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Role of Cyanobacteria In Bioremediation of Polluted Water

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Abstract

Water bodies are polluted by variety of pollutants released from activities, like, mining, energy generation, urban waste disposal, agricultural and industrial discharge or crude oil/fuel exploration and refining. These pollutants can be poisonous, mutagenic, carcinogenic, terratogenic as well as bioaccumulative and need to be treated. Their eco-friendly treatment is the need of the hour. Cyanobacteria could be a potential option for waste water treatment. Their dominance and survival ability in a variety of habitats from saline or acidic condition to hot springs and extremely low temperature habitats along with their nutrient utilization and contaminant removing capability make them useful in waste water treatment. This review is an attempt to summarize the role of cyanobacteria in bioremediation of polluted water.

Keywords

Cyanoremediation, waste water, pollutants, cyanobacteria

Introduction

Water bodies are polluted by variety of pollutants released from agricultural runoff, domestic, industrial and sewage discharge that can be poisonous, mutagenic, carcinogenic, terratogenic as well as bioaccumulative and need to be treated. Bioremediation is the process of removing pollutants from the environment using biological organisms, like, fungi, bacteria or algae. When the bioremediating organism is cyanobacteria, the process is called as cyanoremediation. Small size, cosmopolitan nature, high reproduction rate, survivability under prevailing harsh environmental conditions and pollutant removal capability are some of the characteristics that determine the micro-organisms applicability for bioremediation (Zinicovscaia and Cepoi, 2016). Use of cyanobacteria as bioremediator is economically feasible as besides above nature these organisms requires less input and can survive in a variety of habitats from saline or acidic condition to hot springs and extremely low temperature habitats of frozen ponds of Antarctica (Panosyan, 2015). Moreover cyanoremediation is a clean green technology which employs blue-green algal strains, like, *Nostoc*, *Anabaena*, *Phormidium*, *Spirulina*, *Oscillatoria*, *Aulosira*, *Aphanocapsa*, *Lyngbya*, etc. as a promising bioremediators for metal ions, polycyclic aromatic hydrocarbons, organo-phosphorous and other environmental pollutants (Gothawal and Chillara, 2011). Thus the diverse pollutant degradation capability of cyanobacteria is a clean green approach that makes them a best choice in cleaning of pollutants from the environment (Pavan Kumar *et al.*, 2016, Dutta *et al.*, 2022). This review has been undertaken to explore cyanobacterial capability in bioremediation of polluted water.

Objective of study

To review the importance of cyanoremediation as an eco-friendly method in treatment of polluted water.

Review of Literature

Cyanobacteria or blue-green algae are the first photosynthetic microorganisms on earth that are responsible for oxygenation of earth's atmosphere over the past three billion years (Rasmussen et al., 2008). They are also the probable ancestors of chloroplast and major primary producers. Increase in anthropogenic activities for more economic gains are increasing pollutants in earth's atmosphere. Cleaning of these pollutants through eco-friendly method is the need of the hour. Bioremediation is a branch of biology that employs microorganisms, like cyanobacteria, in the removal of contaminants from soil, water and other habitats. Several researches on cyanobacterial remediation of sewage water, toxins, heavy metals, industrial waste, oil spills, pesticides, radioactive compounds and other pollutants has been conducted to provide an environment friendly method of cleaning earth's surface (Sood et al., 2015; Papadopoulos, 2020; Ahmad, 2022).

Main Text**Cyanoremediation of Polluted Water**

Pollutants released in water from various sources change the colour and odour of water and make it unfit for consumption, recreation or other activities. Cyanobacteria are the most suitable candidates for wastewater treatment as they have simple growth requirements, enhance O₂ content of water through photosynthesis, distress BOD & COD and are tolerant to extreme temperatures and salt concentration (Ahmad, 2022). Besides this its huge biomass can be used as food and extraction of high value compounds. Isolation and use of local cyanobacterial strain offers a cheap method for remediation of toxic pollutants in waste water. Some species act as indicators or markers of particular habitat as their existence indicate their adaptation to that habitat (Subramaniyan, 2012). Cyanoremediation of polluted water is reviewed under following sub-headings:

Cyanoremediation of Sewage Water

Cyanobacteria indirectly reduce the nutrient load present in sewage / municipal waste water by using it as culture medium for their growth making the water useful for other applications (Sood et al., 2015). Sewage water treated by *Oscillatoria* and *Scytonema* was found to reduce the turbidity, total suspended solid, electrical conductivity, alkalinity and hardness of waste water (Dhamotharan, 2008). The use of *Spirulina* in sewage treatment and recycling has been focused to promote economic development and environment sustainability as besides removal of harmful pollutants from waste water the harvested algal biomass can be used as food rich in vitamins, minerals and protein (Bai and Saravana, 2023).

