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Mob: +92 300 3008585, Fax: +92 41 8815544

E-mail: editorpjn@gmail.com

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Advanced Oxidative Removal of C.I. Food Red 17 Dye from an Aqueous Solution

Irfan Ahmed Shaikh[1], Soniya Munir[1], Farooq Ahmed[2], Tanveer Hussain[3] and Iftikhar Ahmad[1]
[1]College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan
[2]Department of Textile Engineering, Mehran University of Engineering and Technology, Jamshoro, Pakistan
[3]National Textile University, Faisalabad, Pakistan

Abstract: Food colours are extensively used in food processing industries and their discharge as coloured effluents has become a critical issue. This study investigated an efficient method of removing C.I. Food Red 17 dye from an aqueous solution using Ozone (O_3) as an Advanced Oxidation Process (AOP). Ozonation at varied doses, pH and temperatures yielded significant reduction of colour and COD values. An ozone dose of 300 mg/h at pH 7, 9 and 11 yielded more than 90% decolourization in 60, 50 and 20 min of treatments, respectively. Optimal process conditions for set of experiments pertaining to varied dye concentration showed 95% colour removal for 100 ppm dye concentration in 40 min of ozonation using 300 mg/h ozone dose at pH 11. Ozonation at low temperature (30°C) resulted 85% COD removal and 99% decolourization. The study concluded that ozone oxidation is an environmental friendly treatment technique which can remove colour and COD from wastewater to an extent which can make it reusable.

Key words: Ozone, food dye, wastewater, colour, COD, effluent treatment

INTRODUCTION

Food processing industries are considered hostile to the natural environment because they usually discharge large quantities of effluents containing substantial amount of organic load which make them difficult-to-treat waste waters. Food dyes are extensively used in fruit juices, powdered beverages, sweets, dairy products, chewing gums, bakery products, fruits and vegetables, desserts, soups, sauces, pharmaceutics and cosmetic products (Hale, 2014). As a result, wastewater from such industries is always coloured (Downham and Collins, 2000).

The reaction of dyes with food product is not complete and considerable portion of dyes remain in the wastewater discharge (Koprivanac and Kusic, 2008). The food dyes are usually acid dyes and their chemical structures are usually based on substituted aromatic rings which are connected by one or more azo groups such as -C = C-, -N = N-, -C = O, -C = N- (Chen *et al*., 2004). The dye residues in water are not only objectionable pollutant on aesthetic grounds, but they also interfere with the transmission of light required for photosynthesis and upset the biological metabolism processes, which cause the destruction of aquatic life and ecosystem (Gupta, 2009). Consequently, environmental regulations compel food industry to treat coloured wastewater before discharge.

Several different techniques based on chemical, physical and biological principles have been studied for the treatment of waste waters that contain food dyes, such as precipitation, coagulation, flocculation, flotation, filtration, oxidation and ion exchange (Crini and Badot, 2008; Martin *et al*., 2013; Xue *et al*., 2012; Dotto *et al*., 2012). Among these, advanced oxidation processes (AOPs) are regarded an alternative, eco-friendly and efficient technologies in relation to the existing slow and expensive treatment methods due to quick and complete removal of dyes from wastewater (Sreethawong and Chavadej, 2008; Tiwari *et al*., 2009; Torres *et al*., 2011). Ozone as an important member of AOPs family was used in this investigation for the removal of food colour from an aqueous solution. Ozone is thermodynamically unstable gas and quickly reacts with most organic compounds. In an aqueous solution, ozone can react with variety of materials (M) in two possible ways: firstly, through direct action of molecular ozone and secondly through reaction with radical species (Langlais *et al*., 1991). The two important reactions of ozone in water are displayed in Fig. 1.

Results obtained in this study showed that the use of ozone in the decolourization of C.I. Food Red 17 dye is a feasible solution for water treatment and its possible reuse.

