Original Research Paper

Volume - 12 | Issue - 05 | May - 2022 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Microbiology

BIOREMEDIATION POTENTIALS OF EPS: A MINI REVIEW.

Baishali Pandit Assistant Professor, Department of Botany, Surendranath College, 24/2, M. G. Road, Sealdah, Kolkata, West Bengal.

ABSTRACT EPSs are complex biomolecules composed of proteins, polysaccharides, lipids, and their derivatives. Microorganisms continuously secrete EPS throughout their development and metabolism. The EPS derived from various microbial aggregates have been found to have diverse composition. They are important for microbial cell aggregation, biofilm formation, immunomodulation, and are also commercially utilized as food industry gelling agents, heavy metal contaminant sequestration, and other processes (Chug et al., 2021). The ionizable functional groups of EPS, including carboxyl, amine, and hydroxyl, aid in the sequestration of metal ions. Previous research has found a link between microbes' ability to eliminate metals and their synthesis of EPS. EPSs produced by microbes are non-toxic, biocompatible, and biodegradable polymers with several uses in various sectors (Siddharth et al., 2021). Bioremediation by bacterial EPSs can be a cost-effective, sustainable, and simple alternative which is also ecologically viable.

KEYWORDS : Exopolysaccharides, microbes, biofilms, biodegradable, polymers, bioremediation.

INTRODUCTION

Polysaccharides are the most prevalent macromolecules on our planet, consisting of monomeric sugars connected by glycosidic linkages. Plants, mammals, algae, fungus, bacteria, and archaea are all known to produce them, and they are recognized to serve an important role in preserving structural integrity and functionality of cells. Extracellular polysaccharides, also known as exopolysaccharides (EPSs), are complex biopolymers with high molecular weight and include non-carbohydrate organic compounds as components, such as proteins, lipids, humic substances, or extracellular DNA (Rana and Upadhyay, 2020).

As a survival strategy, microorganisms thriving in unfavourable settings generate and surround themselves with an EPS layer (Merino et al., 2019; López-Ortega et al., 2021). EPS protects bacteria from variations and extremes of temperature, salinity, aridity, and desiccation. The host bacteria are additionally protected by the EPS matrix from antimicrobial medications and medicines (Merino et al., 2019; Wang et al., 2019). EPS is a natural component of biofilms and aids bacterial surface attachment, colonization, and nutrient uptake (Wang et al., 2019). Some EPSs from marine isolates, including sphingan, gellan gum, welan, rhamsan, and diutan, are recognized for their extreme sliminess or high viscosity, making them useful as a transparent thickening agent, stabilizer, and binder, especially in the food and cosmetics sectors. Other possible EPS uses (from halophiles) are as emulsifiers and surfactants, for bioremediation of oil-contaminated areas and in-situ degradation of long-chain n-alkanes and petroleum hydrocarbons.

Bioremediation By EPS

Bioremediation is the environmentally benign technique of employing microorganisms to detoxify toxic chemicals from soil, water, and air. Because no harsh chemicals are employed in bioremediation, the environmental impact is decreased. Bioremediation has several advantages over other methods, including no or minimal disruption of surrounding land or wildlife, reduced noise and dust during treatment, and the avoidance of harsh chemicals. When compared to traditional decontamination methods, bioremediation seems more cost-effective. Xenobiotic compounds, aromatic hydrocarbons, volatile organic compounds, pesticides, herbicides, heavy metals, radionuclides, crude oil, jet fuels, petroleum products, and explosives are all degraded or treated by bioremediation.

Microbes, particularly bacteria, are easy to grow and manipulate genetically, making them ideal for bioremediation. Importantly, as microbes are adapted to survive in a variety of environments, they are extremely efficient at degrading natural organic compounds or waste pollutants via a variety of catabolic pathways. The success of bioremediation is dependent on the preservation of environmental conditions that promote microbial biodegradation of contaminants. The transformation and breakdown of environmental contaminants or wastes into less hazardous or innocuous elements such as carbon dioxide and water is dependent on the enzymatic activities of microorganisms. Transfer of electrons from electron donors to electron acceptors is required in the metabolic pathways involved in this process. The electron donors provide bacteria with food, which is normally scarce in a non-contaminated environment. In a polluted environment, however, the discharge of an organic electron donor may encourage bacteria to compete for available acceptors in order to restore system equilibrium. In anaerobic and aerobic modes of degradation, microorganisms can breakdown contaminants without or with the use of oxygen. Microbes employ oxygen as the ultimate electron acceptor in aerobic degradation to transform organic and inorganic pollutants into innocuous products, which are often carbon dioxide and water.

