Two Dimension Nanomaterials and Their Derivatives as Effective Antimicrobials

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Abstract

Millions of people die all around the world due to microbial infection related diseases every year [1]. The atrocious situation occurred due to the abusive use of antibiotics, especially in developing countries. Increasing instances of antibiotic resistance due to emergence of super bugs have led to burgeoning research interest in development of new generation antibacterial. Hence, to sustain a prosperous society critical approach must be taken in development of novel bactericidal weapons. Reports have revealed the considerable disinfecting ability and biocompatibility of two-dimension nanomaterials (2D-NMs) [2]. Recently, new 2D-NMs beyond graphene, such as MXenes, Transition Metal Dichalcogenides (TMDs), Black phosphorous (BP), Layered Double Hydroxides (LDHs), graphitic carbon nitride (g-C_3N_4), have been tremendously explored for their application as antimicrobials against different strains of bacteria [3]. The 2D-NMs due to their interesting ultrathin structure and intriguing physiochemical properties such as optical, magnetic, and electronic properties can be recognised as suitable candidates for sterilization [4]. The key property that controls the optical and electrical properties is band gap. In particular, 2D-NMs exhibits highly tunable band gap that may be achieved by controlling the number of layers, hetero structuring, strain engineering, chemical doping, alloying, intercalation, substrate engineering as well as external electric field [5]. Graphene with zero band gap behaves as metal [6], whereas TMDs family composed of semiconductors (MoS_2, $MoSe_2$), metals ($NbTe_2$, $TaTe_2$), and superconductors (NbS_2, $NbSe_2$) corresponding to different band gaps [7]. The antibacterial mechanism of 2D-NMs is attributed mainly to the direct physical interaction, reactive oxygen species (ROS) generation, light mediated photothermal therapy, metal ion incursion, piezoelectric effect, photocatalytic ablation and Polysulfane release [8-11]. Following these multiple biological pathways, the 2D-NMs in comparison to antibiotics are less resistible. The interplay between nanosheets and bacteria leads to deleterious degradation of cellular components, proteins, lipids and nucleic acids and ultimately leads to bacterial cell death [12]. The antibacterial performance of these 2D-NMs can be tuned by changing shape, size, and orientation of the nanosheet [13, 14], by functionalising with different functional groups such as NH_2, SH, COOH [15]etc., by incorporation of metal nano-particles (NPs), metal oxide NPs [16], halogens, polymers or quaternary ammonium/phosphonium salts [17] into the 2D-NMs nanosheets. On modification, these nanohybrids exhibits enhanced antibacterial activity against most common bacterial strains such as *E. coli, B. subtilis, S. aureus, P. aeruginosa* [18, 19]etc . The bactericidal efficiency of different nanohybrids can be determined by agar disk diffusion method, direct contact test, fluorescence based-bioassay test and flow cytofluorometric method [20].

Based on the previous reports, more studies need to be conducted to further unveil the antibacterial mechanism for bacterial ablation and explore their practical applications in clinical trials. Construction of 2D-NMs based materials for efficient and non-invasive antimicrobial applications is still an imperative matter. Additionally, some other novel antibacterial strategies like Z-scheme heterojunction and photoelectrochemical sterilisation, are still under construction and are worth for advances in this field [21, 22].

Through online poster presentation, in this webinar I am presenting the antimicrobial efficacy and potential of different 2D NMs and will also highlight the importance of these materials towards future medicine and technologies. Finally, the implications of these materials over traditional antimicrobials including antibiotics, antiseptics, antimicrobial peptides will also be presented. Eventually, we will address the challenges and future development trends of 2D-NMs as antibacterial.

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