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Green Synthesis Methods of Nanostructures for Environmental and Biomedical Applications

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Green synthesis is a trustworthy, long-lasting, and ecologically friendly process for producing various materials and nanoparticles. Materials research is very interested in "green" synthesis as well as other topics like hybrid materials, bioinspired nanoparticles made of components, metal/metal oxide, and so on. Green synthesis is seen as an essential instrument to lessen the negative consequences connected to traditional techniques the process of nanoparticles' method of synthesis is often used in labs and businesses. Utilizing natural extracts for nanoscale metal and metal oxide particles, such as copper oxide (CuO), gold (Au), silver (Ag), and zinc oxide (ZnO), we outlined the basic principles and methods of green synthesis techniques in this study. Additionally, We looked at the operation of biological components and important phytochemicals, including reducing agents and solvent systems (including flavonoids, alkaloids, terpenoids, amides, and aldehydes). Additional considerations on nanoparticle stability/toxicity and associated surface engineering techniques for guaranteeing biocompatibility are also included. In terms of antibacterial effectiveness, catalytic process, the elimination of dyes and pollutants, and heavy metal ion detection, these synthesized compounds were then reviewed for their potential for environmental remediation. So, it is anticipated that the Synthesis of green materials and nanoparticles using materials and nanoparticles obtained from biocomponents will be employed widely in environmental and biomedical applications.

Keywords: Green synthesis, Nanostructures, Nanoparticles, Hybrid materials, Bioinspired materials.

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1. INTRODUCTION

A subfield of material science known as nanotechnology involves the use of physical or chemical techniques to create nanoparticles with certain desired features. A particle averaging a size of less than 100 nm is considered a nanoparticle by definition [1]. Because of their distinctive physical, chemical, thermal, and electrical characteristics, these materials have several uses in fields including healthcare, agriculture, electronics, cars, and sustainability. The first method involves utilizing any mechanical method to first divide a solid mass into smaller nanosized particles (for example, mechanical grinding), which is followed by bringing the particle size under control [2]. However, using this approach, it is challenging to obtain the preferred narrow size. The second procedure begins with the substance at the atomic scale; it is subsequently produced using chemical methods, such as hydrothermal synthesis, to the required nanoscale, solifluorogel, gas phase, thermolysis, and hydrolysis. Although laser ablation, aerosol technologies, photochemical reduction, and UV irradiation all result in the production of nanoparticles, they are more expensive and also cause the release of hazardous byproducts [3]. Furthermore, these techniques make it difficult to regulate the nanoparticles' size, composition, and surface chemistry. However, a bottom-up strategy is preferred to create nanoparticles because it allows for more authority over the size and shape of the particles created and progresses from Simpler molecules followed by clusters, and finally nanoparticles [4]. Nanoscale metal oxide particles have been shown to function as a contemporary, reasonably priced disinfectant as a result of the creation of unique features for instance, antimicrobial, antifungal, UV filtering, high catalytic, and photochemical activity. Clinical issues, pollutant removal, and other industrial uses for these particles hold great promise. As a result of making FeNPs from naturally biodegradable material, which is known as "green manufacturing", enzymes, bacteria, fungus, algae, and yeast, as well as plant extracts, all play important roles [5]. Synthesis of plant extracts is one of them that has an advantage since it reduces reaction time and maintains cell structure, which lessens the risk of future contamination.

2. RELATED WORKS

Due to the widely acknowledged benefits of being affordable, environmentally friendly, convenient, and having the potential to be scaled up into massive

