GREEN SYNTHESISED ZINC OXIDE NANOPARTICLES WITH STROBILANTHES ALTERNATA AND MIMOSA DIPLOTRICHA PLANT EXTRACT- BENEFITS

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Abstract

Zinc oxide nanoparticles (ZnO NPs) are widely employed in various industries and research institutions due to their significant applications as antioxidants, anti-inflammatory and anti-diabetic medicines. However, the conventional synthesis methods face environmental and economic challenges, leading to the exploration of alternative approaches. Among these alternatives, the biological synthesis method utilizing plant sources has emerged as a promising option, offering numerous health, environmental, economic, and medicinal benefits.

ZnO NPs manufactured from plant derivatives have unique features that promote agricultural efficiency, such as the production of chemical fertilisers, chemical insecticides, and fumigants. Such Phyto synthesized ZnO NPs have widespread use in the manufacture of chemicals having anticancer, antiseptic and antifungal properties. Strobilanthes alternata is used in Indonesia to solve urinary problems, check and repair hemorrhages, halt diarrhea, and cure sexual infections. The leaves and stem extracts of Mimosa diplotricha, have been applied topically to enhance wound healing within conventional medicine. The substance in the plant is thought to have anti-inflammatory and antibacterial qualities.

This review offers a succinct explanation of the significance of these two medicinal plants in the synthesis of ZnO NPs and its applications in agriculture, medicine, and textiles. The antibacterial and photocatalytic activities of the nanoparticles isolated from the two plant species, will also help the researchers in the future.

Keywords- Antibacterial activity, Green synthesis, Photocatalytic degradation, Zinc oxide nanoparticles,

1. Introduction

The nanoparticles of metal and metal oxide are finding broad use in a variety of industries, particularly farming, pharmacy stores, chemical catalysis, medical treatment, textiles and clothing, and the building sector. Zinc oxide nanoparticles (ZnO NPs) in particular have been promising in antimicrobial treatment, coating [2], cosmetics, medicine, photocatalysis, pesticides, sunscreen, agriculture, and antimicrobial compounds. These nanoparticles have exceptional antibacterial properties [1], making them useful in surgical tapes, antiseptic creams, shampoos, and calamine lotions because they effectively suppress bacterial development even at low concentrations. ZnO NPs have also received Food and Drug Administration (FDA) clearance for antimicrobial purposes [3] and biosafety-defining properties.

ZnO NPs are nowadays being used in technological devices, elastomer production, biosensors, transducers, medicinal products, and biomedicine [4]. Natural sources as reducing agents have gained support among researchers due to their environmentally benign character, use of non-hazardous chemicals, simplicity of operation, low energy consumption, and cost-effectiveness [5]. Plant-based extracts, including biologic molecules. and secondary compounds such as tannins, flavanones, saponins, polyphenols etc. outperform microorganisms in the reduction of zinc precursors [6]. The performance of plant products such as alkaloids, and terpenoids are found to be outstanding among others.

Phyto extract-derived ZnO NPs show improved antibacterial activity against human pathogens and are beneficial against fungal and bacteria-related diseases [7]. A number of plant species, such as Bauhinia racemosa, Trifolium, Justicia adhatoda, Physalis alkekengi L., Cassia auriculata, pretence blossoms, Pongamia pinnata, Limonia acidissima, Cochlospermum religiosum, Sedum alfredii Hance, Aspidoterys cordata, and aloe barbadensis, have been discovered as dependable resources for establishing NPs.

The structural features and multidimensional identities of ZnO NPs were evaluated using UV-visible spectroscopy, scanning digging microscopes, atomic force microscopy, microscopes with checking electrons, continuously scattered light, microscopy with transmission electrons, Fourier spread spectral analysis, IR spectroscopy, energy-dispersive X-ray analysis, differential electron calorimetry, and particle diameter examination.

This review paper contains detailed scientific data on recent advancements in the manufacture and characterization of ZnO NPs from botanical resources. It also discusses the most recent advancements in the application of ZnO NPs produced through photosynthesis.

2.Method of synthesis

2.1 Physical synthesis methods

It involves utilizing physical processes to create zinc oxide nanoparticles (ZnO NPs). Below are some common physical techniques employed for producing nano zinc oxide:

1. It entails using physical procedures to create zinc oxide nanoparticles (ZnO NPs). Several renowned physical methods for producing nanozinc oxide are as follows:
2. Sol-Gel approach: In this approach, a colloidal solution (sol) is prepared, which subsequently gels and dries to produce ZnO NPs. To obtain the required nanoparticles, a metal in the precursor category is generally hydrolyzed, condensed, and subsequently calcined [9].
3. Vapour Phase Deposition: This method creates ZnO NPs by condensing zinc vapour onto the surface of a substrate. Chemical vapour deposition (CVD) or physical vapour deposition (PVD) techniques are often used. The zinc precursor is vaporised and then deposited onto a substrate under closely controlled conditions in order to produce nanoparticles [8].

