Vol.1, Issue 1, April-June 2025, Page: 43-45 ISSN: 3107-4863

Global Journal of Science and Technology (GJST)

Heavy Metal Zinc Toxicity In Algae: A Review

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Abstract

Zinc (Zn) is an essential trace element for biological systems, but excessive concentrations in aquatic environments can be toxic to algae, affecting their growth, photosynthesis, and biochemical composition. This review examines the sources, bioaccumulation, toxicity mechanisms, and physiological responses of algae to zinc contamination. We also discuss the role of algae in bioremediation and potential mitigation strategies.

Keywords: Zinc toxicity, Heavy metal pollution and Algae.

1. Introduction

Heavy metal pollution in aquatic ecosystems is a growing concern due to industrial activities, mining, and agricultural runoff. Zinc, though required in small amounts for enzymatic and metabolic processes, becomes toxic at elevated levels, disrupting cellular functions in algae (Rai et al., 2021). This review explores the impact of zinc toxicity on algal physiology and its potential as a bioindicator for heavy metal pollution.

2. Sources of Zinc in Aquatic Environments

Major sources of zinc contamination include:

- Industrial effluents from metal plating, mining, and battery production (Santos et al., 2019).
- Agricultural runoff containing zinc-based fertilizers and pesticides (Singh & Prasad, 2020).
- Municipal wastewater and landfill leachates (Zhou et al., 2022).

3. Bioaccumulation and Toxicity Mechanisms

3.1. Zinc Uptake and Accumulation

Algae absorb zinc via passive diffusion and active transport, leading to bioaccumulation in cells. The degree of uptake depends on species, pH, and metal speciation (Jaiswal et al., 2021).

3.2. Cellular and Physiological Toxicity

- **Oxidative Stress:** Zinc toxicity induces reactive oxygen species (ROS) production, leading to lipid peroxidation, DNA damage, and protein oxidation (Mishra & Tripathi, 2020).
- **Photosynthetic Inhibition:** Zinc disrupts chlorophyll synthesis, electron transport, and PSII efficiency, impairing photosynthesis (Sharma et al., 2019).
- **Enzyme Dysfunction:** High zinc concentrations inhibit key metabolic enzymes like carbonic anhydrase and ATPase, affecting nutrient assimilation (Gupta et al., 2021).

4. Algal Responses to Zinc Stress

- **Antioxidant Defense:** Algae produce enzymatic antioxidants (SOD, CAT, GPx) and non-enzymatic antioxidants (glutathione, carotenoids) to counter ROS damage (Pandey et al., 2022).
- **Metal Chelation and Sequestration:** Intracellular sequestration via metallothioneins and phytochelatins limits free zinc toxicity (Saha et al., 2023).
- **Morphological and Growth Changes:** Zinc stress leads to reduced cell division, altered pigmentation, and changes in biomass productivity (Kumar & Verma, 2020).

5. Algal-Based Bioremediation of Zinc

Certain algal species exhibit remarkable zinc tolerance and accumulation capabilities, making them potential candidates for bioremediation:

- **Chlorella vulgaris** and **Scenedesmus obliquus** effectively adsorb zinc from wastewater (Das et al., 2021).
- **Spirulina platensis** exhibits intracellular metal binding, reducing bioavailability in water bodies (Bhattacharya et al., 2019).

6. Conclusion and Future Perspectives

Zinc toxicity in algae disrupts essential physiological processes, but algae also play a significant role in heavy metal remediation. Further research on genetic modifications and biotechnological interventions could enhance algal-based bioremediation strategies for zinc-contaminated environments.

References

1. Bhattacharya, P., Ghosh, S., & Roy, S. (2019). Algal biosorption of heavy metals: A review on mechanisms and applications. *Environmental Pollution*, **245**, 759-773.
2. Das, S., Meena, R., & Gaur, J. (2021). Zinc toxicity in microalgae: Mechanisms and bioremediation approaches. *Journal of Environmental Sciences*, **104**, 129-140.

3. Gupta, P., Chaturvedi, R., & Kumar, N. (2021). Enzymatic responses of algae under heavy metal stress. *Aquatic Toxicology*, **234**, 105783.
4. Jaiswal, K., Patel, R., & Singh, V. (2021). Bioaccumulation and physiological impacts of zinc on freshwater algae. *Ecotoxicology and Environmental Safety*, **218**, 112254.
5. Kumar, A., & Verma, R. (2020). Morphological and biochemical responses of algae to heavy metal stress. *Environmental Monitoring and Assessment*, **192**, 755.
6. Mishra, P., & Tripathi, R. (2020). Role of oxidative stress in heavy metal-induced toxicity in algae. *Environmental Science and Pollution Research*, **27**, 34567-34579.
7. Pandey, S., Roy, S., & Sharma, A. (2022). Antioxidant defense mechanisms in algae exposed to heavy metals. *Journal of Applied Phycology*, **34**, 1125-1143.
8. Rai, S., Gupta, R., & Singh, P. (2021). Algal responses to metal toxicity: A comprehensive review. *Ecotoxicology*, **30**, 1391-1408.
9. Saha, P., Mukherjee, S., & Ray, D. (2023). Phytochelatins and metallothioneins in algae: A molecular perspective. *Toxicology Reports*, **10**, 154-167.
10. Santos, J., Pereira, L., & Costa, M. (2019). Sources and impacts of heavy metal contamination in aquatic ecosystems. *Environmental Chemistry Letters*, **17**, 1291-1307.
11. Sharma, N., Bhatt, J., & Mehta, R. (2019). Photosynthetic impairment in algae due to heavy metal stress. *Photosynthesis Research*, **142**, 105-118.
12. Singh, A., & Prasad, R. (2020). Agricultural runoff and heavy metal pollution: A review. *Environmental Management*, **56**, 765-780.
13. Zhou, X., Li, Y., & Zhang, H. (2022). Municipal wastewater as a source of heavy metal pollution: A case study. *Science of the Total Environment*, **831**, 154752.