International Journal of Education and Science Research Review

E-ISSN 2348-6457

Volume-6, Issue-3 May- June 2019

P-ISSN 2349-1817

www.ijesrr.org

Email- editor@ijesrr.org

GREEN SYNTHESIS OF NANOMATERIALS FOR ENVIRONMENTAL APPLICATIONS

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ABSTRACT

The synthesis of nanomaterials has garnered significant attention due to their remarkable properties and potential applications in various fields. However, the conventional methods of nanomaterial synthesis often involve hazardous chemicals and energy-intensive processes. This study focuses on the green synthesis of nanomaterials, emphasizing environmentally friendly and sustainable approaches for their production, with a primary focus on applications in environmental remediation and sustainability. The research begins by discussing the principles of green chemistry and its application to nanomaterial synthesis. We explore the use of environmentally benign precursors and sustainable reaction conditions, highlighting the reduction of waste and energy consumption in the synthesis process. The study covers a wide range of green synthesis techniques, including plant-mediated synthesis, microbial synthesis, and template-based approaches. We delve into the mechanisms underlying these methods and their advantages in terms of biocompatibility and eco-friendliness. One of the central themes of this research is the application of green-synthesized nanomaterials in environmental remediation. We examine their use in removing contaminants from air and water, including heavy metals, organic pollutants, and emerging contaminants. The study also explores their role in sustainable agriculture and soil remediation. we discuss the potential of green-synthesized nanomaterials in renewable energy applications, such as solar cells, photocatalysis, and energy storage devices. These materials hold promise for enhancing the efficiency and sustainability of renewable energy technologies. this study highlights the importance of green synthesis methods for nanomaterials and their versatile applications in addressing environmental challenges and promoting sustainability. By emphasizing eco-friendly approaches to nanomaterial synthesis, we aim to contribute to the development of environmentally conscious technologies and solutions.

keywords: *Nanomaterials, Green ,Synthesis, Environmental*

Introduction

Feynman (1960) pondered on the fine nature of nanoparticles by saying "there is plenty of room at the bottom". It turned out that his prediction was correct: the technology and science that underpins miniaturization has opened up novel paths for dealing with the production and characterization of nanomaterials as well as their use in society. Because these entities function as bridges to control the gap between bulk components and atomic or molecule assemblies, the resultant scientific interest in NPs can be related to the fact that this distinction can be managed by the entities themselves. At the nanoscale, several different well-characterized bulk materials exhibit noteworthy property changes. NPs have a high aspect ratio, which, in comparison to the vast majority of materials, makes it possible for them to have better reactivity as well as efficacy. Researchers have proven their competence over the course of time and generated nano-sized complements for composites, in addition to unique materials that are based on nanotechnology. The capture of photographs with a greater resolution, the creation of a large number of nano-sized sensors for detecting environmental pollution, an increase in the number of optoelectronics methods, and the development of nano-engineered solar applications are all significant and vital uses of nanotechnology. The nanoscale is the focus of study in the field of nanotechnology. There is evidence that nanostructures have been around since the origin of life. The accumulation of claims for nanostructured materials in a variety of disciplines, such as catalysis, has resulted in the emergence of a large demand for nanotechnology. Carbon-based materials and mineral elemental blends that demonstrate prospective optoelectronic and dimensional properties that are greater than the majority of their complements have been found by professionals in the field of materials science over the past several centuries. Inorganic NPs comprise magnetic, noble metal, and semiconductor NPs, whereas organic NPs consist of carbon arranged in liposomes, fullerenes, dendrimers, and polymeric micelles. Organic NPs contain carbon in the organization of polymeric micelles. study uses metallic NPs because the precise characteristics of metallic NPs are difficult to reach in isolated molecules. This makes metallic NPs significant to the field of study. In the field of nanotechnology, the production of metallic NPs serves as an active topic in theoretical and, more crucially, "applied research". This study focuses on modern research efforts that deal with the green synthesis of inorganic nanoparticles (NPs), which offers benefits over traditional methods that involve chemical agents that are harmful to the environment. These advantages are discussed in further detail in the following paragraphs. This article examines conventional synthetic processes, with a particular emphasis on recent advancements in the creation of environmentally friendly methods to the production of metal, metal oxide, and other significant NPs. After that, it moves on to talk about the methods of creation as well as the circumstances that affect the surface shape, dispersity, and other features of these biosynthesized NPs. The research concludes with a review of the current position and future projections for the manufacturing of nanoparticles using a variety of environmentally friendly methods. In a nutshell, nanomaterials are in very high demand for a variety of applications ranging from biomedical to bioenergy. This is because the nano size is accompanied by a high surface area that can facilitate loading of the molecule of interest for a variety of scientific applications including drug delivery systems for various disease conditions, particularly cancer. It is of the utmost importance, when employing nanomaterials as a drug carrier, to conduct an analysis of the carrier's level of toxicity. It was the realization of this notion that led to the development of green synthesis, which can replace the chemical processes that generate hazardous nanocarriers. The production of a metal oxide that is capable of responding to various stimuli has the potential to be an efficient method for targeting medicine delivery to the desired spot. In addition to their usage in medicine delivery applications, these nanoparticles have the potential to be put to good use in bioremediation. This is because they have the ability to decompose a pollutant without having a negative impact on the ecosystem, as the nanocarriers are made from natural components. This research focuses primarily on the development of novel and cutting-edge environmentally friendly synthesis methods for metal oxide nanoparticles that are responsive to a variety of stimuli. This leads to the production of prominent and cost-effective nanomaterials that are suitable for a wide range of applications. The biodegradability of these nanomaterials also contributes to the novelty of this body of work. This environmentally friendly synthesis does not only result in the production of extremely effective nanocarriers, but it also carries out the task that is required of it without causing any harm to live beings or the surrounding environment.