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4. Laser Ablation: Laser treatment entails exposing a solid zinc projectile in a liquid media with an extremely energetic laser ray. The strong laser light vaporises the target material, leading it to aggregate and generate ZnO NPs throughout the liquid [9].]
5. Temperature Breakdown: An appropriate zinc precursor, such as zinc acetate or zinc nitrate, is carefully heated in order to encourage thermal decomposition and the formation of ZnO NPs. The chemical methods for producing zinc oxide nanoparticles (ZnO NPs) include micro-emulsion, chemically driven reduction, precipitation, hydrothermal processes, and sol-gel method [11]. The sol-gel synthesis method is particularly popular since it employs chemical reagents and zinc precursor salts to regulate the pH of the solution and prevent $Zn(OH)_2$ precipitation. The mixture is subsequently subjected to high temperatures, resulting in the formation of ZnO NPs. The stabilisation of compounds such as citrates or polyvinylpyrrolidone is frequently employed during manufacture to regulate the form and structure of ZnO NPs and avoid aggregation [12]. The amount of zinc precursor and other chemicals used in the production process influences the size and form of the resulting ZnO NPs significantly. Adjusting the concentrations improved the size of ZnO NPs, ranging from nanometers to micrometres [12]. Chemical procedures, on the other hand, have limitations since they require plenty of energy, utilise hazardous chemicals, and necessitate expensive equipment. Traces of these dangerous compounds were discovered in the nanoparticles, suggesting possible dangers and restricting their consumption. [26]. This is typically carried out under controlled conditions in an extreme temperatures furnace.
6. Spray Pyrolysis: Spray pyrolysis involves spraying a zinc precursor-containing solution over a heated substrate. The precursor pyrolyzes as the solvent evaporates, resulting in the production of ZnO NPs on the substrate [10].

These physical procedures allow for precise control of the size, shape, and properties of the ZnO NPs produced. However, they usually require specialised equipment and controlled environments, making them more suitable for laboratory or industrial-scale synthesis.

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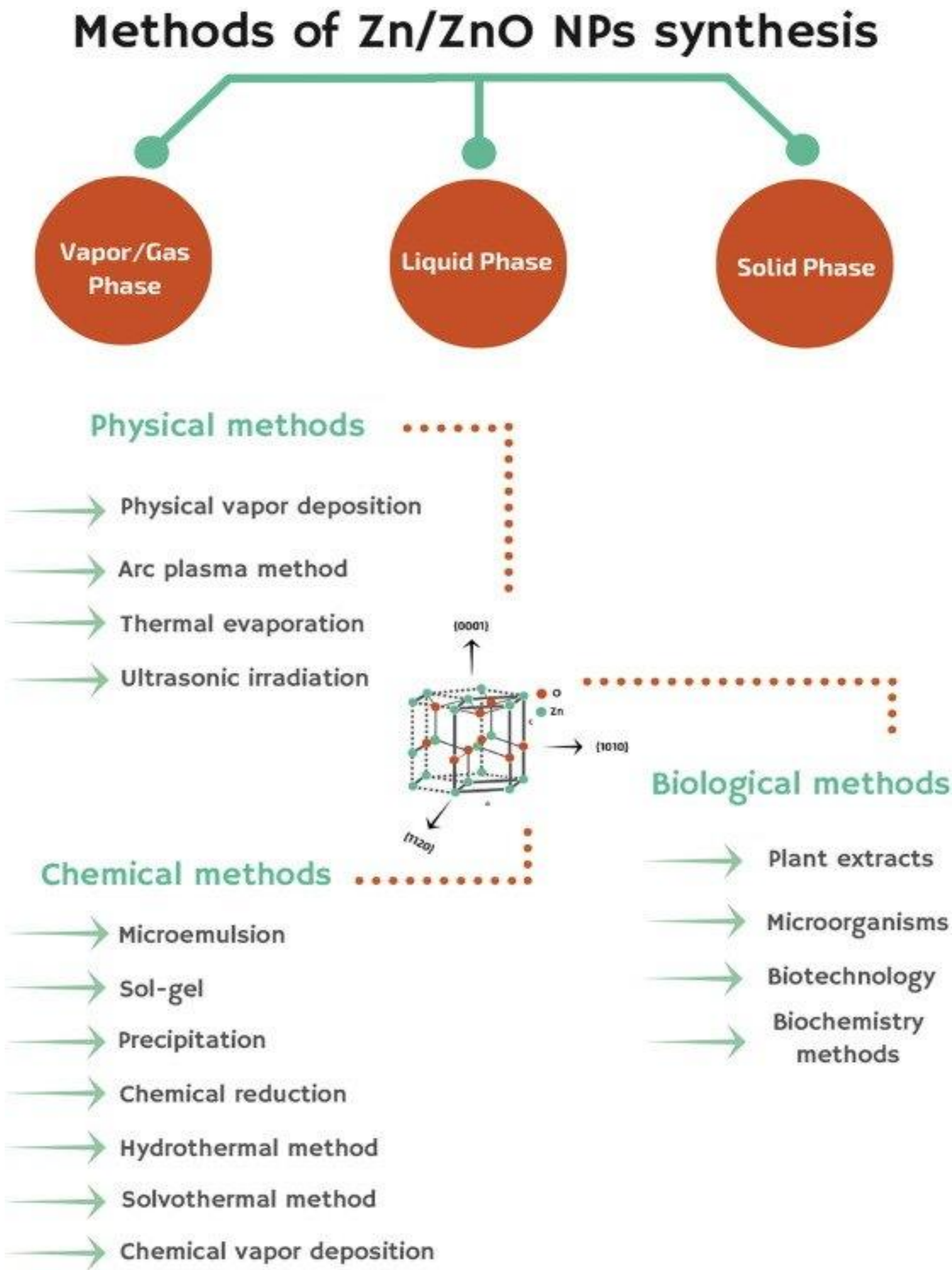

