GREEN CHEMISTRY: AN ENVIRONMENTAL FRIENDLY WAY TO NANOMATERIALS SYNTHESIS

Abstract

This study provides a comprehensive overview of Green Chemistry: An environmental friendly way to nanomaterial synthesis. This study tells about what Green chemistry is and how it is related to Green nanotechnology. Detailed insights of Green chemistry and it's twelve basic foundations also lighten up in this study.

Furthurmore, this study tells about how and where green chemistry can be used also, elucidate Green nanotechnology and different ways to scheme green nanomaterials with detailed methodologies of nanoparticles synthesis which comprises of Top-down methods, solid state synthesis methods and liquid state synthesis methods with discussing different Green methods of nanoparticles synthesis with discussing their applications in different fields.

The synthesis of nanomaterials via green way have immense applications and a key method of environmental friendly way to nanochemistry.

Keywords: Green Chemistry, nanomaterial synthesis, Nanotechnology, nanochemistry

Authors

Taranveer Kaur
Research Scholar
Department of Centre for Nanoscience & Nanotechnology
Panjab University
Chandigarh. India.
sainitaran711@gmail.com

Uday Karanbir Singh
Department of Centre for Nanoscience & Nanotechnology
Panjab University
Chandigarh. India.

Harpreet Kaur
Department of Centre for Nanoscience & Nanotechnology
Panjab University
Chandigarh. India.

Pushpinder Kaur
Department of Chemistry
Sri Guru Gobind Singh College
Sector-26, Chandigarh, India.

Richa Rastogi
Department of Centre for Nanoscience & Nanotechnology
Panjab University
Chandigarh. India.
richa.bend@gmail.com

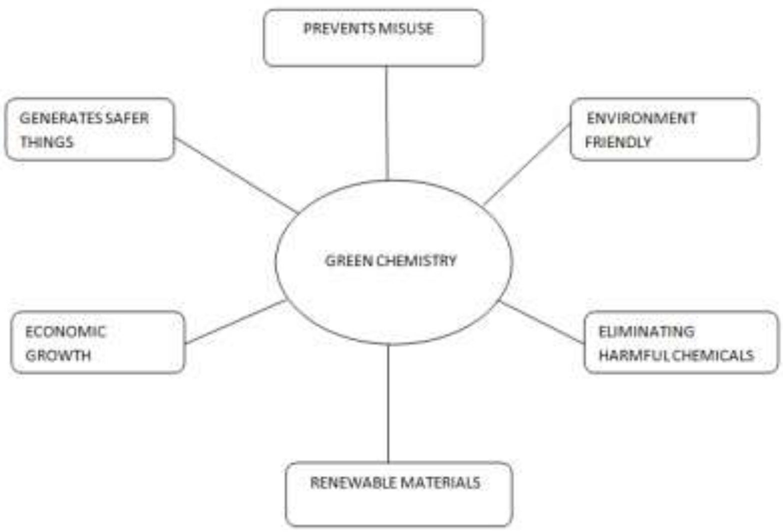
I. INTRODUCTION

Nanotechnology is seen as a crucial 21st century technology and has created a lot of excitement around the world, but it has slowed down due to a lack of understanding of the risks involved with it and a lack of policies to control new concerns. However, researchers keep working to overcome obstacles in the areas of managing, producing, funding, regulatory, and technical concerns[1]. The use of synthetic mixtures and physical tactics had fallen out of favor over the last several years, but the researchers' serious worldview was changed by the realization of their destructive human health implications. "Green synthesis" is now used to describe the strategies of plants or their metabolites combining nanoparticles (NPs)[2]. In order to achieve sustainability, green nanotechnology involves the biocompatible synthesis of nanomaterials from natural bioactive reagents such as microbes, various bio-waste like fruit peels, eggshells, agricultural residues, vegetable waste, plant materials and others. It is a strategy that is inexpensive, straightforward, low-risk, nonhazardous, safe and ecologically friendly. Green nanotechnology is a key component of biocompatible technologies intended to improve the environment and transform extra bio-active goods into more profit making and sustainable green nanomaterials[3].

