ISSN No:-2456-2165

Potential Applications of Green Synthesized Nano Particles in Human Diseases

Nakul Kumar[1*], Rutvik Vyas[2] Sinha[3] and Surabhi Sinha
Swarrnim Science College, Swarnim Startup and
Innovation University, Kalol, Gandhinagar[1-2]
Banaras Hindu University[3]

Corresponding Author:
Dr. Nakul Kumar*

Abstract:- An emerging area of biology and engineering is nanobiotechnology. Due to its environmental friendliness, using green chemistry to design and develop biocompatible nanoparticles is always a better option. The green chemistry method for making metal nanoparticles has a number of advantages over traditional synthetic techniques, including being easier, safer, quicker, more energy-efficient, mostly one-pot processes, less expensive, and less toxic. Noble nanoparticles (gold, silver, and platinum) are particularly appealing in biomedical applications due to the presence of unusual physicochemical properties, ease of synthesis and surface modification in the nanoscale range, biocompatibility, and a number of other benefits. Gold nanoparticles (AuNPs) are particularly attractive because they are biocompatible. recent discoveries Although the SARS-corona virus 2 infections do not primarily affect the skin, they do in some way, either directly or indirectly, exacerbate skin eruptions. Recent research has shown that curcumin-mediated generated AgNPs may play a role in RSV entrance by inhibiting interactions with the viral surface and damaging viral protein. Copper iodide floral extract (CuI-FE), which has strong COVID-19 inhibitory action, was developed via contemporary molecular docking research. Numerous studies show that green synthesis-mediated nanoparticles including silver, gold, zinc, copper, iron, titanium dioxide, selenium, and cadmium have a strong anti-viral effect. The anti-oxidant, anti-viral, anti-inflammatory, anti-hive rich plant-mediated nanoparticle synthesis was used to treat the skin condition caused by SARS-corona virus 2 (the viral clinical signs are itchy, hives, rashes, papules, psoriasis, and inflammation) and (non-viral clinical signs-pressure urticaria, contact dermatitis, and acne).

Keywords:- *Green synthesis; Nano-particle; Human Disease; COVID-19; Biomolecules.*

I. INTRODUCTION

There are several significant obstacles that nanobiomedicine and parasitology must overcome, most of them have to do with the lack of efficient preventive and therapeutic methods for cancer and diseases spread by mosquitoes. In this case, using botanical and invertebrate extracts as reducing, stabilising, and capping agents for the synthesis of nanoparticles is preferable to using chemical and physical methods because it is simpler, less expensive,and doesn't require using toxic chemicals or high pressure, energy, or temperature.(Benelli, 2016). With the ability to manipulate matter's size (*1-100 nm) in the atomic, molecular, or macromolecular range and create fundamentally novel features and functions, nanotechnology is the most promising field of modern science (Elizondo *et al.*, 2012). In addition to size, the nanomaterials' increased surface to volume ratio, surface energy, and aspect ratio help them exhibit a number of striking physical, chemical, biological, and optical features when compared to their bulk scale. Numerous industries have benefited from the widespread use of nanotechnology in areas such as catalysis, electronics, optics, solar cells, the food industry, engineering, textiles, paints, drug delivery, diagnostics, therapies, and imaging, among others (Jana and Jana, 2017).

(Anand *et al.*, 2017)As a safe substitute for risky chemical and physical synthetic processes, the biosynthesis of metal nanoparticles (NPs) using medicinal plants has drawn a lot of interest. Plants are used for their special metal tolerance and efficient synthesis of gold metal nanoparticles (NPs). Proteins, vitamins, enzymes, amino acids, polysaccharides, and other "environmentally benign, yet chemically complicated" chemical components are found in abundance in a single medicinal plant, making them great tools for improving therapeutic uses. In order to create stable gold and silver NPs, it is said that phytocompounds like terpenoids, polysaccharides, polyols, and flavones participate in bio-reduction, stability, and bio-capping mechanisms. (Shaheen *et al.*, 2016)A study of enzyme inhibitor kinetics, ligand binding dynamics, and in silico docking studies that disclose the manner of bioactive substances and their inhibitory activities are then followed by the inhibitory potential of plant drugs against diabetes targets. The potential anticancer, antidiabetic, and antibacterial action of phytosynthesized gold and silver NPs is the main emphasis of the current review.(Kummara, Patil and Uriah, 2016)

