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Comprehensive Review on Biological Synthesis of Copper Nanoparticles and Their Multivariate Applications

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ABSTRACT

The world dealing with nanoscale is rapidly gaining importance in wide variety of fields. High pace emergence of nanoparticle applications is demanding the use of biological resources for their clean, nontoxic and ecofriendly synthesis. Copper Nanoparticles (CuNPs) have exceptionally favourable physic chemical properties such as high electrical conduction, high surface activity and excellent biocompatibility which encourage their applications in agricultural and industrial domains. Applicability in magnetic nano devices, multiple electronic devices and integration in materials and medicines in turn enhance the significance of CuNPs. The synthesis of CuNPs is possible by physical, chemical as well as biological methods but due to high energy demand, high cost, long time requirement and toxicity related issues, physical and chemical methods face drawbacks. Use of biological methods can fulfill the shortcoming faced by the other two methods and can render safe, economical, sustainable and eco friendly synthesis. Biological resources comprising simple bacteria to complex higher organisms are being exploited for the synthesis of NPs. Hence this review deals with CuNPs and their potential applications along with various biological synthesis strategies and their advantages over one another.

Keywords: Copper nanoparticles; Biological synthesis; Application of CuNPs; Biological resources; Biocompatibility

INTRODUCTION

Nanoparticles (NPs) ranges from 1-100 nm in size, and are also called zero dimensional Nanomaterials (NMs). NPs carry unique biological, optical and physiochemical properties which are broadly applied in medical, environmental, genetic engineering and industrial fields. They are categorized into organic (Carbon NPs) and inorganic NPs (magnetic NPs, semiconductor NPs and noble metal NPs like gold and silver). Metals like aluminum, zinc, titanium, iron, copper etc are also widely used in the synthesis of NPs due to their comparable inertness at nano scale. They can be naturally occurring in volcanic ashes, dust storms etc. or in combustion products like welding smoke, cigarette smoke etc. but man-made NPs like fullerenes, quantum dots, metal nanoparticles etc. are of main importance as they can be used for wide range of purposes. The synthetically produced man made NPs are selectively produced and tailored for specific properties like shape, size and surface area, and fabrication of specific NMs. The branch of science dealing with the synthesis and wide applications of NPs is known as Nanotechnology. NPs can be synthesized by various methods which broadly include

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chemical, physical, and biological methods. Chemical and physical methods consist of sol gel, chemical or physical vapor deposition, and lithography and electro deposition. But the use of these methods is restricted due to high energy demand, toxic solvents involved, high cost, elongated time and non-ecofriendly nature. On the other hand biological methods being safe, economical, sustainable and eco-friendly prove themselves a better option. Biological methods are based on the bottom up approach which involves redox reaction, and include wide range of plants and microorganisms for NPs synthesis. It can be further divided into intracellular and extracellular production of NPs which consist of microbial cells (algae, human cell, bacteria, fungi and yeast) and plant extracts respectively. Microbial cells produce metabolites and protein which has the potential to reduce metal ions into atomic metal which gives NPs. Literature available on CuNPs synthesis reported that it is susceptible to oxidation. Thus most booming chemical synthesis of metallic CuNPs is either conducted in organic or aqueous phase to avoid potential oxidation of Cu. Presently, pure metallic CuNPs biosynthesis in aqueous phase is a challenging task for bio nanotechnologists.

LITERATURE REVIEW

Henceforward this review focuses on CuNPs and its synthesis strategies, how these strategies differ from one another in various aspects and applications of CuNPs to provide necessary background information for further research and advancement in the applications of Cu-based NPs [1-4].

