Decolorization of Blue CL-BR dye by AOPs using bleach wastewater as source of $\text{H}_2\text{O}_2$

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Abstract

This research was focused on the investigation of the efficacy of advanced oxidation processes (Fenton, ozonation and UV/$\text{H}_2\text{O}_2$) for decolorization of reactive azo dye (Blue CL-BR) using bleach wastewater as possible source of $\text{H}_2\text{O}_2$. All the experiments were performed on the laboratory scale set-up. The results showed that colour removal efficiencies by UV or bleach ($\text{H}_2\text{O}_2$) alone were not so efficient. Fenton process with bleach wastewater was found to be the most effective at process conditions such as pH of 3 and $\text{H}_2\text{O}_2$/Fe$^{2+}$ ratio of 24:1, resulting in 64% colour removal. Almost complete colour removal, i.e., 99% and 95% were achieved by UV/$\text{H}_2\text{O}_2$ and UV/bleach wastewater in 30 and 60 min, respectively. Ozonation proved an efficient method for decolorization of Blue CL-BR dye at alkaline pH. It was possible to achieve 98% colour removal with 30 min of ozonation at pH 9. The colour removal of dye was found to follow first order kinetics.

Key words: azo dye; bleach wastewater; Fenton; hydrogen peroxide; ozone

Introduction

The textile industry being water intensive in nature uses colossal quantity of water during the “wet processes”, such as, dyeing, printing and finishing operations. Hydrogen peroxide is usually used for bleaching of cotton fabrics. The bleaching chemicals have to be removed, generally through a number of rinsing stages or by the addition of a reducing agent to neutralise the bleach. In the both cases, large volume of wastewater is generated. In bleaching wastewater the environmental concerns are associated with the use of strong complexing agents. A strong alkaline effluent is produced if the rinsing water after mercerizing is not recovered or re-used. On the other hand, dyeing effluents are characterized by high levels of colour caused by residual dyes that are not fixed to fibres in the dying process with significant quantity of auxiliary chemicals. The presence of dyes in receiving media is easily detectable even when released in small concentrations (Nigam et al., 2000) and causes aesthetic problems. The accumulation of colour hampers sunlight penetration, thus impeding the photosynthetic activity of aquatic plants and seriously threatening the whole ecosystem (Kuo, 1992; Georgiou et al., 2003). Furthermore, dyes in effluents are degraded by microorganisms yielding potentially carcinogenic amines that spread in the ecosystem (Chung and Stevens, 1993; Georgiou et al., 2003).

“Azo-reactive” is probably the main class of textile dyes utilized for cotton fibres while the toxicity of azo dyes is significantly higher as compared to other types of dyes (Grau, 1996). Advanced oxidation processes (AOPs) are widely used for removal of colour from dyeing wastewater (Zhang et al., 2004; Shu and Chang, 2005; Shu, 2006; Yasar et al., 2006). Processes involving $\text{H}_2\text{O}_2$ are based on the generation of hydroxyl radicals by the dissociation of hydrogen peroxide. The use of bleaching wastewater as a source of hydrogen peroxide can be a new option that can considerably reduce resource consumption and environmental pollution without incurring expensive investments of a technical and financial nature.

This study was focused on colour removal of reactive dye (Blue CL-BR) by AOPs. The objectives of the study were to investigate the efficiency of bleach wastewater as a source of hydrogen peroxide for various processes (Fenton, ozone, $\text{O}_3$/H$_2\text{O}_2$, and UV/$\text{H}_2\text{O}_2$) to reduce colour and to compare it with the results of analytical grade hydrogen peroxide. The effects of the key operating variables such as pH, hydrogen peroxide and ferrous doses on the decolorisation kinetics were also studied.

1 Materials and methods

1.1 Materials

Blue CL-BR dye was obtained from Clariant Pakistan. Aqueous solution of dye was prepared by distilled deionized water (DDW). First the stock solution of 1000
mg/L was prepared and all the experiments were carried out on 100 mg/L dye solutions. The hydrogen peroxide solution (30%) of analytical grade, FeSO₄·7H₂O, KIO₃, and Na₂S₂O₅ were obtained from Merck, Germany and extra pure starch of BDH England were used. Bleach waste water was collected from a finishing mill. Waste water was highly alkaline (10.5); TDS contents were 3809 mg/L with conductivity of 5860 µS. H₂O₂ content of wastewater was determined using standard technique after Gordon et al. (1992). H₂O₂ concentration was 1.5 mg/ml of wastewater.

