Synthesis of nanoparticles using algae and its application in dye degradation – A review

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ABSTRACT: *The advancing growth and development in the nanotechnologial field has resulted in the synthesis and usage of various nanoparticles. Synthesis of nanoparticles is done by physical, chemical and biological methods. The shortcomings of the physical and chemical methods are the main reason for opting biological methods. These biological methods of synthesizing nanoparticles, called green synthesis, make use of microorganisms and plants. The hunt for a safer and efficient way to obtain these nanoparticles led to the usage of algae to reduce metallic ions into metallic nanoparticles. Various microalgae and macroalgae are used to get nanoparticles like gold, silver, iron oxide and copper oxide. Nanoparticles have plenty of applications in different fields of science, including medicine, electronics, material science and environment. One of the foremost issues affecting the earth's environment is pollution of water by effluents from dye based industries. In this review, we focus on the synthesis of nanoparticles using various algae and its application in degrading dye effluents before they are let into water bodies.*

Key Words: *Nanoparticles, algae, dye degradation.*

1. Introduction
1.1 Algae
Algae are ubiquitous organisms widely found in marine and fresh water environments. Algae, in general, can be categorized into two kingdoms- eukaryotic unicellular algae fall under kingdom Protista and eukaryotic multicellular algae fall under kingdom Plantae. Although they belong to kingdom Plantae, algae are thalloid in nature, i.e they are not differentiated into distinct root, stem and leaves.
Algae may be microscopic or macroscopic. They are classified into many classes based on the cell structure and the pigments present. However, the main classification includes 3 groups- Chlorophyta (green algae), Phaeophyta (brown algae) and Rhodophyta (red algae). Algae exist in different sizes and shapes. They may be found occurring as single cells, filaments or colonies. Apart from the aquatic regions, algae can grow in rocks, damp soil and tree barks as well. Since algae are photosynthetic, they need moisture and sunlight for their growth and sustenance [1].
Algae significantly play many roles in balancing our environment and are beneficial to living forms in many ways. In the marine ecosystem, algae, in the form of phytoplanktons, help small fishes survive and thus form the basis for protecting the entire marine food chain. Algae make up almost half of the oxygen we need to survive. Researchers believe that in the earlier years, when the earth was still barren [2], it was algae (prokaryotic cyanobacteria) that gave life to our planet by producing oxygen [3].
Owing to their ecological importance, algae have attracted many researchers in the recent years to get novel products from them .Different classes of algae have different benefits. Microalgae are used extensively for biofuel production [4]. Algae in general, are used in cosmetics [5] and paints. Since algae are rich in compounds with medicinal properties, they are of more interest in the pharmaceutical industries. They are rich in proteins and so edible algae are consumed in various parts of the world [6]. Algae are efficient in synthesizing nanoparticles, which find good application in delivering drugs specifically [7].
1.2 Nanoparticles
Nanotechnology, the science of engineering and developing nanoscale (10^{-9}m) structures, is flourishing to reach its zenith in the upcoming years. One of the important outcomes of nanotechnology is the synthesis of nanoparticles .These nanoparticles have promising antimicrobial properties and are also used in drug delivery, effluent treatment, material science, electronics and so on[8]. Various organic and inorganic nanoparticles are being synthesized by physical, chemical and biological methods. Owing to more stability, inorganic nanoparticles are preferred more. Laser ablation, high energy ball milling, microemulsion techniques, chemical reduction, UV photoreduction, sol-gel techniques are some of the non- biological methods used for nanoparticles synthesis [9]. But these methods have a lot of drawbacks. They are toxic, preparation is tedious and takes time and these methods are costly too[10]. To overcome these drawbacks,

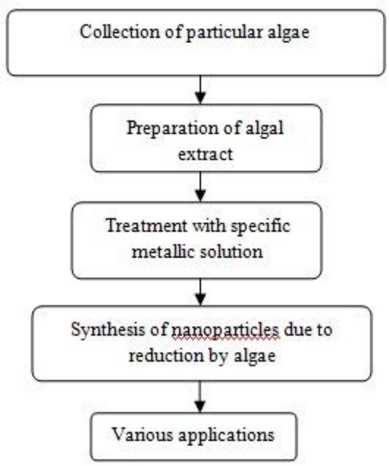
nanoparticles are now being synthesized using biological sources like bacteria, fungi, algae and plants. This method, known as green synthesis [11] , is safe, cheaper, eco- friendly and the sources are easily available. These organisms contain metabolites which have the ability to reduce metal ions into metallic nanoparticles [12].

2. Algae for nanoparticle synthesis

In this paper, we focus on the synthesis of nanoparticles using algae. When given a suitable environment, algae grow abundantly on their own, without needing our least care. Hence, they can be used even in excess, without the fear of it getting extinct. Using algae is an eco- friendly approach and is less toxic and cost effective. The disposal of the waste is also easy.