Copper Nanomaterials: Synthesis Methods and Challenges

CuNPs are fairly susceptible toward aqueous environment, when CuNPs are located in the open air, clumping occurs instantaneously, because of outside oxidation. To overcome such aggregations, and gas which is inert in nature, for example argon or nitrogen is used. Various solvents which is consist inorganic solvents have been used in few cases. The application of defensive polymers or detergents is frequently used for the production of CuNPs. CuNPs can be synthesized by several different techniques, usually classified as bottom up which include chemical and biological methods and other approaches. Through the bottom up method, the organization of NPs is built by various stages such as atoms, molecules or in form of clusters. In the latter approach that is top down approach, a mass portion of mandatory material is abridged to nano sized proportions with the help of different techniques (Figure 1). Chemical reduction, micro emulsion (colloidal) techniques, sono chemical reduction, electro chemical, microwave assisted, and hydrothermal syntheses are the most important methods to produce the NPs by the bottom up approach based chemical method. Biological methods are also based on bottom up approach. Physical methods for NPs fabrication include, vacuum vapor deposition, laser (pulse) ablation, Pulsed Wire Discharge (PWD) and mechanical milling. An extensive variety of NPs might be synthesized by physical methods with slight alterations for various metals; however the most important restrictions of these approaches are the superiority of the product that is fewer in contrast to NPs created by chemical methods. Typically these techniques need expensive vacuum systems or equipment's to set up NPs. Throughout the chemical production procedure of CuNPs, the development and morphology might be regulated through standardizing reaction conditions, like temperature of surface denaturing agents and amount, presence of precursors, solvents and stabilizing agents used. With these optimum reaction conditions, a narrow size distribution throughout chemical production may be attaining. Synthesized these CuNPs approaches are suitable for laboratory scale production as; these methods are not inexpensive for a large-scale or profitable system. In green nano biotechnology, NPs or NMs can be synthesized with the usage of biological routes such as involving microorganisms, plant extracts, and viruses or their products like proteins, lipids etc, with the help of various biotechnological tools. Based on several aspects, NPs produced by green technology are far superior and of fine quality to those manufactured by physical and chemical methods as green techniques eradicate the use of expensive materials, utilize least energy, and can produce various products which are friendly to environment and benevolent products and byproducts. Accordingly, photosynthetic route of nanotechnology is a potential alternate way for production of biocompatible stable NPs. Biological method based production of NPs utilizes the bottom up approach in which synthesis takes place by reducing and stabilizing agents. Generally there are three steps are used for the NPs fabrication by gical route: the optional of solvent system, and the alternative of an environmental friendly material also used as a capping agent [5-9]. The wealthy biodiversity of biological components has been explored for the production of bio nanomaterials, which are ecofriendly and may be used in different medical applications.

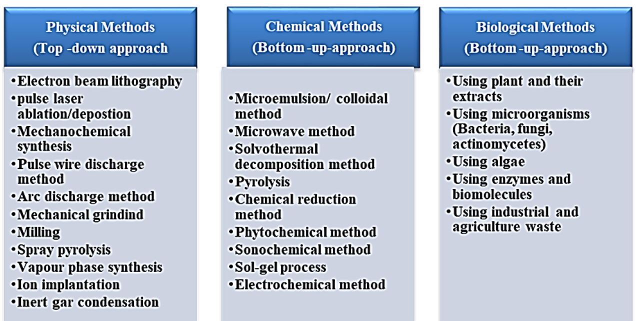

Figure 1: Various methods for synthesizing copper nanoparticles.

Biological Methods for Copper Nanomaterials Production

Biological synthesis of NPs is included in a bottom up method, including the oxidation/reduction which is the important reaction which is found throughout the process of synthesis. NPs are the reduced form of metal compounds due to the microbial enzymes or the phyto constituents as they comprise antioxidant or reducing properties.