Unsurprisingly, usage of nano-structured materials has led to increased concerns about environmental safety and human health, which has favored growth of a sub-categorized devoted to environmentally friendly and non hazardous design solutions. Innovative approaches could reduce the hazards that nanomaterials pose to human health and environment throughout the course of their lifespan, for instance by substituting acceptable eco-friendly processes or products for harmful ones. Green nanotechnology uses the tenets of green chemistry to create nanomaterials that are sustainable in their creation, usage, and disposal[4].

II. GREEN CHEMISTRY

While talking about green chemistry at first what's important is what is green chemistry??



Aspects of Green Chemistry [5]

Green Chemistry can be elucidated as “Generating chemical components and strategies to decrease or get rid of the usage and creation of insecure chemicals.” This elucidation came in light for the first time at the start of the 1990s[6] .The foremost component of green chemistry is the idea of design. Design is an expression of human intention which cannot be done accidently. It comprises synthesis, and methodical and innovation conceptualization. "Design guidelines" are the Twelve foundations of Green Chemistry[7][8] and are discussed below:

1. **Prevention** Avoiding waste is preferable to treating or disposing up waste that has already been produced.

2. **Atom Economy** The aim of the synthetic approach is to imcooperate all the components involved/used during the reaction process into final products.

3. **Chemical Synthesis that is Less Hazardous** Synthetic methods should be developed whenever possible to use and produce chemicals that are safe for both environment and people.

4. **Designing Chemicals Safe by design** while designing chemical products it must be kept in mind that amount of toxicity should be very less.

5. **More Secure Accessories and solvents** Auxiliary substances (like separating agents, solvents etc.) should be ignored whenever possible and if used, they should be safe.

6. **Energy-Efficient Design** Chemical processes' energy requirements should be considered for their effects on the environment and the economy, and should kept minimum. If possible, synthetic method should be done at pressure and temperature of the environment. .

7. **Renewably Sourced Feed-Stocks Should Use** A feedstock or raw resource should be renewable whenever it is technically and economically feasible, rather than depleting.

8. **Cut Back on Derivatives** Use of blocking groups, protection/ deprotection, and temporary modification of physical/chemical processes should be avoided/ minimized when not necessary because they require extra reagents and produce waste.

9. **Catalysis** Catalytic reagents, which ought to be as selective as possible, outperform stoichiometric reagents**.**

10. **Creating a Degradable Design** When a chemical product's useful life is over, it should be designed to degrade into harm free degradation products and do not continue in the environment. .

11. **Instantaneous Evaluation to Prevent Pollution** Further development of analytical techniques is required to provide instantaneous, monitoring during process and command before potentially dangerous compounds emerge.

12. **Chemistry that is inherently safer for preventing accidents** Substances and their forms that were used in a chemical method should be used to lessen the possibility of chemical mishappenings like blasts, catching fires and others.

For the simplicity of 12 foundations of green chemistry a acronym 'PRODUCTIVELY' was revised which binds up the soul of all foundations in just two or three words.

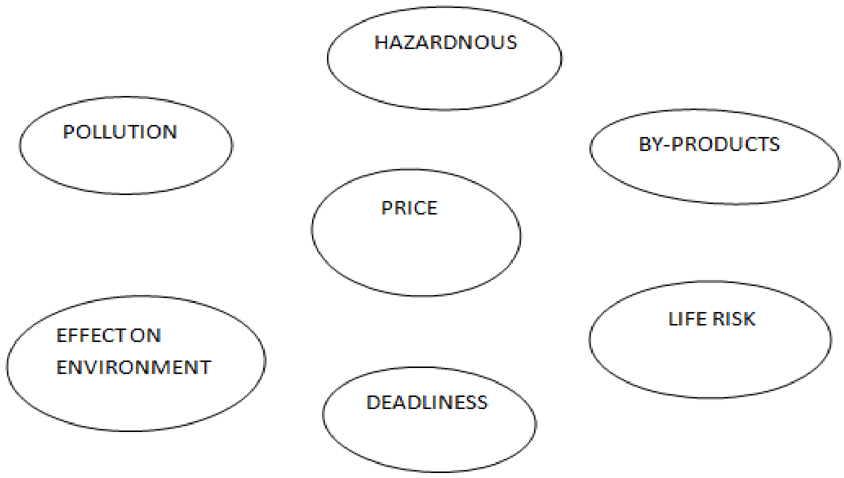
P- Prevents misuse
R- Renewable materials
O- Omit by-products steps
D- Degradable synthetic products
U-Use safe chemical methods
C- Catalytic reagents
T- Temperature, Pressure ambient
I- In-process monitoring
V- Very few additional substances
E- E-factor, increase feed in product
L- Low pathogenicity of chemical products
Y- Yes, it is safe/protected from harm