A JQ-6M Puretech model ozone generator was used. The ozonation was carried out in bubble column reactor of 1 L capacity with internal diameter of 3.3 cm. The ozone was supplied at the bottom of the reactor through a diffuser at a rate of 300 mg/h produced by using air. The volume of the dye solution used for analysis was 500 ml.

The optimal UV and UV light assisted experiments were carried out in a cylindrical photo-reactor with an internal diameter of 5 cm and total volume of 1 L. The reactor was wrapped with aluminium foil to enhance the absorbance of UV. A low pressure mercury lamp model PENRAY 3SC9 UPLAND USA with irradiation intensity of 5 mW/cm² and wavelength of 254 nm was immersed in 300 ml dye solution in the reactor while ensuring its position at the center. Experiments were performed at ambient temperature and no lamp cooling was provided.

The set-up for H₂O₂, bleach wastewater and Fenton process was consisted of a graduated Pyrex glass vessel of 250 ml with magnetic stirring facility at a rate of 120 r/min. All the experiments were carried out in batch mode on a sample volume of 100 ml.

1.2 Experimental

Ozone dose was varied from 50 to 300 mg/L of wastewater. The ozonation was performed at various pH (11, 9, 7, and 5) to study the effect of pH on ozonation. In the experiments involving H₂O₂ and bleach wastewater, first the dose of the oxidant was added and then ozonation was carried out at pH 9 at constant ozone dose of 200 mg/L. Ozone treated effluent was sampled at regular intervals for the determination of colour concentrations. UV irradiation time was varied from 5 min to 1 h. For combinations of H₂O₂/UV, 2.21 mmol/L of H₂O₂ was added to the sample and then UV was applied at pH 7.

Bleach wastewater doses such as 5, 10, 15, 20, 25, 50, 75 and 100 ml/L were used for chemical treatment. The amount of H₂O₂ present in these different doses was 7.5, 15, 22.5, 30, 37.5, 75, 112.5 and 150 mg/L, respectively. These doses were then converted into molar values for convenience in representing molar ratio. Their corresponding molar values were 0.22, 0.44, 0.66, 0.88, 1.1, 2.21, 3.31 and 4.41 mmol/L, respectively. Further experiments involving ferrous sulphate were carried out with varying amount of H₂O₂ and bleach wastewater (1.1, 2.21, 3.31 and 4.41 mmol/L) and ferrous was kept constant at 0.09 mmol/L. In another set various ferrous doses (0.09, 0.18, 0.27, and 0.36 mmol/L) were applied and H₂O₂ content (analytical grade H₂O₂ and in bleach wastewater) was kept constant at 2.21 mmol/L. These experiments were performed by adjusting pH at 3±0.1 using 0.2 mol/L H₂SO₄ (few drops). After the reaction (40 min) residual iron was removed by raising the pH to 9.0 by adding 1 mol/L NaOH. The precipitates were allowed to settle and the supernatant was taken for analysis. Finally the effect of pH was monitored by varying pH (2, 3, 4, 5 and 6) using optimal ratio (2.21 and 0.18 mmol/L) of bleach wastewater and ferrous sulphate.

2 Results and discussion

2.1 Effect of Fenton’s process on colour removal

Several researchers (Bali et al., 2004; Ince and Gonenc, 1997) reported that the rate of decolorization by H₂O₂ alone was very low for many dyes. Similar results were obtained for bleach wastewater (Table 1).

| Table 1 Effect of bleach wastewater on colour removal |
|---|---|---|---|---|
| Bleach wastewater (ml/L) | H₂O₂ contents (mmol/L) | Colour removal (%) |
| | | 1 h | 3 h | 24 h |
| 5 | 0.22 | 0.14 | 0.37 | 0.45 |
| 10 | 0.44 | 0.50 | 0.74 | 0.85 |
| 15 | 0.66 | 0.65 | 0.96 | 1.04 |
| 20 | 0.88 | 0.87 | 1.19 | 1.50 |
| 25 | 1.10 | 1.07 | 1.41 | 1.73 |
| 50 | 2.21 | 1.99 | 3.48 | 6.07 |
| 75 | 3.31 | 1.81 | 2.49 | 4.08 |
| 100 | 4.41 | 1.03 | 1.42 | 2.28 |

