International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 25-07-2023, Accepted: 10-08-2023, Published: 26-08-2023
Volume 5, Issue 3, 2023, Page No. 15-18

Bioremediation: A sustainable tool for environmental wellbeing

Eshwar D Muley, Akash S Chavan*, Sameer R Naphade
Department of Zoology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

Abstract
Bioremediation may be a biotechnical handle, which cleans up the defilement. It is an effective waste management procedure which includes the utilize of life forms to evacuate or utilize the toxins from a contaminated range. There are a few cures where contaminated materials are is decontaminated by chemical treatment, cremation, and burial in a landfill. There are other sorts of squander administration method which incorporate strong squander administration, atomic squander administration, etc. Bioremediation is diverse because it doesn't employ poisonous chemicals. The present article flashes on the various types, techniques and contribution of bioremediation in sustainable environment.

Keywords: Bioremediation, waste management, decontaminated, evacuation, sustainable

Introduction

Bioremediation is the process by which living organisms degrade or transform hazardous organic contaminants to inorganic components, such as CO_2, H_2O and NO_3 (Luqueno *et al*. 2011) [11]. It involves the degradation of pollutants, as well as removal of the pollutants from the environment without degrading it (Broda, 1992) [1]. Bioremediation is an effective alternative to conventional cleaning strategies, substantial research in this field is rapidly increasing. The rise in global population has resulted in the increased exploitation of natural resources and sources to respond to the high demands of the population for food, energy, and other needs. Industrial development is a result of these increased requirements; however, it has resulted in the production of huge number of various organic and inorganic chemicals that have directly and indirectly caused pollution of the habitats. Bioremediation is more effective as compared to other ordinary remediation strategies due to its low cost and ecofriendly strategies. It includes a few methods in a hierarchical relationship *viz*., bioreactors, bio-slurping, bioventing, bio-sparging, and phytoremediation (Yadav *et al*., 2021) [30]. Bioremediation involves the use of living microorganisms to degrade environmental pollutants. This technology is eco-friendly and more reliable, cheaper and easier to deploy than physical and chemical methods (Machin-Ramirez *et al*. 2008) [12]. It is a technology for removal of pollutants from the environment and restoring the original natural surroundings and preventing further pollution (Sasikumar and Papinazath 2003) [19]. Bioremediation is limited to biodegradable compounds. All compounds are not susceptible to rapid and complete degradation, and there are some concerns that the products of biodegradation may be more persistent or toxic than the parent compounds. Bioremediation is cost-effective, sustainable approach as compared to conventional techniques to clean up the contaminated soil, sediments, and water with the help of the naturally occurring organisms such as fungi, bacteria, or their enzymes (USEPA 2006; 2012). The present article flashes on various types, techniques of bioremediation which are beneficial in order to eliminate various hazardous compounds.

Types of Bio-remediation

Bioremediation can be classified into two categories, based on the removal and transport of waste materials.

1. In Situ Bioremediation

In situ bioremediation is the biological treatment of contaminated soil and groundwater without digging or pumping and treating above groundwater. It implies various biological treatments to clean up hazardous compounds present in the environment. The optimization, control of microbial transformations of organic contaminants needs the integration of many scientific and engineering techniques. Some of the in-situ bioremediation strategies have been discussed below:

