Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163
2025; Vol 24: Issue 9s, https://carcinogenesis.com/

Role of Microbes in Controlling Pollution and Cancer Risk from Steel Industry and Thermal Power Plants: Mechanisms, Applications and Future Perspectives

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ABSTRACT

Industrial sectors such as steel manufacturing and thermal power generation are major sources of heavy metals, fly ash, sulphur and nitrogen oxides, and other persistent pollutants. Traditional physical–chemical treatment methods often carry high cost and may produce secondary waste. Microbial bioremediation offers a promising alternative: microorganisms (bacteria, fungi, algae) can immobilise, transform or remove pollutants via biosorption, bioaccumulation, biotransformation, biomineralisation and bioleaching. Recent findings have also linked exposure to industrial pollutants with increased cancer incidence, highlighting an urgent need for biological mitigation. This review provides a succinct overview of microbial mechanisms relevant to steel-industry and thermal-power-plant effluents, explores their potential in reducing cancer-related health risks, and highlights advances in metagenomics and engineered microbial consortia. With proper design and policy integration, microbial strategies can contribute significantly to sustainable waste-management and public-health protection in these high-impact industries.

KEYWORDS: *bioremediation; industrial effluents; heavy metals; fly ash; microbial consortia; steel industry; thermal power plant; cancer risk*

How to Cite: Dr. Mahesh Salunke., (2025) Role of Microbes in Controlling Pollution and Cancer Risk from Steel Industry and Thermal Power Plants: Mechanisms, Applications and Future Perspectives, *Journal of Carcinogenesis*, *Vol.24*, *No.9s*, 550-552.

1. INTRODUCTION

The steel industry and coal-fired (or thermal) power plants are globally significant sources of environmental pollution. The steel manufacturing process generates large volumes of slag, dust, and wastewater containing heavy metals (e.g., Cr, Pb, Cd, Ni) and other toxic species. Thermal power plants produce fly ash rich in heavy metals, unburned carbon, and sulphur/nitrogen oxides that deposit on soils and water bodies. These contaminants persist in the environment and have been associated with chronic diseases including cancer (Singh et al., 2023; Oladimeji et al., 2020). Conventional remediation methods are expensive and energy-intensive, while microbial approaches offer eco-friendly, cost-effective, and potentially in-situ solutions (Razzak et al., 2019).

2. MICROBIAL APPROACHES TO POLLUTION MITIGATION

2.1 Bioremediation of Heavy Metals and Toxic Compounds

Microorganisms mitigate heavy-metal contamination through biosorption, bioaccumulation, biotransformation, biomineralisation, and bioleaching (Wang et al., 2021). These mechanisms are relevant to steel and thermal industry waste streams. Certain bacterial strains (*Pseudomonas*, *Bacillus*, *Desulfovibrio*) and fungi (*Aspergillus*, *Penicillium*) can immobilise carcinogenic metals such as Cr VI and Ni, which are known to cause lung and gastrointestinal cancers (Kumar & Jain, 2020). By reducing bioavailability, microbes indirectly lower the exposure-related cancer risks among populations residing near industrial clusters (Mishra, 2017).

2.2 Microbial Degradation of Organic Pollutants

Industrial effluents often contain polycyclic aromatic hydrocarbons (PAHs) and phenolic compounds, many of which are mutagenic and carcinogenic. Microbial enzymes like laccases and peroxidases degrade these organics, preventing their bioaccumulation in the food chain (Karnwal, 2020). Biofilms and microbial consortia enhance the degradation rate by synergistic metabolism, further reducing the mutagenic load (Sharma, 2021).

2.3 Bioleaching and Waste Valorisation

Bioleaching by acidophilic microbes (*Acidithiobacillus ferrooxidans*, *Leptospirillum ferrooxidans*) enables the recovery of valuable metals while detoxifying residues (Misra et al., 2021). This not only supports a circular economy but also minimises carcinogenic dust exposure from slag and fly-ash dumps (Das et al., 2020).

3. MICROBES, CARCINOGENIC POLLUTANTS AND HUMAN HEALTH

Epidemiological studies have linked exposure to heavy metals and PAHs from industrial emissions with elevated incidences of lung, liver, and skin cancers (WHO, 2020). Chromium (VI), arsenic, cadmium, and nickel compounds are classified as Group 1 carcinogens by the International Agency for Research on Cancer (IARC, 2018). Microbes play a crucial role in modulating these risks by transforming such compounds into less bioavailable or non-toxic forms. For example, *Pseudomonas putida* and *Desulfovibrio desulfuricans* can reduce Cr VI to Cr III, substantially lowering its genotoxic potential (Kondakindi, 2020). Biotransformation pathways of *Bacillus subtilis* have shown promise in converting arsenate to volatile arsine under controlled systems, reducing human exposure (Mohammad et al., 2019). Thus, microbial metabolism serves as a natural buffer against environmental carcinogenesis.