Figure 1: Various methods of preparation of Zinc oxide Nano particle

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2.2 Chemical methods

Chemically Related methods for producing zinc oxide nanomaterials (ZnO NPs) include hydrothermal treatment processes, micro-emulsion, precipitation, and sol-gel synthesis [11]. The sol-gel synthesis method is particularly popular since it employs chemical reagents and zinc precursor salts to regulate the pH of the final product and avoid $Zn(OH)_2$ precipitation. The resulting solution is then heated to high temperatures, producing ZnO NPs. Stabilizers, such as citrates or polyvinylpyrrolidone, are widely employed in the manufacture of ZnO NPs to regulate their morphology and avoid aggregation [12]. The amount of zinc precursor used along with other substances employed in the procedure for synthesis has a significant influence on the size and shape of the final ZnO NPs. Changing the amount of zinc oxide produced ZnO NPs with sizes varying from nanometers to micrometres [12]. Chemical techniques, on the other hand, have limitations since they take a lot of energy, involve dangerous chemicals, and require costly machinery. The remains of these hazardous compounds have been discovered in nanoparticles that have been synthesised, suggesting that they could pose risks and restricting their use [13].

2.3 Biological methods

The method of producing zinc oxide nanoparticles (ZnO NPs) by biological means is referred to as environmentally friendly synthesis or biosynthesis. Microbes such as algae, fungi, yeast, bacteria, and plant extracts are used as reducing agents [14]. While utilizing microbes as reducing agents offers advantages such as effectiveness, there are challenges associated with ensuring safety due to the toxicity of particular bacteria and the difficulty in maintaining sufficient incubation phase conditions [15]. Because of the considerable availability of phytochemicals or secondary metabolic products, plant extracts have proven to be particularly efficient in the production of ZnO NPs [16]. Saponins, tannins, terpenoids, alkaloids, methylxanthines, phenolic acids, and flavonoids have been discovered to be good zinc forerunner reduction agents.

The application of the use of plant extracts in synthesis has multiple benefits, including safety, cost-effectiveness, friendly to the environment, non-toxicity, biological compatibility, and the ability to generate in a big scale. [17].

3 **Strobilanthes alternata**

It is a tropical plant which is frequently referred to as the "Persian Shield," and belongs to the Acanthaceae category. It is well-known for its brilliant, glossy purple foliage, which make it a favorite decorative plant. Strobilanthes alternata is endemic to Burma (formerly Burma) and can be discovered in other Southeast Asian nations such as Thailand and Vietnam. It was additionally introduced as an attractive plant in various regions of the globe as well.

3.1 *Morphology*: The plant in question is grassy and evergreen, blooming to an elevation of 1 to 3 feet (30 to 90 cm) and spreading similarly. Strobilanthes alternata is distinguished by its beautiful, lance-shaped leaves. The leaves are enormous, averaging 4 to 7 inches (10 to 18 cm) in length, and have a distinctive metallic purple colour with green veins.

