Electrooxidation of polar benzotriazole - The impact of supporting electrolyte

Helena Prosen¹, Borislav N. Malinović², Eva Korenčić¹, Jernej Markelj¹, Stefan Vranješ², Tijana Đuričić²

¹University of Ljubljana, Faculty of Chemistry and Chemical Technology, Ljubljana, Republic of Slovenia ²University of Banja Luka, Faculty of Technology, 78000 Banja Luka, B&H

ISSN 2712-1267 UDC: 541.135.52:[544.6:621.35 https://doi.org/10.7251/JCTE2001028P Original scientific paper

Paper received: 11 Sep 2020 Paper accepted: 28 Oct 2020 Paper available from 30 Dec 2020 at https://glasnik.tf.unibl.org

Keywords: electrochemical treatment, wastewater, BDD anode.

Polar benzotriazoles are heterocyclic compounds widely used in industry, and as such are easily released into the environment. These compounds show harmful and toxic effects on plants and some aquatic organisms, biodegrade quite slowly, and some, depending on the structure, have the ability to bioaccumulate. They can only be partially removed by conventional wastewater treatment, and are therefore found in a variety of waters, as well as solid waste. In this paper, synthetic wastewater containing polar benzotriazole was treated by an electrooxidation process. The efficiency of the treatment was tested depending on various parameters, such as: anode material (mixed metal oxide - MMO and boron-doped diamond - BDD), applied current density (10 and 20 mA/cm²), type of supporting electrolyte (NaCl, Na₂CO₃, Na₂SO₄, H₂SO₄) and treatment time (0.5 - 2.5 h). Obtained results showed the treatment was more effective at higher current density and by using BDD anode. Also, the efficiency of the treatment increases with the prolongation of the electrolysis time. After 2.5 h of treatment, 97.9% of benzotriazole was removed, in the presence of sulfuric acid as supporting electrolyte.

INTRODUCTION

In recent years, electrochemical technologies have been intensively developed for the treatment of wastewater, which is one of the global environmental problems. Generally, electrochemical processes can be classified as classical electrochemical treatments (electrodeposition / electroreduction, electrocoagulation, electroflotation, electrodialysis, and electrofiltration), electrochemical advanced oxidation process - EAOPs (electrochemical oxidation, electro-Fenton, photoelectrochemical and sono-electrochemical technologies, and capacitive deionization). and combined electrochemical treatments. The combination of two or more different processes often leads to greater process efficiency, reduced reaction time and increased process economy (Malinovic et al., 2021 - in press).

The main advantage of this technology is its environmental compatibility due to the fact that it involves the use of a very pure reagent - electrons. This means that treatment does not require the addition of any chemicals (e.g. coagulants, flocculants, oxidizing agents etc.), compared to classical chemical treatment. The proper choice of technique and electrode material can in some cases completely avoid the formation

*Corresponding author: Tijana Djuricic, University of Banja Luka, Faculty of Technology, Bulevar Vojvode Stepe Stepanovića 73, Banja Luka, RS, B&H; email: tijana.djuricic@tf.unibl.org of by-products (secondary pollution), and allow for the complete removal and even mineralization of a wide range of different pollutants. The equipment is relatively simple, easily amenable to automation and modular adaptation (Malinovic et al., 2021 – in press).

Investment costs depend on many factors, primarily on the composition and the amount of wastewater, the type of electrode material, and the desired degree of purification. Of course, it must be emphasized that many other challenges need to be faced in order to achieve high treatment efficiency and low energy consumption, but a combination of these treatments as a pre- or post-treatment with conventional wastewater treatment systems could be an effective and environmental friendly option that can be realized (Ali Khan et al., 2020). Also, a combination with other advanced oxidation processes can improve the degradation efficiency of pollutants because of the synergetic effect.