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production, many researchers have focused this review on gathering detailed information about new advancements in the biological technique of CuONP synthesis, characterization, and applications based on prior scientific results [6]. The study [7] examined Cobalt and cobalt oxide nanoparticles' major recent breakthroughs in green synthesis and their potential for ecologically friendly manufacturing are highlighted. These developments are particularly relevant to the biomedical and catalytic uses of these materials. The study [8] focused on three characteristics of ZnO NMs. First, we look at green ways to make ZnO NMs as an alternative to traditional synthesis techniques, since the latter have environmental hazards including the need for risky and costly precursors as well as the generation of undesirable byproducts. Additionally, using green techniques can result in significant and varied morphologies. The study [9] described a straightforward, effective, and eco-friendly method for producing ZnO nanoparticles (ZnO NPs) utilizing orange fruit skin extract. This strategy intends to increase the antibacterial activity and biological uses of ZnO nanoparticles while minimizing the usage of hazardous chemicals in nanoparticle manufacturing. The study [10] discusses recent advancements and achievements in the use of environmentally friendly AuNPs for the treatment of cancer, as well as various mechanisms of action for their anticancer and cytotoxic effects, including reactive oxygen species (ROS), dysfunctional mitochondria caused by ROS, and caspase activation. The potential uses of metal oxide nanostructures produced from phytochemicals in the environment, energy storage cleanup, and bio-related applications will also be covered in the paper [11]. The article [12] discussed the widely used AuNP synthesis techniques and addressed their well-established uses in a variety of situations, particularly in biological sensing. This study [13] discussed ecologically safe extract of the aerial portions of D. tortuosa was used as a lowering plus a capping agent in the synthesis of zinc oxide nanoparticles (ZnO.NPs).

3. METHODS

To avoid the production of unwelcome or hazardous byproducts, trustworthy, sustainable, and environmentally friendly synthesis techniques must be developed. Utilizing the best natural resources and solvable systems – like doing this requires the use of organic systems. Utilizing a green production method, metal nanoparticles have been created to receive various biological components. When compared to employing bacteria and/or fungus to produce nanoparticles on a large scale, using plant extracts is a comparatively rapid and simple process. This is true of all known green techniques nanoparticles made via synthesis for metal/metal oxide. Generally speaking, these substances are considered to be biogenic nanoparticles (Fig. 1).

Several response parameters, circumstances, and variables including solvent, temperature, pressure, and pH, are important for green synthesis techniques using biologically derived precursors. The presence of beneficial Plant-based chemicals in different plant extracts, especially leaves, for instance, ketone bodies, amides, terpenoids, flavones, aldehydes, and carboxylic acids, For the creation of metal/metal oxide nanoparticles, phenols, and ascorbic acids have prompted a thorough examination of plant biodiversity. Metal salts may be converted into metal nanoparticles by using these components. The core characteristics of these nanomaterials have been researched and used for biomedical tests, antimicrobial, optical imaging, catalysis, molecular sensing, and labeling biological processes.

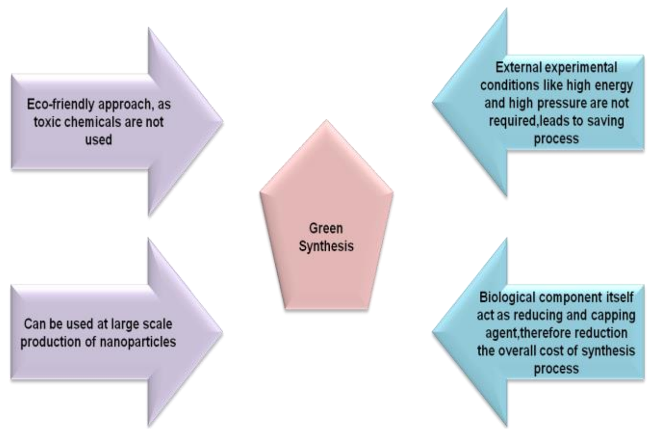

Fig. 1 – Key merits of green synthesis methods

The most current research on environmentally friendly metal/metal oxide nanoparticle manufacturing is presented here, highlighting their benefits compared to chemical synthesis techniques. Additionally, we discussed how solvent technologies (for synthetic materials and other biological (natural extracts) components operate, including the advantages they have over other conventional elements and solvents, as well as extracts from plants, bacteria, algae, and fungi. The main objective of this evaluation of the literature is to provide thorough procedures for green synthesis and their useful applications for environmental restoration. As a resource for readers with a wide range of interests in the topic, our main aim is to properly explain green synthesis processes and the elements that go into them. This will assist researchers employed in this emerging field.

3.1 Biological Components for Green Synthesis

Numerous chemistry and physics together methods call for high radiation, very poisonous reductants, and stabilizing agents, all of which may have detrimental impacts on marine life and people. A green method of creating metallic nanoparticles, in contrast, is a one-pot or one-step eco-favorable bio reduction process that needs just a little amount of energy to start the reaction. The cost-effectiveness of this reduction technique.