Synthesis of NPs via Bio/Green Synthesis

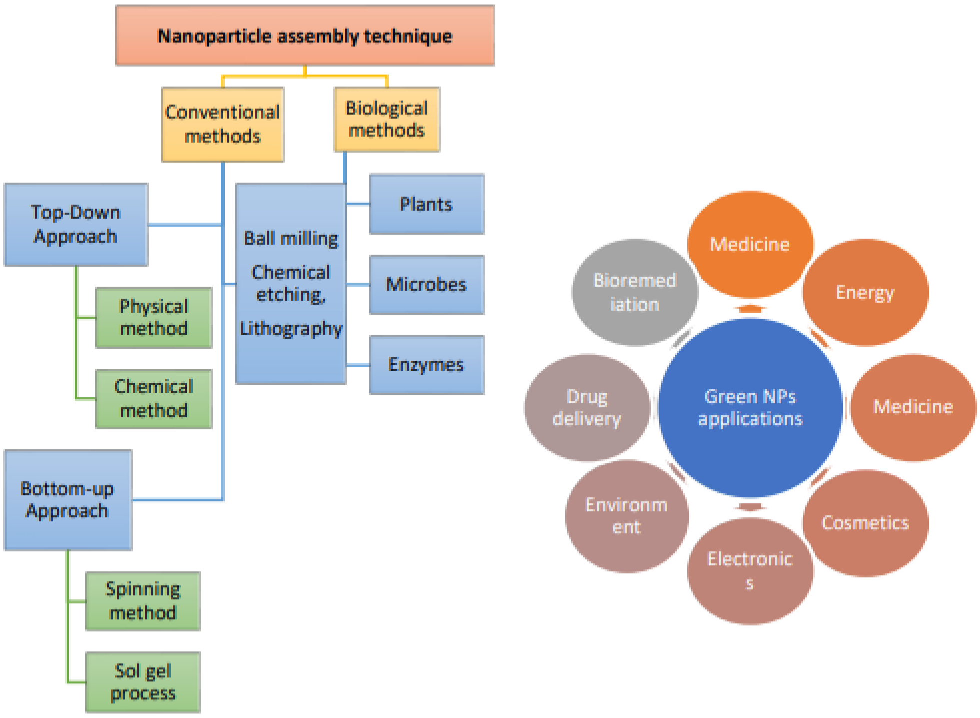
In prior studies, both the top-down methodology and the bottom-up method were discovered as possible paths leading to the creation of metallic nanoparticles (NPs). The etching of nanoscopic features onto a substrate using electron beams is an example of a top-down technique. This is followed by the use of appropriate engraving and deposition procedures. Top-down methods are those that start at the top and work their way down. Some examples of top-down methods are the physical processes of evaporation–condensation and the technique of laser ablation. In this approach, a radiator is used to assist in the process of evaporating the primary resources, which comprise the vast bulk of the metal components that were initially there. The vapor that was evaporated is then permitted to cool at a suitably high pace with the aid of the steep temperature gradient that is placed in the vicinity of the heater surface. This is done in order to ensure that the desired temperature is maintained. When present in high quantities, the rapid heating and cooling makes the NPs unstable. This instability is caused by the NPs. In the process of evaporation–condensation, an inert gas is utilized, however in laser ablation, a laser is aimed towards a metallic item that is dissolved in a solution. This is in contrast to the process of evaporation–condensation, which uses an inert gas. For example, silver nano-spheroids with a diameter ranging from 20 to 50 nanometers might be created using laser ablation in water by employing femtosecond laser pulses operating at 800 nm. One of the most major limitations is that the surface structure does not provide enough support by itself. Due to the high feature relation, defects of this kind can have a substantial influence on the physical features of metallic NPs as well as the interactions that they have with their surroundings . This can be the case because defects of this sort can have a major impact on the high feature relation. The chemical reduction approach is by far the most popular strategy, and it makes use of a broad variety of carbon-based and mineral-reducing mediators. The process also reduces minerals. In general, various reducing mediators such as sodium citrate, ascorbate, elemental hydrogen, sodium borohydride ($NaBH4$), polyols, Tollen's reagent, N, N-dimethylformamide (DMF), and poly (ethylene glycol)-block copolymers are employed for the reduction of metal ions in aqueous as well as non-aqueous solutions, leading to the formation of zerovalent metal, followed by agglomeration into oligomeric clusters. The creation of metallic colloidal particles from these clusters is the ultimate outcome of this process. It is also essential to keep in mind that the vast majority of these techniques include the utilization of protective mediators, which are frequently polymers, in the role of stabilizers in order to stop the accumulation of NPs. The functionality of the interactions that take place inside the particle surfaces is altered when surfactants and polymers (including thiols, amines, acids, and alcohols) are present. This is the case. This prevents the particles from agglomerating, sedimentating, and losing the surface properties that make them unique, and it also stabilizes the growth of the particles. The majority of these technologies are still in the process of being developed since considerable challenges still need to be addressed in order to extract and purify the produced NPs in preparation for further usageThe majority of these technologies are still in the process of being developed.

