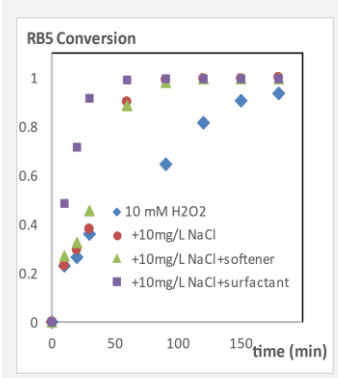
Hydrodynamic cavitation for degradation of a reactive dye: influence of auxiliaries

ORAL
Ph.D. Student: N
Journal: JECE

***M.A. Ayude*[1,2]**, *S. Napoleone*[3,4], *S. Fleite*[3,4,5], *L. Doumic*[1,2],. *M. Cassanello*[3,4] *(1) Departamento de Ingeniería Química y de Alimentos, Universidad Nacional de Mar del Plata (UNMdP), Argentina, mayude@fi.mdp.edu.ar (2) División Catalizadores y Superficies, Instituto de Investigaciones en Ciencia y Tecnología de Materiales (INTEMA) – CONICET/UNMdP, Argentina (3) Instituto de Tecnología de Alimentos y Procesos Químicos (ITAPROQ) – CONICET/Universidad de Buenos Aires, Argentina (4) Laboratorio de Reactores y sistemas para la Industria (LARSI), Departamento de Industrias, FCEyN, Universidad de Buenos Aires, Argentina (5) Cátedra de Química Inorgánica y Analítica, Facultad de Agronomía, Universidad de Buenos Aires, Argentina.*



Reactive dyes are recalcitrant compounds strongly resistant to biodegradation and oxidations. Different Advanced Oxidation Processes (AOPs) have been applied to discolor and degrade these type of dyes. Degradation of Reactive Black 5 (RB5), an extensively used dye, has been studied as a benchmark to test different AOPs. In this work a vortex-type hydrodynamic cavitation device is used to analyze the feasibility of degrading RB5 from a simulated textile effluent. Complete discoloration of RB5 aqueous solutions can be attained after 5 h using 10mM hydrogen peroxide. Discoloration rate is strongly enhanced after addition of the amount of salt remaining in the real effluent. Mineralization attained with hydrodynamic cavitation is also increased by salt addition. Other common auxiliaries used, a softener and a surfactant, do not decrease the efficiency of hydrodyamic cavitation for RB5 disoloration.

Introduction

Reactive Black 5 (RB5) is extensively used in textile industries due to its applicability both in natural and synthetic fibers. It contains functional groups able to form covalent bonds with the fibers [1], making it very resistant to oxidations. Moreover, it is recalcitrant to biodegradation and highly soluble in water, so it may easily reach and contaminate the receiving water courses. Many techniques have been developed to remove dyes remaining in textile wastewaters to attenuate their negative impact on the environment. Advanced oxidation processes (AOPs) like Fenton, sonoFenton, dielectric discharge and supported iron based magnetic particles with peroxymonosulfate have been applied for RB5 degradation [2-4]. Combined processes including photocatalysis, iron assisted sono-photo catalysis and electrochemical oxidation [1,5,6] have shown to be successful in achieving RB5 discoloration and mineralization. During the dyeing process, apart from the dye, other auxiliaries are used. Significant amount of salt (NaCl), surfactants and softeners are added to the dying cube at different stages, which partially remain in the wastewater with the excess dye. However, the effect of these additional compounds has been scarcely examined.
Hydrodynamic cavitation is an AOP that has been used to remove recalcitrant organic compounds. Although discoloration is generally attained without reactants addition, hydrogen peroxide is frequently used to promote mineralization by enhancing the amount of hydroxyl radicals' formation rate. Different cavitation devices have been used. Among the ones without moving parts, the vortex type cavitation developed by Ranade [7] generally provides excellent degradation rates with lower pressure drop and with low effect on the equipment material, since the cavitation is promoted far from the wall.

In this work, the feasibility of removing RB5 from a model solution using a vortex type cavitation device has been examined. The effect of adding auxiliaries (salt, softener, and surfactant with the proportion measured in the real effluent) has been analyzed.

Material and Methods

Hydrodynamic cavitation was attained using a 6mm throat diameter vortex-type cavitation device procured from Vivira Process Technology Ltd. Experiments in the cavitation unit were performed at 3.5 bar pressure loss. The solution was recirculated from a 3.5 L tank using a 1 HP centrifugal pump. The temperature in the cavitation system was kept around 323 K.
The reactive black 5 (RB5) dye, the softener and the surfactant used were provided by a local textile industry. NaCl p.a. and distilled water were used for experiments to avoid the influence of impurities.