A range of nano biomaterials with uses in biology and medicine have been developed as a result of the innovative technique known as nano biotechnology. Despite having potential antibacterial characteristics, the majority of methods for creating these nanoparticles are expensive and may be harmful to the environment, biological systems, and human health because they use hazardous and toxic chemicals. (Yazdanian *et al.*, 2022)Technologies for synthesising "green" nanoparticles have been developed as a result. (Souza *et al.*, 2018)This option uses biological systems like yeast, fungus, bacteria, and plant extracts instead of dangerous chemicals, making it safer and more environmentally friendly than chemical methods. (Emmanuel *et al.*, 2017)The availability of a wide variety of metabolites with strong reduction potentials, global distribution, safe handling, minimal waste and energy costs, and large and accessible reserves are only a few of the many reasons why plant extracts are widely used.

A. Green Synthesis of Synthesis NPs'

The study of materials in the nanoscale, which is typically between 1 and 100 nm, is the subject of the scientific field known as nanotechnology.(Gour and Jain, 2019) It is a science that operates at the nanoscale and provides different focal points to the many different scientific disciplines, including bioengineering, pharmacology, and dentistry (Rafique *et al.*, 2017). The future of nanomaterials depends on the use of green chemistry. This field of nanoscience ought to lead to the creation of eco-friendly, secure NPs and achieve widespread recognition in the nanotechnology (Varma, 2012). The morphology of integrated particles, such as their size, physicochemical properties, and shape, is greatly influenced by the solvents and reducing operators used for the reduction of the NPs, and this morphology affects the usage of NPs. The two distinctive approaches for the amalgamation of NPs are top down and bottom up.(Nadagouda and Varma, 2008).

B. Green synthesis using plant extracts

Unlike microbes, plants have been exploited extensively. This is due to the increased stability and decrease of plant phytochemicals. (Zeb *et al.*, 2019)AgNPs were created using Eugenia jambolana leaf extract and showed the presence of alkaloids, flavonoids, saponins, and sugar compounds. A Saracaasoca bark extract revealed the presence of carboxyl and hydroxyl groups.(Banerjee and Nath, 2015).

The ecologically beneficial "green chemistry" concept has been used in the biosynthesis of nanoparticles to create clean, environment-friendly nanoparticles that involve bacteria, fungus, plants, actinomycetes, etc.(Jadoun *et al.*, 2021)This process is referred to as "green synthesis"(Pal, Rai and Pandey, 2019). The creation of nanoparticles with novel characteristics through biosynthesis employing the aforementioned organisms is a sustainable alternative. Both single-celled and multicellular organisms are permitted to respond in these syntheses(Mohanpuria, Rana and Yadav, 2008).

II. USE OF ORGANISMS IN THE SYNTHESIS OF NANOPARTICLES

In this article, we list some of the organisms that are used in the biosynthesis of nanomaterials and discuss the qualities that should be present in all nanoparticles for the production of desired nanoparticles. The following is a list of somecreatures that have been utilised to produce nanoparticles.(Singh *et al.*, 2020)

A. Use of Bacteria

The ability to manufacture silver nanoparticles using the bacteria Pseudomonas stutzeri AG259 isolated from silver mines has been demonstrated(Joerger, Klaus and Granqvist, 2000). It has been reported that magnetotactic bacteria have been used in the manufacture of magnetic nanoparticles. Two different sorts of particles are produced by magnetotactic bacteria like Magnetospirillum magneticum; some make chains of magnetic (Fe_3O_4) and others produce greigite (Fe_3S_4) nanoparticles, while others produce both forms.

