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PFAS BIOADSORPTION: NOVEL WAYS OF TRANSFORMING WASTE INTO BIOSORBENTS

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Introduction
PFAS, including PFOS and PFOA, are synthetic surfactants extensively used in firefighting foams, coatings, and industrial processes. Due to their chemical stability and resistance to degradation, these compounds are now widespread in surface waters, groundwater, and even drinking water sources. Their toxicity and bioaccumulative nature have prompted regulatory restrictions and stimulated global interest in developing efficient removal technologies.
Conventional water treatment plants are ineffective in removing PFAS, which has led to increased research into advanced and sustainable methods such as adsorption. Among emerging materials, agri-waste biosorbents offer an attractive solution, combining low cost, renewable origin, and environmental benefits. Orange peel, rich in functional groups (e.g., carboxyl, hydroxyl), has shown promise in binding organic pollutants through multiple mechanisms.
This study evaluates the effectiveness of orange peel in adsorbing PFOS and PFOA from aqueous solutions, under varied conditions. The influence of pH, contact time, sorbent dose, and initial concentration was analyzed to determine optimal parameters for maximum removal efficiency, supporting a waste-to-resource approach in PFAS remediation.

Materials and methods
Orange peel waste was washed, dried, and ground into fine powder (particle size <1 mm) and used without chemical modification. Adsorption experiments were performed in 50 mL solutions containing 10 mg/L of PFOS or PFOA, with 50 mg of biosorbent added. pH values (1–5) were adjusted with HCl or NaOH. Contact time varied from 0 to 6 hours. Additional tests were conducted to evaluate the effect of adsorbent dose (50–200 mg) and initial PFOS concentration (1–50 mg/L). After treatment, samples were filtered and PFAS concentrations determined by LC-MS/MS. Removal efficiency (%) was calculated based on initial and final concentrations.

Results and conclusions
Orange peel demonstrated high adsorption potential for PFOS, reaching 99% removal at pH 2 and 89% after 1 hour. PFOA removal was more moderate, with a maximum of 74% after 3 hours. pH strongly influenced PFOS adsorption: acidic

conditions (pH 1–2) favored high efficiency, while efficiency dropped sharply above pH 3 (Figure 1). PFOA showed less pH dependence but lower overall adsorption rates.

Regarding contact time, PFOS removal was rapid, achieving >80% within the first 30 minutes, while PFOA required up to 3 hours for optimal performance. At higher contact times, both compounds showed slight declines in efficiency, possibly due to desorption or equilibrium saturation.

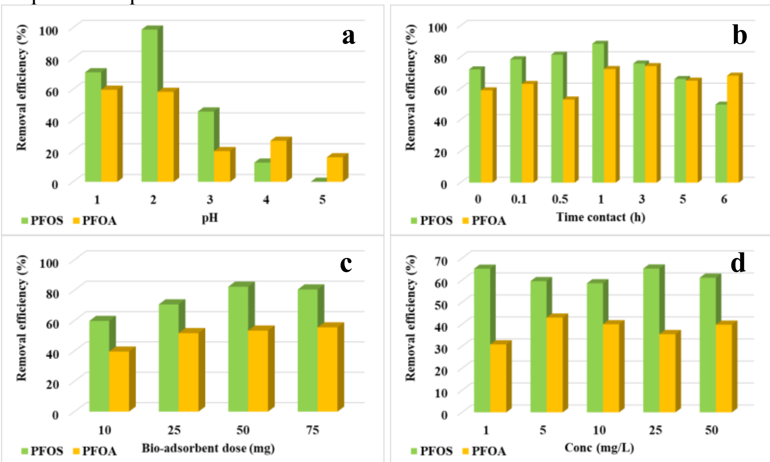

Figure 1. Removal efficiency of PFOS and PFOA from aqueous solutions using orange peel biosorbents under different experimental conditions: (a) effect of solution pH (1–5); (b) effect of contact time (0–6 h); (c) effect of adsorbent dose (50–200 mg); (d) effect of initial PFOS concentration (1–50 mg/L).

The optimal adsorbent dose was 100 mg, resulting in 82% PFOS and 53% PFOA removal. Higher doses (e.g., 200 mg) did not significantly enhance removal, suggesting saturation of active sites. Adsorption performance was stable across PFOS concentrations from 1–50 mg/L, with removal rates remaining above 59%.

These findings confirm that orange peel is an effective biosorbent for PFOS and moderately effective for PFOA. The study supports the valorization of agri-waste in water treatment and highlights the importance of process optimization to enhance PFAS removal in sustainable and circular economy contexts.

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