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ASSESSMENT ON THE THERAPEUTIC APPLICATIONS OF ZINC OXIDE NANOPARTICLES

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Abstract

The production and application of materials at the nanoscale are the focus of nanotechnology. In general, nanoparticles exhibit distinct properties and a large surface area per unit volume. Due to the abundance of zinc and the relatively easy conversion of its oxide to nanostructures, zinc oxide (ZnO) - based nanomaterials have been known to have a wide range of applications for several essential demands since the inception of nanoscience. The food, pharmaceutical, and cosmetic industries can all greatly benefit from the use of nanoparticles, making

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this a significant area of research. Green production of nanoparticles of zinc oxide (ZnO NPs). Future materials for biomedical uses may be ZnO nanoparticles.

Keywords: Zinc, ZnO NPs, Medicinal Applications, Zinc oxide nanoparticles.

Introduction

In recent years, among metal oxide NPs, a lot of research focused on zinc oxide, because it has strange chemical, optical, magnetically and mechanical characteristics that are clearly unlike those of corresponding bulk materials [1]. Currently, nanotechnology is available in different scientific fields. Also, different techniques have been utilized for the operation of nanoparticles (NPs) in nano-scale range. NPs are an extensive type of materials comprising particulate materials which possess at least one dimension below 100 nm [2].
ZnO nanoparticles also have great photocatalytic activity among all the inorganic photocatalytic materials because of their advanced oxidation property. They are widely used for the removal of pollutants like dyes, toxins and pigments from the environment [3-5]. The mechanism involved in the degradation of the pollutant is illustrated in Scheme 2. When irradiated with UV light, the electrons from the valence band get quickly excited and jump to the conduction band. ZnO is an n-type semiconductor with a wide bandgap of 3.37 eV [6] and a large exciton binding energy of 60 meV [7]. This results in the generation of electron-hole pairs as there will be vacant sites in the valence band. Thus, the valence band is accumulated with holes and the conduction band with electrons. These hole in the valence band, upon reaction with water molecules forms hydroxyl groups which when reacts with the dye produce the degradation products along with carbon dioxide and water. The degradation can also happen due to the reaction between the oxygen atoms with the electrons in the conduction band reducing the oxygen to O_2-. Recent studies have reported that the use of nanomaterials resulted in high-performance waste water treatment [8-10]. Various environmentally friendly methods like the embedded ZnO nanoparticles in a surface layer of clay used as a matrix has been reported in the past for the adsorption and photocatalytic degradation of pollutants in wastewater [11]. Wang et al. investigated and synthesized a novel clay nano-based catalyst of ZnO/TiO_2/rectorite for photodegradation and adsorption of methylene blue from the aqueous phase [12]. Several studies also revealed that the same experiment using different dyes in varying conditions showed the degradation of the photocatalytic activity of the nanocomposites in the removal of the dyes [13-15].

Zinc Oxide Structure

Zinc oxide nanoparticles are categorized among the materials that have potential applications in many areas of nanotechnology [16, 17]. ZnO possesses one-, two- and three- dimensional structures. 1D structure involves tubes, needles, ribbons, nanorods helixes, belts, combs, wires, rings and springs [18]. Two- dimensional structure involves nanoplates and nanosheets that can give us zinc oxide. However, three-dimensional structure of zinc oxide includes snowflakes, coniferous, urchin-like flowers and dandelions. Zinc oxide gives greatly different particles among materials [19]. Also, zinc oxide in different shapes and structures can be seen in Fig. 1.

