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# A Comprehensive Review on Microalgae: A Potential Low-Cost Green Option for Manufacturing of Nanoparticles

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**Abstract**: *An environmentally friendly substitute for the conventional chemical methods of synthesis is the recent development of nanoparticle production from biological sources. Microalgae stand out among the many green sources investigated for their prominent advantages in terms of their ease of growth and capacity to endure harsh pH and temperature conditions, making these organisms as potential low-cost, environmentally friendly machinery for the mass synthesis of nanoparticles. Algae are attracting a lot of attention as potential renewable alternatives to the conventional chemical synthesis because of their capacity to treat wastewater, production of a wide range of commercially significant nanomaterials, economically viable growth-associated products, and inherent carbon reduction potentials. The commercial large-scale use of these biological agents is still a loose concept, despite the fact that numerous reviews have emphasized the significance of algal bio factories. It is important that individual research findings on the prospects of algae for nanoparticle production be updated and comprehended together in a way to facilitate scale-up and commercialization of the technology. This is because there is an urgent need to develop efficient alternatives to the currently used sources for nanoparticle synthesis and environmental sustainability. The current mini review gives a brief overview of the development and benefits of microalgae, as well as the most recent developments in the use of microalgae in the biogenesis of nanoparticles and quantum dots. It also makes note of the biosensing and environmental pollution detection capabilities of the nanomaterials derived from microalgae.*

**Keywords:** Biosynthesis, Nanoparticles, Microalgae, Cost-effective, Green factory

## I. INTRODUCTION

Scientific communities around the world have a very clear understanding of the global environmental situation, and distributing clean water, food, and renewable energy in an equal way has long been a source of difficulty and concern. With an increase in population, the globe is quickly transitioning to a resource-intensive lifestyle, and the dynamics of resource usage are frightening, particularly in view of the combined negative effects due to climate change and variations in land use pattern. According to recent projections, demand for sustainable green alternatives is anticipated to increase over the next upcoming years, necessitating a special focus on transdisciplinary holistic approaches that push the idea of turning waste into income. Although academics, policymakers, and the general public are encouraged to participate in the larger picture, it is equally crucial that the scientific community has access to concrete, rigorous data on resource usage for the global situation. In the realm of materials science, green synthesis has emerged as a dependable, long-lasting, and environmentally friendly method for the synthesis of several nanomaterials, including metal oxides, hybrids, and bio-inspired materials[1].

Metallic nanoparticles have fascinated scientists for more than a century and are now widely used in engineering and the health sciences[2]. The synthesis of metal nanoparticles is a significant area of research in nanotechnology because of their anomalous size (length spanning within 1-200 nm) and shape-dependent properties, as well as their appealing applications in medicine, biofuel production, catalysis, electronics, and biotechnology [3]. In order to lessen the negative impacts of nanoparticles frequently utilized in laboratories and industry by conventional synthesis methods, green synthesis is seen as a crucial instrument. The current evaluation covered all of the recognized green synthesis techniques now in use around the world, however it solely paid attention to algae-based green synthesis.

Microalgae are among the earliest tiny plants known to science. In comparison to larger plants, they are much more effective as cell factories for the manufacture of nanoparticles. Algae are aquatic filamentous photosynthetic creatures that belong to the plant family. These algae can be broadly divided into two groups: macroalgae and microalgae[4]. Microalgae cannot be seen without a microscope, whereas macroalgae may be counted with the human eye. In contrast to most biomass, both algae can be harvested multiple times in a single year. Algae can also develop on their own, without the assistance of any additional fertilisers or chemicals from outside sources. Microalgae multiply incredibly quickly; on average, they double their mass ten times faster than higher plants. It is well known that different species of microalgae decrease metal ions.

Algae are considered to be the ancestors of microscopic plants and have minimal benefits over bigger plants in terms of growth rate and food requirements for creating nanoparticles [5]. Metal nanoparticles have been a significant product of microalgae. Biotechnology advancements have predicted that the nanoparticles produced from microalgae offer enormous potential for the large-scale production of metal nanoparticles with potential applications in a variety of industries. The goal of this paper is to increase researchers' understanding of the green synthesis process for creating nanoparticles by utilizing Microalgae species and outlining its numerous benefits and drawbacks.

