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Treatability of Synthetic Wastewater Containing Reactive Yellow 145 Dyestuff by Ozonation Process

Pınar Nazire TANATTI*[1]

Abstract

When the textile industry wastewater volume and considering the composition appears to be one of the most environmentally hazardous industries. Due to textile dyeing industry wastewater's basic properties, additional precautions are required besides conventional wastewater treatment to remove color. The most basic approach is to remove the wastewater colour and break down the chromophores and double bonds that make up the color by oxidative means. In this study, the treatability of wastewater containing Reactive Yellow 145 (RY 145) dyestuff by ozonation process has been investigated. The initial concentration of the wastewater containing RY 145 is 50 mg / L. In the study, pH, O_3 dose and reaction time parameters have been studied in RY 145 dye removal. The most appropriate removal of RY 145 from wastewater have occurred at pH 5, 0.05 g / L.h O_3 dose and 10 minutes reaction time. The removal efficiency of RY 145 has obtained as 99.07% under optimum conditions.

Keywords: Reactive Yellow 145, ozone, ozonation, advanced oxidation process

1. INTRODUCTION

Industrial growth and urbanization cause complexity in the structure of the wastewater discharged into the environment and an increase in its volume [1]. Today one of the most critical global challenges have water pollution from dyes [2]. These dyes and pigments are widely used as colorants in textiles, paints and cosmetics [3]. A large amount of wastewater is generated at the end of the production process in which dyes and chemicals, most of which are auxiliary chemicals and surfactants, are used in the textile industries [4]. The resulting wastewater is dangerous and toxic because it contains compounds known to be carcinogenic, such as various chemicals and large amounts of dyes, usually organic compounds of complex structures [5,6]. Dyestuffs used in the textile industry are classified depending on the chemical structure and dyeing properties [7]. In the chemical structures of dyestuffs, nitro (-NO_2), nitroso (-N = O), azo (-N = N-), carbonyl (-C = O), ethenyl (-C = C-) and thiocarbonyl (-CH = S) contain groups [8].

These dyes used in the textile industry cause significant environmental effects. If water rich in dyestuffs is discharged without treatment, this waters will have negative effects on the receiving environment. Dyeing wastes given to the receiving environment from the textile industry cause the receiving water to change colour and become dyed. Depending on the dye used, they have a toxic effect on plant and animal life,

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prevent the river's self-purification capacity (assimilation capacity), cause the receiving water to color, reduce the light transmittance of the water, and decrease the photosynthesis rate of the aquatic flora. Therefore, in terms of ecology color removal processes enter into an important role in the treatment of wastewater containing high amounts of dyestuffs. Membrane [9], adsorption [10], electrochemical oxidation [11], coagulation [12], flocculation [13] and oxidation [14] methods were applied in the treatment of dye containing wastewater.

In the treatment of wastewater containing azo dyes, advanced Oxidation processes (AOPs) change the chemical structure of the azo dye and even break it down completely [15]. Ozonation, one of the AOPs, has high purification efficiencies in dye removal. Ozone is a strong oxidizer (redox potential 2.07 V) and reacts rapidly with organic and inorganic substances in aqueous solutions with its special dipole structure [16]. Ozone reacts with organic materials in two ways, directly in aqueous solutions and indirectly through hydroxyl radicals formed by its decomposition. Hydroxyl radicals have higher oxidisation compared to ozone (redox potential 2.33 V) and oxidize pollutants in water to the mineralization stage without any discrimination [17-19]. The ozone molecule selectively reacts with compounds containing C = C bonds, some functional groups (OH, CH_3, OCH_3) and anions (N, P, O, S) [20] but OH· oxidation is not selective [21]. As a result of the electrophilic nature of ozone, it generally reacts with aromatic rings by electrophilic substitution or 1,3-dipolar organic replacement reactions [22]. Many pollutants such as textile wastewater [23], water containing dyestuffs [24], water containing diethyl phthalate [25], water containing organic micropollutants [26], biodiesel wastewater [27], water containing Bisphenol A [28] and pharmaceutical wastewater [29] are treated from wastewater with the ozonation process.