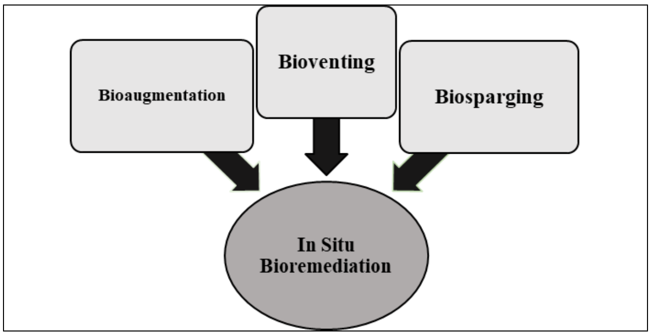

Fig1

a. Bioventing

Bioventing or Bio-ventilation is an in-situ treatment technology that uses microorganisms to biodegrade organic components in water systems. Bacterial and archaeal activities have been enhanced by bio-aeration, which stimulates the natural in situ biodegradation of hydrocarbon derivatives using air, the flow of oxygen and essential nutrients. to render pollutants harmless (Philp and Atlas, 2005) [18]. This method can destroy degradable contaminants in the air by transporting oxygen and some nutrients to existing microorganisms in the soil. Oxygen flow is maintained and monitored to support this microbial activity (Das and Dash, 2014) [3].

b. Bio-sparging

Bio-sparging is an in-situ treatment method that uses native microorganisms to break down organic components in the saturation zone. This technique involves the injection of air (or oxygen) and nutrients (if needed) into the saturation zone to stimulate the biological activity of local microorganisms. bio-sparging is more successful for natural treatment of petroleum hydrocarbon items (benzene, toluene, ethylbenzene, xylene, diesel, and lamp fuel) spills like sullied aquifers (Kao *et al*., 2008) [8]. Lambert *et al*. (2009) [9] found that bio-sparging was supportive in increasing high-impact biodegradation and volatilization of remaining hydrocarbons (pentane, hexane and fragrant hydrocarbons) created at the source zone.

c. Bioaugmentation

Bioaugmentation is the manual expansion of natural culture to an environment such as a bioreactor, with the purposeful of treating sewage or other sullied materials. Bioaugmentation introduces some specific pre-grown microorganisms to the soil in order to increase the biological degradation and stimulate the elimination of contaminants (Wang *et al*., 2017) [29]. Tyagi *et al*., (2010) concluded that, Addition of pre-grown microbial cultures to enhance the degradation of unwanted compounds (bioaugmentation), injection of nutrients and other supplementary components to the native microbial population to induce propagation at a hastened rate (bio-stimulation). Bioaugmentation approaches focus on the use of microbial consortia that are prepared for the specific physicochemical properties of bioprocesses (Van der Gast *et al*., 2004) [27]. Bioaugmentation employs included microorganisms to "reinforce" organic squander treatment populaces so that they can viably diminish the contaminant stack by changing it into less perilous compounds (Herrero and Stuckey, 2015) [5]. A few common supplements utilized for bio-stimulation are water-soluble compounds (e.g., KNO3, NaNO3, NH3NO3, K2HPO4, and MgNH4PO4) and slow-release fertilizers like customblen, IBDU, and max-bac (Nikolopoulou & Kalogerakis, 2008) [16]. Several factors must be considered for the success of the biofortification process. Among them are the potential of microbial strains or populations and the ability of newly added microbial strains to compete with native microorganisms, predators, and abiotic factors. is key (Thompson *et al*., 2005) [22]. Huilin Ma *et al*., (2022) [6] concluded that the bioaugmentation is basically an alternation in metabolic work brought by changes within the microbial community structure. Within the handle of direction, we ought to not as it were considered as the routine strategies such as strain choice, dosing mode and immobilization strategy, but moreover pay consideration to the versatility in large-scale application.

2. Ex Situ Bioremediation

Ex-situ bioremediation is a biological process in which excavated soil is placed in a lined aboveground treatment area and aerated after treatment to help native microbial populations break down substances. organic pollution. It involves the treatment of contaminants, away from the site. It is generally carried out for soil and sediments which are excavated from their site and spread to some other area where it has to be treated. Some of the ex-situ bioremediation strategies have been discussed below:

