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ANTIMICROBIAL MECHANISM OF METAL OXIDE NANOMATERIAL AND ANTIMICROBIAL PEPTIDES

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Abstract*:* Metal oxide nanomaterials and antimicrobial peptides are considered to be important candidates who can disinfect and control the microbial population by various mechanisms and at the same time are environmentally friendly and release no potentially toxic compounds. The aim of this review article is to highlight mechanism of metal oxide nanomaterials and antimicrobial peptides as a potential candidate for disinfection and microbial control

Keywords: - Nanomaterials; water; disinfection; microbial control; metal oxides nanomaterial.

Introduction: Antimicrobial mechanism and microbial control: On the basis of their structural properties and functional characteristics, nanomaterials fall into three general Type *viz*; naturally occurring antibacterial substances, metals and metal oxides, and novel engineered nanomaterials. Nanomaterials have different modes of antibacterial and microbial control mechanisms. They interfere in the plasma membrane electron transport system, disrupt cell envelopes or produce secondary reactive oxygen species (ROS) (Fig.1).

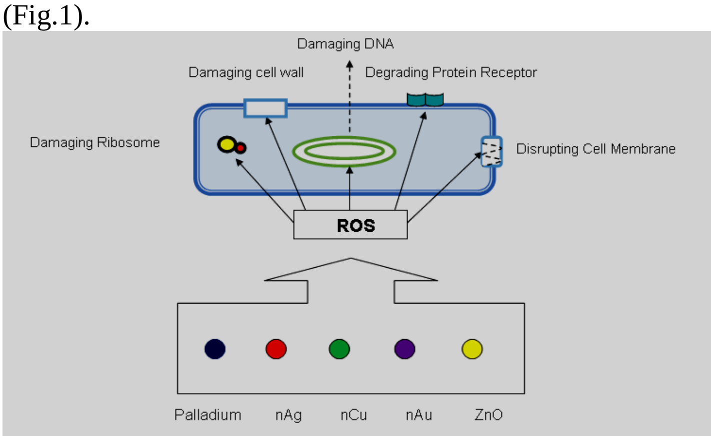

Fig.1 Mechanism exerted by nanomaterials against microorganisms

Metal Oxides Nanomatrial: Titania (TiO_2): Titania (TiO_2) is hydrophilic semiconductor photo catalyst metal oxides. Antimicrobial properties of TiO_2 are associated to its crystal structure, shape and size[5]. TiO_2 photo catalytic inactivation of bacteria has gained over the last two decades[12,21]. It has been proposed that oxidative burst generated by reactive oxygen species (ROS) is preliminary responsible for killing microorganisms. Photo catalytic properties of TiO_2 is greatly improved by advent of nanotechnology, when exposed to non-lethal ultraviolet radiation, it generates hydroxyl radicals (OH*) and reactive oxygen species (*O_2^-) inactivating microorganism by oxidizing the polyunsaturated phospholipids mechanism of the cell membrane of the microbes[1,3].

Titania nanoparticles have broad biocidal activity including Gram-positive and Gram- negative bacteria, and fungi, and of particular significance against multiple drug resistance bacteria[10]. As illustrated by Kubacaka et al., (2014), photo catalytic activity of TiO_2 triggers the reduce action of a large range of genes/proteins specific for regulatory, signaling and growth functions.

Doping TiO_2 with silver greatly improves photocatalytic properties of TiO_2, reducing reaction time for complete removal of bacteria1[3,15] and viruses[9]. Ag believed to improve photocatalytic activity by facilitating electron-hole separation and providing extra surface area for adsorption[18]. More importantly TiO_2 is environmentally friendly and releases no potentially toxic nanoparticles.

