Electrochemical Decolourisation Of Reactive Dye Effluent Solution

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Abstract:

To evaluate the decolourisation efficiency of metals, platinised titanium, mild steel, aluminium, stainless steel and copper were used as anodes for decolourization of dye effluent solution. Declorization efficiency was calculated before decolorization and after decolorization. The result of this investigation study reveal that the % of decolorization efficiency of various anodes are in the following decreasing order.

.platinised titanium > copper >aluminium..

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Key words: *Decolourisation of dye Effluent , Electrochemical decolourisation,Decolorization efficiency*

1.Introduction

The textile industry is estimated to consume as much as two-third of the total annual production of dyes (Melgoza et al., 2004). Azo dyes are the largest and most versatile class of dyes and are commonly used to dye various materials such as textiles leathers ,plastics ,cosmetics and food (Anliker,1979 ; Blumel et al ., 2002). They are the major group of dyes used in the textile industry and contribute between 50-65% of the colours in textile dyes (Chung and Stevens ,1993; Melgoza et al.,2004).

The inefficiencies in the dyeing process result in dyestuff losses between 2-50% to the waste water with the lower limit for basic dyes and the upper for azo dyes (Melgoza et al., 2004).Ultimately these dyes find their way to the environment and end up contaminating rivers and groundwater in the locale of the industries (Melgoza et al., 2004).

Colours in water bodies reduce light penetration, alter the pH, increase the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) and thereby make aquatic life difficult (Ajayi and Osibanjo,1980). Dye house effluents are therefore of serious environmental concern.[1]

Several treatments of textile effluents to achieve decolourisation have been reported. These include physiochemical methods such as filtration, specific coagulation, use of activated carbon and chemical flocculation .Some of these methods are effective but quite expensive (Do et al., 2002; Marier et al., 2004).[5,6]

Although, biotreatment offers a cheaper and environmentally friendlier alternative for colour removal in textile effluents, it has its own demerits. Anaerobic decolourisation of azo dyes produces aromatic amines which are toxic to aquatic life (Chung and Stevens,1993), mutagenic to humans and cannot be degraded further under anaerobic conditions (Chung and Cerniglia,1992; Goncalves et al.,2000). It has been reported that the only safe biodegradation method for azo dyes is combined aerobic treatment[10;11] (Mabrouk and Yusef ,2008).However ,there are very few reports of aerobic bacteria that can grow with azo compounds (Blumel et al.,2002)[2,3,4, 8,10,12,13 ,14]

Electrochemical methods can also be used to decolourise dyes. Methyl orange (Rajendran et al., 2009) fluorescein (Sathiyabama et al., 2009) Eriochrome Black -T (Sathiyabama et al., 2006) have been decolourised by electrochemical method[15,16, 18]

Recently electrochemical methods (Kariyajjana var et al., 2010 ; Del Rio ,et al., 2010; Atheswaran and Raju , 2010; Del Rio et al., 2009) and chemical methods (Pereira et al.,

2010; Hsiao and Tseng, 2010; Mucor mucedo moturi and charya, 2010; Ramachandran et al., 2010) have been used to decolourize various dye solutions[9]

The removal of pollutants from effluents by electrochemical degradation[9] has become an attractive method in recent years. This paper deals with the removal of reactive textile dye Cibacron Navy W-B (CNWB) from an aqueous medium by the electrochemical method using graphite carbon electrodes. Electrochemical behavior of reactive azo dye CNWB was performed with cyclic voltammetry in sulphuric acid medium using glassy carbon as working electrode. The potential range selected for the dye was in the range +700 mV to -450 mV. The voltammetric curve of CNWB shows cathodic peaks at +50 mV, -155 mV and -317 mV and anodic peaks at +382 mV and +547 mV, respectively. The decolourisation efficiency was assessed through UV-Visible studies. The LC-MS of the dye were analyzed before and after electrochemical treatment and confirmed that the azo groups and aromatic rings were destroyed. The effect of pH and nature of supporting electrolytes on the electrochemical degradation of dye was also studied. The maximum Chemical Oxygen Demand (COD) removal efficiency was ~100% for the dye solutions at 5 gL-1 of NaCl concentration. The results revealed the suitability of the present process for the effective degradation of dye effluents (Kariyajjanavar et al. 2010).