The most important role of supporting electrolyte is to increase the conductivity of wastewater in case of its low conductivity, which affects the increase of energy efficiency. The addition of appropriate ions increases the conductivity, and additional oxidizing agents can be formed by electrogeneration, such as active chlorine species. In the presence of chloride ions, the electrochemical oxidation of organic matter is usually accelerated. In this case, organic matter can be oxidized at the electrode or in solution by a chemical reaction (Groenen Serrano, 2018). However, the addition of some anions, such as chlorides, can lead to the formation of undesirable byproducts - organochlorinated species. Organochlorinated products exhibit increased toxicity and are usually more recalcitrant than the parent molecules (Moreira et al., 2017).

Benzotriazoles group of widespread are а environmental pollutants, classified as contaminants of emerging concern. 1H-Benzotriazole (BTA) and its polar derivatives, such as Tolyltriazole, are used as anticorrosive agents in industrial fluids, de-icing liquids, households products, etc. High production, widespread use, and insufficient removal in the wastewater treatment plants due to their low biodegradability has led to their ubiquitous presence in environmental waters (Shi et al. 2019). A survey conducted in 2013 in European Union countries has shown their presence in >97% of effluent wastewater, which are the main entry route to the environment (Wang et al. 2016). Despite some chronic adverse health effects (Speltini et al. 2016), they are currently not regulated in the European Union, and their limit concentrations in the environment haven't as yet been established.

Various procedures have been developed to transform or degrade BTA into less harmful products, mostly advanced oxidation processes, such as different photolysis methods (Ahmadi et al., 2016; Benitez et al., 2013; Borowska et al., 2016; Neamtua et al., 2014; Serdechanova et al., 2014) or photocatalysis (Xu et al., 2013); oxidation with ferrate (VI) ion (Yang et al., 2011); Ru/TiO₂-catalyzed oxidation with permanganate (Zhang et al., 2014); ozonation (Mawhinney et al., 2012) and a combination with peroxymonosulfate and ultrasound (Ghanbari et al., 2020); electron beam (2.5 MeV), and addition of persulfate ions (Roshani et al., 2011); Fe⁰/persulfate activated by weak magnetic field (Xiong et al., 2014); by radiation on TiO₂ (Felis et al., 2016); and by UV/chlorination process (Lee et al., 2019). Although most of these treatments were successful, one of the disadvantages is the addition of other chemicals into the treated sample (Benitez et al., 2013; Felis et al., 2016; Ghanbari et al., 2020; Lee et al., 2019; Mawhinney et al., 2012; Neamtua et al., 2014; Roshani et al., 2011; Wu et al., 2013; Xiong et al., 2014; Xu, et al. 2013; Yang et al., 2011; Zhang et al., 2014), except for the pure photocatalytic process (Borowska et al., 2016; Serdechanova et al., 2014). To date, only a few studies researched the electrochemical treatment of BTA, mostly with different photo-electric methods (Ahmadi et al., 2016; Ahmadi and Ghanbari, 2018; Ding et al., 2010; Wu et al., 2013). Only one study on electrooxidation of BTA was found (Xing et al., 2012), where the process was conducted with boron-doped diamond anode in Na₂SO₄ as supporting electrolyte. After 5 h, 72% of BTA was degraded.

In this paper, electrooxidation was more extensively investigated as a tool to degrade 1*H*-benzotriazole as a relevant pollutant in waste and environmental waters. Its removal was examined in synthetic wastewater. The impact of different supporting electrolytes on the degradation efficiency of BTA from wastewater was studied.

MATERIALS AND METHODS

Chemicals

To prepare the synthetic wastewater, 1*H*-benzotriazole, 99.0% (Acros Organics) was dissolved in distilled water to a concentration of 1 mM. This solution was stored in the refrigerator until used in experiments. As supporting electrolytes, different chemicals were used: sodium chloride, 99.5% NaCl (LachNer), sodium sulfate, 99% Na₂SO₄ (LachNer), sodium carbonate, 99.5% Na₂CO₃ (Merck Alkaloid), and sulphuric (VI) acid, 96% H₂SO₄ (LachNer). For the purpose of cleaning the electrodes, hydrochloric acid, 35% HCl (LachNer) and acetone, C₃H₆O (LachNer) were used.

