ISBN: 978-93-94570-82-5

7. New Trends in Environmental Biotechnology for Air Pollution Control

Ajit D. Gaikwad

[M. Tech (Chemical and Biotechnology), M-SET Life sciences],
Project. Tech supp-II, ICMR NIV PUNE.

7.1 Introduction:

Industrialization and increased human activity have led to environmental degradation due to soil, water, and air pollution. Although there are set regulations each industry should follow to conserve the environment, it remains a daunting task. Scientists have realized that if you can't control the waste being released, you can manage it.

Initially, chemicals were used to treat waste and other pollutants. However, chemicals turned out to be costly and inefficient. With technological advancement and enhancement in knowledge, scientists now develop sustainable waste treatment and pollutant removal strategies. This branch of biotechnology relies on beneficial microorganisms to create a safe, greener environment.

Technology is a great industry as it has improved the human lifestyle and the world at large. However, it has also had detrimental environmental effects due to high pollution and increased human activity. As a solution to pollution, scientists developed environmental biotechnology.

Biotechnology provides a plethora of opportunities for effectively addressing issues pertaining to the monitoring, assessment, modeling, and treatment of contaminated water, air, and solid waste streams.

Also offers the most economical and environmentally benign method for air pollution control when dealing with the removal of odorous and toxic contaminants from industrial and municipal airstreams.

Environmental biotechnology is a branch of science that uses living organisms and innovation to solve environmental problems effectively. This is one industry that has experienced positive results following tech advancement and discoveries. Environmental Biotechnology manipulates microbial organisms while exploiting their beneficial properties to serve the human community. This has paved the way for efficient environmental conservation strategies against global warming and climate change.

With the promising advancements in environmental biotechnology, there's no telling what to expect in the future. Today, you can control pollution better and exercise environmental remediation thanks to advancements in environmental biotechnology.

But here are the environmental biotechnology trends shaping the industry in 2023! The rapidly increasing industrialization has adversely affected the environment due to deterioration of water and air quality. The continuous addition of hazardous chemicals, gaseous contaminants, and particulate materials to our environment imposed the life-threatening challenges for flora and fauna. There is an urgent need to adopt the sustainable technologies to reduce the contamination occurring in air and water resources.

In this context, source tracking of environmental pollutants and process modeling using biological based methods are becoming increasingly important, mainly owing to the accuracy and robustness of such techniques. ***Environmental Monitoring and Modeling*.**

In developing countries, water, air, and soil pollution has become a persisting environmental problem due to rapid industrialization and urbanization. Using environmental Kuznets curve (EKC) it was observed that, during early stages of economic development in a particular region, the environment paid a high price for economic growth as the human race used technology to exploit all possible valuable resources.

Nevertheless, in agricultural areas, N, P, and K compounds are easily transported by farmland drainage and surface water to valuable water resources resulting in the deterioration of water quality that warrants the use of novel biosensors to monitor water quality.

Recently, it has been proposed that cellular-based biosensor technologies, that is, the bioelectric recognition assay (BERA), utilize live, functional cells in a gel matrix coupled with a sensor system that is able to measure changes in the cellular electric properties. Cells that are able to specifically interact with a target analyte produce a unique pattern of electrical potential as a result of their interaction with this analyte.

Concerning modeling, traditionally, the performance of many bioprocesses [1] has been modeled/predicted using process-based models that are based on mass balance principles, simple reaction kinetics, and a plug flow of water/air stream.

An alternate modeling procedure consists of a data driven approach wherein the principles of artificial intelligence (AI) are applied with the help of neural networks [2, 3]. The concept of neural network modeling has widespread applications in the fields of applied biosciences and bioengineering.

7.1.1 Pollutant Removal and Toxicity:

Environmental pollutants such as heavy metals and pesticides are commonly present in water emanating from acid mine drainage or other industries and from agricultural runoffs. These toxic pollutants can accumulate in living organisms and produce adverse effect such as carcinogenicity and acute toxicity.

Complete mineralization and/or removal of these pollutants and their toxic byproducts can be achieved using biological process that uses active bacterial/fungal/mixed microbial cultures.

7.1.2 Biofuels Production:

Biohydrogen production through anaerobic fermentation is a sustainable alternative for managing the recent (dogging) energy crisis and creating a sustainable green environment. Fermentative hydrogen production processes are technically feasible and economically cost-competitive and have large-scale commercialization implications [6, 7].

Besides some of the pure microbial species, that can be used to produce biofuels, as of late, it was shown that microbes present in the sediments of mangroves have the capability to yield biohydrogen.

Mangrove sediments are inherently rich in organic content and offer the following advantages: flexible substrate utilization and the simplicity of handling, no major storage problems, minimal pre-culturing requirements, and sediments being available at low cost.

7.2 Microbial Products for the Environment:

With increasing concern for the natural environment, biosynthetic and biodegradable biopolymers such as poly-β-hydroxybutyrate (PHB) have attracted great interest because of their excellent biodegradability and being environmentally benign and sustainable.

