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Review Article

A Review: Green Synthesis of Nanoparticles from Seaweeds and Its some Applications

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Abstract

Since last decade, for the need of bio-safety, peoples are trying to replace all chemical originated metal Nanoparticles by eco-friendly bio-originated Nanoparticles, as the chemical originated Nanoparticles have hazardous effect to the environment. Therefore, researchers tried biological sources to biosynthesize the Nanoparticles to reduce its hazardous effects. The marine renewable resources are available throughout the year, so researchers are focus to marine resources such as marine macro algae and microalgae, mangrove, and sea grasses. The marine macro algae are abundantly available throughout the year along the coastal areas of India and different parts of the world. There are approximately 841 seaweeds are identified from Indian coastal area. Some of them are utilized for biosynthesis of Silver, Gold and metallic Nanoparticles. This review is focus on the accumulation of some marine macro algae, which yet use for biosynthesis of Nanoparticles and its application in some major industrial field.

Keywords: Nanoparticles; Biosynthesis; Anti-foulants; Dye degradation; Applications

Introduction

In aquatic ecosystem, the submerged surfaces are inhabited with a wide range of living organisms from bacteria to invertebrates [1]. Bio fouling is undesired growth and accumulation of microbes, plants and animals to a surface of natural or any artificial structures which are long time exposed with water. It is yet one of the major unsolved problems currently affecting the shipping industry. To solve this consisting problem, Nanoparticles were applied for coating the ships and the other artificial structures within the ocean. However, to decrease the side effect and the gradual poisoning of chemical derived Nanoparticles, the present generation focused on the biosynthesized Nanoparticles for coating and try to solve of this consisting problem of accumulation of living organisms.

For its special characteristics, Nanoparticles are used for various field of application. In general, Gold, Silver and Platinum, the noble metals Nanoparticles are widely applied to different field such as preparation of toothpaste, various biomedical applications and pharmaceutical applications. In India and China, it had been reported that gold (red colloidal) had revitalization medicinal applications similarly; gold Nanoparticles had drug delivery and diagnostic applications. There are many applications of Nanoparticles in various fields. This review focused biosynthesis of Nanoparticles and its applications to bio fouling and dye degradation.

Biosynthesis of Nanoparticles by Marine Plants

Biosynthesis of Gold Nanoparticles

The biosynthesis of gold Nanoparticles is done by single step reduction of aqueous chloroaurate ions by *Fucus spiralis*. The biosynthesized gold Nanoparticles are varied in shapes and ranges from 5-40 nm in size [2]. This study also reveals that the shape and sizes of biosynthesis gold Nanoparticles depends on pH values, time of reduction and also the rate of coagulation by crystal growth [2]. The Single cell protein (*Spirullina platensis*) uses for biosynthesized of Silver (7-16 nm), gold (6-10 nm) and bimetallic (17-25 nm) Nanoparticles which demonstrate that the biosynthesis and size of Nanoparticles depends on temperature and duration of reduction [3]. The CdS Nanocrystallites are biosynthesized by the Cd presence in phytoplankton *Phaeodactylum tricornutum*. The aqueous solution of *Sargassum wightii* applied to extracellular biosynthesis of gold Nanoparticles which are mono-disperse and specific in shape [3]. The fucoidans, o-fucoidan from *Cladosiphon okamuranus* and t-fucoidan from *Kjellamaniella crassifolia* use for to biosynthesize the gold Nanoparticles. Both synthesize spherical and 8-10 nm sizes Nanoparticles but the o-fucoidan synthesis well mono-disperse linear polymer and t-fucoidan synthesize less disperse branched polymer [4]. The extracellular polysaccharides of dried *Sargassum wightii* synthesize gold Nanoparticles [3]. Similar study shows that the biosynthesis, stability of biosynthesized Nanoparticles, shape and sizes of gold Nanoparticles by *Sargassum wightii* also depend on temperature, pH and duration of reduction. The gold Nanoparticles fabrication changes with change of nitrate reductase, pH and temperature [5]. The various shapes such as square, rectangle and triangle and 60nm size gold Nanoparticles synthesize from brown seaweed *Turbinaria conoides* and its inhibits growth of *Streptococcus sp.*, Bacillus subtilis and *Klebsiella pneumoniae* [6]. The aqueous extract of *Dictyota bartayresiana* synthesizes gold Nanoparticles of 548-564 nm which confirm the presence of amine, poly phenol and carboxylic group. It has inhibitory effect against *Fusarium dimerum* and *Humicola insulans* better than commercial antifungal drugs. The 53-67 nm metallic gold Nanoparticles synthesize with the aqueous extract of *Padina gymnospora* [7].

