Removal of an Azo Dye (Orange G) By Various Methods in Homogenous Phase. Comparative Study

H. Cheninia, K. Djebbar*a, S.M. Zendaouib, T. Sehilia, B. Zouchouneb

a Laboratoire des Sciences et Technologie de l’Environnement, Université Mentouri-Constantine.
b Laboratoire de chimie moléculaire du contrôle de l’environnement et des mesures Physico-chimiques, Université Mentouri-Constantine.

Received on March 12, 2011 Accepted on June 14, 2011

Abstract

The dyes are considered as one of the biggest sources of water pollution. Degradation of these compounds have to be carried out via, photolysis, acetone/UV and AOT's (Advanced Oxidation Technologies) due to their weak biodegradation or their high persistence in different compartments of the environment. In this study, UV alone and combined to acetone, H$_2$O$_2$, S$_2$O$_8^{2-}$, Fenton and photo-Fenton reactions were investigated in lab-scale experiments for the degradation of Orange G. The attribution of UV-vis bands of dye has been performed by molecular modelisation, using Density Functional Theory DT-DFT and to be compared the experimental ones. The degradation rate is strongly dependent on the initial concentrations of the H$_2$O$_2$, S$_2$O$_8^{2-}$, acetone and Fe$^{2+}$. The effect of these parameters has been studied and the optimum operational conditions of these processes were found.

Keywords: Advanced oxidation Technologies; Azo dye; Orange G; photoFenton; Theorical electronic spectra.

Introduction

The release of colored wastewaters from the textile industry is a current problem encountered by developed and under developed countries over the world. This release in natural environment, mainly in aqueous medium, is undesirable because of the transformation on toxic and carcinogenic of these compounds in the aquatic life. Azo dyes, constituted mostly by aromatic moieties and linked together by –N=N- bonding (a type of chromophore), represents the largest class among these pollutants \cite{1-2}. They are also very resistant to biodegradation.

Various physico-chemical and biological methods were used in the past to remove color from dye containing wastewaters. These techniques included for example: filtration, coagulation, precipitation, adsorption, ion exchange, classical oxidation.... However, we have observed an efficiency lack because of the pollution transfer from one phase to another leading therefore a further costly treatment. In latter decenies, a promising route to traditional methods is “Advanced oxidation process”. This system is based on production of very reactive species either in homogeneous or heterogeneous medium: the radicals OH*.

\* Corresponding author: Tel : +213 774821717 ; e-mail : kedjeebbar@yahoo.fr
They are able to oxidize rapidly, efficiently and non-selectively an elevated number of organic pollutants \([3-6]\). Those containing iron II and III, coupled or non-coupled with UV radiations needed an acidic medium upon their use (pH=3) to prevent formation of their precipitation\([7]\).

The aim of the present work is to analyze the possibility of decolourization of OG by different AOTs such as: UV/H\(_2\)O\(_2\), UV/S\(_2\)O\(_8^{2-}\), Fenton, photoFenton and also by the use of a photosensitized component like “acetone”. The effects of the initial concentration of acetone, hydrogen peroxide, persulfate, ferrous in reactive OG oxidation were also investigated and compared.

**Experimental and modeling details**

**Material**

The azo dye, OG was purchased from Biochem-Chemopharma and used without further purification. Molecular structure of OG is a non-hydrolysed form, characterized by \(-\text{N}=\text{N}-\) bonding:

![Molecular structure of OG](image)

Iron (II) sulphate hexahydrate was provide by Labosi puriss (\(> 99\%\)). Aqueous solution containing 33 wt % of hydrogen peroxide (purity 99.9 %) and Sodium persulfate were obtained from prolabo. pH of the reaction solutions was adjusted using HCl and NaOH solutions. Double distilled water was used throughout this study.