Bacteria and Fungi: A particularly effective method for producing clearly stated monodispersed nanoparticle morphologies is biosynthesis carried out by fungus nanoparticles made of metal or metal oxide.

Considering that they contain a variety of enzymes within cells, they function as more effective Biological weapons for the creation of metal and metal oxide nanoparticles.

Compared to bacteria, the competent fungus can generate additional nanoparticles. Fungi have several advantages over other creatures as a result of The existence of amino acids, enzymes, and decreased sugar agents on the cell's exterior. Reduced via the enzyme (reductase) inside the fungal cell or on its surface is the most likely mechanism for the creation inside the metallic nanoparticles. Silver, gold, titanium dioxide, and zinc oxide are only a few nanoparticles made of metals and/or oxides of metal that are created by various fungi, as detailed in Table 1.

Table 1 – Examples of chemically reduced metallic nanoparticles made in Ils

S. no	Reducing agent	Ionic liquid	Metal NPs	Metal salt	Size (nm)
1	H_2NNH_2-H_2O (hydrazine hydrate)	[BMIm][BF_4]	Cu	$Cu(OAc)_2$-H2o	81–131
2	Me_2NCHO (DMF)	[Me_2NH_2][Me_2NCO_2] with small amounts of DMF	$HAuBr_4$		3–5
3	Glycerol	[EMIm][TfO], [EMIm][$MeSO_3$]	Au	$HAuCl_4$-$3H_2O$	4–6 low temp. 6–5 aggregate at a higher temp
4	$NaBH_4$	[BMIm][BF_4] in a microfluidic reactor	Au	$HAuCl_4$	0.6-5
5	$NaBH_4$	[ShexMIm][Cl]	Au	$HAuCl_4$	6
6	H2, 85 °C, 4 atmBIm as scavenger	[BMIm][BF_4] [BMIm][PF_6]	Ag	$AgBF_4$	0.9–2.9 1.2–4.5
7	H_2	[BMIm][BF_4] [BMpy][TfO]	Ag	$AgBF_4$	~8 (DLS) ~12 (DLS)
8	[BMIm][BH_4]	[BMIm][BF_4] purified and H_2O	Ag	$AgBF_4$	0.7–4.5 4.1 0.8-4.6
9	Tween 85	[BMIm][PF_6]	Ag	$AgNO_3$	4–11
10	Ascorbic acid	[BMIm] [$C_{12}H_{25}OSO_3$] (lauryl sulfate)	Au	$HAuCl_4$	21–51

Yeast: Single-celled creatures called yeasts are found in eukaryotic cells. There are 1500 different species of yeast in all. Numerous research teams have shown the effective nanoparticle, for manufacturing processes and nanomaterials using yeast. According to reports that a fermented solution and a yeast strain that can tolerate silver can biosynthesize nanostructures of gold and silver. Innumerable metallic nanoparticles are created by using a range of species, as mentioned in Table 1.

Plants: Heavy metals may accumulate in the body and cause different various plant regions quantities. Plant extract-based biosynthetic methods have gained more attention as a consequence of an efficient, achievable, inexpensive, and wonderful alternative to conventional preparation techniques for nanoparticle manufacturing. In a "one-pot" process of synthesizing, various plants' metallic nanoparticles may be reduced and stabilized using this method. To learn more about the uses of granules of metallic and metal oxide, several researchers have created the particles utilizing plant leaf extracts and green synthesis techniques.