Therefore, Fe(II) was used as catalyst to accelerate the production of OH· radical for colour removal of dye. The selection of an optimum H₂O₂ concentration for the decolorization of the dye by Fenton’s process is important from practical point of view (due to the cost of H₂O₂). Several studies (Neamtu et al., 2003; Azbar et al., 2004; Sevimli and Kinaci, 2002) are also available on attempts to find optimal H₂O₂ and Fe²⁺ doses, but still lack consensus on the ratio of H₂O₂/Fe(II) that gives the best results. Thus, first optimization of H₂O₂ content in bleach wastewater was done using various doses of 1.10, 2.21, 3.31 and 4.41 mmol/L while 0.09 mmol/L of Fe²⁺ was kept constant. The results demonstrated that H₂O₂ (analytical grade) dose of 4.4 mmol/L gave 53% colour removal (Table 2). While with H₂O₂ (bleach wastewater) 62% colour removal was achieved at a dose of 2.2 mmol/L; and further increase in H₂O₂ doses (3.31 and 4.41 mmol/L) beyond optimal dose results in decline in colour removal to 60% and 59%, respectively (Table 3). Results show higher efficiency of H₂O₂ (bleach wastewater) as compared to H₂O₂ analytical grade even at lower dose. This could be attributed to excessive solids in bleach wastewater which remove colorant by simple adsorption without involving chemical reactions while an iron-based coagulant provides ferrous ions (Fe²⁺) to further degrade the dye (Wilcock, 1992). During the process, precipitates of Fe(OH)₂ and Fe(OH)₃ are formed and remain in the solution. Their gelatinous suspension removes colorants by complexation and electrostatic attraction followed by coagulation with
H$_2$O$_2$ (bleach wastewater) in the presence of suspended and colloidal particles. In Fenton process ferrous dose not only accelerate the production of OH radicals but also provided additional benefit of coagulation by iron ions. These radicals led to rapid breaking of conjugated double bond of chromophores (Guivarch et al., 2003).

The selected dose of Fe$_{2+}$(0.09 mmol/L) was also investigated with higher ferrous doses (0.18, 0.27 and 0.36 mmol/L) at constant H$_2$O$_2$ content (2.21 mmol/L) of bleach wastewater. Results demonstrated that Fe$_{2+}$ dose of 0.09 mmol/L gave colour removal of 62% beyond which no appreciable increase in colour removal (63.7%, 64.1% and 64.7%) were obtained (Table 4). Therefore, a molar ratio of 24:1 (H$_2$O$_2$/Fe$_{2+}$) was achieved of H$_2$O$_2$ and Fe$_{2+}$. In previous studies (Ince and Tezcanli, 1999; Dutta et al., 2001; Perez et al., 2002), H$_2$O$_2$/Fe$_{2+}$ ratios recommended for different dyes are from 10:1 to 40:1 for H$_2$O$_2$ analytical grade.

The optimization of pH was performed at various pH values from 2 to 6. The results showed that the pH had a significant effect on the colour removal by Fenton’s process (Fig.1). The optimum pH for Blue CL-BR was found to be pH 3, where the maximum colour removal of 64% was achieved (Perez et al., 2002; Kang et al., 2002). The hydroxyl radical generation is directly affected by the pH and are formed efficiently under acidic conditions. The low activity detected for high pH has been reported in the literature (Perez et al., 2002; Lee et al., 2003) and can be explained by the formation of Fe(OH)$_3$. A low pH is also essential to keep ferric ion in solution. At a pH less than 3, Fe(III) is in the solution; at a pH greater than 3 and less than 5, Fe(III) is out of solution in colloidal form; and above pH 5, it precipitates as Fe$_3$O$_4$·H$_2$O.

2.2 Effect of UV irradiation on colour removal

UV alone did not show appreciable decolorization in case of Blue CL-BR, i.e. 1 h exposure to UV resulted in an unsatisfactory colour removal of 31% (Fig.2). This paucity in colour removal is justified as UV irradiation of

![Fig. 1](image_url)

**Fig. 1** Dye colour removal by Fenton process at various pH (H$_2$O$_2$ = 2.21 mmol/L, Fe$_{2+}$ = 0.18 mmol/L).

![Fig. 2](image_url)

**Fig. 2** Colour removal of Blue CL-BR dye by UV alone, UV/H$_2$O$_2$ (H$_2$O$_2$ = 2.21 mmol/L) and UV/Bleach wastewater (2.21 mmol/L) at pH 7.