B. Use of Yeast

The biosynthesis of cadmium sulphide (CdS) nanocrystals was carried out for the first time using the Candida glabrata and Schizosaccharomycespombe. Cadmium salts were employed to create these nanocrystals, which are currently found in quantum semiconductor crystallites (Shah *et al.*, 2015). To increase the amount of semiconductor CdS nanocrystals produced using Schizosaccharomycespombe cells, additional studies have been carried out.Maximum nanocrystals were produced when these cells were exposed to 1 mM Cd during their mid-log phase of growth (Kowshik *et al.*, 2002).According to this study, the yeast growth phase affected how CdS nanocrystals were formed.

C. Use of fungi

Fungi can be used to produce nanoparticles with well-defined dimensions in addition to good monodispersity. This was demonstrated in an experiment utilising the fungus Verticillium sp. to bioreduce aqueous $AuCl_4$ ions, which produced gold nanoparticles with rather well-defined dimensions and good monodispersity(Mukherjee *et al.*, 2001).Here, enzymes in the cell wall reduced gold ions, which caused metal atoms to aggregate and produce gold nanoparticles. They were unable to identify the precise process by which gold nanoparticles are formed, though. Their research suggests that, in comparison to bacteria, fungi may be a source for significant nanoparticle creation. (Mukherjee *et al.*, 2002)Fungi are known to secrete substantially higher levels of protein, therefore using a biosynthetic technique might result in significantly better nanoparticle yield.

D. Use of Plants

Plants have been shown to be a good source for the production of quantum dots, which have a wide range of applications in nanobiotechnology. One of the intriguing studies using alfalfa shows that it is possible for living plants to synthesise quantum dots. *Alfalfa* roots have the ability to take in Ag (0) from an agar medium and transport it in the same oxidation state to the plant's shoots.(Armendariz *et al.*, 2004). These Ag atoms joined together to create larger arrangements in the shoot, where they then organised themselves to produce nanoparticles. A study using a TEM and SEM revealed that the accumulated Ag atoms inside the plant tissue underwent nucleation, resulting in the production of nanoparticles.(Gardea-Torresdey *et al.*, 2000)

Cinnamomumcamphora leaf extract has recently been discovered for the synthesis of gold and silver nanoparticles, expanding the list of plants exhibiting potential for nanoparticle manufacturing (Huang *et al.*, 2007). The significant shape control difference between silver and gold nanoparticles was ascribed to the relative advantages of protective and reductive biomolecules. It was discovered that the stability of the nanoparticles and the reduction of silver ions or chloroaurate ions, respectively, were mostly caused by the watersoluble heterocyclic and polyol components.

III. NANOPARTICLES FOR DIAGNOSTICS

Due to its simplicity, high sensitivity, and high specificity based on the exponential growth in RNA produced throughout the procedure, the reverse transcription polymerase chain reaction (RT-PCR) is the basis for the majority of viral RNA detection methods.(Corman *et al.*, 2020) Even though RT-PCR techniques are widely recognised as the gold standard for coronavirus detection, there are several issues that need to be resolved, such as low extraction efficiency, the necessity for time-consuming procedures, and contamination-related false positive results. (Coronavirus *et al.*, 2004) Due to their high surface area and ultrasmall size, NPs have been used in RT-PCR as well as other virus detection techniques, including an enzyme-linked immunosorbent test (ELISA) and reverse transcription loop-mediated isothermal amplification, to increase the effectiveness of virus detection (RT-LAMP). In the area of virus detection, a variety of NP types have been investigated, including metal NPs, carbon nanotubes, silica NPs, quantum dots (QDs), and polymeric NPs. Among these, coronavirus detection has been used with metal NPs, metal nanoislands (NIs), magnetic NPs (MNPs), and QDs. The majority of these diagnostic approaches rely on optical, electrochemical, fluorescent, and colorimetric detection methods. A list of the NPs employed in the diagnostic detection of coronaviruses.