3.2 Solvent System-Based Green Synthesis

Whether it is green synthesis solvent systems may be a crucial part of the synthesis process. For synthesis procedures, water is consistently regarded as the optimum and most appropriate solvent system. The optimum solvent, in Sheldon's opinion, is water, while the worst solvent is none at all. synthesis process, different plants widely accessible cleaner on earth is water. As a solution, freshwater was previously used for various nanoparticles after the creation of nanoscience and nanotechnology. For instance, room temperature synthesis of Au and Ag's nanoparticles employing the dual-purpose molecule gallic acid in an aqueous solution. Gold was produced using a laser ablation procedure in a solution of water nanoparticles. The oxygen in the water causes the manufactured gold nanoparticles to partially oxidize, which ultimately increased their chemical reactivity and had a significant effect on their development. The use of ionic liquids as opposed to conventional solvents has the following advantages. (a) A lot of polar biological molecules, gases, and metal catalysts may be readily dissolved in ILs to support biocatalysts. (b) ILs can operate across a broad temperature range thanks to their positive thermal stabilities. The majority of them melt below the surroundings and start to degrade at temperatures over 300 or 400 °C. As a result, they provide a wider temperature range for synthesis (e.g., three to four times that of water). (c) By altering the cations and anions that are linked to them, it is possible to change the solubility characteristics of IL. (d) ILs lack coordination, in contrast to other polar solvents or alcohols. However, they exhibit polarities similar to those of alcohol. The absence of vapor pressure in ILs prevents them from evaporating into the environment as volatile solvents do. ILs have two distinct functions because they include both cations and anions (f). Ionic liquids cannot be used to create metallic nanoparticles because of issues with their biodegradability. Many novels, possibly Ionic fluids that are safe are being created with the highest biodegradation efficiency to help mitigate these non-biodegradability concerns.

3.3 Stability and Toxicity of the Nanoparticles

The impact of dispersed nanoparticles is determined by their ability to form metastable suspended in water or aerosols in ambient fluids. dispersion and mobility. By estimating the likelihood that the nanoparticles are to combine or engage in the environment's media, one may assess the environmental stability of the nanoparticles. The rate of particle collision is a time-dependent phenomenon known as "aggregation," while "suspension stability" is mostly impacted by the particle size and attraction for additional particles and ambient elements. After entering the aquatic environment, it was discovered that the "green" synthesis of AgNPs from tea leaf extraction remained stable. The finished product served as evidence of the stability of AgNPs (in an aqueous media) produced utilizing plant compounds and solutions. It has been suggested that surface complexation influences the inherent stability of nanoparticles by controlling their colloidal stability. A mechanistic knowledge of the mechanisms related to surface combination allowed for the theoretical prediction of the nature and stability of nanoparticles. Altering the functionality, edge capping, and particle size steps may be used to alter the dissolving rate or colloidal strength of nanomaterials.

3.4 Microorganism-based Mechanism

Different microorganisms are used in various processes to create nanoparticles. The first step is the capture of metallic ions either on the outside or inside of the microbial cells, and the second is the reduction of these stopped ions that had turned formed metal nanoparticles by the activity of enzymes. According to the following hypothesis, a description of the process for the formation of nanomaterials of gold and silver aided by microorganisms from Verticillium sp. or algal biomass. Utilizing the electrostatic bonds of ionized cell wall protein and ions, the silver or gold ions were first attracted to the surface of fungal cells. (b) Following this, silver or gold ions underwent bioreduction to form silver or gold nuclei, which subsequently expanded. The two essential components in the creation of Nicotinamide adenine dinucleotide (NADH) and Fad-dependent nitrate reductase are components of nanoparticles. Showed that the formation of reduced silver nanoparticles by B. licheniformis was caused by nitrate reductase. However, little is known about the bio reduction processes that lead to the formation of metallic salt ions and the subsequent metallic nanoparticles produced by microbes.

3.5 Plant Leaf Extract-based Mechanism

Plant leaf extract is using a variety of reaction conditions, coupled with metal precursor solutions to produce nanoparticles. It is accepted that the variables influencing the conditions of the leafy plant gather, such as heat, pH, metal salt concentration, and kind of phytochemical, determine the pace of nanoparticle creation furthermore to the particle yield and stabilization. In contrast compared to bacteria and fungus, which require a longer time to incubate, the Plant extracted leaves include compounds that have exceptional abilities to decrease metal ions in a considerably shorter amount of time.

