A Novel Approach in Synthesis of Nano particles

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1.1 Introduction

Nanotechnology and nano science is an ever growing field that covers the basic understanding of physical, chemical and biological properties in atomic and sub-atomic levels with potential application in fields ranging from electronics to cosmetics. Generally, Nano technology talks about the plan, creation and use of materials at molecular, atomic and macro molecular level and to produce nano sized materials. The word nano is derived from Greek word which defines small/dwarf and its size is about 10^9 metres. These nanoparticles have high surface area and high friction of surface atoms while compared to bulk surface compounds. The nanoparticles exhibit unique physical, chemical and biological properties at nano scale compared to their respective particles at higher scales. This phenomenon have wide range of applications due to a relatively larger surface area to the volume, increased reactivity or stability in a chemical process, enhanced mechanical strength, etc.

The Nanotechnology field has emerged as one of most active researches in modern material science. In science and technology, the nanotechnology is a fast-growing field with their applications in which this technology manufactures the new materials in level of nanoscale. So, by considering this material size and applications these nano materials are also called as wonder of modern science.

The exact history of the utilization of nano sized objects by humans is difficult to clarify. However, the history of nano material utilization is ancient, and human beings used these materials a long time ago for various applications, unknowingly. About 4500 years ago, humans exploited asbestos nano fibers to reinforce ceramic mixtures. The ancient

Egyptians were familiar with PbS nanoparticles about 4000 years ago and used them in an ancient hair-dyeing formula.

Currently, nanomaterials find commercial roles in scratch-free paints, surface coatings, electronics, cosmetics, environmental remediation, sports equipment, sensors, and energy storage devices. Nanotechnology is the key for a clean and sustainable future.

1.2 Classification of Nano particles:

The classification of Nano particles based on following sources clearly represented in Fig. 1.

- Origin
- Dimension
- Structure

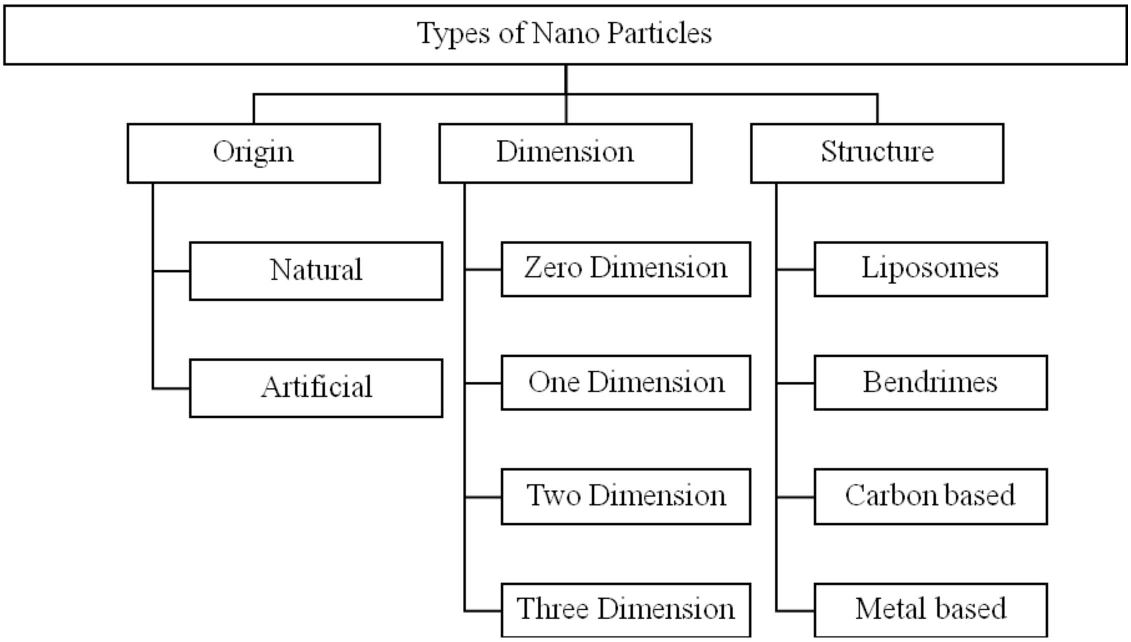

Fig. 1: Classification of nanoparticles based on different sources

1.2.1 Based on Origin:

Nanoparticles can also be divided according to their composition, meaning according to the material from which they are produced. These include in particular organic, inorganic, and carbon-based nanoparticles Carbon-based nanoparticles consist only of carbon atoms and have different morphologies.

Nano Particles which are synthesized from extract of nature such as plants are known as Natural nano particles or organic nanoparticles and which are originated from artificial extracts are known as Artificial nano particles or Inorganic nanoparticles. Artificial Nano Particles are applied in manufacturing of Carbon Nano Tubes, quantum dots, nano shells, metal nano particles like nano rods, and Nano membrane. Nano membrane is used in Reverse Osmosis in water treatment and on other hand organic / natural nanoparticles manufacture particles like liposomes, hydrogels, micelles, etc.[1] Classification of nanoparticles based on origin is evidently represented in Fig.2.

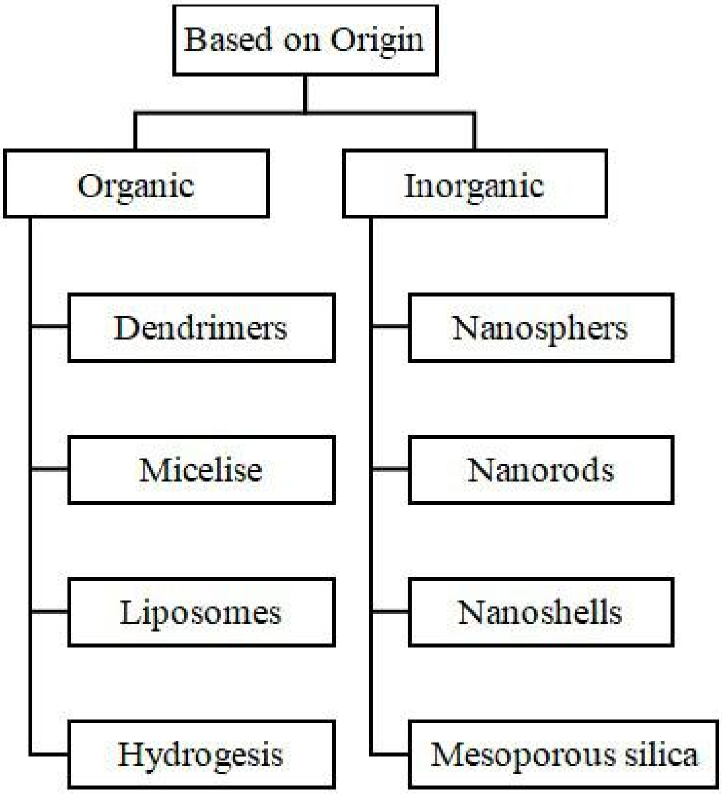

Fig. 2: Classification of Nanomaterials based on Origin

1.2.2 Based on Dimension:

In this type, based on dimension, different types of nanomaterials were prepared with composition like carbon, metal, semiconductor, metal oxide, polymer, lipids, etc., in which different dimension scales can be manufactured. Classification of nanoparticles based on origin is distinctly represented in Fig.3.

