Int. J. Chem. Sci.: 11(3), 2013, 1314-1320
ISSN 0972-768X
www.sadgurupublications.com

HYDRODYNAMIC CAVITATION USING DEGRADATION OF REACTIVE ORANGE 4 DYE

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ABSTRACT

In the present work, degradation of reactive orange 4 dye (RO4) has been investigated using hydrodynamic cavitation (HC) reactor. During the experiments carried out that time, these conditions or parameters are followed. The different concentration effects are constant prime operating parameters such as pressure and solution pH at 5 bar and 2, respectively. The degradation of RO4 has obtained higher at concentration of 40 ppm.

Key words: Reactive orange 4, Hybrid techniques, Hydrodynamic cavitation,

INTRODUCTION

Synthetic dyes are present in all spheres of our everyday life and its application is consistently growing[1]. The dye pollutants from the textile industry are a most important of environment pollution. These effluents are toxic and mostly non biodegradable. It is often more important than other colorless organic substances[2-5]. Their removal from water is thus ecologically necessary to offer a cleaner environment as a requirement for human health and has attracted the attention of environmentalists, technologists and entrepreneurs. A variety of physical, chemical and biological methods are presently available for the treatment of wastewater discharged from various industries. These effluents contain large amounts of organic compounds such as textile dyes, aromatic compounds, chlorinated hydrocarbons, and phenolic compounds. The waste water containing colored solution is the source of aesthetic pollution, eutrophication, and perturbation in aquatic life due to organic nature and toxicity. Many types of dyes mostly used in textile and paper industries. Around 50-70% dyes are of azo class dyes[6,7]. The industries involving production and application of dyes in the waste water, poses the major threat to the surrounding ecosystems due to health hazards

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caused by toxicity[8]. The different conventional methods are available for the treatment of wastewater, such as the biological treatment methods (aerobic and anaerobic), adsorption, coagulation and flocculation. The main problem is associated with the commonly used and cost effective biological treatment methods. The biological methods are not able to completely degrade the dye effluent because the complex and refractory nature of dye molecules. The other methods are available such as coagulation/flocculation and adsorption do not involves the chemical transformation and therefore generally transfer waste components from one phase to another[9,10].

Therefore, to find the other effective treatment or methods that can degrade complex bio-refractory molecules. The further degradation are using other conventional methods, also improving its efficiency. The alternative methods are involving the chemical transformation of organic pollutants by oxidation into CO_2, H_2O, etc. as end products. In hydroxyl radicals ($^{\bullet}OH$) are generated and it has higher oxidation potential. The hydroxyl radicals ($^{\bullet}OH$) oxidize organic pollutants present in wastewater[11]. Various AOPs have been used by many researchers for the waste water treatment such as Fenton oxidation, cavitation, H_2O_2, electrochemical oxidation, photolysis, etc.

Cavitation is one such recent technique, which has been extensively studied for the treatment of wastewater. Cavitation is ability of degradation of organic pollutant than the other conventional methods. Cavitation is defined as the phenomena of formation, growth and collapse of micro-bubbles or cavities, where this process occurs in a few milliseconds and at multiple locations in the reactor and thus releasing large magnitude of energy[12,13]. In Hydrodynamic cavitation (HC), cavities are formed due to pressure variation in the flowing liquid, by change in the flow area such as venture, orifice plate etc.[14] According to the Bernoulli principle, when the liquid passes through the constriction such as venturi, the kinetic head increases at the expenses of pressure head. If the throttling of the constriction is sufficient, the pressure at the throat of the venturi equals or falls below the vapor pressure of the liquid and thus the vaporous cavities are formed. The collapse of these micro bubbles/cavities, generates localized ''hot spots'' with transient temperature of the order of 10,000 K and pressures of about 1000 atm[12]. During these conditions water molecules are dissociated into $^{\bullet}OH$ and $H^{\bullet}$ radicals. $^{\bullet}OH$ radicals react with organic pollutant and oxidize/mineralize them.

In the present work, the venturi is the cavitating devices. The degradation of RO4 has been carried out using HC. The aim of this study was to explore the possibility of HC for the degradation of RO4.

