Title : Green and sustainable technological applications in nanotechnology

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1.1 Introduction

1.1.1 Definition

Nanotechnology

The range of 1 to 100 nanometers is known as the nano scale. In its purest form, technology relates to the anticipated capacity to build things from the ground up using already available methods and equipment to create finished, high-performing products. It is the molecular engineering of functioning systems. Because it will have a profound effect on practically all industries and facets of society in its advanced form, it is frequently referred to as general purpose technology.

In 1959, famous physicist Richard Feynman initially raised the ideas that would eventually give rise to nanotechnology in his own lecture "there is plenty of room at the bottom," where he was highlighted the potential for synthesis through the straight control over atoms. "Norio Taniguchi" coined the term "nanotechnology" for the first time in 1974 (1). Consequently, the field has been researching and applying for close to 50 years now.

The capacity to view nanoscale particles has created a wide range of opportunities in a number of scientific and industrial fields. It can be used for a variety of purposes since, at its core, it is a collection of methods that enable the manipulation of attributes at a very tiny scale. It offers many benefits in a variety of industries, including the food industry, fuels, solar cells, fuel cells, sporting goods and environmental, medical (nano medicine), privacy and security (nano electronics), clothing (fabric), and environmental (e.g., water purification systems). As a result, it has many benefits, is gaining momentum, and is generating a lot of conversation. It is true that nanotechnology has enabled us to make significant contributions to the world, but there are also certain drawbacks to this technology.

One of the most exciting essential enabling technologies of the twenty-first century is nanotechnology (2).

Researchers are currently looking on how to make it more environmentally friendly. Because it emphasises on micro scale, which had to overcome to make sure and manufacture eco-friendly processes, this has been dubbed "Green Technology." By actively combating toxins and destructive processes or by changing the conditions that give rise to them, green technology reduces their effects. It is a technology that is resource-conserving and friendly, created and applied in a way that doesn't harm the environment (1).

1.1.2 Green Nanotechnology

Green technology

This one is a series of processes and materials that is always changing, ranging from ways to produce energy to non-toxic cleaning supplies. Global warming is caused by the release of harmful substances into the environment as a result of fast industrialisation and urbanization. The average world temperature has risen at the quickest rate ever seen during the previous 50 years. When they accumulate in the atmosphere, carbon dioxide and greenhouse gases as well as other air pollutants absorb sunlight that has already been reflected off the surface of the earth. Contaminants hold heat that would otherwise escape into space when they stay in the air for years or even decades, making the planet hotter than it would otherwise be. The greenhouse effect is to blame for this. When fossil fuels are burned, nitric, carbonic, and sulfuric acids are created that ultimately fall to Earth, causing acid rain, which has an impact on both the natural areas and built environment. Due to the acids' abiility to destroy calcium carbonate, marble and limestone monuments and sculptures are particularly susceptible. Additionally, radioactive materials from fossil fuels—primarily thorium and uranium —are released into the environment. Additionally, these environmental pollutions have an influence on individuals because when people breathe in the air borne fossil fuel particles, it has a detrimental effect on their health. Acute respiratory conditions, premature death, exacerbated asthma, chronic bronchitis, and diminished lung function are among these health impacts. Among the greatest examples of green technology one is the solar cell. Through the process of photovoltaics, electrical energy is directly formed from light energy by a solar cell. Solar power generation reduces pollution and greenhouse gas emissions by eliminating the need for fossil fuels. Despite the market's youth, investor interest is quite strong due to concerns about global warming and the declining availability of numerous natural resources. Future generations can also profit from it because it employs naturally replenishable materials. It can successfully alter trash output and patterns in a way that won't hurt the environment.

As a result of using green technology:

- Boosting the standard of living for people
- Life expectancy and asset value
- Decrease energy use
- Use fewer non-renewable resources.

When building structures, a green approach is used to encourage healthier, better, and conducive conditions for both the internal patrons and the environment as a whole.

1. Sustainability
2. Source Minimization
3. Creativity
4. Power
5. Green Architecture
6. Green Chemistry (1)

Green Nanotechnology

Many people consider nanoparticles to be the essential building components of nanotechnology. Numerous approaches including biological, chemical, hybrid and physical ones can be used to create them.

Green technology, in its broadest sense, refers to the production of nanoparticles using biological processes, which involves plants, microbes, viruses or their by-products, such as lipids and proteins, and various biotechnological tools. Based on a number of factors, green technology-produced nanoparticles are significantly superior to those made via chemical and physical processes.

Green methods, for instance, don't use costly chemicals, use less energy, and produce products and by-products that are good for the environment. In order to create less dangerous chemical products and byproducts chemical technologists , scientists, researchers and chemists now use the principles of green chemistry as a reference manual (1).

Green nanotechnology development and commercialization challenges :

1) For researchers in the early stages of green nanoscience discovery, there are no precise design standards.