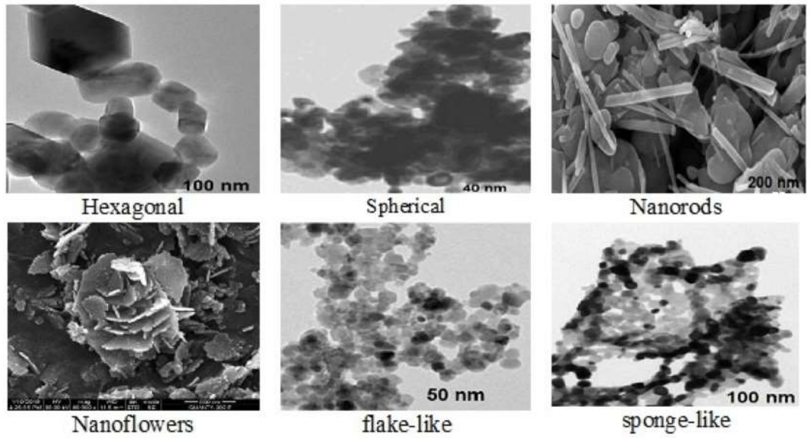
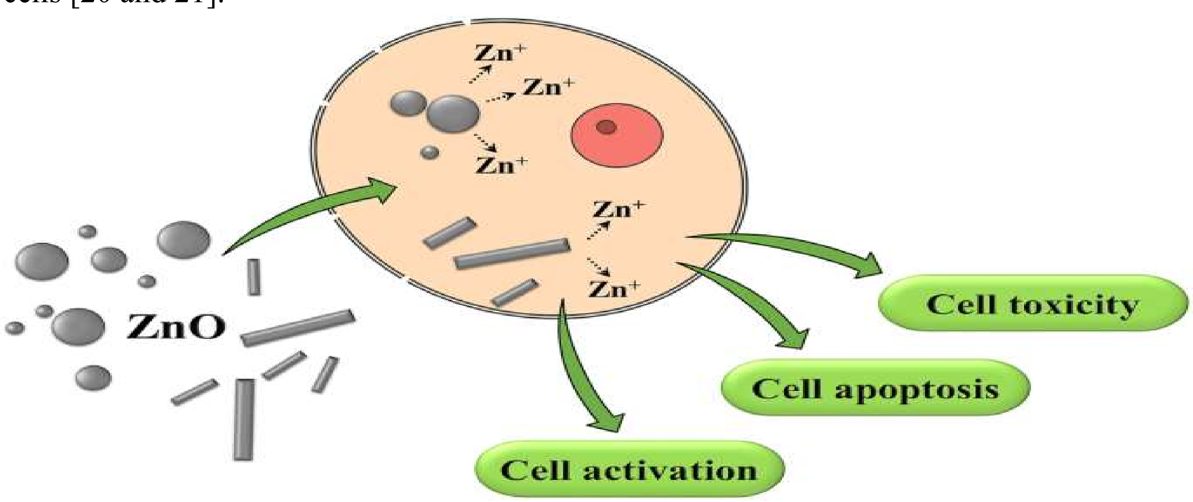


Figure1:
The different shapes of one-dimensional ZnO nanoparticles developed from plants mediate

MECHANISM OF ZINC OXIDE NANOPARTICLES:

Zinc oxide nanoparticles have peak effect on the cell surface and initiated when subject to UV-Visible light to produce ROS, such as hydroxyl radicals, superoxide anion, and hydrogen peroxide. They penetrate the cell body where O^{2-}, ROS Species carrying negative charge remain on cell surface. Zn^{2+} release when it is triggered by the assemble zinc oxide nanoparticles in cytoplasm or outer membrane 2 of bacterial cells, which might cause disintegration of cell membrane, damage of membrane protein and genomic instability which leads to death of bacterial cells [20 and 21].

Figure 2:



Schematic representation of mechanism of zinc nanoparticles

APPLICATIONS:

Antibacterial activity:

Zinc oxide nanoparticles shows diverse morphologies and it shows impressive antibacterial activity around wide ranges of bacteria. Previous reports revealed by decreasing particle size, the antibacterial activity of zinc oxide nanoparticles increases and also increases with increasing powder concentration. The large surface area to volume ratio of nanoparticles shows high antibacterial property, where it binds a greater number of ligands on its surface. The mechanism of zinc oxide nanoparticles towards antibacterial activity is based on induced oxidative stress. The oxidative stress is formed in bacterial cell because of the interaction between Zn^{+} ion and thiol group of bacterial respiratory enzyme, where increase in the reactive oxygen species (ROS) causes bacterial cell damage and death. Zinc oxide nanoparticles shows potent antibacterial activity towards both gram- positive and gram-negative bacteria. Zinc oxide nanoparticles inhibits food borne and most dangerous pathogens as an antibacterial agent [22].

Antimicrobial activity:

Zinc oxide nanoparticles shows good antimicrobial activity because it produces the free radical, especially on the oxide surface. Inorganic oxides show advantage over organic antimicrobial agents because of their properties like stability on pressure, higher temperature, long shelf life, robustness etc. Zinc oxide nanoparticles reveal higher antimicrobial property due to its smaller size, higher porosity and larger specific area. In cosmetics, personal care products and functional textile fabrics, the principle involved for the designing was the antimicrobial effects of zinc oxide nanoparticles [23]. Zinc oxide nanoparticles interact with water, which gives numerous reactive oxygen species, singlet oxygen or superoxide anion (O^{-}), primarily hydroxyl radicals (OH^{-}) and hydrogen peroxide (H_2O_2), which has important role in showing antimicrobial activity by the nanoparticles.

2

Antioxidant activity

Zinc oxide nanoparticles exhibit antioxidant property because of the electron density transfer at oxygen and property rely on structural configuration of oxygen atom. The naturally obtained substance shows high protective activity of natural antioxidant from higher plants against chronic disorder which originated from oxidative process. Zinc behaves as an antioxidant because of its free radicals to decrease cell membrane damage. It also acts as a cofactor or component of many enzymes which effect oxidative process. The increased sensitivity of certain oxidative stress is due to the chronic effect of antioxidant. Removal of peroxide from the body is due to the antioxidant enzyme catalase and the destruction of structure of the mitochondrial membrane is been protected [24].