**Photoreactor and light source**

Aqueous solutions were irradiated at 253.7 nm in cylindrical reactor quartz (100 cm of length and 2 cm in diameter), located on one of the principal axis of the assembly and equipped with three symmetrical externals low-pressure mercury lamps (germicide lamp, Philips TUV 15 W) emitting mainly at 254 nm. The reactor is surrounded symmetrically by these lamps. The temperature of the reactor was maintained between 18 and 20 °C by the use of an air flow provided by a Ventilator. The entire system is placed in a cylindrical enclosure(8). See figure 1.
Analytical methods

The UV-vis spectra of dye were recorded from 200 to 800 nm using a UV-vis spectrophotometer (Unicam Helios “α”) with a spectrometric quartz cell (1 cm path length). The maximum absorbance wavelength ($\lambda_{\text{max}}$) of OG is 476 nm. Therefore, the residual concentrations of the dye in the mixture and withdrawn at different reaction times, were determined by measuring the absorption intensity at $\lambda_{\text{max}} = 476$ nm with and by the use of a calibration curve. Results of the efficiency were expressed in percentage according to the following relation: $E(\%) = 1 - \frac{C_t}{C_0}$ where $C_0$ is the initial concentration and $C_t$ the residual concentration at instant $t$.

Computational Methods

Density functional theory (DFT) calculations were carried out on the studied compound using the Amsterdam Density Functional (ADF) program [9], developed by Baerends and coworkers [10]. Electron correlation was treated within the local density approximation (LDA) in the Vosko–Wilk–Nusair parametrization [11]. The non-local corrections of Becke and Perdew were added to the exchange and correlation (BP86) energies, respectively [12-13]. The numerical integration procedure applied for the calculations was developed by Velde et al. [14]. All atoms were described by a triple STO basis set present in the program database. A frozen-core approximation was used to treat the core shells up to 1s for C, N and O, 2p for the S atom. Full geometry optimizations were carried out using the analytical gradient method implemented by Verluis and Ziegler [15]. Frequencies calculations [16] were performed on the studied compound to check that the optimized structure is at local minima, the optimum geometry was determined by minimizing the energy with respect to all geometrical parameters without molecular symmetry constraints. In the time-dependent density
functional theory (TD-DFT) formalism\cite{17}, the calculations were performed with the RESPONSE module of the ADF program. In this regard, the electronic transitions, excitation energies and oscillator strengths have been computed using the iterative DAVIDSON method. In TD-DFT, the “asymptotically correct” Van Leeuwen–Baerends potential (LB94) have been used \cite{18}. Only spin-allowed transitions have been taken into account. Moreover, only transitions with non negligible oscillator strengths are reported and discussed.

**Results and discussion**

**UV–Vis spectrum of Orange G**

The theoretical UV–vis spectra of Orange G is reported in figure (2).

![Figure 2: Theoretical electronic spectra of OG](image)

We observed mainly three absorption bands located at 350, 420 and 476 nm respectively and which can be described as followed:

* The band A centered at 350 nm which absorbs relatively at high energy is attributed to HOMO-7 -> LUMO transition, which derives from $\pi-\pi^*$ transition between $\pi$ system of naphtalenic ring, the $\text{SO}_3$ groups and the $\pi^*$ system of the –N=N- azo link as encountered and discussed in previous works \cite{19}.

* The Visible band B located at 420 nm corresponds to HOMO-4 -> LUMO (68%) and HOMO-5 -> LUMO (22%) transitions which are typically a $\pi-\pi^*$ transition between $\pi$ system of the $\text{SO}_3$ groups, naphtalenic ring and $\pi^*$ system of –N=N- azo link.

* The strong band C centered at 478 nm which absorbs relatively at low energy is assigned to the HOMO-1 -> LUMO (71%) and HOMO-2 -> LUMO+1 (17%) electronic transitions, where the LUMO is principally the $\pi^*$ system of –N=N- azo link, while the HOMO and HOMO-1 are mainly localized on $\text{SO}_3$ groups.
It is noteworthy to mention that the chemical structure of this dye is composed of a conjugated system allowing a more increasing intensity of these transitions, producing thus, the colour of this system. Moreover, natural band analysis indicates that molecular orbital are mainly composed of $\pi$ atomic orbital, so electronic transition are mainly derived from the contribution of bands $\pi \rightarrow \pi^*$ bands.

The TD-DFT is particularly well suited to low energy valence excited states that can be discussed by combinations of single excitations. Electronic transitions were determined from excited state calculations by using this method for the three lowest energy transitions of molecule. These are identified and calculated transitions occurring at 478 nm, 420 nm and 350 nm. The experimental spectra presents almost the same absorption bands located mainly at 332, 400 and 476 nm and provides an acceptable shift were its value does not exceed 22 nm, mainly, for both bands A and B (Table 1). Similar work was reported in the literature \[20\].