i. **Zero Dimension Nano Particles:**

These are of Spherical and Cubical shape and these are widely applied in areas such as Quantum dots, Rings, atomic clusters and in metal nano particles.

ii. **One Dimension Nano particles:**

These are applied in manufacturing of Nano wires, fibers and filaments, whiskers and belts, spirals and springs and Nanorods.

iii. **Two-Dimensional Nano Particles:**

These are applied in manufacturing of Particles like Nano films, Nano sheets, Nano walls, Nano discs etc.

iv. **Three-Dimensional Nano Particles:**

These are applied in manufacturing of Embedded clusters, Equiaxed crystallites, Furnace.[2] .

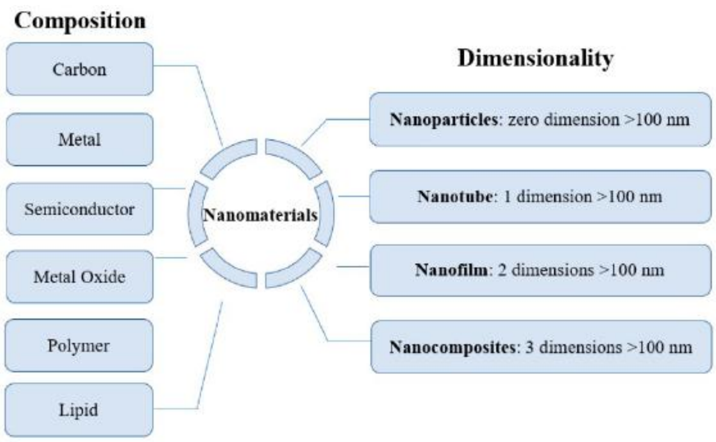

Fig. 3: Classification of Nanomaterials based on Dimension

1.2.3 Based on Structure:

i. **Liposomes:**

These are of bi-layered and lipid nano-formulations and excellent drug delivery vehicles, transporting cargo of interest within a protective, outer layer of lipids.[3] Fig.4. represents structure of liposomes and lipid nano particle.

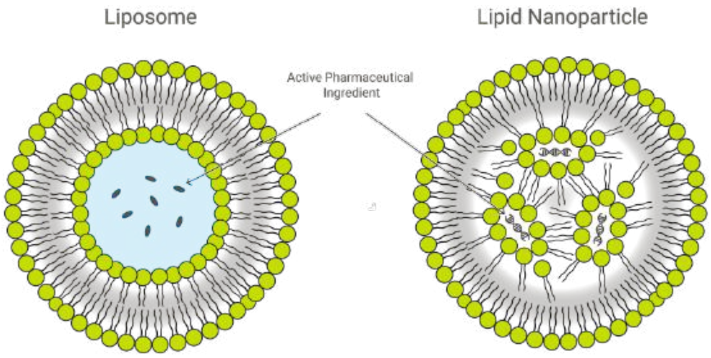

Fig.4 : Liposomes and Lipid Nano Paricle

ii. **Dendrimers:**

These are generally radially symmetric molecules with well-defined and controlled structures that has typically symmetric core, an inner and outer shell.[3] Fig.5. shows structures of dendrimers.

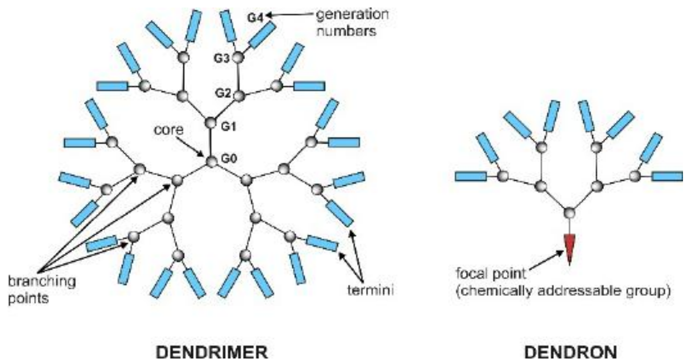

Fig. 5: Dendimer and Dendron

iii. **Carbon based:**

These are generally of hollow cage like architecture generally used in manufacturing of carbon nano tubes & fullerene and compose very unique physical and mechanical properties [3]. Structures of carbon based nanomaterials is clearly represented in Fig.6..

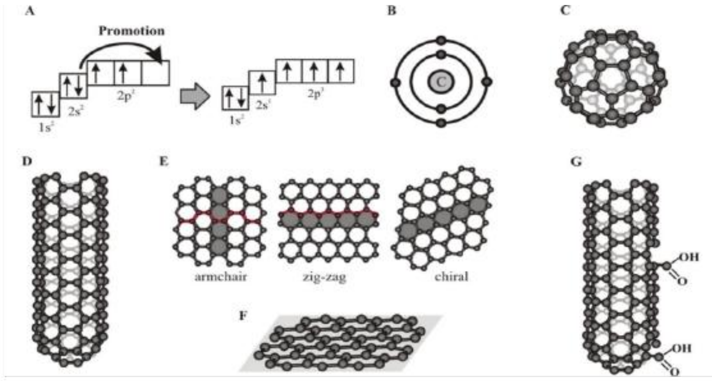

Fig. 6: Structure of carbon atom and Carbon based Nanomaterials

iv. Metal based:

These are widely used in bio medical fields, as metal ions are essential in living organisms. These have a metal core composed of inorganic metal or metal oxide that is usually covered with a shell made up of organic or inorganic material [3]. Various metal based nanomaterails are shown in Fig.7.

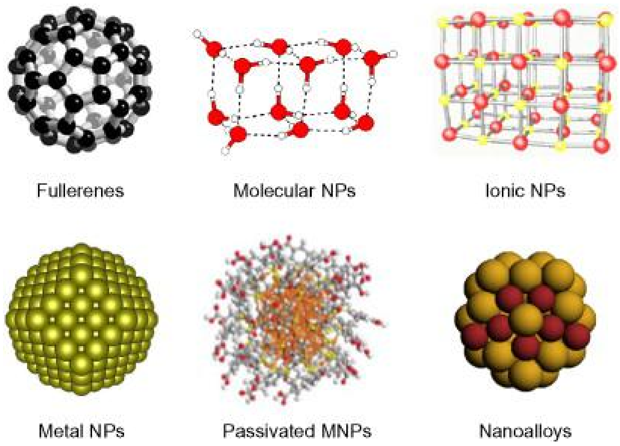

Fig. 7: Metal based Nanomaterials

1.3 Approaches for synthesis of nanomaterials:

Nano particles can be synthesized in two ways, which are Top-Down approach and Bottom-Up approach and represented Fig.8.

