Research Output Journal of Public Health and Medicine 3(1):41-45, 2024

ROJPHM ISSN: 1115-6147

https://rojournals.org/roj-public-health-and-medicine/

Microbial Bioremediation of Emerging Contaminants in Urban Water Systems

Emeribe Chiemeka Elochi

Western Illinois University, Macomb Illinois USA

ABSTRACT

Urban water systems are increasingly contaminated with a variety of emerging contaminants, including pharmaceuticals, personal care products, pesticides, industrial chemicals, and multidrug-resistant bacteria. These contaminants pose significant risks to human and environmental health, necessitating effective remediation strategies. Microbial bioremediation offers a promising, eco-friendly solution for the removal and degradation of these pollutants. This paper reviews the principles of microbial bioremediation, key microorganisms involved, techniques for monitoring bioremediation processes, and successful case studies. Emphasis is placed on the development and optimization of microbial consortia for effective contaminant removal, as well as the challenges and future directions in the field.

Keywords: Emerging Contaminants, Urban Water Systems, Microbial Bioremediation, Environmental Remediation, Water Pollution.

INTRODUCTION

Urban water systems serve diverse functions such as drinking water supply, food supply from aquaculture, and recreational activities that have significant ecological and economic impacts. Global population growth, together with urbanization, has led to the discharge of a wide range of contaminants into urban water systems, where the major contaminants include nutrients (e.g., phosphate and nitrate), heavy metals (e.g., cadmium and chromium), residual pharmaceuticals, personal care products, pesticides, illicit drugs, industrial chemicals, and multidrug-resistant bacteria (the completed ATNC calls these pollutants of high concern). In comparison to traditional pollutants (e.g., heavy metal and pesticides), these contaminants are discovered in the environment and concern is growing with international scientists because they may pose biological endocrine disruption or carry risks of antimicrobial resistance (AMR), among other concerns. These contaminants are broadly termed "emerging contaminants" [1, 2, 3]. Emerging contaminants are indicators of concern for current and future chemical contamination in the environment and urinary concentration. They have adverse effects on human reproductive and developmental processes, endocrine systems, and may be carcinogens. Antibiotics and chemicals used in animal husbandry can also have negative impacts on drug efficacy and contribute to the rise of new infectious diseases. These contaminants are recognized as "contaminants of emerging concern" due to their potential unknown impacts on soil, health, well-being, and ecological and social services. Further studies are needed to assess their risks to human and environmental health. Cleaning these contaminants from water systems is challenging with current technologies, and they pose a danger to aquatic life. Cost-effective remediation strategies are urgently required [4, 5, 6].

PRINCIPLES OF MICROBIAL BIOREMEDIATION

Emerging contaminants have stirred considerable concern in the last two decades, mainly because of their potential toxic properties and bioaccumulation effects. After the discovery of their prevalence in living organisms, significant attention has been given to their monitoring, removal, and potential risks to human health. Microbial bioremediation has caught the eyes of several research groups as a low-cost and sustainable strategy for the treatment and removal of emerging contaminants present in contaminated aqueous systems. Microorganisms, comprising algae and bacteria, have been reported to degrade or transform emerging contaminants with a good removal rate and efficiency, and the number of microorganisms isolated and characterized as degrading emerging contaminants has been increasing. This review describes the recent advances in microbial-based organisms used as a strategy for the removal of emerging contaminants present in urban water systems [7, 8, 9]. Bioremediation is recognized as an eco-friendly and sustainable approach to eliminate the hazard, toxicity, and generation of any intermediates during the degradation process. The removal of chemicals and organic pollutants by microorganisms, algae, and fungi is termed as bioremediation. Briefly, bioremediation involves a series of metabolic reactions mediated by living organisms. The pollutants will be converted into non-harmful molecules, together with CO_2, methane, and biomass as the end product when organics are used as the energy source. In the process of microbial bioremediation, various physiological groups of microorganisms, including but not limited to bacteria, actinobacteria, fungi, and algae, play a crucial role in degrading and eliminating organic pollutants. In addition to known and straightforward biodegradation mechanisms, such as enzymatic reactions, another premise of bioremediation is the bioavailability of the compound, which is the first described and a major decision in the development of a bioremediation strategy [10, 11].