Electrolysis

The experimental part presents the application of the electrooxidation (EO) process of synthetic wastewater containing 1*H*-benzotriazole. A batch electrochemical reactor, made of polyester, with the possibility of constant mixing, in which two electrodes were placed, was used for experimental research. All the experiments were performed at an ambient temperature, with the initial wastewater volume of 400 cm³, and stirred by a magnetic stirring bar (300 rpm).

The applied anodes for the EO process were BDD (boron-doped diamond on a niobium substrate, Metachem, Germany; which is made in the form of a BDD grid - "mesh" type B) and mixed metal oxide -MMO (mixtures of oxides of IrO₂ and RuO₂ on a titanium substrate, Metachem, Germany; which is made in the form of a MMO grid - "mesh" type A). Useful surface of both anodes was 28.26 cm², and the stainless steel (SS) plate was used as cathode (EN 1.4301/AISI 304; max. 0.07% C, 18.1% Cr, 8.2% Ni). The BDD and MMO electrodes were welded to a metal support and built into the reactor (Figure 1). The distance between electrodes was 2 cm. Before each experiment, BDD and MMO electrodes were immersed in dilute solution of hydrohloric acid to remove contaminants, and then washed with distilled water. Stainless steel cathode was polished, immersed in diluted solution of hydrochloric acid, degreased in acetone, and then washed with distilled water. The electrodes were connected to power source (Atten, APS3005SI; 30V, 5A), and the electrolysis was performed at a desired current density.

_				
	Supporting electrolyte	Concentration (mol/L)	Conductivity (mS/cm)	pН
	NaCl	0.20	18.17	5.80
	Na ₂ CO ₃	0.15	18.14	11.74
	H ₂ SO ₄	0.05	18.33	1.23
	Na_2SO_4	0.13	18.25	5.51

Table 1. The concentrations of supporting electrolytes, conductivity and pH of synthetic wastewater

Different supporting electrolytes were used in different concentrations in order to achieve approximately the same conductivity (Table 1). The pH of the synthetic wastewater ranged from a strongly acidic to a strongly basic, depending on the applied supporting electrolyte. The concentrations of added supporting electrolytes and conductivity of synthetic wastewater with 1*H*-benzotriazole are given in Table 1.

Analytical determination of BTA and its degradation products

The concentration of BTA in the samples of synthetic wastewater before and after treatment were determined by high-performance liquid chromatographic method with diode-array detector (HPLC-DAD). The analysis was performed on an Agilent 1100 Series HPLC-DAD instrument (Agilent, USA). The Kinetex XB-C18 column (Phenomenex, USA, 150 × 4.6 mm, 5 μm) was used at room temperature. The mobile phase consisted of acetonitrile (A) and 0.1 % HCOOH in MQ (B), with the gradient profile: 5 % A, ramp to 15 % A in 0.5 min, then to 35 % A in 12.5 min, then to 100 % A in the next 7 min. The flow rate was 0.7 mL/min, and the injection volume was 20 µL. BTA was monitored at the wavelength of 260 nm. Quantification was performed by external calibration using standard solutions of BTA. The method was linear in the 0.5–50.0 mg/L range.

RESULTS AND DISCUSSION

In the first part of the research, the efficiencies of the used electrode materials at different current densities during 2 h electrolysis duration were examined. The results are presented in relation to the selected electrode pairs (BDD - SS and MMO - SS).

The tested MMO anode is a mixture of oxides RuO_2 and IrO_2 , in a non-stoichiometric ratio, which are deposited on a titanium base. The mixture of these oxides was chosen due to the low overvoltage of chlorine and hypochlorite separation (additional oxidizing agent). In the case when the wastewater does not contain chlorides (as a supporting electrolyte), these species will not be generated, and it is expected that the process will show lower efficiency values, in contrast to the case when chloride ions are present in the solution.



Figure 1. The scheme of a laboratory batch reactor: 1 – source of electric power; 2 – electrochemical cell;
3 – anode; 4 – cathode; 5 – magnetic stir bar; 6 – magnetic stirrer/heater; 7 – cathode holder.