MATERIALS AND METHODS

Food dye characteristics: The commercial food azo dye, C.I. Food Red 17, w as obtained from a local chemical store and used without further purification. Its purity, molecular weight and molecular formula are 85%, 496 and $C_{18}H_{14}N_2Na_2O_8S_2$, respectively. The maximum absorption (λ_{max}) of the dye was recorded at 500 nm wavelength. The stock solutions of known

Corresponding Author: Irfan Ahmed Shaikh, College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan

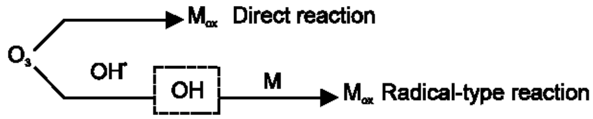

Fig. 1: Reactivity of ozone in water

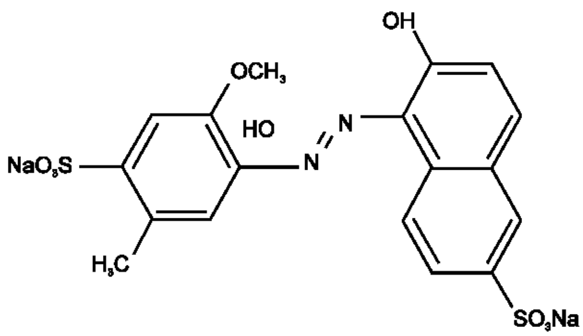

Fig. 2: Chemical structure of C.I. food red 17

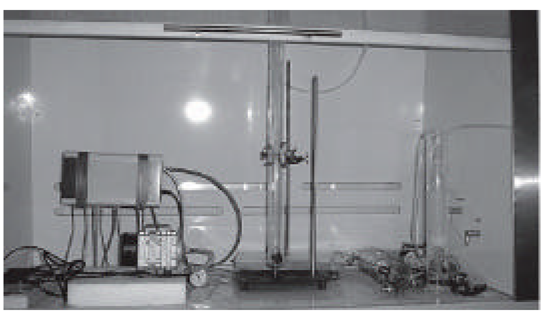

Fig. 3: Experimental set-up for ozone COD and colour removal

concentrations (100-300 ppm) of dyes were prepared by dissolving in distilled water and filtration through Millipore filter 0.45 µm. The chemical structure of the dye is shown in Fig. 2.

Ozonation of C.I. food red 17: Ozone oxidation was performed in bubble column reactor with an internal diameter of 3.3 cm. Ozone was generated in JQ-6M PURETECH ozone generator to produce ozone from air and was injected at the bottom of the reactor via stone diffuser at an ozone production rate of 500 mg/h. Fig. 3 shows the experimental set-up. Ozone dose varied from 100 to 500 mg/h. The influence of pH (7 to 11) and temperature (25 to 60°C) was also observed using at constant ozone dose of 300 mg/h. All experiments were carried out on a 200 mL sample in a batch mode. Aqueous solutions of C.I. Food Red 17 having varied dye concentrations at varied ozone doses, exposure time, temperature and pH were treated in this experimental set-up.

Assessment of COD and colour: Tests to find COD (chemical oxygen demand) values in the aqueous solution before and after ozone treatment was carried out using potassium dichromate and sulfuric acid at 150°C for 2 h according to Hach method no. 8000. The colour of the aqueous solution was determined by Perkin Elmer UV/Vis spectrophotometer Lambda 25 for maximum absorbance at the characteristic wavelength specific to each dye. The percentage colour removal (%) removal or decolourization was calculated using the following relationship:

$$D\,(\%) = \frac{A_0 - A_t}{A_0} \times 100$$

where, D: Decolorization (%), C_0: Initial absorption of dye, C_t: Absorption of dye at time t.

RESULTS AND DISCUSSION

Effect of pH: The effect of varied pH on decolorization of C.I. Food Red 17 by ozone is presented in Fig. 4. From this figure, it was evident that maximum colour removal efficiency (90-100%) for pH 7, 9 and 11 were 60, 40 and 30 min, respectively. For shorter time ozone exposure, the colour removal efficiency (%) increases with the increase in pH. At neutral pH value of 7, the maximum colour removal of 91% was observed in 60 min of ozonation, whereas at pH 9 and 11, the same colour removal efficiency could be attained within 30 min.