A wide range of mechanical and irradiation-assisted techniques have been utilized in order to successfully produce metallic nanoparticles (NPs). The green synthesis of metal oxides using the sonochemical approach has lately gained popularity as a consequence of an uncommon chemical reaction generated by cavitation in aqueous medium at a temperature of 5000 °C and a pressure of 1800 kpa. This reaction occurred as a result of the rare combination of temperature and pressure. This is due to the fact that the sonochemical approach is the only method that makes it possible to combine the chemical components at the atomic level. This reaction requires a temperature of 5000 °C and a pressure of 1800 kpa in order to take place. Pérez-Beltrán utilized a method that involved high-energy sonochemistry in the year 2021 in order to manufacture a magnetic iron oxide nanoparticle. As the two most essential aspects of the procedure, he identified an amplitude of 2826 J and a duration of 1 minute as being of primary significance. This cutting-edge and environmentally friendly sonochemistry-based synthesis took about one minute to complete and produced nanoparticles with a particle size of 11.2 nm. The biosensing of mercury in water was accomplished with the assistance of these nanoparticles

. Copper oxide nanoparticles may be ultrasonically created using Dactylopius coccus, and then they can be thermally destroyed at 60 degrees Celsius for the purpose of medication release in breast cancer applications, according to the findings of another study that was carried out by Goudarzi. The research was carried out by the same researcher. This research was completed in its entirety.

Applications of Nanoparticles

NPs provide a wide range of fantastic benefits that may be applied to a variety of applications throughout daily life. As a result, it is essential to do exhaustive research on NPs. The methods for producing nanoparticles and the uses of NPs that were covered in this review are represented pictorially in Figure 1, which may be found below. NPs that may be used in the human body include those that have been biosynthesized from noble metals. These NPs have a wide range of significant uses. They employ the molecular engine to solve problems with pharmaceutical treatments, and they use molecular information to support and increase human fitness on the molecular scale. This ultimately contributes to the maintenance and improvement of human health. With the help of Azoarcus sp. CIB, Fernández-Llamosas was able to biosynthesize selenium nanoparticles, which are associated with a wide variety of positive effects on human health. Figure 2 depicts the categorization of several approaches to the production of nanoparticles as well as the uses of these approaches. In terms of their applications in the field of biomedical research, NPs are the answer to a number of the problems that still exist in the medical industry. The production of NPs utilizing extracts of leaves (plant) and/or bark allows more comprehensive applications in the fields of biotechnology, sensors, medicine, catalysis, optical devices, coatings, medication delivery [49], water remediation, and agriculture. Because the NPs can be identified by imaging tools and have sensitivity down to the micro and/or nanomolar range, they are well suited for applications such as imaging, treatment, and the administration of pharmaceuticals . NPs of varying diameters can serve a variety of distinct biological purposes. It has even been possible to load NPs onto TiO_2 nanotube implants such that they can be used as materials for orthopedic implants. The biocompatibility of the implants is improved thanks to the NPs, which eventually results in a longer life lifetime for the implant as well as increased efficacy of the implant.



(a) (b)

Figure 1. A categorization of the many approaches to the production of nanoparticles (a) and the uses to which they may be put (b).

Environment and Energy

When it comes to environmentally friendly operations and cleaning up the environment, nanomaterials are of the utmost importance. Both in the treatment of pollutants and in the cleanup of hazardous waste sites, they show promise as a viable solution. The photocatalytic breakdown of Acid Blue-74 by the nanoparticles is seen in Figure 2. Nanoscale surface coverings that clean themselves can reduce the need for various chemicals that are typically used for cleaning during normal maintenance procedures. The development of fast advancing applications for the disinfection of water and the cleanup of heavy metals in the soil have contributed to the increased interest in Fe NPs. NPs are used as alternatives to pesticides in the treatment and management of plant disease. Additionally, they perform the function of efficient fertilizers that are favorable to the environment and are able to increase agricultural yield. Coating optical instruments used in solar energy applications with magnetite (Fe_3O_4) and a siliceous substance created by utilizing bacterial cells and diatoms has been shown to be effective.