And the 12 condensed foundations are mentioned former[9].

III. GREENCHEMISTRY-SCOPE AND APPLICATIONS

Green ideas promote safe, eco-friendly, and clean methods for creating, processing, and using any physical thing. The application of this idea goes beyond industry to include research institutions, governmental agencies, environmental protection organizations and others that prompted the creation of paperback or altred processes for the sustainable creating, as well as controlling of chemical substances to lessen risks to environment and the human health[8].

Following the foundations of green chemistry, several cutting-edge ideas were created for companies to discover data for the evaluation and guess of green chemicals and one known is the green chemistry expert system (GCES), offers recommendations on how firms might apply green chemistry sustainably. It contains data on chemical compounds, the yield produced from those reactions. In order to estimate the amounts of the products and their waste, it also recognizes the characteristics of the reaction process. It offers guidance on safer chemical synthesis techniques. Additionally, this source offers details on the physical-chemical characteristics and the circumstances of various alternative, less dangerous compounds' reactions[10]. The main goal of green chemistry is to build a sustainable future; it is not only a lab curiosity. Companies are now able to market these concepts because of the increasing number of green approaches created by educational and corporate experts. By implementing the green chemistry principles, industry, from small firms to huge organizations, has already taken significant steps towards sustainability. The creation of less dangerous commercial products and processes, the transition from less efficient chemical synthesis to biocompatible synthesis, and the substitution of materials based on oil with raw material which is renewable are some examples of the significant steps that have been taken and will ultimately have significant effects on the global chemical markets[11].



What Green Chemistry Reduces? [5]

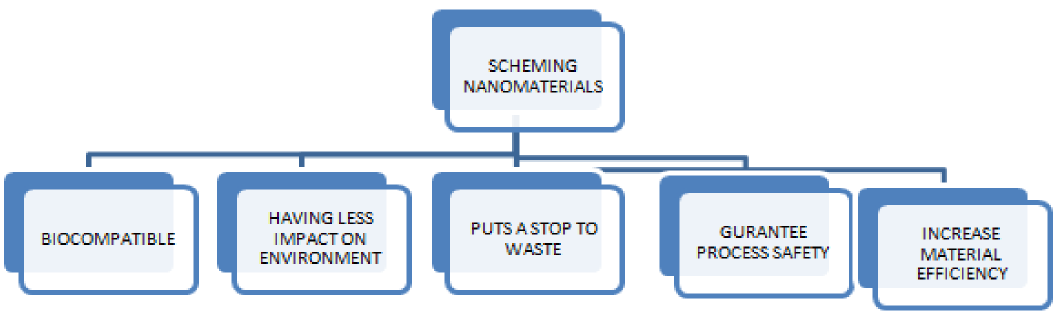
IV. GREEN NANOTECHNOLOGY

Green chemistry cum the skeleton of the foundations of Green Chemistry have been incorporated into green nanotechnology[12]. While talking about green nanotechnology, new design guidelines have been established for engineering non dangerous nanomaterials, which are safer not only during the product phase but also throughout the life cycle of the material. Design guidelines based on green chemistry must be followed in order to realize this ideal. This innovative method makes it easier to create safer, essential tools for the fusion of nonhazardous, commercial-grade nanomaterials.

