IJBPAS, January, 2022, 11(1): 207-216

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)
'A Bridge Between Laboratory and Reader'

www.ijbpas.com

POTENTIAL APPLICATION OF DIATOMS

SHRIVASTAV A* AND DAKI S

Department of Microbiology, Parul institute of Applied Sciences, Parul University, Vadodara, Gujarat, India

***Corresponding Author: E Mail:** Anupama.shrivastav82045@paruluniversity.ac.in

Received 10th March 2021; Revised 8th April 2021; Accepted 10th May 2021; Available online 1st Jan. 2022

https://doi.org/10.31032/IJBPAS/2022/11.1.5824

ABSTRACT

Diatoms are microalgal processing eukaryotic nature. Which are commonly present in every aqueous habitat with wide variety of species, thriving around different area. Diatoms are quite promising biological agents which can be exploited for varied number of applications like for biomineralization, waste degradation in reducing metal toxicity, in synthesis of biomaterial, for synthesis of nano material, use as filtrate in water purification, as biodevices, as biofuels, for use in immunodiagnostic and nanomedicine. Present review summaries all the potential application of such promising microbes for development of future technologies thriving on diatoms as their active biological components.

Keywords: Cadmium, Platinum, reactive oxygen species (ROS), self-assembled monolayers (SAM), Diatomaceous earth (DE)

INTRODUCTION

Diatoms are single cell eukaryotic microalgae that are established in every habitat where water is present. Their abundance and broad distribution make them standard tools for a wide range of function both, as fossils and living organisms. Examples of their broad range of applications include oil exploration, forensic examination and environmental indication. Currently, the emphasis is on their use in nanotechnology and biotechnology, as well as nanofabrication techniques, chemo and bio-sensing, particle sorting, and molecule regulation in micro and nano fluidics, as well as their use in studying environmentally friendly issues such as humidity transition, acidification, and eutrophication of aqueous habitats.

Diatoms are highly robust organisms, and can inhabit virtually all photic zones from the equator to seemingly inhospitable oceanice where they are highly advantageous indicators of environmental conditions in their rapid response to environmental changes, , including their ability to use their "normal antifreeze" ice-binding proteins to respond to sea ice freezing around them.Thus, in all climate zones, diatoms show an exceedingly high degree of flexibility that offer exciting possibilities in biotechnological utilization despite challenging conditions **[1, 2]**. Under mild physiological conditions, diatom silica walls reach a high degree of complexity and hierarchical structure. As a result, the biological processes that produce patterned biosilica are of interest to the rapidly growing field of nanotechnology. Biosilica and silicon are widely used in electrical, optical, and structural materials in various ways. For decades, there has been intensive research into the uses of silicon and silica, raising the question of how much diversity is left for innovation with this element. Silica nanoparticles have proved to be useful in biosensor design, drug delivery, cell labelling, cell separation, contrast agents for magnetic resonance and ultrasound medical imaging, and as a targeting and therapeutic tool for drug- or enzyme-released systems.Silica bodies are opal phytoliths (Phyto means 'plant' and lithos means 'rock' in Greek) produced by plants although soluble silica from the bottom water is absorbed by the roots and carried to totally various parts of the plant system through the vascular system. Non siliceous phytoliths, such as calcium oxalate, are found in some plants **[3]**. Toxicity research has been done for diatoms. However, the data gathered from these experiments is focused on the findings of a few freshwater green algae that are easy to culture.Although toxicity tests with isolated species can provide useful indications for environmental risk assessments of test compounds, they cannot predict changes at different organizational levels in natural communities. Assessment of impacts of chemical contamination on the environment should take into account the natural variability of biological systems in space and time, and it is particularly noteworthy that any endpoint used to evaluate toxicity may be expected to vary in magnitude under different environmental and biological factors **[4, 5]**.

The categorization composition of benthonic algae communities has been widely used for the observation of water quality. Water quality observation programs have focused on comparisons of water chemistry with criteria derived ultimately from bioassays. However, assessment of community composition has many benefits over physical and chemical measurements of water quality, and also the use of biological communities as indicators of water quality is evolving as our understanding of the interactions between water qualities and also the integrity of biological communities improves **[6]**.

Application of diatoms in biomineralization

Biomineralization is the method of synthesising mineral elements from organic compounds in biosystems. This technique involves the use of microorganisms to provide processes, equipment, and specifications. Bacteria, fungi, and diatoms are often used to achieve this purpose. Diatoms are more widely used due to their large abundance.

