours. Around 12 % of engineered material colours utilized every year is lost amid make and handling operation and 20 % of these colours enter the earth through effluents that outcome from the treatment of leftover mechanical waters. The release of these effluents into characteristic water bodies is tastefully disappointing and it additionally hinders light entrance that adversely influences the organic procedures inside a stream [1]. Subsequently, expulsion of colours from fluid arrangement turns out to be ecologically essential. Because of their manufactured birthplaces and aromatic structures, which are organically non-degradable, it is difficult to treat colour effluents.

Rhodamine B (RhB) is a planned essential colour granting red shading in fluid arrangement. At first it was utilized as a colourant in materials and as a water tracer fluorescent. Rhodamine B is highly toxic if gulped by individuals and creatures

and makes bothering the skin, eyes and respiratory tract. Rhodamine B is a fundamental colour because of their high tectorial esteem are the brightest class of water solvent colours, which is generally utilized as a colourant in materials and sustenance materials and as organic stains in biochemical research facilities at high fixations [2]. The cancer causing nature, conceptive and formative lethality, neurotoxicity and endless poisonous quality of rhodamine B towards people and creatures have been accounted for. Therefore, a powerful and sparing system for expelling rhodamine B colour from wastewaters is required [3,4]. In any case, no report available in literature for the treatment of rhodamine B from wastewater utilizing photoelectrocoagulation strategy.

Ordinarily connected treatment techniques for shading expulsion from colour debased effluents comprise of different procedures including physical, synthetic and organic decolourization strategies. Today, there is a critical need to develop more productive and low cost method for treatment of wastewaters. As of late, propelled oxidation forms and electrochemical strategies have been produced to treat the contaminants present in drinking water and mechanical effluents [4]. In the course

of recent decades there has been developing enthusiasm for the utilization of electrochemical strategy, for example, electrocoagulation, electroflotation and electrooxidation for the successful treatment of natural contaminations. Electrocoagulation is a complicated procedure with a large number of instrument working synergistically to expel the toxins in wastewaters. It offers the likelihood of anodic oxidation and *in situ* age of dynamic adsorbents, (for example, hydrous ferric oxides and hydroxides of aluminum). In the meantime, cathodic responses happen and the development of hydrogen gas is included, causing buoyancy of the sponges [5,6]. The electrocoagulation procedure has been effectively used to treat an assortment of mechanical wastewaters and in addition particular inorganic and natural toxins [7].

In the previous years, few trials have been completed to remove shading from wastewater by photoelectrocoagulation [5,8]. The exhibitions of UV in electrocoagulation cell (photoelectrocoagulation) for shading expulsion from rhodamine B dye from watery arrangement were not assessed. Just a not very many reports on the joined utilization of both Fe and Al terminals in a similar cell has been accounted for Farhadi *et al.* [5] and Govindaraj *et al.* [6]. In this investigation, Fe and Al anodes helped with UV light illumination was utilized as a part of all trials. The motivation behind this examination was to research the decolourization of rhodamine B by the photoelectrocoagulation procedure. The operational factors, for example, connected current thickness, electrolysis time, beginning pH, colour fixation, electrolyte sort and electrolyte focus, were examined.

EXPERIMENTAL

Preparation of rhodamine B colour wastewater: In the present study, dye stock arrangement of 1000 mg L⁻¹ was prepared by dissolving rhodamine B colour (Merk Chem, Mumbai, India), with twofold refined water. The colour working arrangement centralization of 50 mg L⁻¹ was set up by dissolving the colour stock arrangement into refined water and included fitting measure of supporting electrolyte. The pH of the engineered wastewater was balanced by 0.1 M hydrochloric corrosive or 0.1 M sodium hydroxide (Merck, India) and measured by an Elico pH meter (India). The conductivity of arrangements was raised and changed in accordance with various esteems by the expansion of NaCl. Every one of the examinations were completed in copy and at encompassing temperature.

Photoelectrocoagulation reactor: The photoelectrocoagulation tests were performed in a 750 mL photoelectrochemical reactor furnished with UV light with a quartz jacketed 15 W inundation low weight mercury bend light (Philips, show TUV) as illumination at 254 nm source and anode get together inside a solitary compartment round and hollow glass cell. The reactor is associated with a cooling water course shower for controlling temperature at 27 ± 2 °C. In the highest point of the reactor there is an arrangement for holding the UV light, cathodes, gas outlet and thermometer. An interior light source encompassed by a quartz coat and the light source is UV light [8].

