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Review on Biosynthesis and Characterization of Nanoparticles

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Abstract: The most emerging branch in the field of life science is Nano-biotechnology. The nanomaterial is created and utilized in the different fields of Science and mostly abundantly in the medical science, because these nanoparticles are used as a probe or vehicle for the drug/biomolecules delivery in the cellular system of the animals. Nanoparticles are synthesized by Physical, Chemical as well as Biological methods, and now a days the natural synthesis of nanoparticles are the main concentration of the researchers. That's why this article elaborates the outline for the nanoparticles synthesis.

Keywords: Nanoparticles, Biosynthesis, Characterization, Application

Introduction:

Nanotechnology is the emerging branch of science having many advantages in the various fields like Material Science, Electronics and Medical Science [1]. In short the technique of synthesis and their use in the different fields at nanoscale dimension [2,3]. The blend of Nano and Biological tools results in the synthesis of nanomaterial likes nanoparticles, nanotubes and Fullerene etc.

The term Nano is derived from the Latin that means Dwarf, Nanotechnology is the discipline that deals with the processes that occurs at molecular and Nano scale size[4].

Nanoparticles are the smallest material ranging from 1nm to 100 nm in size. They are synthesized by chemically, physically as well as by natural means. Now a days in the field of green chemistry synthesis of metal based nanoparticles has becomes a key attention of the researchers [5].

There are many types of Nanoparticles which are classified on the basis different parameters, like Metal Based Nanoparticles, Carbon Based Nanoparticles, Ceramic Nanoparticles, Semiconductor and Polymeric Nanoparticles etc.[6,7]

Carbon Nanoparticles:

The carbon nanoparticles were discovered in 1991 by Sumio Iijima[8]. Carbon nanoparticles are the biocompatible and chemically inert in nature. They are synthesized by using the carbon soot. Carbon nanomaterial is in the various forms like nanotubes, particle, diamond, carbon dot etc.[9,10] These carbon nanomaterial used for different purposes like in sensor probe.[11].

Metal Nanoparticles:

Metal Nanoparticles are those which are synthesized by using metals like gold, platinum, silver, zinc, cerium, iron, and thallium etc. These metals are not present in free form, they are always conjugated with some ions. So that these are reduced to form a metal oxide by using the reducing agent. Many of the researchers synthesized Silver, Zinc nanoparticles by using green reducing agents[12–14].

Ceramic Nanoparticles:

Ceramic Nanoparticles are said to be inorganic nanoparticles, these are normally having a low electrical, thermal conductivity and highly resistant to the environmental changes. These are based on materials that have properties lying between metals and non-metals and composed of inorganic compounds such as silica or alumina, and having a porous characteristics[15,16].

Semiconductor Nanoparticles:

Semiconductor Nanoparticles have a unique properties such as quantum size effects, nonlinear optical properties and luminescence [17].

Polymeric Nanoparticles:

Polymeric nanoparticles are composed of Decomposable and biocompatible polymers [18]. There are two main approaches for the synthesis of nanoparticles are 'Top-Down' and 'Bottom-Up' in the top down approach a scattering of already existing polymer takes place resulting into the synthesis of Polymeric nanoparticles where as in case of bottom-up approach during polymerization of the monomers leads to the synthesis of the polymeric nanoparticles [19].