Fabrication of Copper Nanoparticles using Micro-organism

Presently, the production of metal NPs have gained wide recognition due to its ample range of advantages in different areas. Many researches in nanotechnology now a day are focusing on acclimatizing the electrical, optical and electronic properties of NPs. According to a past research, spherical CuNPs have been synthesized by a rapid biological method, by non-pathogenic *Pseudomonas stutzeri.* CuNPs recommend elevated attraction for surface active groups of bacteria and have been engaged for *B Sub ili*. In a pioneering approach, *Pseudomonas stutzeri* bacterial strain was used for CuNPs fabrication from electroplating wastewater. The bacterial strain was notable and isolated from soil and establishes that it formed 50-150 nm sized cubical CuNPs. CuNPs take part in essential tasks in optics, electronics, and antimicrobial areas. Al-Ahram and Ahmed, reported synthesis of CuNPs with different measures by a simplistic and superficial chemical copper nitrate Cu $(NO_3)_2$ reduction solution using Isopropyl Alcohol (IPA) as a reducing agent and Cetyl Trimethyl Ammonium Bromide (CTAB) as a capping agent. The Cu $(NO_3)_2$ and CTAB concentration ratios relationship and the measures such as size and shape of the CuNPs were clarify and illuminated by optical measurements. According to reports a hexagonal CuNPs were formed at a high CTAB concentration, On the contrary, high concentration of copper nitrate were induced formation of spherical CuNPs. TEM investigation demonstrated that, the CuNPs were found in various sizes, and exhibited at 551-572 nm which have characteristic adsorption bands. Different sized and shaped CuNPs has the electro catalytic activities towards H_2O_2. Electro catalytic action was powerfully which is based on the CuNPs microstructures. Additionally, the planned sensor established noteworthy antimicrobial activities against gram negative *(E. coli)* bacteria. Synthesized copper NPs by using extracellular reduction process with salmonella typhimurium, which was further reported to be an easier technique to the fabrication of CuNPs. Herein process, salmonella typhimurium culture supernatant was introduced in aqueous copper nitrate solution (1 mM), and copper NPs having average diameter of 49 nm. A gram-negative bacterium from the midget of *S. ibara* sp. which is found an insect of the Cerambycidae family of beetles. According to this is a unique bacterium which is quite precise for the fabrication of CuO. By following the reaction systematically, they could delineate and outline that the fabrication of nanoparticles occurs within cell. However, this particular process results in the killing of bacterial cells. Fungi produce enzymes and proteins like reducing and dropping agents which might be used for the assimilation of metal NPs from metal salts. Large scale synthesis of NPs from diverse and unlike fungal strains has potential efficacy because they may be developed even *in vitro*. More than the modern time, different approaches have been prepared to create succumb of NPs of varying shape, size, and stability. These NPs can be distinguished by using thermo gravimetric analysis; X-Ray Diffract meter (XRD), SEM/TEM, zeta potential measurements etc. A natural and likely process (biological system) developed by for the fabrication of NPs and feasible exclusion of Cu from waste water through the yeast *Rhodotorul amucilaginosa* dead biomass. Biomass of *Rhodotorul amucilaginosa* was used to investigate, estimate and observe the equilibrium and kinetics of Cu bio sorption through the yeast. Intracellularly synthesized NPs were widely spherical in shape (approximately 10.5 nm). Arrangement of metallic Cu can be analysed by X-ray Photoelectron Spectroscopy (XPS). Dead biomass of *Rhodotorul amucilaginosa* can be considered as a potential, rapid and economic to synthesis of CuNPs and also a may be nano adsorbent in bioremediation of wastewater procedure. **Table 1** summarizes the various reported studies for antimicrobial activity against different pathogens [10-13].

Table 1: Green synthesized CuNPs showing anti-microbial activity against various pathogens.

Biological entity	MOs species	Size of NPs
Bacteria	*Escherichia coli*	
	M. psychrotoleransand M. morganii RP42	15-20 nm
	Pseudomonas fluorescens .	49 nm
	Pseudomonas stutzeri	8-15 nm
	Pseudomonas aeruginosa	15-21 nm
	klebsiella pneumonia, propioni bacterium acnes, salmonella typhi	10-60 nm
	S. enterica	15-21 nm
	M. luteus	15-21 nm
	E. aerogenes	15-21 nm
	Pseudomonas stutzeri	50-150 nm

	Serratia	-
	Streptomyces sp	-
Fungi	*Fusarium oxysporum*	93-115 nm
	Hypocrealixii	24.5 nm
	Candida albicans	50-300 nm
	Penicillium aurantiogriseum, Penicillium citrinum, Penicillium waksmanii	
Algae	*Bifurcari abifurcata*	5–45 nm.

Green Synthesis of Copper Nanoparticles Using Plants

Foliages have revealed noteworthy ability in heavy metal growth that reported detoxification and toxic metal hyper through natural herbs such as *Thlaspi caerulescens* and *Arabidopsis halleri* investigated the production of AuNPs and AgNPs within live *Medicago sativa* (alfalfa) by Au and Ag ion utilization respectively by using solid media. It has also been reported that the alfalfa plants were grown-up in an AuCl abundant environment. Which has been confirmed by various techniques such as X-Ray Absorption Spectroscopy (XAS) and TEM?.