3.2 *Decorative plant* :Strobilanthes alternata is planted largely as a decorative plant in landscaping, scenery, and interior settings. It grows best in warm, tropical areas and loves partial shade to full sun. To keep its brilliant leaves, it needs well-drained soil and regular watering. In regions with colder temperatures, it can be planted as an annual or in pots that can be carried inside throughout wintertime.

3.3 *Uses and Benefits*: Strobilanthes alternata is frequently referred to as decorative plants in lawns, borders and pots because of its eye-catching leaf. Its brilliant purple foliage stands out against other flora, giving aesthetic appeal to settings. Furthermore, some individuals believe that the herb may have medical benefits. Strobilanthes alternata is used in Indonesia to solve urinary problems, check and repair hemorrhages, halt diarrhea, and cure sexual infections [32], despite the fact that scientific study regarding this topic is scarce.

3.4 *Care and Maintenance*: It is critical to offer appropriate sunshine, regular irrigation, and soil that drains well to guarantee the health and vitality of Strobilanthes alternata. Pruning can be used to keep the plant compact and stimulate bushier growth. Frost protection is required in areas where winters are chilly. The kind of plant is widespread in the United States and, to a lesser extent, the United Kingdom for use in gardening baskets that hang. Hemigraphis colorata Blume [33] is the scientific name for Red flame ivy.

Figure 2: image of Strobilanthes alternata

4 Mimosa diplotricha

It is a species of Mimosa endemic to both Central and South America. It is also known as the Giant Sensitive Plant or the Nemu-nemu plant. While it is largely considered an invasive plant in many areas, it has some historical therapeutic benefits. It should be noted that the information presented here is based on traditional knowledge and may not be validated by substantial scientific investigation. The following are some of the traditional therapeutic applications of Mimosa diplotricha:

4.1 *Wound Healing*: Various portions of Mimosa diplotricha, such as leaves and stem extracts, have been applied topically to enhance wound development within conventional medicine. The substance in the plant is thought to have anti-inflammatory in nature and antibacterial qualities that may assist in wound healing[34].

4.2 *Digestive Issues*: According to certain traditional medicines, the plant's leaves can be used to relieve intestinal pain such as stomachaches, indigestion, and diarrhoea. For this reason, the leaves can be made into a tea or stew.

4.3 *Anti-inflammatory and Pain Relief*: Because of its possible anti-inflammatory characteristics, the herb has been employed in traditional systems of medicine. It has been used to help decrease inflammation and discomfort linked with illnesses such as rheumatism and pain in the joint.

4.4 Skin Conditions: Mimosa diplotricha has been used traditionally to address certain skin conditions, such as rashes, eczema, and insect bites. The leaves or extracts may be applied topically to soothe skin irritation.

4.5 *Diuretic characteristics*: According to certain traditional usage, the plant has diuretic characteristics, which may assist boost urine output and make it easier to get rid of toxins from the body. However, there are few scientific research that back up this assertion [5].

It's important to note that further research and scientific confirmation are needed to support the traditional medical usage of Mimosa diplotricha. Before utilizing a herbal cure for therapeutic purposes, care should be taken and expert medical advice is necessary.

Figure 3: image of Mimosa diplotricha

5. Applications

Biomedicine and Healthcare: Green-synthesised nanoparticles made of zinc oxide (ZnO NPs have shown remarkable possibilities in biomedicine and healthcare. Antimicrobial characteristics of these nanoparticles make them appropriate for the development of antibacterial and antifungal drugs [18]. ZnO nanoparticles have also shown specific toxicity to cancer cells, implying their potential as anticancer agents [19]. They have also been investigated for use in medication delivery systems, wound treatment, and the engineering of tissues [20].

Environmental Remediation: Green-synthesised ZnO NPs are being explored to help in environmental remediation. They are effective in degrading organic pollutants such as dyes and pesticides via photocatalytic reactions [21]. Furthermore, ZnO NPs have been studied for their prospective applications in water purification, air filtration, and the elimination of heavy metals from sources of contaminated water [22].

Agriculture and Crop Protection: Green-synthesized ZnO NPs have demonstrated promise in the protection of crops and farm. They've successfully been employed as nano-fertilizers to boost plant growth and yields crops. These nanoparticles also have antibacterial effect against plant diseases, making them a natural crop protection and disease control option. In addition, ZnO NPs have been shown to promote seed germination and also increase tolerance to stress in plants [23].