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Biosynthesis of Silver Nanoparticles

The biosynthesized Silver Nanoparticles from *Hypnea musciformis* water extract had antibacterial and antifungal activity [8]. Kumar reported that *Sargassum tenerrimum* biosynthesized Silver Nanoparticles had human MTCC pathogenic inhibitory activity [9]. The biosynthesized Silver Nanoparticles from *Gelidiella acerosa* reportedly had antifungal activity rather than Clotrimazole [10]. The biosynthesized Silver Nanoparticles of *Ulva lactuc*a reportedly had antimicrobial activity [11]. The interesting biosynthesis of Silver Nanoparticles is done by the metals silver ions 63.7% to 56.0% including *Codium capitatum* water extract. In this synthesis no chemical solution use, so it is completely eco-friendly [12]. The 96nm size spherical Silver Nanoparticles are biosynthesized by *Turbinaria conoides* aqueous extract and these biosynthesized Silver Nanoparticles are highly toxic to the growth of some MTCC human pathogenic bacteria such as Bacillus subtilis (MTCC3053), and *Klebsiella planticola* (MTCC2277) [13]. The 14nm spherical Silver Nanoparticles synthesizes by *Padina tetrastromatica* which also have antimicrobial activity [14]. The methanolic extract of *Sargassum polycystum* biosynthesizes 5-7 nm Silver Nanoparticles which active inhibitory potential against some human pathogens. The biosynthesized spherical, polydispersed Silver Nanoparticles and fatty acids extract of *Padina tetrastromatica* had anti-cancer activity against breast cancer cell line MCF [15,16]. Shiny reportedly explained the spherical 25-40 nm Silver Nanoparticles of *Padina gymnospora* antibacterial and also medical wound dressing in hospital [17].

The spherical 25-40 nm silver Nanoparticles synthesize by *Padina gymnospora* has inhibitory activity against *Bacillus cereus* and *Escherichia coli* which has its medicinal application for wound dressing in hospital [17]. Some seaweed *Caulerpa pelteta* (green), *Hypnea Valencia* (red) and *Sargassum mariocystum* (brown) biosynthesizes various shapes such as spherical, triangle, rectangle, radial and spheres 96-110 nm Zinc Nanoparticles of at pH 8 and temperature 80°C. The biosynthesized Zinc Nanoparticles contains reactive oxygen species which shows antibacterial activity against the pathogens *Streptococcus mutans*, *Vibrio cholerae*, *M. luteus*, *Klebsiella pneumoniae* and *Neisseria gonorrohea* [18]. The biosynthesized Silver Nano material from the aqueous extract of *Sargassum longifoliums*, brown seaweed have antifungal activity against *Candida albicans*, *Aspergillus fumigatus* and *Fusarium sp. S. longifolium*, it may be due to the bio-component present on it, similarly due to its Nano size and spherical shape [19]. The Nano-size materials have increase surface area, so that area protect the fungal growth [20]. The positively charged silver Nano-materials attach with the present negatively charged particles within the fungal growth area by electrostatic attraction which may inhibits fungal growth [21]. Positively charged silver ions may attach with negatively charged cell membranes of microbes by electrostatic attraction [21]. Due to smaller size, Silver nanoparticles have high permeability and create proton leakage which helps to transfer the ROS through membrane [20,22,23]. The conidial fungal germination inhibits by Silver nanoparticles, reasonably have potential to inhibit spore producing fungus [24]. The insulin deficiency develops clinical syndrome diabetes. The silver nanoparticles biosynthesizes by *Colpomenia sinuosa* have antidiabetic potential which inhibits the α-glucosidase and α-amylase enzymes production which is responsible for diabetes production [25]. The

Table 1: List of Seaweeds, which utilized for Nanoparticles synthesis.