According to recent literature (Groenen Serrano, 2018), the anodes in AOPs can be "active" (low oxygen evolution overpotential) or "inactive" (high oxygen evolution overpotential). Boron-doped diamond - BDD anodes belong to the group of "inactive" anodes, and they are poor electrocatalysts for the oxygen evolution overpotential, while the mixed metal oxide - MMO anodes belong to the group of "active" anodes and they are good electrocatalysts for oxygen evolution. On "inactive" anodes, there is a weak connection between the electrode and the hydroxyl radical, therefore, the oxidation is mediated by OH. giving complete degradation. Generated hydroxyl radicals on the BDD electrode surface has the highest oxidation potential and will exhibit a fast and strong reaction, and favor complete mineralization (Groenen Serrano, 2018). But, on these "inactive" anodes, direct electrooxidation can also occur.

From Figure 2 it can be seen that there is a relatively small difference in the concentrations of the remaining BTA after treatment with both used anodes, but in the further research only BDD anode was used due to a slightly higher achieved efficiency. At a higher current density, a higher decomposition efficiency was achieved, so in a further study a current density of 20 mA/cm² was used, which is in accordance with the previous research (Xing et al., 2012).



Figure 2. The impact of anode material and current density on BTA degradation $(\gamma_{BTA.initial} = 120 \text{ mg/L}, c_{NaCl} = 0.2 \text{ mol/L}, \text{ stirring 300 rpm})$

The supporting electrolyte plays an important role in electrochemical treatments. It serves to increase the electrical conductivity of the treated water (and reduce electricity consumption), and in the process of anodic oxidation can lead to the formation of secondary oxidants that will increase the efficiency of the process itself. But, it is important to emphasize that the supporting electrolyte can react with pollutants that decompose during anodic oxidation, and generate secondary pollution. Sodium chloride was first used as supporting electrolyte. But, it is known that in the electrolyte containing Cl⁻, a large number of degradation products can generate. The toxicity of chlorinated organic compounds could be problematic, as chlorinated organic compounds have relatively high toxicity (Li et al., 2017). For this reason, we used several supporting electrolytes in this study. Figure 3 shows the effect of electrolysis duration on BTA degradation with different supporting electrolytes. At shorter treatment times (0.5, 1, and 1.5 h) BTA is better degraded in the presence of NaCl as a supporting electrolyte, while at longer treatment



Figure 3. The impact of electrolysis duration and supporting electrolyte on BTA degradation $(\gamma_{RTA initial} = 120 \text{ mg/L}, j = 20 \text{ mA/cm}^2, stirring 300 \text{ rpm})$

time (2 and 2.5 h) it is more efficiently degraded in the presence of H_2SO_4 . After 2.5 h of treatment, the following benzotriazole removal efficiencies were achieved: 88.5% (Na_2CO_3), 91.5% (Na_2SO_4), 94.4% (NaCl), and 97.9% (H_2SO_4). For this reason, as well as because secondary organochlorinated compounds were formed in the presence of chloride ions, H_2SO_4 was selected as the optimal supporting electrolyte for the electrooxidation of BTA.

It can be concluded that the process can be described by a first order rate, which is confirmed by a relatively high correlation coefficient, R^2 = 0.9805 (Figure 4). The reaction rate constant of electrooxidation of BTA amounts to k= -1.505 h⁻¹.



Figure 4. The impact of electrolysis duration on BTA degradation with H_2SO_4 as supporting electrolyte $(\gamma_{BTA,initial} = 120 \text{ mg/L}, \text{ stirring 300 rpm})$

CONCLUSION

Based on the obtained results, it can be concluded that electrooxidation is an effective treatment for the degradation of polar benzotriazoles. The treatment efficiency depends on the electrode material, applied current density, electrolysis duration, as well as the used supporting electrolyte. The use of sulfuric acid as supporting electrolyte for 2.5 h of treatment leads to almost complete degradation of benzotriazole, and the formation of undesirable byproducts, organochlorinated species, is avoided.