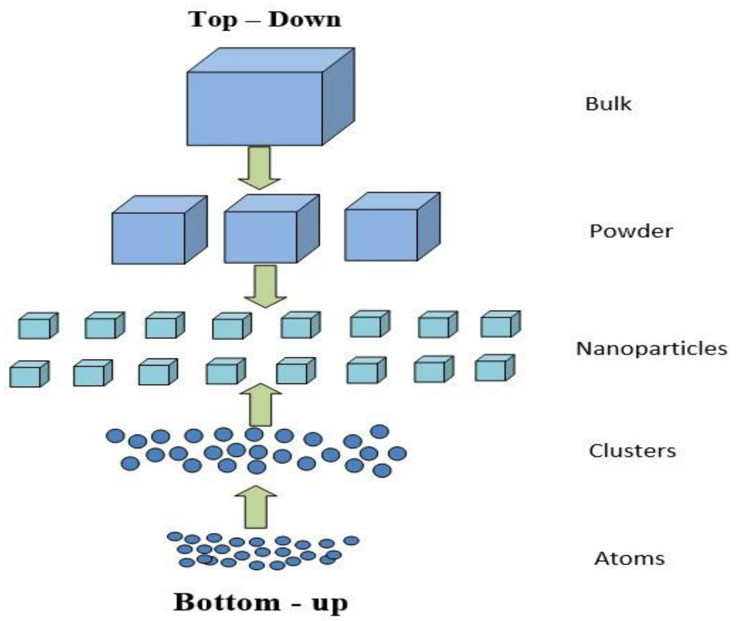

Fig. 8: Representation of Top-Down and Bottom-Up approach

Top-down or destructive method is the reduction of a bulk material to nanometric scale particles. Mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition are some of the most widely used nanoparticle synthesis methods used in Top-down approach

In Bottom-Up approach atoms will be converted into clusters form by methods like Chemical Precipitation, Solgel, Aerosol Techniques, etc and clearly shown in Fig. 9.

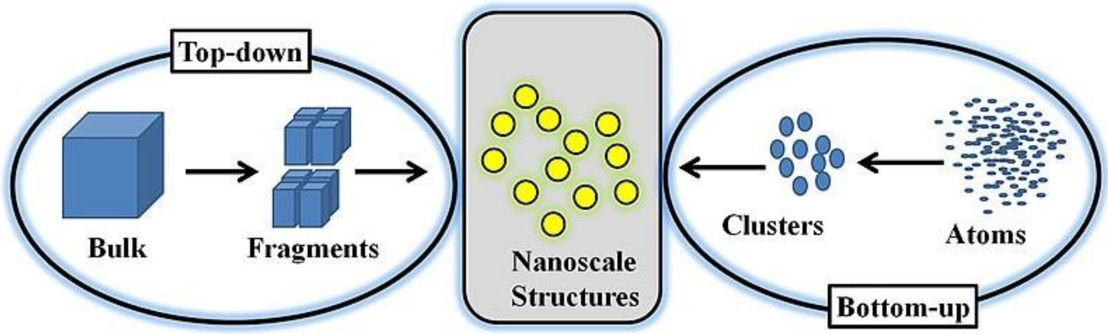

Fig. 9[I] Top-down approach　　Fig. 9[II] Bottom-up approach

2. Synthesis Methods:

There are three foremost synthetic routes can be applied to prepare nanoparticles, which are physical, chemical and biological routes, used very commonly and which are characterized in Fig.10.

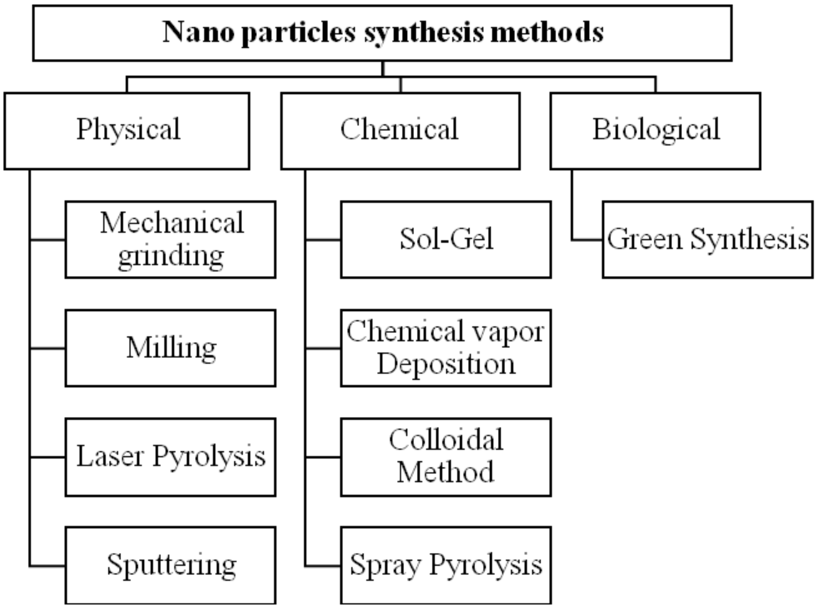

Fig.10. Classification of Nano Particle synthesis methods

2.1 Physical synthesis method:

Laser ablation and evaporation-condensation is the most commonly used physical methods to synthesize the nanoparticles. The thin films which are prepared using this method does not contain the solvent contamination and produces uniform particle size, have high purity. More over in this method the nanoparticles prepared are highly efficient. In preparation of nano particles from this method needs high energy and also the cost of equipment is very high.

Mechanical Milling and Grinding methods: Which are employed for placing the powdered mixture in the mill or by grinding, while in ball mill the powder is subjected to collisions by high-energy from balls. This has been proved that mechanical milling can successfully produce uniform and fine oxide particles. These alloying processes of grinding and milling can be done by using different apparatus such as attritor and horizontal ball mill.

Laser Pyrolysis method: Laser pyrolysis is one of the important vapor phase nanoparticle synthesis methods. In laser pyrolysis, a laser beam is used to selectively heat a gas stream containing nanoparticle precursors, such that they decompose, inducing nucleation of nanoparticles. In which a continuous wave of CO_2 laser to heat-up the reactant gases, which results in molecular decomposition for formation of vapors that initiates the nucleation and then to the growth of nanoparticles.