Zinc Oxide (ZnO): Nanoscale zinc oxide ZnO crystals with varying morphologies show significant antibacterial action against a wide group of bacteria [2,14]. ZnO nanoparticles show antibacterial action by interacting with bacterial cell surface/ or with cellular matrix when it enters inside the cell. Many researchers have fabricated zinc nanoparticles by various physical and chemical methods to allow better control and morphologies[7]. For example, Wahab *et al.* (2010) carried a non-hydrolytic solution method by zinc acetate dihydrate to prepare ZnO-NPs. The method yielded nanoparticle structures of spherical surface that showed high antibacterial action against the tested pathogens. Similarly, Wahab et al., (2014) used spherical ZnO-NPs obtain by soft chemical

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solution method, against (*E. coli*, *S. aureus*, *P. aeruginosa*, *B. subtilis,* and *S. acidaminiphila*) and cancer cells (HepG2 and MCF-7 cell lines).

Doping techniques have provided new insight for increasing antibacterial activity of ZnO-NPs. When synthesized in heterojunction of silver loaded ZnO through UV light decay process, ZnO-NPs showed higher antibacterial activity against *E.coli.* comparable results were obtained when ZnO-doped samples were used against *S. aureus.* These results were promising as *S. aureus* is well known for causing contamination in hospital implants leading to serious infections[16].

Antibacterial activity of ZnO-NPs has been raised to a number of issues, but the exact toxicity mechanism is still not understood and needs deep explanation. However, distinctive mechanism have been put forward in the literature; direct contact of ZnO-NPs with cell surface, resulting in damaging of cell wall[22], liberation of antimicrobial Zn^{+} ions[8] and ROS formation[11].

Antimicrobial peptides: Antimicrobial peptides (AMP) also called Host defense peptide (HDP) are part of the innate immune response of all living organisms. Naturally occurring biomolecules such as chitin and silk moth cecropins have been long used for their antimicrobial properties. Chitosan is a natural harmless biopolymer derivative of deacetylation of chitin. Qi *et al.,* (2004) reported that chitosan nanoparticles give higher affinity because of large surface area, binding tightly to the surface of the bacterial cells, which disrupt the membrane and lead to the leakage of the intracellular component, thus killing the bacterial cell. Nanoscale chitosan and its derivatives have been reported to show antimicrobial property towards bacteria, viruses, and fungi. Within bacteria, the antimicrobial activity of chitosan is higher for Gram-positive bacteria than Gram-negative bacteria. Chitosan prevents the reproduction of bacteriophages in bacteria, and induces fight towards viral diseases in plants.

Silver nanoparticles (nAg): Silver nanoparticles are the most widely studied nanoparticles for their antimicrobial and biocidal activity. This historically recognized nanoscale particle is used in the wide range of applications including disinfection of water, preservation of food items and for sterilization of medical appliances. The synthesis of metallic silver nanoparticles involves both biological and physicochemical approaches. Several methods including chemical reduction, microwave-assisted synthesis, ultrasonic-assisted reduction, electrochemical reduction, are used for synthesis of silver nanoparticles.

Synthesis of nanoparticles by different biological means or their sources have been reported widely. These natural sources may be extracted from plants, bacteria or fungi or these organisms as a whole. Researchers have found a precise green route for the synthesis of Silver nanoparticles.

Numerous studies have revealed a wide range of significant antibacterial, antimicrobial, anticancer and anti-oxidative activity of Ag-NPs. Additionally, Ag-NPs have been shown to relate with the HIV-1 virus and inhibit its ability to combine host cells. Therefore, Ag-NPs are believed to have the potential application for the treatment of several diseases. Silver nanoparticles interact with thiol group in proteins, resulting in inactivation of enzymes and generation of reactive oxygen species (ROS).These nanoparticles are also reported to prevent DNA replication and interact with plasma membrane disintegrating the electron transport system and damaging the DNA.

Photo catalytic properties of Ag-NPs in the presence of UV-C and UV-A radiation were studied and these studies have shown enhanced in UV inactivation of bacteria and viruses. Some of the researchers have hypothesized that complexation of Ag^{+} with cysteine helps in photodimerization of viral DNA and hence stop its replication[9].

Conclusions: Metal oxide nanomaterial and antimicrobial peptides can be considered as potential agents for disinfection and microbial control.

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