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Review

A review on marine based nanoparticles and their potential applications

Chinnappan Ravinder Singh*, Kandasamy Kathiresan and Sekar Anandhan

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences,
Annamalai University, Parangipettai - 608 502, Tamil Nadu, India.

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The increasing demands on nanoparticles have wide pertinent in almost all the fields. Marine ecosystem has variety of living resources, which includes prokaryotes like microorganism to eukaryotic organism like higher plants and animals. The present review dealt with the application of marine organisms in nanotechnology. Our discussion mainly focused on what the marine organisms are involved in and what type of nanoparticles is synthesized, including size and, medical and medicinal applications. Based on our observation through this review, it will be a good reference document for the further research on marine ecosystem to develop drug from sea.

Key words: Nanomaterial, marine animals, mangroves, marine microbes.

INTRODUCTION

In the recent years, biologically synthesized nanoparticles are of considerable interest in the area of biology and medicine due to their unique particle size and shape-dependence and their physical, chemical and biological properties (Ko et al., 2007). Most of the previous studies employed biomolecules (proteins, amino acids, carbo-hydrates and sugars), different type of whole cells of various microorganisms (bacteria, fungi and algae), or dissimilar plant resources (roots, leaves, flowers, bark powders, seeds, roots and fruits) for the synthesis of metal nanoparticles (Dahl et al., 2007; Kumar and Yadav, 2009; Huang et al., 2009; Laura et al., 2010). Marine organisms are rich source of bioactive compounds with remarkable impact in the field of pharmaceutical, industrial and biotechnological product developments. In recent years, the researchers focusing research on synthesis of nanoparticles from marine sources (Asmathunisha and Kathiresan, 2013) and as such they are both biocompatible and biodegradable which includes seashells, pearls and fish bones, and the particles ranged from 1 to 100 nm size. Biological entities from marine resources have typical nanostructures like diatoms and sponges are constructed with nanostructured cover of silica and coral reefs are with calcium which are arranged in significant architectures (Hoek et al., 1995). This review critically evaluates the existing knowledge on potential applications (Table 1) and current information about research on nanoparticles derived from marine organisms. This may help to fill the current knowledge gap and find exact remedy for serious problems.

*Corresponding author. E-mail: chinnaravinder@yahoo.co.in.

MARINE FLORA-BASED NANOPARTICLES

Biosynthesis of nanoparticles by means of physical and chemical processes is highly expensive. In order to reduce the inevitable expenses in downstream processing of the synthesized nanomaterials and to increase the application of nanoparticles, the scientific community targeted the biological organisms. Nature has devised various processes for the synthesis of nano- and micro-length scaled inorganic materials which have contributed to the development of relatively new and largely unexplored area of research based on the biosynthesis of nanomaterials (Mohanpuria et al., 2008). Plants are important, safe and easily available source for nanoparticle synthesis with broad variability of metabolites that may aid in reduction. Numbers of plant are being currently investigated for nanoparticle synthesis for their efficacy and so many researches has been done with plants with respect to phytochemicals. The main phytochemicals responsible for their activity have been identified as terpenoids, flavones, ketones, aldehydes, amides and carboxylic acids (Prathna et al., 2010). In this regard, plants and plant part extracts based biosynthesis has been found to be cost effective and ecofriendly (Casida and Quistad, 2005). Environmental conditions of marine ecosystem and characterization of marine plants are extremely different from terrestrial ecosystem. Therefore, the marine plants might produce different types of bioactive compounds including polyphenols, flavonoids, alkaloids and tannins (Gnanadesigan et al., 2011a; Ravikumar et al., 2011a, 2011b; Ravikumar et al., 2010). Particularly, the biosynthesis of nanoparticles from mangroves and mangrove associates are very limited. Costal plants especially mangroves and mangrove associates are the good source of nanoparticles. In this respects, 26 costal flora were recorded for the production of silver nanoparticle by Asmathunisha (2010). An efficient and eco-friendly one-pot green synthesis of AgNPs using extracts of mangrove leaf buds has been reported (Umashankari et al., 2012).

In addition, the synthesized nanomaterials has number of applications as evidenced by the earlier reports in which antibacterial activity of silver nanoparticles from *Rhizophora mucronata* against marine ornamental fish pathogens such as *Proteus* spp., *Pseudomonas florescence* and *Flavobacterium* spp., isolated from an infected fish, *Dascyllus trimaculatus* (Umayaparvathi et al., 2013), and anti-cancer activity of silver nanoparticles from *Suaeda monoica* (Sathyavani et al., 2012) are reported. As per the preceding research biological synthesis of nanoparticles from the costal flora is a rich source for disease control.