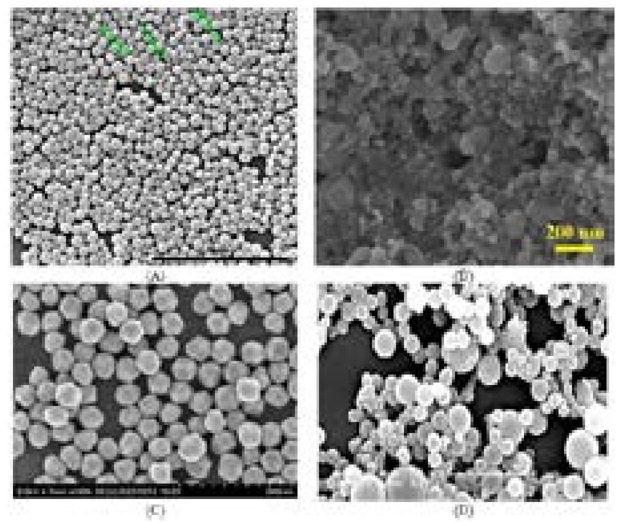

Figure 1. SEM Images of Different of Nanoparticles (A) Carbon Nanoparticle[20], (B) Silver Nanoparticle[21], (C) Gold Nanoparticles[22] & (D)TiO_2 Nanoparticles[23]

Synthesis Mechanism:

Various mechanism developed by the researchers for nanoparticle synthesis, consider an example of silver nanoparticles, reduction of the silver nitrate is carried by using the reducing agents from the biotic sources likewise for Copper oxide and Zinc oxide nanoparticles synthesis reduction of the Zinc nitrate and Copper Nitrate were carried by the same biological sources or extracts.

In case of Titanium dioxide nanoparticles Sol

Gel method [24–27] is mostly preferred for the synthesis. Lead Nanoparticles were synthesized by using a unique method that is the fungal cultures were grown on the medium having the different concentration of Lead (0.2-1.5 µm) resulting in to the utilization of lead by growing fungi through the reduction. The (SEM) Scanning Electron Microscopic images shows the accumulation of Lead particles outside and inside of the cell [28].

In the following Table 1. Synthesis of different nanoparticles from different biotic sources were elaborated.

Table 1. Nanoparticle Biosynthesis by using the Biotic Sources:

Sr. No.	Plant Material	Chemicals	Methodology	Size (nm) & Shape	Functional Groups	Reference
1.	**Silver Nanoparticles**					
1.1	***Barleria prionitis***: Leaf extract (5 gram of the leaf powder boiled in 100 ml of distilled water for 5 min, then centrifuged for 3000 rpm for 10 min. supernatant were filtered through the whatman No. 1 filter paper and the filtrate is collected and used for the nanoparticle biosynthesis	1mM $AgNO_3$	95 ml of the 1mM $AgNO_3$ and 5 ml of filtrate is mixed to initiate the reaction. The reaction mixture incubated at 40°C for 5 h in a shaker incubator. Reduction of Ag^+ ions to AgNPs was confirmed by visible colour change and by using UV-visible spectrometry at regular intervals.	10-20 nm & Spherical in shape	Amine, Alkane, Ether, Alkene	[29]
1.2	***Helicteres isora***: **A)Root Extract:** 1 g of root powder was mixed with 100 ml of water and kept on orbital shaker at 120 rpm for 12 h. After that, the extracts were filtered with Whatman No. 1 filter paper and the filtrate is collected and used for the nanoparticle biosynthesis	1mM $AgNO_3$	1:1 proportion of Plant Extract and the silver nitrate mixed in incubated at the room temperature for 6 hours. Nanoparticles ware collected by centrifugation at 18000 rpm for 20 min. the collected pellet were washed three times with doubled distilled water. And then transferred in to the Petriplate and dried at room temperature.	16-95 nm & Spherical in Shape	Hydroxyl group (–OH) of phenolic compounds –O–H– and C=O (aromatic and carbonyl groups)	[30]
	B) Fruit Extract: The surface of the fruits was cleaned with double distilled water those fruits were dried up to 10 days at room temperature under shade. 5 grams of dried H. isora. Fruits was crushed with mortar and pestle into fine powder, boiled with 100 ml of deionized water at 80^{0}C for 30 minutes under magnetic stirrer with constant stirring. The extract was filtered through Whatman No.1 filter paper. The filtrate was collected and used for the nanoparticle biosynthesis	1mM $AgNO_3$	Silver nanoparticles are synthesized by adding 10 ml of extract into 100 ml of 1 mM $AgNO_3$ solution at ambient conditions for about 150 min with constant stirring. The formed silver nanoparticles are confirmed by visually (light yellow colour to reddish brown).	35-40 nm & Spherical in Shape	N-H (Secondary amine), –OH (Hydroxyl group), $–NH_2$ C-N,	[31]
1.3	**Mulberry:** Mulberry leaves were washed several times with water to remove the dust particles and then sun dried to remove the residual moisture and made it a fine powder	1mM to 4mM $AgNO_3$	5 ml of the leaf extract were added to the 50 ml of 1 mM of $AgNO_3$ at room temperature. After 60 min change in the colour indicates the synthesis of nanoparticles (The concentrations of $AgNO_3$ solution and mulberry leaves extract were also varied at 1-4 mM & 5-10% by volume, respectively)	20-40 nm & cubical in shape	Carboxyl (-C=O), hydroxyl (-OH) and amine (N-H)	[32]