**Nanoparticle Synthesis through a Bio-Based Method:**

Based on where the generated nanoparticles are found, biosynthetic processes are divided into intracellular and extracellular synthesis [6]. In order to better understand the synthesis processes, as well as to facilitate scale-up and downstream processing, extracellular manufacturing of nanoparticles, for instance, is also being developed. Hence, using algae to create inorganic nanoparticles has attracted a lot of interest from researchers [7]. For the creation of nanoparticles utilizing algae, there are three main methods. There are two additional common approaches in addition to directly using live algae cells for nanoparticle synthesis: lysis of algal cells followed by extraction using various downstream process techniques like centrifugation and filtration, and harvesting of nanoparticles from the supernatants of the algal broth [7]. The last ten years have seen a surge in interest in the field of catalytic processing of algal biomass.

Future economic growth from algae should be significant if efficient upstream and downstream processing can be created. The ability of algae to hyperaccumulate heavy metal ions and transform into more flexible shapes is well known [8]. A model organism for creating bio-nanomaterials has so been suggested as algae. Physical parameters such as pH, precursor concentration, reaction duration, exposure time, and temperature control the nucleation, development, and stabilization of nanoparticles. The size and morphology of the cells can be changed, as well as the avoidance of agglomeration, by adjusting these variables. Depending on the type of algae and its age, algal extracts (phycocyanin and phycoerythrin) contain various concentrations of carbohydrates, vitamins, nutrients, oils, fats, polyunsaturated fatty acids, bioactive substances like antioxidants (polyphenols and tocopherols), pigments like carotenoids (carotene and xanthophyll), chlorophylls, and phycobilin's.Theoretically, these active substances have been referred to as reducing and stabilizing agents in nanoparticle synthesis [8].

Due to their ability to reduce metal ions, nanoparticles made from a variety of algal resources have emerged as one of the newest and most creative fields of biochemical research [9]. Depending on the algae species and method of activity, nanoparticles can be synthesized intracellularly or extracellularly. The newest and most promising species employed for the manufacture of nanomaterials are algae, particularly microalgae. Algae are a more promising alternative for a nanomaterial synthesis agent than other living things or biomaterials. To cultivate diverse algae species, the researchers employed a variety of techniques, including open culture systems (such as open ponds, tanks, and raceway ponds) and closed cultivation systems (such as photo bioreactors) [10]. The majority of experiments show that the production of metal nanoparticles using algae takes place in the following key steps: i) An algal extract is heated or boiled in water or an organic solution for a predetermined amount of time. ii) The creation of molar solutions of ionic metallic compounds. iii) Both algal and ionic metallic compound solutions are incubated for a predetermined amount of time under carefully monitored conditions, either with frequent stirring or without stirring.

Algal cells have lower food requirements than prokaryotic and eukaryotic species, and they also require less upkeep of environmental factors like light and temperature. Many algae that develop in a contaminated environment that contains both metals and non-metals exhibit the ability to withstand significant amounts of metal or non-metal elements. Algae have efficiently developed defense-related mechanisms in order to reduce and improve their survival in greater metal concentrations and the damaging effects of metal ions. Considering how common they are in both freshwater and saltwater, how affordable they are, how easily they can be recycled, and how well they can absorb metals, algae are great bio-sorbents. In a one-step procedure, metallic salt-containing aqueous solution is administered directly to the cells as they are being cultivated in order to produce metallic nanoparticles using microalgal live cells. The creation of colloids is frequently caused by the discharge of the nanoparticles into the culture medium after they have been manufactured and are wrapped in the matrix. This settles into the photo bioreactor because of its weight. The addition of new culture media allows for repeated cycles of nanoparticle production to be carried out as necessary. Moreover, even when imprisoned inside organic vesicles, microalgae maintained their ability to synthesize nanoparticles. A thorough review of the literature reveals that microalgae have been heavily utilised for the production of silver nanoparticles over the past few years. Neochlorisoleoabundans aqueous extract was used in Bao et alnwork .'s on the production of AgNPs. The authors assert that light and chlorophyll content are critical components of biosynthesis[11]. Findings show that stirring the extract during the experiment has a positive impact on the size and shape of the nanoparticles. According to a review, AgNPs produced by microalgae may be able to control infections in agricultural activities[12]. It has been discovered that Galdieria sp. microalgae may also produce iron (II) and zinc nanoparticles (Zn NPs), in addition to AgNPs[13]. Some recent studies on the biogenesis of nanoparticles from microalgae are notable for producing copper nanoparticles (CuNPs) using Chlorella kessleri, AgNPs using Gelidiumamansi, and Tetraselmissuecica[14,15].

