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GREEN NANOTECHNOLOGY: A REVIEW

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Abstract:

The emergence of nanoparticles (NPs) has attracted tremendous interest of the scientific community for decades due to their unique properties and potential applications in diverse areas, including drug delivery and therapy. There is a need for a new discipline- nano toxicology-that would evaluate the health threats posed by nanoparticles, and would enable safe development of the emerging nanotechnology industry related to biotherapy. Green Nanotechnology gives the opportunity in lowering the risk of using nano materials, limiting the risk of producing nanomaterials, and using nano materials to lower the risk of producing unwanted chemical intermediates and end-products.

Keywords: *Nanoparticles, Green chemistry, Green synthesis, Chemical synthesis, Biological application.*

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INTRODUCTION:

Nanotechnology is the engineering of functional systems at the molecular scale, which is about 1 to 100 nanometers. Nanotechnology covers a unique phenomenon that enables novel application in different fields. Nanotechnology promises a sustainable future by its growth in green chemistry to develop green nanotechnology. Green nanotechnology means the application of green chemistry and green engineering principles in the field of nanotechnology to manipulate the molecules within a nanoscale range. Green nanotechnology grounds on field of Green Chemistry that reflects the main aim of nanotechnology to create eco-friendly nano-objects to reduce human health and environmental hazards by application of green nano-products by manipulating the molecules within a nanoscale range. Green nanotechnology simply refers to field of nanotechnology to enhance the environmental sustainability and to maintain eco-friendly environment. Green nanoparticles synthesized from the different green nano technological approaches consist of a well-defined chemical composition, size and applications in many technological fields. Green nanoparticles developed through eco-friendly techniques have considerable importance in areas of medical biology, industrial microbiology, environmental microbiology, bioremediation, clean technology and electronics [1].

NANOPARTICLE SYNTHESIS BY GREEN ROUTE

There are two methods for the synthesis of nanoparticles, one includes Chemical synthesis and other focused on Green synthesis. The importance of nanotechnology in research field emphasis on the synthesis of nanoparticles with different chemical compositions, sizes, morphologies and controlled dispersities. The nanoparticle synthesized through the chemical methods involve Chemical reduction using different metals and chemicals such as sodium citrate, ascorbate, sodium borohydride, etc. Whereas in Green way for the synthesis of nanoparticle green reducing agents are employed using phytochemical extracts of different natural products such as leaf extract, juice extract, extract from medicinal plants etc. to provide unlimited opportunities for new discoveries[2].

The chemical method involves toxic solvents, high pressure, energy and high temperature for the preparation of nanoparticles. Green synthesis involves the synthesis of nanoparticles through aqueous extract of green product (such as plant extract of Musa balbisiana (banana), Azadirachta indica (neem) and Ocimum tenuiflorum (black tulsi) and metal ions (such as sliver ions). The fixed ratio of plant extract and silver ions were mixed and kept at room temperature for reduction the change in color was noticed at regular intervals of time from yellow to reddish brown or dark brown that confirmed the formation of nanoparticles. Further, the synthesized nanoparticles were characterized by using UV, XRD and FTIR data.

GREEN SYNTHESIS

Green synthesis approaches include mixed-valence polyoxo metalates, polysaccharides, tollens because plant extract termed as phytochemical are rich in phenolic compounds, alkaloids, diterpenoid, steroid and other compounds which inhibit the development of various microorganisms as phytochemicals act as reducing and capping agent in the reduction of metal ions to metal nanoparticles[3].