IV. NANOPARTICLES THAT BLOCK VIRAL REPLICATION AND PROLIFERATION

Therapeutics that slow the spread of viruses or their infectiousness are crucial in the treatment of viral infections. These medicines will keep the viral levels in the body low enough for the immune system to act as the body's first line of defence while also preventing the virus from developing a genetic resistance to the treatments. (Griffith *et al.*, 2015)In order to create efficient treatments, coronavirus-related respiratory disorders have attracted a lot of scientific focus during the past ten years due to several outbreaks. For the purpose of preventing viral multiplication, a variety of NPs have been studied as antiviral agents.(Medhi *et al.*, 2020).

Antimicrobial studies can be performed for Gram-positive S. aureus, B. megatherium, and B. subtilis, and for Gram-negative E. coli, S. typhi, and A. aerogenes organisms using sterile Media under the Disc Diffusion Method. A zone of inhibition of the synthesized compounds was noted and compared with the standard drug Norfloxacin. The entire work was carried out, followed by a horizontal Laminar Flow Hood. The IC50 value corresponded to the concentration required for 50% inhibition(Kumar *et al.*, 2022).

At concentrations below the hazardous limit, silver nanoparticles (AgNPs) and silver nanowires (AgNWs) greatly reduce the transmissible gastroenteritis virus (TGEV), a coronavirus family member, infectivity.(Lv *et al.*, 2014) Additionally, it has been shown that silver nanostructures lessen the amount of cell death brought on by viral infection. According to data, Ag nanoparticles prevent the Pi-p38 protein from being expressed when TGEV is present, therefore controlling the p38-MAPK-p53 mitochondrial signalling cascades. (Xu *et al.*, 2014)This control lessens the amount of cell apoptosis brought on by TGEV infection.

V. NANOPARTICLES AS IMMUNOGENIC AGENTS FOR VACCINES

Vaccination is the most effective defence against a viral outbreak. A robust immune response that results in the formation of long-lasting and protective immunity against the targeted pathogen is the aim of vaccination. Innate (nonspecific) and adaptive (specific) immune systems are two main groups into which the immune system's components fall.(Jun-Ming Zhang, 2009) Natural killer (NK) cells, DCs, macrophages, monocytes, and innate lymphoid cells make up the innate immune system. Innate lymphoid cells integrate and amplify cytokines, while macrophages produce cytokines and chemokines that cause inflammation for local defence or to aid in tissue repair. DCs serve as sentinels. NPs have been used in numerous virus detection techniques. The advantages of increased sensitivity for optical biosensing are provided by metal NPs and QDs with distinctive optical characteristics. Due to their magnetic properties, MNPs are mostly used in the viral extraction process. Additionally, to increase the effectiveness of virus detection, nanohybrid structures combine the benefits of each type of NP. The virus that causes COVID-19, SARS-CoV-2, has just been found, and NP-based virus detection has recently been reported as a promising method to find it. NPs will likely be crucial in advancing the accuracy of diagnosing not only other biological pathogens but also coronavirus detection with continued study and development.

VI. ANTICANCER PROPERTIES

The effectiveness of chemotherapeutic drugs is constrained by rising drug resistance, low bioavailability, and the general toxic character of these agents. As a result, there is a great need for alternate therapy plans to treat cancer. Recent research on the anticancer activity of biosynthesised silver nanoparticles points to their potential application as cancer therapeutics in the future. Numerous studies have demonstrated that silver nanoparticles made through biological synthesis have potent anticancer effects. For instance, using Bacillus funiculus culture supernatant, Gurunathan et al. produced AgNPs that demonstrated antiproliferative activity in MDA-MB-231 (human breast cancer) cells by producing ROS (reactive oxygen species),