By fermenting pollutants, certain bacteria may be able to break them down. Pollutants that are electron givers may be quickly decomposed by aerobic bacteria in the presence of oxygen, whereas pollutants that are poor electron donors may be degraded in anaerobic circumstances. Many redox reactions also immobilize trace elements that have been identified in polluted areas. Changes in metal oxidation potential are also linked to changes in toxicity or solubility, as seen with uranium and chromium. In the case of heavy metals, the conversion of sulphate to sulphide alters solubility, making it easier for sulphur-reducing bacteria to immobilize and remove sulphate from wastewater.

Role Of Biofilms In Bioremediation

A biofilm is a collection of microorganisms adhered to a biological or inert surface and wrapped in a self-synthesized matrix of water, proteins, carbohydrates, and extracellular DNA. Different microbial species present in biofilm consortia, each with their own metabolic degradation pathway, may be capable of degrading multiple contaminants individually or collectively. Biofilm-forming bacteria have evolved to survive and are well-suited for bioremediation because they compete for nutrients and oxygen, and reports suggest that biofilms are resistant to harsh environments and effectively carry out the process of bioremediation. Biofilm-mediated remediation is a cost-effective and environmentally acceptable method of removing contaminants from the environment. Biofilms are effective for bioremediation because they absorb, immobilise, and decompose a variety of contaminants. Indigenous inhabitants of extremely polluted areas have developed bacterial biofilms to thrive, endure, and survive in the tough environment. Most bacteria prefer to live in biofilm mode in natural environments, enclosed in a matrix formed by extracellular polymeric substances (EPSs). Polysaccharides, proteins, lipids, nucleic acids, humic compounds, and water are all found in EPS in both bound and secreted forms. The composition of EPS varies by species and is influenced by factors such as growth conditions, the surface on which biofilms develop, and environmental stress. Microbes are more resistant to environmental stress, shear stress, acid stress, antimicrobial agents, UV damage, desiccation, predation, biocides, solvents, and high concentrations of harmful compounds and pollutants in the biofilm matrix than in planktonic cells.

Biofilm-forming microorganisms, excel in bioremediation because they are trapped in EPS that also immobilises pollutants during decomposition. Aerobes and anaerobes, heterotrophs with nitrifiers, and sulphate reducers with sulphate oxidizers are all brought together in close proximity by the three-dimensional structure of EPS, which facilitates quicker degradation of various pollutants in natural and manmade systems. Heavy metals are removed from the aqueous phase using cyanobacterial EPS as a biosorbent. Surfactants in EPS may also help microbes solubilize hydrophobic or other refractory substrates that would otherwise be unavailable to them. Pollutants like heavy metals and organic substances are decontaminated by extracellular enzymes found in biofilm EPS. Because of the presence of several negatively charged functional groups in EPS, it acts as a trap for metals and metalloids, allowing for the formation of complexes with heavy metals and organic pollutants and their subsequent removal. Lead, copper, manganese, magnesium, zinc, cadmium, iron, and nickel are among the metals known to bind to EPS. Nutrient restriction can also boost EPS production, which can help the microbes absorb more metals and contaminants from the environment. The EPS of biofilms containing phosphorous-accumulating bacteria acts as a reservoir, allowing phosphorous to be removed and recovered from wastewater.

Heavy Metal Biosorption and Bioaccumulation

Bacterial EPSs play an important role in metal biosorption, they can efficiently bioremediate harmful heavy metal-containing wastewater and reduce the deleterious effects of xenobiotics. Polyanionic bacterial EPSs interact with positively charged metal ions (an ionic exchange mechanism occurs), thereby reducing the harmful substances to benign ones (Joulak et al., 2020b). The interaction of single or multiple metal ion solutions with anionic bacterial EPSs is regulated by their size, ionic nature, and charge (Zhao et al., 2020). For the treatment of high-salt containing wastewaters, microbial EPS is utilised to scavenge Na+, allowing those microorganisms to survive in high-NaCl environments. This Na+ scavenging property of EPSs is also used in biofilm reactors. They have potential uses in industrial applications such as bioleaching (Zhang et al., 2019), immobilisation of metals such as cadmium, and bio emulsification. EPSs have also been used to reduce the harmful effects of Pb through biosorption, metal chelation using siderophores, and metallothionein synthesis (Mitra et al., 2021). Bacterial EPS may thus be used to remediate Pb from industrial wastewater in a more cost-effective manner than the traditional physical and chemical methods (Mitra et al., 2021). It has been observed that EPS generated by *Sphingomonas sp. MKIV* can eliminate over 90% of toxic ionic liquids from waste effluent (Koutinas et al., 2019). Another recent study found that heteropolymeric EPS from *Streptomyces sp*. can remove more than 93 percent of Sr2+ from radioactive solution (Koutinas et al., 2019). Additionally, electroactive bacteria such as *Shewanella oneidensis* (sorption followed by reduction of U(VI)) and *Pseudomonas putida* (reduction of arsenate and biotransformation of dibenzothiophene) have been reported to effectively treat metallic minerals (e.g., uranium and arsenate) and organic pollutants (e.g., dibenzothiophene) present in wastewater. An EPS derived from the acidophilic sulphur-oxidizing bacteria *Acidithiobacillus thiooxidans* was shown to be responsible for metal bioleaching. Similar bioleaching activity for metal sulphides from natural mineral substrates like pyrite has been reported for EPS derived from the thermoacidophilic archaeon *Acidianus sp. DSM 29099*, as well as the thermophilic *Acidithiobacillus caldus* (Zhang et al., 2019, Huang et al., 2019). EPS from *Exiguobacterium profundum PT2* has been found to have arsenic biosorption properties. Deschatre et al. (2015) also provided a brief report on the role of EPS as an effective silver biosorbent, a discovery that can be further investigated as a viable method for extracting precious metals from their respective sources. EPS can thus be used for the remediation of metal and organic pollutants (Giovanella et al., 2020; Kaushik et al., 2021), xenobiotic compounds (Jeong and Choi, 2020; Shukla and Singh, 2020), radionucleotides, plastics and various agrochemicals (Kour et al., 2021), and synthetic pollutants (Kour et al., 2021, Bhatt et al., 2021).