KEY MICROORGANISMS INVOLVED IN BIOREMEDIATION

Key biocatalysts involved in the degradation of emerging contaminants encode certain characteristics that may make them prime candidates to being involved in efficient, cost-effective bioremediation schemes. These may be strict behavior relative to the original pathways of metabolism or evolved versatility to deal with a multitude of contaminants, abiotic/physicochemical factors, and/or biotic competition. Often, these microorganisms are supplied with features to enhance mass transfer or facilitate the colonization or attachment in natural environments [12, 13]. Next to these microorganisms, there are generalist bacteria or fungal species, which are of relevance for the mineralization or removal of small amounts of contaminants under extreme conditions of accumulated stressors in engineered bioprocesses, which are more used in the design of biological effluent treatment following conventional treatment processes. Importantly, these species also play a role in promoting the loss of contaminants in trading zones between natural environments and effluents [14, 15]. These properties provide them the possibility to interact or be part of the microbial consortia capable of biodegrading (additional) pollutants in the same instances. Microorganisms that can efficiently break down or convert persistent compounds into less harmful substances by operating in consortia are becoming more important in new developments with mixed cultures like development of microbial fuel cells, whole cell biosensors, and of microbial self-healing or self-sealing concrete. Unlike typical pollutant degraders, however, those capable of degrading emerging contaminants are typically not fast-growing microorganisms, and are found in low abundance in the environment. For practical purposes, these microorganisms must often be isolated and enriched from environments contaminated with the pollutant of interest, to produce starter or seed cultures for bioreactors [16, 17].

TECHNIQUES FOR MONITORING AND ASSESSING BIOREMEDIATION PROCESSES

Monitoring and assessing the efficiency, reliability, and robustness of bioremediation processes is essential, as is assessing whether treatment goals are being achieved. There are reproducible techniques for monitoring and analyzing the behavior and metabolic activity of developed pure and mixed cultures, which is a major challenge in current ecotoxicology and environmental quality assessment. Furthermore, the targeted contaminants may have variable pchem types (hydrophobic and hydrophilic contaminants), logKow values, and half-lives that affect assessment success and make the validation of a number of chronological criteria practically impossible [18, 19]. Physicochemical examination of the effluents from pilot- or full-scale systems is not as strongly embraced today, and the focus has shifted toward the quantification of microbial ecology development in a more accurate way. The development of an emerging transcriptional activation technique has the potential to contribute significantly to the investigation of environmental bioremediation. Earlier work showed that the surrogate gfp gene, which encodes a green fluorescent protein (GFP), was cloned and expressed under the control of the alkB, ermC, and anfG gene promoter of the gene-regulation genes. The developed Escherichia Coli was applicable for the direct nullification of hydrocarbon and heavy metals in vitro [20, 21]. These studies have shown that during bioremediation, the levels of particular RNA would vary in agreement with the amount of gene-related products inside the network, and this would have a positive impact on the research done in such a field. In a current study, a more comprehensive understanding of genetic influences controlled by chemicals was required. Thus, the design of suitable target genes, for example in the case of endocrine and non-endocrine randomized xenobiotic metabolism, should be chosen specifically to outline specific hypotheses for single or bioavailability-ecotoxicity effect-based endpoints. Furthermore, template-based constraints may also be used in a stepwise approach designed to take into account additional cellular exchanges, metabolic processes, and limitations within the cellular target space [22, 23].

CASE STUDIES OF SUCCESSFUL BIOREMEDIATION PROJECTS

Throughout the world, there have been many successful full-scale bioremediation projects. This section will describe three case studies, all located in Australia, to demonstrate some of the key considerations and design criteria that were implemented [24, 25].

Case Study 1: Elsa Dixon Park

This recreational site along the Parramatta River in the urban metropolis of Sydney was part of a highly urbanized stormwater catchment and suffered from pollution from heavy metal contamination since the park was utilized as a gas works from 1898 to 1975. This 18-hectare area had deep deposits of coal tars and was heavily contaminated with heavy metals like lead, copper, chromium, and zinc. The contamination spread under the road near the site. Over the years, various strategies were investigated to treat the site, including burning and capping the soil and advancing some of the soils in depot and landfill sites. By the 1970s, the site became a noxious waste spill from the Department of Environmental Conservation [26, 27].