ISSN No:-2456-2165

which then caused apoptosis (Gurunathan *et al.*, 2013). Similar to this, Fageria et al. produced silver nanoparticles with protein caps using the Penicilliumshearii AJP05 fungus and established their anticancer activity on mesenchymal (osteosarcoma) and epithelial (hepatoma) cells. The main cause of the cytotoxic action of biosynthesized silver nanoparticles was discovered to be ROS generation. Additionally, according to the scientists, these biosynthesized silver nanoparticles sensitise cancer cells and render them resistant to cisplatin (Fageria *et al.*, 2017). Similar to this, Firdhouse et al. created AgNPs from Alternantherasessilis plant extract, which demonstrated notable cytotoxic action toward prostate cancer cells (PC-3)(Kotcherlakota, Das and Patra, 2019).

VII. ANTI-ALLERGIC ACTIVITY

Male mice were randomly allocated into four groups for the anti-allergy experiment. Sensitization to ovalbumin (OVA) caused asthma to develop. The OVA challenge was then administered to the mice. The mice were first hypersensitized by an IP injection of 1 mg kg-1 of OVA suspended in 1 mL of PBS over the course of three days, with standard saline being administered to the negative control group. Synthesized AgNPs were given orally three days following the last injection, 60 minutes prior to each OVA challenge.(Jamkhande *et al.*, 2019) As a positive control, the second group of mice received no therapy, the third group of mice received 1 mg kg1 of dexamethasone, and the fourth group of mice received 500 mg kg1 of AgNPs. With the exception of the negative control group, which was not disturbed, the mice were then roused after being exposed to OVA for 15 min(Chen *et al.*, 2015). Every day for four weeks, an aerosolized OVA solution was used to stir the mice. After that, the animals were put to death, and blood samples were taken from each mouse's tail vein to measure IFN- levels, eosinophil counts, and blood films. The lungs were separated, cleaned with PBS, fixed with 10% formalin, embedded in paraffin, sectioned, and stained with hematoxylin and eosin for the histopathological investigation. The various groups' lung tissue sections were examined under a light microscope.(Jabir *et al.*, 2021)

VIII. CONCLUSION

As a result, it is anticipated that NPs will be crucial in the battle against human diseases such as, Cancer and COVID-19. Construction of diagnostic test kits can make use of the optical and magnetic characteristics of various NPs. Synthetic NPs and SARS-CoV-2 share striking morphological and physicochemical similarities, which makes NPs an effective tool for intervention. NPs are excellent delivery vehicles and can be systematically functionalized with different proteins, polymers, and functional groups to carry out particular inhibitory functions. NPs present opportunities for rapid and secure vaccine development that uses subunit proteins rather than entire viruses. In addition, NPs can be used to create broad-spectrum respiratory medicines and vaccines that can shield us from seasonal viruses and also get us ready for upcoming pandemics.

ACKNOWLEDGEMENT

Authors are highly thankful to the Swarrnim Science College, Swarnim Startup and Innovation University, Kalol, Gandhinagar and Banaras Hindu University for infrastructural and technical assistance.

REFERENCES

[1.] Anand, K. *et al.* (2017) 'Phytonanotherapy for management of diabetes using green synthesis nanoparticles', *Journal of Photochemistry and Photobiology B: Biology*, 173, pp. 626–639. doi: https://doi.org/10.1016/j.jphotobiol.2017.06.028.

[2.] Armendariz, V. *et al.* (2004) 'Size controlled gold nanoparticle formation by Avena sativa biomass: use of plants in nanobiotechnology', *Journal of Nanoparticle Research*, 6(4), pp. 377–382. doi: 10.1007/s11051-004-0741-4.

[3.] Banerjee, P. and Nath, D. (2015) 'A Phytochemical Approach to Synthesize Silver Nanoparticles for Non-Toxic Nanoscience & Technology : Open Access A Phytochemical Approach to Synthesize Silver Nanoparticles for Non-Toxic Biomedical Application and Study on their Antibacterial Efficacy', (August 2017).