S.No.	Name of seaweed	Nanoparticles
1.	*Sargassum wightii*	Gold & Silver
2.	*Sargassum longifolium*	Silver
3.	*Sargassum muticum*	Magnetic Iron Oxide (Fe_3O_4)
3.	*Stoechospermum marginatum*	Gold
4.	*Sargassum tenerrimum*	Silver
5.	*Padina tetrastromatica*	Silver
6.	(*E. coli*, *Pseudomonas* sp.), Cyanobacteria (*Spirulina platensis*, *Oscillatoria willei*, *Phormidium tenue*)	Inorganic Nanoparticles
7.	Algae (*Navicula atomus*, *Diadesmis gallica*, *Stauroneis* sp. *Sargassum wightii*, *Fucus vesiculosus*)	Inorganic Nanoparticles
8.	Mangroves (*Rhizophora mucronata*, *Xylocarpus mekongensis*), salt marshes (*Sesuvium portulacastrum* and *Suaeda* sp.) and sand dune (*Citrullus colocynthis*)	Inorganic Nanoparticles
9.	*Sargassum plagiophyllum*	Silver chloride Nanoparticles
10.	*Sargassum myriocystum*	Gold
11.	*Ulva lactuca*	Silver
12.	*Codium capitatum*	Silver
13.	*Turbinaria conoides*	Gold
14.	blue green alga *Spirulina platensis*	Gold
15.	*Padina tetrastromatica*	Silver
16.	*Avicennia marina*	Silver
17.	*Gelidiella sp.*	Silver
18.	*Chaetomorpha linum*	Silver
19.	*Acanthophora spicifera*	Silver
20.	*Kappaphycus alvarezii*	Silver
21.	*Gracilaria corticata*	Silver
22.	*Sargassum polycystum*	Silver
23.	*Corallina officinalis*	Gold
24.	*Sargassum muticum*	Silver
25.	*Dictyota bartayresiana*	Silver
26.	*Sargassum polyphyllum*	Silver
27.	*Caulerpa racemosa*	Silver
28.	*Ulva flexuosa*	Silver
29.	*Sargassum cinereum*	Silver
30.	*Halymenia porphyroides*	Silver
31.	*Gracilaria corticata*	Silver
32.	*Enteromorpha flexuosa*	Silver
33.	*Pterocladiella capillacea*	Silver
34.	*Amphora sp.*	Silver
35.	*(Padina tetrastromatica and Turbinaria ornata)*	Gold
36.	*Hypnea musciformis*	Silver
37.	*Sargassum polycystum*	Silver
38.	*Colpomenia sinuosa*	Silver
39.	Algae (Shewanella)	Gold
40.	*Gracilaria dura*	Silver nanocoposite and Nanoparticles

41.	*Cladosiphon okamuranus* & Kjellamaniella crassifolia	Gold
42.	*Chaetomorpha linum*	Silver
43.	*Gracilaria corticata*	Silver
44.	*Laminaria japonica*	Gold
45.	*Corallina officinalis*	Gold
46.	*Chlorella vulgaris*	Gold
47.	*Laminaria Japonica*	Gold
48.	*Sargassum plagiophyllum*.	Silver chloride Nanoparticles
49.	*Corallina officinalis*	Gold
50.	*Gelidiella acerosa*	Silver
51.	*Gelidiella acerosa*	Silver
52.	*Ecklonia cava*	Gold
53.	*Gracilaria verrucosa*	Gold
54.	*Colpomenia sinuosa*	Silver
55.	*Gracilaria corticata*	Silver
56.	*Hypnea musciformis*	Silver
57.	*Pterocladiella capillacea*	Silver
58.	*Sargassum wightii*.	Silver
59.	*Gracilaria edulis*	Metallic Silver and Zinc oxide Nanoparticles
60.	*Ulva reticulata*	Silver
61.	*Sargassum swartzii*	Gold
62.	*Prasiola crispa*	Gold
63.	*Galaxaura elongata*	Gold
64.	*Padina pavonica*	Silver
65.	*Lemanea fluviatilis*	Gold
66.	*Halymenia poryphyroides*	Silver
67.	*Ulva fasciata*	Silver
68.	*Microalga Scenedesmus sp.*	Silver

34-80 nm colloidal silver nanoparticle synthesizes by *Halymenia poryphyroides* have great efficacy against *Salmonella typhi*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Proteus vulgaris* and *Salmonella typhi* [26]. The cubical shape 18-90 nm and 20-90 nm biosynthesized Silver nanoparticles have aqueous extracts of *Turbinaria ornata* and *Padina tetrastromatica* have antimicrobial and antifungal activity. The Nanoparticles have carbonyl groups, aromatic alcohols, amines and hydroxyl groups [27].

Application of Gold and Silver Nanoparticles in Various Fields

The low resistance gold Nanoparticles uses for flexible electronics, the gold Nano-wires use for electronic devices, and the gold Nano-particulate apply for flexible electronics ink; Nano rod which will be useful in electronic devices and it also uses the rapid biomedical assays. The gold-silica Nano-shells destroy cancer cells; the gold Nanoparticles improve decorative coatings using thiol, the thermosetting gold Nanoparticles exhibits novel aesthetic effects, the gold Nanoparticles use for pollution control and also synthesis of some chemicals [2]. Due to special chemical reactivity and unique physical properties, Nanoparticles uses for drug delivery, anti-bacterial and viral agent, genetic disorder detection, bio-sensing, labelling of biological applications, and sequencing of DNA and gene therapy. The brown seaweed extracted polysaccharides used as anti-peptic-ulcer, anti-coagulant, anti-inflammation, anti-aging compound, anti-cancer, whitening agent and anti-viral agent [28].

