

A Comparative Analysis of Bioremediation Technique for Treating Industrial Wastewater

Aakanksha Chourasia¹, Pritha Pal^{1*}

¹Department of Microbiology, School of Life Sciences, Swami Vivekananda University, Barrackpore, West Bengal-700121

*Corresponding author: Dr. Pritha Pal, Assistant Professor,
Department of Microbiology, School of Life Sciences, Swami
Vivekananda University, Barrackpore, West Bengal-700121,
Corresponding Email: prithap@svu.ac.in

ABSTRACT

The rise in heavy metal concentrations in wastewater can be attributed to industrial and developmental activities, coupled with inadequate treatment before disposal, leading to considerable environmental issues. Lead (Pb) is a highly toxic heavy metal commonly used across various industries, including paint, batteries, electroplating, tanneries, paper and pulp mills, textile mills, smelting, and mining. As a result, significant amounts of lead are produced during the disposal of wastewater from these companies. The potential bioavailability of lead poses a significant health risk to children, resulting in cognitive impairment. The removal of this heavy metal from industrial effluents is essential before their release into the environment and natural land or water. Lead remediation in industrial wastewater is carried out using a range of conventional techniques. The main limitations of these methods are their limited effectiveness and lack of adequate technical knowledge. The widespread acceptance and cost-effectiveness of microbial lead treatment for industrial wastewater have recently surfaced as a practical alternative. Utilizing biotechnological techniques for the recovery of metals from effluents rich in heavy metals released into ponds is advisable. Microorganisms can effectively remove heavy metals by encapsulating them within their cell membranes.

Hazardous metals can be eliminated or converted into harmless molecules through the process of bioremediation. This paper provides a comprehensive analysis of the function of microbial remediation in the management of industrial wastewater.

Keywords: *lead, toxic Heavy metals, health risk, industrial waste water, microbial remediation.*

INTRODUCTION

On a global scale, significant volumes of wastewater are produced as a result of industrial growth and the trend of urbanization. Approximately 22% of the world's water supply is consumed by the industrial sector. About 80% of all generated wastewater is discharged into rivers, negatively impacting aquatic ecosystems and harming the environment. According to The Trade Council, Embassy of Denmark, India, 2015, India produces approximately 44 million litres of industrial effluent each day, with about 6.2 billion litres released into the nation's natural water bodies without treatment (Dutta et al. 2021). A wide array of industries plays a crucial role in the introduction of metals into wastewater. These include sectors such as chemical production, distilleries, sugar processing, food and dairy, paper and pulp, textile bleaching and dyeing, mining and quarries, battery manufacturing, nuclear power, organic chemicals, leather and tannery, iron and steel, soap and detergent, electric power generation, metal refining, pesticide and biocide production, petroleum and petrochemical, pharmaceuticals, metal processing, and electroplating. Copper (Cu), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Iron (Fe), Lead (Pb), Nickel (Ni), and Arsenic (As) are metals released by these industries (Awuchi et al. 2020). The lack of adequate wastewater treatment facilities, marked by electrical malfunctions, poor maintenance, and a shortage of skilled personnel, leads to the frequent release of untreated wastewater into water bodies, negatively impacting local aquatic ecosystems. Contaminated water supplies, particularly groundwater, represent a significant risk to human health and contribute to ecological degradation (Bora et al. 2019; Dutta et al. 2021). As a result, with an increasing number of enterprises regularly

using resources like water, there is a growing amount of wastewater released into the environment, which includes a range of harmful heavy metals. The management of industrial wastewater has become a significant concern on a global scale. The treatment of wastewater through various methods has been the subject of extensive scientific inquiry and analysis to date (Lee et al. 2019; Alalwan et al. 2020; Babincev et al. 2020; Mustafa et al. 2020). The ongoing application of these techniques reveals considerable challenges, such as low efficiency, the requirement for substantial amounts of solvents and reagents, and the generation of secondary pollutants, including waste residues, sludge, wastewater, and toxic compounds (Gebretsadik et al. 2020). As a result, the need for efficient wastewater treatment that is both cost-effective and has minimal negative impact on the environment has become critically important worldwide (Dutta et al. 2021). Traditional approaches, including physical, chemical, and thermal treatments, exhibit several significant drawbacks, such as the production of harmful byproducts, the need to transport contaminated soil or water for cleanup, elevated treatment expenses, and inadequate recovery of natural ecosystems and wildlife. The use of bioremediation techniques that incorporate organisms like microorganisms (including bacteria, fungi, and Actinomycetes) or their byproducts can effectively reduce and neutralize pollutants in industrial wastewater through conventional biological processes, whether aerobic or anaerobic (Arora 2018; Saxena et al. 2016).