Case Study 2: Coogee Beach Secondary Treatment Plant

Waste from the two adjacent wastewater leachate systems that serve Sydney's eastern suburbs, Bondi and Manly, had been piped down to Coogee's wastewater treatment plant since the 1930s. Because of its position on the beach and the close relationship to the most popularly attended beach in Sydney, the Coogee plant, located 8 km from the Sydney central business district, attended to the reuse or discharge of tertiary effluent. The plant was undersized; the effluent spent an average of 18 hours only in the oxidation pond systems detention time, when complete consolidation could take at least 25 hours. Since the tertiary assessments are often not met and are not utilized for irrigation, the facility utilizes spray irrigation fields to distribute the waste over about 8.6 acres of land [28, 29, 30].

CONCLUSION

The growing presence of emerging contaminants in urban water systems poses a significant challenge to environmental and public health. Traditional remediation methods are often insufficient for addressing these complex pollutants, highlighting the need for innovative solutions such as microbial bioremediation. By leveraging the natural metabolic processes of microorganisms, bioremediation offers a sustainable and cost-effective approach to degrade or transform emerging contaminants into less harmful substances. While promising, the success of microbial bioremediation depends on the careful selection and optimization of microbial consortia, as well as robust monitoring and assessment techniques. Future research should focus on enhancing the efficiency and scalability of bioremediation processes, ensuring their viability as a mainstream solution for water treatment.

REFERENCES

1. Kumar M, Sridharan S, Sawarkar AD, Shakeel A, Anerao P, Mannina G, Sharma P, Pandey A. Current research trends on emerging contaminants pharmaceutical and personal care products (PPCPs): a comprehensive review. Science of The Total Environment. 2023 Feb 10;859:160031. academia.edu

2. Reyes NJ, Geronimo FK, Yano KA, Guerra HB, Kim LH. Pharmaceutical and personal care products in different matrices: occurrence, pathways, and treatment processes. Water. 2021 Apr 22;13(9):1159. mdpi.com

3. Golovko O, Örn S, Sörengård M, Frieberg K, Nassazzi W, Lai FY, Ahrens L. Occurrence and removal of chemicals of emerging concern in wastewater treatment plants and their impact on receiving water systems. Science of the Total Environment. 2021 Feb 1;754:142122. sciencedirect.com

4. Vasilachi IC, Asiminicesei DM, Fertu DI, Gavrilescu M. Occurrence and fate of emerging pollutants in water environment and options for their removal. Water. 2021. mdpi.com

5. Koch N, Islam NF, Sonowal S, Prasad R, Sarma H. Environmental antibiotics and resistance genes as emerging contaminants: methods of detection and bioremediation. Current research in microbial sciences. 2021 Dec 1;2:100027. sciencedirect.com

