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GREEN NANOPARTICLE SYNTHESIS AND THEIR APPLICATIONS

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ABSTRACT: As we are well aware that the production of metallic nanoparticles by the physical and chemical method has numerous drawbacks along with the use of toxic chemicals, high energy expenditure and non- biodegradable products. Hence, researchers are showing great interest in the biological synthesis of nanoparticles. The biological method provides clean, bio-degradable, non-toxic and eco-friendly methods for nanoparticles synthesis as compared to a conventional method like physical and chemical. This review concentrates on biological method specially biosynthesis of different types of nanoparticles using bacteria and their application in different fields.

INTRODUCTION: Nanotechnology is derived from the term of nano which is the billionth of meter or 10^{-9}m. The Nano comes ultimately from the Greek word for dwarf and is also related to the Spanish word Nino [1]. It is predicted that in the 21st century, nanotechnology will significantly influence science, economy and daily life and will become one of the driving forces of the next industrial revolution. Nanotechnology comprising synthesis and solicitations of nanoscale resources is an emerging field of nanoscience. Their unique size and shape, volume-surface ratio, increase their physical, chemical and biological properties [2]. The relevance of Nanotechnology relies on the particular biophysical properties of nanoscale objects and their particular interaction with living beings such as high diffusion in organs and tissues [3].

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Due to their unique properties, it is applicable in medical, electronic, material sciences, pharmaceuticals, agriculture, catalyst, drug delivery, *etc*. Nanoparticles are synthesized by physical, chemical, and biological or green methods. Physical and chemical are not so good due to the use of toxic chemical, hazardous radiation, cost-effective, flammable and do not dispose of in the environment. In biological method plant, fungi, algae, and bacteria are used in nowadays. Bacteria have a better option for the production of nanoparticles. Bacteria have ability such as fast-growing, ubiquitous in nature, no culture maintenance problem, easy genomic manipulation as compare to other biological agents. Bacteria can grow cheap source, cost-effective, eco-friendly and product are biodegradable.

Physical and Chemical Methods: Nanotechnology is currently a frontier of research due to wide applications of nanomaterials in biomedical, agricultural, catalysis, optical and electronic fields [4-7]. Various physical and chemical processes have been exploited in the synthesis of several inorganic metal nanoparticles by wet and dry approaches *viz*., ultraviolet irradiation, aerosol technologies, lithography, laser ablation, ultrasonic fields, and photochemical reduction techniques. However, these methodologies remain expensive and involve the use of hazardous chemicals [8, 9]. Hazardous substances such as sodium borohydride, tetrakis hydroxymethyl phosphonium chloride (THPC), poly-N-vinyl pyrrolidone (PVP), and hydroxylamine have been used for the synthesis of nanoparticles in the traditional wet methods. Other dry methods such as UV irradiation, aerosol and lithography are also not considered environment-friendly. The use of such toxic chemicals is still the subject of paramount concern because toxic chemicals on the surface of nanoparticles and non-polar solvents in the synthesis limit their applications in clinical fields [10-12]. The inorganic nanoparticles (NP) have invoked a lot of interest owing to their distinct physical, chemical and biological properties as compared to the respective bulk materials [13, 14].

The high energy requirement in physical methods of nanoparticle synthesis and the waste disposal problems in chemical synthesis, due to the heavy use of organic solvents, toxic reducing agents and capping agents, both methods are costly and generate toxic byproduct are major demerits of the conventional nanoparticle synthesis [15-17]. Hence, the development of clean, biocompatible, non-toxic and eco-friendly methods for nanoparticles synthesis deserves merit. These biological methods are regarded as safe, cost-effective, sustainable and environmental friendly processes [18]. Green approach for the synthesis of nanomaterials utilizes biological components, primarily prokaryotes and eukaryotes. Microbes play direct or indirect roles in several biological activities. “Green chemistry” explores the biological pathway and biological resource like a plant, plant extract, fungi, bacteria, a virus for bioproduction of nanoparticles [19].