Metallic Al and Fe plates (98 % purity) each with breadth 3.8 cm and length 12.5 cm and it's thickness of 0.8 cm was

used as electrodes for photoelectrocoagulation. The gaps between the plates were maintained at 7 mm to minimize the ohm losses. An active total anodic surface area of Fe or Al plates was 102 cm². The solution was stirred at 200 rpm using magnetic stirrer. Electric power was supplied by a regulated DC power supply was obtained from M/s Mighty Electronics Equipments Corporation Pvt. Ltd., Coimbatore, India. A set of four electrodes (two for anode and two for cathode) are alternatively looped internally [4]. The UV lamp and electrodes are connected to the respective terminals of the power source.

Analytical procedure: In each experiment, 500 mL of synthetic wastewater containing 50 mg L⁻¹ rhodamine B dye solution and sodium chloride (as a supporting electrolyte) with desired concentration was used in a 0.75 L glass photoelectrochemical reactor. The anode and cathode leads were connected to the respective terminals of the DC rectifier and electric power was supplied by a stabilized power source equipped with digital ammeter and voltmeter. After adjusting the solution pH to the desired value, the applied current density, stirring speed at 200 rpm maintained to get homogeneous solution in the batch reactor. At different electrolysis times, 25 mL of treated solution was taken, settled for 30 min, filtered by membrane filter and colour intensity was measured at λ_{max} = 541 by using UV-visible spectrophotometer (Shimadzu UV-1700 spectrophotometer, Japan). Before and at the end of each run, electrode surfaces were thoroughly polished with emery paper and then washed with acetone, immersed for at least 5 min in dilute HCl solution and then washed with distilled water. After the experiment, the power was switched off and the electrodes were disconnected.

Analysis and calculations: The colour removal was chosen as a key parameter for evaluating the effect of electrochemical treatment process. Colour removal efficiency was determined according to eqn. 1:

$$\text{Colour removal efficiency (\%)} = \left(\frac{A_o - A}{A_o} \right) \times 100 \quad (1)$$

where, A_o and A are the light absorbance of dye before and after electrochemical treatment, respectively.

In this study, after photoelectrocoagulation was run for a certain period of time, the sludge that formed during the photoelectrocoagulation process was filtered and the precipitate was dried in a hot air oven and then ground to a fine powder and then analysis was carried out to confirm the nature of the sludge formed during the process.

RESULTS AND DISCUSSION

The photoelectrocoagulation process is affected by several operating parameters, such as initial pH, electrolyte type, electrolyte concentration, current density and treatment time. In the present work, Al and Fe were selected as the electrode material because of its low-cost value, ready availability, non-harmfulness and it requires comparatively less oxidation potential.

Effect of electrolyte: To study the effect of electrolyte on the colour removal of rhodamine B dye, the experiments were carried out in the presence of different conductive electrolytes such as NaCl, Na₂SO₄ and NaNO₃. Current density of 10 mA cm⁻², electrolyte concentration of 0.05 M and treatment

time of 30 min and at pH 7 were uniformly maintained during experiments. The results obtained from these experiments were shown in Fig. 1.

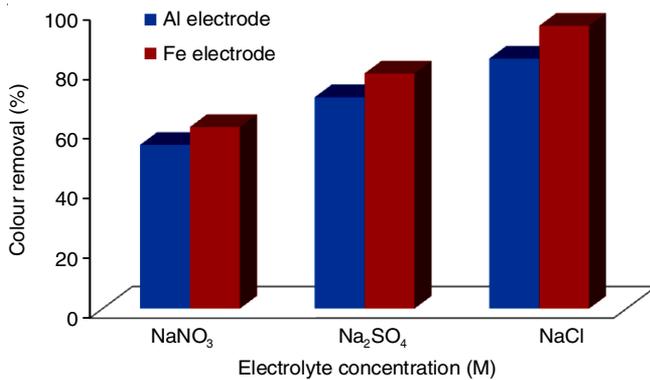


Fig. 1. Effect of electrolytes on colour removal

Conversely, the colour removal is very marginal in the presence of Na₂SO₄ and NaNO₃. However in the presence of chloride ion, the passivation is curtailed since the adsorbed chloride ion promotes the dissolution of iron [9]. Though nitrates generally accelerate the corrosion of iron in acidic solutions the effect is very marginal in neutral solutions. Sulfate ions have least influence on corrosion of iron compared to chlorides and nitrates. Thus it is evident that the chloride ion plays an important role in the anodic dissolution of iron. NaCl appears to be the most effective conductive electrolyte with a maximum colour removal efficiency of 84 and 95 % was observed for Al and Fe electrodes, respectively. The results in this study have indicated that NaCl is the best conductive electrolyte, among the studied electrolyte. Hence, NaCl was selected as the conductive electrolyte for rest of the experiments.