2) New commercial manufacturing methods are needed for many green nanomaterials, which raises the demand for engineering research, coordination and fundamental research of the two between the business and research groups.

3) There is a dearth of engineers and scientists with experience in the development of green nanotechnology.

4) Toxicology and analytical practices must be created and regularly revised to take into account new scientific findings.

5) There is still uncertainties, as well as green innovations frequently face difficult regulatory hurdles than older or more traditional chemicals.

6) Since there are so few commercial-grade products that can be performance-comparisoned with traditional materials, it is unclear what the end market will demand (1).

1.2 Green Chemistry Principles Applied to Nanoscience

Nanotechnologies have developed recently from a diverse research concept to a major scientific discipline. Over the past ten years, global interest in nanotechnology has grown quickly, resulting in the creation of innovative materials, improved sensors, and nanoscale device parts . The surface structure, shape and size of nanoparticles affect a number of attributes that are well-known to be persistent in bulk materials . Several metal nanoparticles (MNPs) have been created using a variety of physical and chemical techniques . However, these methods continue to be costly and contain dangerous chemicals that pose a number of biological dangers. Consequently, increased interest in the creation of alternate, sustainable, and ecologically beneficial techniques (3).

1.2.1 Nanomaterial manufacturing

A) Bottom-up approaches

1) Vapour phase techniques

i) Aerosol based processes

Aerosol-based methods are a popular way to produce nanoparticles in industrial settings . An aerosol is a collection of particles, either solid or liquid, suspended in gaseous environments like air. Size of Particles might be as small as a molecule or as large as 100 lm. Many years before the fundamental physics and engineering of aerosols were comprehended, their usage was known. Examples include the use of titania particles and carbon black as reinforcements in the manufacture of plastics and paints respectively. Another illustration is flame pyrolysis, which produces fumed titania and silica from respective tetra chlorides.

ii) Molecular or Atomic condensation (gas condensation)

The vacuum chamber, the gas condensation system's primary components which has a heating component, vaporising the metal that needs to be done, equipment for gathering pumping system and powder. An adequate temperature must be reached before heating a bulk substance (much below the boiling temperature but well above the melting point) inside of that is targeted at a chamber with either an that is targeted at a chamber with either an inert gas environment or a reactive gas atmosphere or inert gas environment. While the gas pressure is low enough to permit spherical particle formation, it is powerful enough to promote particle synthesis. Due to the metal atoms' interaction with the gas molecules, which caused their rapid cooling, nanoparticles were first formed through nucleation.

iii) Arc discharge generation

Using an energy source as electric arc is another way to vaporize metals. This method relies on charging two electrodes made of the target metal while they are in contact with an inert gas. Up until the breakdown voltage is attained, a significant current is applied. A little amount of metal from one electrode to the other is vaporized as a result of the arc formed across the two electrodes. This process yields extremely few metal nanoparticles, yet it is distinguished by a high degree of repeatability.

iv) Plasma process

The two types of plasma processes are microwave plasma process and plasma spray synthesis. Particles carrying electric charges that originate in the plasma zone are used in the microwave plasma process. As a result, the advantages of the charged particles can reduce aggregation and coagulation.

The creation of nanoparticles can be done using the plasma spray synthesis technique even outside. The collection of the created nanoparticles is difficult due to the extraordinarily high flow velocity of the nanoparticles .

v) Chemical vapor deposition

In order to deposit a thin solid coating onto the substrate, a chemical interaction between a gaseous precursor and substrate surface is activated in a process known as chemical vapour deposition (CVD). Thermally enhanced chemical vapour deposition (PECVD), which dramatically lowers the process temperature when compared to thermal CVD, can activate materials by increasing temperatures. Due to its low setup costs, high production yield, and simplicity of scaling up, this method is a commonly utilized materials processing technology.

2) Liquid phase techniques

i) Sol-gel

The creation of colloidal nanoparticles from liquid phase using The sol to gel method is a widely used industrial procedure. A chemical procedure called the "sol-gel process" is hydrolysis or condensation processes based. Particles that are nanoscale precipitate with the right ratio of reactants. The use of sol-gel methods has various benefits, including quick shape and embedding, flexibility, and low processing temperatures.

ii) Solvothermal method

For the manufacture of both crystalline non-oxide and oxide containing materials, the solvothermal approach is suitable. This technique can be used to create crystalline solids, such as non-oxide or oxide nanoparticles and silicate materials with high porosity like zeolites . Non-oxide nanomaterials such as semiconductors (such as GaN), carbides, diamonds, carbon nanotubes , as well as phosphides, borides, nitrides, chalcogenides examples that can be created by the solvothermal process

iii) Sonochemical method

The application of chemicals causes molecules to go through chemical reactions strong ultrasonic radiation in the area of study known as sonochemistry. The main mechanism underlying the sonochemical reaction is acoustic cavitation, which involves the formation, expansion, and collapse of bubbles in a liquid exposed to ultrasound.