Table 2 Effect of various doses of hydrogen peroxide on colour removal of Blue dye by Fenton process ($C_{FeSO_4 \cdot 7H_2O} = 0.09$ mmol/L)

<table>
<thead>
<tr>
<th>H$_2$O$_2$ dose (mmol/L)</th>
<th>15 min</th>
<th>30 min</th>
<th>45 min</th>
<th>60 min</th>
<th>75 min</th>
<th>90 min</th>
<th>120 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10</td>
<td>7.8</td>
<td>11.6</td>
<td>20.4</td>
<td>21.8</td>
<td>23.9</td>
<td>25.0</td>
<td>27.4</td>
</tr>
<tr>
<td>2.21</td>
<td>21.8</td>
<td>28.0</td>
<td>32.0</td>
<td>36.4</td>
<td>38.2</td>
<td>40.0</td>
<td>43.0</td>
</tr>
<tr>
<td>3.31</td>
<td>23.5</td>
<td>29.0</td>
<td>34.0</td>
<td>37.0</td>
<td>38.7</td>
<td>41.5</td>
<td>48.3</td>
</tr>
<tr>
<td>4.41</td>
<td>28.9</td>
<td>37.0</td>
<td>43.3</td>
<td>45.2</td>
<td>46.7</td>
<td>48.0</td>
<td>53.0</td>
</tr>
</tbody>
</table>

Table 3 Effect of various doses of bleach wastewater on colour removal of Blue dye by Fenton process ($C_{FeSO_4 \cdot 7H_2O} = 0.09$ mmol/L)

<table>
<thead>
<tr>
<th>Bleach wastewater (H$_2$O$_2$ mmol/L)</th>
<th>15 min</th>
<th>30 min</th>
<th>45 min</th>
<th>60 min</th>
<th>75 min</th>
<th>90 min</th>
<th>120 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10</td>
<td>27.6</td>
<td>36.4</td>
<td>42.4</td>
<td>46.1</td>
<td>49.9</td>
<td>52.9</td>
<td>59.6</td>
</tr>
<tr>
<td>2.21</td>
<td>29.1</td>
<td>37.6</td>
<td>43.8</td>
<td>48.3</td>
<td>51.3</td>
<td>54.0</td>
<td>62.0</td>
</tr>
<tr>
<td>3.31</td>
<td>29.5</td>
<td>39.1</td>
<td>43.1</td>
<td>47.6</td>
<td>50.5</td>
<td>53.0</td>
<td>60.2</td>
</tr>
<tr>
<td>4.41</td>
<td>28.3</td>
<td>39.1</td>
<td>42.2</td>
<td>46.7</td>
<td>47.4</td>
<td>49.5</td>
<td>59.4</td>
</tr>
</tbody>
</table>

Table 4 Effect of various ferrous doses on colour removal of Blue dye by Fenton process (H$_2$O$_2$ content (bleach wastewater) = 2.21 mmol/L)

<table>
<thead>
<tr>
<th>Ferrous dose (mmol/L)</th>
<th>10 min</th>
<th>20 min</th>
<th>30 min</th>
<th>40 min</th>
<th>50 min</th>
<th>60 min</th>
<th>120 min</th>
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<tbody>
<tr>
<td>0.09</td>
<td>29.1</td>
<td>37.6</td>
<td>43.8</td>
<td>48.3</td>
<td>51.3</td>
<td>54.0</td>
<td>62.0</td>
</tr>
<tr>
<td>0.18</td>
<td>32.0</td>
<td>39.5</td>
<td>45.8</td>
<td>50.3</td>
<td>53.5</td>
<td>55.5</td>
<td>63.7</td>
</tr>
<tr>
<td>0.27</td>
<td>34.2</td>
<td>41.8</td>
<td>47.5</td>
<td>51.7</td>
<td>55.0</td>
<td>56.8</td>
<td>64.1</td>
</tr>
<tr>
<td>0.36</td>
<td>36.8</td>
<td>43.9</td>
<td>49.8</td>
<td>54.2</td>
<td>56.7</td>
<td>57.6</td>
<td>64.7</td>
</tr>
</tbody>
</table>
organic compounds is of a rather complex nature, it can be speculated that during UV exposure an electronically excited state of the dye was generated where further decomposition of excited molecules to radicals and/or oxidized species did not occur (Arslan and Balcioglu, 2001). From the initial results it could be inferred that Blue CL-BR is photolytically stable and its complete oxidation (total dissolved solids, total suspended solids) in bleach wastewater (Shu et al., 1994). The introduction of bleach wastewater resulted in 95% colour removal, however, comparatively longer irradiation period (1 h) is required (Fig.2). This extension in UV exposure time is probably by the limited penetrations of photons due to the presence of impurities (total dissolved solids, total suspended solids) in bleach wastewater.