Effect of pH: The effect of initial pH has been explored at constant current density of 10 mA cm⁻² with an initial pH varying in the range between 3 and 11 and treatment time of 30 min for Fe and Al electrodes. The effect of initial pH on the colour removal percentages for Al and Fe electrodes were shown in Fig. 2.

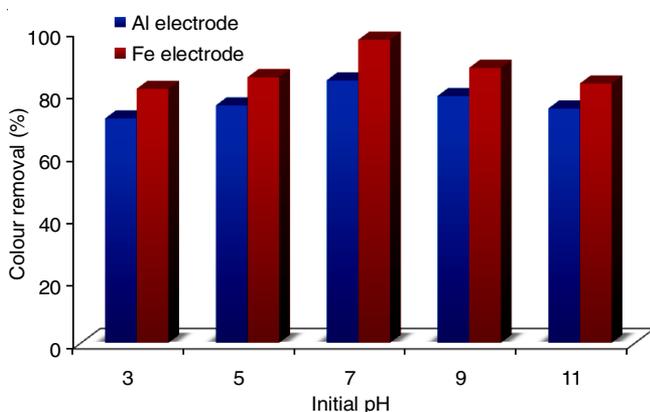


Fig. 2. Effect of initial pH on colour removal

The shading evacuation was increments with expanding pH from 3 to 7 and most extreme effectiveness was seen at nonpartisan pH (84 % for Al cathode and 97 % for Fe terminal)

at past that the productivity diminish. This can be clarified that the dissolvability of Fe(OH)₃ increments past the electrolyte at the pH estimation of 7 coming about arrangement of solvent Fe(OH)₄–which does not add to the COD lessening [10]. At acidic conditions, a lot of irons are as Fe²⁺, which is steady and solvent in squander, bringing about a lessened arrangement of coagulant and contamination evacuation [11]. On account of Fe anode, the most extreme shading evacuation of 97 % was seen at pH 7.

Impact of supporting electrolyte fixation: Arrangement conductivity increments as the supporting electrolyte fixation builds, so the present going through the circuit increments in the potentiostatic mode [12]. In light of preparatory trial comes about, the impact of supporting electrolyte focus has been investigated inside the scope of 0.025 M and 0.1 M. In this manner, keeping in mind the end goal to decide the impact of supporting electrolyte focus on the shading evacuation and the outcomes are exhibited in Fig. 3.

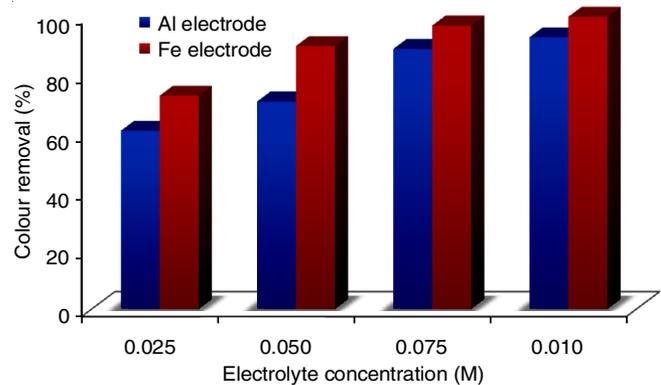


Fig. 3. Effect of different electrolyte concentration on colour removal

After 30 min of treatment, when the grouping of the supporting electrolyte expanded from 0.025 to 0.1 M, the shading expulsion effectiveness enhanced essentially from 61 to 93 %, utilizing Al terminal. In the other hand, expanded 73 to 100 % of shading expulsion was observed when Fe terminal utilized under the same exploratory conditions. It can be inferred that the most noteworthy expulsion rate are the point at which the direct centralization of supporting electrolyte of 0.05 M.

Impact of current thickness: In all photograph electrochemical procedures, the present thickness is a standout amongst the most imperative parameters by controlling the response rate inside the reactor. It is notable that the measure of current thickness decides the coagulant generation rate and modifies the rate and size of the air pocket creation and subsequently influences the development of flocs [13]. Trials were done by shifting connected current thickness at introductory pH 7 for both Fe terminal Al cathode. The outcomes acquired from this analysis were delineated in Fig. 4.