B) Top-down approaches

1) Solid phase techniques

i) Mechanical attrition (milling/mechanochemical processing)

Since its development as an industrial process in 1970, mechanical attrition (MA) has been used to create new alloys and phase combinations from powder particles. The quantity restrictions for nanocrystalline preparation can be circumvented by this technology, allowing for the mass production of nanocrystalline powders. Additionally, it provides a variety of approaches for creating nanostructured powders with a variety of topologies, including crystalline/crystalline or crystalline/amorphous and atomic bonding with metal/metal, metal/semiconductor, metal/ceramic, etc. This method allows for the creation of complex materials with particular interface-boundary or grain patterns. Because it is usually difficult to distinguish a glassy structure from a nano-crystalline structure, research is concentrated on nanocrystalline nanomaterials that have grain or interphase barriers between the nanophase domains .

Two different processes for making nanopowder have been developed as a result of mechanical milling. In the first, while milling a single phase powder, the fracture and cold welding points must be balanced.

As a result, Mechanochemical Processing, which employs the second approach of mechanical attrition, is a ground-breaking, affordable method of producing a range of nanopowders (4) .

1.2.2 Plant-mediated Green Nanomaterial Synthesis and its Use

Due to its rapid expansion, single-step technique, non-pathogenic character, eco-friendliness and cost-effective protocol for the synthesis of NPs, the utilization of plants and plant extracts in "green synthesis" has grabbed interest (5) Researchers' attention has recently been drawn to the creation of effective green chemistry techniques for the synthesis of MNPs utilizing extracts of plant for the reasons listed

- Chemical reduction processes used to create nanoparticles (such as DMF, sodium borohydride, ethylene glycol and hydrazine hydrate) may result in dangerous chemicals compounds to adhere to the surfaces of the particles, raising concerns about toxicity. As a viable alternative to chemical processes and physical techniques, the biological synthesis of metal nanoparticles using plants (living plant, plant extracts and inactivated plant tissue) has drawn considerable attention.

Green chemistry, or the production of metal nanoparticles by biosynthesis, avoids the use of harmful, toxic and expensive chemicals. Materials for plants are easily accessible. Plant diversity offers a wide range of species that may one day be used for quick, one-step protocols connected to the fundamentals of green chemistry. Compared to microbes, plants make nanoparticles that are more stable and synthesize them at a faster rate. Using plant extracts to create metal nanoparticles is very affordable, making it a viable and cost-effective alternative for mass production.Plant extracts may function in NP production as capping and reducing agents.The manufacturing of NPs and stability of those NPs are accelerated by the presence of a wide variety of biomolecules in plant extracts.These techniques do not necessitate high temperatures, pressures, or energy levels. A solvent that can be utilized is water (3).

Sr no	*Year*	*Author*	*Formulation*	*Source*	*Findings*	*Ref*
1	2003	Shankar et al	Ag-nps	Geranium leaf extract	Stable formulation having particle size 40 nm	(7)
2	2009	Kasthuri et al	Ag-nps	Apiin leaf extract as	Particles size 21–39 nm in diameter	(8)

				reducing and capping agent		
3	2010	Dwivedi and Gopal	Ag-nps	Chenopodium album	Size 10–30 nm	(10)
4	2012	Ahmad and Sharma	Ag-nps	Ananas comosus (pineapple juice)	Spherical nps with an average diameter of 12 nm	(13)
5	2012	Gavhane et al	Ag-nps	Extract of Neem and Triphala	Spherical particles size range of 43 nm and 59 nm.	
6	2012	Rout et al	Ag-nps	Ocimum sanctum leaf extract as stabilizing agent	Spherical-shaped Ag-nps	(14)
7	2014	Murugan et al	Ag-nps	Acacia leucophloea extract	Size range upto 38–72 nm	(17)
8	2014	Arokiyaraj et al	Ag-nps	Chrysanthemum indicum. L	17–29 nm	(18)
9	2015	Velmurugan et al	Ag-nps	Peanut shell extract	Nps were mostly spherical and oval in shape with an average diameter up to 10–50 nm	(19)
10	2015	Ashokkumar et al	Ag-nps	Extract of Abutilon indicum a	High antimicrobial activity against S. Typhi, E. Coli, S. Aureus, and B. Subtilis microorganism	(21)

1.2.3 Nano contact sensors

A nanosensor is a sensor that is constructed on the nanoscale, and its major function is to collect data at the atomic level and convert it to data that can be easily examined. A chemical or physical sensor built with nanoscale components, typically microscopic or sub microscopic in size, can also be described as these devices. These sensors are incredibly sensitive and may pick up even the smallest amounts of potentially dangerous substances, such as single virus particles. Ion detectors built on silicon nanowires are one type of level sensor. Silicon becomes extremely flexible and mechanically durable when it is micromachined to a nanoscale thickness. On a micron-sized device, an array of nanowires can be designed, producing extremely high ionic sensitivity in a condensed space. Due to the device's extremely high surface to volume ratio, the nanowire is exceedingly sensitive to ionic concentration (22).