In this case, diatoms are capable of producing the majority of mineral materials. Biosilica, a component of diatom structure, is created by diatoms that grow only in natural water and in the presence of sunlight, requiring no high-temperature or high-pressure processing.Frustules have a wide range of industrial applications due to their specific structure; they are used in water filters, construction materials, and chromatography support **[7, 8]**. The processing of platinum metal (Pt) by diatoms such as *Melosiranummuloides* in culture has recently been demonstrated. The cultivation of *Melosiranummuloides* in the presence of dihydrogen hexa-chloroplatinate, hexahydrate in order to introduce Pt into frustules was demonstrated in that report. Platinum (Pt)can be inserted into frustules during the cultivation of living diatom cells, according to the findings.Cadmium metal (Cd) is another element that diatoms can produce during their growth. Addition of mineral to *Pinnularia sp*. Culture resulted within the look of Cadmium (Cd) crystals in diatom's frustule. When cadmium sulphide was applied to *Pinnularia sp.* culture, Cd crystals appeared in the diatom's frustule. The findings revealed a straightforward and low-cost chemical deposition method for coating intricately patterned diatom frustules biosilica with optoelectronic semiconductor thin films **[9]**.

Application of diatoms in waste degradation

Unwanted substances are inevitably created during everyday activities and are referred to as wastes. They are known as solid and liquid wastes, as well as gaseous emissions, depending on their physical condition. Sanitary refuse is the systematic, cost-effective, and sanitary collection, storage, and disposal of solid wastes.

The pollutant delivered out of a specific sector is referred to as industrial waste. The design of industry, raw materials used, manufacturing housekeeping, and method all affect the quality and quantity of waste.Pollution of the environment is characterised as the pollution of water or the alteration of natural water's physical, chemical, or biological properties.Water or other sources are said to be contaminated when their quality or composition changes, either naturally or as a result of human activity, making them unfit for domestic, agricultural, manufacturing, recreational, or wildlife survival uses.An agent that affects the aesthetic, physical, chemical, and biological quality and wholesomeness of water is referred to as an environmental pollutant **[10, 11]**. These materials must be treated and kept under control. To overcome this problem, some methods are used all over the world. These approaches include physical, chemical, and biological degradation. Chemical and physical approaches are not deemed appropriate for extracting these contaminants due to the release of materials.As a result, biological methods and their distinct characteristics suited them for use in waste biodegradation. The transformation or mineralization of pollutants into less toxic, more mobile, or more toxic but less mobile forms is a biological process.The ability to kill a wide variety of organic compounds, the possible benefit to soil structure and fertility, and their generally nontoxic, "green" image are the key advantages of these methods. Bacteria, algae, and diatoms are used in the biodegradation process.Diatoms are widely used in waste degradation due to their special structure and biological properties **[12, 13]**.

Application on diatoms and metal toxicity

Toxic metal pollution of soil and water is becoming more common, posing a global challenge that requires more attention from scientists. Toxic metal waste is a major source of concern, and water quality testing and monitoring are becoming standard procedures. A variety of freshwater algae genera, including blue-green algae, filamentous greens, and diatoms, have been found to have metal-tolerant populations at metal-contaminated sites. Diatoms are useful bioindicators for measuring metal concentrations in a number of environments. If the aim of toxicity testing is to predict a metal's quantitative impact under specific field conditions, the tests must be refined. In terms of toxicity-influencing variables including chelating agents, the assay medium should be close to water at the field site. Some studies used this method to assess microalgae sensitivity to certain ions, finding that microalgae in young biofilms were more sensitive to Zn or Cd than microalgae in old biofilms, with the difference noticeable even when both types of biofilms were taken from a clean stream. Microalgal communities in the River Ter, N-E Spain, were examined for copper toxicity at two separate seasons (spring and summer) to investigate the impact of seasons on the toxicity response of microalgae to toxicants. The resistance to copper in microalgal populations was found to be lower in the spring than in the summer, according to the results of this report. Cadmium levels in soils and waters have been rising as a result of human activities, causing problems for many species in the primary trophic levels, such as microalgae. Cadmium toxicity is caused by the displacement of zinc and copper in metalloenzymes, as well as the formation of reactive oxygen species (ROS), which causes oxidative stress **[14]**.