MARINE MICROORGANISM-BASED NANOPARTICLES

Microorganisms ranging from bacteria to fungi have been used in recent years as explained in detail in the Table 1 to develop non-toxic and environment friendly methods to synthesize nanoparticles (Bhattacharya and Rajinder, 2005). Some microorganisms can survive and grow even at high metal ion concentration due to their extraordinary resistant capability (Husseiny et al., 2007; Mohanpuria et al., 2007). Synthesis of nanoparticle using microbes offers better size control through compartmentalization in the periplasmic space and vesicles. The rate of intracellular particle formation and therefore, size of the nanoparticles could, to an extent, be manipulated by controlling parameters such as pH, temperature, substrate concentration and time of exposure to substrate (Gericke and Pinches, 2006). Marine microbes play several important roles in synthesis of nano-based drugs for human life improvement. Marine microbes have potential ability to synthesize nanoparticle for the reason that the marine microbes exist in the sea bottom, over millions of years in the past for reducing the vast amount of inorganic elements deep in the sea. Additionally, nanoparticles synthesized by microorganisms tend to be stabilized by peptides such as phytochelatins, thus preventing aggregation (Kang et al., 2008). These short peptides are synthesized in response to heavy metal stress and have been implicated as a universal mechanism to sequester metal ions in bacteria (Pages et al., 2008) and fungi (Guimaraes-Suares et al., 2007).

Nanotechnology involved in number of fields resulted in fulfilling the requirement of the human beings. In this the DNA, RNA and protein-based applications induced by nanotechnology are known as biomolecular nanotechhnology, the medical applications such as treatment and disease diagnosis are coming under the nanomedical technology (Sandhu, 2006). Many microorganisms are known to produce nanostructured particles with properties similar to chemically synthesized materials. This is the evidence documented earlier, formation of magnetic nanoparticles by magnetotactic bacteria, the production of silver nanoparticles within the periplasmic space of *Pseudomonas stutzeri* and the formation of palladium nanoparticles using sulphate reducing bacteria (Gericke and Pinches, 2006). Intracellular SNPs synthesized by a marine bacterium, *Idiomarina sp. PR58-8* which was found to be highly silver tolerant (Sachin Seshadri et al., 2012). The mangrove derived microbes *Escherichia coli*, *Aspergillus niger*, *Penicillium fellutanum* and Thraustochytrids capable of reducing the silver ions in faster rate with various antimicrobial applications (Kathiresan et al., 2009; Burja and Radianingtyas, 2005; Adams et al., 2006; Raghukumar, 2008; Gomathi, 2009; Kathiresan et al., 2010). Similar to this marine bacteria and fungi some of the mangrove-derived yeast species like *Pichia capsulata* and *Rhodosporidium diobovatum* also reported to have the nanoparticles synthesizing capacity (Manivannan et al., 2010; Seshadri et al., 2011). The marine cyanobacterium, *Oscillatoria willei* is known to

Table 1. Overview on nanoparticle biosynthesis by marine resources.

Marine sources and year	Type of nanoparticle	Size (nm)	Name of the Species	Biological activity	Author
Mangroves					
2013	Silver	4-26	*Rhizophora mucronata*	Antimicrobial	Umayaparvathi et al., 2013
2012	Silver	71-110	*Avicennia marina* (leaf, bark and root)	Antimicrobial	Gnanadesigan et al., 2012
2011	Silver	60-95	*Rhizophora mucronata*	Larvicidal	Gnanadesigan et al., 2011a
2011	Silver	-	*Rhizophora apiculata*	Antibacterial	Antony et al., 2011
2010	Silver	5–20	*Xylocarpus mekongensis*	Antimicrobial	Asmathunisha, 2010
Coastal plant					
2012	Silver	5-25	*Prosopis chilensis*	Antibacterial to control vibriosis in *Penaeus monodon*	Kathiresan et al., 2013
Salt marshes					
2012	Silver	31	*Suaeda monoica*	Anti-cancer	Satyavani et al., 2012
2010	Silver	50-90	*Sesuvium portulacastrum*	Antimicrobial	Asmathunisha, 2010
Sand dune					
2012	Silver	85-100	*Citrullus colosynthis*	Anti-cancer	Satyavani et al., 2011
Algae					
2014	Silver Gold	2-17 2-19	*Turbinaria conoides*	Antibiofilm activity	Vijayan et al., 2014
2014	Silver	-	*Colpomenia sinuosa*	Anti-diabetic activity	Vishnu Kiran and Murugesan, 2014
2013	Silver	25-40	*Padina gymnospora*	Antibacterial	Shiny et al., 2013
2013	Silver	45-76	*Sargassum cinereum*	Antibacterial	Mohandass et al., 2013
2013	Gold	45-57	*Gracilaria corticata*	Antimicrobial and antioxidant	Naveena and Prakash, 2013
2013	Gold	60	*Turbinaria conoides*	Antibacterial	Rajeshkumar et al., 2013
2012	Silver	33-40	*Sargassum ilicifolium*	Antibacterial and *in vitro* cytotoxicity	Kumar et al., 2012
2012	Silver	28-41	*Ulva fasciata*	Antibacterial	Rajesh et al., 2012
2012	Silver	10-30	*Ulva lactuca*	Antibacterial	Bharathiraja et al., 2012
2012	Silver	20-30	*Urospora* sp.	Antibacterial	Suriya et al., 2012