Figure 2 shows various methods for nanoparticles synthesis through green route. An extremely important role is played by various plant metabolites, such as polyphenols, carbohydrates specially sugars, alkaloids, terpenoids and proteins to produce NP by the reduction of metal ions. Biological synthesis of AuNPs using *N. arbortristis* resulted in synthesis of spherical shaped AuNPs. It was explained by that low molecular weight biomolecules such as below 3 kDa resulted in decline of chloroaurate ions foremost to the synthesis of Au nano triangles by Aloe Vera plant extracts. Stable AuNPs were also synthesized at room temperature for long duration using *C. sativum* leaf extract. Methanol extra ctofeucalyptushybrid (safeda) leaf was also reported for the fabrication of AgNPs (50-150 nm).

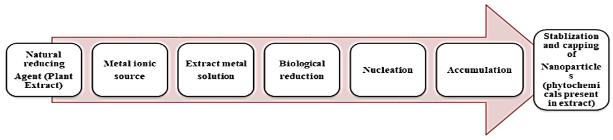

Figure 2: Schematic diagram of green synthesis of nanoparticles using plant extracts.

Which might be presence of different phytoconstitutes such as flavonoid and terpenoid that are also accountable for stabilization of produced AgNPs? The saucuparia leaves extract was also utilized as reducing agent for AuNPs and AgNPs fabrication (**Table 2**) [14-16].

Table 2. Studies for the synthesis of Copper NPs using plants.

Plant	Size of particles
Calotropis procera L.	15 ± 1.7 nm
Euphorbia nivulia	-
Gum karaya	4.8 ± 1.6 nm
Helianthus annus	-
Citrus	10-60 nm
Lantana camara	Average of 20 nm
Ginkgo biloba Linn	15-20 nm
Magnolia	40-100 nm
Vitis vinifira extract	384 nm
Eucalyptus groups	572 nm
Guva leaf extract	-
Magnolia kobus	average size 37 -110 nm

Medicago sativa	-
Euphorbiaceae latex	10.5 nm
Ocimum sanctum	77 nm
Soy beans	-
Syzygium aromaticum	5-40 nm
Capparis zeylanica	60-100 nm
Tridax procumbens	-
Zingiber officinale	40 and 25 nm
Nerium oleander	325-370 nm
Eclipta prostrata	23 – 57 nm
Cassia fistula	239 nm
Gymnemasylvestre	65-184 nm
Delonix elata flower	328 nm
Caesalpinia pulcherrima	18-20 nm
Anthemis xylopoda	-
Curcumin leaf extract	60- 100 nm

DISCUSSION

Applications of Copper Nanoparticles

CuNPs are being given attention due to their attractive properties and potential applications in various industries. CuNPs have potential applications in optics, electronics, manufacturing of lubrications, human health, agriculture, nano fluids, medicine, conductive films, conductive inks and pastes and antimicrobial agents.

Copper NPs in Human Health

CuNPs is a vital component necessary for normal physiological functions in humans, including formation of hemoglobin, metabolism of drugs, carbohydrate, catecholamine biosynthesis, and antioxidant defense mechanism. Though, when the intake of Cu goes beyond the biological tolerance, it could create unpleasant effects, including hemolysis, gastrointestinal distress, liver and kidney damage. Current toxicological investigations of NPs have discovered that NPs tend to reveal fairly diverse toxicological effects *in vivo* in contrast to larger particles of the same chemical constituents. CuNPs exhibit cytotoxic effects on various cell lines. Hence the immense potential of CuNPs in biomedical applications and toxicity studies are mostly restricted to *in vitro* studies. Worldwide potable water is one of the most important aspects and water contamination by microorganism is a big threat. CuNPs have been used as decontaminator for water. Further, the bacterial resistance to antimicrobial drugs has been increased, and now it is considered one of the most important challenges for public health worldwide. CuNPs can stabilize on carbon; polymers, sepiolite, and polyurethane foam which give potential antibacterial activity. Also, it offers a new strategy against drug antimicrobial resistance. Currently, it has been reported that the incorporation of CuNPs to orthodontics adhesives showed significant bactericidal effects against *S. aureus, E. coli,* and *S. mutans,* without altering the shear bond strength, and also increasing their adhesive properties by the addition as nano filler. Nanotechnology provides a cost effective way by applying a surface treatment of metals oxidizing nanoparticles used as an antimicrobial substance. An innovative nanoparticle treatment may convert antimicrobial medical devices. Materials nanostructured have unique physicochemical properties promising for dental applications. CuNPs can be used for screening of different diseases such as hemoglobinopathies, alike, β-thalassemia, because the aggregates could precipitate to a human hemoglobin mutant. Elevated antithrombic activity and imaging applications of CuNPs have also been investigated [17].