Biological Method: The biological process is the more acceptable green route, which is not energy intensive and is also eco-friendly. This biogenic approach is greatly indented with bacteria by providing ambient conditions such as temperature and pH *etc*. The nanoparticles synthesized by the biological process have higher catalytic reactivity and greater specific surface area [20]. Application of microorganisms is one of the most conspicuous methods among various bio-methods of nanoparticle production [19, 21-25]. Microbial cells offer many advantages like wide physiological diversity, small size, genetic manipulability, and controlled culturability; they are thus regarded as ideal producers for the synthesis of the diversity of nanostructures, materials and instruments for nanosciences [26].

Biological method for nanoparticles synthesis is a better option as compared to physical and chemical method. In the biological resource are a plant, plant extract, algae, fungi, bacteria, and viruses. Research has seriously focused on prokaryotes that means of synthesis of metallic nanoparticles. Due to the environment is rich with prokaryotes organisms and their ability to familiarize to thrilling conditions; bacteria are a good choice for study. Bacteria is fast growing, inexpensive to cultivate and easy to manipulate. Growth conditions such as temperature, oxygenation and incubation time can be easily controlled.

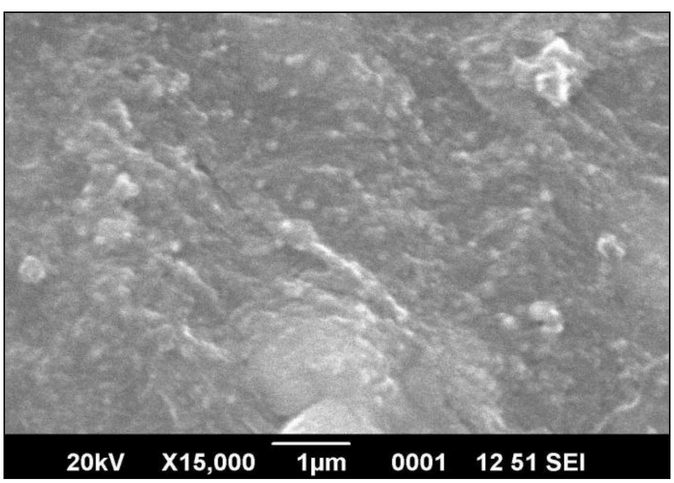

FIG. 1: SEM MICROGRAPH OF SILVER NANOPARTICLES

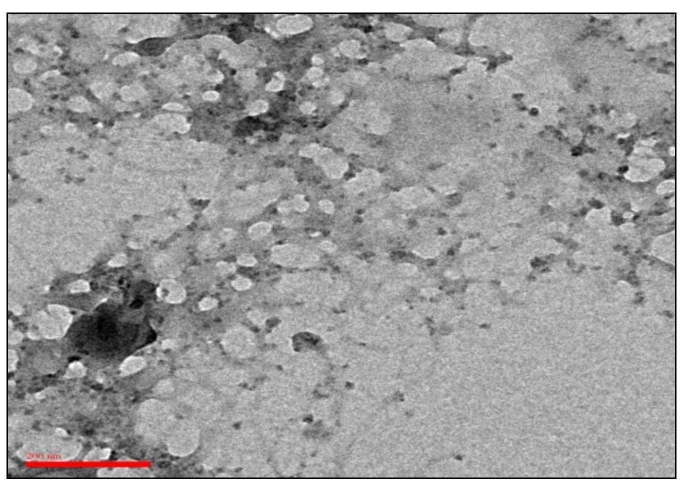

FIG. 2: TEM MICROGRAPH OF SILVER NANOPARTICLES

Nanoparticles Synthesis Mechanism used by Biological Agent: Biological resources have different mechanisms for synthesis of nanoparticles. In the biological synthesis of nanoparticles, the reducing agent and stabilizers molecules produced by bacteria, fungi, algae, and plant. In the biological synthesis, toxic and organic reagent is avoided. Nanoparticles are usually formed following this way: metal ions are first trapped on the surface or inside of the microbial cells. The trapped metal ions are then reduced to nanoparticles in the presence of enzymes. In general, microorganisms impact mineral formation in two distinct ways. The possible mechanism of biological nanoparticles synthesis involved enzymatic and non-enzymatic reduction.