Table 1. Contd.

2012	Gold	18.7-93.7	*Stoechospermum marginatum*	Antibacteial	Arockiya et al., 2012
2012	Silver	10-72	*Padina pavonica*	Microbicidal	Sahayaraj et al., 2012
2011	Silver	22	*Gelidiella acerosa*	Antifungal	Vivek et al., 2011
2011	Silver	35	*Gracilaria edulis*	-	Murugesan et al., 2011
2011	Gold	15-20	*Laminaria japonica*	-	Ghodake and Lee, 2011
2007	Gold	8-12	*Sargassum wightii*	-	Singaravelu et al., 2007
Marine microbes (Cyanobacteria)					
2013	Silver	44-79	*Microcoleus* sp.	Antimicrobial	Sudha et al., 2013
2013	gold	60	*Turbinaria conoides*	Antimicrobial	Rajeshkumar et al., 2013
2012	Cadmium	5	*Phormidium tenue*	-	MubarakAli et al., 2012
2011	Silver	100-200	*Oscillatoria willei*	-	MubarakAli et al., 2011
2008	Silver Gold Biometallic	7-16 6-10 17-25	*Spirulina platensis*	-	Govindaraju et al., 2008
Bacteria					
2014	Silver	5-30	*Shewanella algae*	Pest Control	Babu et al., 2014
2013	Silver Gold	40-60 10-50	*Stenottrophomonas* sp	-	Malhotra et al., 2013
2013	Gold	35-65	*Klebsiella pneumoniae*	-	Malarkodi et al., 2013
2013	Silver	50-100	*Vibrio alginolyticus*	-	Rajeshkumar et al., 2013
2013	Silver	42-94	*Pseudomonas aeruginosa*	Antibacterial and Anti fungal	Rajeshkumar et al., 2013
2012	Silver	1-10	*Pseudomonas fluorescens*	Antimicrobial	Prabhawathi et al., 2012
2012	Gold	10	*Marinobacter pelagius*	-	Sharma et al., 2012
2012	Silver	25-50	*Bacillus subtilis*	Anti fungal	Vijayaraghavan et al., 2012
2012	Silver	25	*Idiomarina sp. PR58-8*	-	Seshadri et al., 2012
2011	Silver	20-100	*Pseudomonas* sp.	-	Muthukannan and Karuppiah, 2011
2010	Silver	5-20	*E. coli*	Antimicrobial	Kathiresan et al., 2010
Fungi					
2014	Silver	2-22	*Aspergillus flavus*	-	Vala et al., 2014
2010	Silver	5-35	*Aspergillus niger*	Antimicrobial	Kathiresan et al., 2010

Table 1. Contd.

2009	Silver	50-100	*Thraustochytrium* sp.	-	Gomathi, 2009
2009	Silver	5-20	*Penicillium fellutanum*	-	Kathiresan et al., 2009
Yeast					
2011	Lead	2-5	*Rhodosporidium diobovatum*	-	Seshadri et al., 2011
2010	Silver	50-100	*Pichia capsulata*	-	Manivannan et al., 2010
2009	Gold	7.5-23	*Yarrowia lipolytica* NCIM 3589	Cell-associated nanoparticle synthesis	Pimprikar et al., 2009
Actinomycetes					
2014	Gold	10-20	*Streptomyces hygroscopicus*	-	Waghmare et al., 2014
2013	Gold	5-50	*Streptomyces* sp	Antimalarial	Karthik et al., 2013
Diatoms					
2011	Gold Gold-Silica	9-22	*Navicula atomus, Diadesmis gallica*	-	Schrofel et al., 2011
Marine animals					
2013	Silver	10.5	*Saccostrea cucullata* (Oyster)	Antimicrobial	Umayaparvathi et al., 2013
2010	Gold	7-20	*Acanthella elongata* (Sponges)	-	Inbakandan et al., 2010
2009	Silver	5-10	Cod liver oil (Fin fish)	-	Khanna and Nair, 2009