ROS can react with lipids, proteins, photo-synthetic pigments, and nucleic acids, causing lipid peroxidation, decreases in chlorophyll and accessory pigment content, membrane damage, inactivation of enzymes, DNA alterations, and protein oxidation, all of which can affect cell growth and viability **[15]**. Cadmium (Cd) is a priority pollutant whose toxicity is primarily due to its ability to bind to sulfhydryl groups in proteins or to displace essential metals in metalloenzymes. Metal toxicity in aquatic organisms has recently been predicted using a new method called the subcellular partitioning model (SPM), which takes into account metal cellular fates. Under different irradiance levels, the bioaccumulation, subcellular distribution, and toxicity of Cd in a marine diatom, *Thalassiosira nordenskioeldii*, were studied. According to the results, intracellular soluble Cd may be the best indicator of Cd toxicity under various nutrient conditions **[16]**. Furthermore, findings from other studies revealed that the majority of Cd in the diatom *Thalassiosira weissflogii* was distributed in the insoluble fraction (a mixture of metal-rich granules, cellular waste, and organelles).While there was a clear association between [Cd2+] and growth inhibition across all irradiance therapies, variations in Cd toxicity cannot be fully explained by [Cd2+], owing to the diatoms' different bioaccumulation potentials.

Application of diatoms within the synthesis of biomaterial

Due to the aforementioned characteristics and qualities, diatoms are known as one-of-a-kind devices in the biosynthesis of biomaterial. Diatoms are abundant and important members of the phytoplankton population, contributing significantly to total marine primary production. Many of these materials are extracted and used.Synthetic nanotechnology, on the other hand, has recently accelerated due to an almost insatiable global demand for ever smaller structures for electronic, optical, chemical, and biomedical products **[17]**.

Diatoms are a major group of phytoplankton that, through the construction of their cell walls, account for approximately 40% of ocean carbon fixation and the vast majority of biogenic silica production. Enzymes, biofuels, biosilica, and mineral materials are all made with these microorganisms. The most popular methods of silica synthesis necessitate high temperatures and acidic pH, which imposes high costs on producers. Microorganisms, on the other hand, can make silica, and this process is well represented in the most recent literature on the molecular biology of enzyme mediated silica formation in marine and freshwater organisms, as well as the production of strategies for using biocatalytically shaped silica ("biosilica"), which may be more advantageous than silica made by chemical methods. Spicule synthesis is a rapid technique. Freshwater species evolved at a rate of 5 µm per hour, according to studies. As a result, these microorganisms must remove vast quantities of silicic acid from the ambient water, which is silicon-deficient, a process that obviously requires a lot of energy. The carotenoids β-carotene, violaxanthin (Vio), diadinoxanthin (Ddx), and diatoxanthin (Dtx), as well as the chlorophyllous pigments chlorophyll a, c1, and c2, were recently identified in extensive research findings; these carotenoids include b-carotene, violaxanthin (Vio), diadino-xanthin. The amount of carotenoid in the atmosphere can be changed, and the density of these compounds can be calculated using spectrochemical and chemical analysis. Furthermore, the biosynthetic pathway for carotenoids is now well known in higher plants, while much knowledge is lacking in diatoms **[18]**.

Application as source of Nanomaterials

Diatoms have the ability to self-replicate and can be engineered into a cost-effective and programmable industrialised device. Attempts to replace silicon with metal oxides with well-established optical, electrical, thermal, biological, and chemical properties, such as germanium, titanium, and even zinc, have yielded impressive results. Used diatom to controllably fabricate semiconductor titanium dioxide nanostructured on a massively parallel scale using a bottom-up self-assembly course **[19]**.

By cultivating the diatom *Pinnularia sp*. in a controlled two-stage bioreactor process, they metabolically incorporated nano-structured TiO2 into the diatom, creating a nano-composite of titanium and silicon. Especially useful in dye-sensitized solar cells for better light trapping efficiency and organised photocatalysts for better toxic chemical breakdown.

Lang *et al*. (2013) used live diatom cells to create organo-silica assemblies with no loss of frustule patterning. The addition of different metals to already existing silica flakes increases their toughness and usefulness in a number of nano technological applications **[20]**.

Application of Filterant in Water Purification

Diatomaceous earth (DE) is a filtration-capable heterogeneous concoction of the fossil residue of dead diatoms. Diatoms are preferable to DE because they can be grown in a single culture, ensuring uniform permeability and pore size. They can be shipped in small numbers at a low cost and cultured to the desired confluence, making them suitable for industrial processes **[21]**.

Application as Biodevices

Self-assembled monolayers were used to grow diatom cells. The self-assembled monolayers (SAM) process was used to unlock the surface of glass by adding trifluoromethyl, methyl, carboxyl, and amino groups, after which diatoms were cultured on the modified glass surface. Diatoms developed a 2D array after rinsing post-adhesion, enhancing their use in bio-device growth. Freshwater diatoms have been used to create water quality biosensors. To build a 2D array, researchers used alternating current dielectrophoresis to chain live diatom cells **[22]**.