The high production cost of PHB can be curtailed by strain development, improving fermentation and separation processes, and using inexpensive carbon source. Due to recent advancements in fermentation technology and allied sciences, alternative purification solutions are under investigation, among which microbiological ways of utilization of byproducts are very interesting and promising. Such a solution could result in better overall process productivity and facilitate the downstream processing.

Concerning the use of enzymes, owing to its lignolytic enzyme system, the white-rot fungus *Phanerochaete chrysosporium* has been applied in many bioremediation studies

7.3 Microbial Enhanced Oil Recovery (MEOR):

Technological advancement has allowed scientists to apply different molecular approaches to encourage hydrocarbon utilization in oil wells. This purifies the oil, therefore, reducing processing costs for increased profitability.

Genomic and proteomic isolations allow for profiling through technologies like fingerprinting and sequencing. This enables scientists to better understand each community and species for creative exploitation.

In MEOR, scientists cultivate hydrocarbon-consuming bacteria that remove pollutants from wells underground, therefore, cleaning the soil. This promotes environmental bioremediation. MEOR also enables investors to identify new oil wells even with the depleting oilfields.

7.4 Types of EOR Methods:

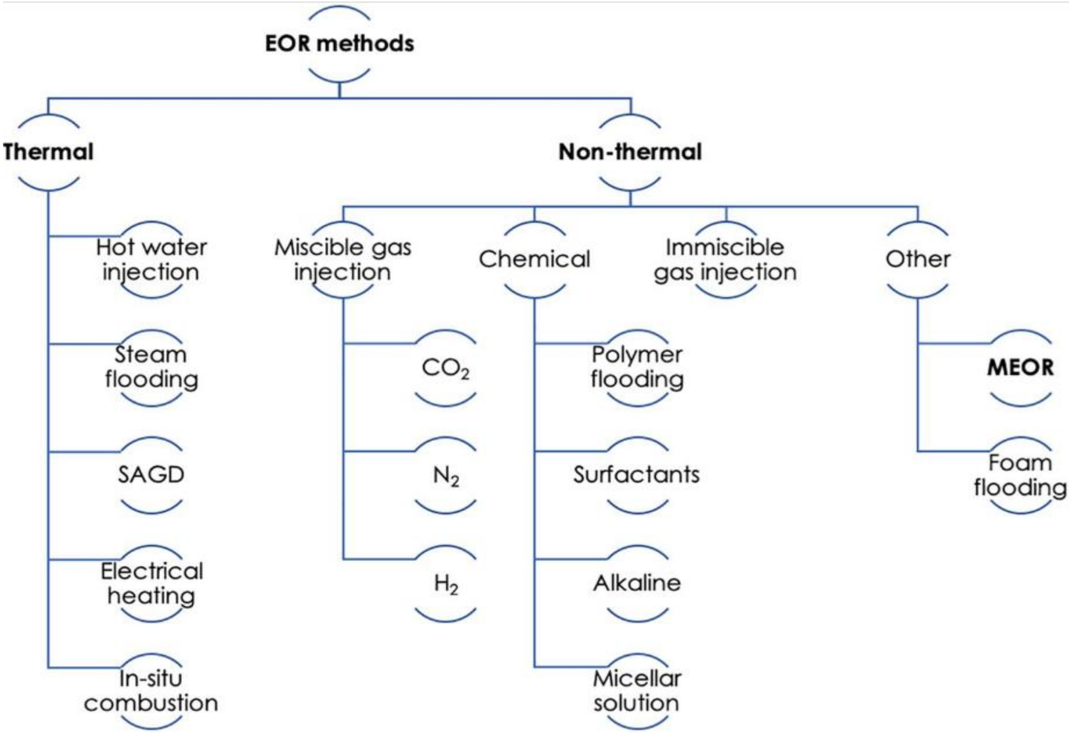

Figure 7.1: Types of EOR Methods

7.4.1 Bio-Electrochemical Systems:

Bio-electrochemical systems like microbial electrolysis cells or microbial fuel cells are the innovation behind fuel production from biodegradable organic matter. The systems use a biofilm catalyst to create electrical energy or hydrogen. Besides reducing energy consumption during waste treatment, bio-electrochemical systems will generate adequate electrical energy for industrial or domestic use.

7.4.2 Microbial Electro-Remediation:

Environmental biotechnologists recognize the important role that bio-electrochemical systems in waste remediation. To exploit the capabilities of this technology, these scientists turn to microbial electro-remediation. This innovative waste management strategy aims to generate sustainable energy through electro-genesis while recovering the resources.

7.4.3 Industrial Waste Treatment:

Industrial waste is the leading cause of environmental pollution, hence blamed for the climate change effects being experienced on earth.

However, advancements in environmental biotechnology have given the world a second chance at saving this planet. Using microorganisms, biotechnologists can technically and economically treat waste. This process relies on controlled biodegradation and detoxification for a quality environment.

Companies are now using bio-augmentation to accelerate the degradation process to treat large volumes of waste. This innovation comes in handy when you have a low volume of microorganisms for successful bioremediation. Bio-augmentation allows the waste treatment system to achieve its goal regardless of the underlying extraneous factors.