secrete the protein which is responsible for reduction of silver ions and stabilization of silver nanoparticles (Mubarak et al., 2011). Recent records of Mubarak et al. (2012) have reported the synthesis and characterization of cadmium sulphide (CdS) nanoparticles from the marine cyanobacterium, *Phormidium tenue* NTDM05.

MARINE ALGAE-BASED NANOPARTICLES

Marine algae is widely used in food, medicine, and manufacturing industries (Chapman and Chapman, 1980; Yang, 2002) as explained in detail in the Table 1. It is a rich source of biologically active compounds, such as polysaccharides (alginate, laminaran, fucoidan), polyphenols, carotenoids, fiber, protein, vitamins and minerals (Kushnerova et al., 2010; Mizuno et al., 2009; Zyyagintsseva et al., 2003). The algal phytochemicals include hydroxyl, carboxyl, and amino functional groups, which can serve both as effective metal-reducing agents and as capping agents to provide a robust coating on the metal nanoparticles in a single step.

MARINE ANIMALS-BASED NANOPARTICLES

Dolphins and whales have rough skin surface due to the presence of nanoridges. These ridges enclose a pore size of 0.2 μm^2 which is below the size of marine fouling organisms and hence there is no attachment of biofoulers(Kathiresan, 2007). Nano scaled structures found on shark skin and 'brick-and-mortar' arrangement like micro-architecture on nacre (mother of pearl) paved a way for the latest advances on production of synthetic designed materials, in particular to be used in biomedicl applications (Luz and Mano, 2009; Dean and Bushan, 2010). An outline of findings on biosynthesis of nanoparticles from marine resources is presented in Table 1.

MARINE BASED NANOPARTICLES ON INSECT/PEST MANAGEMENT

Crop loss to the turn of 30% in plants caused due to the insect pests infesting several crop plants. The use of chemical insecticides and pesticides in crop protection disturb the soil health, water bodies and finally it affects human health (Vinutha et al., 2013). The potential application and benefits of nanotechnology are enormous. Recently, Babu et al. (2014) synthesized silver nanoparticles from marine bacterium Shewanella algae to control pests. Nanotechnology in agriculture plays an important role in the slow release effects which includes pest control with increased shelf-life to various applications in the agricultural fields. More number of nanoparticles have been developed using marine organisms like plants, animals, microbes etc., for variety of application mentioned in the Table 1. But very few findings were reported for the insect pest management. It needs more attention for crop protection, to meet the satisfactory level of production and to increase our economic status of country. The agricultural application of nanotechnology can suggest development of efficient and potential implications for overcoming the management of pests in crops. Nanoparticles can be used in the formulations of pesticides, insecticides, insect repellents, pheromones and fertilizers (Barik et al., 2008).

CONCLUSION

Synthesis of nanoparticle with the help of marine resources accomplishes the need for safe, stable and environment friendly particles since it involves diverse marine ecosystem that is freely available and moreover this biological synthesizing method does not involve harmful solvents and reduced downstream processing steps which shrink the cost for their synthesis. An important challenge in nanoparticle synthesizing technology is to tailor the properties of nanoparticles by controlling their size and shape. Using marine organisms and their bioactive substances, the biosynthesis of nanoparticles extra-cellularly would be constructive if it is produced in a controlled manner to their size and shape. Nanoparticles of desired size and shape have been obtained successfully using living organisms-simple unicellular organisms to highly complex eukaryotes. The marine ecosystem has captured a major attention in recent years, as they contain valuable resources that are yet to be explored much for the beneficial aspects of human life. The field of nano biotechnology is still in its infancy and more research needs to be focused on the mechanistics of nanoparticle formation from the marine resources which may lead to fine tune the process ultimately leading to the synthesis of nanoparticles with a strict control over the size and shape parameters. Therefore, it needs collaborative research of various disciplines to develop simple and cost-effective techniques to improve the quality of life.

Conflict of Interests

The authors have not declared any conflict of interests.

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