Acknowledgements: This work was supported in part by the Ministry of Scientific and Technological Development, Higher Education and Information Society, the Government of the Republic of Srpska, under Bilateral Project 19/6-020/964-11/18 and National scientific project 19.032/961-49/19, as well as by Slovenian Research Agency (research core funding No. P1-0153).

REFERENCES

- Ahmadi, M., & Ghanbari, F. (2018). Degradation of organic pollutants by photoelectro-peroxone/ ZVI process: Synergistic, kinetic and feasibility studies. Journal of Environmental Managing 228, 32–39. <u>https://doi.org/10.1016/j.jenvman.2018.08.102</u>
- Ahmadi, M., Ghanbari, F., & Madihi-Bidgoli, S. (2016).
 Photoperoxi-coagulation using activated carbon fiber cathode as an efficient method for benzotriazole removal from aqueous solutions: Modeling, optimization and mechanism.
 Journal of Photochemistry and Photobiology A: Chemistry, 322-323, 85-94. <u>https://doi.org/10.1016/j.jphotochem.2016.02.025</u>
- Ali Khan, J., Sayed, M., Khan, S., Shah, N. S., Dionysiou, D. D., & Boczkaj, G. (2020). Advanced oxidation processes for the treatment of contaminants of emerging concern, In Hernandez-Maldonado, A., Blaney, L. (Eds.), Contaminants of Emerging Concern in Water and Wastewter. (pp. 299-365). Advanced Treatment Processes.
- Benitez, F. J., Acero, J. L., Real F. J., Roldan, G., & Rodriguez, E. (2013). Photolysis of model emerging contaminants in ultra-pure water: Kinetics, by-products formation and degradation pathways. *Water Research*, 47(2), 870-880. <u>https://doi.org/10.1016/j.</u> watres.2012.11.016
- Borowska, E., Felis, E., & Kalka, J. (2016). Oxidation of benzotriazole and benzothiazole in photochemical processes: Kinetics and formation of transformation products. *Chemical Engineering Journal*, 304, 852–863. https://doi.org/10.1016/j.cej.2016.06.123
- Ding, Y., Yang, C., Zhu, L., & Zhang, J. (2010). Photoelectrochemical activity of liquid phase deposited TiO₂ film for degradation of benzotriazole. *Journal of Hazardous Materials*, 175(1-3), 96-103. <u>https://doi.org/10.1016/j.</u> jhazmat.2009.09.037
- Felis, E., Sochacki, A., & Magiera, S. (2016). Degradation of benzotriazole and benzothiazole in treatment wetlands and by artificial sunlight. *Water Research*, 104, 441–448. <u>https://doi. org/10.1016/j.watres.2016.08.037</u>
- Ghanbari, F., Khatebasreh, M., Mahdavianpour, M., & Lin, K. Y. A. (2020). Oxidative removal of benzotriazole using peroxymonosulfate/ ozone/ultrasound: Synergy, optimization, degradation intermediates and utilizing for real wastewater. *Chemosphere*, 244, 125326 <u>https://doi.org/10.1016/j.</u> <u>chemosphere.2019.125326</u>