Anticancer activity:

Zinc oxide nanoparticles shows good anticancer activity due to its good solubility, effective delivery to the cells and higher toxicity than the individual agents. When concentration of the zinc oxide nanoparticles increases, it also increases cell viability levels and inhibition. Zinc oxide nanoparticles reduces ROS production over the cells which destroys mitochondrial membrane and causes death of cancer tissue. Zinc oxide nanoparticles are able to induce notable selective toxicity against cancer cells without damaging normal cells. Zinc oxide nanoparticles shows various types of surface charge behavior since chemisorption of neutral hydroxyl groups over its surface. At higher pH, protons move towards aqueous medium from the particles surface and allows behind partially bonded oxygen atom with negatively charged surface. Transfer of protons takes place from environment to the particle surface at lower pH, which gives positively charged surface. Zinc nanoparticles exhibits isoelectric point at 9-10, under physiological conditions nanoparticles shows strong positive surface charge [25].

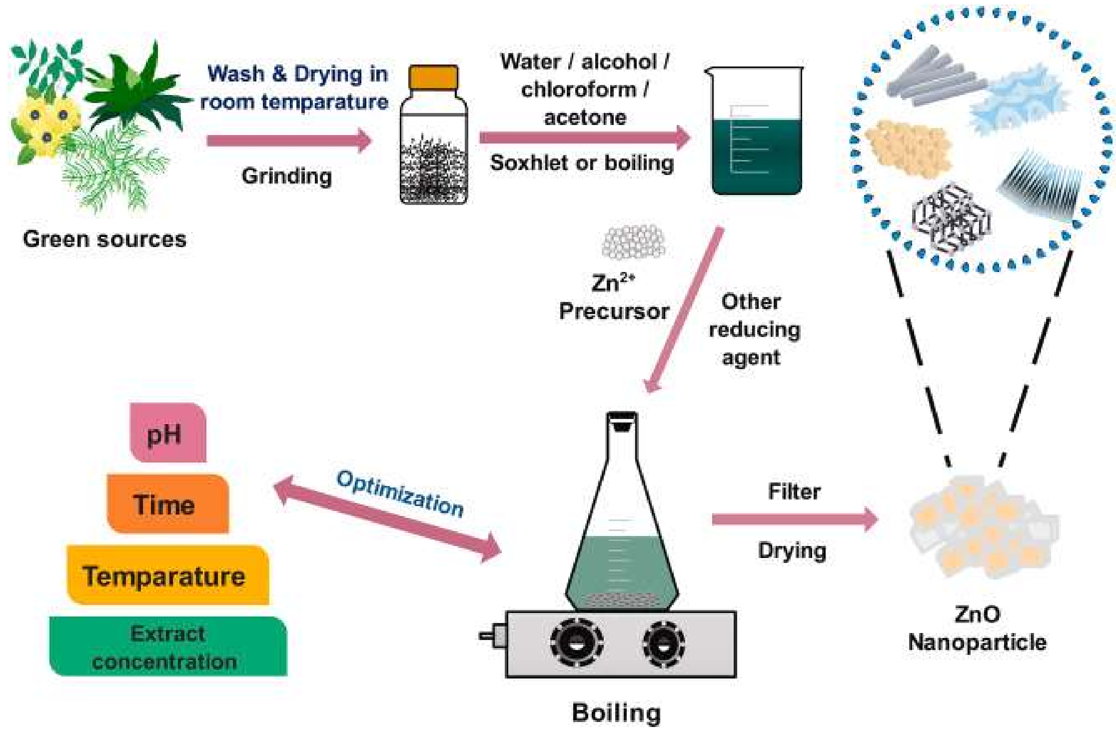


Figure-3

Green synthesis of ZnO Nanoparticles

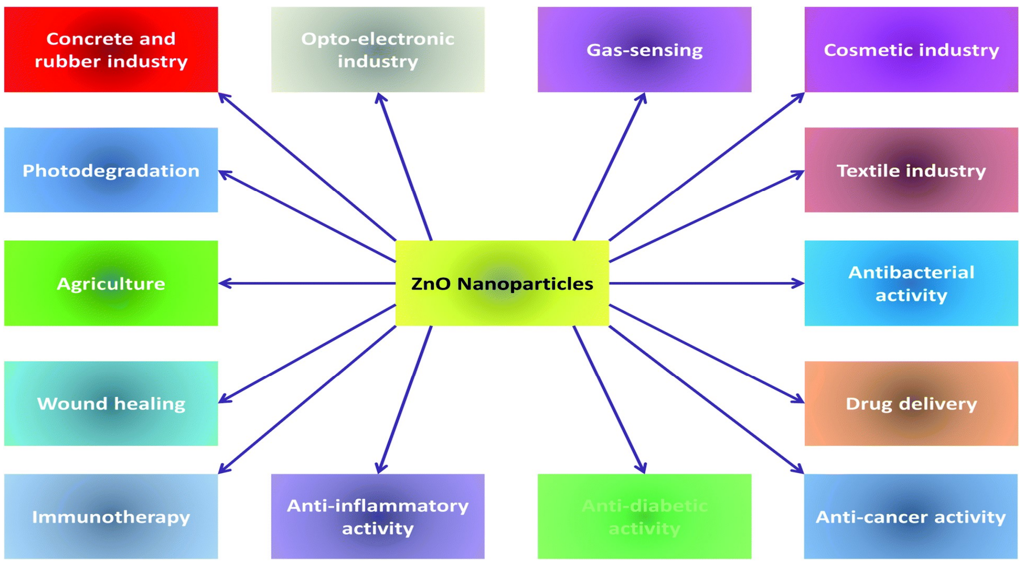


Figure-4

Chart showing zinc oxide applications

Anti-inflammatory activity:

Zinc oxide nanoparticles shows wide ratio of surface area to volume, which is good at blocking inflammation-enhancers such as inflammation and cytokines than that of bulk counter parts. Zinc oxide nanoparticles mechanism involves nitric oxide synthase enzyme inhibition, inhibition of myeloperoxidase, pro-inflammatory cytokines inhibition, NF-κβ pathway inhibition, mast cell degranulation inhibition [26]. In auto-regulating inflammatory process, macrophages play a very important role. There are two types i.e., Pro-inflammatory M_1 macrophages, which promotes the production of inflammation and M_2 macrophages, where it is alternately activated as the response for anti-inflammatory reaction and remodel the process of the affected organs and tissues.

Antidiabetic activity

Zinc oxide nanoparticles exhibits remarkable antidiabetic effect especially glucose tolerance improvement, blood glucose reduction, higher serum insulin, non-esterified fatty acid reduction and reduced triglycerides. Zinc is well familiar to hold on the structure of insulin and it plays an essential role in biosynthesis of insulin secretion and storage. It has been demonstrated that various zinc transporters in β-cell of pancreas like zinc transporter-8 shows potent role in secretion of insulin. The mechanism is followed by various ways like increased phosphorylation of insulin receptor, increase in phosphoinositide 3-kinase, insulin signaling is also been improved by zinc. Thus, zinc and diabetic has very complex inter relationship between them. The significant reduction in fasted blood glucose levels by Zinc oxide nanoparticles to diabetic is seen [27].

