

Review Of Literature On Design Of Biomass-Based Renewable Materials For Environmental Remediation: Ionic Metal And Non Metal Species

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Abstract: Various materials have been used to remove environmental contaminants for decades and have been an effective strategy for environmental cleanups. The current nonrenewable materials used for this purpose could impose secondary hazards and challenges in further downstream treatments. Biomass-based materials present viable, renewable, and sustainable solutions for environmental remediation. Recent biotechnology advances have developed biomaterials with new capacities, such as highly efficient biodegradation and treatment train integration. This review systemically discusses how biotechnology has empowered biomass-derived and bioinspired materials for environmental remediation sustainably and cost-effectively.

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Introduction

In response to the growing global concern over environmental pollution, the exploration of sustainable and eco-friendly materials derived from biomass waste has gained significant traction. This comprehensive review seeks to provide a holistic perspective on the utilization of biomass waste as a renewable carbon source, offering insights into the production of environmentally benign and cost-effective carbon-based materials. These materials, including biochar, carbon nanotubes, and graphene, have shown immense promise in the remediation of polluted soils, industrial wastewater, and contaminated groundwater. The review commences by elucidating the intricate processes involved in the synthesis and functionalization of biomass-derived carbon materials, emphasizing their scalability and economic viability. With their distinctive structural attributes, such as high surface areas, porous architectures, and tunable surface functionalities, these materials emerge as versatile tools in addressing environmental challenges. One of the central themes explored in this review is the pivotal role that carbon materials play in adsorption processes, which represent a green and sustainable technology for the removal of a diverse array of pollutants. These encompass noxious organic compounds, heavy metals, and organic matter, encompassing pollutants found in soils, groundwater, and industrial wastewater. The discussion extends to the underlying mechanisms governing adsorption, shedding light on the efficacy and selectivity of carbon-based materials in different environmental contexts. Furthermore, this review

delves into multifaceted considerations, spanning the spectrum from biomass and biowaste resources to the properties and applications of carbon materials. This holistic approach aims to equip researchers and practitioners with a comprehensive understanding of the synergistic utilization of these materials, ultimately facilitating effective and affordable strategies for combatting industrial wastewater pollution, soil contamination, and groundwater impurities.

Numerous abundant biopolymers are present in our Biosphere, namely cellulose from woody plants and grasses and chitin predominantly biosynthesized by an array of living organisms such as arthropods and fungi, for example. Majority of these polysaccharides, e.g. cellulose, alginic acid, agar, chitin and dextrin's, are naturally occurring molecules and could have numerous industrial applications. Chitosan, deacylated chitin, and chitin have analogous structures, comprise the supporting materials for many animals, and have many attractive properties similar to cellulose (Figure 1) and starch in terms of biocompatibility, nontoxicity, biodegradability, and more importantly, their renewable nature; they have been exploited in diverse areas, e.g. cosmetics, agriculture, biomedical applications and water treatment, among others.¹ Unlike cellulose,² however, the presence of an amino group in chitosan renders it a basic polysaccharide which has the added advantage that it can be easily derivatized to generate chemical entities with useful and desirable functional properties.^{3,4} This Perspective article highlights some of the alluring possibilities these biopolymers offer in

view of the recent advancements in nanotechnology domain;2 some sustainable applications in chemical transformation and environmental remediation are exemplified that may offer sustainable solutions, often utilizing abundant biomass and agricultural residues and seafood waste.⁵ A section on biomass-derived platform chemicals is © 2019 American Chemical Society presented because these carbon-based materials offer many prospects as renewal feedstocks for production of sustainable products including some pretreatment possibilities facilitating the greener processing of biomass materials.