Nanoparticles synthesis from algae is a bottom up approach. Gold, silver, copper oxide, zinc oxide are some of the main nanoparticles that are synthesized using algae. Algal extracts (preferably aqueous or ethanolic extracts) are first prepared. When the extracts are mixed with a particular metallic solution (specific to the type of nanoparticles needed), algae reduce the metal ions, producing metallic nanoparticles. The reduction occurs due to electrostatic interaction between the negatively charged ions in the metallic solution and positively charged functional groups or peptides in algae [13]. Transmission electron microscopy, UV-vis spectroscopy are used to visualize the size and shape of the nanoparticles formed and X ray diffraction techniques are used to examine the reduction of metal ions into metals.

Protocol for nanoparticle synthesis



2.1 Cyanobacteria

Spirulina subsalsa, Lyngbya majuscule (Figure.1) [14], *Plectonema boryanum* [15,16], are some of the blue green algae used for obtaining gold nanoparticles. *Spirulina Platensis* (Figure.1) [17] is used for synthesizing silver nanoparticles.

Spirulina Platensis *Lyngbya majuscule*

Fig.1

2.2 Green algae

Gold nanoparticles - Out of around 8000 species of green algae [3], most of them grow in fresh water. Green algae may be unicellular, or may occur as colonies or filaments. When exposed to hydrogen tetrachloroaurate, algal extracts of *Rhizoclonium fontinale*, *Ulva intestinalis* [18] (Figure.2), *Rhizoclonium* *hieroglyphicum* [14] and *Chlorella Vulgaris* [19] produce purple or ruby red colour, indicating the formation of gold nanoparticles.

Silver nanoparticles - *Caulerpa racemosa* (Figure.2), [20], *Ulva lactuca* [21] are used for reducing silver nitrate solution to produce silver nanoparticles, which is visually observed by a color change to yellowish brown.

Ulva intestinalis *Caulerpa racemosa*

Fig.2

2.3 Brown algae

***Gold* nanoparticles -** Brown algae comprise of larger algae. There are about 1500 species, most of which grow in marine environments. A lot of works have been done for synthesizing nanoparticles using brown algae including *Sargassum wightii* (figure.3) [22], *Stoechospermum marginatum* [23], *Laminaria japonica* [24] and *Turbinaria conoides*.(figure.3)

Silver nanoparticles - Occurrence of yellowish brown color in the reaction mixture (silver nitrate + algal extract) shows the formation of silver nanoparticles in brown algae like *Turbinaria conoides* [25], *Padina pavonia* [26] *and Sargassum cinereum* [17].

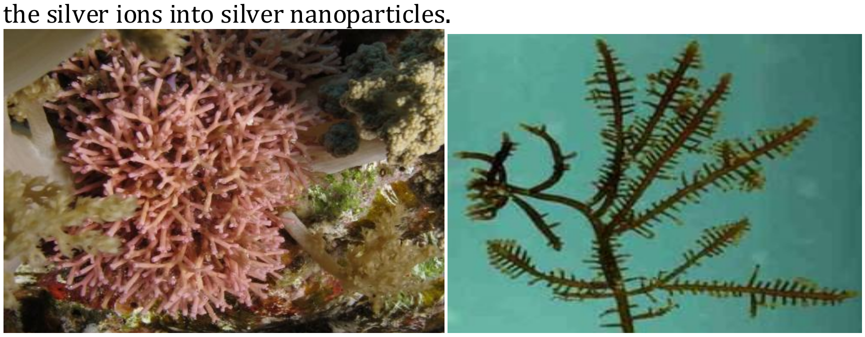
Sargassum wightii *Turbinaria conoides*

Fig.3

2.4 Red algae

Gold nanoparticles - There are almost 5000 species of red algae, most of which are marine. Red algae grow in rocky areas and are significant in coral reefs. *Galaxaura elongata (figure.4) [27], Laurencia papillosa* are treated with chloroauric acid ($HAuCl_4$). Visual monitoring for a colour change to purple shows the formation of gold nanoparticles.

Silver nanoparticles - *Porphyra vietnamensis* [28], *Gelidiella acerosa* [29] when exposed to silver nitrate solution, reduce the silver ions into silver nanoparticles.



Galaxaura elongata *Gelidiella acerosa*

Fig.4

3. Nanoparticles in dye degradation

The major threat to living organisms of this century is pollution, the chief being water contamination. Dye effluents from textile, leather, paper and such industries are one of the key factors affecting water bodies. These dyes are complex, organic compounds that cannot be easily degraded. Obviously, they impose harmful and toxic effects to living beings. This problem can be dealt with by treating the effluents using methods like adsorption, ion exchange process, electrolytic precipitation and usage of various filters [30]. But these methods are not completely effective. They require more time and money, some form sludge and some unwanted by-products [31]. So, scientists, on looking for other ways to manage this problem, have come out with the idea of using nanoparticles to degrade the dye compounds. These dye effluents, after proper treatment, can then be let into water bodies thereby minimizing hazardous effects.