<table>
<thead>
<tr>
<th>Excitation</th>
<th>Wavelength (nm)</th>
<th>Oscillator strength (f)</th>
<th>Energy (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band A</td>
<td>350</td>
<td>332</td>
<td>0.1195</td>
</tr>
<tr>
<td>Band B</td>
<td>420</td>
<td>400</td>
<td>0.1086</td>
</tr>
<tr>
<td>Band C</td>
<td>478</td>
<td>476</td>
<td>0.0948</td>
</tr>
</tbody>
</table>

Table 1: Calculated wavelengths (nm), oscillator strengths (a.u) and excitation energies (eV) of Orange G molecule.

**Photolysis and Acetone /UV processes**

The photolysis of OG was carried out in batch method reactor, at pH 5.8, at concentration of 50 mg L$^{-1}$ and at 254 nm. The results obtained after a long irradiation time, showed a negligible decolorization of the substrate. However, in the presence of acetone, we observed a bleaching process of the substrate. The latter increases as the acetone concentration increases. Complete bleaching of the dye solution is obtained within 60 min for 10$^{-1}$ M concentration of acetone (Figure 3). This important improvement is due to the role played by the photosensitizer which is characterized by energy transfer:

\[ ^1Ac + ^1GS \rightarrow ^3Ac + ^3GS \]

\[ ^3Ac + ^1GS \rightarrow ^1Ac + ^3OG \]

Where $^1GS$ and $^3OG$ represent the ground state and the triplet state of the substrate respectively whereas $^1Ac$ and $^3Ac$ represent the single and excited state of acetone. The unstable state represented by $^3OG$ is thus responsible of this improvement \[21\] which could occur through a particular species: $^1O_2$. 
Figure 3: Decolourization of OG in presence of acetone. \([\text{dye}]_o = 50\ \text{mg/L}, \ \text{pH}_o = 5.8, \ \lambda_{irr} = 254\ \text{nm}

**UV / \text{H}_2\text{O}_2\text{ process}**

The photolysis of the pollutant in the presence of \(\text{H}_2\text{O}_2\) is considered to be a practical way to destroy dyes under mild reaction conditions. The \(\text{H}_2\text{O}_2/\text{UV}\) system generates \(\text{OH}^\cdot\) by directly photolysing the peroxide \(\text{HO-OH}\) bond with UV light below 310 nm depending on the peroxide concentration used. Figure (4) presents the decolourization of OG \((50\ \text{mg L}^{-1})\) in presence of \(\text{H}_2\text{O}_2\) \((10^{-2}\ \text{M})\), as a function of time. The visible band at 476 nm was observed to disappear very fast in 30 min and tend to zero after 30 min, the UV band at 332 nm was also observed to vanish, but at a lower rate than that of visible band.

**Figure 4:** Decolourization of OG in the presence of \(\text{H}_2\text{O}_2\) as a function of time. Reaction conditions: \([\text{dye}]_o = 50\ \text{mg L}^{-1}, [\text{H}_2\text{O}_2]_o = 10^{-2}\ \text{M}, \ \text{pH}_o = 5.8, \ \lambda_{irr} = 254\ \text{nm}\). In insertion: Comparison of degradation rate of color and aromatic fragment. Reaction conditions: \([\text{dye}]_o = 50\ \text{mg L}^{-1}, [\text{H}_2\text{O}_2]_o = 10^{-5}\ \text{M}, \ \lambda_{irr} = 254\ \text{nm}\)
To make a clear comparison of rates of color and aromatic fragment degradation, the absorbance of OG solution at 476 and 332 nm as a function of time were measured and are available (inserted figure 3). It was clearly observed that the absorption peak at 476 nm diminished very fast and nearly completely disappeared under 20 min of H$_2$O$_2$ oxidation. This indicated a complete decolouration of OG (50 mg L$^{-1}$) which can be achieved in 20 min in the presence of $10^{-2}$ M H$_2$O$_2$. The ultraviolet band at 332 nm was also observed to gradually diminish but at a lower rate than that of visible bands, which indicated the destruction of the naphthalene rings.

As reported in the literature $^{[22-23]}$, OH$^\bullet$ radicals can react with most organic compounds by hydrogen abstraction or addition to double bonds. Thus, in case of OG, OH$^\bullet$ radicals first attack azo groups and open the N=N bonds, destructing the long conjugated $\pi$ systems and consequently causing decolourization. In addition, owing to the fact that N=N bonds are easier to be destructed than aromatic ring structures.