CONCLUSION AND FUTURE PROSPECTS

Exopolysaccharides are a major component of the bacterial biofilm that forms in difficult conditions to support microbial growth and survival. It builds a connective network around bacterial cells, allowing them to survive in an otherwise hostile environment of high temperatures, salinity, acidic pH, heavy metals, UV radiation, and other factors. The biotechnological advantages of EPSs produced by microbes are more diverse than traditional biopolymers for use in food (for their unusual gelling and thickening properties), textiles (as surfactants in detergents), cosmeceutical, pharmaceutical, and biomedicine industries due to their non-toxic, biodegradable, and biocompatible nature (for their immunomodulatory and antiviral effects). EPSs have a wide range of unusual structural and functional properties that have implications for rapid, efficient, sensitive, economical, and high-value applications, such as decontamination agents in the mining and textile industries, and wastewater treatment involving biosorption, emulsification, and flocculation of textile dyes, ionic wastes, metal ions, heavy metals, oil, and hydrocarbons, among others. Many bioorganic and inorganic substances, such as uronic acid, lipids, amino acids, and polysaccharides, contribute to the bioremediation efficacy of EPS. In a period of rising water pollution, climate change, and water scarcity, wastewater recycling by EPS has emerged as a perfect solution for the future. However, in order for the bioremediation process to be successfully commercialised for use in industrial wastewater treatment plants, the dosage of metal ions as well as adsorbent (EPS), duration of the interaction, optimal physio-chemical conditions of bacterial growth, biomass concentration, and redox potential of the bacterial EPSs must be strictly regulated and controlled. EPS must be applied periodically in bioremediation. More in-depth understanding of the structure-function correlations of bacterial EPSs is required for realising the full potential of these remarkable biomaterials.