RESULT AND DISCUSSION

Almost every nation around the world has lead, with approximately 800 locations showing significant levels of lead exposure. The World Health Organization reported in 2018 that high levels of lead contamination have put approximately 26 million people at risk and led to 540,000 deaths annually, with developing countries bearing a disproportionate share of this crisis (Rahman et al. 2019). The main sources of heavy metals, especially lead, in wastewater include the chemical, distillery, food and dairy, sugar, pulp and paper, petroleum, soap, detergents, and leather/tannery industries, stemming from various industrial processes and operations (Dutta et

al. 2021). Lead (Pb) ranks as the second most harmful heavy metal found on Earth in terms of pollution (Pratish et al. 2018). Lead levels exceeding the critical threshold have a significant impact on all morphological, physiological, and biochemical systems (Kushwaha et al. 2018). The evaluation of lead toxicity at various trophic levels within the food chain is presently conducted through a range of quantitative metrics. Lead can build up in the soil or move to the aerial parts of plants if it seeps into the soil from any source and subsequently enters the plant's root system (Kumar et al. 2020). Soil pollution negatively impacts plants by disrupting nutrient uptake, changing water dynamics, and producing reactive oxygen species (ROS), which obstruct photosynthesis and cause cell death, resulting in a significant reduction in crop yield (Zulfiqar et al. 2019). Evidence suggests that lead interferes with enzymes related to germination, such as amylase and protease, negatively impacting the development of radicals and hypocotyls. Furthermore, the decreased mobilization of stored nutrients results in lower radical synthesis, compromised proteolytic functions, and disturbances in cellular osmoregulation, all of which obstruct germination and seedling development in the presence of lead. Lead contamination negatively affects the structure and function of seeds, hindering the initial growth and germination of crops. Lead primarily enters the human body through ingestion and inhalation. Regardless of how it enters the body, lead poses a threat to almost every organ. Acute issues stemming from lead poisoning occur far less frequently compared to long-term conditions. Children show similar effects at lower levels of lead exposure, even though the harmful implications are the same for both adults and children (Rahman et al. 2019; Gidlow 2015; Kumar et al. 2020). Both the peripheral and central nervous systems exhibit susceptibility to the impacts of lead (Flora et al. 2012). Exposure to lead, whether in acute or chronic forms, leads to haemolytic anaemia, hypertension, and cardiovascular disease (Gidlow 2015). Acute lead exposure in the renal system leads to the development of Fanconi syndrome, whereas chronic exposure causes nephropathy. Extended exposure to lead poisoning negatively impacts the reproductive systems of both males and females, resulting in