Green-synthesized ZnO NPs are being investigated for energy-related applications. They were previously used as photoactive materials in dye-sensitised solar cells (DSSCs) to improve the absorption of light and electron transfer effectiveness [21]. Furthermore, ZnO NPs show potential in the development of super capacitors and lithium-ion batteries for energy storage [22].

The discoveries presented above are critical for understanding the green production of oxide of zinc nanoparticles (ZnO NPs) and their numerous uses. Khatami and Alijani (2017) carried out the biosynthesis of ZnO NPs using Aspergillus fumigatus, proving the fungi's potential as reducing and stabilizing agents. Dwivedi and Gopal (2018) examined green synthesis techniques such as plant extracts, microbes, and algae, emphasizing their eco-friendliness and cost-effectiveness. Additionally, they emphasized the antimicrobial abilities of the ZnO NPs synthesized using green methods.

Sarsenbayeva et al. (2019) focused on the green synthesis of ZnO NPs using Stevia and Salvia extracts, revealing the photocatalytic activity of the nanoparticles and their promising applications in wastewater treatment and solar cells. This study underscored the importance of green synthesis in achieving sustainable and environmentally friendly nanoparticle production.

Das et al. (2019) analysed the green manufacture of ZnO NPs and looked at their possible for biomedical purposes. They spoke on the biocompatibvia utilizing green protocol, as well as the obstacles and opportunities in biomedical research.

Rathore et al. (2020) reported the green manufacturing of metal oxide nanoparticles, particularly ZnO NPs, and its ecological remediation applications. The review focused on the photocatalytic

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capabilities of green-synthesized ZnO NPs, emphasising their potential for organic pollutant breakdown and heavy metal removal from contaminated water sources.

Goudarzi et al. (2020) observed the green production of ZnO NPs and their agriculture-related uses. They underlined how important ZnO NPs as nano-fertilizers for increasing plant development and crop productivity. They also talked about the ability to kill bacteria of green-synthesized ZnO NPs against plant diseases, as well as its capacity to improve the germination process of seeds and stress in the plant's tolerance. This research shows a growing curiosity in green synthesis methods for producing ZnO NPs, as well as their wide uses in biomedicine, environmental remediation, agriculture, and energy. Green synthesis is a potential strategy for future research and development since it is a sustainable and safe method for the environment and hence is an alternative to standard nanoparticle synthesis methods.

5.1 Photocatalytic activity

Sarsenbayeva et al. (2019) used Stevia and Salvia extracts to test the photocatalytic activity of green-synthesized zinc oxide nanoparticles (ZnO NPs). The researchers wanted to look into the photocatalytic potential of these nanoparticles. The researchers used Stevia and Salvia extracts as natural sources in their study to synthesise ZnO NPs using a green synthesis technique. They tested the photocatalytic activity of the synthesized nanoparticles by observing the degradation of a model organic pollutant in the presence of ultraviolet (UV) light. The results showed that green-synthesized ZnO NPs responded well in photocatalytic decomposition, of organic pollutants.

