

## Chapter-29

### Spirulina for wastewater treatment

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#### Abstract

Due to increase in the release of wastewater from agriculture, industrial and domestic usage. These sources are creating serious environmental and health issues. Biological wastewater treatment by using spirulina is gaining attention over conventional wastewater treatment due to it is cost effective, does not produce secondary pollutants, and requires less energy. Spirulina has high nutrient uptake capacity, generates biomass, and has ability to tolerate high alkaline conditions. This chapter is discussing the use of spirulina for wastewater treatment, composition of wastewater, mechanism of wastewater treatment by spirulina, wastewater as medium for spirulina cultivation, optimization of spirulina in wastewater medium, Harvesting of spirulina cultivated on wastewater and its biomass uses, application and limitations of using spirulina.

**Keywords:** Spirulina, wastewater treatment, heavy metals, pollutants, pathogenic microorganisms

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#### Objective:

1. To treat wastewater cost-effectively, naturally and free from generating secondary pollutants.
2. To provide promising alternative for conventional wastewater treatment methods
3. To highlight the benefits of spirulina biomass after harvesting spirulina cultivated on wastewater
4. To describe different mechanism used by spirulina to treat wastewater
5. To optimize the different conditions to cultivate spirulina on wastewater.

#### Introduction:

Natural supplies of water are getting polluted due to industrial, household and agricultural wastes increasing the content of organic matter, nutrients, heavy metals and pathogenic microorganisms. So, there is a need for effective wastewater treatment to remove pollutants for both environmental and public health concerns(Gopalkrishna V. Gaonkar [et.al](#) 2019). Conventional wastewater treatment is effective but is expensive, energy-intensive and produces secondary pollutants such as sludge. In the past fifteen years, microalgae and cyanobacteria has gained special attention due to their ability to remove pollutants from wastewater(Laliberte, G., [et.al](#) 1994). The removal of nitrogen, phosphorus, heavy metals (lead, cadmium, chromium and mercury), pathogenic microorganisms and along with that production

of useful algal biomass can be an alternative for conventional wastewater treatment (Gilles Laliberte [et.al.](#)). Spirulina is a cyanobacteria which has offer many advantage to treat wastewater:

- 1) Has high nutrient uptake capacity
- 2) Grows in alkaline conditions
- 3) Some species of spirulina are resistant to ammonia toxicity (Belkin, S. And Boussiba, S., 1991)

### **Spirulina:**

Spirulina is a cyanobacteria (Blue green algae), multicellular, filamentous and show symbiotic association with a bacteria which fixes nitrogen from air (M.AhsanB.Habib [et.al.](#)). Spirulina is photosynthetic, autotrophic and has main photosynthetic pigment as phycocyanin. It grows in alkaline saline water with pH 8.5 to 11 at 35°C to 37°C temperature. Glycogen is the main assimilation product in spirulina. Biochemical composition of spirulina :

Spirulina contains protein in between 55 to 70% (Phang [et.al.](#), 2000). It also contains all essential amino acid, essential fatty acid, vitamin (vitB1, vitB2, vitB3, vitB6, vitB9, vitB12, vit C, vit D and vit E), minerals (potassium, calcium, chromium, cobalt, iron, magnesium, manganese, phosphorus, selenium, sodium, zinc) and photosynthetic pigments (Chla, xanthophyll, beta-carotene, phycocyanin).

### **Composition of wastewater :**

The second most populated country in the world is India with 1.4 billion population. In rural regions of India approximately it is estimated that 39,604 million litre per day (MLD) wastewater is generated, while in urban areas 72,308 MLD (Jagdish meena, [et.al.](#); 2025). Main reasons natural water bodies are getting polluted are domestic wastewater, industrial wastewater, agricultural wastewater and storm water runoff (Hanchang Shi; vol I). Domestic wastewater is further divided into two types : greywater (water from laundry, showers etc) and blackwater (water from toilets etc). Industrial wastewater is a liquid waste coming from different industries like textiles and leather, pulp and paper, chemicals, etc. (Yuhua zhou [et.al.](#); 2018). Wastewater has a diverse composition of waste organic, inorganic matter with microorganism. Organic elements such as dye, carbohydrates, lignin, protein and soaps etc. Wastewater also contains inorganic substances like arsenic, cadmium, chromium, copper, lead, mercury, zinc etc. The major concern contaminants are pathogenic microorganisms (viruses, protozoa, bacteria, and helminths). (Jagdish Meena; 2025). Excess nutrients in wastewater contribute to eutrophication of water bodies, while heavy metals and pathogens possess serious health risks.

### **Mechanism of spirulina to treat wastewater:**

- 1) Heavy metal removal : Spirulina is able to grow at extreme environmental conditions and has a high capacity to absorb heavy metals through biosorption and bioaccumulation. The functional group such as carboxyl, hydroxyl and amino group present on cell walls binds to metal ions, thereby reducing metal

toxicity in wastewater. This leads to decrease in total solids, BOD, total hardness of water, calcium hardness, magnesium hardness and COD(Somayeh Dolatabadi [et.al](#); 2016).