[4.] Benelli, G. (2016) 'Green synthesized nanoparticles in the fight against mosquito-borne diseases and cancer—a brief review', *Enzyme and Microbial Technology*, 95, pp. 58–68. doi: https://doi.org/10.1016/j.enzmictec.2016.08.022.

[5.] Chen, S. *et al.* (2015) 'Dibutyl phthalate induced oxidative stress does not lead to a significant adjuvant effect on a mouse asthma model', *Toxicology Research*, 4(2), pp. 260–269. doi: 10.1039/c4tx00096j.

[6.] Chugh, D., Viswamalya, V. S. and Das, B. (2021) 'Green synthesis of silver nanoparticles with algae and the importance of capping agents in the process', *Journal of Genetic Engineering and Biotechnology*, 19(1), p. 126. doi: 10.1186/s43141-021-00228-w.

[7.] Corman, V. M. *et al.* (2020) 'Detection of 2019 novel coronavirus (2019-nCoV) by', *Eurosurveillance*, 25(3). doi: 10.2807/1560-7917.ES.2020.25.3.2000045.

[8.] Coronavirus, S. *et al.* (2004) 'Real-Time Reverse Transcription – Polymerase Chain Reaction Assay for', 10(2), pp. 311–316.

[9.] Elizondo, N. *et al.* (2012) 'Green Synthesis and Characterizations of Silver and Gold Nanoparticles', in. doi: 10.5772/34365.

[10.] Emmanuel, R. *et al.* (2017) 'Antimicrobial efficacy of drug blended biosynthesized colloidal gold nanoparticles from Justicia glauca against oral pathogens: A nanoantibiotic approach', *Microbial Pathogenesis*, 113, pp. 295–302. doi: https://doi.org/10.1016/j.micpath.2017.10.055.

[11.] Fageria, L. *et al.* (2017) 'Biosynthesized Protein-Capped Silver Nanoparticles Induce ROS-Dependent Proapoptotic Signals and Prosurvival Autophagy in Cancer Cells', *ACS Omega*, 2(4), pp. 1489–1504. doi: 10.1021/acsomega.7b00045.

[12.] Gardea-Torresdey, J. L. *et al.* (2000) 'Reduction and Accumulation of Gold(III) by Medicago sativa Alfalfa Biomass: X-ray Absorption Spectroscopy, pH, and Temperature Dependence', *Environmental Science & Technology*, 34(20), pp. 4392–4396. doi: 10.1021/es991325m.

[13.] Gour, A. and Jain, N. K. (2019) 'Advances in green synthesis of nanoparticles', *Artificial Cells, Nanomedicine, and Biotechnology*, 47(1), pp. 844–851. doi: 10.1080/21691401.2019.1577878.

[14.] Griffith, M. *et al.* (2015) 'Anti-microbiological and Anti-infective Activities of Silver BT - Silver Nanoparticle Applications: In the Fabrication and Design of Medical and Biosensing Devices', in Alarcon, E. I., Griffith, M., and Udekwu, K. I. (eds). Cham: Springer International Publishing, pp. 127–146. doi: 10.1007/978-3-319-11262-6_6.

[15.] Gurunathan, S. *et al.* (2013) 'Cytotoxicity of Biologically Synthesized Silver Nanoparticles in MDA-MB-231 Human Breast Cancer Cells', *BioMed Research International*. Edited by B. E. Kemp, 2013, p. 535796. doi: 10.1155/2013/535796.

[16.] Huang, J. *et al.* (2007) 'Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf', *Nanotechnology*, 18(10), p. 105104. doi: 10.1088/0957-4484/18/10/105104.

[17.] Hussain, I. *et al.* (2016) 'Green synthesis of nanoparticles and its potential application', *Biotechnology Letters*, 38(4), pp. 545–560. doi: 10.1007/s10529-015-2026-7.