The enzymatic pathway is either extracellular or intracellular [5, 26, 27]. In the intracellular, the metal ions reduce by enzyme nicotinamide adenine dinucleotide phosphate (NADH), and it protracts the organisms from electron damage. The intracellular enzymatic pathway of reduction of ions is slow [29]. He extracellular pathway of nanoparticles synthesis through reductase enzyme and is faster than their counterpart. The non - enzymatic nanoparticles synthesis is similar to chemical reduction but reducing, and stabilizing agent is the biological source. In the biological synthesis is dependent upon the culture media, pH, temperature and oxygenation, *etc*. The different kinds of microorganisms have a different parameter to produce optimum nanoparticle. The best quality of biological synthesis is the manipulation of culture condition such as pH, the temperature the shape and size of nanoparticles can be modified as well as the effect on nanoparticles production. List of bacterial species involve in intra, and extracellular synthesis of nanoparticles are given in **Table 1**.

TABLE 1: NANOPARTICLES SYNTHESIS BY BACTERIA EITHER INTRA AND EXTRACELLULAR

S. no.	Bacterial name	Nanoparticles	Size	Reference
1	*Vibrio alginolyticus.*	Ag	50-100nm	31
2	endophytic bacterium *Bacillus cereus*	Au	16-40nm	32
3	*Pseudomonas aeruginosa* KUPSB12	Ag	50-85nm	33
4	*Rhod opseudomona ssps.*	Ag	6-10nm	34
5	*Halococcus salifodinae BK6*	Ag	-----	35
6	*Lactobacillus acidophilus, Lactobacillus casei, Bifido bacterium* sp., *Klebsiella pneumonia*	Se	50-500,50-500,400-500,100-550	36
7	*Bacillus strain* CS 11	Ag	42-92nm	37
8	*Lactobacillus crispatus*	Ag	70.98nm	38
9	*Bacillus cereus*	Cds	30-100nm	39
10	*Exiguobacterium mexicanum* PR 10.6.	Ag	5-40nm	40
11	*Acineto bacter sp.* SW 30	Au	20±10nm	41
12	*Alteromonas macleodii*	Ag	70nm	42

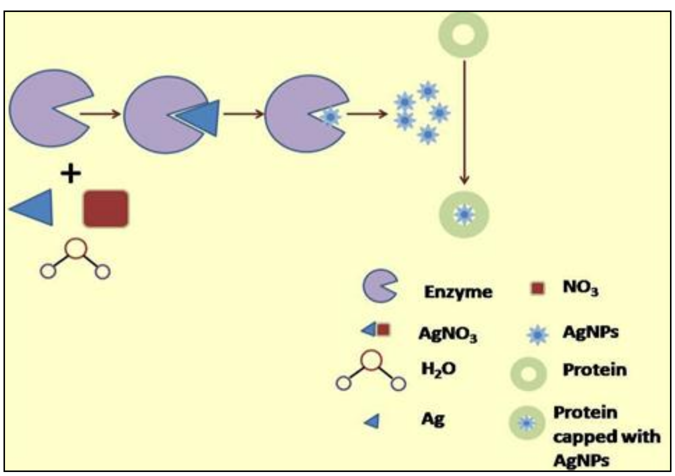

FIG. 3: MECHANISM OF NP SYNTHESIS (FIGURE ADOPTED FORM SAXENA *et al.* [30], 2014)

Application of Nanoparticles: Right now various kinds of nanoparticles are synthesis by biological methods, in which silver nanoparticles (AgNPs) are more concentrate by researcher due to their unique properties.