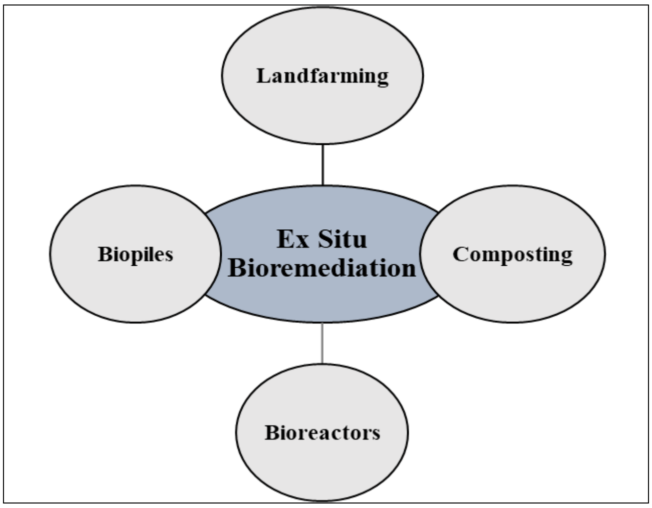

Fig 2

a. Landfarming

Landfarming is ex- situ, solid-phase biotreatment strategy that includes utilization agricultural methods to advance biodegradation of natural contaminants. Landfarming may be an organic strategy which employs normally occurring micro-organisms, such as microscopic organisms and organisms, to dispense with, constrict or change contaminating or sullying substances in soils to diminish the dangers to human wellbeing and the environment (UK EA 2002). Lukic *et al*., (2013) observed that the integration of landfarming and composting can form more favourable conditions for biological activity and has been shown to be both effective and economical in removing organic pollutants from contaminated soils. Landfarming includes the spreading of thin layer of excavated soil that consists of organic contaminants over a large area to enhance attenuation of the contaminants.

b. Composting

Composting is a process by which organic matter, such as leaves and leftovers, breaks down into soil. It is an effective way to recycle your garden and kitchen waste while enriching your garden soil, improving water retention and protecting against erosion. Misra *et al*., (2003) [13] stated that, Composting is an attractive proposition for turning on-farm organic waste materials into a farm resource. But, farmers in many parts of the world, and especially in developing countries, are unable to make the best use of the composting opportunities available to them.

c. Bio-piles

Bio-pile is an ex-situ bioremediation technology that includes the piling of excavated soils in a treatment area including an aeration system. In this technique, contaminated soil is excavated and placed into localized piles and aerated to enhance microbial activity to degrade the contaminants. The water reactor represents an ex-situ treatment of a contaminated environment in which the reactor is pumped from a certain location. It's about biological treatment of contaminated environment using special technology (Vidali, 2001) [28].

d. Bioreactors

An in-situ bioreactor could be a frame of treatment that depends on organic forms to remediate groundwater. Nath *et* *al*., (2014) [15] described the characteristics of membrane-associated bioreactors with special reference to immobilization technology of enzyme and microorganism, hydrodynamic study associated with chemical reactions, and its applications. The bioreactor has different operating modes such as batch, batch and continuous with a variety of designs including slurry phase, separation, stirring tank, biofilter, biofilter, trickling stage, stage boiling, packing bed, lifting machine and membrane bioreactor (Srivastava *et al*., 2021) [20].

Phytoremediation

Phytoremediation refers to the utilization of plants and related soil organisms to decrease the concentrations or harmful impacts of contaminants within the environment. Phytoremediation It is considered as a cost-effective sustainable technology. Phytoremediation is an alternative to engineering procedures which are usually more destructive. Phytoremediation is a less expensive, ecofriendly, has aesthetic approach and it is suitable for developing countries. However, phytoremediation is yet to become a commercially available technology in India (Ghosh and Singh, 2005) [4]. The mechanisms and efficiency of phytoremediation depends on the type of contaminant, bioavailability and soil properties (Cunningham and Ow, 1996) [2]. The Phytoremediation is vast as this technique includes various plant-influenced biological chemical, and physical processes that assist in the uptake, sequestration, degradation, and metabolism of contaminants, either by plants, soil microbes, or plant and microbial interactions (Zouboulis and Katsoyiannis, 2005) [31]. Several technical obstacles must be excluded for the development and growth of this strategy. These include: identification more species that have remediation abilities, optimization, identification of genes responsible for uptake, degradation, reducing the time period required for phytoremediation, designing of suitable methods for contaminated biomass disposal and protecting wildlife from thriving on plants used for remediation.