International Journal of Education and Science Research Review
Volume-6, Issue-3 May- June 2019 E-ISSN 2348-6457 P-ISSN 2349-1817
www.ijesrr.org Email- editor@ijesrr.org

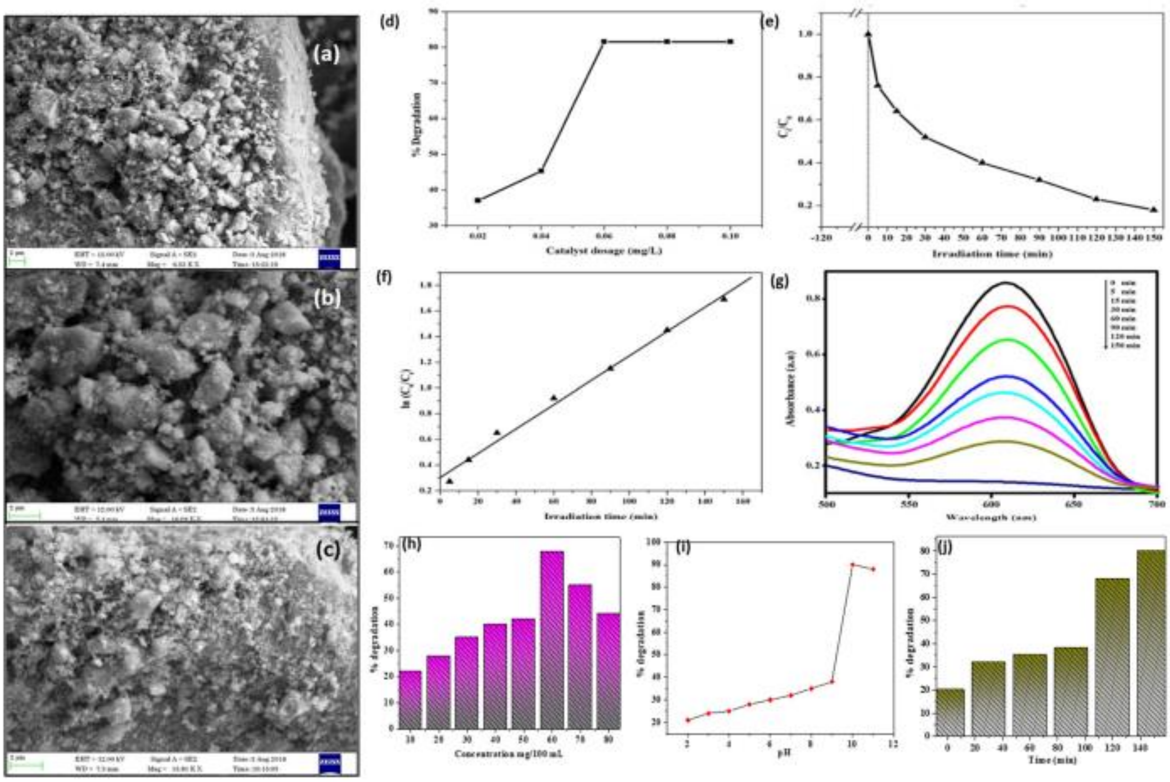


Figure 2. (a–c) FESEM micrographs of green synthesized GGCo-NPs nanoparticles. (d) Effect of initial catalytic dose. (e) Photocatalytic degradation of AB-74 by GCo-NPs under irradiation by sunlight. (f) Pseudo-first-order reaction kinetic model for GCo-NPs as an NP photocatalyst. (g) Absorption Photocatalytic degradation of AB-74, with varying initial dye concentrations (10 mg/100 mL–80 of AB-74, with varying initial dye concentrations (10 mg/100 mL–80 mg/100mL) (h), pH (2–12) (i), contact time (0–150 min) (j) .

Solvents for synthesising nanomaterials

Supercritical fluids, often known as SCF for short, are innovative hybrids that combine liquid and gas states and can take on some of the properties of green mediums, such as high chemical reactivity. They are also capable of dissolving a range of solutes such as liquids while simultaneously maintaining the features of gases such as low viscosity, zero surface tension, and improved diffusivity (Ali et al., 2020). These abilities were discovered by Ali et al., 2020. In addition, SCFs can combine with gases if the temperature and pressure are adjusted in such a way as to program the proper level of solvency. According to Singh et al. (2018), ordinary solvents have the potential to transform into supercritical fluids (SCFs) when subjected to temperatures and pressures that are in excess of their critical points. A few examples of supercritical fluids are supercritical water (SC-W), supercritical carbon dioxide (SC-CO2), and ecologically friendly bio-based solvents such as raw extracts of microbial cells, plants or explants, and animal tissues. Since SC-CO2, which has a SC pressure of 74 bar and a SC temperature of 304 K, can readily pass through extremely small holes such as nanopores, it is an ideal solvent for depositing metal nanoparticles in porous materials (Kharissova et al., 2019; Siril and Turk, 2020). The SC pressure of SC-CO2 is 74 bar, and the SC temperature is 304 K. According to Siril and Turk (2020), it does not catch fire, poses no threat to the environment, is not poisonous, does not react with chemicals, and is more cost-effective.