- **Use of bacteria to synthesize nanoparticles**

Bacteria play a crucial role in metal biogeochemical cycling and mineral formation in surface and subsurface environments. The use of microbial cells for the synthesis of nano sized materials has emerged as a novel approach for the synthesis of metal nanoparticles. Although the efforts directed towards the biosynthesis of nanomaterials are recent, the interactions between microorganisms and metals have been well documented and the ability of microorganisms to extract and/or accumulate metals is employed in commercial biotechnological processes such as bioleaching and bioremediation. Bacteria are known to produce inorganic materials either intra cellularly or extra cellularly. Microorganisms are considered as a potential biofactory for the synthesis of nanoparticles like gold, silver and cadmium sulphide. Silver nanoparticles in the size range of 10–15nm were produced by treating dried cells of *Corynebacterium* with diamine silver complex. The ionized carboxyl group of amino acid residues and the amide of peptide chains were the main groups trapping [Ag(NH3)2+] onto the cell wall and some reducing groups such as aldehyde and ketone were involved in subsequent bio reduction. But it was found that the reaction progressed slowly and could be accelerated in the presence of OH^- [4].

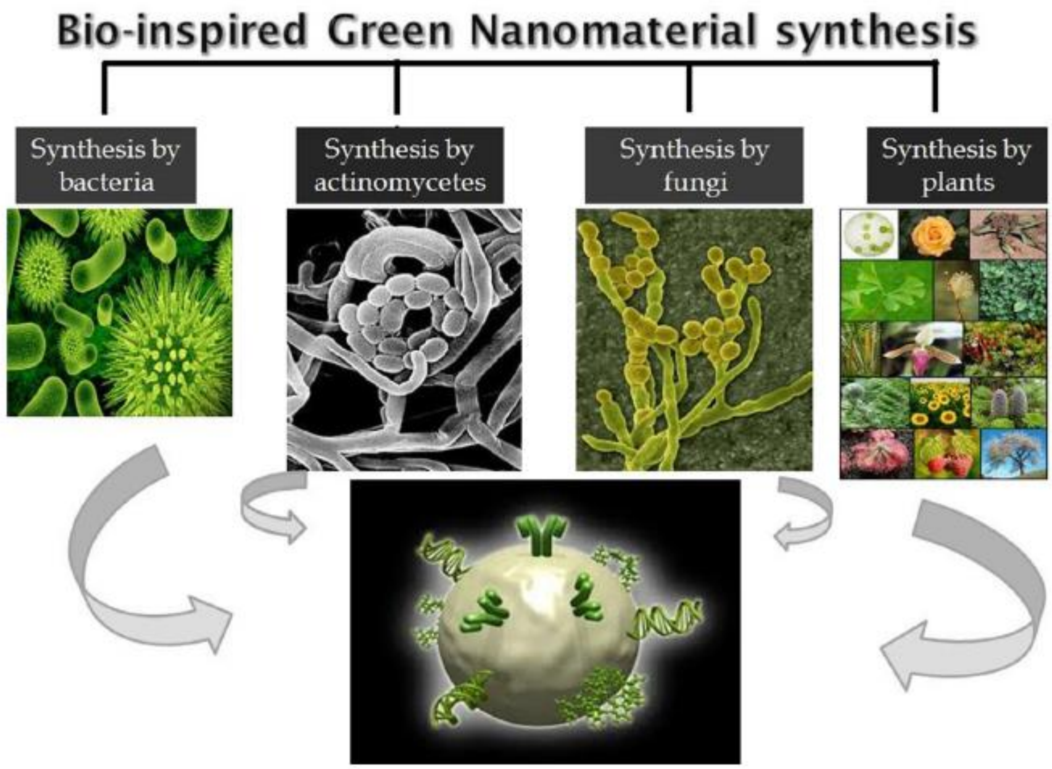

Fig 1: synthesis of green nano materials

- **Use of plants to synthesize nanoparticles**

The advantage of using plants for the synthesis of nanoparticles is that they are easily available, safe to handle and possess a broad variability of metabolites that may aid in reduction. A number of plants are being currently investigated for their role in the synthesis of nanoparticles. Gold nanoparticles with a size range of 2–20 nm have been synthesized using the live alfalfa plants. Nanoparticles of silver, nickel, cobalt, zinc and copper have also been synthesized inside the live plants of Brassica juncea (Indian mustard), Medicago sativa (Alfa lfa) and Heliantu sannus (Sunflower). Certain plants are known to accumulate higher concentrations of metals compared to others and such plants are termed as hyper accumulators. Of the plants investigated, B. juncea had better metal accumulating ability and later assimilating it as nanoparticles. Recently much work has been done