Application of diatoms in Biofuels

Diatoms produce oil as a food reserve during their vegetative process, which keeps them afloat while they wait for favourable conditions. They also contain neutral lipids, which are lipid-fuel precursors, using these oils glands, and they produce a lot more oil than soybean, oil seeds, and palm. said that when diatoms are stressed, they produce significantly more oil because there is less silica or nitrogen in the culture. As diatom oil was compared to known crude oil using micro spectrometry, it was discovered that the former has 60–70 percent more saturated fatty acid than the latter. The fossilised diatoms are responsible for the majority of the existing petrol. Ramachandra *et al*. (2009) also developed a diatom oil production method that saves time. They have successfully changed diatom to secrete oil instead of storing it, allowing for regular oil extraction. Diatoms are adhered to a solar panel on an angiosperm leaf, replacing mesophyll with photosynthetic diatoms **[23]**.

As a result, stomata aid gas exchange, and the leaf provides a humid growth atmosphere for diatoms as they photosynthesize. As a result, they've genetically modified diatoms to secrete gasoline directly, eliminating the need for additional processing. Diatom fuels may be used to replace fossil fuels, lowering greenhouse gas emissions significantly. *Cyclotella cryptica* has been genetically modified to produce biodiesel **[24]**. *Phaeodactylum tricornutum* Bohlin UTEX 640 has been mutated to produce 44 percent more EPA.

Nanomedicine and medical applications

Drug delivery vehicles, medical instruments, and physical therapy applications are all part of nanomedicine, which uses nanomaterials, nanoelectric biosensors, and molecular nanotechnology. However, toxicity, biodegradability, and environmental effects are three main disadvantages of nanomedicine.Instead, diatoms or their derived frustules have complex homogeneity while also overcoming the drawbacks since they are non-toxic, biodegradable, and readily available in nature **[25, 26]**.

CONCLUSION

Diatoms are very important for various biomaterials and have variety of application in many different fields. However due to many different problems during cultivation and maintenance, many part of its wide pool remains unexplored. The future harbours endless possibilities along with endowed challenges and great rewards for every diatomist. The diatoms can also be linked with nanotechnology for novel applications in medical science. Future prospects of research in field of diatoms include investigation of phenotype and genotype of diatoms without altering its structure.Genetically modified diatoms would be the future with applications in the field of recombinant DNA technology as vectors and for improving the nutritional values of certain feedstocks in aquaculture. Diatoms can also be explored for determination of toxicity of particular metal as it can easily cause changes in the biological, physiological and morphological characteristics of different diatoms. Many phases of research in diatoms are still left unexplored which leads to wide possibilities for future researchers.

REFERENCES

[1] Jamali, A.A., Akbari, F., Ghorakhlu, M.M., de la Guardia, M. and Khosroushahi, A.Y., 2012. Applications of diatoms as potential microalgae in nanobiotechnology. *BioImpacts: BI*, *2*(2), p.83.

[2] Chen, X., Ostadi, H. and Jiang, K., 2010. Three-dimensional surface reconstruction of diatomaceous frustules. *Analytical biochemistry*, *403*(1-2), pp. 63-66.

[3] Dolatabadi, J.E.N. and de la Guardia, M., 2011. Applications of diatoms and silica nanotechnology in biosensing, drug and gene delivery, and formation of complex metal nanostructures. *TrAC Trends in Analytical Chemistry*, *30*(9), pp.1538-1548.

[4] Yuan, P., Yang, D., Lin, Z., He, H., Wen, X., Wang, L. and Deng, F., 2006. Influences of pretreatment temperature on the surface silylation of diatomaceous amorphous silica with trimethylchlorosilane. *Journal of non-crystalline solids*, *352* (36-37), pp. 3762-3771.

[5] Mohan, B.S. and Hosetti, B.B., 1999. Aquatic plants for toxicity assessment. *Environmental. Res*, *81* (4), pp. 259-274.

[6] Atazadeh, I., Sharifi, M. and Kelly, M.G., 2007. Evaluation of the trophic diatom index for assessing water quality in River Gharasou, westernIran. *Hydrobiologia*, *589*(1), pp.165-173.

[7] Brunner, E., Gröger, C., Lutz, K., Richthammer, P., Spinde, K. and Sumper, M., 2009. Analytical studies of silica biomineralization: towards an understanding of silica processing by diatoms. *Applied microbiology and biotechnology*, *84*(4), pp.607-616.

[8] Heredia, A., van der Strate, H.J., Delgadillo, I., Basiuk, V.A. and Vrieling, E.G., 2008. Analysis of organo–silica interactions during valve formation in synchronously growing cells of the diatom Naviculapelliculosa. *ChemBioChem*, *9*(4), pp.573-584.

