Non-catalytic ozonation of palm oil mill effluent (POME)

Sajjad Khudhur Abbas Al-Amshawee [a*], Mohd Yusri Bin Mohd Yunus [a,b], Joan G. Lynam [c]

[a*] Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang, 26300 Pahang, Malaysia

[b] Earth Resource and Sustainability Centre (ERAS), Universiti Malaysia Pahang, 26300 Pahang, Malaysia

[c] Department of Chemical Engineering, Louisiana Tech University, P.O. Box 10348, 600 Dan Reneau Drive, Ruston, LA 71272, USA

Corresponding author: Sajjad Khudhur Abbas Al-Amshawee; sajjad.hillawi@hotmail.com; Tel: +6011-60714919

Abstract

Ozonation is recognized as an effective treatment to eliminate complex contaminants in wastewater. So far, past studies often applied ozonation for minutes or a few hours. These studies contradict each other in their findings about the ability of ozone to remove inorganics and organics. The present study, for the first time, applied ozone oxidation at doses of 15 and 30 mg/L for a long duration of 144 hours to process high-strength wastewater, palm oil mill effluent. Both doses effectively dissolved non-biodegradable solids, ultimately enhancing toxicity removal. However, the 15 mg/L dose resulted in a slower start-up, instability in treatment, and lower solid degradation than the 30 mg/L dose because it was inadequate to abate influent pollutants. The undesirable results of the 15 mg/L dose demonstrated the need for a higher dosage of ozone to result in a higher rate of conversion of solids into biodegradable and dissolved solids over a shorter period of time. The high ozone dose (30 mg/L) demonstrated better startup, more stable performance, and higher final effluent quality than the low ozone dose (15 mg/L). The high ozone dose continued to deliver high-

performance treatment over the duration of the study compared to the low ozone dose. During ozonation, particulate matter foams were detected on the surface due to aggregation of solids.

Keywords: Ozonation (O_3); Wastewater treatment; Ozone dosage; Palm oil mill effluent (POME); Ozonation foam.

1.0 Introduction

The release of untreated palm oil mill effluent (POME) into rivers jeopardies the ecosystem, since it contains a high concentration of pollutants [1]. In over 85% of palm oil mills in Malaysia, waste stabilization ponds are used to treat POME due to their affordable capital and operating costs [2]. However, such POME treatment requires a long retention time of about 5.4 months, a large treatment land area of 10,000–50,000 m^2, and it is difficult to preserve the treatment efficiency associated with poor decolorization [3].

The ozonation approach has been introduced as an effective treatment for eliminating complex pollutants in water and wastewater [4]. Ozone is a strong oxidant that can eliminate refractory pollutants that various treatments cannot reduce [5]. Technically, ozone interacts with contaminants transforming them into a simpler form. Different studies have reported that ozone is effective for pollutants degradation because of its intense oxidizing activity [6].

Ozone has often been used to enhance pollutant degradability, wastewater and drinking water disinfection, micropollutant removal, and antibiotic removal. For instance, Li et al. (2019) completely degraded N,N-diethyl-meta-toluamide (DEET) by using ozonation [7]. In other studies, ozonation showed a significant degree of microplastic removal compared to filtration systems, such as membrane disc filter and rapid sand filtration [5].

The major factors influencing ozonation process are pH, ozone dosage and temperature, which significantly affect pollutant mineralization. Most importantly, removing chemical oxygen demand (COD) can be improved by increasing the ozone dosage [7]. Other studies did not investigate the

Tavares, Combined processes of ozonation and supercritical water oxidation for landfill leachate degradation, Waste Manag. 77 (2018) 466–476. https://doi.org/10.1016/j.wasman.2018.04.031.

[45] L. Bilińska, K. Blus, M. Gmurek, S. Ledakowicz, Coupling of electrocoagulation and ozone treatment for textile wastewater reuse, Chem. Eng. J. 358 (2019) 992–1001. https://doi.org/10.1016/j.cej.2018.10.093.

[46] S.N. Malik, P.C. Ghosh, A.N. Vaidya, S.N. Mudliar, Ozone pre-treatment of molasses-based biomethanated distillery wastewater for enhanced bio-composting, J. Environ. Manage. 246 (2019) 42–50. https://doi.org/10.1016/j.jenvman.2019.05.087.

[47] S. Venkatesh, K. Venkatesh, A.R. Quaff, Dye decomposition by combined ozonation and anaerobic treatment: Cost effective technology, J. Appl. Res. Technol. 15 (2017) 340–345. https://doi.org/10.1016/j.jart.2017.02.006.