This method emphasizes product efficacy and desirable accessory packages in addition to safety. In the end, the green nanotechnology approach seeks to develop capable essential methods for consistently producing nanomaterials with clearly defined chemical and physical properties. Similar to green chemistry, this strategy prioritizes environmental and human health safety through sensible product design and process command. [13][14].

V. SCHEMING GREEN NANOMATERIALS

The foundations of green chemistry can be utilized in the following ways in the development of green nonmaterials:



Scheming Aspects of Green Chemistry

- **Scheming Friendly Nanomaterials**: examining the required characteristics of nanomaterials (dimensions, composition, and functionality) biological properties while utilizing safe raw materials.

- **Scheming to Lessen The Effect On Environment:** Examining toxicity of damaged subunits, nanomaterial degradation features, and the employment of biosynthetic methods.

- **Scheming to Put A Stop to Waste:** Restricting the production of undesirable moities or extra-products, eliminating the use of solvents in purification and developing substitute purification methods.

- **Scheming to Guarantee Safe Reaction:** Replacing harmful agents and solvents with

- **Scheming to Increase Material Efficiency:** New safe raw ingredients and solvents are optimized together with real-time monitoring of the synthesis of nanomaterials.

By building in former discussed Scheming techniques in nanofabrication would rise to the creation of justifiable green nanomaterials.

1. **Methodologies of Nanoparticles Synthesis:** Nanoparticles are produced using a variety of techniques, which can be categorized into two groups: bottom-up techniques and top-down techniques. The substance used to make the nanoparticles is the main difference between the two methods. Top-down methods start with bulk material and use various physical, chemical, and mechanical processes to reduce particle size to nanoparticles, whereas bottom-up approaches start with atoms or molecules as the starting material.

   - **Top-Down Methods:** With the help of this, smaller pieces of nanoparticles are produced of large bulk materials. The foundation for the production of nanoparticles is the size reduction of the starting material through various physical and chemical processes. It discusses various methods, such as thermal, laser, and mechanical milling. Despite being simple to use top-down methods are not the best for producing disturbly shaped and extremely small particles. [15].

     - **Mechanosynthetic Methods** The cheapest methods for manufacturing nanomaterials in large quantities are mechanical ones. Ball milling is conceivably the most basic of them all. Ball milling produces nanoparticles by mechanical attrition, which is the transfer of kinetic energy from a grinding media to a material that is undergoing reduction. Nanomaterials are “put back together” in an industrial-scale processes called consolidation and compaction to create materials with improved characteristics. This is approach to create metallic alloys.

     - **Thermal Methods** that provide heat to a manufacturing process because they make up a broad category. Of them, electrospinning is a technique for creating materials for nano-threads. When it comes to energy input, high energy techniques are those that demand an excessive amount of , electricity, solar energy or heat. The foremost regulated method of creating carbon nano-tubes was using arc discharge. Solar flux and laser ablation are also effective. Control over quality and possible upgrade is the issue. Similar to anodizing, top-down chemical fabrication techniques are widespread artificial processes that are always simple to upmarket. Lithographic techniques are top-down techniques capable of producing primarily micron-sized features, despite being energy-intensive and requiring expensive equipment and installations. For many years, published circuits and computer boards have been produced using lithography. Future efforts to miniaturize will be costly because more significant sources (high energy electron shafts and sources with shorter wavelengths), equipment, and installations are required. Nanoprint lithography is lithography, but it doesn't operate in the conventional sense. It resembles template conflation more. To create a pattern, a template material must first be created and stamped into a soft polymeric material. Both the stamped material and the template stamp are created using a top-down approach. Latex spheres are used as templated matrices in nanosphere lithography. So, we can also refer to these methods as the template process[16].

- **Bottom-Up Methods :** Although easily available, inexpensive, and effective, bottom-up methods lack precise control over particle form, size, and dispersion[17].