[9] Gutu, T., Gale, D.K., Jeffryes, C., Wang, W., Chang, C.H., Rorrer, G.L. and Jiao, J., 2009. Electron microscopy and optical characterization of cadmium sulphide nanocrystals deposited on the patterned surface of diatom biosilica. *Journal of Nanomaterials*, *2009*.

[10] Santana-Méridas, O., González-Coloma, A. and Sánchez-Vioque, R., 2012. Agricultural residues as a source of bioactive natural products. *Phytochemistry reviews*, *11*(4), pp. 447-466.

[11] Evans, G.M. and Furlong, J.C., Theory and Application.

[12] Glazer AN and Hiroshi N. **2007**. Microbial Biotechnology. Cambridge: Cambridge University Press. 577p.

[13] Gonçalves, J.F., Tabaldi, L.A., Cargnelutti, D., Pereira, L.B., Maldaner, J., Becker, A.G., Rossato, L.V., Rauber, R., Bagatini, M.D., Bisognin, D.A. and Schetinger, M.R.C., 2009. Cadmium-induced oxidative stress in two potato cultivars. *Biometals*, *22*(5), pp. 779-792.

[14] Qiu, R.L., Zhao, X., Tang, Y.T., Yu, F.M. and Hu, P.J., 2008. Antioxidative response to Cd in a newly discovered cadmium hyper-accumulator, *Arabis paniculata* F. *Chemosphere*, *74*(1), pp.6-12.

[15] Liping, W.A.N.G. and Zheng, B., 2008. Toxic effects of fluoranthene and copper on marine diatom *Phaeodactylum tricornutum*. *Journal of Environmental Sciences*, *20*(11), pp.1363-1372.

[16] Gordon, R., Sterrenburg, F.A. and Sandhage, K.H., 2005. A special issue on diatom nanotechnology. *Journal of Nanoscience and Nanotechnology*, *5*(1), pp.1-4.

[17] Bertrand M. 2010. Carotenoid biosynthesis in diatoms. Photosynth Res, 106(1-2), 89-102

[18] Rorrer, G.L., Chang, C.H., Liu, S.H., Jeffryes, C., Jiao, J. and Hedberg, J.A., 2005. Biosynthesis of silicon–germanium oxide nanocomposites by the marine diatom *Nitzschia frustulum*. *Journal of nanoscience and nanotechnology*, *5*(1), pp.41-49.

[19] Lang, Y., Del Monte, F., Collins, L., Rodriguez, B. J., Thompson, K., Dockery, P., *et al*. (2013). Functionalization of the living diatom *Thalassiosira weissflogii* with thiol moieties. Nat. Commun. 4:2683. doi: 10.1038/ncomms3683.

[20] Lobo, E. A., Oliveira, M. A., Neves, M., and Schuler, S. (1991). Caracterização de ambientes de terrasúmidas, no Estado do Rio Grande do Sul, ondeocorreme spécies de anatídeos com valorcinegético. Acta Biol. Leopoldensia 13, 19–60.

[21] Umemura, K., Ishikawa, M. and Kuroda, R., 2001. Controlled immobilization of DNA molecules using chemical modification of mica surfaces for atomic force microscopy: characterization in air. *Analytical biochemistry*, *290*(2), pp.232-237.

[22] Ramachandra, T.V., Mahapatra, D.M. and Gordon, R., 2009. Milking diatoms for sustainable energy: biochemical engineering versus gasoline-secreting diatom solar panels. *Industrial & Engineering Chemistry Res.*, *48*(19), pp.8769-8788.

[23] Dunahay, T.G., Jarvis, E.E., Dais, S.S. and Roessler, P.G., 1996. Manipulation of microalgal lipid production using genetic engineering. *Applied biochemistry and biotechnology*, *57*(1), pp.223-231.

[24] Alonso, D.L., Segura del Castillo, C.I., Grima, E.M. and Cohen, Z., 1996. First insights into improvement of eicosapentaenoic acid content in *Phaeodactylum tricornutum* (bacillariophyceae) by induced mutagenesis 1. *Journal of Phycology*, *32*(2), pp. 339-345.

[25] Bradbury, J., 2004. Nature's nanotechnologists: unveiling the secrets of diatoms. *PLoS Biol*, *2*(10), p.e306.

[26] Jamali, A.A., Akbari, F., Ghorakhlu, M.M., de la Guardia, M. and Khosroushahi, A.Y., 2012. Applications of diatoms as potential microalgae in nanobiotechnology. *Bio Impacts: BI*, *2*(2), p.83.