2.3 Effect of pH on colour removal by ozone

The effect of pH was evaluated by varying pH from 5 to 11. The results demonstrated that ozonation was effective in basic medium, i.e. colour removal of 98% was achieved at pH 9 (Fig.3). This observation may be explained by the enhancement of ozone decomposition at higher pH values (Aplin and Waite, 2000). In general ozone oxidation pathway consists of a direct oxidation by ozone or a radical oxidation by HO$^\cdot$ radical (Langlais et al., 1991; Masten and Davies, 1994). The solubility of ozone is readily affected by pH. In fact the influence of pH is a result of the relationship between oxidation potential and decomposition behaviour of ozone. In acidic pH, the ozone is available as molecular O$_3$ and in alkaline pH it decomposes into secondary oxidants such as HO$_2^-$, HO$_2^*$ and HO$_3^*$. Among these HO$^\cdot$ is an important one which has rate of attack 10$^6$ to 10$^8$ times faster than the corresponding reaction rate for molecular ozone (Chu and Ma, 2000). The oxidation potential of ozone decreases from 2.08 V at acidic pH to 1.4 V in alkaline solutions. This indicates that ozone solubility decreases (O$_3$ decomposition enhances) with increasing pH resulting in generation of secondary oxidants (Aplin and Waite, 2000; Balcioglu and Arslan, 2001). At higher pH the reaction between hydroxide ions and ozone leads to the formation of super-oxide anion radical O$_2^{-}$ and hydroperoxyl radical HO$_2^*$ which through various steps yield HO$^\cdot$ radicals (Gottschalk et al., 2000). Thus it can be concluded that high initial pH could improve decolorization of dye solutions (Gould and Groff, 1987; Alpin and Waite, 2000).

Following the determination of optimal pH in terms of colour removal the ozone experiments were repeated with O$_3$ alone, O$_3$/H$_2$O$_2$ and O$_3$/bleach wastewater. Ozonation alone resulted in colour removal of 98% after 30 min ozonation (Fig.4). Initial 20 min ozonation resulted in colour removal of 90% beyond which colour removal was not appreciable (Azbar et al., 2004). It was reported (Azbar et al., 2004) that ozone in the presence of H$_2$O$_2$ can produce more hydroxyl radical and is expected to enhance the decolorization rate. Therefore 2.21 mmol/L of H$_2$O$_2$ was added to accelerate the production of OH$^\cdot$ radicals to decolorize dye solution. The results demonstrated that there was no appreciable improvement in colour removal by introduction of H$_2$O$_2$. This discrepancy in result may be explained as H$_2$O$_2$ is not only a producer of hydroxyl radical but also a scavenger of hydroxyl radical (Bali et al., 2004). O$_3$/H$_2$O$_2$ treatment of synthetic dyes also depends on the pH, O$_3$/H$_2$O$_2$ ratio, type of the dye and concentration of H$_2$O$_2$. Some researchers (Beltran et al., 1994; Ledakowicz and Gonera, 1999) have reported that the hydrogen peroxide at higher concentrations act as an inhibitor for the radical reaction mostly by reacting with the hydroxyl radicals, although the exact mechanism is still not clear. They have also indicated that there is an optimum hydrogen peroxide concentration above which the rate of pollutant degradation decreases with an increase in the hydrogen peroxide concentration. It should be noted that along with the consideration of the optimum concentrations of hydrogen peroxide or ozone individually, it is important to consider the ratio of ozone to hydrogen peroxide loading also the optimum dosage has to be in the molar ratio of 0.33 (O$_3$/H$_2$O$_2$), beyond which there is not much increase in the rate of degradation (Glaze and Kang, 1989). Another crucial factor in deciding the efficacy of the combination technique is the operating pH. Investigators (Arslan et al., 1999; Nelieu et al., 2000) have studied the effect of pH on the degradation rate and reported that higher pH is favourable for the degradation due to the ease of generation of free radicals at higher pH. The initial concentration and type of the dye also affect the rate of degradation, although the concentrations of ozone and hydrogen peroxide may be suitably adjusted so as to
treat a particular loading of the pollutant (Echigo et al., 1996; Tanja et al., 2003).