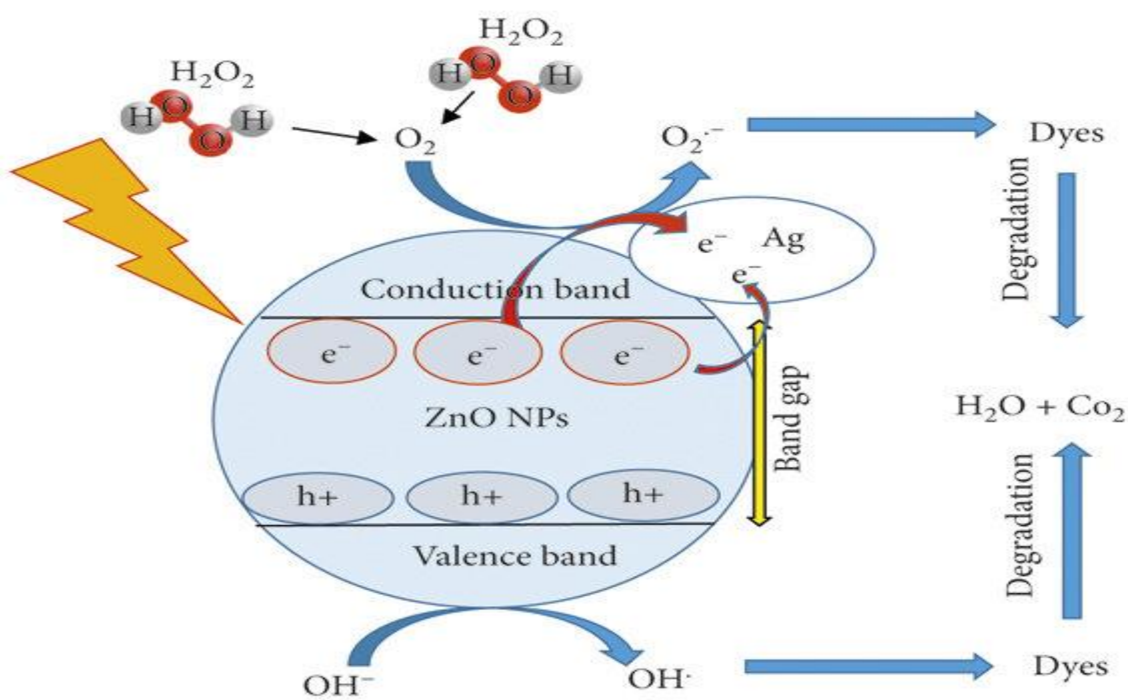

Figure 4: Photocatalytic degradation of Zinc oxide Nanoparticles

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This study's findings show that the potential of green-synthesized ZnO NPs to serve as effective photocatalysts for environmental remediation applications especially, for the treatment of contaminated water. The use of natural extracts in the synthesis process helps to the nanoparticles' sustainability and environmentally friendly design, increasing their appeal for diverse photocatalytic applications.

Many investigations have already been carried out to study the role of prepared ZnO NPs, in the decomposition of dyestuffs and other inorganic pollutants, notably in wastewater, textiles, and municipal effluents [28]. For methylene blue dye breakdown, the contrasting research focused on ZnO NPs synthesized using Allium sativum, Allium cepa, and Petroselinum crispum. The dye was effectively eliminated by all of the generated ZnO NPs, based on the results obtained. The smaller size of the ZnO NPs, as compared to conventional zinc oxide, was found to be an aspect attributing to higher degrading performance through boosting the total reaction sites on the catalyst's outer layer [29].

Another key element influencing the degradation ability of ZnO NPs is the catalyst loading to dyestuff concentration ratio. The degradation efficiency was shown to be inversely related to the dye concentration. Higher amounts of dye narrowed the way of photons striking in the solution, which brings about fewer holes and radicals necessary for the degradation mechanism [30].

In the meantime, topological properties of ZnO NPs were also found to have an important impact on decreasing efficiency, owing to the fact that different shapes provided various degrees of reaction sites. In a study of the decomposition effectiveness of ZnO NPs on Alizarin Red-S dye using various ZnO NP structures, it was discovered that ZnO NPs containing nano-flowers had the greatest abhorrent efficiency in comparison to other forms [31].

These results highlight the significance of biosynthesized ZnO NPs for dye degradation, including the size of particles, catalyst concentration, and morphological characteristics impacting overall breakdown percentages.