Quantum dots

The typical composition of QDs is MX, where M is typically zinc (Zn) or cadmium (Cd), and X is tellurium (Te), sulphur (S) or selenium (Se). To make QDs with highly tuned qualities, a second MX alloy, called the shell, is frequently coated on top of the QDs

QDs make good optical transducers because of their distinctively narrow fluorescence emission bands and large absorption bands. In addition, Quantum dots emission wavelengths can be easily modified by altering the QD's size, shape, or composition. Quantum dots are therefore perfect for multiplex detection of various different analytes. Because QDs have a wide range of shapes, sizes, and chemical compositions, they can be excited by a single energy source.

Metal and metal oxide nanoparticles

Noble metal nanoparticles have been widely used in a variety of sensor applications due to their versatility in shape production, high extinction coefficient (>31011 M1 cm1), and ease of surface functionalization.

Carbon-based nanomaterials

In nano-enabled sensors, carbon nanotubes and graphene are frequently used due to their substantial surface area, mechanical strength, high thermal conductivity and superior electrical conductivity (23) .

1.2.4 Nanomaterials for wastewater treatment

Sources of wastewater

Residential and non-residential sources make up the two primary categories of wastewater sources. Public dwellings release residential effluent, sometimes known as sewage, which has been heavily diluted. The remaining 0.10% of sewage is made up of inorganic solids, dissolved organic compounds, biodegradable, nutrients, suspended solids, metals and pathogenic microorganisms. Sewage is composed of 99.90% water.5

Application of Nanotechnology in Water and Wastewater Treatment

Membranes used in water treatment are made using nanotechnology. Theron et al. (2008) recently reported the creation of the following nanomaterial-based water filtration membranes. Nano reactive membranes made of metal nanoparticles and other nanomaterials and nanostructured membranes made of nanomaterials like carbon nanotubes, nanoparticles, and dendrimers.

Adsorption, on the other hand, is viewed as an effective, efficient, and cost-effective way to eliminate water pollutants . Adsorbents that work well include:

i) activated carbon,

ii) clay minerals and silicas

iii) zeolites

iv) metal oxides, and

v) modified composites

TiO2-mediated photocatalyst-mediated water disinfection and organic compound degradation are becoming more and more popular due to the efficiency of the photocatalyst as shown by several scientific investigations . The world's food security will ultimately depend on how effectively nanotechnology is used for water remediation.

Nanomaterials and membrane filtration

Membrane filtration (NF, MF, RO and UF) has been crucial in lowering pollutants and generating high-quality, clean water because of coagulation, flocculation, sedimentation, and activated carbon each remove a specific range of water pollutants. The creation of ceramic and polymeric membranes has improved the use of membranes over the past twenty years. However, membrane fouling is a significant flaw in the membrane filtration procedure and a significant issue that calls into question the practicality of using membrane. According to Cohen (2006), structuring membrane surfaces at the molecular and nanoscale is a viable strategy for enhancing membrane performance while reducing fouling. As "molecular sieve materials," porous carbons have enormous promise for adsorption and membrane synthesis for water filtration. Srivastava et al. created carbon nanotube-based water filters . The poliovirus sabin 1 and bacterial pathogens Staphylococcus aureus and Escherichia coli were successfully removed from contaminated water using those reusable filters. Linder and Oren were able to manipulate the nanofiltration membranes nano- structure to create a surface with salt rejection selectivity . Membranes that reject more than 70% of NaCl and fewer than 40% of $CaCl_2$ were created in a single solution. To preserve the Na to Ca ratio at the ideal level for agricultural use and to reduce membrane fouling by calcium sulphate or carbonate salts, it is crucial to choose monovalent or divalent cations carefully. Wegmann et al. modified the nanostructure surface of microporous ceramics using a similar method to achieve effective virus filtration. The process involved applying a hydrated trium oxide colloidal nanodispersion to the interior surface area of highly porous materials. The surface was then heated to create an electropositive Y_2O_3 coating. From feed water with a pH in range 5-9, modified nanostructure filters were able to exclude 99.99% of 25 nm diameter MS2 bacteriophages. Water treatment businesses are already promoting water filtration membranes made of nanoparticles.

Nanowire membranes ranged in thickness from 20 to 100 nm and were flexible. It has good antifouling properties and shown comparable photocatalytic activity to P-25 for the breakdown of humic acid in water. Zhang et al (2008). Several researchers investigated composite photocatalytic membranes, which combine the membrane process' separation technology with catalysts' photocatalytic activity. When photocatalysis is combined with membrane separation,

TiO_2/Al_2O_3 composite membranes made by extrusion and sol-gel/slip casting successfully degraded Direct Black168 dye (82% elimination). Similar to Yang and Li (2008), who successfully created inside-out tubular TiO_2/Al_2O_3 composite membranes using the extrusion method and the sol-gel/slip casting method (24).