EXPERIMENTAL

Materials and methods

RO4 dye (molecular weight: 781.47 g/mol; molecular formula: $C_{24}H_{13}Cl_2N_6Na_3O_{10}S_3$; λ_{max} : 490 nm). The chemical structure of RO4 is shown in Fig. 1. The solution of RO4 was prepared in tap water for all the experiments. H_2O_2 (30% w/v), sodium hydroxide (NaOH) and sulphuric acid (H_2SO_4) of AR grade are used.

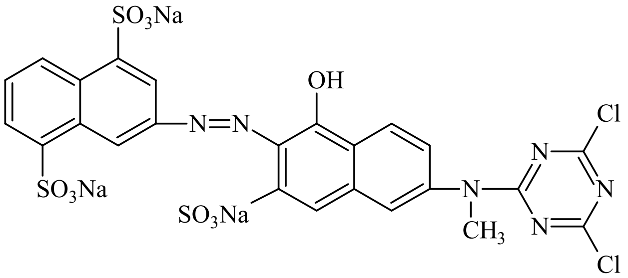

Fig. 1: Chemical structure of RO4

Experimental setup and methodology

The experimental setup is shown in Fig. 2. The setup includes a holding tank of 15 L volume, a positive displacement pump, control valves (V1, V2, and V3), flow meter, and pressure gauges. The suction side of the pump is connected to the bottom of the tank and discharge from the pump branches into two lines: the main line and a bypass line. The main line houses cavitating device.

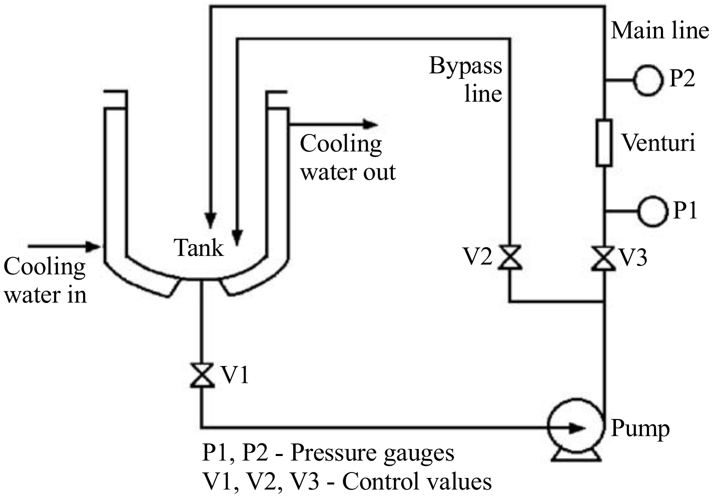

Fig. 2: Schematic representation of HC reactor set-up

The degradation using HC was carried out using circular venturi as a cavitating device. The study degradation of RO4 was conducted using HC alone at inlet pressure (5 bar) and solution pH (2) to establish the optimum conditions for getting maximum possible degradation using HC. The pH of the solution was maintained by adding appropriate quantity of H_2SO_4 and NaOH. 5 L solution RO4 was taken in HC reactor, and total circulation time was 120 min taken. The sample taken was regular interval of 15 min and analyzed the extending of decolourization. The collected samples were analyzed using UV-Spectrophotmeter to observe a change in the absorbance of RO4 with time.

RESULTS AND DISCUSSION

Degradation kinetics

The degradation of RO4 in aqueous solution by using hydrodynamic cavitation was investigated. It was found that concentration of RO4 in aqueous solution decreased exponentially with reaction time, rate of degradation of RO4 can be obtained by the following equation.

$$\ln \frac{C_{Ao}}{C_A} = kt \qquad \ldots(1)$$

Where C_A is the concentration of RO4 at time t, C_{A0} is the initial concentration of RO4, k is the rate constant and t is the time of degradation. This result indicated that the degradation of RO4 follows a first order kinetics (Fig. 3).