To date, nanoparticles are mostly prepared from metals, *i.e.*, silver [43]gold [44], iron [45], palladium [46], titanium [47], selenium [48], uranium [49], magnetite (Fe_3O_4) [50], zinc [51] and copper [52]. These metallic nanoparticles are used in pharmaceuticals, agriculture, optics, electronics, catalysis, bio-medicine, magnetics, mechanics, energy science, *etc*.

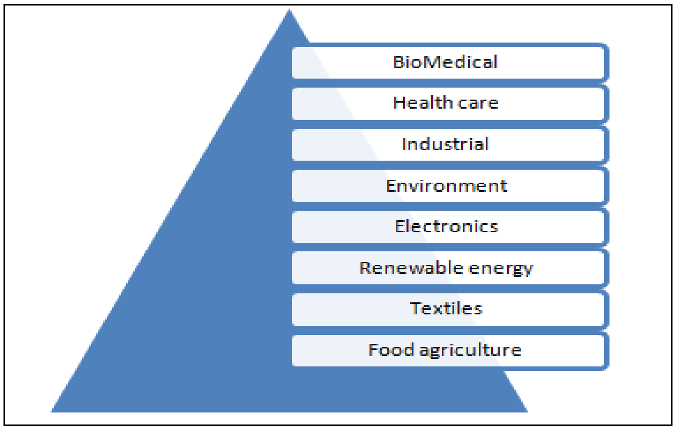

FIG. 4: APPLICATION OF NANOPARTICLES IN VARIOUS FIELDS

AgNPs have the great attention due to their medical application. Huge number of bacteria has been reported as AgNPs synthesis. AgNPs report as having highly antimicrobial properties and therapeutically potential. Recently, the antitumor activity of AgNPs against various cancerous cell lines was also reported [53]. It can create reactive oxygen species (ROS) which cause irreversible damage to bacteria and also have a strong affinity in binding to DNA or RNA which interferes with the microbial replication process [54]. Recently, AgNPs used in biomedical application such as diagnostic applicative biological tags, anti-fungal, anti-inflammatory, anti-angiogenic, and anti-permeability [55-57] wound dressings and healing [58-63]. They are used in HIV treatment, food packaging, and as catalyzes in chemical reactions [11]. A gold nanoparticle (AuNPs) is used as equal to silver nanoparticles. The gold nanoparticles have high chemical and thermal stability, and electronic properties increase their application in various filed. In biomedicine, AuNPs are used in several purposes such as leukemia therapy [64], bio-molecular immobilization [65] and biosensor design. It is used as anti-angiogenesis, anti-malaria and an anti-arthritic agent is also reported by [66].

Magnetic nanoparticles have too much scientific awareness by using magnetic nanoparticles for biological and medical purposes [67]. Magnetic iron oxide-based inorganic nanoparticles have been synthesized and tested for various applications in medicine: as imaging agents, as heat mediators in hyperthermia treatments, in tissue repair, immunoassay, detoxification of biological fluids, cell separation, as magnetic guidance in drug delivery.

Titanium dioxide (TiO_2) is materials have high importance in various fields such as paints and varnishes, paper and plastics, photocatalysis, gas sensors, solar cell devices, and biomaterials. TiO_2 is efficient photocatalysts, used in the removal of environmental contamination such as air and water cleaning and surface cleaning. Titanium pins are used in medical applications due to their non-reactive nature when contacting bone and flesh[68].

CONCLUSION: The review focus on nanoparticles synthesis by bacteria and their applications. The review summarizes the importance of bacteria in biological methods. The main emphasis should be to improve the synthesis efficiency and control of nanoparticles size and morphology, stability of nanoparticles as well as increase their application in medical and another field also.

Future Prospects: Due to the large drawback of the physical and chemical method the researcher is focusing on the biological method. In the biological method, various biological resources are available such as plant, fungi, algae, bacteria, and virus. Bacteria are a better option as compared to other biological sources since the growth of bacteria, culture condition, pH and temperature, and other factors can be varied easily, and size, shape, and morphology of nanoparticles can be controlled. Hence, more research needs to do on understanding the cellular and molecular level of synthesis.

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