with regard to plant assisted reduction of metal nanoparticles and the respective role of phytochemicals. The main phytochemicals responsible have been identified as terpenoids, flavones, ketones, aldehydes, amides and carboxylic acids in the light of IR spectroscopic studies. The main water soluble phytochemicals are flavones, organic acids and quinones which are responsible for immediate reduction. The phytochemicals present in Bryophyllum sp. (Xerophytes), Cyprus sp. (Mesophytes) and Hydrilla sp. (Hydrophytes) were studied for their role in the synthesis of silver nanoparticles. The Xerophytes were found to contain emodin, an anthraquinone which could undergo radial tautomerization leading to the formation of silver nanoparticles [4].

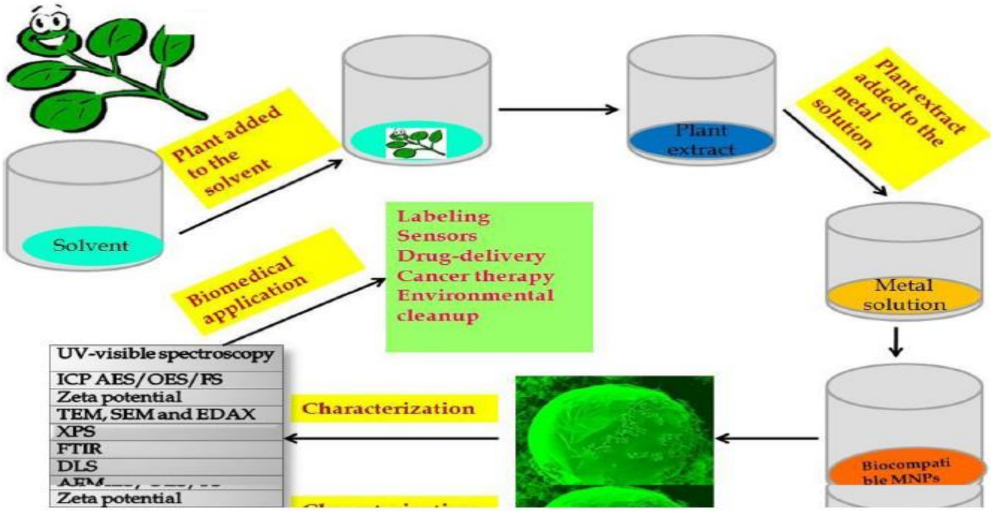

Fig 2: Schematic representation of plant as a source of green nanosynthesis, its characterization and biomedical application.

GREEN NANOTECHNOLOGY AND ITS GOAL

- the use of cost-effective, nontoxic precursors
- minimization of carcinogenic reagents and solvents
- reduction of experiments carried out with either pyrophoric compounds or unstable precursors to avoid risk
- use of relatively few numbers of reagents, i.e. atom economy, coupled with a conscious effort to circumvent the generation of greenhouse gases
- minimization of reaction steps leading to a reduction in waste, reagent use, and power consumption
- development of reactions to generate high-purity materials with little if any byproducts through high-yield processes
- ambient temperature and pressure synthesis
- efficiency of scale-up

BIO-INSPIRED GREEN NANOPARTICLES OVER CHEMICALLY SYNTHESIZED NANOPARTICLES

To reduce generation of hazardous waste and to develop energy-effective production routes, 'green' chemistry and biochemical processes are progressively integrating with modern developments in science and technology. Hence, any synthetic route or chemical process should address the fundamental principles of 'green chemistry' by using environmentally benign solvents and nontoxic chemicals. The green synthesis of NPs should involve three main steps based on green chemistry perspectives, namely

(1) Selection of a biocompatible and nontoxic solvent medium
(2) Selection of environmentally benign reducing agents, and
(3) Selection of nontoxic substances for stabilization of the nanoparticles.