In this study, dye removal has been investigated by using the ozonation method in waters containing RY 145. Dye is one of the most important problems processes from textile industry processes. Especially, there is a very dense dye material from the dying tank. It has been aimed to determine the optimum conditions by examining the pH, ozone (O_3) dose and reaction time parameters in the water with an initial RY 145 concentration of 50 mg / L. By using the ozone process, dye removal was achieved with less chemicals and shorter reaction time.

2. MATERIAL AND METHODS

2.1. RY 145 Sample Preparation and Measurement Method

Commercially available RY 145 ($C_{28}H_{20}ClN_9O_{16}S_5Na_4$) [30] dye has been used in the experiments. The molecular structure of RY 145 is shown in Fig. 1 [31]. 1 L stock solution containing 1000 mg/L RY 145 was prepared. By using the prepared stock solution, synthetic water with a total volume of 3 L and a concentration of 50 mg/L was obtained. Then, experiments have been conducted with solution containing an initial concentration of 50 mg / L RY 145 dye. All experiments have been performed on a synthetic water sample containing RY 145. In order to measure the values of RY 145 solution before and after treatment, the λ_{max} value of the dye has determined by spectrum scanning. The λ_{max} value of RY 145 has been found to be 413 nm after spectrum scanning.

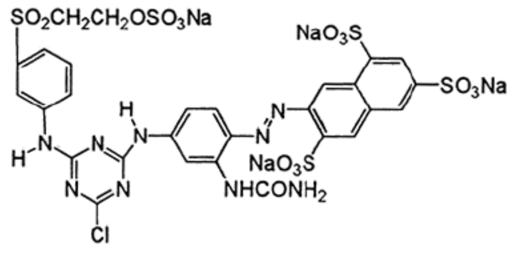

Figure 1 Molecular structure of RY 145

The calibration curve was prepared by taking measurements of the solutions prepared between 0.1 mg / L and 50 mg / L at 413 nm for the measurement of the dye with λ_{max} value during treatment. The regression coefficient (R^2) of the calibration curve obtained has found to be 0.9936. The line equation obtained from the calibration curve is given in Equation (1).

$$\text{RY 145 (mg/L)} = \frac{\text{ABS}}{0{,}0135} \quad (1)$$

2.2. Experimental reactor desing

Ozone is a very strong oxidant (E ° = + 2.07 V). Organic pollutants are oxidized by direct reaction (pH ≤ 2) with molecular ozone or indirect reactions (pH ≥ 7) from OH˙ resulting from ozone decomposition under alkaline conditions [32,33].

The reactor used for RY 145 removal is given in Figure 2. SABO brand ozone generator with a capacity of 15 g / L.h has been used in the experiments. Experiments have carried out using a 250 mL glass reactor as the reactor.

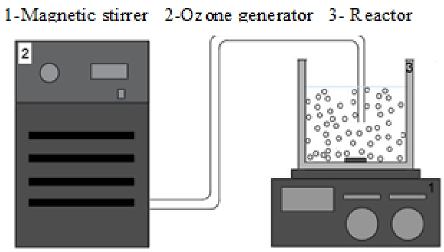

Figure 2 Ozonation reactor

3. RESULTS AND DISCUSSION

3.1. Effect of initial pH

The direct ozone reaction occurs at acidic pHs and in the presence of inhibitory scavengers that cause ozone degradation. OH˙ has a high-speed and non-selective nature. Therefore, the indirect reaction occurs predominantly under radical type chain reaction or alkaline conditions and in the presence of solvents that trigger OH˙ formation [21,34]. In addition, at low ozone dosages, due to radical scavengers such as carbonate and bicarbonate in wastewater, oxidation with molecular ozone occurs as a more dominant mechanism [35]. The direct and indirect reactions of ozone are given in the equations below [36].

Direct reactions:

$$O_3 + R \rightarrow \text{Products} \quad (2)$$

Indirect reactions: (total reaction)

$$3O_3 + H_2O \rightarrow 2OH^{\cdot} + 4O_2 \quad (3)$$

In order to investigate the effect of pH on dye removal efficiencies in wastewater with an initial concentration of 50 mg / L RY 145, a dose of 0.025 g / L.h O_3 and pH 3,5,7,9 and 11 at a reaction time of 5 minutes have been studied. RY 145 removal efficiencies are given in Figure 3. RY 145 removal efficiencies at pH 3, pH 5, pH 7, pH 9 and pH 11 have been found to be 49.93%, 69.66%, 57.90%, 55.02% and 66.62%, respectively, under the specified experimental conditions. The lowest removal efficiency has obtained at pH 3 in the ozone method. RY 145 removal efficiencies are high at pH 5 and pH 9. However, the highest removal efficiency is obtained at pH 5. In addition, considering that the initial pH of the solution is 6.86 and the highest RY 145 removal efficiency was obtained at pH 5, the most suitable pH was determined as 5.

