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A review of the application of agricultural wastes as precursor materials for the adsorption of per- and polyfluoroalkyl substances: A focus on current approaches and methodologies

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HIGHLIGHTS

- Agro-waste materials employed as adsorbents for pollutants' removal were appraised.
- An assessment of techniques for producing adsorbents from agricultural wastes is provided.
- Hydrophobic interactions are responsible for the adsorption of PFAS from aqueous media.
- Maize tassel-silver nanoparticles have the potential to remove PFAS from water systems.

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ABSTRACT

There is an abundant body of literature surrounding the use of agricultural wastes for the adsorption of pollutants from aqueous solutions. This area of research is often considered as an alternative to conventional treatment techniques. In the past, the research focus centred on the adsorption of toxic metals. Presently, there is an increase in the calls, for researchers to explore new adsorbent materials for the removal of organic pollutants. Since once ingested, these organic pollutants have health impacts such as chronic kidney and liver diseases and endocrine disruption. Hence, there is an increasing need to discover new and efficient ways of removing organic pollutants from water systems. It is worth mentioning that most agricultural wastes are not usually utilized in their original state, but rather modified in diverse ways to increase the material's surface area of adsorption and porosity. Thermal treatment, carbonization, chemical and physical activation, nanostructuring, grafting with copolymers and many others are some of the widely used methodologies; that are currently being employed for modifying agricultural waste materials for use as adsorbents. In this review, therefore, a discourse on a range of agricultural wastes that have been used as adsorbents for the removal of per- and polyfluoroalkyl substances (PFAS) from aqueous media is provided. A proposition of the use of maize tassel–silver nanoparticles as new comers is made. This review article serves to give key insights on the technical realizations in the area of adsorption of PFAS by utilizing agricultural wastes as precursor materials for preparing adsorbents.

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Contents

1. Introduction

Modernization and increase in population have contributed to the continuous release of new and emerging chemical compounds into water sources (Kumar et al., 2009). Of all the persistent pollutants, certain organic compounds have been implicated in much of water pollution globally. A wide range of the implicated organic compounds have been found to exert toxic and detrimental effects on both the biotic and abiotic components of the environment. Therefore, the occurrence of organic pollutants in water has been an issue of utmost concern for the water industry at large, due to the acute toxicities, persistency and carcinogenicity of some of the pollutants (Ali et al., 2012).

Generally, processes that have been utilized to remove chemical pollutants from different aqueous matrices include, but not limited to, membrane filtration, precipitation, ion exchange, solvent extraction and adsorption (Fu and Wang, 2011). Some of the drawbacks associated with these processes include: low removal efficiencies, high cost of regeneration, deposition of sludge, high energy demand, high reagent requirements, amongst others (Kumar et al., 2009). Multiple researches lend credence to the postulation that adsorption still remains one of the preferred techniques for pollutant removal from aqueous media since it is safer and easier to use.

In a nutshell, adsorption involves an interaction between the outer surface of an adsorbent and that of a pollutant (Wahi et al., 2013). This interaction brings about the adhesion of the particles of the adsorbate on the surface of the adsorbent. A major quality of an adsorbent is the amount of adsorbate it can accumulate. This is usually calculated from the adsorption isotherms (Gupta, 2009). The adsorption process is dependent on several factors such as initial level of pollutant, solution pH, adsorbent dosage, rate of mixing and temperature. Absorption, on the other hand, entails the uptake of fluid into the matrix of a material. In this case, the sorbate's molecules penetrate the material during absorption (Norizan et al., 2012). In recent times, the quest for complementary or alternative techniques for removing pollutants from the water system, with minimal environmental impacts has heightened. This quest has led to the employ of adsorption as a technique for pollutants' removal.

Adsorption is a widely used technology for organic pollutants removal from aqueous matrices. A wide variety of agricultural waste materials have been used for the preparation of activated carbons, and often times, these are referred to as 'biosorbents', also known as agricultural based-adsorbents (Crini, 2005; Yu et al., 2008; Zhou et al., 2011). Biosorption allows for the passive concentration and binding of pollutants on the cellular structure of the specific biomaterial (Volesky and Holan, 1995). They can be regenerated for multiple re-use (Volesky, 1990). Functional groups that have the potential to attract and sequester metals in agricultural based-adsorbents include, but not limited to; carboxyl and sulfhydryl groups, hydroxyls in polysaccharides, amino, amido, acetamido groups in chitin and phosphates in nucleic acids (Sud et al., 2008; Volesky and Holan, 1995). Over the years, the literature has been enriched with various applications which are based on the adsorption techniques for the removal of pollutants from aqueous waste streams (Adegoke and Bello, 2015; Malik, 2003; Radhika and Palanivelu, 2006). This vast body of knowledge has shown that agricultural-based adsorbents are promising