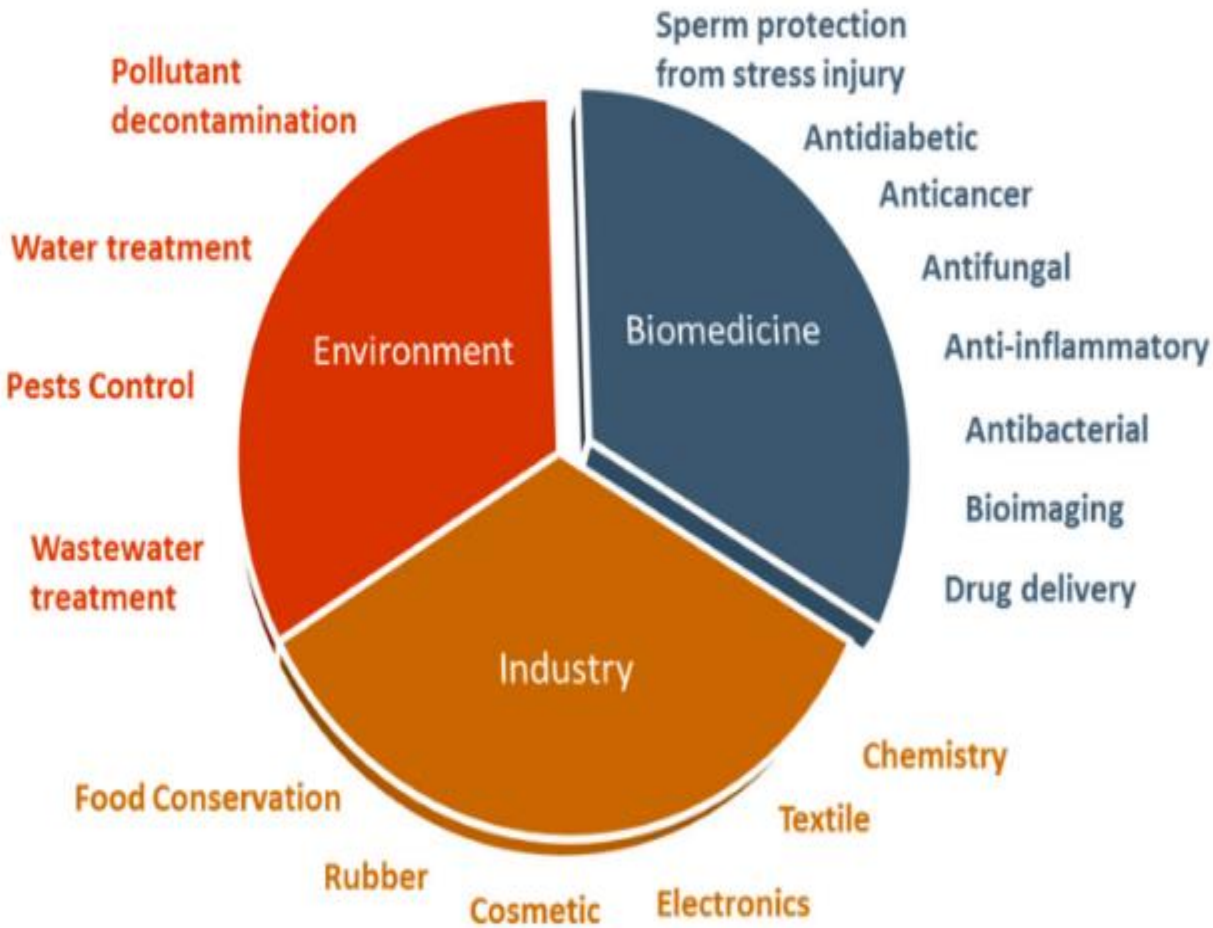

Figure 5: Various Applications of Zinc Oxide Nanoparticles

5.2 Antibacterial activity

Zinc oxide nanoparticles (ZnO NPs) have been broadly researched for their antibacterial characteristics, exhibiting significant efficiency against both bacteria and fungi [24]. ZnO NPs synthesised using diverse methods, in particular, have exhibited high detecting antibacterial agents and anti-fungal properties action.

The growth of spores from bacteria, including Escherichia coli and Staphylococcus aureus, was considerably suppressed when exposed to ZnO NPs [25]. The amount of bacterial growth suppression ranged from 5.1% to 100% for E. coli and 23.43% to 99.48% for S. aureus, with larger concentrations of ZnO NPs having a greater suppressive impact that others have.