- 2) Reduces nutrient load : For the growth of spirulina, it absorbs nitrogen and phosphorus from wastewater. Nitrogen is absorbed in the form of ammonia, nitrate or nitrite. While phosphorus absorbs phosphate. This nutrient removal reduces eutrophication potential(Gogate, P. R [et.al](#); 2004).
- 3) Photosynthetic oxygenation : During photosynthesis, spirulina releases oxygen into the wastewater. This enhances aerobic microbial activity, leading to effective degradation of organic matter and reduction in BOD and COD.
- 4) Pathogens suppression : The alkaline pH created by spirulina growth, along with oxygenation and production of bioactive compounds, inhibits the growth of pathogenic microorganisms. Spirulina is an effective choice for bioremediation as it is with several bioactive compounds and catalytic enzymes which helps to remove pathogenic microorganisms(Ayyaraju middepogu, [et.al](#); 2023).

#### **Wastewater as medium for spirulina cultivation :**

Three major challenges were addressed to use wastewater as medium for spirulina cultivation : variability in composition of the wastewater, toxicity of wastewater and colour of the wastewater (Hou ren lim., [et.al](#); 2021). These factors mainly influence the growth, biomass and nutrient removal ability of spirulina(ZHAI, J., LI, X, LI, W., RAHAMAN, M. H., ZHAO, Y., WEI, B., WEI, H., 2017). Toxic components (i.e. ammonia, chromium and phenol) inhibit the growth of spirulina after exceeding certain limits(Magro., C. D., [et.al](#) 2012). Colour of wastewater decreases the penetration of sunlight, this affects the productivity of spirulina (Mezommo, N., [et.al](#) 2010). Spirulina biomass productivity is low in wastewater as compared to chemical based culture media(Hou ren lim., [et.al](#) 2021).

#### **Optimization of spirulina in wastewater medium :**

Wastewater contains high amounts of nitrogen, phosphorus, ammonia, and carbon ; this causes inappropriate growth of spirulina and requires other nutrients to be added to improve spirulina productivity (Cheunbarn., S., [et.al](#) 2010). Spirulina assimilate inorganic components like carbon in carbon dioxide and bicarbonate form(Larsdotter., K., 2006), phosphorus in H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, HPO<sub>4</sub><sup>-2</sup> form(Whitton., R., [et.al.](#), 2015). Inorganic nitrogen and phosphorus are assimilated into amino acids and nucleotides, respectively (Whitton., R., [et.al.](#), 2015). Other physiochemical factors also affects spirulina growth like temperature (Subhash., G. V., [et.al.](#), 2014), light intensity (Bahman., M. [et.al.](#), 2020), pH and colour of light. Optimizing them at appropriate conditions like temperature at 30°C, 5800 blue light lux intensity, and scale up the biomass of spirulina.

#### **Harvesting of spirulina cultivated on wastewater :**

Spirulina harvested after cultivating on wastewater, may have high content of heavy metals, this harvested biomass of spirulina can be used as biofertilizer production, biofuel and biogas generation, biochar preparation and use as animal feed after safety assessment (Wuang. shy chy., [et.al](#)).

**Spirulina as biofertilizer/biostimulator:** spirulina has high content of free amino acid as well as macronutrients and micronutrients also has growth promoting substances which are directly absorbed by plant leaves(Sumit sow & Shivani ranjan., 2021).

**Spirulina as biofortification agent:** plants zinc deficiency can be overcome by combining spirulina with organic manure(Sumit sow & Shivani ranjan., 2021).

**Spirulina as biochar:** spirulina derived biochar can be used to remove heavy metals from contaminated agricultural soil. Spirulina biochar is prepared by using pyrolysis, as it contains abundant nitrogen rich compounds, such as protein, which acts as a nitrogen source. Spirulina protein pyrolysis introduces a nitrogen functional group, resulting in nitrogen doped biochar. By using FIR and X-ray photoelectron spectroscopy it analyze that the spirulina biochar has functional group like pyridine - N and pyrrole N on them; which helps them to adsorb heavy metals contaminated soil(Eunji myung., [et.al.](#), 2024).

**Spirulina as biofuel:** spirulina cultivated on wastewater is an effective energy source for biofuel application, thus providing economic benefits(S.chakravarty., [et.al.](#), 2022). Spirulina biofuel would be a great alternative for traditional fossil fuels. By analyzing the functional group and chemical analysis of the spirulina biofuel by using elemental analyzer, fourier transform infrared spectroscopy (FTIR) and gas chromatograph mass spectrometry along with that by analyzing the biofuel standards with ASTM standards showed and ensured potential spirulina biofuel as compatible with diesel engines, maximizing environmental and economical benefits(Suresh vellaiyan., 2024).

#### **Applications of using spirulina for wastewater treatment :**

- I) Reduces natural waterbodies pollution
- II) Improve water quality by removing heavy metals
- III) Spirulina biomass is used further as biofertilizer, biofuel, animal feed and biochar
- IV) Spirulina cultivation releases oxygen

#### **Limitations of using spirulina :**

Due to various factors like toxic pollutants, colour of the wastewater, light intensity, variability in the nutrient composition of wastewater, and other physiochemical factors like temperature, pH also lowers growth of spirulina. These reasons lead to low biomass productivity of spirulina as compared to chemical based media (ex., Zarrouk medium). Other microorganisms present in wastewater also compete with spirulina for nutrients.

## Conclusion :

Spirulina is a promising agent to use for wastewater treatment as it is used for nutrient removal, improved water quality and to increase photosynthesis to release oxygen. The ability of spirulina to reduce BOD, COD and heavy metals plays a multifunctional role in wastewater purification. It is cost-effective, sustainable and does not produce sludge in large quantities unlike other conventional wastewater treatment methods. Furthermore, the biomass of spirulina harvested after cultivation can be used for various applications like biofertilizer, biofuel, biochar and as animal feed. With further research, spirulina based technologies can play a significant role in wastewater treatment.

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