Employing these principles in nano science will facilitate the production and processing of inherently safer nanomaterials and nanostructured devices. Green nanotechnology thus aims to the application of green chemistry principles in designing nanoscale products, and the development of nanomaterial production methods with reduced hazardous waste generation and safer applications [4].

GREEN NANOMATERIAL - BIOTHERAPEUTIC TOOL

Green-nanotechnology and molecular biology are rapidly enabling the development of multifunctional NPs with different specific functional properties for better disease diagnosis and therapy. The preparation of functionalized nanoparticles within a green context poses interrelated challenges in terms of maintaining product integrity (such as structure, shape and size disparity, functionality, purity and stability) while employing greener methods whenever possible. For example, control over particle size and disparity may reduce purification requirements by eliminating the need for extensive separations, while the ability to control surface functionalization, intended to enhance particle stability and dictate surface chemistry, solubility, and the degree of particle interactions, helps to better define the safety and reactivity of nanoparticles. Nanosynthesis methods are being refined in such a way that they are convenient and scalable, whether it involves the direct synthesis of a functionalized material or the preparation of a versatile precursor particle whose surface properties can be easily modified to meet the demands of a given application. This is accomplished through extremely controlled nanofabrication methodologies which result in the generation of molecularly defined nanoscale materials and devices that harbor known physical properties unique to each material in question and useful for particular medical applications. NPs are being developed as drug and gene carriers, improving treatment efficacy and reducing side effects. The imaging, delivery facilities and other functions have been integrated during NP formulation, enabling simultaneous in vivo diagnostic imaging and drug or gene delivery for real-time treatment tracking[5].