REFERENCES

1. Banerjee, A., Sarkar, S., Govil, T., et al. (2021) Extremophilic Exopolysaccharides: Biotechnologies and Wastewater Remediation. Front. Microbiol., 12, 721365. doi: 10.3389/fmicb.2021.721365
2. Bhatt, P., Gangola, S., Bhandari, G., et al. (2021). New insights into the degradation of synthetic pollutants in contaminated environments. Chemosphere, 268, 128827. doi: 10.1016/j.chemosphere.2020.128827
3. Chug, R., Das Mukherji, M., Upadhyay, E., and Singh Gour, V. (2021). Investigating the promising potential of bacterial EPS for mitigating environmental issues Eco. Env. & Cons. 27 (February Suppl. Issue), S226-S228.
4. Giovanella, P., Vieira, G. A. L., Ramos Otero, I. V., et al. (2020). Metal and organic pollutants bioremediation by extremophile microorganisms. J. Hazard. Mater., 382, 121024. doi: 10.1016/j. jhazmat.2019.121024
5. Guarin, T. C., and Pagilla, K. R. (2021). Microbial community in biofilters for water reuse applications: a critical review. Sci. Total Environ., 773, 145655. doi: 10.1016/j.scitotenv.2021.145655
6. Huang, Z., Feng, S., Tong, Y., and Yang, H. (2019). Enhanced "contact mechanism" for interaction of extracellular polymeric substances with low-grade copper-bearing sulfide ore in bioleaching by moderately thermophilic *Acidithiobacillus caldus*. J. Environ. Manag., 242, 11–21. doi: 10.1016/j.jenvman.2019.04.030
7. Jeong, S.W., and Choi, Y. J. (2020). Extremophilic microorganisms for the treatment of toxic pollutants in the environment. Molecules, 25:4916. doi: 10.3390/ molecules25214916
8. Joulak, I., Azabou, S., Finore, I., et al. (2020a). Structural characterization and functional properties of novel exopolysaccharide from the extremely halotolerant *Halomonas elongata* S6. Int. J. Biol. Macromol. 164, 95–104. doi: 10.1016/j.ijbiomac.2020.07.088
9. Joulak, I., Finore, I., Poli, A., et al. (2020b). Hetero-exopolysaccharide from the extremely halophilic *Halomonas smyrnensis K2*: production, characterization and functional properties in vitro. 3 Biotech, 10, 395. doi: 10.1007/s13205-020-02356-5
10. Kaushik, S., Alatawi, A., Djiwanti, S. R., Pande, A., Skotti, E., and Soni, V. (2021). "Potential of extremophiles for bioremediation," in Microbial Rejuvenation of Polluted Environment: Vol. 1. eds. D. G. Panpatte and Y. K. Jhala (Singapore: Springer Singapore), 293–328.
11. Koutinas, M., Vasquez, M. I., Nicolaou, E., et al. (2019). Biodegradation and toxicity of emerging contaminants: isolation of an exopolysaccharide-producing *Sphingomonas sp*. for ionic liquids bioremediation. J. Hazard. Mater., 365, 88–96. doi: 10.1016/j.jhazmat.2018.10.059
12. Kour, D., Kaur, T., Devi, R., Yadav, A., Singh, M., Joshi, D., et al. (2021). Beneficial microbiomes for bioremediation of diverse contaminated environments for environmental sustainability: present status and future challenges. Environ. Sci. Pollut. Res. Int., 28, 24917–24939. doi: 10.1007/s11356-021-13252-7
13. López-Ortega, M. A., Chavarría-Hernández, N., del Rocío López-Cuellar, M., and Rodríguez-Hernández, A. I. (2021). A review of extracellular polysaccharides from extreme niches: an emerging natural source for the biotechnology. From the adverse to diverse! Int. J. Biol. Macromol., 30, 559–577. doi: 10.1016/j.ijbiomac.2021.02.101
14. Maurya, A., and Raj, A. (2020). "Recent advances in the application of biofilm in bioremediation of industrial wastewater and organic pollutants," in Microorganisms for Sustainable Environment and Health. eds. P. Chowdhary, et al. (India: Elsevier), 81–118. doi:10.1016/B978-0-12-819001-2.00005-X
15. Merino, N., Aronson, H. S., Bojanova, D. P., et al. (2019). Living at the extremes: extremophiles and the limits of life in a planetary context. Front. Microbiol., 10, 780. doi: 10.3389/ fmicb.2019.00780
16. Mitra, A., Chatterjee, S., Kataki, S., Rastogi, R. P., and Gupta, D. K. (2021). Bacterial tolerance strategies against lead toxicity and their relevance in bioremediation application. Environ. Sci. Pollut. Res., 28, 14271–14284. doi: 10.1007/s11356-021-12583-9
17. Pereira, S. B., Sousa, A., Santos, M., Araújo, M., Serôdio, F., Granja, P., et al. (2019). Strategies to obtain designer polymers based on cyanobacterial extracellular polymeric substances (EPS). Int. J. Mol. Sci., 20, 5693. doi: 10.3390/ ijms20225693
18. Rana, S., and Upadhyay, L. S. B. (2020). Microbial exopolysaccharides: synthesis pathways, types and their commercial applications. Int. J. Biol. Macromol., 157, 577–583. doi: 10.1016/j.ijbiomac.2020.04.084
19. Shukla, A. K., and Singh, A. K. (2020). Exploitation of potential extremophiles for bioremediation of xenobiotics compounds: a biotechnological approach. Curr. Genomics, 21, 161–167. doi: 10.2174/1389202921999200422122253
20. Siddharth, T., Sridhar, P., Vinila, V., and Tyagi, R. D. (2021). Environmental applications of microbial extracellular polymeric substance (EPS): a review. J. Environ. Manag., 287:112307. doi: 10.1016/j.jenvman.2021.112307
21. Zhao, Y., Zhuang, X., Ahmad, S., Sung, S., and Ni, S. Q. (2020). Biotreatment of high-salinity wastewater: current methods and future directions. World J. Microbiol. Biotechnol., 36, 1–11. doi: 10.1007/s11274-020-02815-4
22. Zhang, R., Neu, T. R., Blanchard, V., Vera, M., and Sand, W. (2019). Biofilm dynamics and EPS production of a thermoacidophilic bioleaching archaeon. New Biotechnol., 51, 21–30. doi: 10.1016/j.nbt.2019.02.002