According to Siril and Turk's 2020 research, supercritical carbon dioxide possesses thermophysical properties that include characteristics linked to densities and diffusivities that are comparable to those of liquids, but with the viscosities of gases. Producing metal nanostructures in bulk can be accomplished by the use of a process referred to as supercritical fluid reactive deposition (SFRD), which is a bottom-up method. Because of its great wettability, SC-CO2 is ideally suited for the deposition of nanoparticles on very hydrophobic surfaces, such as virgin graphene and polymers. The metals may be created using this method, and the ultimate recovery of the result can be carried out using degasification. Both of these steps are necessary. An experiment was conducted to create a novel sorbent for the extraction of pesticides in the magnetic solid phase. The purpose of this experiment was to assist the agro-alimentary sector by synthesizing a number of new magnetic nanoparticles utilizing a SC-CO2 reaction medium. These magnetic nanoparticles, which contained carbon nanotubes, had an octadecyl group-modified silica (Nano SiO2C18) coating applied to them. A research of analyte desorption and adsorption was done by creating similar magnetic (Moreno et al., 2018). The purpose of this study was to examine the efficacy of different magnetic composites based on their preparation techniques, as well as methods of SC-CO2 and decomposition with high thermal. According to the findings, a combination of the two nanomaterials was superior than a single sorbent in terms of the amount of analytes that could be absorbed by the mixture. The results showed that the detection limits lie between 0.07 and 0.60 g mL1 and that the recovery values of these substances ranged from 78 to 95% when this mixture of nanomaterials prepared from both methods was utilized to extract pesticides (sulfonylureas and neonicotinoids) from fruit juices and water samples. These pesticides were extracted using both of the methods described above. In addition, SC-W can be utilized in the role of reaction medium.

According to the findings of Kim et al. (2016), an experiment was carried out in which sub and SC-W as well as methanol were used for the purpose of synthesizing tungsten blue oxide (WO3x) and tungsten oxide (WO3). According to the findings, the hydrothermal reduction of tungsten oxides using glycerol was much less successful than using sub- or supercritical concentrations of methanol. According to Kharissova et al.'s 2019 research, SC-W has the ability to mix with both organic and inorganic molecules in order to produce a homogeneous phase. Its critical pressure is 22.1 megapascals, and its critical temperature is 646 degrees Kelvin. Alterations in molecular density, thermal conductivity, viscosity, and the diffusion coefficient all contribute to the fact that reactions in SC-W can take place via a variety of distinct pathways. Around the critical point, the dielectric constant of water, which is 78 when it is at room temperature, declines to the point where the values are near to those of solvents that are polar and organic. Hydrothermally, in SC-W, the formation of metal oxides is possible by the introduction of H2O2 and the establishment of an environment in which oxidation may take place. According to Duan et al. (2015), a hydrothermal synthetic approach may be accomplished by placing the water in an instrument known as an autoclave, which is then subjected to a greater temperature and pressure. In this approach, the dielectric constant plays a key role in influencing the solubility, equilibrium, and pace of reaction, which ultimately determines the nanoparticles that are produced.

The production of nanoparticles from biological sources may be broken down into two distinct categories: i) plant-based sources, and ii) animal-based sources. According to Shanker et al. (2016), these two sources are responsible for the production of natural compounds that have low levels of toxicity and display a variety of biological and medicinal qualities. Products derived from plants may be utilized in the production of nanoparticles on a massive scale with relative ease. Because of their abundance and ease of access, the leaves, tubers, bark, buds, fruits, and seeds of plants are being utilized for this purpose. This is because various components of the plants may be harvested in large quantities. In one study, the preparation of cadmium oxide

(CdO) nanoparticles was carried out utilizing an extract from maize husk (Bakayoko et al., 2019). This strategy was favorable to the environment, economical, and straightforward. The chelating agent that aided in the formation of CdO nanoparticles was the corn extract, which performed the job of an effective chelating agent. Other examples of biogenic green extracts for green synthesis of nanoparticles like metallic nanoparticles and metal oxide nanoparticles are Camellia sinensis (tea leaves), Emblica Officinalis (amla or Indian Gooseberry), Aegle marmelos (bael), Dalbergia sissoo (Indian rosewood), Sapindus mukorossi (raw reetha) and many more (Shanker et al., 2016).

