



AGNIESZKA GRDULSKA  
ROBERT KOWALIK  
Kielce University of Technology  
e-mail: rkowalik@tu.kielce.pl

Manuscript submitted 2020.08.03 – revised 2020.08.23,  
initially accepted for publication 2020.09.04, published in September 2020

# ESTROGEN REMOVAL FROM WASTEWATER

## USUWANIE ESTROGENU ZE ŚCIEKÓW

DOI: 10.30540/sae-2020-014

### Abstract

Currently, a significant problem of water and sewage management is the presence of human hormones, especially estrogens and progestagens, consumed by women in contraceptives and then excreted from the body. While other drugs are used by a small part of the population and rather sporadically, hormonal contraception is used by a large number of women, which contributes to their high concentration in sewage. Even relatively low estrogen concentrations (compared to other drugs) can have harmful effects on the body, disturbing the hormonal balance and leading to various endocrine disorders. In this paper the types of individual estrogen groups were characterized. Next, different methods of their removal from wastewater were presented. The parameters of estrogen removal efficiency depend on which parameters. Next, the effectiveness of each method was compared, also taking into account economic aspects. The work was summarized with appropriate conclusions.

**Keywords:** estrogens, hormones in sewage, methods of estrogen removal from sewage, sewage treatment

### Streszczenie

Obecnie istotnym problemem gospodarki wodno-ściekowej jest obecność w ściekach ludzkich hormonów, a zwłaszcza estrogenów i progestagenów, spożywanych przez kobiety w preparatach antykoncepcyjnych i wydalanych następnie z organizmu. O ile po inne leki sięga niewielka część populacji i to raczej sporadycznie, o tyle z antykoncepcji hormonalnej korzysta olbrzymia liczba kobiet, co przyczynia się do wysokiego ich stężenia w ściekach. Nawet stosunkowo małe stężenie estrogenów (w porównaniu z innymi lekami) może mieć szkodliwe skutki dla organizmu, zaburzając w nim równowagę hormonalną i prowadząc do różnych schorzeń endokrynologicznych. W pracy scharakteryzowano rodzaje poszczególnych grup estrogenów. Następnie przedstawiono różne metody ich usuwania ze ścieków. Przedstawiono, od jakich parametrów zależy efektywność usuwania estrogenów. Następnie porównano skuteczność każdej z metod, biorąc również pod uwagę aspekty ekonomiczne. Pracę podsumowano odpowiednimi wnioskami.

**Słowa kluczowe:** estrogeny, hormony w ściekach, metody usuwania estrogenów ze ścieków, oczyszczanie ścieków

### 1 REFERENCES

- [1] Stasinakis A., Gatidou G. *Micropollutants and aquatic environment*. 2016
- [2] Lester J.N. and Edge D., *Sewage and sewage sludge treatment*. In *Pollution Causes, Effects and Control*, Edited by Harrison R.M., 113–144. Cambridge, UK: The Royal Society of Chemistry. 2000.
- [3] Birkett J.W., Lester J.N., *Endocrine Disrupters in Wastewater and Sludge Treatment Processes*, 2003.
- [4] Adeel M., Song X., Wang Y., Francis D., Yang Y., *Environmental impact of estrogens on human, animal and plant life: „A critical review*. Environment International”. Vol 99. 2017
- [5] Grdulska A., Kowalik R., *Pharmaceuticals in water and wastewater – overview*. Structure and Environment, Vol. 2, 2020, pp. 79-84.
- [6] Servos M.R., Bennie D.T., Burnison, B.K., Jurkovic, A., McInnis, R., Neheli, T., Schnell A., Seto, P., Smyth S.A., Ternes T.A. *Distribution of estrogens, 17 [beta]-estradiol and estrone*, [in:] *Canadian municipal wastewater treatment plants*. Sci. Total Environ., 336, 2005. pp. 155-170.
- [7] Shi J., Fujisawa S., Nakai S. Hosomi M., *Biodegradation of natural and synthetic estrogens by nitrifying activated sludge and ammonia-oxidizing bacterium, Nitrosomonas europaea*. Water Res., 38, 2004, pp. 2323–2330.