- Groenen Serrano, K. (2018). Indirect electrochemical oxidation using hydroxyl radical, active chlorine, and peroxodisulfate, In Martínez-Huitle, C. A., Rodrigo, M. A., Scialdone, O. (Eds), *Electrochemical water and wastewater treatment*. (pp. 133-164). Butterworth-Heinemann.
- Lee, J. E., Kim. M. K., Lee, J. Y., Lee, Y. M., & Zoh, K. D. (2019). Degradation kinetics and pathway of 1H-benzotriazole during UV/chlorination process. *Chemical Engineering Journal*, 359, 1502-1508. <u>https://doi.org/10.1016/j.</u> cej.2018.11.026
- Li, H., Long, Y., Zhu, X., Tian, Y., & Ye, J. (2017). Influencing factors and chlorinated byproducts in electrochemical oxidation of bisphenol A with boron-doped diamond anodes. *Electrochimica Acta*, 246, 1121–1130. <u>https://</u> doi.org/10.1016/j.electacta.2017.06.163
- Malinovic, B. N., Markelj, J., Prosen, H., Zgajnar-Gotvajn, A., & Kralj-Cigic, I. (2021 – in press). Electrochemical treatments for the removal of emerging contaminants, In Morin-Crini, N., Lichtfouse, É., Crini, G. (Eds.), *Emerging contaminants*. Springer Nature.
- Mawhinney, D. B., Vanderford, B. J., & Snyder, S. A. (2012). Transformation of 1H-benzotriazole by ozone in aqueous solution. *Environmental Science* & *Technology*, 46(13), 7102–7111. https://doi.org/10.1021/es300338e
- Moreira, F. C., Boaventura, R. A. R., Brillas, E., & Vílar, V. J. P. (2017). Electrochemical advanced oxidation processes: A review on their application to synthetic and real wastewaters. *Applied Catalysis B: Environmental*, 202, 217-261. https://doi.org/10.1016/j.apcatb.2016.08.037
- Neamtua, M., Grandjean, D., Sienkiewicz, A., Le Faucheur, S., Slaveykova, V. I., Colmenarese, J. J. V., Pulgarine, C., & Alencastro, L. F. (2014). Degradation of eight relevant micropollutants in different water matrices by neutral photo-Fenton process under UV₂₅₄ and simulated solar light irradiation – A comparative study. *Applied Catalysis B: Environmental*, 158–159, 30–37. https://doi.org/10.1016/j.apcatb.2014.04.001
- Roshani, B., Karpel, N., & Leitner, V. (2011). The influence of persulfate addition for the degradation of micropollutants by ionizing radiation. *Chemical Engineering Journal*, 168(2), 784–789. <u>https://</u> doi.org/10.1016/j.cej.2010.12.023
- Serdechnova, M., Ivanov, V. L., Rosario M., Domingues, M., Evtuguin, D. V., Ferreiraa, M. G. S., & Zheludkevichae, M. L. (2014). Photodegradation of 2-mercaptobenzothiazole

and 1,2,3-benzotriazole corrosion inhibitors in aqueous solutions and organic solvents. *Physical Chemistry Chemical Physics*, 16(45), 25152-25160. <u>https://doi.org/10.1039/</u> C4CP03867C

- Shi, Z-Q., Liu, Y-S., Xiong, Q., Cai, W-W., & Ying, G-G. (2019) Occurrence, toxicity and transformation of six typical benzotriazoles in the environment: a review. *Science of the Total Environment*, 661, 407–421. <u>https://doi.org/10.1016/j.scitotenv.2019.01.138</u>
- Speltini, A., Sturini, M., Maraschi, F., Porta, A., & Profumo, A. (2016) Fast low-pressurized microwaveassisted extraction of benzotriazole, benzothiazole and benezenesulfonamide compounds from soil samples. *Talanta* 147, 322–327. <u>https://doi.org/10.1016/j.</u> talanta.2015.09.074
- Wang, L., Zhang, J., Sun, H., & Zhou, Q. (2016) Widespread occurrence of benzotriazoles and benzothiazoles in tap water: influencing factors and contribution to human exposure. *Environmental Science and Technology*, 50(5), 2709–2717. <u>https://doi.org/10.1021/</u> acs.est.5b06093
- Wu, J., Pu, W., Yang, C., Zhang, M., & Zhang, J. (2013). Removal of benzotriazole by heterogeneous photoelectro-Fenton like process using ZnFe₂O₄ nanoparticles as catalyst. *Journal of Environmental Sciences*, 25(4), 801-807. <u>https://</u> doi.org/10.1016/S1001-0742(12)60117-X