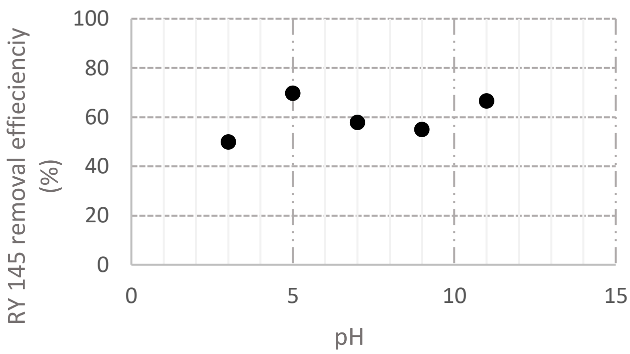

Figure 3 The effect of pH on RY 145 removal efficiency (O_3 dose: 0.025 g / L.h; Reaction time: 5 min)

The treatability of wastewater containing 500 mg / L RY 145 has investigated by ultraviolet-enhanced ozonation process and then pH 8 was determined as the optimum pH. In addition, RY 145 removal efficiency is around 80% in 150 minutes reaction time [37]. In addition, the optimum pH of RY 145 was obtained in the treatment of H_2O_2 / UV AOP. The removal efficiency of RY 145 in 1 hour reaction time was found to be 99% [30]. It is clear that there is RY 145 removal in both ozonation and H_2O_2 / UV process. However, in this study, both the removal efficiencies are high in RY 145 removal by ozonation, and the reaction time is short. In addition, the optimum pH value found in the treatment of RY 145 by ozonation is the value that should not be spent too much chemical for its adjustment, considering the initial pH of the water.

3.2. Effect of O_3 dose

In order to examine the removal efficiency of wastewater containing RY 145 dye, O_3 dose has been studied between 0.0125 g / L.h and 0.125 g / L.h. Ozone solubility levels was measured in water and the concentration depending on the flow rate is given in the Table 1.

Table 1 The ozone concentration in water depending on the flow rate

Flow rate (g/L.h)	0.0125	0.05	0.075	0.1	0.15	0.3
Ozone concentration (mg/L)	0,19	0.64	1.08	1.3	1.8	2.6

While investigating the effect of O_3 dose on removal efficiencies by ozonation method, studies have been conducted at pH 5 and 5 min reaction time. Figure 3 shows The effect of O_3 dose on RY 145 removal efficiency. In the beginning, while the removal efficiency of RY 145 increases with the increase of O_3 dose, Figure 4 is shown that there is a slow increase in removal efficiency after 0.05 g / L.h O_3 dose. RY 145 removal efficiency has obtained 26.25% at a dose of 0.0125 g / L.h O_3, while RY 145 removal efficiency at a dose of 0.125 g / L.h O_3 has achieved 96.93%. At the ozone dose of 0.05 g / L.h, a rapid decrease in the removal efficiency after RY 145 removal has been determined. RY 145 removal efficiencies have been found 95.36%, 96.79% and 96.93% at 0.05 g / L.h, 0.1 g / L.h and 0.125 g / L.h O_3 doses. Although the ozone dose concentration increases from the ozone dose of 0.05 g / L.h, the increase in removal efficiency is approximately 1.5%. For this reason, the most suitable ozone dose has been determined as 0.05 g / L.h on the most suitable RY 145 removal efficiency.