Silver particles synthesized using *Hypnea musciformis* (a red alga) act as a photocatalyst and help in degrading methyl orange dye in the presence of light [32]. Silver nanoparticles derived using red algae, *Gracilaria corticata* have the ability to degrade malachite green dye [33]. Gold nanoparticles from brown algae *Turbinaria conoides* and *Sargassum tenerrimum* are found to degrade Rhodamine B, and Sulforhodamine [34].

4. Conclusion

Although there are thousands of species of algae, it is quite sad that the numerous uses of algae are not explored much as compared to other organisms. Algae are a god sent gift to us. Obtaining nanoparticles using algae is a convenient, simple and an eco- friendly process. It is cheaper and safer than other physical and chemical methods available.

4.1 Future perspectives

Nanoparticles have good antibacterial [35] and antifungal properties. They can be used as carriers for drugs. They have a number of applications in food processing, medicine, cosmetics and paint industries. Thus, green synthesis of nanoparticles from algae can be considered as a good alternate to many existing processes and it will be a boon to various fields of science.

References

1. Michael. J. Pelczar (2001), Microbiology, Algae, Tata McGraw-Hill Education Pvt. Ltd, fifth edition.
2. Kump, L. R. (2008). The rise of atmospheric oxygen. Nature, 451(7176), 277.
3. Chapman, R. L. (2013). Algae: the world's most important "plants"—an introduction. Mitigation and Adaptation Strategies for Global Change, 18(1), 5-12.
4. Demirbas, A. (2010). Use of algae as biofuel sources. Energy conversion and management, 51(12), 2738-2749.
5. Wang, H. M. D., Chen, C. C., Huynh, P., & Chang, J. S. (2015). Exploring the potential of using algae in cosmetics. Bioresource technology, 184, 355-362.
6. Jennifer Kite, 'See How Algae Could Change Our World' , Jun 15, 2018 (web article, available from https://www.forbes.com/sites/jenniferhicks/2018/06/15/see-how-algae-could-change-our-world/)
7. De Jong, W. H., & Borm, P. J. (2008). Drug delivery and nanoparticles: applications and hazards. International journal of nanomedicine, 3(2), 133.
8. Khan, I., Saeed, K., & Khan, I. (2017). Nanoparticles: Properties, applications and toxicities. Arabian Journal of Chemistry.
9. Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2014). Synthesis of silver nanoparticles: chemical, physical and biological methods. Research in pharmaceutical sciences, 9(6), 385.
10. Taheriniya, S., & Behboodi, Z. (2016). COMPARING GREEN CHEMICAL METHODS AND CHEMICAL METHODS FOR THE SYNTHESIS OF TITANIUM DIOXIDE NANOPARTICLES. International Journal of Pharmaceutical Sciences and Research, 7(12), 4927-4932.
11. Parveen, K., Banse, V., & Ledwani, L. (2016, April). Green synthesis of nanoparticles: Their advantages and disadvantages. In AIP Conference Proceedings (Vol. 1724, No. 1, p. 020048). AIP Publishing.
12. Makarov, V. V., Love, A. J., Sinitsyna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E., & Kalinina, N. O. (2014). "Green" nanotechnologies: synthesis of metal nanoparticles using plants. Acta Naturae (англоязычная версия), 6(1 (20)).
13. Vijayaraghavan, K., Mahadevan, A., Sathishkumar, M., Pavagadhi, S., & Balasubramanian, R. (2011). Biosynthesis of Au (0) from Au (III) via biosorption and bioreduction using brown marine alga Turbinaria conoides. Chemical engineering journal, 167(1), 223-227.
14. Chakraborty, N., Banerjee, A., Lahiri, S., Panda, A., Ghosh, A. N., & Pal, R. (2009). Biorecovery of gold using cyanobacteria and an eukaryotic alga with special reference to nanogold formation–a novel phenomenon. Journal of Applied Phycology, 21(1), 145.
15. Lengke, M. F., Fleet, M. E., & Southam, G. (2006). Morphology of gold nanoparticles synthesized by filamentous cyanobacteria from gold (I)– thiosulfate and gold (III)– chloride complexes. Langmuir, 22(6), \2780-2787.