1.2.5 Nanocatalysis or photocatalysis

Nanocatalysts

Nanocatalysts are frequently utilized in the treatment of water because of their and ability to increase surface catalytic activity, shape-dependent properties, very high surface-to-mass ratio, halogenated herbicides, azo dyes, polychlorinated biphenyls, pesticides and nitro aromatics are only a few examples of environmental toxins that they help degrade better. For several pollutants, the catalytic activities have been demonstrated on a large scale. According to studies, N-doped TiO_2 and ZrO_2 NPs are extremely effective silver nanocatalysts for degrading microbial pollutants found in water. Excellent photocatalytic activity, hydrophilicity, cost-effectiveness and reduced human toxicity, increased chemical stability are all displayed by nanoTiO_2 (25).

Nanocatalysis

The control and determination of functional qualities are the main demands of nanoscience; current catalysis research does not satisfy these demands. The creation and functional characterisation of "nanocatalysts" are extremely unpredictable and subject to large fluctuations in the pertinent properties . Zeolites are a notable exception, at least in the mesoscopic size regime, to the generally poor state of multiscale mastery in catalyst creation. If the word "nanocatalysis" is taken to mean a vision in which one might regard a catalyst to be a hierarchical system of fundamental structural units (active sites) with defined assembling procedures for various length scales, the title question may be answered. As a result of interactions between the catalyst and the reactant as well as the reactor, dynamic functional materials are produced.

Thus, nanocatalysis is the study of the synthesis, in situ characterisation, and control of the kinetics of chemical reactions involving supramolecular materials. The materials are expressly constructed over length scales greater than that of a single active site, which distinguishes it from conventional catalysis. In this manner, a synthetic reality is created out of the physical chemistry information regarding the multidimensionality of catalysts . In situ characterisation has a different role in nanocatalysis than the commonly performed work of locating active areas in a specific system. It is employed in the current setting to assess synthetic techniques; it examines the catalyst's genesis and determines its dynamic character. Instead of evaluating whole libraries under a single set of conditions, nanocatalysts require functional characterization using kinetic experiments that investigate the parameter space of sustained operation for each material individually. This is how empirical catalyst optimization is now conducted. High-throughput kinetic testing may be appropriate if the testing procedures and the apparatus allow for the investigation of different parameter spaces and are not solely designed to increase sample throughput (27).

Metal Oxide and Metal Sulfide Photocatalysts

Other metal oxide and metal sulphide nanomaterials have been used as photocatalysts for the breakdown of organic pollutants, including ZnO, Fe2O3, CdS, and ZnSn. Several techniques, including ball milling, hydrothermal treatment, chemical bath deposition, and the sol-gel method, have been used to create those nanomaterials.

Particle size was found to depend on milling duration and heat treatment temperature by Ao et al and Shen et al. While it rose at higher heat treatment temperatures, particle size dropped as milling time was increased. Much study has been devoted to controlling the shape of materials in order to optimize the photocatalytic activity of ZnO and enhance its physical and chemical properties. Nanowire, nanorods, nanotubes, and nanodisks are only a few examples of the various nanostructured ZnO nanomaterials that have been created.

To increase the photocatalytic reactivity, ZnO nanodisks, nanorods, nanotubes, and have also been reported to be synthesized in addition to nanowires.

Zn nanowires were thermally oxidized by Lu et al. to produce ZnO nanotubes.

Zn nanowires were initially formed on Si substrates in the furnace chamber, where they were subsequently oxidized at various temperatures between 400 and 700 °C while being held under 20 Pa of pressure. Well-defined, crack-free ZnO nanotubes with an outer diameter of 60 to 130 nm and a surface area of 30.7 m2 g-1 BET were created at a temperature of 400 °C.

In a dimethyl sulfoxide (DMSO)-H2O system, Zhai et al. revealed the chemical hydrolysis approach used to create hierarchical ZnO nanodisks.

90% DMSO was used to create nanodisks that were uniformly between 200 and 300 nm in size. Numerous nanocrystallines measuring 20–40 nm made up the nanodisks. With 60, 70, and 80% DMSO, respectively, hexagonal nanorings, and microtyres (1.1 m in diameter) were produced. Nanodisks, nanorings, nanoparticles, and microtyres all had BET surface areas of 37.3, 21.9, 26.1, and 12.8, respectively.

The pH of the solution had an impact on particle size and form. The creation of hematite through thermal dehydration was described by Zhou et al . By heating -FeOOH precursors at 300 °C in air for 1 hour, 40 nm long, 11 nm wide, and 93 m2 g-1 BET surface area of -Fe2O3 nanorods were produced.

ZnS has a comparatively large bandgap (3.6 eV) in comparison to CdS, which is a restriction on using the solar spectrum's visible light region. Therefore, ZnS photocatalysts were activated using UV light sources.