Silver Nanoparticles exhibit tremendous applications in drug delivery [29], wound healing [30], sensor applications [31-33] cosmetics [34], textile industry and also used antimicrobial agent in paint [35]. Silver Nanoparticles were actively involved in the medical sciences due to their antimicrobial actions in food pathogens such as *Staphylococcus aureus* and *Escherichia coli, Klebsiella mobilis, Bacillus subtilis, Klebsiella pneumoniae, Pseudomonas aeruginosa* [36-38], meningitis causative microbe *Cryptococcus neoformans* [28], methicillin-resistant *Staphylococcus aureus*, methicillin-resistant *Staphylococcus epidermidis*, *Streptococcus pyogenes*, and *Salmonella typhi* and having good antifungal activities against *Candida albicans*, *Aspergillus niger*, *Penicillium citrium* and *Aureobasidium pullulans* were isolated from waste suspension of kitchen drainage synthesis [34]. The gold, silver and platinum noble metal Nanoparticles used for toothpaste preparation, it also used for pharmaceutical and medicine preparation. The eco-friendly spherical shaped (15nm) Silver Nanoparticles biosynthesized from *Rhizophora apiculata* had high antibacterial activity in compare to gentamicin and chloramphenical [39]. Research showed that gold Nanoparticles useful for breast cancer treatment [40]. The gold Nanoparticles from red seaweed *Corallina officinalis* have cytotoxic effect on MCF-7 breast cancer [41].

Application as Anti-foulants

The biosynthesized gold Nanoparticles has anti-bioflim activity against the common marine bioflim forming bacteria such as *A. hydrophila, Salmonella sp.* and *S. liquefaciens* [42]. The crude extracts of seaweeds such as *Sarconema furcellatum*, *Sargassum wightii* and sea grass *Syringodium isoetifolium*, *Cymodocea serrulata* have anti-microfouling activity against the microfoulers such as 7±0.16 to 13±0.26 mm antibacterial activity, 50-300 μg/ml anti-microalgal, LC50 133.88μg/ml; P<0.001 Artemia cytotoxicity and anti-crustacean activity; the mortality of micro-fouler increase with increasing of the concentration of crude seaweeds extract [43]. Due to presence some important functional groups such as aliphatic (fatty acid), amide I and II (NH_2), amino, phosphoryl, hydroxyl and carbonyl, the mangrove *Rhizophora apiculata*, *Rhizophora mucronata* and *Avicennia marina* extract shows higher antifouling activity against some fouling bacteria such as *Bacillus sp., Flavobacterium sp., Cytophaga sp.* and *Pseudomonas sp.* than seaweeds extract Halimeda macroloba, Ulva reticulate and Sargassum wightii, similarly the sea grass extract *Halodule pinifolia*, *Cymodocea serrulata* also shows lowest anti-foulants activity than mangrove extract [44]. The chemical constituents and the anti-feedant, antibacterial, and anti-larval activities of the South China Sea grass *Enhalus acoroides*. Eleven pure compounds are including four flavonoids and five steroids were obtained. Among these compounds, three flavonoids were anti-feedant against second-instar larvae of *Spodoptera litura*, two flavonoids had antibacterial activity towards several marine bacteria, and one flavonoid showed strong anti-larval activity against *Bugula neritina larvae* [45]. The *Ulva fasciata* crude ethyl acetate extract mediated biosynthesized crystalline, spherical, poly-dispersed 28-41 nm size range Silver Nanoparticles had inhibitory activity14.00±0.58 mm against *Xanthomonas campestris pv. malvacearum* [46].

Application of Nanoparticles in Dye Degradation

The *Padina tetrastromatica*, leaf extract was used for biosynthesis of Silver Nanoparticles which degrade the direct brown 95 and Congo red dye which is eco-friendly and less expensive method. It used in water purification and it has photo catalytic activity [47-54] (Table 1).

Future Prospects

Smaller the size of Nanoparticles, the efficiency of activity and the stability is more than the other, so this review aim is to survey the green originated Nanoparticles until yet, so in future that can be used in the applied field for numerous purposes. Research is a continuous process and researchers in various fields are everyday contributing more significant solution to solve the leading problem.

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Conflict of Interest

There are no conflicts of interest to be declared.

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