- **Solid State Methods**

- **Physical Vapor Deposition Method:** Using the physical deposition technique, material is deposited on a surface as either a thin film or as nanoparticles. Before being further condensed on a substrate, material is first vaporized using carefully controlled vacuum techniques like thermal evaporation and sputtering deposition. Physical vapor deposition techniques, such as pulsed vapor deposition, are frequently used to create a thin layer of lanthanum strontium cobalt.

  When a solid target is subjected to pulsed laser deposition, ablated species are generated in plasma as a result of the laser ablation. Then, to produce a film, these ablated species are deposited on a substrate. Carbon nanotubes are frequently coated using this technique with thin films and metal nanoparticles[15].

- **Chemical Vapor Deposition Method:** Chemical vapor deposition was first described and patented in the late 19th century, and the process was used to make carbon fiber filaments and color pigments for electric lamps. In order to deposit a thin film of the target material on a surface, this method of deposition uses the chemical reaction between gaseous molecules containing the atoms necessary for film formation. The target material, which is released as a volatile molecule and serves as a precursor, interacts chemically with the substrate surface, the precursor fragment, and the target material in a series of reactions to form a thin film. Atomic layer deposition (ALD) thin films are frequently produced in this method by the surface chemical reaction.[15].

- **Liquid State Synthesis Method**

Sol Gel Method: For the first time, Livage et al. (1988) reviewed the sol gel chemistry of transition essence oxides. The sol gel system of conflation of nanoparticles involves either: a) Direct mixing of essence and essence oxide or nanoparticles within a pre-hydrolyzed silica sol, or b) Mixing preformed colloids essence (oxide) with a sol containing the matrix forming species, followed by gel conformation. c) Before hydrolysis, complexing the essence with silone and reducing the essence. Colloidal suspense (sol) and gelatin are used in this system to introduce a network conformation and create a network in a continuous liquid phase (gel). Colloids are fused using the ions of essence alkoxides and aloxysilanes as a precursor. The two silanes that are most frequently used to create silica gel are tetramethoxysilane (TMS) and tetraethoxysilane. Essence alkoxides are the organometallic precursors for colorful essences like titanium, silica, aluminum, and a variety of other elements. They are insoluble in water. Alcohal is a common detergent in US dollars. An initial homogeneous result of one or more named alkoxides is set in this system, and a catalyst is added to start a reaction at a controlled pH. The sol-gel conformation consists of four main processes: flyspeck growth, condensation, hydrolysis, and agglomeration.

In straight rush of essence/ essence oxide fashion, essence oxide patches are rained from silica sol typically by low-temperature heat treatment [15]. Thin flicks are substantially synthesised by this method.

In general, the "bottom-up" strategy, also known as wet chemistry, is focused mostly on solution phase chemistry and differs from the "top-down" strategy in that it employs physical means to minimize crystal size[18]

However, environmentally friendly green technologies means green methods are affordable, widespread, and produce stable information[19].

2. **Green Synthesis of Nanomaterials:** Green synthesis of nanomaterials, includes synthesis using microbes,plant extracts or using plant based phytochemicals. Strategies for biosynthesis or "green synthesis" have been developed as a new way to address the problems with physical and chemical approaches. One of these is plant-mediated green synthesis of NPs, which is highly regarded and widely used in the modern, fast-paced world. The advantages of green chemistry over chemical techniques include its simplicity, economy, environmental friendliness, ease of scaling up, lack of high temperature, pressure, and energy, biocompatibility, lack of use of dangerous chemicals, and safety for therapeutic purposes in humans [20].