Using the chemical properties of photography as a basis, we hypothesized that the principal reducing agent for silver ions that are reduced to silver nanoparticles by non-cyclic photophosphorylation would be hydroquinone, plastohydroquinone, or quinol (an alcoholic molecule). Therefore, our work demonstrates that plants produced metallic nanoparticles extracellularly using biomolecules and heterocyclic chemicals found in the plant extract. Numerous plant phytochemicals, such as alkaloids, terpenoids, phenolic acids, sugars, polyphones, and proteins, have a history of playing a significant role part in the bioreduction of metal salts into metallic nanoparticles. As an example, it has been shown that geranium leaf extract contains terpenoids that actively contribute to the transformation of silver ions into nanoparticles. Eugenol, a key terpenoid found in Cinnamomumzeylanisum (cinnamon) extracts, is essential in support of the metal's bioreductionsalts $HAuCl_4$ and $AgNO_3$ into the corresponding metal nanoparticles. According to FTIR data, eugenol-derived-OH groups vanish during the synthesis of Au and Ag nanoparticles. Alkenes, carbonyl, and chloride functional groups first occurred after the creation of the Au nanoparticles. R-CH and -OH (aqueous) are only a few of the other groups that were discovered both before and after the creation of Au nanoparticles.

3.6 Multiple Mechanisms

The most esteemed inorganic nanoparticles are silver nanoparticles, which are effective antibacterial, antifungal, antiviral, and anti-inflammatory compounds. An analysis of the literature produced the following results techniques to characterize silver nanoparticles' antibacterial potential:

(1) interactions between Ag NPs and disulfide or sulfhydryl groups of enzymes disturb metabolic activities, resulting in cell death;
(2) the microbial outer covering denaturing;
(3) the creation of pits/gaps leading to disintegration of the cell membrane.

Examining the shape-dependent antibacterial activity. Truncated triangular nanoparticles are extremely reactive due to their surfaces' improved antibacterial activity.

CONCLUSION

Over the last ten years, the green production of Particles of metallic and oxides of metal have been one of the most alluring study fields. Several different types of natural extracts, including biocomponents including plant, bacterium, fungal, and yeast to obtain, have been used as effective materials for the creation of synthetic production of materials. Plant extract is one of them, and research has shown that it is very effective as decreases and stabilizes agents for the production of controlled compounds. Probable future research and development of "green" materials and nanoparticle synthesis should focus on transferring laboratory-based work to an industrial scale while taking into account historical and contemporary difficulties, in particular the impact on human health and the environment. However, it is anticipated that the Synthesis of green materials and nanoparticles using materials and nanoparticles obtained from biocomponents will be employed widely, in other fields, such as environmental clean-up crucial fields like the pharmaceutical, food, and cosmetic industries.

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Методи зеленого синтезу наноструктур для навколишнього середовища та біомедичних застосувань

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«Зелений» синтез – це надійний, довготривалий і екологічно чистий процес виробництва різних матеріалів і наночастинок, таких як гібридні матеріали, біоінспіровані наночастинки, матеріали метал/оксид металу тощо. Екологічний синтез розглядається як важливий інструмент для зменшення негативних наслідків, пов'язаних із традиційними методами, процес синтезу наночастинок часто використовується в лабораторіях і на підприемствах. Використовуючи природні екстракти для нанорозмірних частинок металів і оксидів металів, таких як оксид міді (CuO), золото (Au), срібло (Ag) і оксид цинку (ZnO), в роботі викладені основні принципи та методи «зелених» методів синтезу. Крім того, нами розглянута роботу біологічних компонентів і важливих фітохімічних речовин, включаючи відновники та системи розчинників (включно з флавоноїдами, алкалоїдами, терпеноїдами, амідами та альдегідами). Розглянуто питання стосовно стабільності/токсичності наночастинок і відповідних методів інженерії поверхні для гарантування біосумісності. З точки зору антибактеріальної ефективності, каталітичного процесу, усунення барвників і забруднювачів, а також виявлення іонів важких металів, ці синтезовані сполуки потім були розглянуті на предмет їх потенціалу для відновлення навколишнього середовища. Таким чином, очікується, що синтез «зелених» матеріалів і наночастинок з використанням матеріалів і наночастинок, отриманих з біокомпонентів, буде широко використовуватися в екологічних і біомедичних додатках.

Ключові слова: «Зелений» синтез, Наноструктури, Наночастинки, Гібридні матеріали, Біосумісні матеріали.