- Xing, X., Zhu, X., Li, H., Jiang, Y., & Ni, J. (2012). Electrochemical oxidation of nitrogenheterocyclic compounds at borondoped diamond electrode. *Chemosphere*, *86*(4), 368-375. <u>https://doi.org/10.1016/j.</u> <u>chemosphere.2011.10.020</u>
- Xiong, X., Sun, B., Zhang, J., Gao, N., Shen, J., Li, J., & Guan, X. (2014). Activating persulfate by fe^o coupling with weak magnetic field: performance and mechanism. *Water Research*, 62, 53–62. https://doi.org/10.1016/j.watres.2014.05.042
- Xu, J., Li, L., Guo, C., Zhang, Y., & Wang, S. (2013). Removal of benzotriazole from solution by BiOBr photocatalysis under simulated solar irradiation. *Chemical Engineering Journal*, 221, 230–237. <u>https://doi.org/10.1016/j.</u> <u>cej.2013.01.081</u>
- Yang, B., Ying, G. G., Zhang, L. J., Zhou, L. J., Liu, S., & Fang, Y. X. (2011). Kinetics modeling and reaction mechanism of ferrate(vi) oxidation of benzotriazoles. *Water Research*, 45(6), 2261-2269. <u>https://doi.org/10.1016/j.</u> watres.2011.01.022
- Zhang, J., Sun, B., Xiong, X., Gao, N., Song, W., Du, E., Guan, X., & Zhou, G. (2014). Removal of emerging pollutants by Ru/TiO₂-catalyzed permanganate oxidation. *Water Research*, 63, 262-270. <u>https://doi.org/10.1016/j.</u> watres.2014.06.028

Elektrooksidacija polarnog benzotriazola – Uticaj pomoćnog elektrolita

Helena Prosen¹, Borislav N. Malinović², Eva Korenčić¹, Jernej Markelj¹, Stefan Vranješ², Tijana Đuričić²

¹Univerzitet u Ljubljani, Fakultet za hemiju i hemijsku tehnologiju, 1000 Ljubljana, Republika Slovenija ²Univerzitet u Banjoj Luci, Tehnološki fakultet, Banja Luka, B&H

Ključne riječi:

elektrohemijski tretman, otpadna voda, BDD anoda.

Polarni benzotriazoli (BTA) su heterociklična jedinjenja široko rasprostranjena u industriji, te kao takvi lako dospijevaju u životnu sredinu. Ova jedinjenja pokazuju štetne i toksične efekte na biljke i neke vodene organizme, biorazgrađuju se prilično sporo, a neki zavisno od strukture imaju sposobnost bioakumulacije. lako su klasifikovani kao supstance koje izazivaju zabrinutost, njihove granične koncentracije u okolini trenutno još nisu utvrđene i regulisane u Evropskoj uniji. Mogu biti samo djelimično uklonjeni konvencionalnim tretmanima obrade otpadnih voda, te se stoga nalaze u različitim vodama kao i čvrstom otpadu. U ovom radu sintetička otpadna voda koja sadrži polarni benzotriazol (1H-benzotriazol) tretirana je postupkom elektrooksidacije. Za potrebe eksperimentalnog dijela istraživanja korišten je šaržni elektrohemijski reaktor, izrađen od poliestera, sa mogućnošću stalnog miješanja, u koji su smještene dvije elektrode. Efikasnost tretmana ispitana je u zavisnosti od različitih parametara, kao što su: anodni materijal (miješani metalni oksid - MMO i borom dopovan dijamant -BDD), primijenjena gustina struje (10 i 20 mA/cm²), vrsta pomoćnog elektrolita (NaCl, Na₂CO₂, Na₂SO₄, H_aSO₄) i vrijeme trajanja tretmana (0.5 – 2.5 h). Koncentracija BTA u uzorcima sintetičke otpadne vode prije i poslije tretmana određena je metodom tečne hromatografije visokih performansi sa detektorom sa serijom dioda (HPLC-DAD). Rezultati ispitivanja su pokazali da je tretman efikasniji pri većoj gustini struje i primjenom BDD anode. Takođe, efikasnost tretmana raste sa produženjem vremena elektrolize. Pri kraćem vremenu tretmana BTA se bolje razgrađuje u prisustvu NaCl kao pomoćnog elektrolita, dok se pri dužim tretmanima (2 i 2,5 h) efikasnije razgrađuje u prisustvu H₂SO₄. Nakon 2.5 h tretmana 97.9% benzotriazola je uklonjeno u prisustvu sumporne kiseline kao pomoćnog elektrolita.