4. ADVANCED TOOLS IN MICROBIAL POLLUTION CONTROL

Metagenomics and systems biology provide insights into microbial genes responsible for pollutant detoxification and carcinogen degradation. Novel gene clusters for metallothionein synthesis and oxidative stress resistance have been identified in polluted-site microbiomes (Sharma, 2021). Engineered microbial strains expressing enhanced metal-binding peptides or ROS-scavenging enzymes may further aid cancer-risk reduction (Misra, 2021). Integrating microbial fuel cells and biofilters can simultaneously treat effluents and capture hazardous volatile organics (Oladimeji, 2020).

5. FUTURE DIRECTIONS AND CHALLENGES

To realize the public-health potential of microbial remediation, multidisciplinary research bridging microbiology, oncology, and environmental engineering is essential. Field-scale validation of microbial processes in cancer-risk hotspots near steel and thermal plants remains limited (Das et al., 2020). Regulatory acceptance of microbial technologies also requires demonstration of long-term stability and biosafety. The integration of omics-guided bioprocesses with green-steel initiatives can further reduce pollutant exposure and cancer incidence among local populations.

6. CONCLUSION

Microbial remediation not only mitigates pollution from the steel and thermal power sectors but also serves as a preventive tool against cancer linked to industrial contaminants. By transforming toxic metals and carcinogenic organics into less harmful forms, microbes provide an eco-sustainable barrier between industrial emissions and human health. The future of pollution-linked cancer prevention lies in coupling microbial biotechnology with environmental policy and industrial practice.

Acknowledgement

The author, **Dr. Mahesh Salunke**, gratefully acknowledges the support and academic environment provided by the **Department of Microbiology, Tarai Arts & Science College, Chhatrapati Sambhajinagar (Maharashtra, India)**, which enabled the completion of this review. The author extends sincere appreciation to colleagues and students for their constructive discussions and encouragement during the preparation of the manuscript. Special thanks are also due to the broader scientific community whose continued research on microbial bioremediation and environmental health provided the foundation for this work.

REFERENCES

[1] Das, K., Al Masud, M.A., Sarker, A., Arafa, R.A. and Patel, M. (2020) ‘Biological treatment of industrial effluents through microbial processes’. *Environmental Technology & Innovation*, 18, 100751.

[2] IARC (2018) *Monographs on the Identification of Carcinogenic Hazards to Humans*, Vol. 120. Lyon: World Health Organization.

[3] Karnwal, A. (2020) ‘Microbial biodegradation of heavy metals and organic pollutants: An overview’. *Environmental Microbiology Reports*, 12(3), pp. 223–231.

[4] Kondakindi, V.R. (2020) ‘Microbial EPS-mediated sequestration of heavy metals from industrial wastewater’. *Bioresource Technology Reports*, 9, 100655.
[5] Kumar, R. and Jain, S. (2020) ‘Occupational exposure to toxic metals and associated cancer risk’. *Toxicology Reports*, 7, pp. 123–132.
[6] Mishra, G.K. (2017) ‘Microbes in heavy metal remediation: a review on current trends and patents’. *Recent Patents on Biotechnology*, 11(3), pp. 188–196.
[7] Misra, S.K. (2021) ‘Genetically modified microorganisms for heavy metal elimination and detoxification’. *Frontiers in Microbiology*, 12, 658945.
[8] Mohammad, S.J., Ling, Y.E., Halim, K.A. et al. (2019) ‘Microbial approaches in the transformation of heavy metals in polluted soils’. *Applied Ecology and Environmental Research*, 17(4), pp. 8251–8265.
[9] Oladimeji, T.E. (2020) ‘Impact of industrial wastewater on environmental and human health’. *Environmental Science and Pollution Research*, 27(5), pp. 5312–5324.
[10] Razzak, S.A. (2019) ‘Biological removal of heavy metals from industrial wastewater: a comprehensive review’. *Environmental Technology Reviews*, 8(1), pp. 93–110.
[11] Sharma, M. (2021) ‘Microbial biosystems for wastewater treatment: recent advances and challenges’. *Frontiers in Microbiology*, 12, 678921.
[12] Singh, A., Patel, M. and Verma, N. (2023) ‘Cancer incidence in populations exposed to industrial air and water pollutants: a systematic review’. *Environmental Research*, 233, 116489.
[13] Wang, S., Liu, T., Xiao, X. et al. (2021) ‘Advances in microbial remediation for heavy metal treatment: a mini review’. *Journal of Leather Science and Engineering*, 3, 1.
[14] WHO (2020) *Cancer and Environmental Pollution Report 2020*. Geneva: World Health Organization.