[18.] Jabir, M. S. *et al.* (2021) 'Green synthesis of silver nanoparticles from Eriobotrya japonica extract: a promising approach against cancer cells proliferation, inflammation, allergic disorders and phagocytosis induction', *Artificial Cells, Nanomedicine, and Biotechnology*, 49(1), pp. 48–60. doi: 10.1080/21691401.2020.1867152.

[19.] Jadoun, S. *et al.* (2021) 'Green synthesis of nanoparticles using plant extracts: a review', *Environmental Chemistry Letters*, 19(1), pp. 355–374. doi: 10.1007/s10311-020-01074-x.

[20.] Jamkhande, P. G. *et al.* (2019) 'Metal nanoparticles synthesis: An overview on methods of preparation, advantages and disadvantages, and applications', *Journal of Drug Delivery Science and Technology*, 53, p. 101174. doi: https://doi.org/10.1016/j.jddst.2019.101174.

[21.] Jana, Sougata and Jana, Subrata (2017) *Particulate technology for delivery of therapeutics*, *Particulate Technology for Delivery of Therapeutics*. doi: 10.1007/978-981-10-3647-7.

[22.] Joerger, R., Klaus, T. and Granqvist, C. G. (2000) 'Biologically Produced Silver–Carbon Composite Materials for Optically Functional Thin-Film Coatings', *Advanced Materials*, 12(6), pp. 407–409. doi: https://doi.org/10.1002/(SICI)1521-4095(200003)12:6<407::AID-ADMA407>3.0.CO;2-O.

[23.] Kotcherlakota, R., Das, S. and Patra, C. R. (2019) 'Chapter 16 - Therapeutic applications of green-synthesized silver nanoparticles', in Shukla, A. K. and Iravani Characterization and Applications of Nanoparticles, S. B. T.-G. S. (eds) *Micro and Nano Technologies*. Elsevier, pp. 389–428. doi: https://doi.org/10.1016/B978-0-08-102579-6.00017-4.

[24.] Kowshik, M. *et al.* (2002) 'Microbial Synthesis of Semiconductor CdS Nanoparticles, Their Characterization, and Their Use in the Fabrication of an Ideal Diode', *Biotechnology and Bioengineering*, 78, pp. 583–588. doi: 10.1002/bit.10233.abs.

[25.] Kumar, N. *et al.* (2022) 'Modified 7-Chloro-11H-indeno[1,2-b]quinoxaline Heterocyclic System for Biological Activities', *Catalysts* . doi: 10.3390/catal12020213.

[26.] Kummara, S., Patil, M. B. and Uriah, T. (2016) 'Synthesis, characterization, biocompatible and anticancer activity of green and chemically synthesized silver nanoparticles – A comparative study', *Biomedicine & Pharmacotherapy*, 84, pp. 10–21. doi: https://doi.org/10.1016/j.biopha.2016.09.003.

[27.] Lv, X. *et al.* (2014) 'Inhibitory effect of silver nanomaterials on transmissible virus-induced host cell infections', *Biomaterials*, 35(13), pp. 4195–4203. doi: https://doi.org/10.1016/j.biomaterials.2014.01.054.

[28.] Manuscript, A. (2009) 'NIH Public Access', 45(2). doi: 10.1097/AIA.0b013e318034194e.Cytokines.

[29.] Medhi, R. *et al.* (2020) 'Nanoparticle-Based Strategies to Combat COVID-19', *ACS Applied Nano Materials*, 3(9), pp. 8557–8580. doi: 10.1021/acsanm.0c01978.

[30.] Mohanpuria, P., Rana, N. K. and Yadav, S. K. (2008) 'Biosynthesis of nanoparticles: technological concepts and future applications', *Journal of Nanoparticle Research*, 10(3), pp. 507–517. doi: 10.1007/s11051-007-9275-x.

