

**TREATABILITY STUDY OF THE INDUSTRIAL
EFFLUENT BY ADVANCED OXIDATION
PROCESSES**

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**DEPARTMENT OF CHEMICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
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EFFLUENT BY ADVANCED OXIDATION
PROCESSES**

by

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DEPARTMENT OF CHEMICAL ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled, “**Treatability study of the industrial effluent by advanced oxidation processes**” being submitted by **Mr. Bharadwaj Adiraju** to the Indian Institute of Technology Delhi for the award of **Doctor of Philosophy** is a record of bonafide research work carried out by him under my guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology Delhi.

The research report and results presented in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Water is the life-blood of environment, a precious natural resource and an important input to the industrial activities. By the year 2050, it is expected that more than 2 billion people of the world would live under conditions of high water stress. Keeping the future scenario in focus, immediate steps need to be taken by the utility producers and consumers in industries to optimize consumption, improve quality and maximize the water reuse. The textile industry wastewater varies extensively in terms of composition due to the impurity in fibers and the chemicals used in the different processes. Colouring matter is the major contaminate in the textile effluent and has to be removed before discharging the effluent into aqueous system. Various techniques such as physical, chemical, biological, advanced oxidation and electrochemical are used for the treatment of the industrial effluent. The commonly used conventional biological treatment processes are time consuming, need large operational area and are not effective for the effluent containing toxic elements. In electrocoagulation technique, there is an in-situ generation of the coagulant due to the dissolution of the sacrificial anode by the application of the current between the electrodes. But the cost of electricity and the sacrificial anode can enhance the cost of operation in electrocoagulation.

In the present study, ozonation has been explored for the treatment of the textile industry effluent. Ozonation of the synthetic dye solution containing Acid red 131 mono-azo dye was carried out in a semi-batch reactor. The effect of the ozone dose, the initial dye concentration in the solution and the solution pH on the rate of decolourization was studied and the results were analyzed in terms of colour removal efficiency. The colour removal efficiency was found to increase with an increase in the ozone dose. Alkaline pH of the synthetic dye solution was found suitable for the ozonation and 100 % colour removal efficiency was obtained

after 23 min of ozone treatment at solution pH 11. The colour removal efficiency was found to decrease with an increase in the initial dye concentration of the synthetic dye solution. The results of the kinetic study show that the ozonation of the dye follows a pseudo-first-order reaction with respect to the dye concentration in the solution. Experiments were also performed to remove the dye from the real textile industry effluent by oxidation with ozone and 100% colour removal efficiency was obtained after 110 min. The quantity of ozone and the power consumption for the ozone generation were determined.

The oxidation with ozone in presence of UV light in a solution containing Acid red 131 dye was investigated in batch mode of operation and studied the effect of various operating parameters such as ozone dose, solution pH and initial dye concentration on colour removal efficiency have been studied. The pseudo-first order reaction rate constants were determined for decolourization of Acid red 131 dye oxidation with ozone in presence of UV light at different initial dye concentrations in the solution, ozone dose and the solution pH values. The results did not show remarkable enhancement in colour removal efficiency compared to oxidation with ozone alone.

Ozone in combination with hydrogen peroxide (H_2O_2) was used for the oxidation of a mono-azo dye solution containing Acid red 131 dye. There is no significant enhancement in the colour removal efficiency obtained by oxidation by the combination of ozone and hydrogen peroxide compared to the oxidation with ozone only. The treatment performance of oxidation with ozone and hydrogen peroxide depend on the solution pH. High decolourization in alkaline media (pH = 11) is due to the generation of hydroxyl radicals that have a higher oxidation potential than molecular ozone. The results shows that complete colour

removal was obtained within 20 min, at optimum hydrogen peroxide dose of 41.3 g/L and ozone dose of 12 g/m³.

Oxidation by hydrogen peroxide in presence of UV light, was studied for the decolourization of the synthetic dye solution containing Acid red 131 dye. The CRE obtained by oxidation with hydrogen peroxide was very low (15.8 %). A significant increase in CRE (90 %) was obtained by oxidation with hydrogen peroxide in presence of UV light as the oxidation with hydrogen peroxide needs to be activated by UV light to achieve higher CRE.

The decolourization of the synthetic dye solution containing Reactive blue 19 dye was performed by the Fenton and the photo-Fenton processes. The effect of the dose of the hydrogen peroxide and the ferrous ions and the solution pH on the rate of decolourisation was studied and the optimum conditions were obtained. The maximum colour removal efficiency of 93.3 % and 97.5 % was obtained after 360 min of oxidation at the optimum conditions (solution pH: 3, H₂O₂: 50 g/L, Fe²⁺ 4 mg/L) by the Fenton and the photo-Fenton process respectively. The experimental data was analyzed using the first and second-order and Behnajady- Modirshahla- Ghanbery (BMG) kinetic models and the kinetic data was in good agreement with the BMG model. Experiments were also performed to treat the real textile industry effluent containing the Reactive blue 19 dye and the colour removal efficiency of 84 % and 97 % was obtained after 540 min of the treatment by the Fenton and the photo-Fenton process respectively.

Experiments were conducted to explore the use of ozonation for the treatment of distillery effluent. The experimental results show that the maximum chemical oxygen demand (COD) removal of 90 % was obtained under optimum conditions in 40 min of the ozone

treatment. A maximum COD removal of 43.7 % was obtained after 360 min of oxidation with H₂O₂ only.

It was found from the experimental study that advanced oxidation processes (ozonation, peroxidation, Fenton and photo-Fenton processes) has the potential to be employed for the treatment of industrial effluent (textile dyeing and distillery effluent).

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Abbreviations

| | |
|-----|----------------------------------|
| BOD | Biochemical oxygen demand (mg/L) |
| COD | Chemical oxygen demand (mg/L) |
| DOC | Dissolved organic carbon (mg/L) |
| TDS | Total dissolved solids (mg/L) |
| TOC | Total organic carbon (mg/L) |
| TSS | Total suspended solids (mg/L) |

Nomenclature

| | |
|-------|----------------------------------|
| AOPs | Advanced oxidation process |
| AOX | Absorbable organic halogens |
| C_0 | Initial dye concentration (mg/L) |
| CC | Chemical coagulation |
| CRE | Colour removal efficiency |
| CTC | Chlorotetracycline |
| CWAO | Catalytic wet air oxidation |
| DBP | Disinfection by-products |

| | |
|------|-------------------------------|
| DEET | N,N-diethyl-meta-toluamide |
| ENR | Enrofloxacin |
| GEM | Gemfibrozil |
| NDPP | N-dimethylpropyl-2pyrrolidone |
| UV | Ultraviolet |
| WAO | Wet air oxidation |