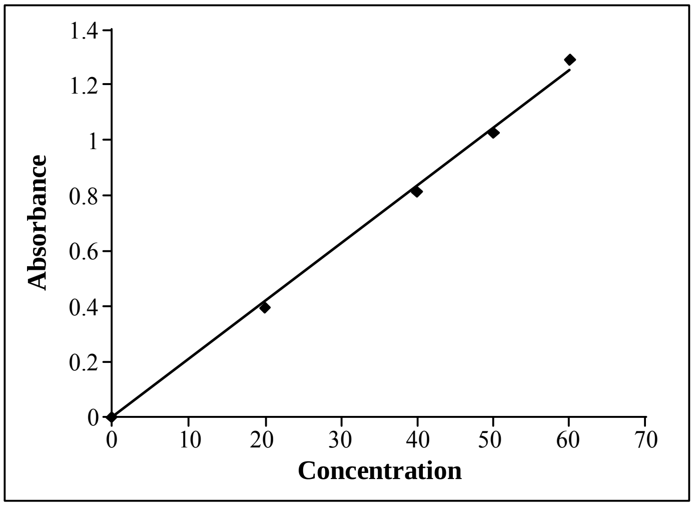

Fig. 3: First order kinetics of RO4 using HC at pressure 5 bar and pH 2

Effect of initial concentration

The degradation of RO4 has been studied at different concentrations at constant pressure and solution of pH such as 5 bar and 2, respectively. The experiment carried out at different concentrations of RO4 solution (20, 40, 50, 60 ppm). The rate constant and the extent of decolourization of RO4 at different concentrations are tabulated in Table 1.

Table 1: Decolourization rate constant, k and extent of decolourization at various concentrations using HC

Concentration (ppm)	% Decolourization in 120 min	$k \times 10^3$ min^{-1}
20	74.56	17.26
40	34.03	4.73
50	28.07	3.54
60	20.57	2.34

The maximum decolourization of 34.03% in 120 min of operation time with rate constant of 4.73×10^{-3} min^{-1} was observed. Here concentration study has find out optimum concentration, 40 ppm is the optimum concentration. In 20 ppm concentration study has better result than the 40 ppm, but 20 ppm concentration is very small amount of dye concentration in waste water or organic pollutant, so here 40 ppm consider as optimum concentration. The result obtained shown in Fig. 4 and 5. In Fig. 4, the ln (C_{a0}/C_a) vs time and in Fig. 5 the concentration (ppm) vs time is shown.

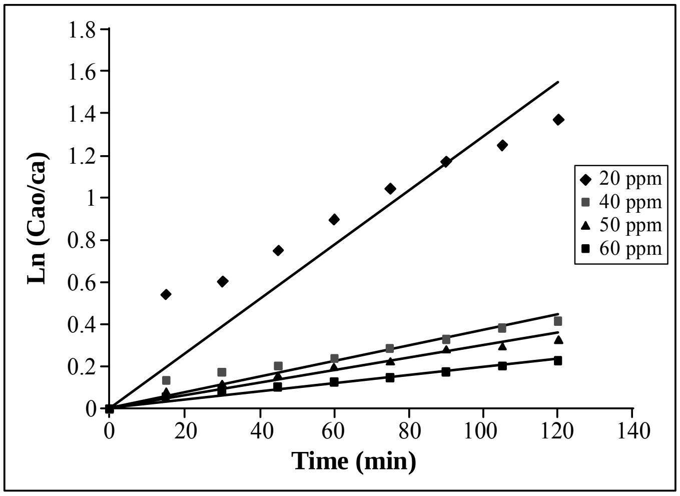

Fig. 4: First order decolourization rate of RO4 using HC at pressure 5 bar and pH 2