   - **Microbial Synthesisof Nanoparticles :** Biosynthesis is a multistep, complex conflation method controlled by catalytic enzymes that uses natural products to produce the material. It is one of the strategies for creating green nanomaterials. As fungi, actinomycetes, and algae are used to produce nanomaterials, green biosynthesis incorporates a variety of methodologies. Bacteria are well known for producing inorganic materials both intracellularly and extracellularly. They have also shown that they are capable of producing essential nanoparticles through biosynthesis. In order to successfully produce iron and gold nanopatch production, Geobacterferrireducens and Bacillus subtilis were independently developed.[21]. The natural conflation of tableware using Aspergillus flavus and Fusarium oxysporum, a green process using fungi also produced gold nanoparticles. [22]. Actinomycetes are efficient biogenic microorganisms that share traits with both fungi and prokaryotic bacteria. In the presence of alkaline conditions, actinomycete species like Thermomonospora and Rhodococcus have been observed to be capable of producing gold nanoparticles. Additionally, successful nanomaterial biosynthesis using algae has been accomplished. For instance, the Sargassummuticum brown alga is capable of producing iron oxide nanomaterials via biogenetic synthesis.[23]. also, the intracellular conflation of some other nanomaterials and gold was also explored in plants such a sBrassicjuncea, Festucarubra, and Medicago etc.

Microbial Synthesis of Nanoparticles

Nanomaterials	Biosynthetic Agent	Applications	References
Gold Nanospheres	Pseudomonas denitrificans- bacteria	Stable GNP, comtrol over the size an shape	[24]
Gold Nanoparticle	Prasiolacrispa- fresh water green algae	Nearly spherical shape and average crystallite size 9.8nm	[25]
Gold Nanoparticle	Sargassumswartzii- marine algae	Induced cytotoxicity, mitochondrial damage	[26]
Silver Nanoparticle	Bacillus lichen infirmis- soil bacteria	Antibacterial and antibiofilm activity	[27]
Palladium Nanoparticle	Chlorellavulgaris- single cell green algae	Rapid synthesis , stabilized particles	[28]
Silver Nanoparticle	Bacillus methylotrophicus – methanol-utilizing bacterium	Remarkable antimicrobial activity	[29]

- **Green Synthesis Using Plants:** Almost every part of the plant has been used for nanoparticle synthesis like Leaves, roots, fruits, seeds etc. Plant extracts contain a variety of compounds besides reducing polysaccharides, such as flavonoids, terpenoids, polyphenols,ascorbic acid, tannic acid, amides, carboxylic acid and aldehydes, which create the ideal redox conditions for the synthesis of nanomaterials from their parent one. These green reagents work as potent reducing agents unaccompanied by endangering the manufactured nanostructures since phyto chemicals are present in plant extracts. Furthermore, thanks to the capping effects of phytochemicals, which do not alter the desirable qualities[30][31]. Leaves extracts such as Mangifera Indica, SyzygiumCumini ,Carica Papaya ,tea leaves ,aloe-vera and many more been utilized for the biosynthesis of nanoparticles[32][33].

Nanomaterials can be synthesized using root, seed and fruit extracts. The biological technique is always appealing and environmentally beneficial when producing ZnO nanoparticles. Zingiber officinale(ginger) aqueous root extracts may be used to make ZnO nanoparticles. The flavonoid test indicated that the root extracts were abundant in flavonoids, which improved the biogenic production of ZnO nanoparticles[34].Silver nanoparticles can be prepared from dried roasted Coffea Arabica seed extract[35], silver nanoparticles can also be prepared from papaya fruit extract[36].

- **Synthesis of Nanoparticles using Natural Plant Based Products:** Plant based natural products have been used by many researchers for synthesis of nanoparticles. Clove oil is one such product. Sesquiterpenes (- and -Caryophyllenes), phenols (Eugenol with about 3% Acetyleugenol), esters, alcohols, and ketones are present in small amounts in clove oil. It has been utilized to create silver nanoparticles. The proton donation of the eugenol structure, which reduces Ag+ to Ag0 and produces AgNPs, is the most likely mechanism for the reduction of Ag+ using clove oil. Additionally, the essential oil's phytochemical constituents interact with the NPs' surface, stabilizing and preserving them[37].