Effect of dye concentration: The influence of dye concentration on colour removal efficiency is shown in Fig. 5. From this figure it is observed that maximum colour removal efficiencies in the range of 90-100% can be achieved for all concentrations of dye studied. To achieve 90% or greater colour removal efficiency at these dye concentrations, i.e., 100, 200 and 300 ppm, the ozonation timings taken were 30, 50 and 60 min, respectively. It was noticed that an increase in dye concentration from 100 to 300 mg/L had yielded low decolorization efficiency at shorter time intervals. From this data, it was clearly noticed that dye degradation rate varied considerably with dye concentrations. The results correlated with other studies (Srinivasan *et al.*, 2009; Colindres *et al.*, 2010).

Effect of temperature on COD and colour removal: Figure 6 displays the influence of temperature on the efficiency of ozone for COD and colour removal of aqueous solution containing 200 ppm of C.I. Food Red 17 dye at pH 11. Temperature of aqueous solution was maintained between 30 to 60°C and complete colour removal 99 and 84% COD removal were achieved at 30°C. Both COD and colour removals gradually decreased with an increase in temperature from 30 to 60°C. These results could be attributed to the occurring of two simultaneous effects, increase in the rate constant of the reaction and the indirect effect through the variation of ozone solubility with temperature.

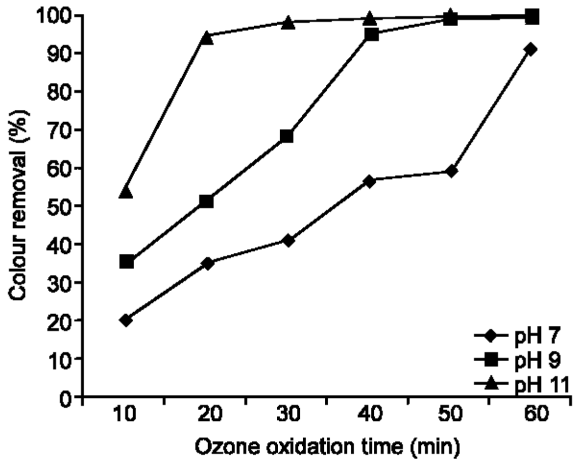

Fig. 4: Effect of pH on colour removal efficiency

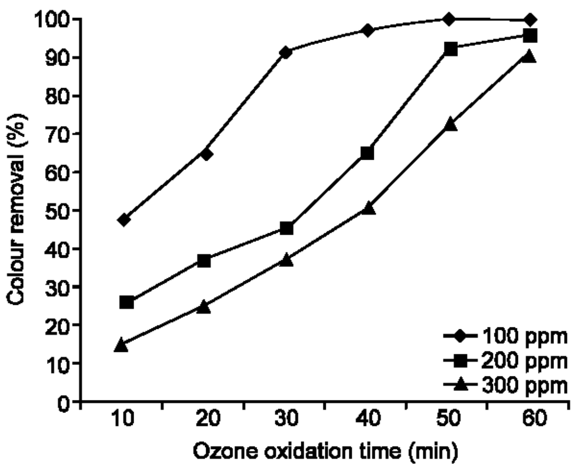

Fig. 5: Effect of dye concentration on colour removal efficiency

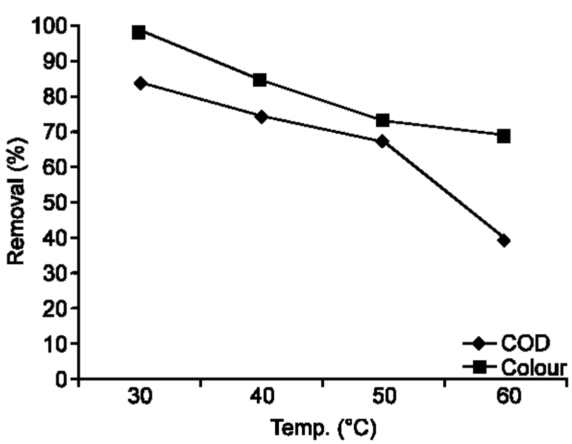

Fig. 6: Effect of temperature on colour removal efficiency

Because of increase in the temperature of aqueous solution, solubility of ozone gas decreases, thus reducing the amount of ozone available for the reaction, which may result in reduced degradation of C.I. Food Red 17 dye. Results do correlates with the findings of similar work (Wu and Wang, 2001; Meijers *et al.*, 1995).