Sputtering method: It is an ejection method through which the micron sized particles of a material get ejected from their material surface. The sputtering is caused by the exchange of momentum between ions and atoms of the element. There are many techniques for sputtering such as radio sputtering, DC diode sputtering etc. It is a widely used technique in several industries for production of thin films of materials.

2.2 Chemical Synthesis Method:

The preparation of nanoparticles by chemical method is classified as sol-gel method, precipitation method, electrochemical method, spray pyrolysis. By this method, desired size particles are obtained but they may be toxic.

Sol-Gel Method: It is a wet-chemical process containing a chemical solution acting as a precursor for an integrated system of discrete particles. Metal oxides and chlorides are the typically used precursors in sol-gel process. The precursor used in this method is dispersed in a host liquid either by shaking, stirring or sonication.

Chemical Vapor Deposition Method: It is a chemical technique where the substances in vapor phase are condensed. This vapor deposition is generally utilized to produce composite material films and for infiltration of fabric to produce different nanomaterials.

Spray Pyrolysis Method: by which a nanostructure is obtained precursor containing solution is injected onto substrate in the furnace that leads to decomposition of the precursor forms desired material on substrate.

Colloidal method: This synthesis method used for traditional nanoparticle preparation by use of wet chemistry, by generating the particles in a solution firstly, then dropping the particles on a substrate and then removing of the solvent.

Despite of these demerits in chemical approach, biological method is preferred where there is less chemical usage and also toxicity of prepared nanoparticles is reduced when compared to the chemical synthesis method. Biological method is cost efficient and also can be prepared in eco friendly manner.

2.3 Biological Method: It is a sustainable approach for nanoparticles synthesis, which uses plant extracts or natural materials as stabilizers or reducing agents. This method is eco-friendly, cost effective and does not involve the use of toxic chemicals. This method can also be used to prepare various nanoparticles by using different leaf extracts.

3.1 A Novel Approach: Green Synthesis Method:

Physical method involves physical forces, which attracts the nano sized particles and forms well defined and stable nano structures. But the disadvantage of this method is high cost of equipment and requires high temperatures. Chemical methods involves in toxicity (i.e., toxic chemicals) that may not be handled physically. Whereas the biological method is an eco-friendly & cost-effective method for synthesis of NPs. Green synthesis is one type of biological methods used in recent days for production of nano particles.

3.2 Green Synthesis Approach:

Green Synthesis is an approach to produce Nano particles using plant extract. Which includes fungi, bacteria etc. The toxicity, chemicals cost in this method is very less compared to physical & chemical methods.

3.3. Significance of plants in green synthesis of nanoparticles

For the evolution of spot-less and eco-friendly nanoparticles green synthesis uses plants. Plants consisting antioxidants like saponins, polysaccharides, vitamins, amino acids, tannins are reductive so they can be used as the reducing agents and also acts as capping agents. Plants are called as the chemical factories of nature with little sustenance and are economical [10]. In contrast with other bio-synthesis methods like using microorganisms as they are done by complex gestures of conserving the microbial cultures, plant aided synthesis of nanoparticles is proved to be more advantageous [11].

Plant supported synthesis is favored due to the kinetics for this path is sufficiently higher than in the remaining biosynthetic paths. The phyto chemicals available in plant extract like polyphenols, polyols are accountable for the bio reduction of metallic ions. Many nanoparticles such as zinc oxide, gold, iron, silver have been fabricated smoothly using plant assisted green approach [11].

The below table. 1 shows, the plants that can used for preparation of leaf extract for different nanoparticles in origin country (INDIA).

Table.1: Details of Different kinds of plants in India used for synthesis of nanoparticles

Leaf Name	Part taken for extraction	Nano particle	Size(nm)	Image	Application	References
Neem	Fresh leaves	Ag	18(XRD)		Used in Medicines	K. Elumalai et al,□2017
Buchu	Dry leaves	Fe	15.8(TEM)		Used in Medicines	F.T.Thema et al,□2017
Aloevera	Leaf extract	Au	8-20(XRD)		Used in Cosmetics	K.Ali et al, 2016
Coptis Rhizome	Dried Rhizome	Zn	2.9-25.2(TEM)		Used in Ayurvedic	P.C.Nagajyothi sci al, 2017
Bhiumala	Leaf extract	Mg	25.61(XRD)		Used to cure Liver Disorders	M.Ramesh et al,□2018
Indian Beech	Fresh leaves	Zn	26(XRD)		Used to make	M.Sudharshan sci al, 2017
Red clover	Flower	Ag	60-70(XRD)		Used in Food Production	R.Dobrucka sci al, 2019
Water Hyacinth	Leaf extract	Zn	32(XRD)		Used in filtration	M.Swathi sci al, 2017
Red Rubin Basil	Leaf extract	Fe	14.28(XRD)		Used in medicine	G.Nagendra et al,2017
Black nightshade	Leaf extract	Zn	20-30(XRD)		Used in Scalimg	Sd.Faheen et al, 2018
Yellow Elder	Leaf extract	Zn	13(SEM)		Used in Filtration	A.Kasturi et al, 2017
Eucalyptus	Leaf extract	Zn	18.6(SEM)		Used in medicines	S.Eswar et al, 2020

The nanoparticles can be synthesized in green synthesis technique by using various kinds of raw materials like roots of plants, leaves of plants, flowers of plants, peels of fruits, seeds of fruits, etc., from the table 1 it can be seen that that different kinds of plants were used to synthesize different type of nanoparticles in which we can observe that same nanoparticles can be synthesized from different plants and same plant parts can synthesize different nanoparticles. The plants which we are using to make nanoparticle should be non-toxic and maybe or may not used as ayurvedic ingredient like neem, Tulasi, rose leaf, etc., Due to this reason the nanoparticles which are preparing using this extract does not contain toxic elements so we can use them in various applications as mentioned in table 1. It was confided from literature that, part of plant contain to synthesize nanoparticles should not contain toxic elements which cause harm and should have to contain high percentage of Phyto chemicals which plays a vital role in synthesis process.

3.4 Preparation of Leaf Extract of *Tecoma Stans:*

Tecoma stans leaves, whose regular name is *yellow bells* which is a species of *flowering perennial shrub* which belongs to *trumpet family* and these plants can be collected from Visakhapatnam, Andhra Pradesh, India. These tecoma Stans plant leaves have low literature papers when compared to other plants and these plants can also found in most locations in our locality which are easily available. And also this plant have high value of phyto chemicals, which is the most essential chemical that should present in leaf of plant to synthesize nanoparticle with its extract. More overly this plant does not consist of any toxic elements in it so the nanoparticles which are synthesized by this plant extract can be used in wide range of applications. A sample Tecoma Stans plant leaves available in Visakhapatnam, Andhra pradesh regions is shown in Fig.11.