The feasibility of decolourisation / degradation of secondary treated pulp and paper industrial wastewater was investigated by Electro-Fenton process. The wastewater was dark brown in colour, toxic odorous, having high COD (34800 mg/L), BOD3 (4900 mg/L) and non-biodegradable (0.14 - BOD 3/COD ratio). The study was carried out to evaluate the effects of the operating variables, viz. pH, dosage of Fe2+, concentration of hydrogen peroxide, current efficiency and contact time. The kinetic results show pseudo-first order degradation, with a rate constant of reaction between COD/COD. The maximum colour removal up to 95% and COD removal upto 90% were obtained at pH 3, Fe^{2+} dosage 125 mg/L, concentration of H_2O_2 1500 mg/L, applied current 2.2 A for 120 minutes of contact time. This feasibility study has proved that Electro-Fenton process could be an appropriate tertiary treatment for secondary treated pulp and paper industrial wastewater (Kanmani, 2010).

The electrochemical oxidation[17] of a synthetic wastewater containing Acid Yellow 1 on boron-doped diamond was investigated. The influence of applied current (0.5-3 A), dye concentration (1-3 g L-1), temperature (25-40 °C) and flow-rate (75-300 L h-1) on colour removal and current efficiency was evaluated. It was demonstrated that the complete decolourization and COD removal were achieved in any experimental

conditions indicating that the electrochemical oxidation on BDD electrodes is a suitable method for treatment of wastewaters polluted with synthetic dyes. In particular it was found that the decay of Acid Yellow 1 follows a pseudo-first-order kinetic and the oxidation rate was favoured by increasing current and flow-rate, while it was almost unaffected by solution temperature (Rodriguez et al. 2009).

Electrochemical decolourisation of Reactive Orange 16 was carried out in an electrochemical flow-cell, using as working electrodes a Pt thin film deposited on a Ti substrate (Pt/Ti) prepared by the Pechini method and a pure platinum (Pt) foil.

Using the Pt/Ti electrodes better results for dye decolourisation were obtained under milder conditions than those used for pure Pt. For the Pt electrode, colour removal of 93 % (λ = 493 nm) was obtained after 60 min, at 2.2 V vs. RHE, using 0.017 mol L-1 NaCl + 0.5 mol L-1 H2SO4 solution. For the Pt/Ti electrode there was better colour removal, 98%, than for the Pt electrode. Moreover, we used 0.017 mol L-1 NaCl solution and the applied potential was 1.8 V. Under this condition after 15 min of electrolysis, more than 80% of colour was removed. The rate reaction constant, assuming a first order reaction, was 0.024 min -1 and 0.06 (Gomes et al. 2009) [7].

The present work was undertaken to decolourise an aqueous solution of dye effluent by electrochemical methods using platinised titanium, mild steel, copper,aluminium and stainless steel as anodes and graphite as cathode.

2.Exprimental

The optical density of the dye effluent solution before and after decolourisation was measured by the instrument Photoelectric Colorimeter -112.Graphite was used as cathode. Platinised titanium /mild steel / Copper/ Aluminium /SS were used as anodes. The electrolysis was carried out in an undivided cell with a stirring bar (Fig-1)**.**
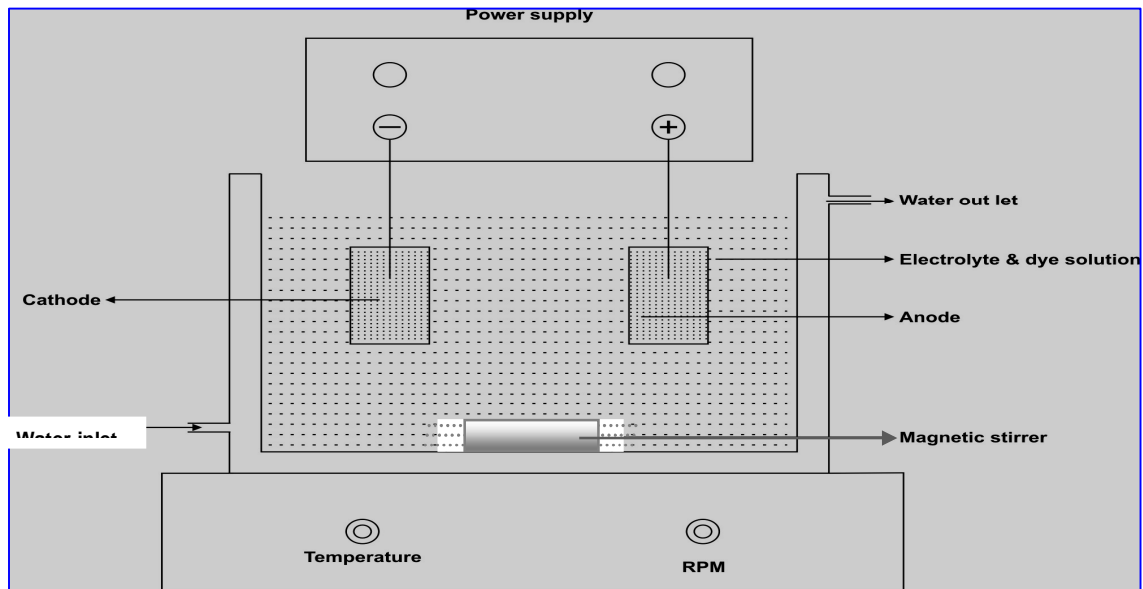
Figure 1: Schematic diagram of experimental set up