**Kinetics of decolourization**

The effect of hydrogen peroxide shows the concentration of OG as a function of reaction time when different concentration of H$_2$O$_2$ was used (Figure 5). As it can be seen, the effect of increasing [H$_2$O$_2$]$_o$ from $5 \times 10^{-4}$ M to $5 \times 10^{-2}$ M was first positive for the degradation of OG. The increase of H$_2$O$_2$ concentration generates more hydroxyl-free radicals, which causes dye discoloration. However, further increases in H$_2$O$_2$ concentration above certain limits (critical concentration) will not increase the rate of dye destruction as it acts as a hydroxyl radical scavenger instead of a free-radical generator $^{[24-25]}$.

![Figure 5](image)

**Figure 5:** Effect of initial H$_2$O$_2$ concentration on the degradation of OG. [dye]$_o$ = 50 mg.L$^{-1}$, $\lambda_{ir}$=254 nm
Generally, the degradation rate of organic compounds increases as the \( \text{H}_2\text{O}_2 \) concentration increases until a critical \( \text{H}_2\text{O}_2 \) concentration is achieved.

It can be postulated that \( \text{H}_2\text{O}_2 \) should be added at an optimum concentration to achieve the best degradation; hence \( 10^{-2} \text{ M} \) of \( \text{H}_2\text{O}_2 \) concentration appears to be an optimum dosage for 50 mg. l\(^{-1}\) of OG in \( \text{H}_2\text{O}_2/\text{UV} \) process. The efficiency of this system was verified on several organic compounds \(^{[4,26-27]}\).

**\( \text{UV/S}_2\text{O}_8^{2-} \) process**

Persulfate ions in the presence of ultraviolet (UV) light are able to oxidize many organic substances. In this study, the effect of persulphate ion on the degradation of the OG was investigated (concentration of Na\(_2\)S\(_2\)O\(_8\) : \( 5 \times 10^{-4} \) to \( 5 \times 10^{-2} \)). The figure (6) shows that the percentage degradation of the dye increased with increasing amount of persulfate ion concentration and achieved 98.57 % degradation within 7 min irradiation time with \( 5 \times 10^{-2} \text{ M} \) persulfate ion concentration instead of 16.52 % degradation in the presence of \( 5 \times 10^{-4} \text{ M} \) of persulfate ion at the same time.

![Figure 6: Effect of initial S\(_2\)O\(_8^{2-}\) concentration on the degradation of OG. [dye]\(_o\) = 50 mg.L\(^{-1}\), pH\(_o\) = 3.4, \( \lambda_{irr}=254 \text{ n} \)](image)

Photolysis of S\(_2\)O\(_8^{2-}\) produces two sulfate radical anions (Eq.3), which are strongly oxidizing species (\( E^o = 2.6 \text{ eV} \)), generating a very reactive ion radical: \( \text{SO}_4^{-} \) which is able to engage in the following three possible modes of reactions with organic compounds: (i) by abstracting a hydrogen atom from saturated carbon. (ii) by adding to unsaturated or aromatic carbon and (iii) by removing one electron from the carboxylate anion and from certain neutral molecules \(^{[28]}\). In addition, it can trap the generated hydroxyl radical according to the equation (Eq.5)

\[
S_2O_8^{2-} + h\nu \rightarrow 2SO_4^{-} \quad (3)
\]

\[
S_2O_8^{2-} + M \rightarrow 2SO_4^{-} + M^* \quad (4)
\]

(\( M \) represents organic compounds)

\[
SO_4^{-} + H_2O \Leftrightarrow OH^* + HSO_4^- \quad (5)
\]
The formation of hydroxyl radical and sulphate radical anion (Eq. 3, 4 and 5) are powerful oxidants that can degrade the dye molecules at faster rate. The $SO_4^{2-}$ has the unique nature of attacking the dye molecule at various positions and hence the fragmentation of the dye molecules is rapid [29].

$$SO_4^{2-} + \text{dye} \rightarrow SO_4^{2-} + \text{dye}^{+} \rightarrow \text{(intermediate)} \quad (6)$$

$$SO_4^{2-} + \text{dye}^{+} \rightarrow SO_4^{2-} + \text{CO}_2 + \text{HNO}_3 + \text{other – inorganics} \quad (7)$$

**Fenton and photo-Fenton processes**

To render the Fenton and photo-Fenton processes competitive with other processes, it is essential that their applications represent a low cost operation, which basically implies a better control of H$_2$O$_2$ dosage. Figure 7 shows the concentration of OG as a function of reaction time when different concentrations of H$_2$O$_2$ were used. As it can be seen, the effect of increasing [H$_2$O$_2$]$_o$ from 10$^{-4}$ M to 10$^{-2}$ M was first positive for the degradation of OG.