In order to biosynthesize nanomaterials, many micro-algal organisms have had their cell biomolecules removed. In this context, it is important to comprehend how operating variables affect microalgae-based nanoparticle synthesis. While current research indicates that employing microalgae for nanoparticle synthesis performs better at higher pH and temperature levels, microalgae growth is still increased under neutral pH and ambient temperature circumstances.

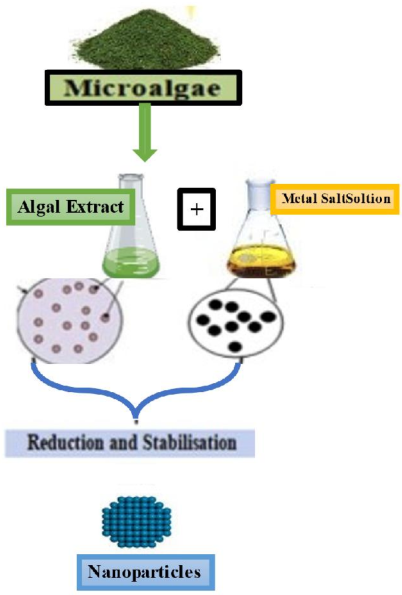


**Fig.1. Nanoparticle Synthesis through a Bio-Based Method**

**Environmental aspects that affect the growth of microalgae:**

**1. pH:**

Microalgae's development and metabolic process are directly impacted by the pH of the growing media. According to published research, neutral pH has been found to be the most favorable for microalgae development and metabolism [16]. When the pH is neutral, the lipid and total chlorophyll contents of the algal colony are improved, increasing the biomass yield. It has also been noted that at pH levels lower than 7, the amount of algal protein was higher. The restricted carbon fixation within cellular composition and its conversion to carbon dioxide could be the cause of the growth slowdown at elevated pH levels. According to certain reports, carbonic anhydrase, a microalgae enzyme that breaks down bicarbonate into carbon dioxide and hydroxyl ions, may be active in alkaline pH environments. Nonetheless, some microalgal species have been reported to thrive in both alkaline and acidic environments[17,18]. Alkaline pH is associated with enhanced cellular flexibility and lengthened cell cycles in a select few species.

**2. Light:**

Photosynthesis is the primary source of energy for algae. Algae go through two stages of photosynthesis: the dark cycle and the light cycle. Light is taken in during the photoperiod and stored as nicotinamide adenine dinucleotide phosphate and adenosine triphosphate. Following that, during the dark cycle, this is used to produce biomass. In three separate scenarios—light limitation, light saturation, and light inhibition—light can have an impact on the development and reproduction of microalgae. Increased light intensity has a good effect on the growth of microalgae when available light is limited. Yet, due to excessive photon absorption in relation to electron turnover, light saturation causes the rate of photosynthesis to decrease.

Increased light intensity also causes the photosynthetic system to become permanently damaged; this is known as photoinhibition[19]. Microalgae's photosynthesis is also influenced by the photoperiod, also known as the length of exposure to light. Some microalgal species may experience enhanced development and higher cell densities as a result of prolonged exposure to light. Algae typically grow well in the light but prefer to reproduce in the dark, usually through binary or multiple fission[20].

**3. Temperature:**

In order for microalgae to develop and survive, temperature is essential. By the end of the twenty-first century, it is predicted that global temperatures will have increased by 1.4 - 5.8$^{o}$C[21]. This will have a substantial impact on the development, distribution, and potential extinction of microalgal species. Higher temperatures have a positive impact on the growth rate of microalgae due to an increase in metabolic rate, temperatures. As a result of increased photosynthetic activity,enhanced microalgae biomass production[22]. Also, a higher level of enzyme activity inside the Calvin cycle encourages cell division. Generally speaking, rising temperatures encourage the growth of microalgae populations up to a point beyond which temperature has a negative impact on growth. The ideal temperature for many microalgae is between 16 and 35 degrees Celsius[23].