Fig.11: Tecoma Stans plant leaves

Using parts of Tecoma Stans plants such as flowers, leaves, roots, stems the nanoparticles can be synthesized. These parts of plants are washed carefully using tap water and disinfected by distilled water and then dried at room temperature. The dried parts are then cut into small pieces, then weighed and then crushed. The crushed sample is mixed with distilled water as per the required concentration and it is boiled along with continual stirring. After some time, the solution is cooled and is filtered using Whatmann filter paper no.1 and for further use the filtrate can be refrigerated [12]. Preparation of leave extract from various parts of plants can be done in two ways, which are "Dry method" and "Wet method".

Wet method: Fresh leaves are collected and rinse them properly with tap water. Here after 30g of rinsed leaves are collected and directly boiled them in distilled water at 45^{0}C for 90 minutes. After, the extract will be filtered using filter paper. The extract will be homogenized by further stirring and centrifuged for two min and obtained extract will be filtered using filter paper.

Dry method: the rinsed leaves are dried for 48 hours at shade region at room temperature and those dried leaves will be finely powdered. After that collect 30g of powdered leaves and dissolved them in 250 ml of distilled water and continuously stir the solution for 45 min using a magnetic stirrer and thermostat by maintaining temperature of 60^{0}C. Now, the extract is filtered using filter paper [11]. In the above-mentioned methods, leaf extract preparation from dry method will gives nanaoparticles of accurate size nanoparticles, when compared to wet method and by this size and they have more applications by efficiency [12]. Leaf extract preparation methodology from dry method is distinctly represented in Fig.12 and Fig. 13.

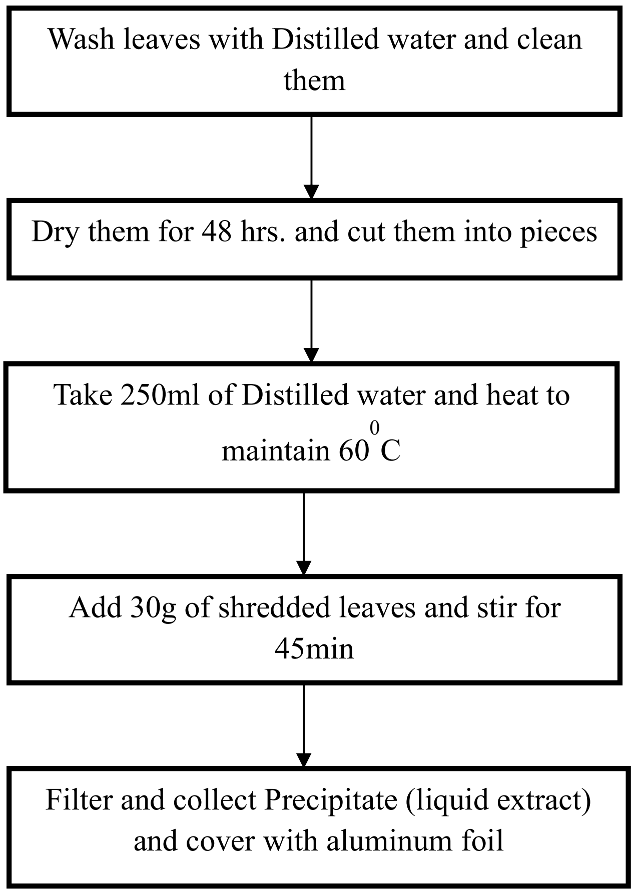

Fig. 12: Flow chart Representation of leaf extract preparation using Dry method

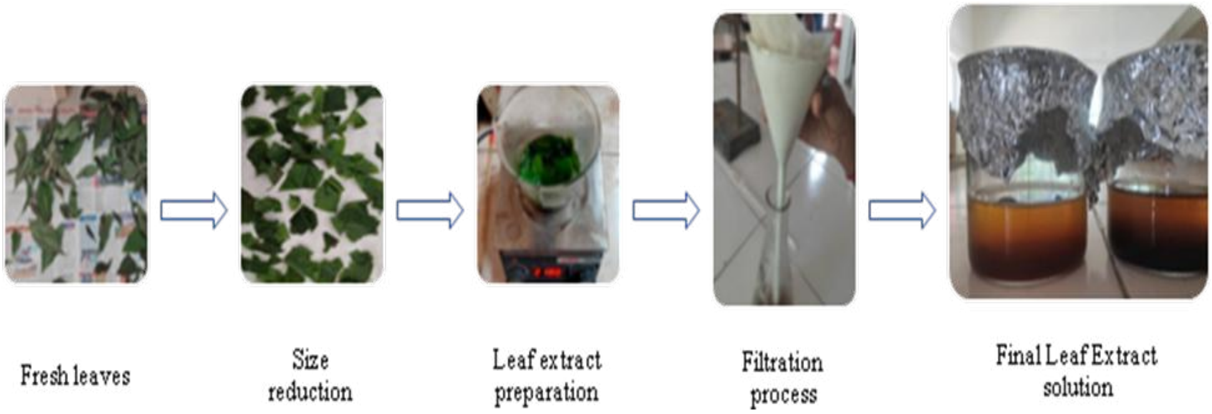

Fig.13: Leaf extract preparation from Tecoma Stans leaves

3.5: Green Synthesis of ZnO NPs using Leaf Extract:

Zinc nanoparticles can prepared by using various chemicals like Zinc Acetate, Zinc Nitrate, etc., Zinc Acetate as parent compound can be used and Leaf extract as reducing agent. 100ml of 0.2 M Zinc Acetate solution collected and stir the solution continuously at 1000 rpm, 60^0C for 10 minutes. After that add 40ml of leaf extract to zinc acetate solution. Thus the mixture is to be continuously stirred at 60^0C by maintaining 10 pH by adding 0.1 N HCl/NaOH till the mixture color changes to yellow precipitate, which indicates that the nanoparticles are formed.

Then the precipitate is filtered and dried and further centrifuged at 4000 rpm for 15 minutes to settle down the unwanted heavy metals. After centrifuge, kept the sample in a hot air oven for 45min. Collect the obtain particles are in a crucible to withstand the high temperature. Thereafter, place the collected particles in a furnace for 2 hours at 400˚C. Use the tong to take the crucible from furnace after two hours. The obtained nanoparticles to be smoothened using a mortar and piston and store it in a moisture free container. Fig.14. clearly represents procedure to synthesize nanoparticles from leaf ectract by green synthesis method and brief schematic representation of synthesis of nano particles is shown in Fig.15.

Thereafter synthesized zinc nano particles to be characterized inorder to conform the formed particles are zinc particles are not.