**Figure 7:** Effect of initial H$_2$O$_2$ concentration on the degradation of OG during Fenton and photo-Fenton oxidation treatment after 10 min. Reaction conditions: [dye]$_o$ = 50 mg.L$^{-1}$, [Fe$^{2+}$]$_o$ = 5 x 10$^{-6}$ M, pH$_o$ =3, $\lambda_{irr}$ =254 nm. In insertion Effect of initial Fe$^{2+}$ concentration on the degradation of OG during Fenton and photo-Fenton oxidation treatment after 10 min. Reaction conditions: [dye]$_o$ = 50 mg.L$^{-1}$, [H$_2$O$_2$]$_o$ = 10$^{-5}$ M, pH$_o$ =3, $\lambda_{irr}$ =254 nm.

This is due to the oxidation power of Fenton process which was improved with increasing OH$^*$ radical amount in solution obtained from the decomposition of increasing hydrogen peroxide. However, with continuous increasing of the initial concentration of H$_2$O$_2$ to 2 x 10$^{-2}$ M and 4 x 10$^{-2}$ M, the degradation rate of OG has
been reduced. This may be explained by the fact that the very reactive OH• radical could be consumed by H2O2 and results in the generation of less reactive HOO• radical (Eq. 8):

\[ \text{H}_2\text{O}_2 + \text{OH}^\bullet \rightarrow \text{HO}_2^\bullet + \text{H}_2\text{O} \]  

(8)

Generally, the degradation rate of organic compounds increases as the H2O2 concentration increases until a critical H2O2 concentration is achieved. However, when a concentration higher than the critical concentration is used, the degradation rate of organic compounds will decrease as a result of the so-called scavenging effect. The optimal H2O2 concentrations for 50 mg L\(^{-1}\) of OG in Fenton and photo-Fenton processes is 10\(^{-2}\) M.

**Effect of the initial Fe\(^{2+}\) concentration**

Amount of ferrous ion is one of the main parameters to influence the Fenton and photo-Fenton processes. To elucidate the role of initial concentration of Fe\(^{2+}\) ([Fe\(^{2+}\)]\(_0\)) on the degradation of OG, a series of experiments were conducted with different [Fe\(^{2+}\)]\(_0\) from 10\(^{-5}\) M to 10\(^{-4}\) M. The results for Fenton and photo-Fenton processes are shown in inserted figure 7 above. From the experimental results it can be seen that decolourization rate of OG distinctly increased with the increasing amount of Fe\(^{2+}\). In the Fenton process, addition of Fe\(^{2+}\) from 10\(^{-5}\) to 10\(^{-4}\) M increases color removal from 14.10 % to 96.72 % at 10 min whereas in photo-Fenton process, the increase is from 82.92 % to 99.93 % for the same time. This is because more OH• radicals are produced with the increase of [Fe\(^{2+}\)]\(_0\) according to Eq. (9)\(^{[30]}\)

\[ \text{Fe}^{2+} + \text{H}_2\text{O}_2 + \text{H}^+ \rightarrow \text{Fe}^{3+} + \text{OH}^\bullet + \text{H}_2\text{O} \]  

(9)

The results show that there is almost no difference between 5 x 10\(^{-5}\) M and 10\(^{-4}\) M of Fe\(^{2+}\) for the dye decolorization during a 10 minutes reaction time for photo-Fenton process. Moreover, many studies have revealed that the use of a much higher concentration of Fe\(^{2+}\) could lead to the self scavenging of OH• radical by Fe\(^{2+}\) (Eq. 10) and inducing finally the decrease in degradation rate of pollutants

\[ \text{OH}^\bullet + \text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{OH}^- \]  

(10)