[48] P. Colindres, H. Yee-Madeira, E. Reguera, Removal of Reactive Black 5 from aqueous solution by ozone for water reuse in textile dyeing processes, Desalination. 258 (2010) 154–158. https://doi.org/10.1016/j.desal.2010.03.021.

[49] I. Ciabatti, F. Tognotti, L. Lombardi, Treatment and reuse of dyeing effluents by potassium ferrate, Desalination. 250 (2010) 222–228. https://doi.org/10.1016/j.desal.2009.06.019.

[50] A. Baban, A. Yediler, D. Lienert, N. Kemerdere, A. Kettrup, Ozonation of high strength segregated effluents from a woollen textile dyeing and finishing plant, Dye. Pigment. 58 (2003) 93–98. https://doi.org/10.1016/S0143-7208(03)00047-0.

[51] G.G. Bessegato, J.C. De Souza, J.C. Cardoso, M.V.B. Zanoni, Assessment of several advanced oxidation processes applied in the treatment of environmental concern constituents from a real hair dye wastewater, J. Environ. Chem. Eng. 6 (2018) 2794–2802. https://doi.org/10.1016/j.jece.2018.04.041.

[52] K. Nadeem, G.T. Guyer, N. Dizge, Polishing of biologically treated textile wastewater through AOPs and recycling for wet processing, J. Water Process Eng. 20 (2017) 29–39. https://doi.org/10.1016/j.jwpe.2017.09.011.

[53] C. Huang, Y. Shi, Z. Sheng, M. Gamal El-Din, Y. Liu, Characterization of microbial communities during start-up of integrated fixed-film activated sludge (IFAS) systems for the treatment of oil sands process-affected water (OSPW), Biochem. Eng. J. 122 (2017) 123–132. https://doi.org/10.1016/j.bej.2017.03.003.

[54] M. Lau, P. Monis, G. Ryan, A. Salveson, N. Fontaine, J. Blackbeard, S. Gray, P. Sanciolo, Selection of surrogate pathogens and process indicator organisms for pasteurisation of municipal wastewater—A survey of literature data on heat inactivation of pathogens, Process Saf. Environ. Prot. 133 (2020) 301–314. https://doi.org/10.1016/j.psep.2019.11.011.

[55] Z. Xiong, H. Zhang, W. Zhang, B. Lai, G. Yao, Removal of nitrophenols and their derivatives by chemical redox: A review, Chem. Eng. J. 359 (2019) 13–31. https://doi.org/10.1016/j.cej.2018.11.111.

[56] U. Bletterie, K. Schilling, L. Delgado, M. Zessner, Ozonation as a Post-Treatment Step for Tannery Wastewater to Reduce Foam Formation in a River, Ozone Sci. Eng. (2012). https://doi.org/10.1080/01919512.2012.713311.

[57] J. Chacana, M.A. Labelle, A. Laporte, A. Gadbois, B. Barbeau, Y. Comeau, Ozonation of Primary Sludge and Digested Sludge to Increase Methane Production in a Chemically Enhanced Primary Treatment Facility, Ozone Sci. Eng. (2017).

https://doi.org/10.1080/01919512.2017.1301247.

[58] E. Kan, S. Kim, M.A. Deshusses, Fenton oxidation of TCE vapors in a foam reactor, Environ. Prog. (2007). https://doi.org/10.1002/ep.10205.

[59] M. Lechuga, A. Fernández-Arteaga, M. Fernández-Serrano, E. Jurado, A. Burgos, F. Ríos, Ozonation of anionic and non-ionic surfactants in aqueous solutions: Impact on aquatic toxicity, J. Surfactants Deterg. (2013). https://doi.org/10.1007/s11743-013-1464-2.

[60] M. Gągol, A. Przyjazny, G. Boczkaj, Effective method of treatment of industrial effluents under basic pH conditions using acoustic cavitation – A comprehensive comparison with hydrodynamic cavitation processes, Chem. Eng. Process. - Process Intensif. 128 (2018) 103–113. https://doi.org/10.1016/j.cep.2018.04.010.

[61] S.K. Al-Amshawee, M.Y.M. Yunus, A review on possible approaches of anaerobic biological processes for palm oil mill effluent: Process, quality, advantages, and limitations, in: IOP Conf. Ser. Mater. Sci. Eng., 2019. https://doi.org/10.1088/1757-899X/702/1/012058.

[62] A.A. Sajjad, Y.H. Teow, A.W.M. Hussain, Sustainable approach of recycling palm oil mill effluent (POME) using integrated biofilm/membrane filtration system for internal plant usage, J. Teknol. 80 (2018) 165–172. https://doi.org/10.11113/jt.v80.11054.