  Ascorbic Acid is another such natural product used for nanoparticle synthesis. Ascorbic acid was pre-owned as a reducing agent to create silver nanoparticles because of its high biodegradability and low toxicity. At typical pH levels for biological systems, the ascorbate ion dominates the species. It serves as an antioxidant and a mild reducing agent. It undergoes oxidation, first forming a radical cation with the loss of one electron, then forming dehydroascorbic acid with the loss of a second electron.[38].

  To make iron nanoparticles, even Green Coffee (G-Coffee) extracts have been used. G- Coffee bean extract (GCBE) has high levels of composites, which are similar to polyphenols and improve the protective effects against recurring conditions brought on by oxidative stress. The phenolic compounds, antioxidants, and a family of esters made of chlorogenic acids (CGA) (a number of hydroxycinnamic and quinic acids) are abundant in GCBE[39].

3. **Applications Of Green Nanomaterials:** In the fast pace era, Numerous industries use nanomaterials. Commercially produced goods include things like cosmetics, electronics, medications, energy storage devices, detergents, water filtration systems, etc. Given the high demand for biocompatible materials in the healthcare sector, this chapter will focus more on the biological uses of green nanoparticles.

   - **Bio-Medical Applications of Green Nanomaterials:** Due to their enhanced biocompatibility, green nanoparticles are often employed in the biomedical industry. The most significant biological uses of greener nanomaterials include diagnosis and treatment. Another application that includes cell isolation and cellular proteomics is cell separation. Green nanomaterials are used for bio-sensing, bio-imaging (MRI, CT), and stem cell tracking in nanomaterial-mediated diagnostics. Green materials' medicinal potential in drug transport, hyperthermia, and antimicrobial-anticancer action has all been studied[7]

- **Diagnosis Applications Of Green Nanomaterials:** Using MRI computed tomography, the metal nanoparticle-mediated diagnostic procedure is established for biological imaging. Excellent superparamagnetic characteristics were produced utilizing a green method that included microwave production of duplex-coated iron oxide nanoparticles, making them ideal for MRI imaging[40]. A bio manufactured iron oxide-gold nanohybrid system for contrast agents in MRI and CT imaging has been created by Narayanan et al.[41]. In addition to being used for bioimaging, nanomaterial-based biosensors are also used for diagnostic purposes. Rose water was used to make reduced graphene oxide-gold nanocomposites for biosensors that electrochemically decrease glucose oxidase and monitor blood glucose levels. [42]. In a different study, Zang et al. used a one-pot green synthesis method to make a self-assembling membrane out of reduced graphene oxide and gold nanoparticles. Using this nanohybrid, hydrogen peroxide, a cancer biomarker, can be detected amperometrically[43]. Bollella et al. developed a new third generation lactose biosensor based on cellobiose dehydrogenase by employing gold and silver nanoparticles in a quercetin-based green synthesis method. Excellent stability and sensitivity for lactose detection were shown by the developed electrochemical sensor[44].

Nanomaterials	Plant Sample	Precursor	Applications	References
Iron Nanoparticles	Sesamum indicum	Ferric chloride	Signficantant typhoid activity	[45]
Iron Nanoparticles	Mangifera-Indica	Ferric Chloride		[32]
Iron Nanoparticles	Syzygium Cumini	Ferric Chloride	Antibacterial and Antifungal	[46]
Iron Nanoparticles	Carica Papaya	Ferric chloride	Photocatalytic and Cytotoxicity	[47]
Iron Nanoparticles	Tea extract	Ferric sulphate		[48]
Iron Nanoparticles	Camellia sinensis (green tea)	Ferric chloride	Degradation of dyes, removal of heavy metals, antibacterial activity	[20]
Siilver NANOPARTICLES	Aloevera	Silver nitrate	Antibacterial activity	[49]
Silver Nanoparticles	Camellia sinensis	Silver nitrate	Sensing of Cu^{2+} and Pb^{2+} ions in aqueous solutions	[50]
Silver Nanoparticles	Impatiens balsamina	Silver nitrate	Antibacterial activity	[51]
Silver Nanoparticles	H.isora	Silver nitrate	Antibacterial and antioxidant activity	[38]

