Int. J. Sci. R. Tech., 2026 3(5)
A Multidisciplinary peer-reviewed Journal
www.ijsrtjournal.com [ISSN: 2394-7063]

Original Article

Algae's Position In Lowering Water Pollution

Bijubala A. Patel*, Dilipkumar D. Patel

Department of Biology, B.K.M. Science College, Valsad, Gujarat State, India.

ABSTRACT

Water pollution is one of the most pressing environmental demanding situations of the twenty-first century, affecting aquatic ecosystems, biodiversity, and human health. speedy industrialization, urbanization, and agricultural intensification have extensively elevated the release of vitamins, heavy metals, organic contaminants, and rising pollutants into herbal water bodies. In current many years, algae have emerged as an powerful, within your budget, and environmentally sustainable organic device for wastewater treatment and water remediation. This overview severely examines the position of algae in decreasing water pollution with a focusing on nutrient removal, heavy steel biosorption, carbon sequestration, and degradation of organic pollution. numerous algal remedy systems, together with excessive-fee algal ponds and image bioreactors, are discussed along with their benefits, obstacles, and big-scale feasibility.several algal lines, such as Chlorella, Scenedesmus quadricauda, Nostoc, Chlamydomonas, Oscillatoria, Anabaena, Oocystis, Coelastrum, and Spirulina , have shown extensive potential in doing away with inorganic pollutants from contaminated sites. these microalgae soak up and metabolize heavy metals and natural compounds thru procedures such as biosorption, bioaccumulation, and biodegradation. Spirogyra is widely used in treating industrial and mining wastewater and plays an important function in stabilization ponds for removal of natural waste.it is used in stabilization ponds to do away with organic waste.

Keywords: Microalgae, Heavy steel elimination, Wastewater treatment, Bioremediation, bioaccumulation, biosorption.

INTRODUCTION

Water pollutants has become a global environmental difficulty because of growing anthropogenic sports. business effluents, home sewage, agricultural runoff, and wrong waste disposal introduce excessive vitamins, toxic metals, pathogens, and synthetic chemicals into water systems. these pollutants degrade water pleasant, disrupt aquatic ecosystems, and pose serious risks to public health. excess vitamins along with nitrogen and phosphorus make contributions to eutrophication, while heavy metals and natural pollution contaminate ingesting water assets. The presence of poisonous metal ions which includes nickel, aluminum, and copper in water or wastewater, even at low concentrations, can purpose critical fitness issues for each human and biotic organisms (Sayadi et al., 2015; Shen et al., 2020; Rasheed et al., 2018; Yan et al., 2020). fearful gadget damage, kidney failure, and most cancers cases had been related to human exposure to these TMs. consequently, their remedy and removals from water resources are essential (Dahiya et al., 2008; Shin et al., 2011; Visa, 2016; Ghaemi et al., 2017). conventional treatment technologies frequently require high strength enter and operational fees. organic remedy methods the usage of microorganisms, specially algae, provide a promising opportunity. Algae are photosynthetic organisms able to soaking up nutrients and contaminants even as generating oxygen, making them valuable in wastewater remediation. microalgae cultures mediated the a hit remediation of the natural compounds from wastewater the use of biosorption, biotransformation, and biodegradation (Wang et al., 2019).

Algal biosorption is used to do away with heavy metals from wastewater. The Algae cells can then make use of the heavy metals for their boom and development. Micro algae cultures mediated the a success remediation of the natural compounds from wastewater the use of biosorption, biotransformation, and biodegradation (Bilal et al., 2021; Bai and Acharya, 2017; Kalra et al., 2021). In bioaccumulation, the pollution input the cell and are metabolized through various pathways.

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The predominant algal strains suggested for the elimination of the organic and inorganic pollution with biomass manufacturing from the contaminated websites are Chlorella species, Scenedesmus quadricauda, (Wang et al., 2019), Nostoc, Chlamydomonas, Oscillitoria, Anabaena (Ghayal and Pandya, 2013) ,Chlorella vulgaris, and Scenedesmus obliquss (Gouveia et al., 2016), Spirulina sp.(Emparan et al., 2019).

- **Cultivation system:**

a) **Open ponds:** Algae can be grown for business cultivation the usage of either an open pond gadget or a closed image bioreactor device (Narala et al., 2016). Open cultivation systems offer numerous advantages, along with minimum capital and operating costs, and lower power necessities for lifestyle blending. Controlling boom parameters together with evaporation and tradition temperature is also hard in open pond systems (Mata et al., 2010,Narala et al., 2016). The open pond system is much less fantastic due to demanding situations in nutrient control.

b) **Closed picture bioreactor device**: Closed cultivation systems, called photograph bioreactors (PBRs), are greater efficient in maintaining 86f68e4d402306ad3cd330d005134dac situations and might triumph over the hazards of open systems. PBRs can be tailored to unique traces, use less area, decorate light availability, and substantially lessen contamination.

- **Mechanisms of Algae-Mediated pollutants reduction:**

Algae utilize several pathways to smooth infected water.

I. **Nutrient uptake:**

Nutrient assimilation is one of the primary processes, wherein nitrogen and phosphorus are absorbed for cellular increase, there for preventing eutrophication. extra nutrients in water bodies frequently result in algal blooms that burn up oxygen degrees and harm aquatic lifestyles. controlled algal structures help regulate nutrient concentrations efficiently.