The effect of bleach wastewater on colour removal was also investigated by adding H2O2 content of 2.21 mmol/L. The results demonstrated that addition of bleach wastewater showed some reduction (86%) in colour removal efficiency. It is likely that bicarbonate is the principal consumer of the hydroxyl radicals, particularly as relatively high concentrations of bicarbonate are present in bleach water. The scavenging effect of bicarbonate also lies in the fact that it reacts with hydroxyl radicals to generate bicarbonate radicals (HCO$^-$_3). This acts as a very selective additional oxidation species and which have a lower reaction rate constant than hydroxyl radicals (Oguza et al., 2006).

2.4 Kinetic studies

The decolorization of dissolved dyes in wastewater is a complex process with many reactions which are difficult to distinguished individually. Therefore an approximate kinetic study for the colour removal of dye solution was performed. Several investigations (Bali et al., 2004; Neamtu et al., 2003) reported that most of the colour removal curves obey first-order kinetics. Therefore, all constants were determined based on the first-order kinetics assumption.

$$\ln(C_0/C_t) = -kt$$  \hspace{1cm} (1)

where, $C_0$ is the initial dye concentration, $C_t$ is the concentration of dye at time $t$, and $k$ is the overall rate constant (time$^{-1}$).

As illustrated in Fig.5 that a typical plot of linear regression ($\ln(C_t/C_0)$) versus time ($t$) for the colour removal of Blue CL-BR dye with Fenton, UV/H2O2, and O3/H2O2 processes gave straight line. Having this straight-line behaviour, the plot confirms the first order kinetics of these various processes. Their corresponding first-order rate constants ($k$) calculated from slopes for Blue CL-BR dye are 0.015, 0.052 and 0.093 min$^{-1}$.

The rates constants determined from graphic method correspond to rate constants (Table 5) measured directly by using equation

$$k = 1/t \ln(C_0/C_t)$$  \hspace{1cm} (2)

Decolorization of dyes following first order kinetics was also verified by half life time (Table 5), i.e., the time in which initial concentration of dye reduced to its half.

$$t_{0.5} = \ln(2/k)$$  \hspace{1cm} (3)

It is evident from Fig.5 that the difference of rates between Fenton and UV/H2O2 processes was started in the beginning (initial 10 min duration gave 34% and 27% colour removal respectively), however, soon as reactions proceed Fenton oxidation attain steady state and thus appreciable difference was observed. This might be due to higher colour removal in Fenton process, where at initial stage H2O2 doses consumed more rapidly (Azbar et al., 2004). Similarly, initial 10 min process gave 52% and 34% colour removal in O3/H2O2 and Fenton processes, respectively. Higher colour removal in O3/H2O2 may be due to efficient hydroxyl radical generation by ozonation (Azbar et al., 2004). It is evident from comparative study of rate constants of various AOPs for decolorization of Blue CL-BR that O3/H2O2 process is 6.2 times faster than Fenton and 1.8 times from UV/H2O2 process.

3 Conclusions

The operating conditions (pH, H2O2 (bleach wastewater) and ferrous dose) have an important influence on Fenton oxidation of Blue CL-BR dye. The results indicate that effective system conditions are pH of 3 and H2O2/Fe$^{2+}$/molar ratio of 24:1 for bleach wastewater. It also revealed that H2O2 (bleach wastewater) was more effective as compared to H2O2 analytical grade in Fenton process. It can be concluded that mixing of bleach wastewater and dye effluent in a ratio of 1:2 could be a promising technique for colour removal without addition of any chemical except iron catalyst. Effective decolorization by UV/H2O2 and UV/bleach wastewater processes are possible. Complete decolorization of dye is possible by ozonation at optimal pH. The rate constants confirm the colour removal of dye follow first order kinetics.

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