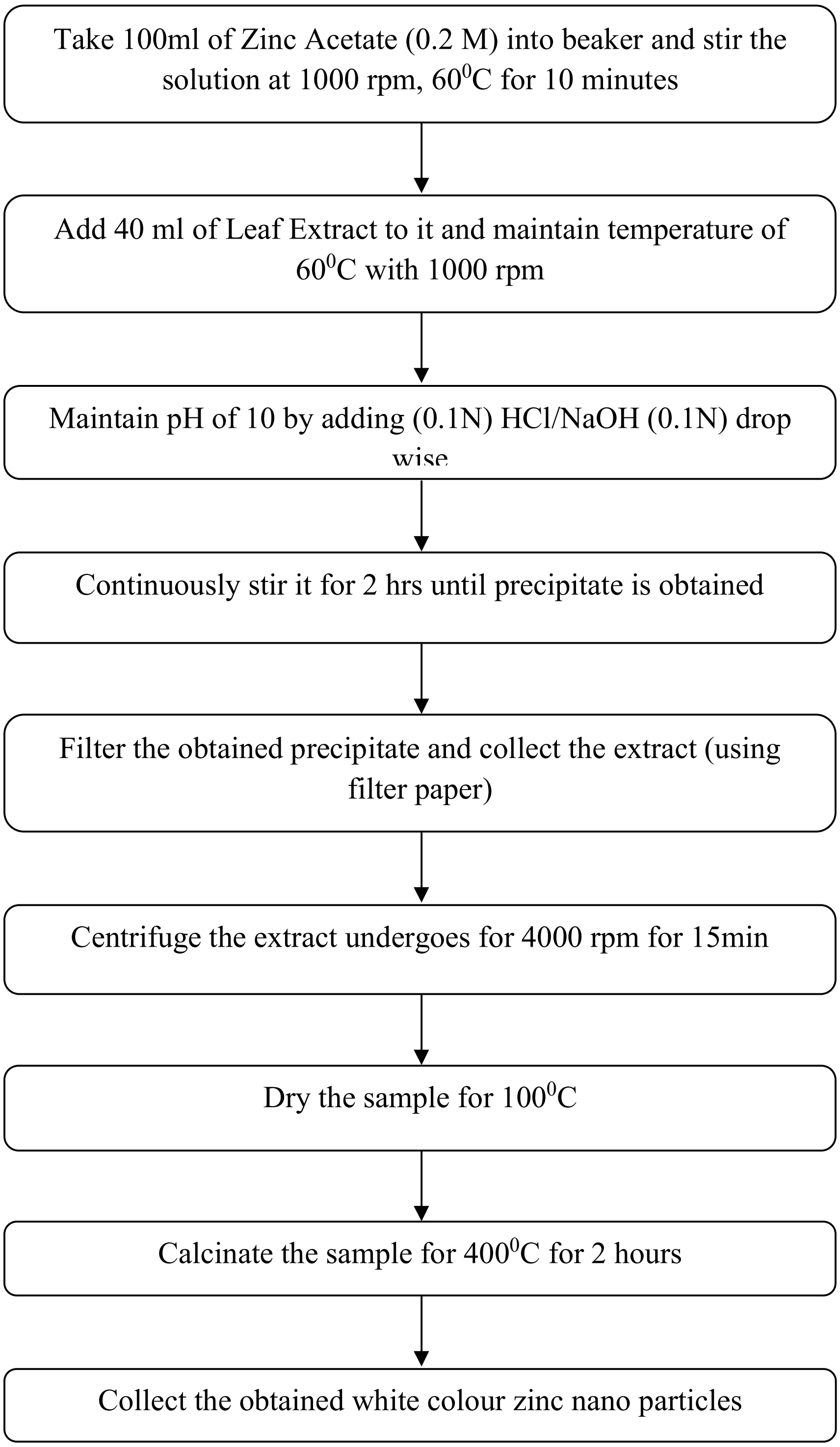

Fig. 14: Flow chart Representation of zinc nano particles preparation using leaf extract

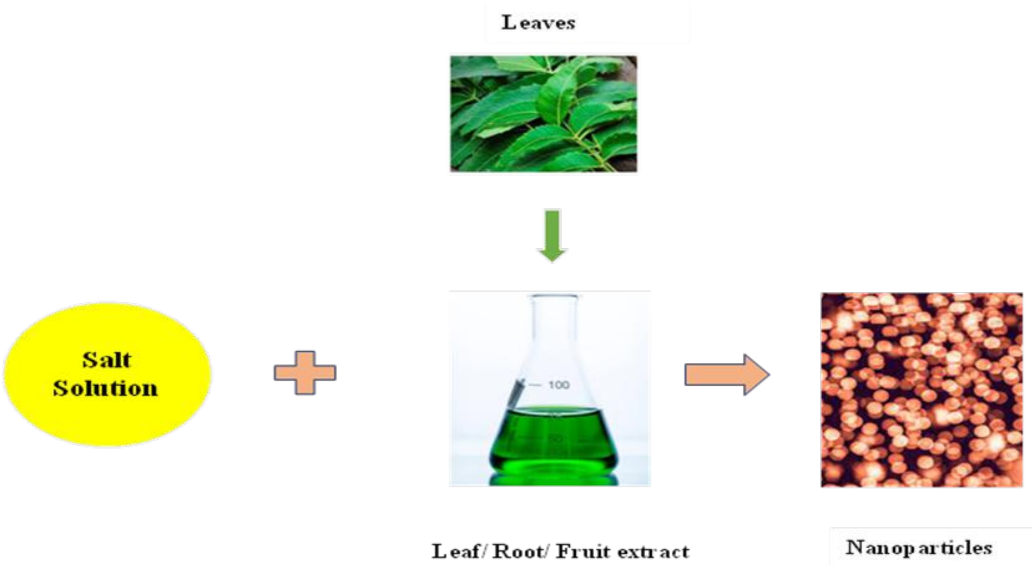

Fig. 15: Schematic representation of zinc nano particles from leaf extract

4. Characterization Techniques:

The characterization of Nanoparticles has been done in so many ways, to know the obtained nano particle size, shape and its characteristics. Some of the characterization techniques have briefly discussed below.

4.1 UV-Visible spectroscopy:

The optical property of synthesized nanoparticles can be observed in various temperatures and concentrations through a absorption spectra using a Ultra-Violet-Visible spectrometer with a wavelength in range between 200 to 800 nm.

UV spectroscopy can be useful for analyzing nanoparticles, particularly if the nanoparticles absorb light in the ultraviolet portion of the electromagnetic spectrum.

UV-Vis spectroscopy determines the amount of light absorbed by a sample over a wide range of wavelengths, typically 190 to 800 nm. UV-Vis spectroscopy can be used to analyse nanoparticles by detecting the change in absorbance of a sample before and after the addition of the nanoparticles. This shift in absorbance can reveal information about the nanoparticles size, shape, and concentration in the sample.