6. Parida VK, Saidulu D, Majumder A, Srivastava A, Gupta B, Gupta AK. Emerging contaminants in wastewater: A critical review on occurrence, existing legislations, risk assessment, and sustainable treatment alternatives. Journal of Environmental Chemical Engineering. 2021 Oct 1;9(5):105966. [HTML]
7. Haripriyan U, Gopinath KP, Arun J, Govarthanan M. Bioremediation of organic pollutants: A mini review on current and critical strategies for wastewater treatment. Archives of Microbiology. 2022 May;204(5):286. [HTML]
8. Mahesh N, Balakumar S, Danya U, Shyamalagowri S, Babu PS, Aravind J, Kamaraj M, Govarthanan M. A review on mitigation of emerging contaminants in an aqueous environment using microbial bio-machines as sustainable tools: Progress and limitations. Journal of Water Process Engineering. 2022 Jun 1;47:102712. [HTML]
9. Preethi PS, Hariharan NM, Vickram S, Rameshpathy M, Manikandan S, Subbaiya R, Karmegam N, Yadav V, Ravindran B, Chang SW, Awasthi MK. Advances in bioremediation of emerging contaminants from industrial wastewater by oxidoreductase enzymes. Bioresource Technology. 2022 Sep 1;359:127444. [HTML]
10. Bhandari S, Poudel DK, Marahatha R, Dawadi S, Khadayat K, Phuyal S, Shrestha S, Gaire S, Basnet K, Khadka U, Parajuli N. Microbial enzymes used in bioremediation. Journal of Chemistry. 2021;2021(1):8849512. wiley.com
11. Sharma B, Shukla P. Designing synthetic microbial communities for effectual bioremediation: A review. Biocatalysis and Biotransformation. 2020. academia.edu
12. Kaur P, Singh A, Sharma J. Microbial enzymes: Versatile tools for pollution abatement. Metagenomics to Bioremediation. 2023. academia.edu
13. Wang M, Ding M, Yuan Y. Bioengineering for the microbial degradation of petroleum hydrocarbon contaminants. Bioengineering. 2023. mdpi.com
14. Qi Q, Hu C, Lin J, Wang X et al. Contamination with multiple heavy metals decreases microbial diversity and favors generalists as the keystones in microbial occurrence networks. Environmental Pollution. 2022. [HTML]
15. Li S, Deng Y, Lian S, Dai C et al. Succession of diversity, functions, and interactions of the fungal community in activated sludge under aromatic hydrocarbon stress. Environmental Research. 2022. [HTML]
16. Bhattacharyya PN, Sonowal S, Bhattacharyya LH, Prasad R, Sarma H. Bioremediation of cytostatic pharmaceutical and personal care products and emerging technologies. Emerging Contaminants in the Environment. 2022 Jan 1:579-601. [HTML]
17. Sivasubramaniyan SG, Kandasamy S, Manickam NK. Novel biotechnological approaches for removal of emerging contaminants. Biotechnology for Zero Waste: Emerging Waste Management Techniques. 2022 Mar 7:397-407. [HTML]
18. Braissant O, Astasov-Frauenhoffer M, Waltimo T, Bonkat G. A review of methods to determine viability, vitality, and metabolic rates in microbiology. Frontiers in Microbiology. 2020 Nov 17;11:547458. frontiersin.org
19. Temple J, Velliou E, Shehata M, Lévy R, Gupta P. Current strategies with implementation of three-dimensional cell culture: the challenge of quantification. Interface Focus. 2022 Aug 12;12(5):20220019. royalsocietypublishing.org
20. Shao J, Li S, Qiu X, Jiang J, Zhang L, Wang P, Si Y, Wu Y, He M, Xiong Q, Zhao L. Engineered poly (A)-surrogates for translational regulation and therapeutic biocomputation in mammalian cells. Cell Research. 2024 Jan;34(1):31-46. nature.com
21. Colameo D. The Role of Posttranscriptional Gene Regulation During Homeostatic Synaptic Plasticity: Neuroscience. 2023. ethz.ch
22. Gunjal A, Gupta S, Nweze JE, Nweze JA. Metagenomics in bioremediation: Recent advances, challenges, and perspectives. Metagenomics to Bioremediation. 2023. academia.edu
23. Salgado EM, Gonçalves AL, Sánchez-Soberón F, Ratola N, Pires JC. Microalgal cultures for the bioremediation of urban wastewaters in the presence of siloxanes. International Journal of Environmental Research and Public Health. 2022 Feb 24;19(5):2634. mdpi.com
24. Pande V, Pandey SC, Sati D, Pande V, Samant M. Bioremediation: an emerging effective approach towards environment restoration. Environmental Sustainability. 2020 Mar;3:91-103. [HTML]

25. King RB, Sheldon JK, Long GM. Practical environmental bioremediation: the field guide. 2023. [HTML]
26. Carlson B, Day M, O'Sullivan S, Kennedy T. The Routledge handbook of Australian Indigenous peoples and futures. 2023. [HTML]
27. Yates K. All The Houses I've Ever Lived In: Finding Home in a System that Fails Us. 2023. [HTML]
28. CASE SDWB, SCUBA GBAY, CLUB D. Sydney Dive Wreck Business Case. gordonsbayscubadiving.com. . gordonsbayscubadiving.com
29. Liang G. In situ remediation options for polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) in Sydney Harbour sediments. 2020. unsw.edu.au
30. Farrelly E. Killing Sydney: The Fight for a City's Soul. 2021. [HTML].

CITATION: Emeribe Chiemeka Elochi. (2024). Microbial Bioremediation of Emerging Contaminants in Urban Water Systems. Research Output Journal of Public Health and Medicine 3(1):41-45.