From the outcomes, the shading evacuation at various current thickness in the scope of 5-25 mA cm⁻² was expanded from 71 to 98 % for Fe cathode and from 56 to 92 % for Al terminal which demonstrating a higher current thickness caused a quicker shading expulsion. This was credited to the way that at high current densities, the degree of anodic disintegration of aluminum and iron expanded, bringing about a more

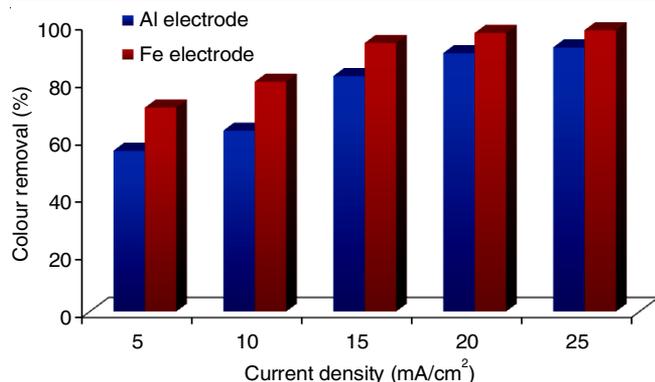


Fig. 4. Effect of current density on colour removal

noteworthy measure of encourage for the expulsion of toxins [14]. As a result the measure of Al or potentially Fe hydroxyl polymers accessible for adsorption of the rhodamine B colour particle likewise increments. The age of different oxidants, for example, O₂, O₃, H₂O₂ and dynamic chlorine species (Cl⁻, Cl₂, HClO and ClO⁻) and most likely different radicals, for example, Cl[•], Cl₂[•], ClO[•] and OH[•] amid the photoelectrocoagulation procedure may oxidize resorcinol from watery arrangement [8].

Impact of treatment time: Photoelectrocoagulation treatment productivity depends specifically on the convergence of particles delivered by the terminals, which thus relies on handling time. At the point when the estimation of time expands, an expansion happens in grouping of metal particles and their hydroxide flocs. Therefore, an expansion in the time expands the shading expulsion effectiveness [15]. The impact of working time was investigated when the present thickness was kept consistent at 10 mA/cm² and the pH 7.0 for both Fe anodes and Al terminals on shading evacuation of rhodamine B colour arrangement. The outcomes are presented in Fig. 5.

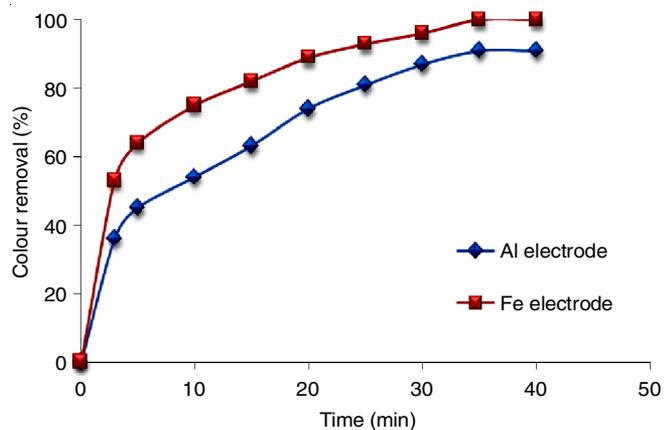


Fig. 5. Effect of treatment time on colour removal

As found in Fig. 5, the total shading expulsion was accomplished under Fe terminals at 35 min yet most extreme shading evacuation was accomplished upto 91 % for Al cathode at 40 min. The working time for Fe and Al cathodes in the electrocoagulation procedure were diverse since the persistent agglomeration of the flocs existed (changing of pH) in a shorter time for Al terminal than that of Fe anode, which in the end settled out from the wastewater.

SEM analysis in slime: SEM images gives data about the morphology of the flocks created by Fe terminals amid photoelectrocoagulation process. Fig. 6 demonstrates the Fe slime flocs made fundamentally out of Fe mixes with rhodamine B colour. From the SEM picture it was noticed that the ooze was crystalline in nature with 0.5 μm for Fe anode.