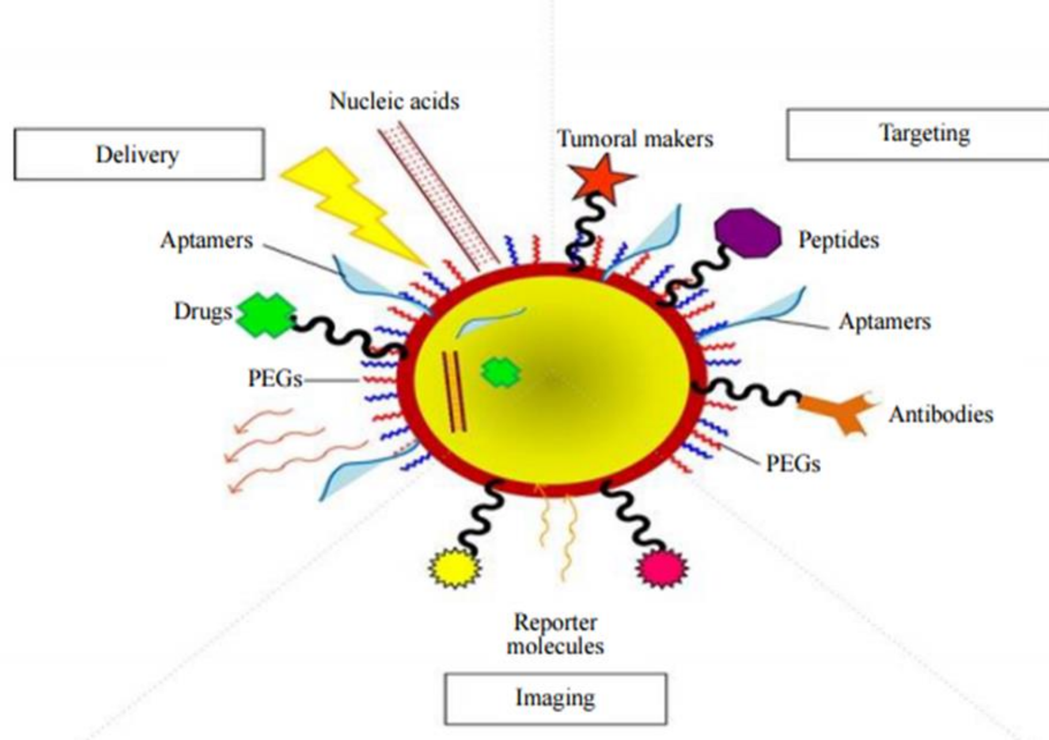

Fig 3: Schematic representation as bio therapeutic tool

THERAPEUTIC APPLICATIONS OF GREEN NANOPARTICLE

- **Nanoshells:**

Nanoshells are nanoparticle beads that consist of a silica core coated with a thin gold shell. Manipulation of the thickness of the core and the outer shell permits these beads to be designed to absorb and scatter specific wavelengths of light across the visible and near-infrared (NIR) spectrum. Their primary application is in thermal ablation therapy by exploiting their ability to absorb light. Meanwhile, their ability to scatter light has potential for cancer imaging. The most useful nanoshells are those that have a silica core diameter of ~120 nm with a 10 nm layer of gold shell, because these strongly absorb NIR light(~800 nm) and can create intense heat that is lethal to cells. By using green nanoparticles NIR light can penetrate several centimeters of human tissue without causing harm, because tissue chromophores do not absorb much energy in the NIR range.

- **Dendrimers:**

Dendrimers are hyper branched, tree-like structures. It contains three different regions: core moiety, branching units, and closely packed surface. It has globular structure and encloses internal cavities. Its size is less than 10 nm. These are used for long circulatory, controlled delivery of bioactive material, targeted delivery of bioactive particles to macrophages and liver targeted delivery. Dendrimers are spherical polymers that are normally less than 5 nm in diameter. Their key useful feature is the polymer branches that provide vast amounts of surface area to which therapeutic agents and targeting molecules could be attached. The prototypical dendrimer starts with an ammonia (NH_3) core that is reacted with acrylic acid to produce a tri-acid molecule. This molecule is then reacted with ethylene diamine to produce a tri-amine, and this is known as generation 0 (G0) products. This tri-amine is reacted with acrylic acid to produce a hexa-acid, and then reacted with ethylene diamine to produce a hexa-amine (G1), and so on. This alternation of reaction with acrylic acid then with ethylene diamine continues until the desired generation is reached. By using green nanoproducts generation of G0 and G1 phases can be avoided. Sugars or other molecules can also be used as the starting core, so long as they have multiple, identical reaction sites. Thus, it is possible to create a surface consisting of multiple amines or multiple acids, and these two kinds of surfaces provide the means of attaching different functional components. In nano medicine, dendrites had been found to be an invaluable tool in attaching fluorescent dyes, enzymes cell identification tags and other molecules because of the many molecular "hooks" present on their surface and it makes them a very important medium in target drug delivery agent in therapeutics.

- **Liposomes:**

Liposomes are spherical vesicles with an aqueous core and a vesicle shell. They contain a single or multiple bilayered membrane structure composed of natural or synthetic lipids. Depending on design, they can range in size from tens of nanometers up to micrometers in size. Green Liposomes have been widely used as pharmaceutical carriers because of their unique abilities to

(a) Encapsulate both hydrophilic and hydrophobic therapeutic agents with high efficiency,
(b) Protect the encapsulated drugs from undesired effects of external conditions,
(c) Be functionalized with specific ligands that can target specific cells, tissues, and organs of interest
(d) Be coated with inert and biocompatible polymers. such as polyethylene glycol (PEG), in turn prolonging the liposome circulation half-life in vivo, and
(e) Form desired formulations with needed composition, size, surface charge, and other properties