Cyanoremediation of Heavy Metals

Heavy metals like, zinc, nickel, cadmium, lead and copper are the most common pollutants released in to the water bodies from industrial and agricultural activities. Most of the physical and chemical methods used to extract heavy metals from the environment are costly and had toxic effect on other species (Rajput and Kumar, 2024). The use of cyanobacteria as biosorbent is not only cheap but efficient and environment friendly. The rate of absorption of heavy metals by cyanobacteria is dependent on availability of unoccupied binding sites on bacterial cell. The unique proton active functional groups in the cell wall composition, mucilage with high binding affinity and presence of polymeric substances in the exo-polysaccharidic (EPS) layer make them as one of the suitable candidates for heavy metal absorption (Kalita and Baruah, 2023). Different cyanobacteria have ability for specific toxic metal absorption. *Spirulina platensis* have potentiality to absorb different metals, like, iron, zinc, selenium, chromium, copper, cadmium and trivalent chromium (Cepoi et al., 2016, Murugesan, et al., 2008; Shashirekha et al., 2008), *Anabaena* sp., are very potent absorbers of lead, cadmium and zinc (El-Bestawy, et al., 2014). Sivakami et al., (2015) assessed the biosorption of three metals (Cd, Hg and Pb) using the cells of *Oscillatoria limosa*. *Oscillatoria angustissima* was reported to show sorption and desorption of cobalt (Ahuja et al., 1999).

Treatment of Industrial Waste Water

Cyanobacteria are known to dominate over other algal groups in survivability in water with industrial effluents, as low oxygen, moderate nutrients and appropriate pH favours their growth. Widely available cyanobacterial species like, *Anabaena variabilis*, *Lyngbya majuscula*, *Nostoc muscorum*, *Nostoc ellipsosporum*, *Oscillatoria salinas* and *Tolypothrix tenuis* are used in the treatment of effluents from textile industry, fertilizer industry, dairy waste water, fish farm and pesticide industry (Pawan Kumar et al., 2016). In a study *Oscillatoria* and *Phormidium* significantly reduced the nitrogen and phosphorus contents from dairy waste water (Kabaria and Ramani, 2018). The two stage treatment method of electrocoagulation (EC) and cyanobacteria-based cultivation for treatment of brewery waste water proved effective in pollutant removal of nitrate, ammonium and total phosphorus (Papadopoulos et al., 2020). The ability of *Spirulina platensis* was tested for removal of a common azo dye, C.I. Basic Red 46 (C.I. BR 46), from contaminated water (Deniz and Kepekci, 2015). Employing *Oscillatoria* for treatment of sugar mill effluents

witnessed reduction in coloration, BOD, COD and TDS after treatment (Abraham and Nanda, 2010).

Cleaning oil-spills

Bioremediation is a cost effective alternative for cleaning the oil spills with the advantage that microbes are able to completely destroy the toxic hydrocarbon compounds. Various studies have shown the effectiveness of cyanoremediation of oil spills. The combined activity of cyanobacteria and hydrocarbon-degrading bacteria & fungi that live in cyanobacterial-dominated mats was found effective in bioremediating oil-polluted coastal areas of subtropical regions like the Arabian Gulf (Radwan and Al-Hasan, 2007). The marine cyanobacteria *Oscillatoria salina*, *Plectonema terebrans* and *Aphanocapsa* sp. were found to have the capability of degrading crude oil. The study on mixed cultures of the three cyanobacterial species (*Oscillatoria salina*, *Plectonema terebrans*, and *Aphanocapsa* sp.) had expressed the capability to remove over 40% of the crude oil (Raghukumar *et al*, 2001). *Nostoc punctiforme* and *Spirulina platensis* degraded aliphatic compounds contents of crude oil (El-Sheekh and Hamouda, 2014).

Cyanoremediation of the radioactive compounds

Radioactive waste comes from nuclear power plants, mining companies, research centres and industries. These radioactive wastes emit radioactive particles which if not controlled can cause serious health implications, like, leukemia, anaemia, haemorrhages, cancer, growth reduction, reproductive deficiencies and cardiovascular diseases. The use of microorganisms for the treatment of radioactive wastes is the most cost effective, environment friendly, efficient and safe method. The results of an experiment conducted to explore the capability of different cyanobacterial species for the removal of radioactive waste exhibited great potential of *Nostoc* and *Trichormus* that consumed 87% and 88% of radioactive molecules respectively (Silva-Stenico, 2024). Erbium, a rare earth element, used particularly in nuclear technology was remediated by *Arthospira platensis* under particular conditions of pH and temperature (Yushin, 2022).

Cyanoremediation of pesticides

Surface and ground water are known to be polluted by the pesticides used for the protection of plants. These pollutants can be carcinogenic and may cause dermatological, neurological, respiratory and reproductive health issues to human beings. Cyanoremediation of pesticides depends on the types of pollutants, physico-chemical characteristics of environment and species of cyanobacteria. *Anabaena* and *Nostoc* were observed to remove glyphosphate. *Spirulina platensis* and *Spirulina maxima* removed chlorpyrifos, *Nostoc hatei* removed carbofuron, *Chlamydomonas reinhardtii* removed fluroxypyr and *Nostoc ellipsosporum* and *Tolypothrix tenuis* removed mancozeb (Abo-Shady *et al.*, 2023). Phenyl urea herbicides were found to be treated by *Microcystis aeruginosa* (Bayazit *et al.* 2020). It is reported that *Anabaena fertilissima* and *Nostoc* sp. has the ability to secrete phosphate solubilizing enzyme that degrade and utilize the chemical pesticides as phosphorus source (Subramanian *et al.*, 1994).

Conclusion

Cyanobacterial treatment of wastewater is useful to mankind as it is an eco-friendly and efficient tool with low cost investment promoting healthier ecosystem and environment sustainability. Furthermore the extracted algal biomass can be used for the production of biofuels, nutritious food and other useful products. Cyanobacteria based waste-water treatment plant is the need of the hour. Furthermore the exploration of unknown cyanobacterial species of different localities with tremendous degradation capability of organic and inorganic pollutants is still required.

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