

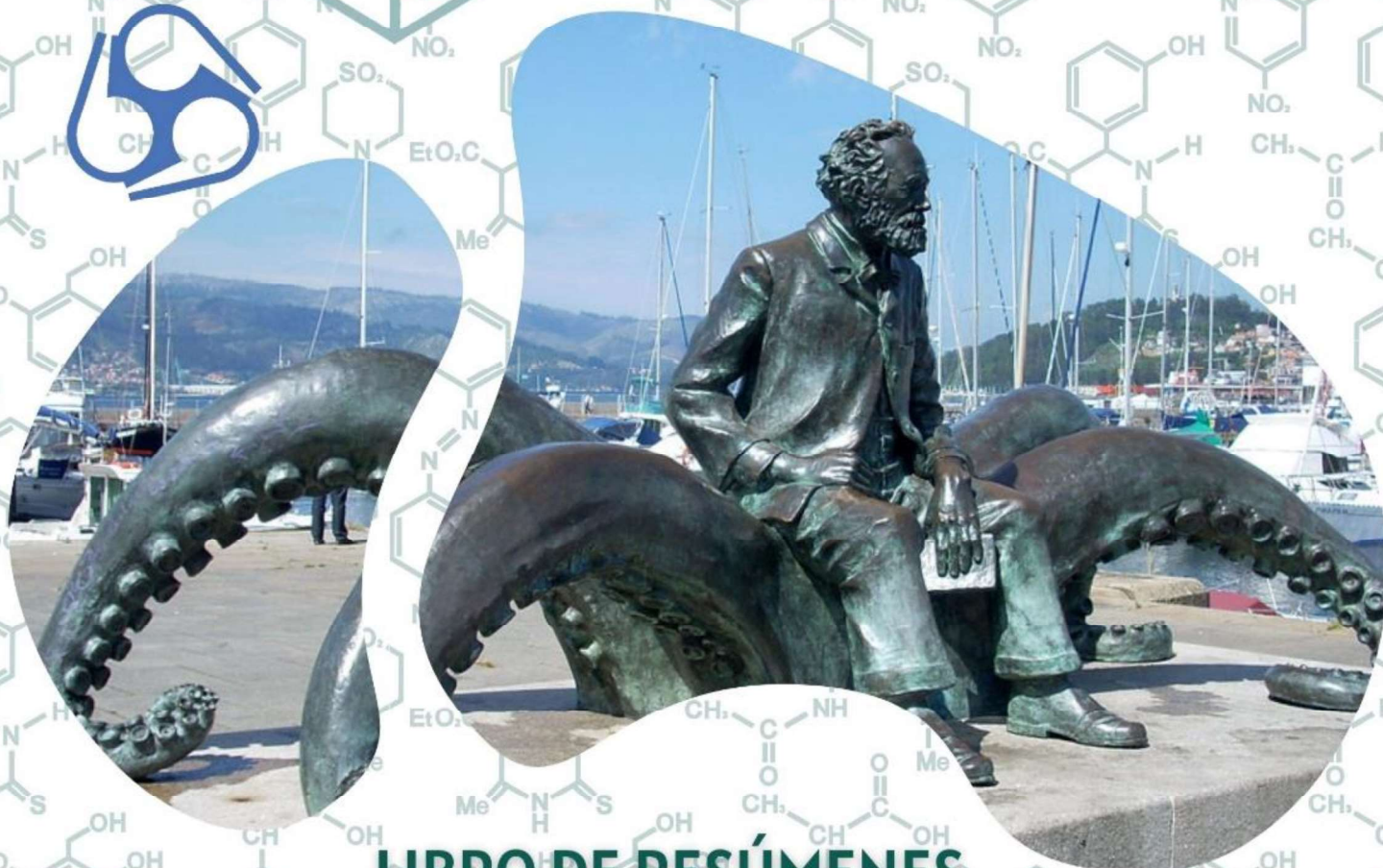
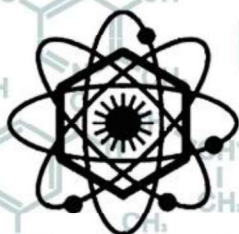
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Estrogen Removal through Adsorption by Carbon Materials Prepared from Biomass Wastes: A Review

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Environmental impacts are an ever-growing concern in various industrial and economic sectors that produce wastes such as heavy metals, pharmaceuticals, pesticides, surfactants, and petroleum derivatives. These substances can be classified as emerging pollutants due to their increasing concentration in water bodies and living beings [1]. Since many of these substances can only be found in very low concentrations, in micrograms per liter ($\mu\text{g/L}$) or nanograms per liter (ng/L), they can also be classified as micropollutants [2].

One type of micropollutant that has been especially concerning are endocrine disruptors, composed of natural hormones, such as estrone (estrogen E1) and 17β -estradiol (estrogen E2), and synthetic hormones, such as 17α -ethinylestradiol (estrogen EE2). Endocrine disruptors can deregulate the endocrine system of both humans and animals and, due to their nature as micropollutants, are not effectively removed by conventional processes in wastewater treatment plants [3].

To establish a state-of-the-art in the particular field of alternative treatment methods based on adsorption, previous studies were selected with topics such as estrogen molecules removed, adsorbent activation type, adsorption capacity, and best fit for isotherm and kinetic models. Hence, a few relevant literature studies concerning biomass waste-based materials are summarized in Table 1.

Table 1. Selected adsorption studies from the literature and the 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	4
EE2	Palm kernel shell	Steam carbonization	1.68	Langmuir	PSO	5
E1, E2, E3	Walnut shell	Pyrolysis	0.80 – 2.80	Freundlich	PSO	6
E2, EE2	Coffee waste	Ca(OH)_2 + pyrolysis	7.584 – 7.833	Sips	General	7
E2	Rice husk	NaOH + pyrolysis	32.41	Langmuir	PSO	8
E2	Corn straw	Pyrolysis	99.8	Langmuir	PSO	9
E2	Wood sawdust	K_2FeO_4 + pyrolysis	99.67 – 133.45	Langmuir	PSO	10

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