Photocatalytic activity:

The photocatalytic activity of zinc oxide nanoparticles shows the greater electron mobility which increases the migration rate of zinc oxide electron is photogenerated, which block the recombination of photogenerated holes and electrons, therefore the photogenerated charge carriers shows increase in the lifetime. There are many methods possible for the photocatalytic reaction rate to increase, which also indicates the decrease in the bandgap, increases in the defect concentration and increases in the surface area. The increase in concentration of the pollutant shows the decrease of the photocatalytic activity, because of which the tendency of the illuminated light beam to reach the catalyst particles will decrease. Zinc oxide nanoparticles has the greater surface area, narrow bandgap, and smaller particle size, which intensify the UV light absorption and the photodecomposition. Therefore, the synthesis of smaller sized nanoparticles is increased through the photocatalytic activity [28].

Wound healing:

Wound healing is an active process, where replacement of injured tissue to its initial state exactly after the injury and the depletion of injured area in a clear-cut indication of healing. The reactive oxygen species is generated by metal oxide nanoparticles which considerably helps in fibroblast proliferation. The interlinkage of the fibroblast cells and zinc oxide nanoparticles was impacted by the surface area and the particle size of nanoparticles. The increased particle size increases the membrane integrity and cell proliferation. Wound contraction is caused by activity of myofibroblasts which reduces wound area. The hydrogel based wound dressing integrates in increasing contact time and further follows keratinocyte migration and enhances re-epithelialization. Zinc oxide nanoparticles dressing increases apoptosis, bacteria clearance, platelet activation, tissue necrosis, re-epithelialization, tissue scar formation, debris removal, angiogenesis and stem cell activation through wound healing [29].

Conclusion

ZnO is a useful, most functional and single material with some distinguished properties; therefore, zinc oxide proposes unbelievable potential to future applications in various fields. The authors believe that this review article intensively focused on ZnO NPs in application points of view. This study indicated that zinc oxide NPs have a plenty of applications.

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Conflict of interest

The creators reported no irreconcilable situation. This report doesn't contain any investigations of human or creature subjects experienced by any of the authors.

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