Copper NPs in Agriculture

The tendency of the NPs to cross the cell barriers and its relations among cellular organelles due to its tiny size and elevated surface reactivity provided efficient phytotoxicity, genotoxicity, in addition to cytotoxic effect. In spite of growing research on the toxicity of various NPs, partial studies are on hand in higher plants. A handful NPs and herbal varieties have been studied, mostly at its extremely premature development stages. Cu is a vital micronutrient integrated into many proteins and metalloenzymes, and performs a noteworthy role in the health and nutrition of plants (**Figure 3**). Toxicity of CuNPs accessible is very less. Overall, Cu toxicity noticeably decrease the uptake of iron by tomato plant, thus imposing visible symptoms of iron insufficiency. Administration of CuO NPs (0.1 to 0.4 g/L) for forty eight hours, stimulated tremendous inhibition in photosynthesis follow by reduction of growth in *Lemna gibba*, has been reported. The cellular uptake of CuNPs was notably greater than the larger particles when plants were treated with NPs. According to few reports difference in DNA damage profiles of ryegrasses from the radish are influenced by plant species and the concentration of NPs. Germination of lettuce seeds has was reported to be affected by the presence of CuNPs at 0.013% (w/w) concentration.

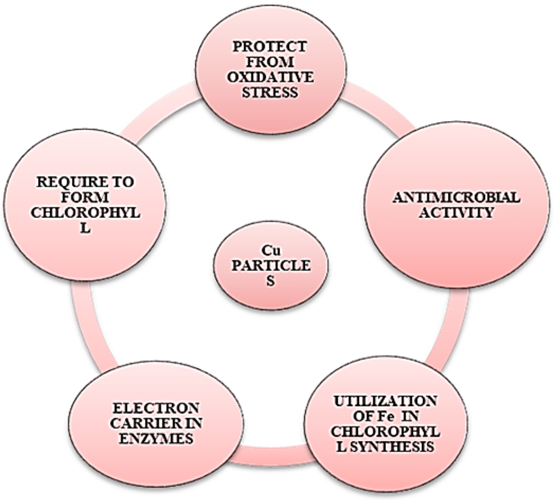

Figure 3: General role of Cu in plants.

Copper NPs as a Catalyst

NPs are as well broadly utilized as catalysts because of the huge specific area and alteration in microelectrode potential values. Stable CuNPs recommend appropriate catalytic properties prepared CuO NPs by *Convolvulus precious* leaves extract, and the activity was tested in the formation of C-N and C-O bonds. The results showed N-arylated and O-arylated products of amides, N-H heterocycles and phenols were produced with good yields. Stabilized CuNPs are more over appropriate for the reduction of dye. The smallest sized NPs showed superior catalytic activity, CuNPs which are stabilized by polymers showed greater catalytic activity for the reduction of nitrobenzene. **Figure 4** shows various applications of Cu as nano catalysts.

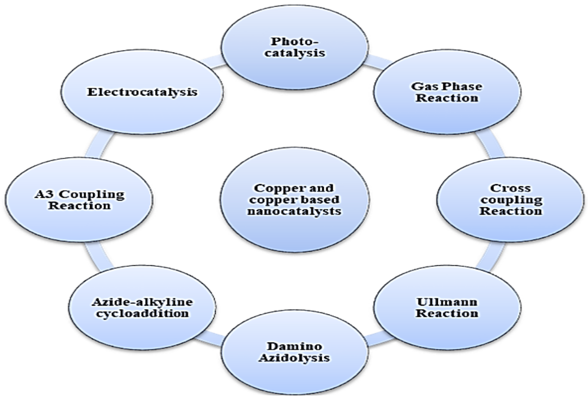

Figure 4: Application of Cu and Cu based nano catalyasts.

