

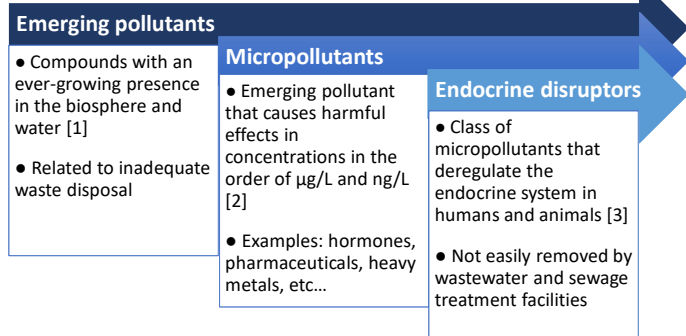
Estrogen removal through adsorption on carbon materials prepared from biomass wastes: A review

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Introduction



To solve the issue of estrogen contamination, several separation methods have been proposed. Adsorption has been studied as a viable and practical alternative with a variety of highly efficient adsorbents, such as resins, silica, clays, zeolites, graphene oxides, chitosan, multi-walled carbon nanotubes and activated carbons [4].

Properties of activated carbon

- Carbonaceous material mainly composed of lignin and cellulose
- Well defined microporous structure
- Rich amount of surface chemical groups (i.e.: hydroxides, ketones, aldehydes, carboxylic acids, etc...)
- High surface area and porous volume

In more recent years, there has been a transition from non-renewable adsorbent sources, like coal, to more green and low-cost sources, like agro-industrial and forestry biomass rich in carbon compounds, such as activated carbon [4].

Types of estrogen

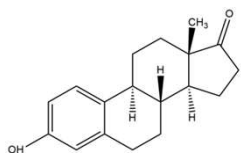


Figure 1. Chemical structure of estrone (estrogen E1).

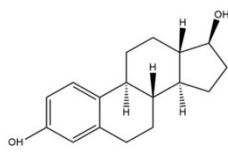


Figure 2. Chemical structure of 17β-estradiol (estrogen E2).

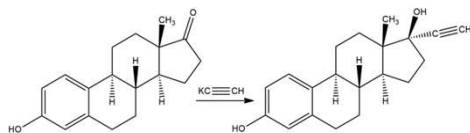


Figure 3. Chemical structure of 17α-ethinylestradiol (estrogen EE2).

Pathways for estrogen contamination

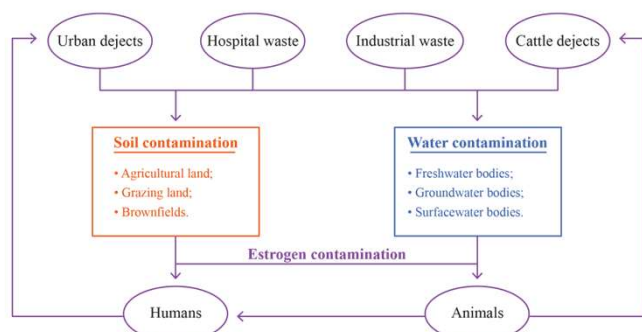


Figure 4. Main pathways for estrogen contamination in humans and animals.

Estrogen contamination in Portugal

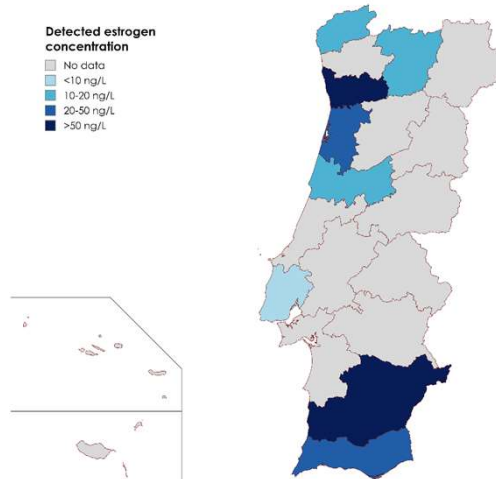


Figure 5. Maximum estrogen concentration detected by district in Portugal. [5-12]