- [8] Yabuuchi E., Yano I., Oyaizu H., Hashimoto Y., Ezaki T. and Yamamoto H., *Proposals of Sphingomonas-paucimobilis* gen-nov and comb nov, *Microbiol. Immunol.*, 34, 1990, pp. 99-119.
- [9] Czajka C., Londry K., *Anaerobic Biotransformation of Estrogens*. *Science of The Total Environment* 367(2-3) 2006.
- [10] Włodarczyk-Makuła M., *Wybrane Związki Endokrynnie aktywne EDC w środowisku wodnym*. LAB Laboratoria, Aparatura, Badania, 19, 2014, pp. 20-25.
- [11] Ternes T.A., Stumpf, M., Mueller J., Haberer K., Wilken R.D. and Servos M., *Behavior and occurrence of estrogens in municipal sewage treatment plants – I. Investigations in Germany, Canada and Brazil*. *Sci. Total Environ.*, 1999, pp. 81-90.
- [12] Johnson A.C., Aerni H.-R., Gerritsen A., Gibert M., Giger W., Hylland K., Jurgens M., Nakari T., Pickering A., Suter M.J.-F., *Comparing steroid estrogen, and nonylphenol content across a range of European sewage plants with different treatment and management practices*. *Water Res.*, 39, 2005, pp. 47–58.
- [13] Jiang J.Q., Yin Q., Zhou J.L., Pearce P., *Occurrence and treatment trials of endocrine disrupting chemicals (EDCs) in wastewaters*. *Chemosphere*, 61, 2005, pp. 544–550.
- [14] Shi J., Fujisawa S., Nakai S. and Hosomi M. *Biodegradation of natural and synthetic estrogens by nitrifying activated sludge and ammonia-oxidizing bacterium Nitrosomonas europaea*. *Water Res.*, 38, 2004, pp. 2323–2330.
- [15] Zhang Z. H., Feng Y. J., Gao P., Liu J. F. and Ren N. Q., *Comparing the adsorption and desorption characteristics of 17 $\alpha$ -ethinylestradiol on sludge derived from different treatment units*. *International Journal of Environment Science and Technology*, 9, (2012), pp. 247-56.
- [16] Bernardelli J., Liz M., Belli T., Lobo-Reico M., Lapolli F., *Removal of estrogens by activated sludge under different conditions using bath experiments*. *Brazilian Journal of Chemical Engineering*. Sao Paulo. Vol 32. No.2. 2015.
- [17] Li F., Desmiarti R., Yuasa A. and Horio A., *Behavior of natural estrogens in semicontinuous activated sludge biodegradation reactors*. *Bioresource Technology*, 99, 2008, pp. 64-71.
- [18] Combalbert S. and Hernandez-Raquet G., *Occurrence, fate, and biodegradation of estrogens in sewage and manure*. *Applied Microbiology and Biotechnology*, 86, 2010, pp. 1671-92.
- [19] Hai F., Yamamoto K., Lee C., *Membrane biological reactors*. Theory, modelling, design, management and applications to wastewater reuse. IWA. 2011
- [20] Clouzot L., Doumenq P., Vanloot P., *Membrane bioreactors for 17 $\alpha$ -ethinylestradiol removal*. *Journal of Membrane Science* 362, 2007, pp. 81-85.
- [21] Weber S., Leuschner P., Kampfer P., Dott W., Hollender J., *Degradation of estradiol and ethinyl estradiol by activated sludge and by a defined mixed culture*. *Appl. Microbiol. Biotechnol.*, 67, 2005, pp. 106-112.
- [22] Wintgens T., Gallenkemper M., Melin T., *Removal of endocrine disrupting compounds with membrane processes in wastewater treatment and reuse*. *Water Sci. Technol.*, 50 (5):2004, pp. 1–8.
- [23] Holbrook R.D., Love N.G., Novak J.T., *Biological wastewater treatment and estrogenic endocrine disrupting compounds: Importance of colloid organic carbon*. *Pract. Periodical Haz. Toxic. Radioactive Waste Manage.*, 7, 2003, pp. 289-296.
- [24] <http://www.writeintheshadows.com/business/biological-nutrient-removal-processes-with-flow-equalization-tanks.html> access 20.07.2020
- [25] Joss A., Andersen H., Ternes T., Richle P.R., Siegrist H., *Removal of estrogens in municipal wastewater treatment under aerobic and anaerobic conditions: Consequences for plant optimization*. *Environ. Sci. Technol.*, 38, 2004, pp. 3047–3055.
- [26] Chiu T., Boobis A., Lester J., *Treatment and removal strategies for estrogens from wastewater*. *Environmental Technology* 29. 2008.
- [27] Schäfer A.I. and Waite T.D., *Removal of endocrine disruptors in advanced treatment – the Australian approach*. [in:] *Proceedings of the IWA World Water Congress, Workshop Endocrine Disruptors*, Melbourne, Australia, 2002, pp. 37-51
- [28] Chang S., Waite T.D., Ong P.E.A., Schafer A.I., Fane A.G., *Assessment of trace estrogenic contaminants removal by coagulant addition, powdered activated carbon adsorption and powdered activated carbon/microfiltration processes*. *J. Environ. Eng.-ASCE*, 130, 2004, pp. 736-742.
- [29] Itoh S., Yoshimura Y., Okada T. Tsujimura Y., *Detection of estrogenic effect formation potential in chlorinated drinking water*. [in:] *2nd IWA Leading Edge Conference on Water and Wastewater Treatment Technologies*, Prague, Czech Republic: IWA. 2004. pp. 60-62
- [30] Nghiem L.D., Manis A., Soldenhoff K. Schafer A.I., *Estrogenic hormone removal from wastewater using NF/RO membranes*. *J. Membr. Sci.*, 242, 2004, pp. 37-45.
- [31] Fukuhara T., Iwasaki S., Kawashima M., Shinohara O. Abe I., *Adsorbability of estrone and 17 beta-estradiol in water onto activated carbon*. *Water Res.*, 40, 2006, pp. 241-248.
- [32] Lee J., Park H. and Yoon J. *Ozonation characteristics of bisphenol A in water*. *Environ. Technol.*, 24, 2002,

- pp. 241-248.
- [33] Rudder J.D., Wiele T.V.D., Dhooge W., Comhaire F., Verstraete W., *Advanced water treatment with manganese oxide for the removal of 17[alpha]-ethynylestradiol (EE2)*. *Water Res.*, 38, 2004. pp. 184-192.
- [34] Lee Y., Yoon J. and Von Gunten U., *Kinetics of the oxidation of phenols and phenolic endocrine disruptors during water treatment with ferrate (Fe(VI))*. *Environ. Sci. Technol.*, 39, 2005, pp. 8978-8984.
- [35] Mizuguchi T., Shibayama Y., Mitamura K. and Shimada, K., *Contribution of glucuronic acid and sulfonic acid moieties during photocatalytic degradation of estrogen conjugates*. *J. Health Sci.*, 51, 2005, pp. 447-452.