In the presence of polymer, Hu et al. used a solution-phase thermal deposition method to create ZnS nanoporous nanoparticles (N-vinyl-2-pyrrolidone).

Monodisperse spherical nanoparticles with a substantial BET surface area (156.1 m2 g-1) and diameters of 60 nm were produced. ZnS microspheres made of intertwined nanosheets were created by hydrothermal processes employing NaOH by Ren et al (26),(27)

1.2.6 Nanofiltration for Water Purification

Nanofiltration

Due to the rapid population expansion, protracted droughts, and rapidly increasing needs, the scarcity of clean water poses a significant concern in the upcoming decade. The most promising potential remedy for the water resources dilemma may be low cost, highly effective nanofiltration. Due to its low energy cost and straightforward operational process, nanofiltration technology is now widely used in the treatment of waste water and drinking water. In this process, the characteristics of nanofiltration membranes (NFMs) are crucial The majority of polymeric NFMs generally offer advantages like flexibility, a straightforward fabrication method, and a low cost, but they also have drawbacks like poor chemical resistance, a short lifespan, and membrane fouling. In contrast, inorganic ceramic NFMs have advantages such as high strength, long lifetime, and solvent resistance, but disadvantages such as a difficult manufacturing process, brittleness and high cost . Therefore, the ideal NFM would be created via a straightforward solution-based polymeric NFM-like technique while combining the best qualities of both membranes.

Expriementations

Hinds and coworkers discovered significant water flux, about 4 orders of magnitude more than conventional hydrodynamic flow prediction, when they experimentally evaluated mass transport via aligned multiwalled CNT membranes with pore diameters of around 7 nm. A number of studies have looked into the usage of membranes made of vertically aligned CNTs for filtration and separation purposes . Aligned CNT membranes unquestionably serve as a fundamental paradigm for research in nanofluidics, which focuses on the behaviour of liquid flowing constrained in nanoscale channels. The methodologies used to prepare CNT-based NFMs, however, frequently experience a number of common issues, including relatively high CNT costs, a lengthy and challenging process to obtain a high density of vertically-aligned CNTs, and challenges to attaining large-scale production. In addition to 1D CNTs, the recently discovered 2D graphene, an atomic layer of graphite, also has better flexibility and solution processibility in addition to remarkable chemical and thermal stabilities.

One of the hardest problems the world faces is a sustainable and inexpensive supply of clean, safe, and enough water. One of the most affordable and extensively used technologies for water purification is membrane separation technology. Since 1980, polymeric membranes have dominated the market, particularly thin-film composite (TFC) and cellulose-based (CA) membranes. The study discoveries and consistent advancement in the development of inorganic membranes have grown quickly and answer certain remaining issues, despite the arduous nature of further polymeric membrane development for improved performance. In addition to traditional ceramic metal oxide membranes, membranes made of graphene oxide (GO), carbon nanotubes (CNTs), and mixed matrix materials (MMMs) have attracted a lot of interest because of their advantageous characteristics, including tunable pore structure, excellent chemical, mechanical, and thermal tolerance, good salt rejection, and/or high water permeability. Modern reverse osmosis (RO) and nanofiltration (NF) membranes are used to retain dissolved species such heavy metals, electrolytes, and inorganic salts in a range of aqueous solutions.

Polymeric Membranes

Due to their superior performance and inexpensive price, polymeric/organic RO (Reverse osmosis) and Nano filtration membranes have dominated the global market since 1980. Table 1 lists a few cutting-edge polymeric RO and NF membranes together with their maker, selective layer composition, operational circumstances, and purification effectiveness. Due to their exceptional performance, thin-film composite (TFC) membranes are currently the industry leaders. Important polymers used to create RO and NF membranes include piperazine, cellulose diacetate, polyamides, cellulose triacetate, cellulose acetate. Polyamide is a macromolecule that occurs both naturally and chemically. It has recurrent amide (-CO-NH-) groups. Wool, angora and silk,are a few examples of natural polyamide (28) .

1.2.7 Environmental Remediation

Applications of green nanoparticles in environmental remediation

The world is moving quickly toward progress thanks to new technology and inventions, while at the same time, legitimate concerns have been raised about the exponential increase in the exploitation of our natural resources. Researchers have recently expressed a strong interest in using nanotechnology for environmental cleanup. The efficacy of nanoparticles in environmental cleanup is boosted by their higher affinity towards pollutants, greater reactivity, and ease of disposal. It is clear from the literature that green production of nanoparticles has two functions. By removing harmful precursors and poisonous by-products, it first offers a clean, non-toxic, environmentally acceptable method of producing nanoparticles, and second, it serves as an efficient and long-lasting method of environmental rehabilitation .