Review of Literature

The issue of pollution has become a major global concern, posing a threat to both developed and developing nations (Wang et al., 2022a, Wang et al., 2022b; Goyat et al., 2022a, Goyat et al., 2022b; Chaudhary et al., 2019; Wang, 2023). It is caused by a variety of factors, including everyday activities, the use of pharmaceuticals and cosmetics, economic growth, textile production, rising living standards, and population growth (Yan et al., 2016a, Yan et al., 2016b; Bai et al., 2022; Gao et al., 2013; Umar et al. 2022, 2023; Gul et al., 2023; Vijeata et al., 2022; Chauhan et al., 2022; Sharma et al., 2022; Talukdar et al., 2022; Kumar et al., 2022; Jasrotia et al., 2022). Developing nations face significant challenges due to industrialization, soil pollution, and toxic heavy metals in groundwater, which contribute to water scarcity (Das et al., 2017, Deveci and Kar, 2013, Edelstein and Ben-Hur, 2018, Shi et al., 2022; Saharan et al., 2023; Ma et al., 2022). Soil and water pollution represent critical environmental challenges, further exacerbated by the expanding global population and its profound consequences on aquatic ecosystems (Liu et al., 2022; Saharan et al., 2022; Saharan et al., 2020). Despite the Earth's surface being predominantly covered by water, amounting to approximately 70%, it is disconcerting to note that a mere fraction, less than 3%, is considered safe for direct human utilization. This alarming discrepancy underscores the urgency of addressing and mitigating these pollution issues to ensure the availability of clean and potable water for both current and future generations (Kumar et al., 2023a, Kumar et al., 2023b; Figueredo et al., 2017, Gul et al., 2023, Gupta and Kua, 2017, Saharan et al., 2020).

According to Fuller et al. (2022), pollution was responsible for nearly 9.0 million premature deaths, with air pollution (including household and ambient air pollution) accounting for the highest number of casualties, causing 6.7 million deaths in 2019. Water contamination was responsible for 1.4 million premature deaths, while lead exposure was linked to 900,000 deaths. This published article reveals that

approximately 9 million people lose their lives each year due to pollution, representing one in six global deaths. Although we have seen a decline in pollution-related mortalities linked to extreme poverty, such as household air and water pollution, this progress is overshadowed by an increase in deaths resulting from modern forms of pollution. These new risks, driven by industrialization and urbanization, include ambient air pollution and exposure to toxic chemicals like lead. Since 2015, deaths related to these factors have risen by 7%, and since 2000, the increase has exceeded 66%.

The World Health Organization (WHO) reports a concerning statistic: approximately 1.1 billion individuals across the globe lack access to a reliable and safe water supply. The primary challenge in providing clean water is the pervasive contamination of water resources by a diverse array of pollutants. These contaminants encompass a wide spectrum, including both common and highly detrimental substances such as organic and inorganic compounds, microbes, bacteria, dyes, pesticides, viruses, and heavy metals (Inamuddin, 2019; Liu et al., 2022; Rezakazemi et al., 2018; Bai et al., 2022; Chauhan et al., 2022; Qi et al., 2019; Hilary et al., 2022). Notably, the presence of toxic heavy metals from industrial activities poses a particularly grave and imminent threat to the quality of freshwater resources. This threat emanates from various industrial processes, including mining, oil refining, electroplating, printing, photographic processes, pesticide production, textile dye manufacturing, paints, and pigments production. These industrial practices collectively contribute to the extensive pollution of freshwater sources with heavy metals such as lead (Pb), copper (Cu), cadmium (Cd), arsenic (As), nickel (Ni), chromium (Cr), zinc (Zn), and mercury (Hg).

Heavy metals hold a distinctive characteristic as non-biodegradable pollutants, which means they persist in the environment for extended periods. They have the propensity to accumulate within the tissues of living organisms, resulting in detrimental health effects (Jia et al., 2018a; Alawady et al., 2020; Zwolak et al., 2019; Yang et al., 2022a, Yang et al., 2022b, Yang et al., 2022c). These adverse consequences include central nervous system (CNS) impairment, reduced energy levels, and damage to vital organs such as the lungs, liver, and kidneys. Moreover, heavy metal contamination in aquatic ecosystems poses a severe threat to marine life, further underscoring the gravity of the issue (Jin et al., 2022; Hoang et al., 2018; Schuler and Relyea, 2018; Kumari et al., 2022). In contrast to organic compounds, heavy metals lack the natural capacity for degradation, and as a result, they continue to persist in the environment, adversely affecting ecosystems and public health. This persistence leads to the accumulation of heavy metal

ions and organic dyes in water bodies, especially in regions proximate to industrial activities, consistently surpassing established safety thresholds (Table 1). Consequently, these pollutants pose an ongoing and substantial risk to both the environment and public health. (Meng et al., 2022; Hussain et al., 2022; Yang et al., 2022a, Yang et al., 2022b, Yang et al., 2022c; Farooq et al., 2022; Kim et al., 2022).