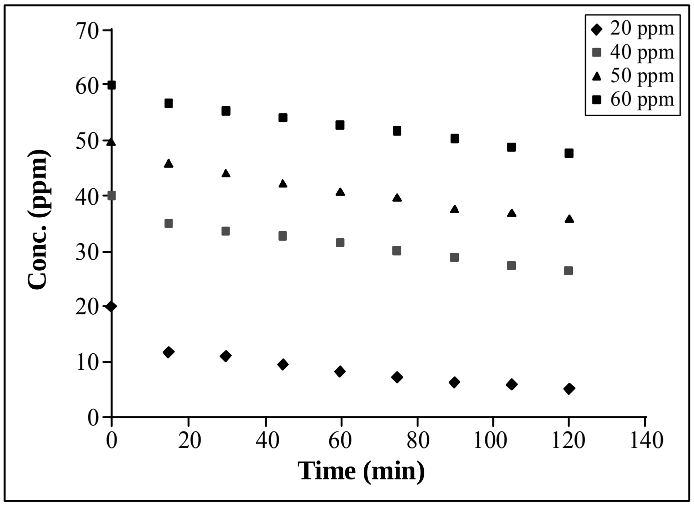

Fig. 5: Concentration of RO4 profile with time using HC at pressure 5 bar and pH 2

CONCLUSION

The present work has shown that RO4 dye can be effective degraded by hydrodynamic cavitation and this degradation followed first order reaction kinetics. Hydrodynamic cavitation is favored under different concentrations, constant operating parameters such pressure and solution of pH, 5 bar pressure and 2, respectively. The maximum degradation of RO4 was 34.03 % and its rate constant was found 4.73×10^{-3} min^{-1}.

REFERENCES

1. C. Zhu, L. Wang, L. Kong, X. Yang, L. Wang, S. Zheng, F. Chen, F. Mai Zhi and H. Zong, Chemosphere., **41**, 303 (2000).
2. H. Chun and W. Yizhong, Chemosphere, **39**, 2107-2115 (1999).
3. S. Ledakowicz, M. Solecka and R. Zylla, J. Biotechnol., **89**, 175-184 (2001).
4. S. Ledakowicz and M. Gonera, Water Res., **33**, 2511-2516 (1999).
5. J. Grzechulska and A. W. Morawski, Appl. Catal., B **36**, 45-51 (2002).
6. G. L. Baughman and E. J. Weber, Transformation of Dyes and Related Compounds in Anoxic Sediments: Kinetics and Products, Environ. Sci. Technol., **28**, 267-276 (1994).

7. S. Papić, D. Vujević, N. Koprivanac, D. Ŝinko, Decolourization and Mineralization of Commercial Reactive Dyes by using Homogeneous and Heterogeneous Fenton and UV/Fenton Processes, J. Hazard. Mater., **164**, 1137-1145 (2009).

8. R. Nilsson, R. Nordlinder, U. Wass, B. Meding and L. Belin, Asthma, Rhinitis and dermatitis in Workers Exposed to Reactive Dyes, Br. J. Ind. Med., **50**, 65-70 (1993).

9. S. Papić, D. Vujević, N. Koprivanac and D. Ŝinko, Decolourization and Mineralization of Commercial Reactive Dyes by using Homogeneous and Heterogeneous Fenton and UV/Fenton Processes, J. Hazard. Mater., **164**, 1137-1145 (2009).

10. M. S. Lucas and J. A. Peres, Decolorization of the Azo Dye Reactive Black 5 by Fenton and Photo-Fenton Oxidation, Dyes Pigm., **71**, 236-244 (2006).

11. Y. G. Adewuyi, Sonochemistry in Environmental Remediation, 2. Heterogeneous Sonophotocatalytic Oxidation Processes for the Treatment of Pollutants in Water, Environ. Sci. Technol., **39**, 8557-8570 (2005).

12. Y. T. Didenko, W. B. McNamara and K. S. Suclick, Hot Spot Conditions During Cavitation in Water, J. Am. Chem. Soc., **121**, 5817-5818 (1999).

13. J. P. Lorimer and T. J. Manson, Sonochemistry Part 1- The Physical Aspects, Chem. Soc. Rev., **16**, 239-274 (1987).

14. P. R. Gogate and A. B. Pandit, Engineering Design Methods for Cavitation Reactors II: Hydrodynamic Cavitation, AIChE J., **46**, 1641-1649 (2000).

Revised : 29.06.2013 *Accepted : 30.06.2013*