reduced libido, abnormal sperm production, and infertility in men, while contributing to miscarriage and premature delivery in women (Rahman et al. 2019; Flora et al. 2011). The increasing occurrence of environmental degradation, the anticipated number of polluted sites, and the ongoing efforts to identify them have led to intensified global initiatives aimed at remediating many of these areas in recent years. This is carried out either to reduce any negative health or environmental effects caused by pollution or to prepare the area for future reconstruction or rehabilitation (Luka et al. 2018; Arora 2018). Bioremediation represents a sustainable approach that, due to its cost-effectiveness and environmental advantages, can effectively address environmental degradation. Bioremediation is a technology that employs biological processes to remove or reduce contaminants in the air, soil, and water. The method utilizes an organism obtained from an external system or the relevant environment to reduce or eliminate the hazardous component. (Sher et al., 2019; Luka et al., 2018; Arora, 2018) (Ashraf et al., 2018; Saravanan, 2022). Microorganisms that employ enzymes to break down pollutants into harmless molecules play a vital role in most bioremediation processes. Bioremediation often necessitates adjustments to environmental conditions to promote microbial growth and degradation, as it can only take place in settings that support microbial activity (Karigar et al. 2011). It is essential that isolated microorganisms can be grown in almost any environmental condition. Microbes exhibit remarkable adaptability, thriving in environments characterized by extreme cold, intense heat, arid deserts, aquatic settings, high oxygen levels, anaerobic conditions, exposure to harmful substances, and diverse waste streams. The two fundamental elements consist of an energy source and a carbon supply (Luka et al. 2018). This method relies on various environmental factors and inputs, including nutrients, oxygen, and other modifications, to enhance microbial activity for the purpose of lead remediation (Gong et al. 2018). Various microbial strains utilize immobilization methods for the bioremediation of lead. The bacteria have evolved various defense mechanisms that enable them to withstand the toxic effects of lead (Pratush et al. 2018).

Microbial remediation entails the use of native or foreign microorganisms to reduce lead concentrations in the environment. *Alcaligenes* sp., *Bacillus firmus*, *Bacillus licheniformis*, *Enterobacter cloacae*, *Escherichia coli*, *Micrococcus luteus*, *Pseudomonas fluorescens*, *Aspergillus niger*, *Aspergillus terreus*, *Aspergillus versicolor*, *Neurospora crassa*, *Penicillium canescens*, *Penicillium chrysogenum*, *Penicillium decumbens*, *Penicillium simplicissimum*, *Saccharomyces cerevisiae*, and *Salmonella typhi* are notable species that demonstrate the ability to biotransform and bind lead from contaminated environments (Kumar et al. 2020; Pratush et al. 2018). The *Bacillus subtilis* mutant strain B38 shows considerable potential for the extraction of heavy metals, especially lead, in China (Wang et al. 2014). The *Aspergillus niger* strain SY1 demonstrated a remarkable capability to remove 99.5% of lead from contaminated sediment through the process of bioleaching (Zeng et al. 2015). Notable organisms involved in biotransformation of lead are *Pseudomonas aeruginosa*, *Synecococcus* sp., and *E. coli*, which possess the capability to remediate lead via biosorption. In *Pseudomonas aeruginosa*, Pb^{2+} associates with molecules featuring carbonyl, phosphate, hydroxyl, and amino groups within the cell wall, whereas in *Synecococcus* sp., it interacts with amide, amino, hydroxyl, or carboxyl groups present in the cell wall. About 97% of the Pb^{2+} in *E. coli* is contained within the cell membrane. *Klebsiella michiganensis*, *Providencia rettgeri*, *Raoultella planticola*, and *Serratia* sp. are acknowledged for their capacity to biosorb lead from both mono- and mixed metal solutions through the secretion of extracellular polymeric substances (EPS) (Arashiro et al. 2018). Potential bio-sorbents include the fungal biomass of *Lepiotahystrix*, *Aspergillus niger*, *Aspergillus terreus*, and *Trichoderma longibrachiatum* (Kumar et al. 2020).

CONCLUSION

An in-depth examination reveals that the substantial discharge of lead from various sectors via wastewater significantly affects the entire ecosystem. The adverse impacts of industries have underscored the urgent need for sustainable technology solutions. The physio-chemical therapy techniques incorporate

numerous chemicals while maintaining an environmentally friendly approach. To effectively address and remove the solid wastes and wastewater generated by industries containing heavy metals, bioremediation technologies could serve as a viable solution. These technologies are cost-effective, environmentally friendly, and present a promising approach to improving environmental quality. This study highlights several microorganisms that have shown the capability to eliminate or remediate harmful issues found in waste materials produced by industrial processes. In light of the vast array of microorganisms available and the numerous eco-friendly and cost-effective methods at our disposal, it is concerning that industrial wastes and wastewater still frequently contribute to environmental pollution and toxicity challenges. On that note, this study serves as a means to enhance the community's goodwill. It is essential to implement appropriate measures to manage heavy metals, especially lead, in an eco-conscious manner. Reducing the reliance on hazardous chemicals is crucial, and it is important to raise awareness among government entities and other organizations regarding this critical matter.