1.4	***Azadirachta indica:*** Leaves surface cleaned with running tap water to remove debris and other contaminate organic contents, followed by double distilled water and air dried at room temperature. About 20 gm. of finely cut leaves were kept in a beaker containing 200 mL double distilled water and boiled for 30 min. The extract was cooled down and filtered with Whatman paper no.1 and extract was stored at 4^0C for further use	1mM to 5mM $AgNO_3$	1 mM solution of silver nitrate was prepared in an Erlenmeyer flask. Then 1, 2, 3, 4 and 5 mL of plant extract was added separately to 10 mL of silver nitrate solution keeping its concentration at 1 mM Silver nanoparticles were also synthesized by varying concentration of $AgNO_3$ (1mM - 5mM) keeping extract concentration constant (1 mL). This setup was incubated in a dark chamber to minimize photo-activation of silver nitrate at room temperature. Reduction of Ag^+ to Ag^0 was confirmed by the colour change of solution from colourless to brown. Its formation was also confirmed by using UV-Visible spectroscopy.	Around 35 nm & Spherical in Shape	Amide, Alkyne	[33]
1.5	***Alpinia galanga*:** Galangal rhizome dried at ambient temperature, powdered by using the grinder to get powder, Rhizome extract was prepared by adding 0.1 g of rhizome powder in 25 ml of distilled water. The mixture was then stirred vigorously for 4 hours in room temperature	1mM $AgNO_3$	Rhizome extract (0.1 g rhizome powder in 25 ml deionized water) was added into silver nitrate, 30 ml of 0.01M $AgNO_3$ solution. The reaction was left for 48 hours under room temperature in dark to avoid any Photochemical reduction.	Spherical in Shape	Hydroxyl (-OH) Carbonyl (C-O) Alkyl	[34]
1.6	***Aloe vera*:** 30gm of the leaf were boiled in 100ml of deionized water and the filtrate ware used for the nanoparticle biosynthesis	30% Ammonia Solution 10^{-2} M $AgNO_3$	For the synthesis of Nanoparticles 2.5ml of 30% Ammonia solution added to the 5ml of 10^{-2} M $AgNO_3$ followed by addition of 5ml of extract (AgNO3 concentration were maintained at 10^{-3} in the reaction mixture) after 24hours incubation the faint yellow coloration indicates the synthesized nanoparticles.	15.2 ± 4.2 nm & Spherical in Shape	Carbonyl (C-O) Hydroxyl (-OH)	[35]
1.7	***Aspergillus clavatus:*** *Aspergillus clavatus* is isolated from the *Azadirachta indica* A. Juss. Mass cultivated in the liquid medium and then 20 grams of biomass is used for preparation of crude extract. This crude extract used as a reducing agent for Silver nanoparticle biosynthesis	1mM $AgNO_3$	10 ml of extract added in to the 90 ml of 1mM $AgNO_3$ and incubated for the reaction.	10-25 nm & Spherical or near to spherical in shape	--	[36]
1.8	***Fusarium oxysporum:*** Biomass ware used for the nanoparticle biosynthesis	1mM $AgNO_3$	10 gram biomass of *Fusarium oxysporum* is added in the flask containing 1nm of $AgNO_3$ and incubated for the reaction and periodically aliquot of the reaction solution were used for UV-Vis measurement.	5-50 nm & Spherical, Triangular in shape	Amide, Carbonyl	[37]
2	**Copper Oxide Nanoparticle:**					