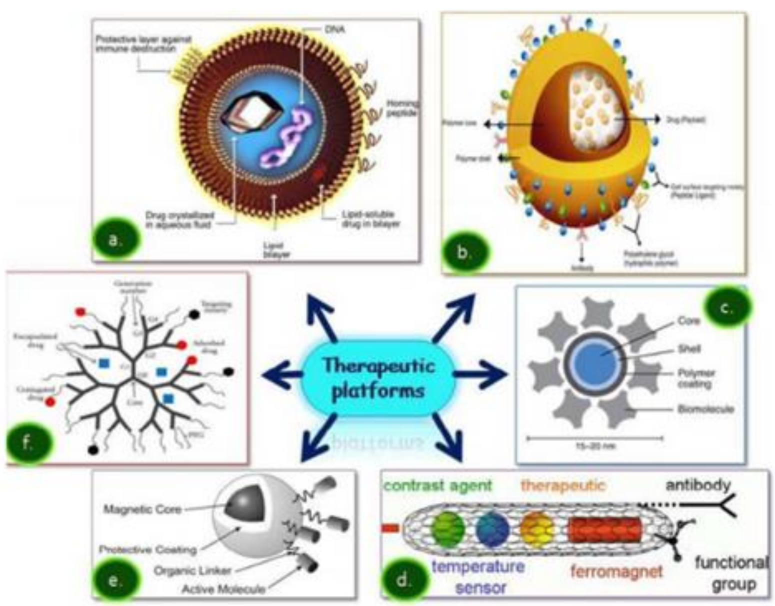

Fig 4: Schematic representation of different therapeutic tool

- **Polymer nanoparticles:**

Polymeric NPs are engineered from biocompatible and biodegradable polymers. Most of these NPs are formulated through a self-assembly process using block-copolymers consisting of two or more polymer chains with different hydrophobicity. These copolymers spontaneously assemble aqueous environment whereas the hydrophilic blocks from the

shell to stabilize the core. The resulted structure is well suited for drug delivery. By using green nanoparticles the micelles self-assembled from amphiphilic dendritic poly(glutamic acid)-β-polyphenylalanine copolymers could release the loaded drug for 60 h and efficiently inhibit the proliferation of Hepatic G2 liver cancer cells. However, the lack of specificity of the normal delivery systems can negate or significantly reduce the benefit. To this end, recent innovative approaches in design of polymer particles have leaded to targeted localization, changes in delivery kinetics, and triggered drug release. Therefore, functional or responsive systems are being pursued in order to improve local or systemic drug delivery, as the release of therapeutic compounds can now be tailored to respond to specific extrinsic stimuli such as temperature, light, pH and ultrasound.

- **Quantum dots:**

Quantum dots are frequently referred to as nano crystals. They range from 2 to 10 nm in diameter and are made of semiconductors. Quantum dots are composed of 10–50 atoms, and they confine electron-hole pairs to a discrete quantized energy level. When excited with ultraviolet light, they fluoresce in different neon colors depending on their size, which determines the energy level of the quantum dot. Larger particles emit light in the red end of the visible spectrum, whereas smaller particles emit in the blue range. Quantum dots can also be attached to various proteins and receptors to monitor with which molecules they interact and in what part of the cell they are found. Because cells are impermeable to quantum dots, they must be coated with special molecules or antibodies to facilitate their uptake by cells. This property can be exploited to devise a method that uses extracellular enzymes to modulate cellular uptake of quantum dots. Because semiconductors are poisonous heavy metals, toxicity is a huge obstacle to clinical application of quantum dots for humans. So we are using green products to avoid these heavy metal poisoning [8].

- **Carbon nanotubes:**

Carbon nanotubes are a distinct molecular form of carbon atoms. There has been tremendous enthusiasm over carbon nanotube applications in many industrial sectors, in part because they have been actively promoted as possessing the advantages of being 100 times stronger than steel with only one-sixth of its weight, and with unusual heat and conductivity properties. In the area of therapeutics, carbon nanotubes have primarily been used for transporting DNA cargoes into the cell and for thermal ablation therapy, in much the same way as the nanoshells. It has been observed oxidative stress and cellular toxicity in human epidermal keratinocytes, after 2 to 18 hours of exposure [7].

GREEN NANOMATERIALS - THERAPEUTIC USE

Current clinical diagnostics and therapeutics platforms are often limited by borderline sensitivity or efficacy levels. These limitation result from low or minimal specificity for the intended target cell or organ, span a multitude of physiological disorders and result in nominal success rates for diagnosis or treatment in many cases. Diagnosis and treatment of diseases such as cancer or viral infections require next generation medical methods. Nanotechnology has the potential to significantly address diagnostics and therapeutics sensitivity and resulting unwanted side effects by providing extremely precise reagents and tools that allow for unparalleled detection and treatment at the clinical level.