II. **Heavy metallic Biosorption:**

Heavy metal removal happens through biosorption and bioaccumulation. Biosorption is a cheap, effective, and excessive-performance approach for wastewater treatment (Ramesh et al., 2023). The algae cells consist of numerous useful agencies like amino (-NH2), carboxyl (-COOH), and hydroxyl (-OH), phosphate, that act as magnets for heavy metals like Pb, Cd, Mg.. and so forth. these practical organizations are responsible for algae's sorption capability in water medium (Khan et al., 2022). The algae cells can then make use of the heavy metals for their increase and development. Metals consisting of lead, cadmium, mercury, chromium, and arsenic can be significantly reduced via algal remedy systems. Algal lines, which include Scenedesmus chlorelloides, cast off molybdenum, Chlamydomonas dispose of lead, Chlorella vulgaris, and Oscillatoria sp. have better performance in putting off zinc, cadmium, and copper, respectively (Molazadeh et al., 2019). The algal strains are capable of metabolizing numerous natural and inorganic pollutants from the wastewaters to generate intermediate metabolites through algae's enzymatic sports.

III. **Sewage Tretment systems:**

Several structures make use of algae for wastewater treatment. Oxidation ponds depend on natural algal growth to treat home sewage in rural and semi-city areas. photograph bioreactors provide managed environments that maximize algal productiveness. Algae are used in oxidation ponds, excessive charge algal ponds to reduce Biochemical oxygen call for (BOD) and Chemical oxygen call for (COD).

IV. **Carbon Dioxide Sequestration:**

Photosynthesis allows carbon dioxide sequestration.

Algae have wiped clean the water, the ensuing biomass may be harvested and processed in to biofules or bio fertilizers. Algae play a vital position in wastewater treatment by making use of nutrient-wealthy effluents for increase. Microalgae efficiently cast off contaminants at the same time as producing biomass appropriate for biofuels and fertilizers.(Sanjita Gurau et.al.2025, Muhammad Imran et.al.2025). Lipid extracted from algal sp. Like Chlorella can transformed into biodiesel. The nutrient rich biomass may be lower back to soil to assist organic farming.

• **Applications:** Algal structures which includes excessive-charge algal ponds (HRAPs), oxidation ponds, and photobioreactors are implemented for municipal and industrial wastewater remedy. those structures improve water pleasant while generating valuable biomass for biofuel and agricultural packages.

business effluents regularly comprise dyes, heavy metals, and poisonous chemical substances. Algae have tested high-highexcellent potential to cast off color and decrease metal concentrations from fabric and electroplating wastewater. Municipal wastewater remedy flowers are increasingly incorporating algal ponds to improve nutrient removal performance whilst decreasing operational expenses. The harvested biomass can be processed into biofertilizer, contributing to nutrient recycling.

In rivers, Lakes, and Ponds micro-algae help neutralize acidic situations lower excessive BOD and COD and increase Dissolved oxygen ranges.

• blessings of Algal-primarily based remedy: blessings of algal remedy include low cost, environmental sustainability, carbon capture, and useful resource recuperation. Algal treatment structures are environmentally sustainable and electricity-green. They reduce dependency on chemical coagulants and synthetic remedy dealers.

Biomass generated in the course of treatment may be transformed into biodiesel, biogas, and other bio-products, improving economic viability.

Algae make a contribution to carbon seize and oxygen production, improving ordinary ecological balance.

• obstacles and demanding situations: huge excessive rate algal ponds require good sized surface area as compared to vertical chemical reactors. big-scale implementation additionally demands giant land location.

Seasonal variations have an effect on increase fees, in particular in open pond systems. Open pond systems are vulnerable to invasive species or zooplankton that may wipe out the algal population.

Biomass harvesting remains strength-intensive and costly. retaining ideal mild, temperature, and nutrient situations requires cautious tracking. The manufacturing and application of algal biomass as a biofertilizer gift sizable challenges. one of the predominant challenges of using algae as a fertilizer is the technical difficulty of scaling up its cultivation to commercial degrees.

some other problem is the sluggish launch of nutrients from algae, and in some cases, positive algal species can produce poisonous compounds which can be dangerous to human beings. (Prakash and Nikhil, 2014).

CONCLUSION

Algae play a important position in lowering water pollution thru nutrient elimination of N and P, heavy steel biosorption, and natural pollutant degradation and carbon sequestration. no matter operational challenges, algal-based systems represent a promising sustainable solution for contemporary wastewater control. Algae-mediated wastewater remedy is a sustainable and efficient era. in addition to cleaning water, the harvested algal biomass may be used for bioenergy (biodiesel/biogas) and fertilizer manufacturing, supporting a round financial system. Algal bio remediation is poised to move from specialised pilot programs to a standard pillar of municipal and commercial water control. Algal biotechnology represents a promising pathway closer to attaining environmental sustainability and water safety in the coming many years.

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HOW TO CITE: Bijubala A. Patel*, Dilipkumar D. Patel, Algae's Position In Lowering Water Pollution, Int. J. Sci. R. Tech., 2026, 3 (5), 824-827. https://doi.org/10.5281/zenodo.20354625