**Advantages of microalgal systems:**

The idea of using algae to remove fertilizers and organic carbon from wastewater was first proposed in the 1950s and has since received extensive attention. The inherent simplicity of process control, lower energy consumption, and the generation of energy combined with nutrient-rich algal biomass for re-use following downstream processing are major benefits of algae-based water treatment systems. The long-term stability under ambient circumstances and quick removal of dissolved organic carbon, ammoniacal nitrogen, and phosphates in a short amount of time are the two main characteristics of an algal-based wastewater treatment system. Algae are also known to create biofuels, many goods with added value that are vital for commerce, nanoparticles, and other photosynthetic creatures. In compared to other organic biomass, these microorganisms have a higher rate of carbon dioxide fixation via photosynthesis, which results in a better efficiency to produce biobased goods. Moreover, the micro algal colonies have a fast rate of growth, particularly in eutrophic environments.

Algae are attracting a lot of attention as potential renewable alternatives to the conventional chemical synthesis options due to their capacity to treat wastewater, production of a wide range of commercially significant nanomaterials, economically viable growth-associated products, and inherent carbon reduction potentials. Despite the fact that many reviews have emphasized the significance of algal bio factories, practical large-scale use of these biological agents is still far off. It is important that individual research findings on the prospects of algae for nanoparticle production are updated and understood together in a way to facilitate scale-up and commercialization of the technology in light of the pressing need to develop efficient alternatives to the currently used sources for nanoparticle synthesis and environmental sustainability.

## II. CONCLUSION

A brief summary of microalgae's capacity to synthesize nanoparticles is provided in the minireview. It is crucial to investigate the potential of these green factories for the synthesis of nanomaterials and other value-added products due to the simplicity of handling microalgal biomass and the adaptation of microalgae to a variety of harsh environmental conditions. Research is now being done to create nanoparticles that are both biosensing and antibacterial. Yet, in order to develop these micro factories for the large-scale production of nanoparticles, it is crucial to describe the bioactive chemicals in microalgae. This is because these green factories have enormous potential.

**Conflict of interest statement:**

No declaration

## REFERENCES

[1] Singh, J., Dutta, T., Kim, K. H., Rawat, M., Samddar, P., and Kumar, P. (2018).'Green'synthesis of metals and their oxide nanoparticles: applications for environmental remediation. J. Nanobiotechnol. 16, 1–24.

[2] Lespes, G., Faucher, S., and Slaveykova, V. I. (2020). Natural nanoparticles,anthropogenic nanoparticles, where is the frontier? Front. Environ. Sci. 8:71.doi: 10.3389/fenvs.2020.00071

[3] Ganesan, R., Narasimhalu, P., Joseph, A. I. J., and Pugazhendhi, A. (2020).Synthesis of silver nanoparticle from X-ray film and its application in production of biofuel from jatropha oil. Int. J. Energy Res. 2020, 1–11.

[4] Leaf, M. C., Gay, J. S. A., Newbould, M. J., Hewitt, O. R., and Rogers, S. L. (2020). Calcareous algae and cyanobacteria. Geol. Today 36, 75–80.

[5] Jacob, J. M., Ravindran, R., Narayanan, M., Samuel, S. M., Pugazhendhi, A., and Kumar, G. (2021). Microalgae: a prospective low cost green alternative for nanoparticle synthesis. Curr. Opin. Environ. Sci. Health 20, 100–163. doi: 10. 1016/j.coesh.2019.12.005.

[6] Öztürk, B. Y. (2019). Intracellular and extracellular green synthesis of silver nanoparticles using Desmodesmus sp.: Their antibacterial and antifungal effects. Caryologia 72, 29–43. doi: 10.13128/cayologia-249.