2.1	***Aloe vera:*** 25gm of the leaf were chopped then boiled in the 100ml deionized water for 5 min at 80°C. After boiling the solution were filtered through the Whatman filter paper of pore size 0.2µm. the filtrate is used for the nanoparticle biosynthesis	10 mM Copper nitrate	50 ml of 10mM the aqueous solution of Copper nitrate were added in the 5 ml of aloe leaf extract in the Erlenmeyer flask under continues stirring at 100°C the change in the deep Blue to colourless and then to brick red and dark red on vigorous stirring for 24 h. indicates the synthesis of nanoparticles. The solution is centrifuged at 10k rpm for 10min at room temperature then the pellet is collected and dried in the watch glass and used for the further characterization	20-30 nm & Spherical in Shape	Hydroxyl, Alkenes & Alkanes	[38]
2.2	**Gum Kereya:** 1gm of the GK powder is mixed in the 1 litre of DW and stirred overnight to make a clear solution. Solution filtered and used for the nanoparticle biosynthesis.	10mM $CuCl_2.2H_2O$ NaOH	0.1ml aliquot of 10mM $CuCl_2.2H_2O$ solution were mixed with the 10ml of GK Solution. The reaction mixture incubated for 1 hour at 75°C at 250 rpm. The colour of the mixtures gradually changed from bluish to black, indicating the formation of CuO nanoparticles.	02-10 nm & Spherical in Shape	Carboxyl (-C=O), hydroxyl (-OH) and amine (N-H)	[39] followed the protocol explained in the [40]
3	**Zinc Oxide Nanoparticles:**					
3.1	***Aloe barbadensis miller*:** Aloe leaf and aloe gel broth extracts at different concentrations (50%, 25%, 15%, 10%, 5%) were prepared with distilled water	Zinc Nitrate & NaOH	In different sets of concentrations (50%, 25%, 15%, 10%, 5%) Zinc nitrate ware dissolved under constant stirring using magnetic stirrer for 5-6 h at 150*C and after cooling the solution were centrifuged and pellet is washed thrice through the centrifugation and dried at 80*C for 7-8 h, resulting dried material crushed and deposited in air tight container	25-55 nm & Spherical in Shape	Carboxyl (-C=O), hydroxyl (-OH)	[41]

Characterization of Nanoparticles:

Satisfactory characterisation of the nanoparticle is one of the main important need in the Nano-biotechnology research. Because the nature of nanoparticle is imperative in the biological activity. So that there are innumerable Characterization methods are used for the analysis of nanomaterial. Those Instrumental based methods are, UV-Visible spectrum analysis, FTIR, XRD, DLS, SEM/TEM observation etc.

UV-Visible measurement:

We know very well every molecule absorb some sort of energy/light and they show the absorption maxima at a specific wavelength likewise nanoparticles also have a specific absorption maxima because of the unique optical properties likes size, shape, concentration, agglomeration state, and refractive index near the nanoparticle surface.

Consider the example of Silver nanoparticle, it show maximum absorption near about 420nm - 450nm [30,42,43] whereas the Copper Nanoparticles shows near about 260nm-280nm[38].

FTIR (Fourier Transform Infrared Spectroscopy)

FTIR is the infrared Spectroscopy in which

IR radiations are passes through the sample, some amount of the radiation absorbed by the molecules present in the sample while remaining will be transmitted. The absorbed molecule results in to the vibration.