Silver Nanoparticles	Green tea	Silver nitrate	Antimicrobial, cytotoxicity	[52]
Silver Nanoparticle	Nicotianatobaccum	Silver nitrate	Antibacterial activity	[53]
Silver Nanoparticle	Crotalaria verrucosa		Economical way to reduce dengue vector larval population	[54]
Cobalt Nanoparticle	Catharanthusroseus	Cobalt chloride	Antioxidant, antibacterial, hemolytic and dye degradation	[55]
Cobalt Nanoparticle	Psidiumguajava	Cobalt nitrate	Photocatalytic, antibacterial and antioxidant activity	[56]
Cobalt Nanoparticle	Populus ciliate	Cobalt nitrate	Antibacterial activity	[57]
Cobalt Nanoparticle	Raphanussativus var. longipinnatus	Cobalt acetate	Antibacterial, Cytotoxicity	[58]
Cobalt Nanoparticle	Eucalyptus	Cobalt chloride	Removal of lead from polluted water	[59]
Gold Nanoparticle	Couroupitaguianensis	Chloroauric acid	Anticancer activity	[60]
Nickel Nanoparicles	Fumaria officinalis	Nickel sulfate	Antioxidant and anti human ovarian cancer activity	[61]
Nickel Nanoparticles	Desmodiumgangeticum	Nickel chloride	Atibacterial, antioxidant and cytotoxicity	[62]

VI. LIMITATIONS OF GREEN NANOTECHNOLOGY

The practical implementation of green chemistry's concepts is a hurdle[8].A systemic risk assessment methodology, a clear waste categorization process, industrially driven and legislative initiatives, and the use of suitable technology to control cum serve nanowaste streams are additional important difficulties facing current nanowaste management[63]. The absence of precise design standards for the creation of green nanomaterials, however, may cause significant issues in the future. The demand for particular guidelines in the development of green products is another issue. Moreover, the production of green nanomaterials is hampered by the relatively frequent updating of toxicity regulations. The wide concept of acceptability, which tension the economic viability of the method, is another problem with green nanotechnology. Another concern is the effectiveness of reprocessing and reusing the green goods utilized in synthesis methods[14]. Energy consumption reduction and energy waste minimization are additional obstacles in the use of green technology. When using green nano production approaches, creating a plant design with lesser energy needs, for instance, might be quite difficult. The industry adoption of cutting-edge green benign technology is one of the obstacles to implementation. Execution may be restricted as a result of process design, legal difficulties, or financial limitations[64].

VII. FUTURE PRESPECTIVE

Because plant extracts include phytochemicals, they function as potent reducing agents without endangering the safety of the nanomaterials that are produced. Plant extracts are a great source of reducing polysaccharides as well as amides, polyphenols, terpenoids, carboxylic acid flavonoids, tannic acid, ascorbic acids, aldehydes, , and other substances that create the ideal redox conditions for the synthesis of nanomaterials from their precursors. Furthermore, phytochemicals act as capping agents to extend the stability of created nanomaterials without modifying their desired properties[64][13]**.**

VIII. CONCLUSION

The desire to create green nanotechnology, which combines green chemical principles with nanotechnology, has been motivated by worries about the safety of nanomaterials for the environment and human health. Green nanotechnology has the potential to solve a number of serious problems related to nano-toxicology. Careful handling and design changes to material synthesis could significantly improve safety levels. Green chemical techniques have enabled the production of safer goods while consuming less energy, raw materials, and harsh chemicals. Implementing the Atom economy allowed for the efficient use of resources and the recycling and reuse of inputs. Process efficiency was achieved by waste minimization and prevention of wasteful intermediates. Adopting biogenic synthesis methodologies has boosted product quality to safer levels instead of using hazardous, chemically synthesized or modified nanoparticles. Green nanotechnology increases the number of biocompatible products that can be supplied to the body safely for diagnostic and therapeutic purposes. Green nanotechnology additionally offers a promising future for the industrial pharmaceutical, cosmetic, electrical, and other sectors without endangering the environment.

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