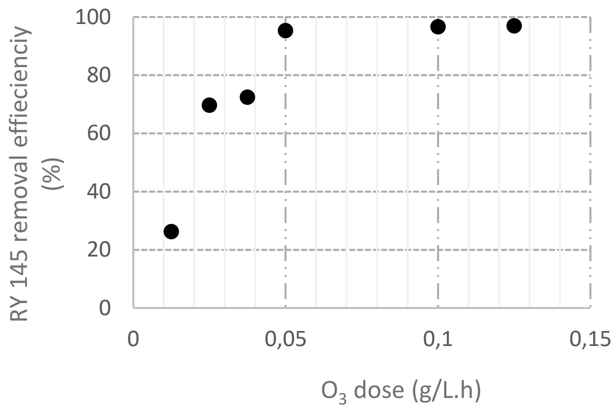

Figure 4 The effect of O_3 dose on RY 145 removal efficiency (pH 5; Reaction time: 5 min)

Even if there is an increase in the ozone dose, the amount of ozone dissolved in the wastewater may have reached saturation, so the increase in removal efficiency is gradually [38].

3.3. Effect of reaction time

The effect of reaction time on RY 145 removal efficiency has been investigated at pH 5 and 0.05 g / L.h O_3 dose. Removal efficiencies for RY 145 are given in Figure 5.

As seen from Figure 5, dye removal efficiencies increase as the reaction time increases. RY 145 removal efficiencies have been studied at reaction times of 1 min to 15 min. Ozone acts to break down compounds with high electron density, such as C = C bonds, activated aromatic systems, and protonated amines [39]. RY 145 removal efficiency has been found 41.59% at 1st min and 99.23% at 15th min. Also, RY 145 removal efficiency has been obtained as 99.07% at 10th min. Depending on the reaction time of RY 145, removal efficiencies increase rapidly until the 6th minute. Increases in removal efficiency after the 6th minute are slow. The removal efficiency has been determined 97.45% in the 6th minute. However, while the RY 145 concentration at the 6th minute was 1.274 mg / L, the RY 145 concentration at the 10th minute was 0.467 mg / L. In addition, the RY 145 concentration at the 15th minute is 0.385 mg / L. Considering the RY 145 concentrations, 10 min has been determined as the optimum reaction time.

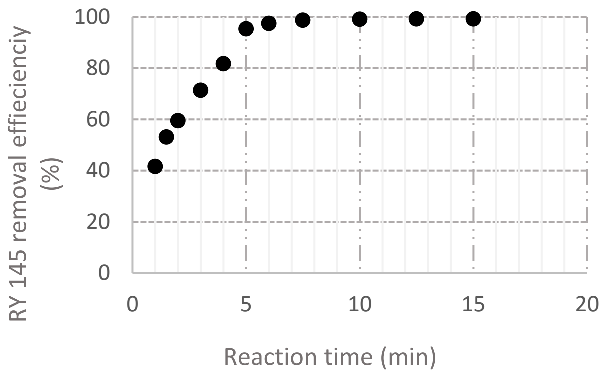

Figure 5 The effect of reaction time on RY 145 removal efficiency (pH 5; O_3 dose: 0.05 g / L.h)

Reaction times vary according to the AOPs used in dye removal. In UV treatment with Ni_3O_4-Co_3O_4 / Al_2O_3 catalyst, RY 145 could be removed in 60 minutes reaction time [40]. In addition, Reactive Golden treatment was studied by electrooxidation from AOPs. In the oxidation using RuO_2 / Ti electrode, only 96.4% efficiency was obtained in 6 hours reaction time [41].

4. RESULT

In the study, ozonation method has been used for the treatment of wastewater containing RY 145 dyestuff prepared synthetically. Optimum conditions in the treatment of RY 145 containing wastewater were found as pH 5, 0.05 g / L.h O_3 dose and 10 minutes reaction time. Optimum conditions in the treatment of RY 145 containing wastewater have been found as pH 5, 0.05 g / L.h O_3 dose and 10 minutes reaction time. Dye removal efficiency was found to be 99.07% under optimum conditions. It has been established that the ozonation method is a suitable process in waters containing RY 145 dyestuff. However, ozonation processes are methods that can be used in different combinations. Under favour this study, it can be predicted that RY 145 studies can be carried out with a more economical and environmentally friendly process by using different ozonation systems.