Ecological Importance of Bioremediation

Bioremediation involves the utilization of biochemical and biological reactions to improve degraded soil, water or air quality. Bioremediation techniques have been effectively applied to trap environmental contaminants from soil and water and different strategies used in the bioremediation process are less-expensive and environment friendly (Shivalkar *et al*., 2021). Bioremediation utilizes microorganisms which may be native or isolated from any other site, naturally occurring bacteria, fungi and plants to detoxify the contaminants which may be harmful to human health and environment (Irfan *et al*., 2022) [7]. The incomplete knowledge of biodegradation processes and the absence of diverse techniques required for applications are considered as major issues in the development of bioremediation (Muller *et al*., 1996). The importance of bioremediation arises from its association with the pillars of sustainable development; including economic, environmental, and social sustainability.

Conclusion

Bioremediation is an important tool available to clean up contaminated sites and it occurs in the presence of microorganisms that can biodegrade the given contaminant and essential nutrients. It is an advancing green innovation where organisms are developed within the presence of sullied soil, sediment, surface, and groundwater to raise the deterioration and evacuation of inorganic and natural poisons. This technology offers an efficient and less expensive way to treat contaminated ground water and soil. Its advantages generally more than the disadvantages. However, it is important to note that bioremediation is not a one-size-fits-all solution. Its effectiveness can vary based on factors like the type of contaminant, the specific environment, and the selected bioremediation strategy. Proper planning, monitoring, and ongoing assessment are necessary to ensure the success of bioremediation projects.

References

1. Broda P. Using microorganism for bioremediation: the barriers to implementation. Trends Biotech,1992:10(9):303-304.
2. Cunningham SD, Ow DW. “Promises and prospect of phytoremediation”. Plant Physiol.,1996:110:715-719.
3. Das S, Dash HR. Microbial bioremediation: A potential tool for restoration of contaminated areas. In Microbial biodegradation and bioremediation, 2014, 1-21. Elsevier.
4. Ghosh M, Singh SP. A review on phytoremediation of heavy metals and utilization of it’s by products. Asian J Energy Environ,2005:6(4):18.
5. Herrero M, Stuckey DC. Bioaugmentation and its application in wastewater treatment: a review. Chemosphere,2015:140:119-128.
6. Huilin Ma, Yingxin Zhao, Kaichao Yang, Yue Wang, Chenggong Zhang, Min Ji. Application oriented bioaugmentation processes: Mechanism, performance improvement and scale-up, Bioresource Technology, 2022, 344. Part B:126192, ISSN 0960-8524.
7. Irfan S, Ranjha MMAN, Shafique B, Ullah MI, Siddiqui AR, Wang L. Bioremediation of soil: an overview. Advances in Bioremediation and Phytoremediation for Sustainable Soil Management: Principles, Monitoring and Remediation, 2022, 1-16.
8. Kao CM, Chen CY, Chen SC, Chien HY, Chen YL. Application of in situ bio-sparging to remediate a petroleum-hydrocarbon spill site: Field and microbial evaluation. Chemosphere,2008:70(8):1492-1499.
9. Lambert JM, Yang T, Thomson NR, Barker JF. Pulsed bio-sparging of a residual fuel source emplaced at CFB borden. International Journal of Soil, Sediment and Water,2009:2(3):6.
10. Lukić B, Panico A, Huguenot D, Fabbricino M, van Hullebusch ED, Esposito G. A review on the efficiency of landfarming integrated with composting as a soil remediation treatment. Environmental Technology Reviews,2017:6(1):94-116.
11. Luqueno FF, Encinas CV, Marsh R, Suarez CM, Nunez EV, Dendooven L. Microbial communities to mitigate contamination of PAH in soil - possibilities and challenges – a review. Env. Sci. Res.,2011:18:12-30.
12. Machin-Ramirez CAI, Okoh DK, Morales M, Mayolo-Deloisa R, Quintero TH. Slurry-phase biodegradation of weathered oily sludge waste. Chemosphere,2008:70:737-744.
13. Misra RV, Roy RN, Hiraoka H. On-farm composting methods. Rome, Italy: UN-FAO, 2003.
14. Mueller JG, Cerniglia CE, Pritchard PH. Bioremediation of environments contaminated by