Copper NPs in Bio Sensing and Bio Labelling

Some reports are available showing that CuNPs can influence fluorescent materials. CuNPs could result in quenching of fluorescence, aggregation of dye, disaggregation of dye, and improvement in fluorescence. This characteristic might be engaged for bio sensing and bio-labeling studied a copper centered metal organic framework (Cu-MOF) for the electrochemical bio sensing platform for the rapid detection of BPA with high sensitivity. Cu-MOF was synthesized and the proposed technique was successfully applied for fast and selective detection of BPA in plastic products.

CuNPs in Protein Analysis

Electrochemical immune sensors are in focus of significant research in recent years which is based on the combination of immunochemical reactions with electrochemical transduction. The usage of NPs as either immobilization platform or labels in immune sensing system had been denoted in past research. There has been a protocol established or the electrical immunoassay which codes to the coexistence of multiple proteins which are based on the usage of various inorganic nanocrystal tracers. For an instantaneous immunoassay of β_2-microglobulin, IgG, BSA, and C-reactive protein in connection with ZnS, CdS, PbS, and CuS colloidal crystals, respectively the idea was established. In another studied interaction of CuNPs with Bovine Serum Albumin (BSA) under physiological conditions. It was reported that binding of BSA to CuNPs involved one single site, and the binding constant decreased with increase in temperature.

CuNPs as Nanofluid

Recently, after the preface of nanofluids, CuNPs get additional consideration due to its outstanding thermal properties. Nanofluids of CuNPs are used in both heating and cooling. It was reported that CuO or Al_2O_3 nanoparticles in water or ethylene glycol exhibited enhanced thermal conductivity, and 20% maximum increase in thermal conductivity was reported with 4 vol% and 35 nm average CuO nanoparticles dispersed in ethylene glycol. Nanofluid containing CuNPs are discrete in ethylene glycol that has a great advanced effective thermal conductivity. This thermal conductivity is more effective either in pure ethylene glycol or ethylene glycol containing the same volume fraction of discrete oxide NPs. They have demonstrated that the efficient thermal conductivity of ethylene glycol is elevated by up to 40% for a Nano fluid consisting of ethylene glycol containing CuNPs (<10 nm).

CuNPs in Printing

Use of AgNPs in conductive inks in ink jet printing technology has already been discussed in the literature. The high cost of AgNPs restricts its use in industrial applications. CuNPs is cheaper than AgNPs and conductivity is not much different from the AgNPs. Therefore, AgNPs can be replaced with the CuNPs. However, oxidation of CuNPs in air is the major challenge in production and application Studied synthesis of Cu ion complex ink, and reported direct writing of conductive dots and lines with the Cu ion ink. Fine patterning for application in electronics was also confirmed with the Cu ion complex ink. Numerous researches have revealed that the preparation of NPs as conductive inkjet inks, and their printing, might yield conductive models which are stable to oxidation for at least several months obviously, the development of a low or non-conductive shell (polymers, surfactants, carbon or silica) on the copper NPs has a harmful effect on the achieved conductivity of the printed pattern which is composed of the CuNPs (except for cases in which the shell is grapheme or a second metal). This innate challenge between conductivity and coating layers has been reported in the literature. Oxidation resistance along with elevated conductivity was achieved by the development of a PVP shell or a silver shell on the CuNPs. Thus this opened novel potentials for applications in printed electronics, such as solar cells, RFID tags and electroluminescence devices.