Water

When it comes to chemical reactions like synthesis, the best and most appropriate solvent to use is water. According to Ali et al.'s research from 2020, it is a universal solvent as well as the cheapest and most easily accessible solvent due to the fact that it is so pervasive. The majority of ionic compounds are able to undergo dissociation when exposed to water, which results in a reduction in the attractive forces that exist between ions and permits the ions to move freely within the solution. Additionally, the adaptable physicochemical properties of water allow it to have exceptionally excellent solubility towards virtually all inorganic chemicals, as well as some organic molecules such as sugar and proteins, than any other solvent at different temperatures and a pressure of 10MPa (Ali et al., 2020). In an aqueous medium, silver (Ag) and gold (Au) nanoparticles may be created utilizing the bifunctional molecule gallic acid. The room temperature synthesis takes place in water, which functions as a solvent for the particles. Because water was the primary green solvent utilized in most of the studies, the derived extracts from plants, animals, and microbes served as the secondary green solvents. These investigations involved the use of a wide variety of green solvents. An investigation into the environmentally friendly production of silver sulphide nanoparticles, known as Ag2SNPs, was carried out by Awwad et al., 2019; the authors of this study used sodium sulphide nonahydrate (Na2S.9H2O), silver nitrate (AgNO3), an aqueous extract of rosemary leaves, and did their work at a temperature of 27 degrees Celsius. It was discovered that the Ag2SNPs had the form of a sphere and had an effective diameter of 14 nm. In yet another experiment, graphite was subjected to an electrolytic oxidation in water, which resulted in the production of graphene oxide in a manner that was both environmentally friendly and risk-free. Within a few of seconds, the graphite lattice will have undergone full oxidation as a result of the electrochemical oxidation reaction. Due to the fact that water has the maximum heat capacity in contrast to all other materials, the production process that involves water requires a significant amount of energy input. This is the case despite the fact that water is the most appropriate solvent (Duan et al., 2015).

Ionic liquid

According to Singh et al. (2018), ionic liquids (ILs) are made up of ions that have melting temperatures that are lower than 100 degrees Celsius. These are non-aqueous, polar, and non-volatile substances. Whether the ILs are hydrophobic or hydrophilic is determined by the properties of the cations and anions that make them up. According to Kharissova et al. (2019), the cations N-alkyl pyridinium, PR4 +, and 1-alkyl-3-methylimidazolium, NR4 + are utilized the most often in the composition. A few examples of common anions include the following: [PF6], [CF3SO3], [BF4], tosylate, [CH3COO], alkyl sulfate, Cl, NO3, and a great deal more. Ethyl, butyl, hexyl, octyl, and decyl are the alkyl chains that are most commonly seen. As a result of their low vapour pressures, ILs are taken into consideration to be possible environmentally friendly replacements for poisonous and volatile organic solvents. According to Kharissova et al.'s 2019 research, the capacity of chemical compounds to form hydrogen bonds and their polarity both have a role in determining whether or not the compounds are soluble in ILs. Chemical reduction is a method that allows for the creation of a wide variety of nanoparticles in ILs, which have a wide variety of reducing agents accessible, including gaseous (H2), organic (ascorbic acid), and inorganic (NaBH4) (Duan et al., 2015). The breakdown of metal carbonyls in ILs, which occurs when the metal ions have already attained the zero-valent oxidation state, is another method for producing nanoparticles in these systems. ILs may also be used with green heating technologies like as microwaves and ultrasound owing to the synergistic effects that result in an increase in the efficiency of reactions depending on the rate of the reaction, the quality of the product, and the amount of time it takes. Because of their large ionic charges, high polarities, and high dielectric constants, ILs have the ability to absorb microwave radiation.

The hydrothermal approach was utilized in a research to produce rare-earth elements, ytterbium oxide (Yb2O3), and ionic liquid - ytterbium oxide (Yb2O3-IL) nanoparticles using extract from Couroupita guianensis Abul leaves (Muthulakshmi and Sundrarajan, 2020). In accordance with the findings, the antibacterial activity of IL-assisted Yb2O3 exhibited a greater degree of inhibition on S. aureus and E. coli in comparison to Yb2O3 nanoparticles and amikacin in its conventional form. The MTT test was performed on breast cancer cells from a patient with MCF-7 to compare the two types of nanoparticles. The results showed that the IL-assisted Yb2O3 nanoparticles were more effective than the Yb2O3 nanoparticles in inhibiting or destroying cancer cells. On the other hand, the anti-inflammatory actions of IL-assisted Yb2O3 nanoparticles revealed a larger percentage of inhibition than Yb2O3. In another experiment, justicia adhatoda was employed as a stabilizing agent or capping for the easy synthesis of yttrium oxide nanoparticles adorned with silver-gold (Pandiyan et al., 2021). This experiment was published in the journal Pandiyan et al., 2021. The XRD investigation (Pandiyan et al., 2021) demonstrated that the Y2O3/Ag-Au nanoparticles obtained a face-centre cubic structure with a crystallite size of 30 nm. This information was obtained from the nanoparticles. Within the scope of this work, the antibacterial and anticancer properties of the nanoparticles were also investigated. In the investigation done on anticancer activity by the human cervical cancer cell line, the Ag-Au/ Y2O3 NPs shown a greater level of activity in fighting cancer against the HeLa cell. Ag-Au/ Y2O3 NPs exhibited stronger antibacterial activity against S. aureus and E. coli, respectively.