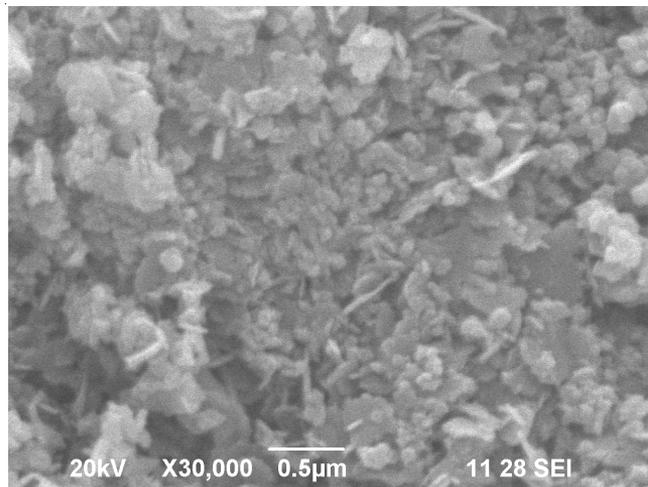


Fig. 6. SEM image for photoelectrocoagulated rhodamine B sludge

FT-IR: The slime framed amid electrocoagulation was investigated by FT-IR spectroscopic procedure to comprehend the idea of adsorption of rhodamine B colour and its coagulants on press hydroxide/oxyhydroxide. The FT-IR range of the slime created from conciliatory Fe anode without rhodamine B colour is displayed in Fig. 7. A solid and wide band around 3757 and 3425 cm⁻¹ showed by press oxy-hydroxide could be credited to extending vibration of -OH, hydroxyl twisting at 1851 and 1627 cm⁻¹. The band at 2924 cm⁻¹ compares to C-H extending vibration. It demonstrates that the rhodamine B colour coagulants result was exhibited on press hydroxide/oxyhydroxide ooze. The pinnacle saw at 2854 cm⁻¹ can be relegated to the -CH introduced in ooze. The band at 2376 cm⁻¹ relates to C-C extending vibration in aromatic rings.

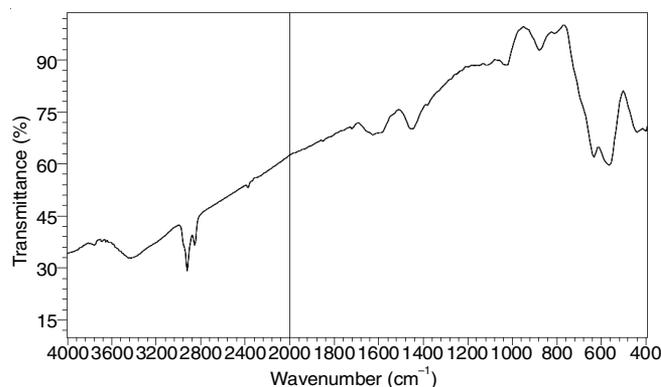


Fig. 7. FT-IR spectrum of sludge generated during photoelectrocoagulation

The bands at 2291 cm⁻¹ relates to C-C extending vibration in alkenes. The groups around 1653 cm⁻¹ compared to the bowing methods of the hints of hydroxyl twisting. A crest at 1458 cm⁻¹ for C=C, retention groups in the locale 1373 cm⁻¹

could be assigned to the C=C extending vibration in fragrant rings of rhodamine B particle. Band for lepidocrocite stage appeared at 1026 cm^{-1} and magnetite (Fe_3O_4 or $\text{Fe}_{3-x}\text{O}_4$) band appeared at 575 cm^{-1} as reported by Gomes *et al.* [16] demonstrated a solid likeness of the primary assimilation groups in different locales. From the above proof, it could be reasoned that rhodamine B colour is CO^- hastened with Fe either by adsorption or complex arrangement. From the FT-IR examines, it make conclusions with respect to the fractional pulverization of rhodamine B colour atoms amid photoelectrocoagulation.

Conclusion

The photoelectrocoagulation treatment of fluid arrangement containing rhodamine B colour has been explored under the few working conditions, for example, conductive electrolytes sorts, electrolyte focus, starting pH, current thickness and treatment time. The outcomes demonstrated that the shading expulsion increments with the expansion in current thickness and NaCl fixation. The most noteworthy shading evacuation was accomplished within the sight of NaCl (0.05 M) among the different conductive electrolytes. The pH was observed to be a vital parameter for the photoelectrocoagulation procedure, the most extreme of shading evacuation was seen at pH 7.0 for Fe anode. The finding of this examination demonstrates that an expansion in the present thickness and preparing time improved the shading expulsion proficiency. The entire shading evacuation was acquired in 35 min of working time for Fe terminal at ideal conditions, for example, beginning pH 7.0, supporting electrolyte of 0.05 M NaCl and connected current thickness of 10 mA/cm^2 and treatment time of 35 min. The X-ray diffraction of the by-product was affirmed normal for stages which are shapeless or ineffectively crystalline in nature. The age of different oxidants, dynamic chlorine species, oxidizing radicals amid the photoelectrocoagulation procedure may oxidize rhodamine B colour from fluid arrangement. The ooze shaped amid photoelectroncoagulation was portrayed by SEM examination and it's affirmed that picture is crystalline in nature. Slime portrayal was broke down by FT-IR spectra and the morphology of ooze was described by SEM were examined.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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