Ethical Approval and Consent to Participate

The manuscript has not been submitted to more than one journal for simultaneous consideration. The submitted work has been original and has not been published elsewhere in any form or language unless the new work concerns an expansion of previous work. A single study has not been split up into several parts to increase the quantity of submissions and not submitted to various journals or to one journal over time. Results have been presented clearly, honestly data manipulation. I have adhered to discipline-specific rules for acquiring, selecting and processing data. The manuscript does not report on or involve the use of any animal or human data or tissue; hence Ethics and Consent Participate is not applicable" in this paper.

Consent for publication

The manuscript does not contain data from any individual person hence "consent to publish" is not applicable.

Funding

There is no funding for the study.

Authors' contributions

NPT has done all the experiments of the study. All parts of the writing belong to NPT.

Competing Interests

There are no competing interests.

Availability of data and materials

The study is an experimental study. All results obtained in the study have been added to the publication. The manuscript does not contain any data, hence "Availability of data and materials" is not applicable.

REFERENCES

[1] V. Vijayakumar, R. Saravanathamizhan, and N. Balasubramanian, "Electro oxidation of dye effluent in a tubular electrochemical reactor using TiO_2/RuO_2 anode," Journal of Water Process Engineering, vol 9, pp. 155–160, 2016.

[2] J. Wu, Q. Li, W. Li, Y. Li, G. Wang, A. Li, and H. Li, "Efficient removal of acid dyes using permanent magnetic resin and its preliminary investigation for advanced treatment of dyeing effluents," Journal of Cleaner Production, vol. 251, 119694, 2020.

[3] E. Pagalan Jr, M. Sebron, S. Gomez, S. J. Salva, R. Ampustaa, A. J. Macarayoa, C. Joynoa, A. Idoa, and R. Arazoa, "Activated carbon from spent coffee grounds as an adsorbent for treatment of water contaminated by aniline yellow dye," Industrial Crops & Products, vol. 145, 111953, 2020.

[4] M. İlter, "Tekstil üretimi ve yardımcı kimyasallar," TMMOB Kimya Mühendisleri Odası, İzmir, 2015.

[5] E. GilPavas, I. Dobrosz-Gómez, and M. Á. Gómez-Garcíac, "Optimization of sequential chemical coagulation - electro-oxidation processfor the treatment of an industrial textile wastewater," Journal of Water Process Engineering, vol. 22, pp. 73-79, 2018.

[6] S. Marimutha, A. J. Antonisamy, S. Malayandi, K. Rajendran, P. C. Tsai, A. Pugazhendhi, and V. K. Ponnusamy, "Silver nanoparticles in dye effluent treatment: A review on synthesis, treatment methods, mechanisms, photocatalytic degradation, toxic effects and mitigation of toxicity," Journal of Photochemistry & Photobiology, B: Biology, vol. 205, 111823, 2020.

[7] A. K. Verma, R. R. Dash, and P. Bhunia, "A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters," Journal of Environmental Management, vol. 93, pp. 154-168, 2012.

[8] G. Lofrano, S. Meriç, G. E. Zengin, and D. Orhon, "Chemical and biological treatment technologies for leather tannery chemicals and wastewaters: a review," Science of Total Environment, vol. 461-462, pp. 265-281, 2013.

[9] U. Habiba, J. J. L. Lee, T. C. Joo, B. C. Ang, and A. M. Afifi, "Degradation of methyl orange and congo red by using chitosan/polyvinyl alcohol/TiO_2 electrospun nanofibrous membrane," International Journal of Biological Macromolecules, vol. 131, pp. 821–827, 2019.

[10] N. Fahmi Khairol, N. Sapawe, and M. Danish, "Excellent performance integrated both adsorption and photocatalytic reaction toward degradation of congo red by CuO/Eggshell," Materials Today: Proceeding, vol. 19, pp. 1340–1345, 2019.

[11] N. P. Shetti, S. J. Malode, R. S. Malladi, S. L. Nargund, S. S. Shukla, and T. M. Aminabhavi, "Electrochemical detection and degradation of textile dye Congo red at graphene oxide modified electrode," Microchemistry Journal, vol. 146, pp. 387–392, 2019.

[12] M. Sillanpää, M. C. Ncibi, A. Matilainen, and M. Vepsäläinen, "Removal of natural organic matter in drinking water treatment by coagulation: a comprehensive review," Chemosphere, vol. 190, pp. 54–71, 2018.