Toxicity of Copper Nanoparticles

CuNPs are being widely used in different scientific fields but still they face some drawbacks related to toxicity. *In vivo* studies on *Allogamus ligonifer* shredder revealed that at high concentrations CuNPs showed lethal effects. In another study it became evident that application of CuNPs on SHSY5Y and H_4 cells resulted in cell death in a dose dependent manner hence poses adverse effects on mammalian cells. Study on plants demonstrated that CuNPs decreases the growth of *Lemna gibba*, an aquatic macrophyte, by 50% more in Cs-CuO form as compared to CuO when coated on surface as polymer, thus reducing their toxic effect on plants. In 2014, a study on soil characteristics reported. featured that these nanoparticles also have significant effect of on soil's enzymatic activity. A study on *Epinephelus coioides* in juvenile state reflected oxidative stress in gills, lungs and muscles due to the presence of CuNPs in their comparative study on three fresh water species of fishes (*Oncorhynchus mykiss*, *Pimephales promelas* and *Danio rerio*) showed temperature dependent effect of CuNPs toxicity, also they revealed that differences in physiological characteristics of fishes leads to differences in sensitivity to the toxic effect on gill pavement cell and gill filament damage. In their study on bio distribution and toxicity of CuNPs resulted in 84.5% of highest dissolution in the gastric condition in comparison to Cu ion dissolution in physiological conditions. They also stated that the toxic effects of CuNPs based on mortality, histopathology and biochemistry are significant at higher concentrations in a sex dependent manner and the major affected organs are spleen, liver and kidney studied the effect of CuNPs on two mammalian and two piscine cell lines and proved that morphology, size of particle and release of ions all three factors have significant effect on toxicity status. They also added that although suspensions of CuNPs have high toxicity towards all four cell types but Cu ions lead to effective toxicity at significant level in mammalian cells. in their study reported that CuNPs when used in agricultural as pesticides poses metabolic effects by accumulating Cu and generating the free radical or reactive oxygen species. They also reported that CuNPs in antifouling paints are released as nano or micro sized particles or as dissolved Cu ions. These released species get oxidized and dissolved thus forms Cu S and other compounds which are insoluble causing accumulations in land and aquatic soil thereby leading to a toxic level and hence creates toxicity. Another study by resulted tissue necrosis and dystrophy due to increase in CuNPs concentration. In this study researchers found that caspase 3 levels were elevated in microgliocytes, liver cells, kidney tubules and spleen cells at various time intervals after the introduction of CuNPs at different concentrations with respect to animal body weight. Hence all the above proven facts conclude that although CuNPs find wide application in different fields of science and technology they can also be toxic to a large extent for the living community therefore wise efforts are required to use them in a manner which can fulfill the purpose along with reduction in toxicity.

Current Research Gap and Future Challenges

NPs are attractive, more capable and potential tools for medical diagnostic and therapeutic applications. But their prospective threat to human health, collectively with environmental issues, has led to discrepancies regarding their usage in various fields. Therefore a comprehensive and ample consideration of the interactions that take place at the nano bio interface is needed in order to design safe, reliable, dependable and potential NPs for biomedical applications. Presently, researchers are looking for new routes for fabrication of metallic NPs also there is no doubt that the nanomedicine field is going to provide multiple new solutions and products that will solve healthcare challenges in the coming decades. Developing a system to obtain NPs that offers least possible harm to the environment and which are inexpensive is the need of the hour, but the road is still long and uncertain, although efforts are increasingly higher. As estimated for 2020, the production of nanoparticles focused on nanomaterials will be 20 times higher than that in the last 10 years.

CONCLUSION

Biological tools are considered as significant nanoparticle factories and hold huge potential as eco-friendly and gainful tools, evading toxic, unkind chemicals and the high energy demand essential for physiochemical synthesis. In the present review, we have discussed the synthesis of CuNPs from a variety of agents, where they serve as capping and stabilizing agents for the fabrication of NPs. In addition recapitulated current research into the fabrication of metallic NPs by biological agents is presented. The fabrication of NPs by biological agents has the efficacy to convey novel sources of new materials that are stable, nontoxic, cost effective, environment friendly, and are produced by green chemistry approach. CuNPs have a huge number of applications alike in non-linear optics, spectrally discerning covering for solar energy absorption, biolabelling, intercalation materials for electrical batteries, as optical receptors, high sensitivity biomolecular detection and diagnostics, antimicrobials and therapeutics, catalysis and microelectronics. So, keeping in view the wide application and effectiveness of CuNPs in various fields, further exhaustive research is in demand for new fabrication materials and reduction of toxicity of CuNPs. Hence, this review is an effort to encourage research and support for the same.

CONFLICT OF INTEREST

There is no conflict of interest.

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