Synthesis of environmentally friendly nanomaterials employing a variety of different synthesis components

In the process of biological synthesis, nanomaterials are created using a variety of synthesis components, such as microorganisms, plant extracts, and certain other biological components. This process is referred to as "biosynthesis." Microorganisms such as bacteria, fungus, viruses, and yeast are referred to as "nano factories" because they are particularly important synthesis components. This is due to the fact that they are both cost-effective and ecologically beneficial (Ghosh et al., 2021). Figure 3 depicts the environmentally friendly procedures that may be used to produce metallic nanoparticles from bacteria, plants, and fungus. According to Ovais et al. (2018), microorganisms have the potential to detoxify heavy metals and accumulate them in the presence of reductase enzymes, which are largely responsible for reducing metal salts to nanomaterials. It is interesting to note that nanoparticles may also be manufactured utilizing a range of plant parts, including as leaves, stems, roots, seeds, and fruits. This method is referred to as phytonanotechnology, and it is still unknown how the specific mechanism of this process works (Ijaz et al., 2020). However, there are certain disadvantages connected with the utilization of microorganisms due to the fact that the collecting, culturing, isolating, and storage of microorganisms need some sophisticated stages in nanoparticle green synthesis. Additionally, in order to recover metal nanoparticles following the use of such technologies, downstream processing is required (Bahrulolum et al., 2021).

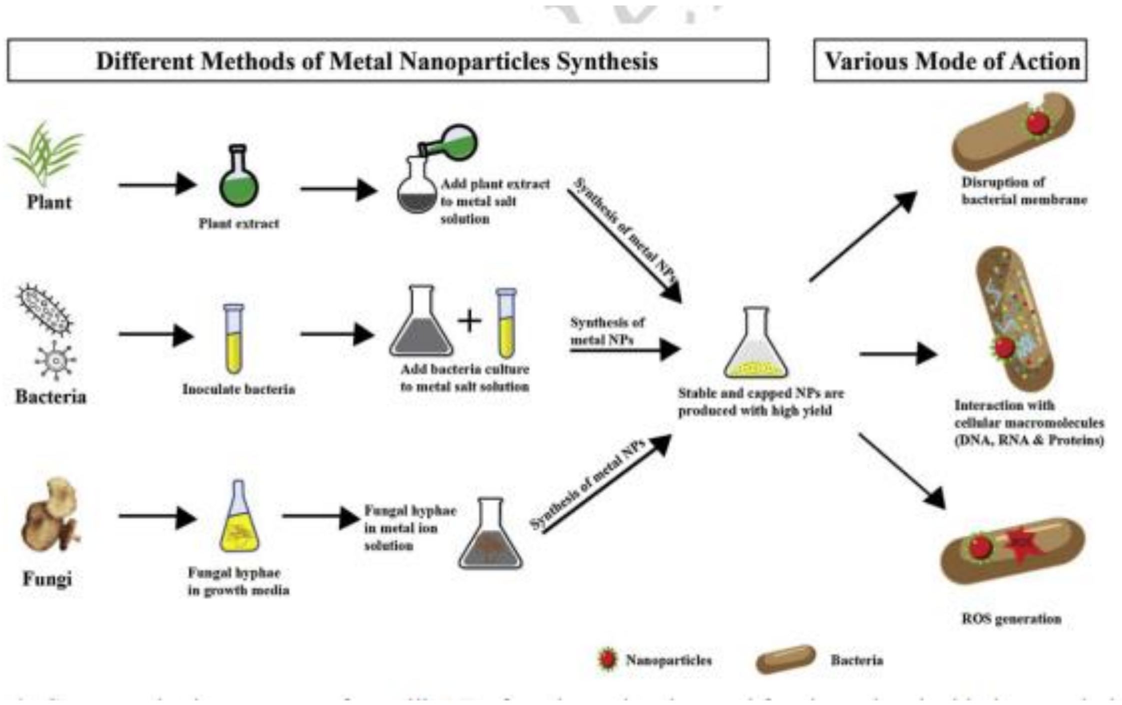


Figure 3: Reprinted with the permission of Elsevier from Singh et al. (2020),

Future perspective of green synthesis for nanomaterials

The green synthesis of nanomaterials is an area that is continually expanding, with applications in a variety of different industries, with the goal of generating unique, well-founded, and ecologically friendly solutions. However, in order to completely utilize and take advantage of the benefits that biogenic nanoparticles offer, certain areas require a greater understanding of, as well as additional improvement in, the relevant research:

- Since green synthesis of NMs is still a relatively new area of research, the potential of many natural materials for the synthesis of biogenic NMs has not been fully investigated. This includes the synthesis of various biopolymers, microorganisms, and waste materials, among other examples. Therefore, there is a need for an expansion of green synthesis, particularly because it offers essential benefits that cannot be substituted by either chemical or physical synthesis. This is especially true given that green synthesis gives these benefits in an environmentally friendly manner.
- Although there has been some progress made in the control of manipulating the morphologies of NMs, there has not been nearly as much progress made in the control of manipulating dimensions, notably size. Within a particular range, the benefits that come with NMs of varying sizes become more restricted. It is absolutely necessary to have a greater degree of control over the morphologies of NMs if one want to open up new fields of application as a result of new features.
- Inadequacy in knowing the underlying mechanics of many of the biosynthesis processes, particularly microbial synthesis, makes it difficult to fully take use of biological agents for NM synthesis. This is especially true in the case of microbial synthesis. Because of this, the techniques of synthesis are unexpected and uneven, even when producing the same substance. The process of synthesis may quickly become tedious and involved, requiring not only a lot of time but also a large quantity of resources.

Therefore, the use of methods of predictable synthesis that are constructed around precisely and theoretically expected mechanisms of synthesis is required. In order to do this, theorems and rules that are universally accepted need to be formulated; this, in turn, calls for the development of more nuanced and precise nano-analysis and detection tools, so that the kinetics of the reactions may be studied.

- It is necessary to have a comprehensive understanding of the biological components, chemical agents, and molecular mechanisms involved in the synthesis process. This understanding must include the recognition and separation of the compounds, as well as the understanding of the structure of the capping and reducing agent. • The effectiveness of green synthesis is still largely restricted to the laboratory phase. Because of the potential for variation from batch to batch, laboratory-controlled biosynthesis cannot yet create vast amounts of uniform NMs. This is due to the fact that the process requires many batches. As a result, there is an urgent need for synthesis methodologies that can be scaled up, are based on continuous flow, are stable, are efficient, and are favorable to the environment. Controlling the flow velocity, viscosity, surface tension, mixing duration, and location of reactants, as well as selecting appropriate solvents, and limiting the contamination of products with reactants are some of the challenges that are now preventing continuous synthesis methods from being implemented. By overcoming the constraints imposed by a continuous flow-based synthesis, it may be possible to manufacture NMs commercially at a high throughput and at a cheap cost. For the manufacturing and deployment of NMs on an industrial scale, more research and technological and economic feasibility studies are necessary.
- The longer incubation period and the high maintenance of microbial synthesis need to be addressed by research that study the optimization of parameters affecting the development of the microorganisms and the syntheses of NMs.
- The majority of commercially accessible nanoproducts for consumers do not prioritize safety and protection of the environment as one of their core goals. In addition, there is an insufficient amount of knowledge on the negative impacts that NMs have. In order to reduce the risk of toxicity associated with the use of NMs, it is necessary to conduct thorough research and gain further insights into the movement and mode of action of the NMs.
- It is strongly suggested to perform an exhaustive investigation of the full life cycle of raw materials, beginning with their manufacturing and ending with their disposal. During the manufacturing, handling, storage, and disposal stages, risk management should receive even more attention than it now does.

Conclusion

Recent developments in the field of environmentally friendly and sustainable remediation have included a growing sense of unease around the unintended effects linked with the proliferation of NPs and a rising demand for greener techniques. Not only does the widespread use of environmentally friendly synthesis have the ability to stop the secondary contamination of natural resources, but it also has the potential to reduce the overall costs of production. In spite of this, there are still gaps in the research that need to be addressed before we can make any forward in the development of this industry. For example, in order to continue with more predicted findings, it is still important to offer an explanation of the particular mechanisms that are involved in green synthesis. Although in-depth assessments of the exact mechanisms are not always evident, the great majority of research depends on realistic standards. The research that is being done on green synthesis at the moment has resulted in the development of NPs with a range of geometric structures. Despite this, there is still a need for methods that can produce more composite forms with more complicated surface areas. In addition, researchers who are interested in green synthesis ought to investigate the potential of modifying the crystal-like architecture of greener nanoparticles (NPs) in the future in order to discover new features that are distinct from those of the material's predominant form. Nanotechnology has recently come to the forefront as an intriguing tool that holds the potential to bring about revolutionary change in a multitude of fields. Nanotechnology is a type of technology that acts on the nanoscale scale and works with atoms, molecules, and macromolecules generally within the range of 1–100 nanometers. The purpose of this technology is to create and make use of different kinds of materials, each of which has its own set of characteristics. Nature is the best possible educator there is when it comes to studying the mechanisms that underlie the synthesis of incredibly small useful materials. It is possible to develop biocompatible and cost-effective particles that have the potential to be used in the field of healthcare by manufacturing metal oxide nanoparticles using microorganisms or plant extracts and applying biological processes. This presents a big possibility for the field of medicine. Future research that is geared toward filling up these knowledge gaps will play an essential part in bringing environmentally friendly synthesis of NMs to the commercial level and in making the most of the opportunities presented by biogenic NMs.

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