Chemical reactions, absorption, photocatalysis, Adsorption and filtration are a few of the technologies that are commonly used in environmental remediation to remove contaminants from various environmental media. Given that they have a high surface area-to-volume ratio, which frequently leads to higher reactivity, nanotechnology-based materials are especially well suited for such processes due to their improved properties and effectiveness. It is discussed how numerous environmental contaminants, including volatile organic compounds, organophosphorus compounds, chlorinated organic compounds, heavy metals, dyes and halogenated herbicides can be remedied using inorganic, polymeric-based and carbon-based nanomaterials. The materials and their uses are heavily highlighted in a number of recent examples (29).

1.3 Green nanotechnology's constraints

Greater attempts are being made as the technology is developed to establish ways to evaluate or measure the impact of nanotechnology on particular policy goals like green growth. This is a really difficult task. It is important to weigh the dangers of adopting new green nanotechnologies against the risks of using existing technologies as well as the costs to people and the environment of not properly solving major global concerns (3).

The field of green nanotechnology is still in its infancy and faces a number of obstacles. The ACS Green Chemistry Institute's report lists the following as the major obstacles facing green nanotechnologies:

Regulatory rules for nanomanufacturing

technical and financial constraints

handling of toxicity-related nanomaterial challenges

Implementing scale-up techniques

Life cycle analysis

Other limitations are

1) Expensive implementation.
2) Information Deficit
3) There are no known substitute chemicals or raw materials
4) Uncertainty regarding effects on performance
5) A shortage of talent and resources (3)

For environmentally friendly and sustainable development, the aforementioned ideas should be carefully studied. Green nanotechnology produces environmentally benign and pollution-reduction products, however the main drawbacks are the expenses and dangers involved in manufacturing nano-based goods. The level of sustainability for greener applications of nanotechnology is a constant worry, notwithstanding advancements in its development. Although the products created by green nanotechnologies are effective, the upstream processing of the products is the main cause for concern. The creation and use of greener nanoproducts are now the subject of research, although there aren't many products that have hit the market yet. The common consensus is that it will take some time before the market potential of green nanotechnology is completely understood (30).

1.4 Conclusion

Nanotechnology provides the opportunity to solve global challenges that have a substantial impact on society. Green nanotechnology, as the name suggests, serves a specific green function. Following a review of the field's accomplishments and applications, the emphasis has switched to nano-based applications, as nanotechnology provides the foundation for considering the use of green chemistry. It has been discovered through research that, despite its numerous advantages, it has significant limitations and challenges to address. Green nanotechnology has the potential to significantly contribute to addressing the green challenge as well as sustainable development. The use of life cycle thinking to examine the environmental implications of nanoproducts will be required for the sustainable development of nanotechnology. In addition, certain factors, such as the potential life cycle assessment of freshly synthesized nano-products via nanomanufacturing before commercial release, must be treated carefully in order to access the contribution to green growth. The application of green chemistry principles to nanotechnology aids in the identification of better products and processes, although there is always room for improvement.

References

1. An Overview on Role of Nanotechnology in Green and Clean Technology [Internet]. Available from: www.austinpublishinggroup.com
2. Pokrajac L, Abbas A, Chrzanowski W, Dias GM, Eggleton BJ, Maguire S, et al. Nanotechnology for a Sustainable Future: Addressing Global Challenges with the International Network4Sustainable Nanotechnology. ACS Nano. 2021 Dec 28;15(12):18608–23.
3. Nasrollahzadeh M, Atarod M, Sajjadi M, Sajadi SM, Issaabadi Z. Plant-Mediated Green Synthesis of Nanostructures: Mechanisms, Characterization, and Applications. In: Interface Science and Technology. Elsevier B.V.; 2019. p. 199–322.
4. Charitidis CA, Georgiou P, Koklioti MA, Trompeta AF, Markakis V. Manufacturing nanomaterials: From research to industry. Vol. 1, Manufacturing Review. EDP Sciences; 2014.
5. Rafique M, Sadaf I, Rafique MS, Tahir MB. A review on green synthesis of silver nanoparticles and their applications. Vol. 45, Artificial Cells, Nanomedicine and Biotechnology. Taylor and Francis Ltd.; 2017. p. 1272–91.
6. Gardea-Torresdey JL, Gomez E, Peralta-Videa JR, Parsons JG, Troiani H, Jose-Yacaman M. Alfalfa sprouts: A natural source for the synthesis of silver nanoparticles. Langmuir. 2003 Feb 18;19(4):1357–61.
7. Shankar SS, Ahmad A, Sastry M. Geranium Leaf Assisted Biosynthesis of Silver Nanoparticles. Biotechnol Prog. 2003 Nov;19(6):1627–31.
8. Kasthuri J, Veerapandian S, Rajendiran N. Biological synthesis of silver and gold nanoparticles using apiin as reducing agent. Colloids Surf B Biointerfaces. 2009 Jan 1;68(1):55–60.
9. Krishnaraj C, Jagan EG, Rajasekar S, Selvakumar P, Kalaichelvan PT, Mohan N. Synthesis of silver nanoparticles using Acalypha indica leaf extracts and its antibacterial activity against water borne pathogens. Colloids Surf B Biointerfaces. 2010 Mar 1;76(1):50–6.