Results and Discussion

RB5 was efectively discoloured by hydrodynamic cavitation in the vortex-type cavitator using pressure drops across the cavitation device from 2 bars. Figure 1 illustrates the RB5 conversion determined from the absorbance at the peak wavelength, when using different concentrations of hydrogen peroxide around the stoichiometric value (10mM). Half or double concentrations led to worsen the dye discolouration. Hydrogen peroxide is consumed up to 90% (not shown) for concentrations below 10mM while less than 30% conversion is reached for 20mM, resulting in lower discoloration rate.
When sodium chloride was added to the RB5 solution in concentrations resembling those measured in the real effluent, the discoloration was markedly enhanced. Total discoloration was attained before 90 minutes even for the

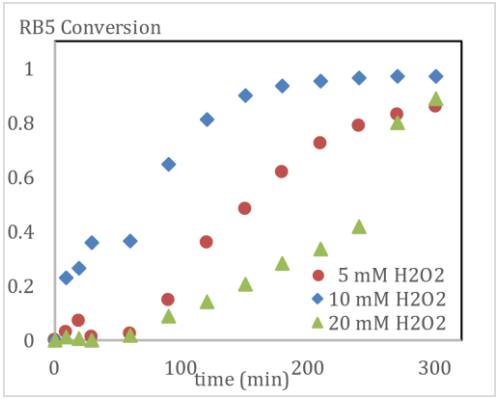


Figure 1. Effect of the oxidant concentration on the conversion of RB5 by hydrodynamic cavitation.

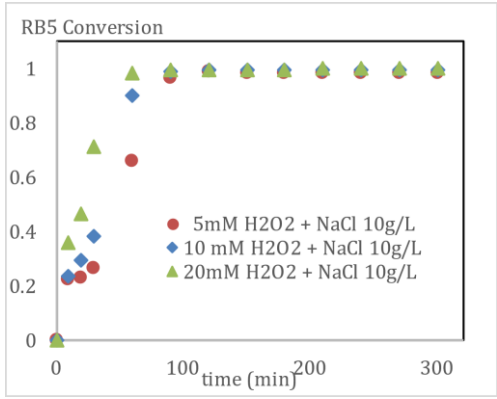


Figure 2. Effect of salt addition on the conversion of RB5 by vortex type hydrodynamic cavitation.

lowest concentration examined (Fig. 2).

Mineralization attained after 300 min also increased strongly with the addition of salt (Fig. 3), which was particularly evident for the lowest concentration of hydrogen peroxide. In a recent contribution [8], we have discussed the effect of hydrodynamic cavitation as related to the existence of supercritical water (SCW) domains that promotes the oxidation of hydrophobic compounds. According to the proposed conceptual model, it is likely that the addition of high salt concentration that increases strongly the ionic force would promote a salting out effect, pushing the organic intermediates, sparingly soluble in water, towards the SCW region around the collapsing cavities, thus increasing the mineralization.

The addition of the other auxiliaries did not decrease the efficiency of cavitation for RB5 discoloration. Softener addition led to negligible modifications while surfactant addition fastened the process (Graphical abstract) .

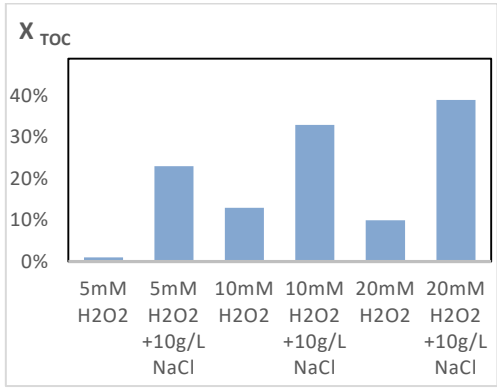


Figure 3. Effect of salt addition on the total organic carbon degradation by vortex type hydrodynamic cavitation.

Conclusions

Hydrodynamic cavitation using a vortex type device successfully discolored and partly mineralized model solutions of RB5. The addition of sodium chloride in the concentration generally found in the real effluent enhanced the effect of cavitation for discoloration and mineralization. Other auxiliaries, softener and surfactant did not interfere in the process. On the contrary, surfactant increased the initial discoloration rate.

Acknowledgments

Financial support from Universidad de Buenos Aires, Argentina (UBACyT 2023 20020220100154BA) and from the National Agency for Promoting Science and Technology (ANPCyT), Argentina (PICT 2019-0955 and PICT-2021-CAT-I-00086) is gratefully acknowledged.

References

[1] D. Jager, D. Kupka, M. Vaclavikova, L. Ivanicova, G. Gallios, *Chemosphere*, 190 (2018) 405.
[2] S. Fadaei, M. Noorisepehr, H. Pourzamani, M. Salari, M. Moradnia, M. Darvishmotevalli, N. Mengelizadeh, *J.of Environ. Chem. Eng.*, 9 (2021) 105414.
[3] Y. Yosofi, S.A. Mousavi, *Desalination and Water Treatment*, 174 (2020) 354.
[4] S. Meriç, D. Kaptan, T. Ölmez, *Chemosphere* 54 (2004) 435.
[5] É. da Silva, É. Ximenes, L. de Sales, E. Dantas, E. Oliveira, T. Simões, A. Ribeiro, O. Sanz, G. Machado, L. Almeida, *Catalysis Today*, 383 (2022) 173.
[6] T. Zhou, T. Lim, X. Wu, *Water Research*, 45 (2011) 2915.
[7] A. Thaker, K. Madane, V. Ranade, *Chemical Engineering Journal*, 474 (2023) 145943.
[8] S. Fleite, M.A. Ayude, V. Ranade, M. Cassanello, *Chem. Eng. Journal Advance*, in press.