7.4.4 Biofuels for Microbial and Process Engineering:

Innovative approaches in environmental biotechnology have paved the way for the sustainable development of biofuels to use in engineering. Environmental biotechnologists use innovative approaches to convert plants into biofuels.

Microalgae such as hyacinth undergo bio-refining to reduce water pollution that has endangered the lives of biotic animals and plants. This will meet the need for alternative energy sources that promote environmental conservation for a quality, greener planet.

7.4.5 Creative Management of Chromium Phytotoxicity:

Chromium is a toxic chemical that will affect the growth of flora and the development of fauna. Because of the danger chromium poses to human life and the environment, environmental biotechnology has created strategies to prevent these phytotoxic effects. The ameliorative approach is the main process of reducing the chromium released in industrial waste and to the environment. Amelioration has limited after-use risks as compared to the traditional metal chelation process.

7.4.6 Enhanced Biological Phosphorous Removal (EBPR):

EBPR is a technologically advanced process of treating sewage in small-scale or domestic wastewater. This system needs an activated sludge that is configured to remove phosphate, which is a toxic pollutant. EBPR is preferable since it's cost-effective and highly sustainable since you only need to obtain the phosphorous-accumulating organisms (PAO).

7.4.7 Biosensors:

Environmental biotechnology has seen the development of biosensors that improve bio-monitoring of environmental changes and treatment processes. Biosensors come with physiochemical detectors that will sense the presence of certain chemicals in wastewater for remediation.

Microarrays can complement the biosensors to determine how toxic or concentrated a certain pollutant is. This is one of the latest environmental biotechnology technologies, aiming to improve waste treatment efficiency.

7.5 Conclusion:

There are various techniques discovered by the scientists recently to rejuvenate the environment naturally. With the help of Biotechnological approach we can solve the environmental issues by optimized and cost effective way, but further research and development study needs to control the air pollution within less time.

7.6 References:

1. Ajjolli Nagaraja, A., Charton, P., Cadet, X. F., Fontaine, N., Delsaut, M., Wiltschi, B., et al. (2020). A machine learning approach for efficient selection of enzyme concentrations and its application for flux optimization. Catalysts 10:291. doi: 10.3390/catal10030291
2. Ali, M., Ishqi, H. M., and Husain, Q. (2020). Enzyme engineering: reshaping the biocatalytic functions. Biotechnol. Bioeng. 117, 1877–1894. doi: 10.1002/bit.27329
3. Ambade, B., Sethi, S. S., Kumar, A., Sankar, T. K., and Kurwadkar, S. (2021a). Health risk assessment, composition, and distribution of polycyclic aromatic hydrocarbons (PAHs) in drinking water of Southern Jharkhand, East India. Arch. Environ. Contam. Toxicol. 80, 120–133. doi: 10.1007/s00244-020-00779-y
4. Cherry, J. R., and Fidantsef, A. L. (2003). Directed evolution of industrial enzymes: an update. Curr. Opin. Biotechnol. 14, 438–443. doi: 10.1016/S0958-1669(03)00099-5
5. Chung, C.-Y., Chung, P.-L., and Liao, S.-W. (2011). Carbon fixation efficiency of plants influenced by sulfur dioxide. Environ. Monit. Assess. 173, 701–707. doi: 10.1007/s10661-010-1416-5
6. Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., et al. (2009). Managing the health effects of climate change: lancet and University College London Institute for Global Health Commission. Lancet 373, 1693–1733. doi: 10.1016/S0140-6736(09)60935-1
7. Crameri, A., Dawes, G., Rodriguez Jr, E., Silver, S., and Stemmer, W. P. (1997). Molecular evolution of an arsenate detoxification pathway by DNA shuffling. Nat. Biotechnol. 15, 436–438. doi: 10.1038/nbt0597-436
8. Holmes, R. W., Anderson, B. S., Phillips, B. M., Hunt, J. W., Crane, D. B., Mekebri, A., et al. (2008). Statewide investigation of the role of pyrethroid pesticides in sediment toxicity in California's urban waterways. Environ. Sci. Technol. 42, 7003–7009. doi: 10.1021/es801346g
9. Jiang, N., Ma, L., and Lu, Y. (2020). Cell-free synthetic biology in the new era of enzyme engineering. Chin. J. Chem. Eng. 28, 2810–2816. doi: 10.1016/j.cjche.2020.05.037
10. Wang, T., Li, J., Xu, J., Fan, X., Zhao, L., Qiao, S., et al. (2018). Rational redesign of the active site of selenosubtilisin with strongly enhanced glutathione peroxidase activity. J. Catal. 359, 27–35. doi: 10.1016/j.jcat.2017.12.006
11. Zhou, K., Ng, W., Cortés-Peña, Y., and Wang, X. (2020). Increasing metabolic pathway flux by using machine learning models. Curr. Opin. Biotechnol. 66, 179–185. doi: 10.1016/j.copbio.2020.08.004