Chapter 11
Synthesis and Characterization of Activated Carbon From Biomass

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ABSTRACT

This chapter discusses current practices and new developments in the preparation of activated carbons for the adsorption of pollutants. There is widespread pollution such as pharmaceuticals and heavy metals in global surface water that needs to be mitigated and carbon sorbents made for it can be part of the solution. Preparing carbons for such challenge requires tailoring carbon's structure and surface chemistry to maximise interaction with low concentrations (part per billion level) of a variety of pollutants. The preparation of effective carbon sorbents constitutes a technical challenge. This chapter explores treatments and analytical approaches for the preparation and development of modified carbons to remove water pollutants. Effective carbons will help to control global contamination problems but should not be the source of more pollution: carbon dioxide emissions during the production and maintenance of carbon sorbents are a concern.

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1. INTRODUCTION

Environmental pollution has a global impact and affects every environmental compartment (United Nations 2024). News today would be finding the sea, lakes, wetlands and rivers free from pollution. Indeed, they are generally polluted, and there are legal frameworks around the world that aim to protect them. Examples of potentially harmful pollutants reaching the environment are pharmaceuticals and other personal care products (Gros et al, 2022) or plastic degradation products (Soltani et al., 2022), which by the action of UV and other natural weathering agents, can leach some of their additives, will fragment (Jansen et al., 2024) and some will subsequently transform further in the environment. Effluents from industrial and household wastewater are an important source (or pathway) to the environment. The impact of exposing the environment to a mixture of pollutants at low concentrations (typically, they are parts per billion level) is very difficult to measure (Wilkinson et al., 2024). Today, surface water and soil, even food, can have traces of pollutants (FAO, United Nations 2021). Even especially protected environmental sites in developed countries can be contaminated (Boxall et al., 2024).

Wastewater treatment and waste management practices are sometimes insufficient for preventing the complete release of contaminants into the environment. This is because of insufficient combined treatments; limited treatment time; ineffective technologies; or having to deal with pollutants that are especially resilient (with structures that will not be degraded or removed by adsorption with the current treatments). The removal of pollutants by adsorption has the advantage of not generating degradation products, and one of their disadvantages is that the adsorbents need to be re-generated once saturated. A traditional sorbent used for removing pollutants from water is carbon, which is used as a final treatment stage (tertiary treatment) (Bhatnagar et al., 2013). Nevertheless, the absorption removal using carbons is affected by the very low concentration of pollutants in water (typically in the $<1\mu g/L$). This is because the sorption process is less effective when removing diluted concentrations of pollutants. Furthermore, carbons used in water treatment were not designed for the specific removal of certain contaminants. These remain in the treated effluents and can impact ecosystems.

Carbons are indeed useful materials because they can be adapted to effectively adsorb a wide range of pollutants that traditionally do not get removed; their selectivity can be enhanced (Liang, Z. et al., 2022, Sailaukhanuly, Y. et al., 2024). Activated carbons are porous and can be made to reach a high specific surface area, which can provide exceptional adsorption capacity. Traditionally, coal has been used in water treatment. Very effective carbons for water treatment can also be prepared synthetically (Busquets et al., 2014). In light of sustainable development and the need for rational use of resources, there is a growing interest in the production of activated carbons from renewable sources, in particular from biomass. The use of agricultural and industrial waste not only reduces the cost of raw materials, but also solves the problem of waste disposal, promoting a circular economy (Li et al., 2008). The relevance of the study of activated carbons is also due to the need to develop cost-effective and environmentally friendly purification methods. Traditional methods, such as membrane filtration, often require significant energy and material costs. At the same time, activated carbons can be used in a wide range of conditions, have a high regeneration capacity and are compatible with various technological processes (Gupta & Suhas, 2009). Current research is focused on developing new methods for synthesizing and modifying activated carbons to improve their efficiency, selectivity for specific pollutants, and scalability. Key challenges are to control the pore structure and surface chemistry of carbons. Physical and chemical activation techniques can control the pore size and distribution, as well as introduce functional groups on the surface that affect the interaction with pollutant molecules (Blankenship, 2013). Surface

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