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Activated carbon nanoparticles from biowaste as new generation antimicrobial agents: A review

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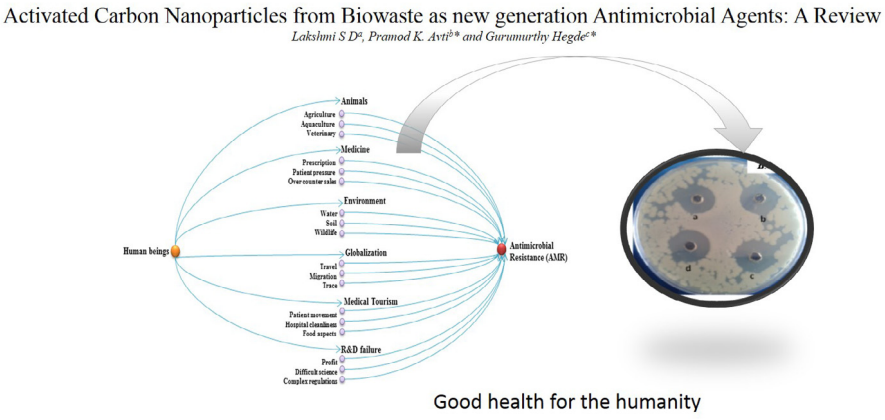
GRAPHICAL ABSTRACT



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ABSTRACT

There is a tremendous global threat by the microbes due to their ability to easily migrate and spread in the environment. Alternatively, resistance mechanisms developed by the microbes against the conventional antimicrobial drugs is of great concern due to significant mortality and morbidity and estimates to about 10 million deaths and 100 trillion USD of the global economic burden by the year 2050. WHO's global surveillance report of 2014 on antibiotic resistance states that at least 50% or more of WHO regions including Africa (77%), West Pacific Region (72%), East Mediterranean region (50%), South East Asia (81%) have developed resistance towards various microbes such as *Escherichia Coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae* etc. This poses various challenges to overcome its pathogenic impacts in biomedical and healthcare sector creating a huge economic burden. In recent years, the synthesis and development of novel and potential antimicrobial agents with high antimicrobial activity is an emerging field of interest. The advent of novel nanomaterials is proven to have potential antimicrobial properties as they efficiently eradicate disease causing pathogens without any side effects due to their unique physico-chemical properties. Among various nanomaterials including carbon, activated carbon based nanoparticles (ACNPs) are emerging as effective antimicrobial agents due to their anti-microbial properties. Development of activated carbon nanoparticles, especially from biowaste derived carbon precursor materials, is a recent upcoming technology due to their easy availability, economic viability and low cost and easy methods

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of production. This review mainly focuses on the recent trends in the development and use of various activated carbon nanoparticles as anti-microbial agents.

Contents

1. Introduction

The diversity of microorganism world, which sustains the ecosystem and thrives in extreme environmental conditions, encompasses different habitat across the globe. They play an important role in regulating the biogeochemical cycle of all organisms including humans. Infection is caused when a micro-organism evades or resists the host defense mechanisms and such microorganisms are called as pathogenic microbes [1]. Antimicrobial resistance is developed in microorganisms due to the inherent genetic changes with use, misuse and overuse of antimicrobial drugs. Development of newer essential antimicrobial agents is the key solution for overcoming antimicrobial resistance (AMR) [2]. This results in hunting of novel and low-cost antimicrobial agents with low to negligible side effects by researchers, pharmaceutical industries and medical communities for the extraction, synthesis and development [3]. Therefore, there is an urgent need to discover the new strategies for identifying novel antimicrobial agent.

In recent years, nanomaterials are developed with a hope to overcome AMR. There are many metal and non-metal nanoparticles which possess biocidal properties such as copper, gold, silver, silica, zinc oxide, carbon-based nanomaterials etc [4–7]. Predominantly, carbon-based nanomaterials have created excitement due to their unique physico-chemical properties such as enhanced magnetic [8,9], electrical [10], optical [11–14], catalytic [15] and antimicrobial properties. They could be used in various fields of applications such as water treatment [16], antimicrobial products [17], catalyst support [18], bio-sensing [19] and other biomedical applications [20–36]. Nowadays, carbon-based nanomaterials are seeking more attention because of their biocidal properties. Some of the different forms of carbon nanomaterials like graphene, fullerene, carbon nanotube, ACNPs etc., have interesting antimicrobial properties [37–39].

Among all carbon-based nanomaterials, ACNPs has distinct physical and chemical properties, surface morphology, uniform particle size, biocompatibility and large surface area [40]. Carbon nanoparticles can be easily synthesized from carbon source materials like coconut shell, cooking oil, rice bran and wood etc [41] by thermal combustion, chemical vapor deposition method, electric arc discharge method and biological method etc. Synthesized carbon nanoparticles are further activated by chemical, physiochemical and physical activation methods to obtain ACNPs [42]. These activation processes predominantly increase the surface area [43–45]. The synthesis of ACNPs from biowaste materials is receiving much attention in the recent past due to the presence of precursor materials in abundance, eco-friendly nature and low cost production [46]. Fig. 1 provides an illustration of synthesis of ACNPs from biowaste materials.

2. Biowaste materials

Compared to all greenhouse gasses, carbon dioxide levels are increasing on a daily basis and tend to account for global warming due to anthropogenic activities [47]. Fossil fuels such as coal, crude oil and natural gas serve as the main source of energy and increases the global economy. Although the non-renewable energy sources are on a decline, search for alternate sources are in progress to meet the huge global energy demand [48]. Since from the last decade, urbanization and modernization resulted in the generation of excess solid biowaste. Main source for biowaste production include the industries, agricultural and municipal solid waste [49]. Biowaste materials are sustainable renewable energy sources and they can solve the problems of greenhouse gas emissions and global energy consumption demand [50]. They majorly contain cellulose, hemicellulose and lignin as major constituents and some minerals as minor constituents [50]. Utilization of biowaste materials for production of ACNPs will be a waste to wealth approach as they are inexpensive, produces less carbon dioxide and they play a significant role in industrial traits [51]. Owing to this strategy, inherent advantages can be expected from them such as simple, safe,