Estrogen impact on human health

Table 1. Summary of disorders in humans provoked by endocrine disruptors. [13]

Type of disorder	Male disorders	Female disorders
Endocrine	Premature puberty	Premature puberty Delayed puberty Disturbed lactation
Reproductive	Infertility (oligospermia)	Disorders in ovulation
Oncological	Testicular cancer	Vaginal cancer (adenocarcinoma) Breast cancer
Fetal/neonatal conditions	Intrauterine growth restriction Sexual deformities such as cryptorchidism and hypospadias	Intrauterine growth restriction

Review on estrogen removal using biomass wastes

Table 2. Selected adsorption studies from literature and respective main results.

Estrogens	Adsorbent	Activation	Adsorption capacity (mg/g)	Isotherm Model	Kinetic Model	Ref
E1, E2	Banana peel	No activation	0.387 – 0.420	Freundlich	PSO	14
EE2	Palm kernel shell	Carbonization	1.68	Langmuir	General	15
E1, E2, E3	Walnut shell	Pyrolysis	0.80 – 2.80	Freundlich	PSO	16
E2	Corn straw	Pyrolysis	99.8	Langmuir	PSO	17
E2	Wood sawdust	K ₂ FeO ₄ + pyrolysis	99.67 – 133.45	Langmuir	PSO	18

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References

- Popov "Removal of emerging pollutants from aqueous matrices", 2020, *MSc. Thesis*, Instituto Politécnico de Bragança.
- N. Souza "Avaliação de micropoluentes emergentes em esgotos e águas superficiais", 2011, *MSc. Thesis*, Universidade Federal do Ceará.
- W. Vieira, M. Farias, M. Spalozzi et al., *Environmental Chemistry Letters*, 2020, **18**, 1113–1143.
- Y. Ouyang, L. Zhou, Z. Liu, J. Heng et al., *Separation and Purification Technology*, 2020, **253**, 117536.
- S. Rocha, V. Domingues, C. Pinho et al., *Bulletin of Environmental Contamination and Toxicology*, 2013, **90**, 73-78.
- M. Rocha, C. Cruzeiro, M. Reis et al., *Environmental Monitoring and Assessment*, 2016, **188**, 240.
- M. Rocha, C. Cruzeiro, M. Reis et al., *Environmental Monitoring and Assessment*, 2014, **186**, 3337-3350.
- M. Rocha, C. Cruzeiro, M. Reis et al., *Environmental Monitoring and Assessment*, 2013, **185**, 8215-8226.
- M. Rocha, C. Cruzeiro, M. Reis et al., *Environmental Monitoring and Assessment*, 2015, **187**, 483.
- M. Rocha, C. Cruzeiro, C. Peixoto et al., *Archives of Environmental Contamination and Toxicology*, 2014, **67**, 389-401.
- C. Ribeiro, M. Tiritan, E. Rocha et al., *Archives of Environmental Contamination and Toxicology*, 2009, **56**, 1-11.
- C. Mansilha, A. Melo, I. Ferreira et al., *Bulletin of Environmental Contamination and Toxicology*, 2011, **87**, 312-318.
- E. Diamanti-Kandarakis, J. Bourguignon, L. Giudice, R. Hauser et al., *Endocrine Reviews*, 2009, **30**(4), 293-342.
- P. Sousa, L. Furtado, J. Neto et al., *Brazilian Journal of Analytical Chemistry*, 2019, **6**, 14-28.
- K. Beri, D. Barbosa, M. Zbair et al., *Energy Nexus*, 2021, **1**, 100009.
- H. Xu, Y. Han, G. Wang et al., *Environmental Technology & Innovation*, 2022, **28**, 102870.
- W. Guo, J. Yue, Q. Zhao et al., *Molecules*, 2022, **27**, 2567.
- Y. Zhou, S. Liu, Y. Liu et al., *International Journal of Environmental Research and Public Health*, 2020, **17**, 8377.