Decolourisation process [7]was carried out in an undivided glass cell, provided with a stirring bar .100 ml of the dye effluent solution was taken . Graphite was used as cathode. One of the metal specimens (platinised titanium / mild steel /Aluminium etc) was used as anode. 20 gm of sodium chloride was added. Current was passed for 5 minutes (3 volts; current density = 0.06 A/cm^2). The pH of the dye solution, before and after decolourisation was measured. The optical density was measured before and after decolourisation. The decolourisation efficiency (DE) was calculated using the relation

$$DE = \frac{OD1 - OD2}{OD1} \times 100$$

Where   OD1   =   Optical Density before decolourisation

          OD2   =   Optical Density after decolourisation

3.Results And Discussion

Cathode   :   Graphite

Current Density   :   0.06 A/cm^2

 Volt   :   3 Volts

Duration Of Electrolysis   :   5 mts

Initial OD   :   0.34

Electrolyte   :   20 gm of NaCl

pH of Dye solution   :   3.5 before electrolysis

The results were summarized in Table 1. It was observed that platinised titanium offered the maximum DE of 88%. ,Copper offers 73 % and Aluminium 67%..This result has 10% lower than Gomes etal (2008). In Gomes etal [7] decolorization efficiency was 98% by using Pt/Ti as anonde.The pH variations during decolorization was noted .

S.NO	Anode	pH after electrolysis	OD after electrolysis	Decolourisation efficiency %
1	Platinised Titanium	3.50	0.04	88%
2	Mild Steel	3.00	0.78	--
3	Cu	3.80	0.09	73%
4	Aluminium (Commercial 95 % pure)	3.20	0.11	67%
5	SS	3.50	0.64	--

Table:1   Decolorization Of Dye Effluent Solution

4.Uv –Visible Fluorescence Spectra

The   UV –visible fluorescence spctra was recorded before decolorization and after decolorization of dye effluent which was given in figures 3 &4.

For before decolorization, two peaks were appeared at 305 nm and 478nm.The two peaks were disappeared and only one peak was appeared at 327 nm .This showed that decolorization of dye effluent had taken place more effectively.
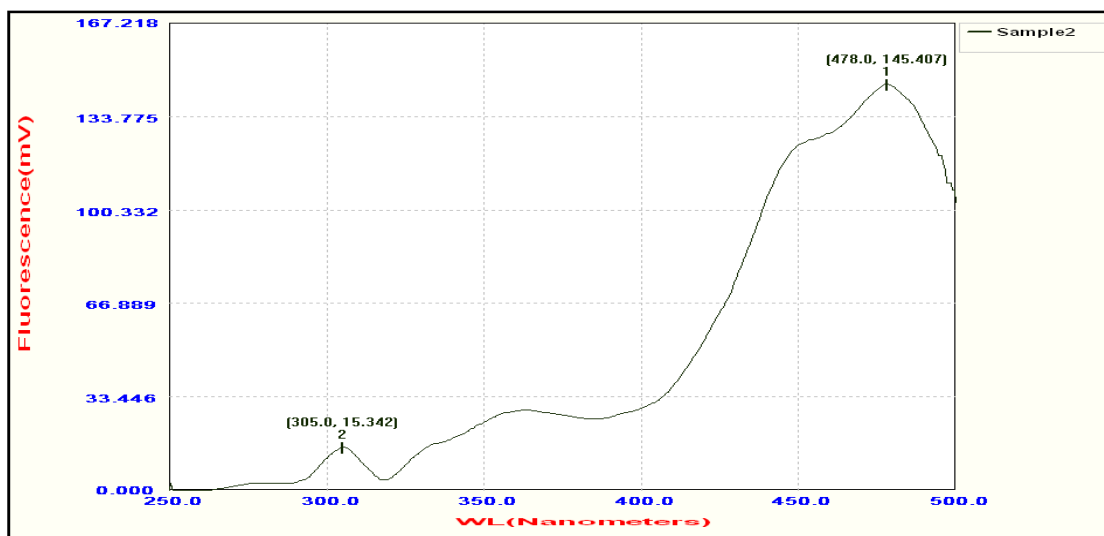