CONFLICT OF INTEREST

There is no conflict of interest related to the study.

ACKNOWLEDGEMENT

I like to express my heartfelt appreciation to the higher authorities of Swami Vivekananda University, Dr. Pritha Pal, Head of the Department of Microbiology, and my Ph.D. mentor for her invaluable guidance and assistance in completing this review project.

REFERENCES

- Alalwan, H. A., Kadhom, M. A., and Alminshid, A. H. (2020). Removal of heavy metals from wastewater using agricultural byproducts. *Journal of Water Supply: Research and Technology-Aqua*, jws2020133, DOI: 10.2166/aqua.2020.133
- Arashiro, T., and Sonia M. (2018). Lead absorption mechanisms in bacteria as strategies for lead bioremediation.

Applied Microbiology and Biotechnology, DOI: 10.1007/s00253-018-8969-6

Arora, N. K. (2018). Bioremediation: a green approach for restoration of polluted ecosystems. *Environmental Sustainability*, 1(4), 305–307, DOI: 10.1007/s42398-018-00036-y

Ashraf, S., Naveed, M., Afzal, M., Ashraf, S., Rehman, K., Hussain, A., Zahir, Z. A. (2018). Bioremediation of tannery effluent by Cr- and salt-tolerant bacterial strains. *Environmental Monitoring and Assessment*, 190(12), DOI: 10.1007/s10661-018-7098-0

Awuchi, C.G., Twinomuhwezi, H., Awuchi, C.G., Igwe, V.S., and Amagwula, I.O. (2020). Industrial waste management, treatment, and health issues: wastewater, solid, and electronic wastes. *European Academic Research*, 8 (2), 1081–1119

Babincev, L., Guresic, D., Draskovic, N., and Jovic, S. (2020). Measurement of heavy metals in industrial wastewater by filters based on perlon and wool. *Journal of Water Process Engineering*, 37(2020), 101354, DOI: 10.1016/j.jwpe.2020.101354

Bora, A. J., and Dutta, R. K. (2019). Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-absorption at optimized pH. *Journal of Water Process Engineering*, 31(2019), 100839, DOI: 10.1016/j.jwpe.2019.100839

Dutta, D., Arya, S., and Kumar, S. (2021). Industrial wastewater treatment: Current trends, bottlenecks, and best practices. *Chemosphere*, 285, 131245, DOI: 10.1016/j.chemosphere.2021.131245

Flora, G., Gupta, D., and Tiwari, A. (2012). Toxicity of lead: a review with recent updates. *Interdisciplinary Toxicology*, 5(2), DOI: 10.2478/v10102-012-0009-2

Flora, S.J.S., Pachauri, V., and Saxena, G. (2011) Arsenic, cadmium and lead. *Reproductive and developmental toxicology*, Academic Press, pp. 415–438

Gebretsadik, H., Gebrekidan, A., Demlie, L., and Suvarapu, L. N. (2020). Removal of heavy metals from aqueous solutions using Eucalyptus Camaldulensis: An alternate low cost adsorbent. *Cogent Chemistry*, 6(1), DOI: 10.1080/23312009.2020.1720892

Gidlow, D. A. (2015). Lead toxicity. *Occupational medicine*, 65, 348–356

Gong, Y., Zhao, D., and Wang, Q. (2018). An overview of field-scale studies on remediation of soil contaminated with heavy metals and metalloids: Technical progress over the last decade. *Water Research*, (2018), S0043135418308212, DOI: 10.1016/j.watres.2018.10.024

Karigar, C. S., and Rao, S. S. (2011). Role of Microbial Enzymes in the Bioremediation of Pollutants: A Review. *Enzyme Research*, 2011, 1–11, DOI: 10.4061/2011/805187