[13] Q. Du, H. Wei, A. Li, and H. Yang, "Evaluation of the starch-based flocculants on flocculation of hairwork wastewater," Science Total Environment, vol. 601–602, pp. 1628–1637, 2017.

[14] P. Tan, Q. Bi, Y. Hu, Z. Fang, Y. Chen, and J. Cheng, "Effect of the degree of oxidation and defects of graphene oxide on adsorption of Cu^{2+} from aqueous solution," Appleid Surface Science, vol. 423, pp. 1141–1151, 2017.

[15] B. L. Alderete, J. Silva, R. Godoi, F. R. Silva, S. R. Taffarel, L. P. Silva, A. L. H. Garcia, H. M. Júnior, H. L. N. Amorim, and J. N. Picad, "Evaluation of toxicity and mutagenicity of a synthetic effluent containing azo dye after Advanced Oxidation Process treatment," Chemosphere, vol. 263, 128291, 2021.

[16] X. Li, W. Chen, L. Ma, H. Wang, and J. Fan, "Industrial wastewater advanced treatment via catalytic ozonation with an Fe-based catalyst," Chemosphere, vol. 195, pp. 336-343, 2018.

[17] R. Rosal, A. Rodríguez, J. A. Perdigon-Melon, A. Petre, and E. García-Calvo, "Oxidati on of dissolved organic matter in the effluent of a sewage treatment plant using ozone combined with hydrogen peroxide (O_3/H_2O_2)," Chemical Engineering Journal, vol. 149, pp. 311-318, 2009.

[18] F. Pan, Y. Luo, J. J. Fan, D. C. Liu, and J. Fu, "Degradation of disperse blue E-4R in aqueous solution by zero-valent iron/ozone," Clean Soil, Air, Water, vol. 40, pp. 422-427, 2012.

[19] Z. Xiong, Y. Yuan, B. Lai, P. Yang, and Y. Zhou, "Mineralization of ammunition wastewater by a micron-size $Fe^{0/}O_3$process (mFe^0/O_3)," RSC Advances, vol. 6, pp. 55726-55735, 2016.

[20] A.B. Alvares, C. Diaper, and S. A. Parsons, "Partial oxidation by ozone to remove recalcitrance from wastewaters – a review," Environmental Technology, vol. 22, pp. 409–427, 2001.

[21] B. Ning, N. Graham, Y. Zhang, M. Nakonechnyc, and M. G. El-Din, "Degradation of endocrine disrupting chemicals by ozone/AOPs," Ozone Science & Engineering, vol. 29, pp. 153–176, 2007.

[22] E. Mvula and C. Sonntag, "Ozonolysis of phenols in aqueous solution," Organic & Biomolecular Chemistry, vol 1, pp. 1749-1756, 2003.

[23] L. Bilińska, K. Blus, M. Gmurek, S. Ledakowicz, "Coupling of electro - coagulation and ozone treatment for textile wastewater reuse," Chemical Engineering Journal, vol. 358, pp. 992–100, 2019.

[24] J.B. Parsa, S.H. Negahdar, "Treatment of wastewater containing Acid Blue 92 dye by advanced ozone-based oxidation methods," Separation and Purification Technology, vol 98, pp. 315-320, 2012.

[25] L. Mansouri, C. Tizaoui, S.U. Geissen, L. Bousselmi, "A comparative study on ozone, hydrogen peroxide and UV based advanced oxidation processes for efficient removal of diethyl phthalate in water," Journal of Hazardous Materials, vol. 363, pp. 401‑411, 2019.

[26] M. Ekblad, P. Falås, H. El-taliawy, F. Nilsson, K. Bester, M. Hagman, M. Cimbritz," Is dissolved COD a suitable design parameter for ozone oxidation of organic micropollutants in wastewater?," Science of the Total Environment, vol. 658, pp. 449–456, 2019.

[27] N.P.Tanatti, M. Mehmetbaşoğlu, İ.A. Şengil, H. Aksu, E. Emin, "Kinetics and thermodynamics of biodiesel wastewater treatment by using ozonation process," Desalination and Water Treatment, vol. 161, pp. 108–115, 2019.

