USING ORGANIC CARRIERS FOR BIOFILMS IN WASTEWATER TREATMENT

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Abstract

This review explores sustainable natural and waste-derived materials as carriers for microbial biofilms in wastewater treatment. Materials like luffa fibers, clays, corncobs, cigarette filters, and textile waste support biofilm growth and pollutant removal. Their potential use in Ukraine aligns with the principles of circular bioeconomy and promotes sustainable wastewater treatment.

Keywords: *biological wastewater treatment, sustainable wastewater treatment, biofilm carriers, organic materials.*

Introductions. Recent research is focused on finding cost-effective, reusable, and environmentally friendly materials to support biofilm growth. Many studies highlight the use of natural materials and different types of waste to replace more expensive synthetic carriers [1, 2, 3]. These alternatives are often easy to obtain and help promote the circular bioeconomy. By incorporating renewable biological materials and waste products as biofilm supports, the approach not only promotes resource recycling but also reduces the depletion of natural resources, waste generation, and environmental emissions.

This study reveals the natural materials that support biofilm growth – such as clays and various plant-based substances like luffa fibers – that are widely used in the modern world. The aim of the research is to provide a primary comprehensive review of the sustainable bacterial biofilm carriers used in biological wastewater treatment.

Materials and methods. The materials for this study were selected based on science literature sources, which helped identify various bacterial biofilm carriers used in the biological treatment of wastewater in the world. The research methodology included the selection, critical analysis, interpretation, and evaluation of publications related to biofilm carriers used in biological wastewater treatment. This approach allowed identify the most relevant natural and waste-derived materials and assess their effectiveness in promoting microbial colonization and pollutant removal.

Results and discussion. The biofilm carriers discussed in the literature [1, 2, 3] include both organic and inorganic materials from natural sources, such as clays, volcanic rocks, bamboo, and luffa fibers. The application of biofilm belongs to biological methods of wastewater treatment. The materials (wood husk, corncob, rubber from used tires, cigarette filter rods, and textile waste) were selected for their potential to serve as sustainable and effective supports for microbial biofilms in the wastewater treatment in Ukraine.

Natural raw materials are especially attractive because they are cheap, eco-friendly, widely available, and durable. Their high porosity makes them suitable for bacterial attachment. Wastes are generated worldwide and comprise a diverse variety of feedstocks such as food (44 %), plastic (12 %), glass (5 %), metal (4 %), wood (2 %) and rubber and leather (2 %) wastes [3]. Wastes are also valuable as carrier materials, especially organic-rich food industry wastes, which offer nutrients such as carbon and nitrogen. These nutrients help bacteria grow without the need for extra additives.

One example is cellulosic materials, which contain glucose and hydroxyl groups that create ion exchange conditions, encouraging bacteria to attach. Cellulose is also porous and stable under different pH and temperature levels [4]. Carriers made from organic materials can act as both biofilm support and a carbon source, which is especially helpful in biological denitrification. Studies [5] have shown that corn and rice straw can successfully support bacterial growth and improve nitrogen removal.

Various organic materials have also been tested as biofilm carriers [6]. Luffa, bamboo, and cactus fiber are the most commonly studied. Luffa is lightweight and porous, with about 60 % α-cellulose and 22 % hemicellulose. It is renewable, widely available, and non-toxic to microorganisms, making it effective in removing nutrients, pharmaceuticals, volatile organic compounds, and water-soluble polymers. For example, modified luffa used in a pilot-scale moving bed biofilm reactor (MBBR) system showed up to 83 % removal of organic compounds and 71 % removal of total nitrogen [7].

Agricultural by-products like rice husks, rice straw, corn straw, and corncobs are also considered promising carriers for microbial attachment. These materials contain functional chemical groups – such as amino, hydroxyl, carboxyl, and phosphate – that can interact with pollutants through adsorption, ion exchange, and other processes. Since they are primarily composed of cellulose, hemicellulose, and lignin, they also offer a renewable source of carbon for bacterial metabolism. For example, alkali-treated corncobs were found to enhance biodegradation and nitrate removal from industrial wastewater, while also reducing levels of hard-to-degrade organic pollutants [8].

Organic materials often have low mechanical strength, poor mass transfer, and degrade quickly. This limits their reuse compared to inorganic options. They may also cause issues such as ammonia release, dissolved organic carbon, and color changes in treated water [9].

Beyond agrowastes, other unconventional waste materials have also been tested as carriers, such as textile waste, rubber, plastic bottles, and cigarette filter rods. Although cigarette filters are not biodegradable, their fibrous structure and large surface area make them capable of retaining a significant amount of microbial biomass. In an anaerobic MBBR setup, cigarette filter rods (wasted filter in tobacco factories) showed satisfactory performance, with chemical oxygen demand (COD) removal rates reaching up to 64,5 % and phosphorus removal close to 68 % [10]. These findings suggest that even non-traditional waste items could have a second life as useful tools in sustainable wastewater treatment systems.

So, both natural and waste-derived materials show promise as sustainable biofilm carriers. While organic carriers offer nutrient support and biodegradability, their lower stability and reusability must be considered. Inorganic materials are more durable but can present operational challenges like clogging. Future research should focus on improving the mechanical properties of organic carriers and combining the strengths of both material types to optimize performance in wastewater treatment systems in Ukraine.

Conclusions. This review confirms that biofilm-based wastewater treatment using sustainable carriers is a promising strategy. The use of natural and waste-derived materials as supports for microbial biofilms shows great potential for advancing sustainable technologies in the field of water treatment – especially in conditions of limited resources and the need to modernize treatment systems.

Organic carriers such as luffa, corncobs, and rice straw offer several advantages, including biodegradability, availability, and nutrient content that support microbial growth. They are well-suited for denitrification processes, as they can serve as an additional carbon source for bacteria. However, these materials also have disadvantages – low durability, the risk of degradation during operation, and the possibility of releasing decomposition products into the water – which can limit their reuse.

An interesting direction involves the use of unconventional waste materials such as textile waste, rubber, and cigarette filters. Their application not only allows for the reuse of waste but also contributes to more sustainable waste management practices. Studies have shown that even non-traditional waste can serve as an effective base for biofilm development and wastewater treatment.

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