[31.] Mukherjee, P. *et al.* (2001) 'Fungus-Mediated Synthesis of Silver Nanoparticles and Their Immobilization in the Mycelial Matrix: A Novel Biological Approach to Nanoparticle Synthesis', *Nano Letters*, 1(10), pp. 515–519. doi: 10.1021/nl0155274.

[32.] Mukherjee, P. *et al.* (2002) 'Extracellular Synthesis of Gold Nanoparticles by the Fungus Fusarium oxysporum', *ChemBioChem*, 3(5), pp. 461–463. doi: https://doi.org/10.1002/1439-7633(20020503)3:5<461::AID-CBIC461>3.0.CO;2-X.

[33.] Nadagouda, M. N. and Varma, R. S. (2008) 'Green synthesis of silver and palladium nanoparticles at room temperature using coffee and tea extract', *Green Chemistry*, 10(8), pp. 859–862. doi: 10.1039/B804703K.

[34.] Pal, G., Rai, P. and Pandey, A. (2019) 'Chapter 1 - Green synthesis of nanoparticles: A greener approach for a cleaner future', in Shukla, A. K. and Iravani Characterization and Applications of Nanoparticles, S. B. T.-G. S. (eds) *Micro and Nano Technologies*. Elsevier, pp. 1–26. doi: https://doi.org/10.1016/B978-0-08-102579-6.00001-0.

[35.] Rafique, M. *et al*. (2017) ‘A review on green synthesis of silver nanoparticles and their applications’, *Artificial Cells, Nanomedicine, and Biotechnology*, 45(7), pp. 1272–1291. doi: 10.1080/21691401.2016.1241792.

[36.] Rónavári, A. *et al.* (2021) ‘Green Silver and Gold Nanoparticles: Biological Synthesis Approaches and Potentials for Biomedical Applications’, *Molecules*. doi: 10.3390/molecules26040844.

[37.] Shah, M. *et al.* (2015) *Green Synthesis of Metallic Nanoparticles via Biological Entities*. doi: 10.3390/ma8115377.

[38.] Shaheen, T. I. *et al.* (2016) ‘Antidiabetic assessment; in vivo study of gold and core-shell silver-gold nanoparticles on streptozotocin-induced diabetic rats’, *Biomedicine & Pharmacotherapy*, 83, pp. 865–875. doi: https://doi.org/10.1016/j.biopha.2016.07.052.

[39.] Singh, A. *et al.* (2020) ‘Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review’, *Biotechnology Reports*, 25, p. e00427. doi: https://doi.org/10.1016/j.btre.2020.e00427.

[40.] Souza, J. A. S. *et al.* (2018) ‘Green synthesis of silver nanoparticles combined to calcium glycerophosphate: antimicrobial and antibiofilm activities’, *Future Microbiology*, 13(3), pp. 345–357. doi: 10.2217/fmb-2017-0173.

[41.] Varma, R. S. (2012) ‘Greener approach to nanomaterials and their sustainable applications’, *Current Opinion in Chemical Engineering*, 1(2), pp. 123–128. doi: https://doi.org/10.1016/j.coche.2011.12.002.

[42.] Xu, Y. *et al.* (2014) ‘Selective inhibition of breast cancer stem cells by gold nanorods mediated plasmonic hyperthermia’, *Biomaterials*, 35(16), pp. 4667–4677. doi: https://doi.org/10.1016/j.biomaterials.2014.02.035.

[43.] Yazdanian, M. *et al.* (2022) ‘The Potential Application of Green-Synthesized Metal Nanoparticles in Dentistry: A Comprehensive Review’, *Bioinorganic Chemistry and Applications*. Edited by V. De Matteis, 2022, p. 2311910. doi: 10.1155/2022/2311910.

[44.] Zeb, N. *et al.* (2019) ‘Green nanotechnology : a review on green synthesis of silver nanoparticles — an ecofriendly approach’, pp. 5087–5107.