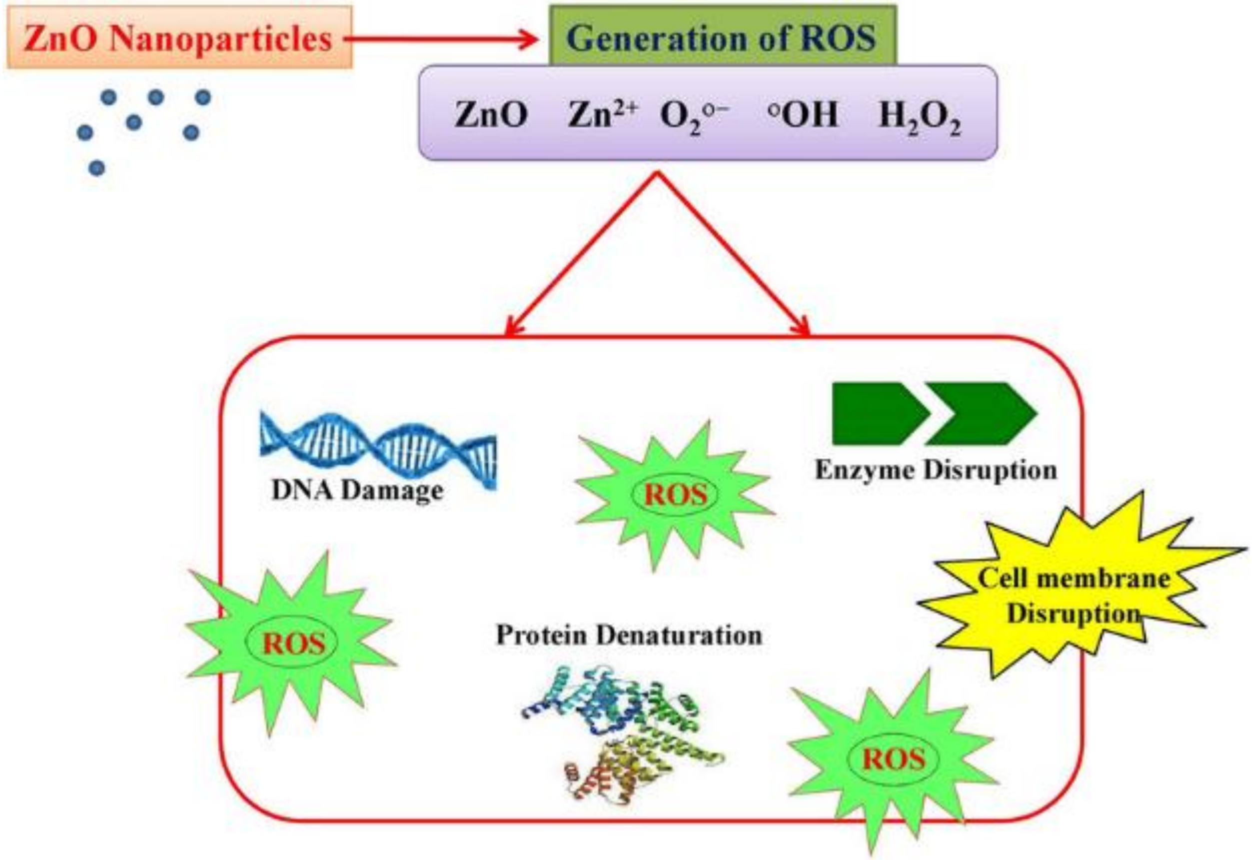

Figure 6: schematic diagram of antibacterial activity Zinc Oxide Nanoparticles

The disc diffusion approach was used to assess the bactericidal effect of ZnO NPs against pathogens such as Clostridium absonum, Streptococcus aureus, and Streptococcus mutans, among others. The results of the investigation revealed a significant degree of antibacterial activity, with higher inhibition regions observed as ZnO NPs concentrations arose. The presence of more hydrogen peroxide (H_2O_2) on the surface of ZnO NPs has been associated with increased antibacterial properties[26].

ZnO nanoparticles derived from the hirta of Euphorbia leaves suppressed the development of Aspergillus nigar, Arthogrophis cuboida, and Aspergillus fumigates. In a different investigation, ZnO NPs were shown to have strong antifungal efficacy against Fusarium oxysporum, Botrytis cinerea, and Alternaria alternative, with zones of inhibition of 64, 128, and 64, respectively.

As a whole, these results indicate the antibacterial and antifungal functions of green-synthesized ZnO NPs against a variety of bacterial and fungal species. The level of concentration of ZnO NPs and the presence of H_2O_2 on their surface are critical elements in their improved antimicrobial properties. potency.

7. Conclusion

The ability to use biological approaches to synthesize zinc oxide nanoparticles (ZnO NPs) is related to the lowering and stabilizing effectiveness of additional metabolites contained in diverse plant extracts. The resulting secondary metabolites operate as reducing agents and stabilizers, allowing ZnO NPs to form more easily. With a better understanding of how ZnO NPs are formed, it is feasible to increase the purity and optimize the reaction conditions for mass-produced goods.

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The effectiveness of ZnO NPs synthesized using plant parts has major agricultural consequences. These miniature particles have been scientifically proven to improve fertilization productivity, implantation rate, root growth, harvest magnitude, and sugar and protein content when applied to crops. The biomolecule composition of the plant extract employed in the manufacturing process is critical in evaluating ZnO NP's effectiveness in various agricultural applications.,ZnO nanoparticles is promising in medicinal uses as well.

Because of their propensity to create reactive oxygen species (ROS) and penetrate microbial cell walls, they might be used to treat tumors and infections caused by bacteria. These nanoparticles open up new avenues for targeted therapies and antibacterial therapeutics. Moreover, ZnO NPs' outstanding prospect reaches ecological purposes. They have demonstrated efficacy in the degradation of colours found in textile industry discharges as well as the processing of organic waste from urban emissions. ZnO NPs play an important role in ecological responsibility and the disposal of waste by helping to reduce contamination of the surroundings

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Further study should focus on creating improved ways for conserving plant extracts over long periods of time in order to encourage large-scale manufacturing of ZnO NPs using extracted plant material. Finding adequate conservation procedures would allow plant extracts to be used as a renewable and plentiful source for the synthesis of ZnO NPs, allowing for their broad production as well as utilization in a variety of industries.

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