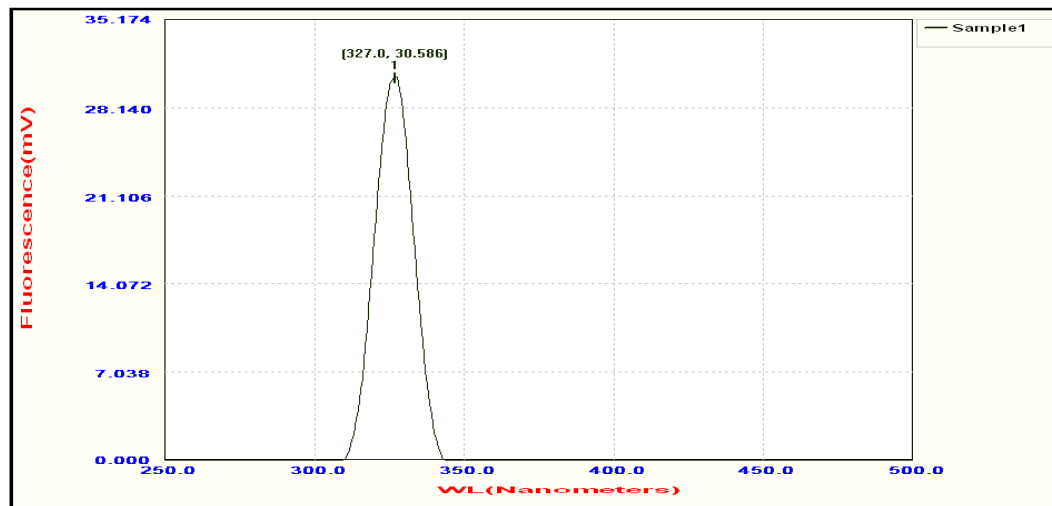*Figure 2: before decolorization of dye effluent*

Figure 3: after   decolourization of dye effluent (when Pt/Ti as anode)

5.Mechanism Of Decolourisation

When sodium chloride solution is electrolysed, positive chloride ion (Cl^+) is produced (Fig 2). It is highly reactive. It decolurises the coloured material into colourless product. Now negative cholside is (Cl^-) is produced. It transfers the electrons to the metal surface and hence Cl^+ is produced (Dalton and Lynch, 1981; Sathiyabama et al., 2009; Rajendran and Trivedi, 1995; Rajendran et al., 2009).[15,16,18]

Various other species have also been proposed responsible for the declourisation of dyes. Some of the reactive species proposed are OCl^- .(Maria Rivea et al, 2011; del Rio et al, 2009)

OH^- Radicals and OCl^- (Leonardo et al., 2009); OH^- O^- and $ClOH$. (Sanroman et al, 2005) and Cl^-, Cl_2^{-}, $ClOH^-$ (Lope and Gutierrez, 2006)

In the case of platinised titanium, the DE is very high 88%. This is attributed to the fact, that this metal readily accepts the electron released by Cl^-. Hence Cl^+ is produced readily, easily and abundantly. This Cl^+ converts the coloured compounds in to colourless products. The decrease in DE of other metals is attributed to the fact that these metals accept the electron from Cl^- less readily and produced Cl^+ species less readily and slowly.
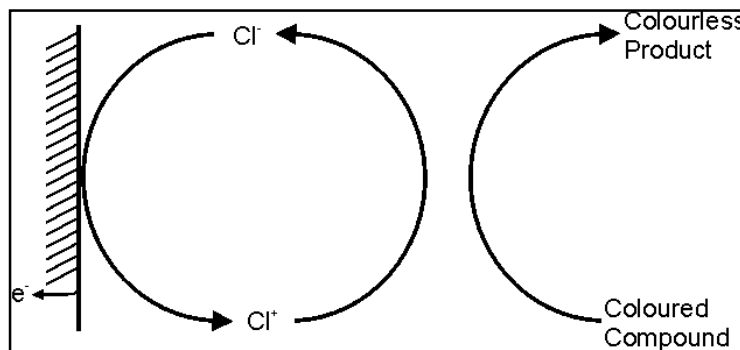
Figure 4: Elect rochemically regenerated   Cl $^+$

6.Conclusion

Eletrochemical decolorization of dye effluent solution   takes less time than any other decolorization methods and platinized titanium has more decolorization efficiency(88%)

7.Acnowldgement

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