The method described above can be used to calculate the amount of light dispersed and absorbed by a nanoparticle. A nanoparticle is put between the light source and the detector, and the light intensity is measured as it travels through the nanoparticle. The wavelength extinction spectrum is used to differentiate these measurements. A plot is created using this data. Spectroscopy is being used to examine the optical properties of nanoparticles.[14]

4.2 Scanning Electron Microscopy:

Scanning electronic Microscopy is a characterization technique which uses electronic beam to examine the surface characteristics like Morphology and Topography of sample taken. It uses an electronic beam and focus to the sample. When the beam with electrons strikes the sample, they produce signals and high-resolution image with help of it.

SEM is mainly used in characterizing nanoparticles, which are extremely small and often difficult to observe with other techniques. Because SEM offers high-resolution imaging capabilities, it can be used to visualize the size, shape, and distribution of nanoparticles. This information is important for understanding how nanoparticles interact with other materials, as well as their potential applications in various fields. To use SEM for nanoparticle characterization, the sample is typically prepared by depositing a thin layer of the material onto a conductive substrate and then sample will be kept in the SEM under vacuum conditions. The SEM beam is then focused onto the sample and obtained signals are used to generate image.

Main advantage of SEM is its ability to give detailed information about the morphology studies of nanoparticles. By examining its surface of the material, SEM can reveal important details about the size and shape of the nanoparticles, as well as any surface features or defects. Additionally, SEM can be used to examine the surface chemistry of nanoparticles by detecting characteristic signals that are generated when the beam is passed through the sample.Another advantage of it is its ability to provide good resolution imaging in real time. This allows researchers to observe changes in the nanoparticle morphology as a result of various treatments or conditions. Additionally, SEM can be used to generate 3D images of the nanoparticles, which can be useful for understanding the distribution of the particles within a material.

Overall, Scanning Electron Microscopy (SEM) is a great tool for characterizing nanoparticles. It offers high-resolution imaging capabilities and the ability to generate detailed information about the shape, distribution and size of particles. Additionally, SEM is used to examine the surface chemistry of nanoparticles, as well as observe changes in morphology over time. As such, SEM is a valuable tool for researchers in a variety of fields, including materials science, nanotechnology, and biomedicine.[15] . Fig. 16 shows a Sample SEM images of Zinc Nanoparticles.

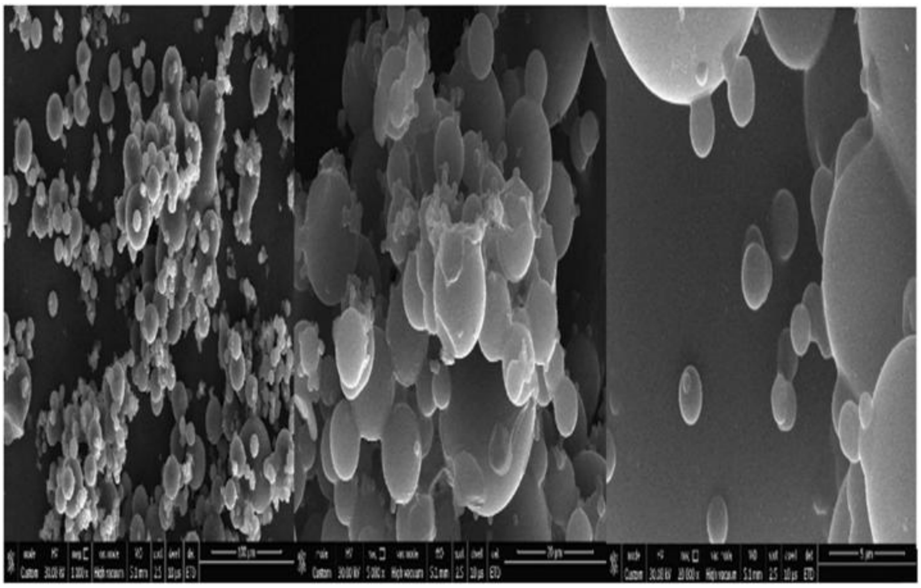

Fig. 16: Sample SEM images of Zinc Nanoparticles (**a**) 1000X Mag. (**b**)5000X Mag (**c**) 20,000X Mag.

4.3 X-Ray Diffraction analysis:

XRD analysis used to study the surface, size and crystalline nature of ZnO NPs in this the scanning should done at 2θ value range of 4° to 80° at $0.02 min^{-1}$. A sample X-Ray diffraction analysis with peak intensities of zinc nanoparticles is shown in Fig. 17.

X-ray diffraction is a process which is used in analyzing materials structure by passing them through the x-ray and observing the result. X-rays are nothing but high frequency electromagnetic radiations with very short wavelength which can pass through any materials even solids. The results of diffraction pattern from the x-ray are used to determine the crystalline structure of material which is being analyzed.

The instrument used to determine the x-ray diffraction is a X-RAY diffractor meter for the crystalline structure material by interacting them with the x-rays. The crystalline structure of the material is determined by the resulting pattern of the diffracted x-rays.

XRD provided data information helps in correlate microscopic observation of green synthesis of zinc oxide nano particles. By using simple precipitation method zinc acetate and tetra methyl ammonium hydroxide together forms zinc oxide. The characterization of ZnO nanoparticles is done by x-ray diffraction analysis.[16]

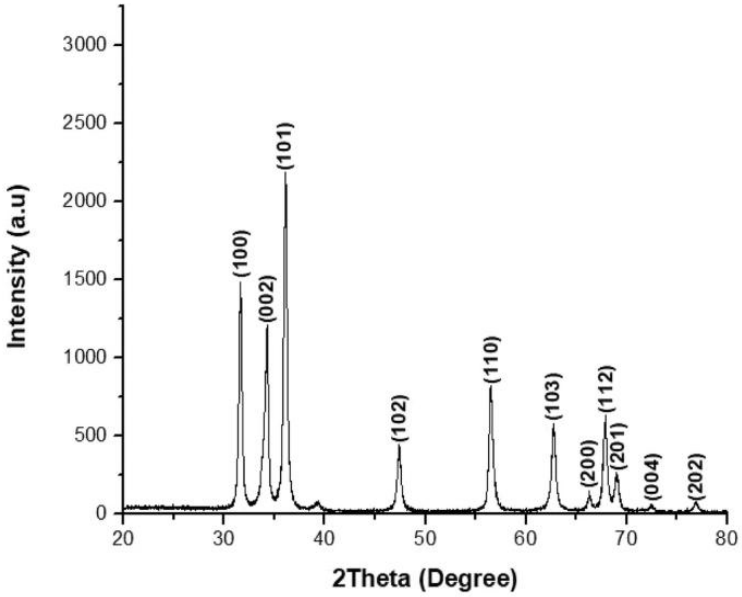

Fig. 17: sample XRD Peak intensities at various Θ values

4.4 Transmission Electron Microscopy:

The TEM analysis talks about the shape and thickness of the nanoparticle in which the average ZnO nanoparticle size is found in range between 50-200 nm. It is a microscopy type which uses electron beam to observe structure of materials. The desired sample is placed and electron beam is focused to produce a high-resolution image on fluorescent screen. TEM allows seeing the materials with extremely higher magnification and greater image resolution which allows observing the structure of sample and its composition. We can say it is a valuable tool for determining the structure of the material which we desire to characterize.