16. Lengke, M. F., Ravel, B., Fleet, M. E., Wanger, G., Gordon, R. A., & Southam, G. (2006). Mechanisms of gold bioaccumulation by filamentous cyanobacteria from gold (III)– chloride complex. Environmental science & technology, 40(20), 6304-6309.
17. Hassaan, M. A., & Hosny, S. (2018). Green Synthesis of Ag and Au Nanoparticles from Micro and Macro Algae-Review. International Journal of Atmospheric and Oceanic Sciences, 2(1), 10.
18. Parial, D., Patra, H. K., Dasgupta, A. K., & Pal, R. (2012). Screening of different algae for green synthesis of gold nanoparticles. European journal of phycology, 47(1), 22-29.
19. Annamalai, J., & Nallamuthu, T. (2015). Characterization of biosynthesized gold nanoparticles from aqueous extract of Chlorella vulgaris and their anti-pathogenic properties. Applied Nanoscience, 5(5), 603-607.
20. Kathiraven, T., Sundaramanickam, A., Shanmugam, N., & Balasubramanian, T. (2015). Green synthesis of silver nanoparticles using marine algae Caulerpa racemosa and their antibacterial activity against some human pathogens. Applied Nanoscience, 5(4), 499-504.
21. Sangeetha, N., & Saravanan, K. (2014). Biogenic silver nanoparticles using marine seaweed (Ulva lactuca) and evaluation of its antibacterial activity. Journal of nanoscience and nanotechnology, 2(1), 99-102.
22. Singaravelu, G., Arockiamary, J. S., Kumar, V. G., & Govindaraju, K. (2007). A novel extracellular synthesis of monodisperse gold nanoparticles using marine alga, Sargassum wightii Greville. Colloids and surfaces B: Biointerfaces, 57(1), 97-101.
23. Rajathi, F. A. A., Parthiban, C., Kumar, V. G., & Anantharaman, P. (2012). Biosynthesis of antibacterial gold nanoparticles using brown alga, Stoechospermum marginatum (kützing). Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 99, 166-173.
24. Ghodake, G., & Lee, D. S. (2011). Biological synthesis of gold nanoparticles using the aqueous extract of the brown algae Laminaria japonica. Journal of Nanoelectronics and Optoelectronics, 6(3), 268-271.
25. Rajeshkumar, S., Kannan, C., & Annadurai, G. (2012). Green synthesis of silver nanoparticles using marine brown algae Turbinaria conoides and its antibacterial activity. International Journal of Pharma and Bio Sciences, 3(4), 502-510.
26. Abdel-Raouf, N., Al-Enazi, N. M., Ibraheem, I. B. M., Alharbi, R. M., & Alkhulaifi, M. M. (2018). Biosynthesis of silver nanoparticles by using of the marine brown alga Padina pavonia and their characterization. Saudi Journal of Biological Sciences.
27. Abdel-Raouf, N., Al-Enazi, N. M., & Ibraheem, I. B. (2017). Green biosynthesis of gold nanoparticles using Galaxaura elongata and characterization of their antibacterial activity. Arabian Journal of Chemistry, 10, S3029-S3039.
28. Venkatpurwar, V., & Pokharkar, V. (2011). Green synthesis of silver nanoparticles using marine polysaccharide: Study of in-vitro antibacterial activity. Materials Letters, 65(6), 999-1002.
29. Vivek, M., Kumar, P. S., Steffi, S., & Sudha, S. (2011). Biogenic silver nanoparticles by Gelidiella acerosa extract and their antifungal effects. Avicenna Journal of Medical Biotechnology, 3(3), 143.
30. Kumar, A., Choudhary, P., & Verma, P. (2011). A comparative study on the treatment methods of textile dye effluents. Global J Environ Res, 5(1), 46-52.
31. Lavanya, C., Dhankar, R., Chhikara, S., & Sheoran, S. (2014). Degradation of toxic dyes: a review. Int J Curr Microbiol App Sci, 3(6), 189-199.
32. Selvam, G. G., & Sivakumar, K. (2015). Phycosynthesis of silver nanoparticles and photocatalytic degradation of methyl orange dye using silver (Ag) nanoparticles synthesized from Hypnea musciformis (Wulfen) JV Lamouroux. Applied Nanoscience, 5(5), 617-622.
33. Poornima, S., & Valivittan, K. (2017). Degradation of Malachite Green (Dye) by using Photo-Catalytic Biogenic Silver Nanoparticles Synthesized using Red Algae (Gracilaria corticata) Aqueous Extract. Int. J. Curr. Microbiol. App. Sci, 6(1), 62-70.
34. Ramakrishna, M., Babu, D. R., Gengan, R. M., Chandra, S., & Rao, G. N. (2016). Green synthesis of gold nanoparticles using marine algae and evaluation of their catalytic activity. Journal of Nanostructure in Chemistry, 6(1), 1-13.
35. Rajeshkumar, S., Malarkodi, C., Vanaja, M., Gnanajobitha, G., Paulkumar, K., Kannan, C., & Annadurai, G. (2013). Antibacterial activity of algae mediated synthesis of gold nanoparticles from Turbinaria conoides. Der Pharma Chemica, 5(2), 224-229.