10. Dwivedi AD, Gopal K. Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract. Colloids Surf A Physicochem Eng Asp. 2010;369(1–3):27–33.

11. Kaviya S, Santhanalakshmi J, Viswanathan B. Green synthesis of silver nanoparticles using Polyalthia longifolia leaf extract along with D-sorbitol: Study of antibacterial activity. Journal of Nanotechnology. Hindawi Limited; 2011.

12. Udayasoorian C, Kumar KV, Jayabalakrishnan RM. EXTRACELLULAR SYNTHESIS OF SILVER NANOPARTICLES USING LEAF EXTRACT OF CASSIA AURICULATA. Vol. 6, Digest Journal of Nanomaterials and Biostructures.

13. Ahmad N, Sharma S. Green Synthesis of Silver Nanoparticles Using Extracts of <i>Ananas comosus</i> Green and Sustainable Chemistry. 2012;02(04):141–7.

14. Rout Y. Green synthesis of silver nanoparticles using Ocimum sanctum (Tulashi) and study of their antibacterial and antifungal activities. J Microbiol Antimicrob. 2012 Nov 30;4(6):103–9.

15. Nakkala JR, Mata R, Gupta AK, Sadras SR. Biological activities of green silver nanoparticles synthesized with Acorous calamus rhizome extract. Eur J Med Chem. 2014 Oct 6;85:784–94.

16. Kumar DA, Palanichamy V, Roopan SM. Green synthesis of silver nanoparticles using Alternanthera dentata leaf extract at room temperature and their antimicrobial activity. Spectrochim Acta A Mol Biomol Spectrosc. 2014 Jun 5;127:168–71.

17. Murugan K, Senthilkumar B, Senbagam D, Al-Sohaibani S. Biosynthesis of silver nanoparticles using Acacia leucophloea extract and their antibacterial activity. Int J Nanomedicine. 2014 Mar 15;9(1):2431–8.

18. Arokiyaraj S, Arasu MV, Vincent S, Prakash NU, Choi SH, Oh YK, et al. Rapid green synthesis of silver nanoparticles from chrysanthemum indicum land its antibacterial and cytotoxic effects: An in vitro study. Int J Nanomedicine. 2014 Jan 7;9(1):379–88.

19. Velmurugan P, Sivakumar S, Young-Chae S, Seong-Ho J, Pyoung-In Y, Jeong-Min S, et al. Synthesis and characterization comparison of peanut shell extract silver nanoparticles with commercial silver nanoparticles and their antifungal activity. Journal of Industrial and Engineering Chemistry. 2015 Nov 25;31:51–4.

20. Yousef H. Nobl charact its an. 13(45):pp. Available from: http://www.acullLength

21. Ashokkumar S, Ravi S, Kathiravan V, Velmurugan S. Synthesis of silver nanoparticles using A. indicum leaf extract and their antibacterial activity. Spectrochim Acta A Mol Biomol Spectrosc. 2015 Jan 5;134:34–9.

22. Chapman D, Trybula W, Fellow I, Fellow S. Meeting the Challenges of Oilfield Exploration Using Intelligent Micro and Nano-Scale Sensors. 2012.

23. Willner MR, Vikesland PJ. Nanomaterial enabled sensors for environmental contaminants Prof Ueli Aebi, Prof Peter Gehr. Vol. 16, Journal of Nanobiotechnology. BioMed Central Ltd.; 2018.

24. Saliby IJ el, Shon HK, Kandasamy J, Vigneswaran S. NANOTECHNOLOGY FOR WASTEWATER TREATMENT: IN BRIEF.

25. Patanjali P, Singh R, Kumar A, Chaudhary P. Nanotechnology for water treatment: A green approach. In: Green Synthesis, Characterization and Applications of Nanoparticles. Elsevier; 2019. p. 485–512.

26. Han C, Andersen J, Pillai SC, Fagan R, Falaras P, Byrne JA, et al. Chapter green nanotechnology: Development of nanomaterials for environmental and energy applications. ACS Symposium Series. 2013 Apr 14;1124:201–29.

27. Khataee AR, Kasiri MB, Alidokht L. Application of response surface methodology in the optimization of photocatalytic removal of environmental pollutants using nanocatalysts. Vol. 32, Environmental Technology. Taylor and Francis Ltd.; 2011. p. 1669–84.

28. Yang Z, Zhou Y, Feng Z, Rui X, Zhang T, Zhang Z. A review on reverse osmosis and nanofiltration membranes for water purification. Vol. 11, Polymers. MDPI AG; 2019.

29. Guerra FD, Attia MF, Whitehead DC, Alexis F. Nanotechnology for environmental remediation: Materials and applications. Vol. 23, Molecules. MDPI AG; 2018.

30. Khan SH. Green Nanotechnology for the Environment and Sustainable Development. In 2020. p. 13–46.