One of its notable advantages is it provide higher resolution images of the thin samples. The taken sample should be very thin, which is less than 100 nanometers, so that it allows the electrons to pass through it without being scattered. Samples are generally prepared by cutting or grinding up to the desired thickness and then placing them on a support film. TEM can also be used to perform analytical techniques like Energy-Dispersive X-ray spectroscopy (EDS) and also electron energy loss spectroscopy. These methods help us to obtain information about the structure of crystal, composition and also electronic structure.

TEM is abundantly usedto characterize nanoparticles and study the formation and growth of nanoparticles in real time. It is used to study the behavior of nanoparticles in biological systems including their interactions with the cells and tissues. It is used to identify and study the toxicity of the sample. TEM is used to study the effect of pH and temperature on properties of nanoparticles. The preparation techniques for TEM includes (FIB) Focused Ion Beam milling, Ion Milling, Mechanical polishing. EDS is used to determine the composition of elements of nanoparticles that works by detecting the emitted X-rays while the electron beam is in interaction with the sample. The size of nanoparticles ranges that are imaged by TEM is from a nanometer to few hundreds of nanoparticles and a sample TEM image is shown in Fig.18.

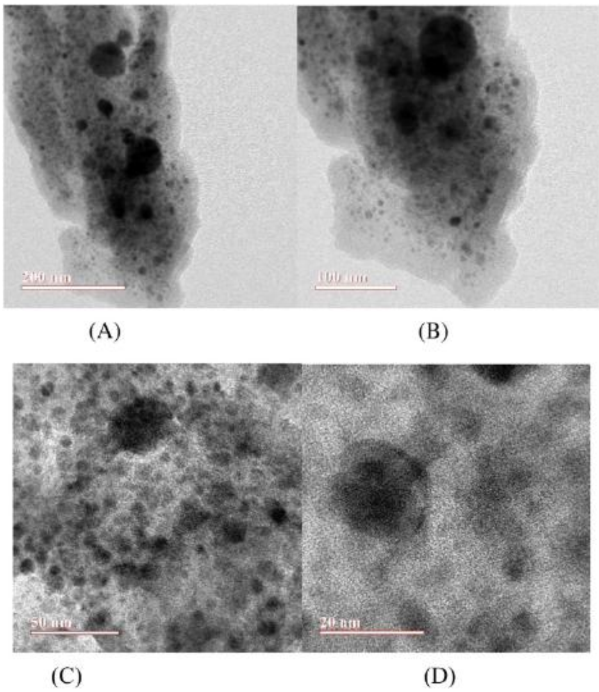

Fig. 17: A sample TEM images of zinc nanoparticles

5. Applications:

Zinc oxide Nanoparticles is an all-rounder when it comes to technical applications. They have wide range of useful applications in various fields like Pharmaceutical, Cosmetics, Paints, Dye decolorization. Adding zinc nano particles rubber improves it vulcanization properties and used in manufacturing of tires. Also, they used as catalyst in manufacturing of cosmetic products in chemical industries.

5.1. Water Filtration:

Nanoparticles are used to filter water due to their nano size and higher surface area to volume ratio. Nanoparticles effectively remove pollutants and contaminants such as heavy metals and bacteria from water. Silver Nano particles are well known for killing bacteria and can be combined with other nanoparticles for better filtration. Nanoparticles can be embedded into numerous membranes and used as filters. Titanium dioxide nanoparticles can breakdown organic pollutants through photo catalytic reactions and breakthrough, Iron nanoparticles can remove arsenic and heavy metals from water.

5.2. Paint Industry:

Wood furniture and walls are the hotspots in the homes that could probably support the growth of microbes like fungi and bacteria. Generally, we use rubber wood and maple to make furniture and decorations in homes, if they are exposed to environment then fungi and bacteria have more probability on the surfaces of them. In these cases, zinc oxide nanoparticles will help by improving the quality of wood surfaces as the nanoparticles are hydrophobic and self-cleansing in nature. The paints which contain zinc oxide nanoparticles have been found to fight against fungi, microbes, corrosion and have self-cleaning properties. In place of petroleum products, it is better suggested to use nanoparticles which are bio-based materials and also renewable resources.[18]

5.3. Medical Field:

Zinc nanoparticles have gained attention in medical field due to its unique properties like surface area to volume ratio, there are many applications of nanoparticles in medical field including wound healing, antibacterial, anti-fungal and anti-virus properties, imaging, biosensors, dental, tissue engineering, bone tissue regeneration, Opthalmic, neurology, cardiovascular, etc.., Zinc nanoparticle promote cell proliferation, collagen synthesis, and angiogenesis, which helps to faster wound healing. Its antibacterial properties are known to its ability to disrupt bacterial cell membrane, and its antifungal properties are attributed to disrupt the fungi cell wall.

Zinc nanoparticle's anti-viral properties fight against various viruses like HIV and Influenza. They are used to cancer treatment mostly because they target cancer cells and induce apoptosis. They are also known as drug carriers, biosensors, agents for imaging contrast.

In dentistry Zinc nanoparticles are used for antibacterial property for remineralization of teeth. They have widely been used in tissue engineering and also in bone regeneration and enhancing bone growth and mineralization. They have been used in ophthalmology, cardiovascular diseases and wound dressing for their anti-bacterial properties for wound healing. They have been incorporated into several lotions for their ability to absorb UV radiation. These unique properties of them making promising candidates of a wide range medical applications

5.4. Antimicrobial agents:

These days, ZnO NP's have shown the best potential as antimicrobial agents due to their properties both physically and chemically. The major properties that make Zinc oxide nanoparticles effective as antifungal and antibacterial agents are: large surface area, small in size and they generate the reactive oxygen species (ROS) when exposed to light. According to studies, ZnO nanoparticles exhibit their properties against the microorganisms such as E. coli bacteria and fungi such as Aspergillus niger. The action of ZnO nanoparticles against the microorganisms haven't yet understood completely but it is known that these may involve in ROS generation that may damage DNA. The toxicity is also very low. Generally, the toxicity of the prepared zinc oxide nanoparticles depends on some major factors like concentration, time and size etc. Finally, ZnO nanoparticles as antibacterial and antifungal agents provides a viable alternative

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