[63] S.K. Al-Amshawee, M.Y. Yunus, A.A. Azoddein, A Review on Aerobic Biological Processes for Palm Oil Mill Effluent: Possible Approaches, IOP Conf. Ser. Mater. Sci. Eng. 736 (2020). https://doi.org/10.1088/1757-899X/736/2/022035.

[64] S.K. Al-Amshawee, M.Y. Yunus, A.A. Azoddein, A Review Study of Biofilm Bacteria and Microalgae Bioremediation for Palm Oil Mill Effluent: Possible Approach, IOP Conf. Ser. Mater. Sci. Eng. 736 (2020). https://doi.org/10.1088/1757-899X/736/2/022034.

[65] S. Al-amshawee, Y. Yunus, Influence of Light Emitting Diode (LED) on Microalgae, J. Chem. Eng. Ind. Biotechnol. 5 (2019) 9–16. https://doi.org/doi.org/10.15282/jceib.v5i2.3771.

[66] S.K. Al-Amshawee, M.Y. Yunus, A.A. Azoddein, A Novel Microbial Biofilm Carrier for Wastewater Remediation, IOP Conf. Ser. Mater. Sci. Eng. 736 (2020). https://doi.org/10.1088/1757-899X/736/7/072006.

[67] S. Al-Amshawee, M.Y.B.M. Yunus, J.G. Lynam, W.H. Lee, F. Dai, I.H. Dakhil, Roughness and wettability of biofilm carriers: A systematic review, Environ. Technol. Innov. (2020) 101233. https://doi.org/10.1016/j.eti.2020.101233.

[68] S. Al-Amshawee, M.Y.B.M. Yunus, Geometry of biofilm carriers: A systematic review deciding the best shape and pore size, Groundw. Sustain. Dev. 12 (2021) 100520. https://doi.org/10.1016/j.gsd.2020.100520.

[69] D.E. Freedman, S.M. Riley, Z.L. Jones, J.S. Rosenblum, J.O. Sharp, J.R. Spear, T.Y. Cath, Biologically active filtration for fracturing flowback and produced water treatment, J. Water Process Eng. 18 (2017) 29–40. https://doi.org/10.1016/j.jwpe.2017.05.008.

[70] A. Dzionek, D. Wojcieszyńska, U. Guzik, Natural carriers in bioremediation: A review, Electron. J. Biotechnol. 23 (2016) 28–36. https://doi.org/10.1016/j.ejbt.2016.07.003.

[71] Q. Gu, T. Sun, G. Wu, M. Li, W. Qiu, Influence of carrier filling ratio on the performance of moving bed biofilm reactor in treating coking wastewater, Bioresour. Technol. 166 (2014) 72–78. https://doi.org/10.1016/j.biortech.2014.05.026.

[72] K.A. Mosa, I. Saadoun, K. Kumar, M. Helmy, O.P. Dhankher, Potential biotechnological strategies for the cleanup of heavy metals and metalloids, Front. Plant Sci. 7 (2016).

https://doi.org/10.3389/fpls.2016.00303.

[73] S.K. Al-Amshawee, M.Y. Yunus, A.A. Azoddein, A Review on Hybrid Processes for Palm Oil Mill Effluent: Possible Approaches, IOP Conf. Ser. Mater. Sci. Eng. 736 (2020). https://doi.org/10.1088/1757-899X/736/2/022036.

[74] Q. Cui, H. Liu, H.W. Yang, Y. Lu, Z. Chen, H.Y. Hu, Bacterial removal performance and community changes during advanced treatment process: A case study at a full-scale water reclamation plant, Sci. Total Environ. 705 (2020). https://doi.org/10.1016/j.scitotenv.2019.135811.

[75] S. Sankaran, S.K. Khanal, A.L. Pometto, J. (Hans) van Leeuwen, Ozone as a selective disinfectant for nonaseptic fungal cultivation on corn-processing wastewater, Bioresour. Technol. 99 (2008) 8265–8272. https://doi.org/10.1016/j.biortech.2008.03.055.

[76] J.A. Malvestiti, A. Cruz-Alcalde, N. López-Vinent, R.F. Dantas, C. Sans, Catalytic ozonation by metal ions for municipal wastewater disinfection and simulataneous micropollutants removal, Appl. Catal. B Environ. 259 (2019). https://doi.org/10.1016/j.apcatb.2019.118104.

[77] R. Anjali, S. Shanthakumar, Insights on the current status of occurrence and removal of antibiotics in wastewater by advanced oxidation processes, J. Environ. Manage. 246 (2019) 51–62. https://doi.org/10.1016/j.jenvman.2019.05.090.