Kumar, A., Kumar, A., M.M.S., C. P., Chaturvedi, A. K., Shabnam, A. A., Subrahmanyam, G., Mondal, R., Gupta, D. K., Malyan, S. K. Kumar, S. S., Khan, S. A., and Yadav, K. K. (2020). Lead Toxicity: Health Hazards, Influence on Food Chain, and Sustainable Remediation Approaches. *International Journal of Environmental Research and Public Health*, 17(7), 2179, DOI: 10.3390/ijerph17072179

Kushwaha, A., Hans, N., Kumar, S., and Rani, R. (2018). A critical review on speciation, mobilization and toxicity of lead in soil-microbe-plant system and bioremediation strategies. *Ecotoxicology and Environmental Safety*, 147 (2018) 1035–1045, DOI: 10.1016/j.ecoenv.2017.09.049

Lee, S. H., Kim, K. H., Lee, M., and Lee, B. D. (2019). Detection status and removal characteristics of pharmaceuticals in wastewater treatment effluent. *Journal of Water Process Engineering*, 31(2019), 100828, DOI: 10.1016/j.jwpe.2019.100828

Luka, Y., Highina, B. K., and Zubairu, A. (2018). Bioremediation: A Solution to Environmental Pollution-A Review. *American Journal of Engineering Research*, e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-7, Issue-2, pp-101-109

Mustafa, R., and Asmatulu, E. (2020). Preparation of activated carbon using fruit, paper and clothing wastes for wastewater treatment. *Journal of Water Process Engineering*, 35(2020), 101239, DOI: 10.1016/j.jwpe.2020.101239

Pratish, A., Kumar, A., and Hu, Z. (2018). Adverse effect of heavy metals (As, Pb, Hg, and Cr) on health and their bioremediation strategies: a review. *International Microbiology*, DOI: 10.1007/s10123-018-0012-3

Rahman, Z., and Singh, V. P. (2019). The relative impact of toxic heavy metals (THMs) (arsenic (As), cadmium (Cd), chromium (Cr)(VI), mercury (Hg), and lead (Pb)) on the total environment: an overview. *Environmental Monitoring and*

Assessment, 191(7), 419, DOI: 10.1007/s10661-019-7528-7

Saravanan, A., Kumar, P., S., Duc, P. A., and Rangasamy, G. (2022). Strategies for microbial bioremediation of environmental pollutants from industrial wastewater: A sustainable approach. *Chemosphere*, 2023 Feb, 313:137323, DOI: 10.1016/j.chemosphere.2022.137323

Saxena, G., Chandra, R., and Bharagava, R. N. (2016). Environmental Pollution, Toxicity Profile and Treatment Approaches for Tannery Wastewater and Its Chemical Pollutants. *Reviews of Environmental Contamination and Toxicology*, 31–69, DOI: 10.1007/398_2015_5009

Sher, S., and Rehman, A. (2019). Use of heavy metals resistant bacteria—a strategy for arsenic bioremediation. *Applied Microbiology and Biotechnology*, DOI: 10.1007/s00253-019-09933-6

Wang, T., Sun, H., Mao, H., Zhang, Y., Wang, C., Zhang, Z., W., and Sun, L. (2014). The immobilization of heavy metals in soil by bioaugmentation of a UV-mutant *Bacillus subtilis* 38 assisted by NovoGrobiostimulation and changes of soil microbial community. *Journal of Hazardous Materials*, 278(2014), 483–490, DOI: 10.1016/j.jhazmat.2014.06.028

Zeng, X., Wei, S., Sun, L., Jacques, D. A., Tang, J., Lian, M., Ji, Z., Wang, J., Zhu, J., and Xu, Z. (2015). Bioleaching of heavy metals from contaminated sediments by the *Aspergillus niger* strain SY1. *Journal of Soils and Sediments*, 15(4), 1029–1038, DOI: 10.1007/s11368-015-1076-8

Zulfiqar, U., Farooq, M., Hussain, S., Maqsood, M., Hussain, M., Ishfaq, M., Ahmad, M., and Anjum, M. Z. (2019). Lead toxicity in plants: Impacts and remediation. *Journal of Environmental Management*, 250(2019), 109557, DOI: 10.1016/j.jenvman.2019.10955.