According to the IR principle molecular vibration takes place after the absorption of IR light[44]. Every bond or a functional group is oblige for the different frequency of absorption. So that a distinguishing peak is observed for the every functional groups or a bond of the molecule[45,46]. The functional groups attached on the nanoparticle will be identified by using this spectroscopy which will give a proper information about the coated molecules on the nanoparticle.

XRD (X-Ray Diffraction):

The solid material shows two different appearance that is amorphous and crystalline nature, in amorphous material atoms are randomly arranged while in crystalline form the atoms are arranged in prescribed order. By using XRD we can study the appearance, average spacing, size, shape and internal stress of nanoparticle[47].

DLS (Dynamic Light Scattering):

DLS is called as Photo correlation Spectroscopy, and this technique is used to measure the particle size. DLS measures the Brownian motion and correlates the motion in to the size of the particle. Brownian motion is the movement of the particle is the solution due to the offensive nature of the solvent, normally larger particle move slowly as compare to the smaller one. The velocity of the Brownian motion is defined as the property called Translational Diffusion Coefficient (D)

The size of the particle is calculated from the translational diffusion coefficient by using the Stokes-Einstein equation,(D_t=kt/3πηD)

In DLS the measured value is refer to how the particle diffuse within a fluid so that it is referred as a Hydrodynamic Diameter. The obtained diameter of the sphere, by this technique is same as translational diffusion coefficient of the particle[48].

SEM (Scanning Electron Microscope) & TEM (Transmission Electron Microscope):

We know very well Electron Microscopes are used when the highest resolution is required. Electron Microscopy is suitable for the observation of nanoparticles and their shape by magnifying at nanoscale. The 1nm -100nm resolution power is used for observation of nanoparticles. Both Scanning as well as Transmission electron microscope can be used for the observation of Nanoparticles[49].

Application of Nanoparticles:

Nanoparticles are used for the different purposes because of their unique chemical and physical properties. In the different fields like Pharmaceuticals, Nano-electronic Biosensors, Medical Science etc.

Nanoparticles have a large specific area and high surface energy, and due to this they can absorb the biomolecules and play an important role in the immobilization of biomolecules in biosensor construction. [50] Four classes of Nanomaterial like Dendrimers, Metal Coated Nanoparticles Zeolites and Carbonaceous Nano-materials are used as separator or filter and media for the water purification[51]. In Medical Science for nanoparticles are not only used for the drug delivery but also for diverse solicitation like Hyperthermia, contrast for the NMR Magnetic Separation and Megnetofection[52]. Even the nanoparticles are used in the cosmetics through the Nano-emulsion in the traditional cosmetic ingredients [53].

The Nanotechnology field not only restricted to the life science but also helpful in the pest management. In agriculture for pest management encapsulation of the agrochemicals to the nanoparticle shows the notable effect on the pest and resulting in to the enhancement of the plant growth[54].

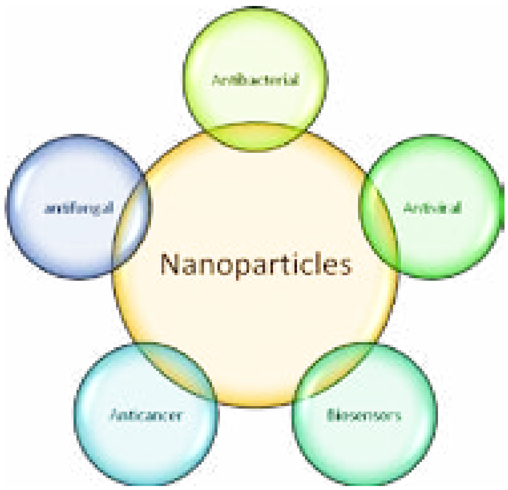

Figure 2. Applications of Nanoparticles

Conclusion:

Due to the huge application of nanoparticles they are utilized in different areas. The green approach towards the nanotechnology made them more applied because of its more stability, due to this the investigators showing their interest in nanotechnology.

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