[78] M. Mainardis, M. Buttazzoni, N. De Bortoli, M. Mion, D. Goi, Evaluation of ozonation applicability to pulp and paper streams for a sustainable wastewater treatment, J. Clean. Prod. 258 (2020). https://doi.org/10.1016/j.jclepro.2020.120781.

[79] T. Krahnstöver, T. Wintgens, Separating powdered activated carbon (PAC) from wastewater - Technical process options and assessment of removal efficiency, J. Environ. Chem. Eng. 6 (2018) 5744–5762. https://doi.org/10.1016/j.jece.2018.09.001.

[80] M. Trojanowicz, A. Bojanowska-Czajka, I. Bartosiewicz, K. Kulisa, Advanced Oxidation/Reduction Processes treatment for aqueous perfluorooctanoate (PFOA) and perfluorooctanesulfonate (PFOS) – A review of recent advances, Chem. Eng. J. 336 (2018) 170–199. https://doi.org/10.1016/j.cej.2017.10.153.

[81] C. De Traversay, R. Bonnard, C. Adrien, F. Luck, Application of static mixers in drinking water treatment: the ozonation process, 2001.

[82] P.R. Gogate, A.B. Pandit, A review of imperative technologies for wastewater treatment II: Hybrid methods, Adv. Environ. Res. 8 (2004) 553–597. https://doi.org/10.1016/S1093-0191(03)00031-5.

[83] K. Li, L. Xu, Y. Zhang, A. Cao, Y. Wang, H. Huang, J. Wang, A novel electro-catalytic membrane contactor for improving the efficiency of ozone on wastewater treatment, Appl. Catal. B Environ. 249 (2019) 316–321. https://doi.org/10.1016/j.apcatb.2019.03.015.

[84] J. Wang, H. Chen, Catalytic ozonation for water and wastewater treatment: Recent advances and perspective, Sci. Total Environ. 704 (2020). https://doi.org/10.1016/j.scitotenv.2019.135249.

[85] J. Araña, J.A. Herrera Melián, J.M. Doña Rodríguez, O. González Díaz, A. Viera, J. Pérez Peña, P.M. Marrero Sosa, V. Espino Jiménez, TiO2-photocatalysis as a tertiary treatment of naturally treated wastewater, Catal. Today. 76 (2002) 279–289. https://doi.org/10.1016/S0920-5861(02)00226-2.

[86] M. Bhuvaneshwari, E. Eltzov, B. Veltman, O. Shapiro, G. Sadhasivam, M. Borisover, Toxicity of

chlorinated and ozonated wastewater effluents probed by genetically modified bioluminescent bacteria and cyanobacteria Spirulina sp., Water Res. 164 (2019). https://doi.org/10.1016/j.watres.2019.114910.

[87] J. Alexander, G. Knopp, A. Dötsch, A. Wieland, T. Schwartz, Ozone treatment of conditioned wastewater selects antibiotic resistance genes, opportunistic bacteria, and induce strong population shifts, Sci. Total Environ. 559 (2016) 103–112. https://doi.org/10.1016/j.scitotenv.2016.03.154.

[88] L. Rizzo, W. Gernjak, P. Krzeminski, S. Malato, C.S. McArdell, J.A.S. Perez, H. Schaar, D. Fatta-Kassinos, Best available technologies and treatment trains to address current challenges in urban wastewater reuse for irrigation of crops in EU countries, Sci. Total Environ. 710 (2020). https://doi.org/10.1016/j.scitotenv.2019.136312.

[89] F. Gagné, C. André, P. Cejka, C. Gagnon, C. Blaise, Toxicological effects of primary-treated urban wastewaters, before and after ozone treatment, on freshwater mussels (Elliptio complanata), Comp. Biochem. Physiol. - C Toxicol. Pharmacol. 145 (2007) 542–552. https://doi.org/10.1016/j.cbpc.2007.01.019.

[90] B.W. SHELDON, A.L. BROWN, Efficacy of Ozone as a Disinfectant for Poultry Carcasses and Chill Water, J. Food Sci. 51 (1986) 305–309. https://doi.org/10.1111/j.1365-2621.1986.tb11116.x.

[91] K. Gan, X. Mou, Y. Xu, H. Wang, Application of ozonated piggery wastewater for cultivation of oil-rich Chlorella pyrenoidosa, Bioresour. Technol. 171 (2014) 285–290. https://doi.org/10.1016/j.biortech.2014.08.105.

[92] J. Wang, J. Shen, D. Ye, X. Yan, Y. Zhang, W. Yang, X. Li, J. Wang, L. Zhang, L. Pan, Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China, Environ. Pollut. 262 (2020). https://doi.org/10.1016/j.envpol.2020.114665.