[28] N.P.Tanatti, E. Balkaya, İ.A. Şengil,"Kinetic and statistical analysis of Bisphenol A in wastewaters by ozonation and electrooxidation – ozonation processes," Desalination and Water Treatment, vol. 204, pp. 429–437, 2020.

[29] J. Zhan, Z. Li, G. Yu, X. Pan, J. Wang, W. Zhu, X. Han, Y. Wang, "Enhanced treatment of pharmaceutical wastewater by combining threedimensional electrochemical process with ozonation to in situ regenerate granular activated carbon particle electrodes,"

Separation and Purification Technology, vol. 208, pp. 12–18, 2019.

[30] T. H. Bokharı, M. Kashıf, I. A. Bhattı, M. Zubaır, S. Adeel, M. Yousaf, M. Ahmad, M. Iqbal, M. Usman, M. Zuber, and A. Mansha, "Degradation study of C.I. Reactive Yellow 145 by advanced oxidation process," Asian Journal of Chemistry, vol. 25, pp. 8668-8672, 2013.

[31] Z. Gündüz, "Decolorization of dye solution containing Reactive Jakofiz Yellow by Electrocoagulation process: Investigation of some electrochemical variables," Omer Halisdemir University Journal of Engineering Sciences, vol. 8, pp. 665-674, 2019.

[32] E.V. Rokhina, J. Virkutyte, R. S. Varma, and V. Jegatheesan, "Treatment of Micropollutants in Water and Wastewater," Integrated Environmental Technology Series, IWA Publishing, London, pp. 360–424, 2010.

[33] R. Broséus, S. Vincent, K. Aboulfad, A. Daneshvar, S. Sauvé, B. Barbeau, and M. Prévost, "Ozone oxidation of pharmaceuticals, endocrine disruptors and pesticides during drinking water treatment," Water Resource, vol. 43, pp. 4707–4717, 2009.

[34] S. Irmak, O. Erbatur, and A. Akgerman, "Degradation of 17[beta]-estradiol and bisphenol A in aqueous medium by using ozone and ozone/UV techniques," Journal of Hazardous Material, vol. 126, pp. 54–62, 2005.

[35] N. Nakada, H. Shinohara, A. Murata, K. Kiri, S. Managaki, N. Sato, and H. Takada, "Removal of selected pharmaceuticals and personal care products (PPCPs) and endocrine-disrupting chemicals (EDCs) during sand filtration and ozonation at a municipal sewage treatment plant," Water Resource, vol. 41, pp. 4373–4382, 2007.

[36] R. H. Waldemer, P. G. C. Gottschalk, J. A. Libra, and A. Saupe, "Ozonation of Water and Waste Water, A Practical Guide to Understanding Ozone and its Applications," 2nd Ed, Wiley-VCH, Germany, 2010.

[37] S. Song, X. Xu, L. Xu, Z. He, H. Ying, J. Chen, and B. Yan, "Mineralization of CI Reactive Yellow 145 in Aqueous Solution by Ultraviolet – Enhanced Ozonation," Industrial & Engineering Chemistry Research, vol. 47, 5, pp. 1386–1391, 2008.

[38] H. Deng, "Ozonation mechanism of carbamazepine and ketoprofen in RO concentrate from municipal wastewater treatment: Kinetic regimes, removal efficiency and matrix effect," Science of Total Environment, vol. 717, pp. 137150, 2020.

[39] M. Deborde, S. Rabouan, J. P. Duguet, and B. Legube, "Kinetics of aqueous ozoneinduced oxidation of some endocrine disruptors," Environmental Science and Technology, vol. 39, pp. 6086–6092, 2005.

[40] E. J. Mohammad, A.J. Lafta, and S. H. Kahdim, "Photocatalytic removal of reactive yellow 145 dye from simulated textile wastewaters over supported (Co, Ni)$_3$O$_4$/Al$_2$O$_3$ co-catalyst," Polish Journal of Chemical Technology, vol. 18, pp. 1-9, 2016.

[41] D. S. Ibrahim, A. P. Anand, A. Muthukrishnaraj, R. Thilakavathi, and N. Balasubramanian, "In situ electro-catalytic treatment of a Reactive Golden Yellow HER synthetic dye effluent," Journal of Environmental Chemical Engineering, vol. 1, pp. 2–8, 2013.