Advances in green-nanotechnology and molecular biology are rapidly enabling the development of multifunctional NPs with different specific functional properties for better disease diagnosis and therapy. Many nano synthesis processes have been developed in recent years, in an effort to produce structures that have a specific form and function relevant to a given application. The preparation of functionalized nanoparticles within a green context poses interrelated challenges in terms of maintaining product integrity (such as structure, shape and size disparity, functionality, purity and stability) while employing greener methods whenever possible. For example, control over particle size and disparity may reduce purification requirements by eliminating the need for extensive separations, while the ability to control surface functionalization, intended to enhance particle stability and dictate surface chemistry, solubility, and the degree of particle interactions, helps to better define the safety and reactivity of nanoparticles. Nano synthesis methods are being refined in such a way that they are convenient and scalable, whether it involves the direct synthesis of a functionalized material or the preparation of a versatile precursor particle whose surface properties can be easily modified to meet the demands of a given application. This is accomplished through extremely controlled nanofabrication methodologies which result in the generation of molecularly defined nano scale materials and devices that harbor known physical properties unique to each material in question and useful for particular medical applications.

NEW APPROACHES IN GREEN NANOTECHNOLOGY

Green nanotechnology heightens the environmental sustainability by enhancement in use of green nano-products because such products offer benefits over the chemically synthesized nano-products. The green nano-products are those that provide solutions to environmental challenges involving direct or indirect application at nanoscale. These nano-products are lightweight nano composites.

The Green nanoparticles synthesized via green chemical principle provides important applications to prevent waste, synthesized less hazardous chemical, renewable feedstock, reduce derivatives. Green nanotechnology not completely fits into the picture of sustainability whereas there is a need to go beyond environmental protection for sustainability. Green synthesized nanomaterials could help to alleviate major sustainability issues of climate change, renewable energy, natural resources and toxic products.

Nanotechnology has grown its importance in research field of medical chemistry. Thus, the involvement of green method of nanoparticle synthesis reports the easiest, efficient, and eco-friendly in comparison to chemical-mediated or microbe mediated synthesis[9].

OTHER APPLICATIONS

- **Solar cells:** Research is going on to use nonmaterial for purposes including more efficient solar cells, practical fuel cells, and environmental friendly batteries. The most nanotech projects related to energy are: storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving, and enhanced renewable energy sources. Solar cells are more efficient as they get tinier and solar energy is a renewable resource. The price per watt of solar energy is reduced sufficiently
- **Nano remediation and water treatment:** Nanotechnology offers nonmaterial for the treatment of surface water, ground water, waste water, and other environmental materials polluted by toxic metal ions, organic and inorganic solutes, and microorganisms.
- **Water filtration:** Nano filtration is a relatively recent membrane filtration process used in water such as surface water and fresh groundwater, with the purpose of softening and removal of disinfection by-product precursors such as natural organic matter and synthetic organic matter. Some water-treatment plants incorporating nanotechnology are made available in the market, with more in efficient. Low-cost nano separation membranes methods have been shown to be effective in potable water conversion.
- **Environmental remediation:** Nano remediation is the use of nanoparticles for environmental remediation. Nano remediation has been most widely used for groundwater treatment, with additional extensive research in waste water treatment. Nano remediation has also been tested for soil and sediment cleanup. Even more preliminary research is exploring the use of nanoparticles to remove toxic materials from gases [10].

CONCLUSION:

The development of ecofriendly drug carriers as possible through the green nanotechnology. The ultimate goal of Green Nanotechnology is to aid sustainability. While no single technology alone can ensure sustainability, newer technologies, especially nanotechnology, can proactively design out pollution, by producing useful, usable, and viable products that promote sustainable development and provide the mainstay for the future global economy. Green nanotechnology definitely be a solution to global warming and energy crises. Health hazards of humans due to use of nano products in therapeutic field also can be reduced by green nanotechnology.

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