polycyclic aromatic hydrocarbons. Biotechnology Research Series,1996:6:125-194.
15. Nath A, Chakraborty S, Bhattacharjee C. Bioreactor and enzymatic reactions in bioremediation. In Microbial Biodegradation and Bioremediation, 2014, 455-495. Elsevier.
16. Nikolopoulou M, Kalogerakis N. Enhanced bioremediation of crude oil utilizing lipophilic fertilizers combined with biosurfactants and molasses. Marine Pollution Bulletin,2008:56(11):1855-1861.
17. Phian S, Nagar S, Kaur J, Rawat CD. Emerging issues and challenges for microbes-assisted remediation. In Microbes and Microbial Biotechnology for Green Remediation, 2022, 47-89. Elsevier.
18. Philp JC, Atlas RM. Bioremediation of contaminated soils and aquifers. In: Atlas RM, Philp JC (eds) Bioremediation: applied microbial solutions for real-world environmental cleanup. American Society for Microbiology (ASM) Press, Washington, DC, 2005, 139–236.
19. Sasikumar CS, Papinazath T. Environmental management: bioremediation of polluted environment. In Proceedings of the third international conference on environment and health Department of Geography, University of Madras, Chennai and Faculty of Environmental Studies, York University, New York, 2003, 465-469.
20. Shivalkar S, Singh V, Sahoo AK, Samanta SK, Gautam PK. Bioremediation: a potential ecological tool for waste management. In Bioremediation for Environmental Sustainability, 2021, 1-21. Elsevier.
21. Srivastava AK, Singh RK, Singh D. Microbe-based bioreactor system for bioremediation of organic contaminants: present and future perspective. In Microbe mediated remediation of environmental contaminants. Woodhead Publishing, 2021, 241-253.
22. Thompson IP, Van Der Gast CJ, Ciric L, Singer AC. Bioaugmentation for bioremediation: the challenge of strain selection. Environmental Microbiology,2005:7(7):909-915.
23. Tyagi M, da Fonseca MMR, de Carvalho CC. Bioaugmentation and bio-stimulation strategies to improve the effectiveness of bioremediation processes. Biodegradation,2011:22:231-241.
24. UK EA. Remedial Treatment Action Data Sheet on Landfarming, Data Sheet No. DS-03, United Kingdom Environment Agency, 2002. Bristol; available at www.environment-agency.gov.uk/research/planning/40381.aspx.
25. United States Environmental Protection Agency (USEPA) (2006) In situ and ex situ biodegradation technologies for remediation of contaminated sites. EPA/625/R-06/015.
26. United States Environmental Protection Agency (USEPA) (2012) A citizen guide to bioremediation. EPA 542-F-12-003.
27. Van Der Gast CJ, Whiteley AS, Thompson IP. Temporal dynamics and degradation activity of bacterial inoculum for treating waste metal-working fluid. Environmental Microbiology,2004:6(3):254-263.
28. Vidali M. Bioremediation. An overview. Pure and Applied Chemistry,2001:73(7):1163–1172. doi: 10.1351/pac200173071163.
29. Wang C, Zhou Z, Liu H, Li J, Wang Y, Xu H. Application of acclimated sewage sludge as a bio-augmentation/bio-stimulation strategy for remediating chlorpyrifos contamination in soil with/without cadmium. Science of the Total Environment,2017:579:657-666.
30. Yadav M, Singh G, Jadeja RN. Bioremediation of organic pollutants: a sustainable green approach. In Sustainable Environmental Clean-up, 2021, 131-147. Elsevier.
31. Zouboulis AI, Katsoyiannis IA. "Recent advances in the bioremediation of arsenic-contaminated groundwaters". Environment International,2005:31(2):213-19.