Polycyclic aromatic hydrocarbons (PAHs) (Fig. 1) are another concern as they are the accumulation of over 100 different polycyclic benzene ring chemical compounds. They are found in waterways worldwide, even in polar and faraway tropical regions, due to their water solubility and slow movement (Wilcke, 2007; Teaf, 2008). PAHs remain in the soil for an extended period of time and can accumulate, making soil pollution extremely harmful to terrestrial and aquatic life (Ziolkowska and Wyzkowski, 2010; Wyzkowski and Ziolkowska, 2013). Plant uptake of PAHs from contaminated soils, as well as the permeation of these compounds into groundwater, can have serious environmental and health consequences (Ukiwe et al., 2013; Rubio-Clemente et al., 2014). Soil is a crucial component of food production and agriculture. Fertile and healthy soil, containing essential nutrients such as nitrogen, phosphorous, and organic matter, can enhance crop yield, quality, and quantity, thereby ensuring food safety and feeding a large portion of the world's population (El-Naggar et al., 2018, El-Naggar et al., 2019b, El-Naggar et al., 2019a; Mekuria et al., 2017). The removal of contaminated soils, in terms of quality improvement and contaminated stabilization, has also been recognized as a crucial component for achieving sustainable development goals (SDGs).

Copper (Cu) and Titanium dioxide (TiO₂) are extensively researched nanomaterials known for their unique properties, including particle size, high surface area, redox properties, surface morphology, and small energy band gaps. As reported in the literature up to 2021, both Cu and TiO₂ nanoparticles exhibit significant potential in various applications, such as adsorption, catalysts, hydrogenation, reduction, oxidation, electrical conductivity, photovoltaics, pigments, sunscreens, photocatalysts, energy storage, optoelectronics, and biomedical uses (Li et al., 2023; Ijaz et al., 2017; Muthuvel et al., 2021; Alsulami and Rajeh, 2022; Kumar et al., 2023a, Kumar et al., 2023b).

Carbon materials derived from bio-based sources, including plants, agricultural residues, and even food waste, offer sustainable alternatives to their conventional counterparts derived from fossil fuels (Mahapatra et al., 2021; Soffian et al., 2022; Mujtaba et al., 2023). These materials have garnered significant attention due to their eco-friendly and sustainable attributes, providing a viable substitute for carbon

materials traditionally sourced from coal and petroleum. Bio-derived carbon materials find a wide array of applications, from enhancing soil fertility and sequestering carbon via biochar to effectively purifying air and water as activated carbon (Amalina et al., 2023, Myung et al., 2019, Naqash et al., 2020). Additionally, they encompass advanced materials such as carbon nanotubes and graphene, renowned for their exceptional properties and versatile applications in electronics, nanotechnology, and composite materials (Ali et al., 2023, Hidayat et al., 2019, Hong et al., 2020, Khin et al., 2012, Li et al., 2019).

Furthermore, biomass-derived carbon fibers, biological carbon products like bacterial cellulose, and bio-based carbon composites make significant contributions to industries spanning aerospace, textiles, water purification, and energy storage (Arun et al., 2022). These materials align seamlessly with sustainability objectives by not only being carbon-neutral but often carbon-negative, thanks to their capacity for carbon sequestration. This mitigates the environmental impact associated with carbon materials derived from fossil fuels. Ongoing research and innovation continuously expand the horizons of possibilities for bio-derived carbon materials across a multitude of sectors, driving forward the cause of sustainability and environmentally conscious material choices. Bioderived carbon materials offer sustainable and environmentally friendly solutions for various industrial applications. These materials can be effectively employed in environmental cleanup, including air pollution control and soil remediation. Additionally, they find applications in diverse industries, including construction materials, packaging, energy storage, agriculture, horticulture, pharmaceuticals, cosmetics, semiconductors, electronics, and environmental remediation (Reichert et al., 2020).