Conclusion: From this experimental study, it was concluded that ozone oxidation was an efficient method for decolorization of dye used in food industry. The efficiency of the ozonation process was further increased at increased pH. The ozonation of the studied C.I. Food Red 17 dye solution for relatively short treatment times, 20 min at pH 11 for instance, appears to be sufficient to achieve almost 100% colour removal. It was observed that pH and dye concentrations played an important role in decolorization of C.I. Food Red 17 dye. Aqueous solutions with high pH values and low dye concentrations were decolourized quicker and more rapidly. Temperature indicated an adverse impact on the removal efficiency of COD and colour because as an increase in temperature (>30°C) was accompanied by reduced COD and colour degradation.

REFERENCES

Chen, H., R.F. Wangand and C.E. Cerniglia, 2004. Molecular cloning, over expression, purification and characterization of an aerobic FMN dependent azoreductase from Enterococcus faecalis. Protein Exp. Purifl, 34: 302-310.

Colindres, P., H. Yee-Madeira and E. Reguera, 2010. Removal of Reactive Black 5 from aqueous solution by ozone for water reuse in textile dyeing processes, Desalination, 258: 154-158.

Crini, G. and P.M. Badot, 2008. Application of chitosan, a natural aminopolysaccharide, for dye removal from aqueous solutions by adsorption processes using batch studies: a review of recent literature. Prog. Polym. Sci., 33: 399-447.

Dotto, G.L., E.C. Lima and L.A.A. Pinto, 2012. Biosorption of food dyes onto spirulina platensis nanoparticles: Equilibrium isotherm and thermodynamic analysis, Bioresour. Technol., 103: 123-130.

Downham, A. and P. Collins, 2000. Coloring our food in the last and next millennium. Int. J. Food Sci. Technol., 35: 5-22.

Gupta, V.K., 2009. Application of low-cost adsorbents for dye removal: A Rev. J. Environ. Manage., 90: 2313-2342.

Hale, S., 2014. Removal of FD and C red no.40 food dye from an aqueous solution by vine-trimming waste, I.J.C.E.A., 5: 420-423.

Koprivanac, N. and H. Kusic, 2008. Hazardous organic pollutants in colored wastewaters, New Science Publishers, New York.

Langlais, B., D.A. Reckhow and D.R. Brink, 1991. Ozone in water treatment, applications and engineering. Chelsea, MI, Lewis Publishers, Inc.

Martin, D.F., R.J. Alessio and C.H. Mccane, 2013. Removal of synthetic food dyes in aqueous solution by Octolig, J. Environ. Sci. Health, Part A: Toxic/Hazardous Substances and Environ. Eng., 48: 495-500.

Meijers, R.T., E.J. Oderwald-Muller, P.A.N.M. Nuhn and J.C. Kruithof, 1995. Degradation of pesticides by ozonation and advanced oxidation. Ozone Sci. Eng., 17: 673.

Sreethawong, T. and S. Chavadej, 2008. Color removal of distillery wastewater by ozonation in the absence and presence of immobilized iron oxide catalyst. J. Hazard. Mater., 155: 486-493.

Srinivasan, S.V., T. Rema, K. Chitra, K. Sri Balakameswari, R. Suthanthararajan, B. Uma Maheswari, E. Ravindranath and S. Rajamani, 2009. Decolourisation of leather dye by ozonation, Desalination, 235: 88-92.

Tiwari, B.K., C.P. O'Donnell, K. Muthukumarappan and P.J. Cullen, 2009. Anthocyanin and colour degradation in ozone treated blackberry juice, Innov. Food Sci. Emerg. Technol., 10: 70-75.

Torres, B., B.K. Tiwari, A. Patras, Hilde H. Wijngaard, N. Brunton, P.J. Cullen and C.P. O'Donnell, 2011. Effect of ozone processing on the colour, rheological properties and phenolic content of apple juice, Food Chem., 124: 721-726.

Wu, J. and T. Wang, 2001. Ozonation of aqueous azo dye in a semibatch reactor. Water Res., 35: 1093-1099.

Xue, H.Y., F. Han and B.Y. He, 2012. Biosorption of food dye onto gelatine microspheres. Equilibrium isotherm and thermodynamics analysis. Adv. Mater. Res., 476: 2239-2242.