[7] Dahoumane, S. A., Mechouet, M., Wijesekera, K., Filipe, C. D. M., Sicard, C., Bazylinski, D. A., et al. (2017). Algae-mediated biosynthesis of inorganic nanomaterials as a promising route in nanobiotechnology-a review. Green Chem. 19, 552–587. doi: 10.1039/c6gc02346k

[8] Fawcett, D., Verduin, J. J., Shah, M., Sharma, S. B., and Poinern, G. E. J. (2017).A review of current research into the biogenic synthesis of metal and metaloxide nanoparticles via marine algae and seagrasses. J. Nanosci. 2017, 1–15.doi: 10.1155/2017/8013850.

[9] Ponnuchamy, K., and Jacob, J. A. (2016). Metal nanoparticles from marineseaweeds–a review. Nanotechnol. Rev. 5, 589–600. doi: 10.1515/ntrev-2016-0010

[10] Narala, R. R., Garg, S., Sharma, K. K., Thomas-Hall, S. R., Deme, M., Li, Y.,et al. (2016). Comparison of microalgae cultivation in photobioreactor, openraceway pond, and a two-stage hybrid system. Front. Energy Res. 4:29. doi:10.3389/fenrg.2016.00029

[11] Bao Z, Lan CQJC, Biointerfaces SB: Mechanism of lightdependentbiosynthesis of silver nanoparticles mediated bycell extract of Neochlorisoleoabundans. Colloids Surf B Biointerfaces
2018, 170:251–257.

[12] Terra ALM, Kosinski RdC, Moreira JB, Costa JAV, Morais MGd:Microalgae biosynthesis of silver nanoparticles for applicationin the control of agricultural pathogens. J Environ SciHealth, Part B 2019:1–8.

[13] Çalõs¸kan G, Mutaf T, Öncel SS¸ , Elibol M: Green synthesis of metal nanoparticles using microalga Galdieria sp. In International conference on medical and biological engineering. Springer; 2019:219–224.

[14] Salas-Herrera G, González-Morales S, Benavides-Mendoza A, Castañeda-Facio AO, Fernández-Luqueño F, AJJoAP Robledo- Olivo: Impact of microalgae culture conditions over the capacity of copper nanoparticle biosynthesis. J Appl Phycol 2019:1–11.

[15] Pugazhendhi A, Prabakar D, Jacob JM, Karuppusamy I, RGJMpSaratale: Synthesis and characterization of silver nanoparticles using Gelidiumamansii and its antimicrobial property against various pathogenic bacteria. MicrobPathog 2018, 114:41–45.

[16] Abinandan S, Subashchandrabose SR, Venkateswarlu K, Perera IA, Megharaj M: Acid-tolerant microalgae can withstand higher concentrations of invasive cadmium and produce sustainable biomass and biodiesel at pH 3.5. Bioresour Technol 2019, 281:469–473.

[17] Vadlamani A, Viamajala S, Pendyala B, Varanasi S: Cultivation of microalgae at extreme alkaline pH conditions: a novel approach for biofuel production. ACS Sustainable Chem Eng 2017, 5:7284–7294.

[18] Kumar KS, Dahms H-U, Won E-J, Lee J-S, Shin K-HJE, Safety e:Microalgae–A promising tool for heavy metal remediation. Ecotoxicol Environ Saf 2015, 113:329–352.

[19] Rastogi RP, Sonani RR, Madamwar D: Chapter 2 - UV photoprotectants from algae—synthesis and bio-functionalities. In Algal green chemistry. Edited by Rastogi RP, Madamwar D, Pandey A, Amsterdam: Elsevier; 2017:17–38.

[20] Abomohra AE-F, El-Sheekh M, Hanelt D: Screening of marine microalgae isolated from the hypersaline Bardawil lagoon for biodiesel feedstock. Renew Energy 2017, 101:1266–1272.

[21] Loganathan GB, Valérie O, Mark L: Factors affecting growth of various microalgal species. Environ Eng Sci 2018, 35:1037–1048.

[22] Pachiappan P, Prasath BB, Perumal S, Ananth S, Shenbaga Devi A, Kumar SD, et al.: Isolation and culture of microalgae. In Advances in marine and brackishwater aquaculture. Edited by Perumal S ART, Pachiappan P, New Delhi: Springer India; 2015: 1–15.

[23] Abu-Ghosh S, Fixler D, Dubinsky Z, Iluz D: Flashing light in microalgae biotechnology. Bioresour Technol 2016, 203:357–363.