Carbon-based materials, such as biochar, carbon nanotubes, and graphene, which can be derived from a variety of biomass waste sources such as agricultural residues, food waste, forestry waste, fruit waste, animal manure, municipal waste, and sludge, are abundant, easily recyclable, and accessible (Akpotu and Moodley, 2018, Dai et al., 2019, Biochar, Shaheen et al., 2019; El-Naggar et al., 2019b, El-Naggar et al., 2019a). Although various chemical, physical, and biological methods have been used to remove polymeric hydrocarbons from the environment, the adsorption method, as a physical technique, has received considerable attention recently. However, there is a lack of review literature on the use of different bio-derived adsorbent materials for removing heavy metals, organic and inorganic pollutants, and polymeric aromatic hydrocarbons in

soil and water environments (Li et al., 2018, Liu and Lu, 2022, Mendonca et al., 2017, Von Lau et al., 2014).

References

- (1) Zeng, J.-B.; He, Y.-S.; Li, S.-L.; Wang, Y.-Z. Chitin Whiskers: An Overview. *Biomacromolecules* 2012, 13, 1–11.
- (2) Kaushik, M.; Moores, A. Review: Nanocelluloses as Versatile Supports for Metal Nanoparticles and their Applications in Catalysis. *Green Chem.* 2016, 18, 622–637.
- (3) Shen, X.; Shamshina, J. L.; Berton, P.; Gurau, G.; Rogers, R. D. Hydrogels based on Cellulose and Chitin: Fabrication, Properties, and Applications. *Green Chem.* 2016, 18, 53–75.
- (4) Datta, K. K. R.; Reddy, B. V. S.; Zboril, R. Polysaccharides as Functional Scaffolds for Noble Metal Nanoparticles and Their Catalytic Applications. In *Encyclopedia of Nanoscience and Nano technology*; Nalwa, H. S., Ed.; American Scientific Publishers, 2017.
- (5) Visakh, P. M.; Thomas, S. Preparation of Bionanomaterials and Their Polymer Nanocomposites from Waste and Biomass. *Waste and Biomass Valorization* 2010, 1, 121–134.
- (6) Den, W.; Sharma, V. K.; Lee, M.; Nadadur, G.; Varma, R. S. Lignocellulosic Biomass Transformations via Greener Oxidative Pretreatment Processes: Access to Energy and Value-Added Chemicals. *Front. Chem.* 2018, DOI: 10.3389/fchem.2018.00141.
- (7) Khan, M. K.; Bsoul, A.; Walus, K.; Hamad, W. Y.; MacLachlan, M. J. Photonic Patterns Printed in Chiral Nematic Mesoporous Resins. *Angew. Chem.* 2015, 127, 4378–4382.
- (8) Kaushik, M.; Basu, K.; Benoit, C.; Cirtiu, C. M.; Vali, H.; Moores, A. Cellulose Nanocrystals as Chiral Inducers: Enantioselective Catalysis and Transmission Electron Microscopy 3D Characterization. *J. Am. Chem. Soc.* 2015, 137, 6124–6127.
- (9) Kaushik, M.; Li, A. U.; Hudson, R.; Masnadi, M.; Li, C.-J.; Moores, A. Reversing Aggregation: Direct Synthesis of Nanocatalysts from Bulk Metal. Cellulose Nanocrystals as Active Support to Access Efficient Hydrogenation Silver Nanocatalysts. *Green Chem.* 2016, 18, 129–133.
- (10) Varma, R. S. Greener Approach to Nanomaterials and Their Sustainable Applications. *Curr. Opin. Chem. Eng.* 2012, 1, 123–128.
- (11) Iyanna, N.; Lalley, J.; Han, C.; Dionysiou, D. D.; Varma, R. S.; Nadagouda, M. N. Synthesis of Silver and Gold Nanoparticles Using Antioxidants from Blackberry, Blueberry,

- Pomegranate and Turmeric Extracts. *ACS Sustainable Chem. Eng.* 2014, 2, 1717–1723.
- (12) Johnson, L.; Thielemans, W.; Walsh, D. A. Synthesis of Carbon-Supported Pt Nanoparticle Electrocatalysts using Nano crystalline Cellulose as Reducing Agent. *Green Chem.* 2011, 13, 1686–1693.
 - (13) Sun, D.

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