**S\(_2\)O\(_8\)\(^{2-}\) / Fe\(^{2+}\)/UV process**

Initial concentration of S\(_2\)O\(_8\)\(^{2-}\) plays an important role in the Fe\(^{2+}\)/S\(_2\)O\(_8\)\(^{2-}\)/UV process. Indeed, the effect of addition of persulfate ion (10\(^{-4}\) to 4 \times 10\(^{-2}\) M) on the decolourization of OG has been studied. The results are shown in figure 8. The addition of S\(_2\)O\(_8\)\(^{2-}\) from 10\(^{-4}\) to 4 \times 10\(^{-2}\) M increases color removal from 12.13 to 99.54 % at the time of 5 minutes.
Similarly to the addition of \( \text{S}_2\text{O}_8^{2-} \), the addition of \( \text{Fe}^{2+} \) could enhance the oxidation of OG in the persulfate system (inserted figure 7). As the amount of \( \text{Fe}^{2+} \) increased, we observed that the rate of OG oxidation by persulfate increased.

The efficiency of \( \text{S}_2\text{O}_8^{2-} / \text{Fe}^{2+} \) process is due to the increase in sulfate radical \( \text{SO}_4^{-} \) (Eq. 11), which is a stronger oxidant (\( E^0 = 2.6 \text{ eV} \)) than persulfate, enhancing therefore and significantly the oxidation of contaminants \(^{31-32}\)

\[
\text{S}_2\text{O}_8^{2-} + \text{Fe}^{2+} \rightarrow \text{SO}_4^{-} + \text{Fe}^{3+} + \text{SO}_4^{2-} \tag{11}
\]

Comparison of photodecolourization between different processes

The examination of whole curves, shows the disappearance of the dye in the group of experiments based on photolysis, Acetone/UV and different ATO’s studied in this work. The results obtained showed that the decolouration rate was quite different for each oxidation process.

After 10 min of reaction time, the relative order established was: photolysis < acetone/UV < \( \text{H}_2\text{O}_2/\text{Fe}^{2+} \) < \( \text{H}_2\text{O}_2/\text{UV} \) < \( \text{S}_2\text{O}_8^{2-}/\text{UV} \) < \( \text{H}_2\text{O}_2/\text{Fe}^{2+}/\text{UV} \) < \( \text{S}_2\text{O}_8^{2-}/\text{Fe}^{2+}/\text{UV} \).

This comparison was possible since almost experiments were almost achieved under identical conditions: batch reactors, \([\text{H}_2\text{O}_2]_o = [\text{S}_2\text{O}_8^{2-}]_o = 10^{-2} \text{ M}, [\text{OG}]_o = 50 \text{ mg.L}^{-1}\), same light intensity (254 nm) and [Acetone ] \( 10^{-2} \) and \( 10^{-1} \text{ M} \).

Concerning the photolysis and Acetone/UV, These results can be explained on the basis of the excited state (triplet state) of the substrate which activated the decolorization process comparatively at the direct UV photolysis. On the other site, the
very enhanced decolorization of our substrate by ATO’s is due to the simultaneous contribution of species such as OH• and SO₄²⁻. We observed also that the best efficiency was obtained by S₂O₈²⁻ / Fe²⁺/UV system. This can be attributed to the activation of Fe²⁺ by S₂O₈²⁻ and UV light (254 nm) through the radical SO₄²⁻.

Conclusion

In this study, photochemical methods like direct UV photolysis, Acetone/UV and some AOT’s (Advanced Oxidation Technologies) were investigated for the color degradation of the OG. Each removal was then examined in the basis of the obtained results. Before the utilization of photochemical methods the theoretical spectra was in good enough agreement with the experimental one. The system using acetone/UV provided (concentration of acetone 0.1 M) better results than direct UV photolysis, in the decolouration process of the OG, demonstrating therefore the important role played by the sensitizer. Indeed, the colour was removed completely after an irradiation time of 60 min. However this efficiency was not sufficient by comparison to that obtained by AOT’s. in this condition, the bleaching process was totally reached at 30 min for H₂O₂/Fe²⁺/UV and S₂O₈²⁻/Fe²⁺/UV, which represents then the best performance. On the other hand, by considering the UV visible spectra of OG during its photodegradation par H₂O₂/UV, we can conclude that radicals OH• destroy first the azo group - N=N- ; the aromatic rings being difficult to open.

This work, which was undertaken in a lab scale experiments, could benefit the treatment of real wastewater which remain complicated by the high concentration of dyes and their mixture.

References