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Ex-Situ and In-Situ bioremediation strategies and their limitations for Solid Waste Management: A Mini-Review

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Abstract:

The term "waste management" refers to any trash that isn't in a gaseous or liquid state, although it also includes container - based gaseous and gaseous waste. Solid waste generated trash, agricultural residues, industrial garbage, ashes from thermal plants, and toxic materials are the principal categories of solid waste. Biological treatment is well-defined as the process of biologically degrading organic wastes in controlled circumstances to a benign state or to concentrations lower then regulatory concentration limits. Because biological treatment is only effective when conditions are favorable for microbial growth and activity. There are basically two types of remediation in situ and ex situ remediation. In situ remediation have landfill, aerobic composting, anaerobic digestion. Ex-situ remediation has biopile and bioreactors. But there are the limitations for the bioremediation. For example, bioremediation is only possible with biodegradable chemicals.

Keywords: Solid waste, Waste management, Ex-situ remediation, In-situ remediation, Pollutants.

Introduction

Waste management is a huge phenomenon, with expanding population, urbanization, and globalization all contributing to massive waste production. Problems are growing more as a result of expanding urbanization, financial development and industrialization, requiring immediate action. Poorly maintained land fill sites are responsible for ground water contamination due to leaching and for air contamination due to open dumping of solid waste (Maity et al., 2017). Immediate interaction with solid garbage causes different chronic and infectious diseases, with waste workers and rag pickers being especially susceptible. Effective solid waste management decreases or removes negative effects on the environment and human health, while also promoting economic development and quality of life (Kaza et al., 2018). The term "waste management" refers to any trash that isn't in a gaseous or liquid state, although it also includes container - based gaseous and gaseous waste. Solid waste generated from agricultural residues, industrial garbage, ashes from thermal plants, and toxic materials are the principal categories of solid waste (Chaiyarit et al., 2021). The employment of microbial metabolism to remove contaminants is known as bioremediation. Biological treatment might take place as a result of natural attenuation or as a result of intrinsic biological treatment. Bioremediators are microorganisms that execute the function of bioremediation (Mueller *et al.,* 2020). It is defined as either in situ or ex situ. Biological treatment can be utilized on contamination that has been removed from its initial location. Phytoremediation, bioaugmentation, biosorption, land farming, bioreactor, composting, biostimulation, rhizofiltration, and bioventing are examples of bioremediation technologies. It known as low-cost, low-technology approaches that are widely accepted by the public and can frequently be carried out on-site (Iqbal et al., 2021). Incineration and chemical decomposition are two technologies that have been used. They can be very effective at decreasing levels of a variety of pollutants, but they have a number of disadvantages, including complexities, cost for variety of applications, and widespread understanding, particularly for combustion, which may enhance contamination visibility both for site workers and near the areas (Niu et al., 2009).

Principle of Bioremediation

Biological treatment is known as the method of biologically degrading organic wastes under controlled circumstances from a complex state in to simpler ones (Colberg et al., 2021). Because biological treatment is just compelling when ecological circumstances take into consideration microbial development and action, it is often used to control natural elements to accelerate microbial development and destruction. Most bioremediation systems are operated in aerobic settings, however operating one under anaerobic environments might allow bacteria to digest compounds that would otherwise be resistant to degradation (Vedali, 2017).

Bioremediation strategies

***In-Situ* Bioremediation**

The use of bioremediation to the removal of hazardous chemicals presents in the subsurface is known as in-situ bioremediation. The integration of several scientific and engineering disciplines is necessary for the improvement and control of microbial alterations of natural contaminants.

Landfill

Dumping of solid waste has arrived at a critical stage that needs to be enhanced. As a result, services that allow for the treatment and discarding of rising volumes of MSW must be established (Sharholy et al., 2019). The Department of

Environment defines a landfill as "managed dumping of Garbage on land." Because there is a diminished connection between the environment and waste, disposal requires a separate space. As a result, a good dump allows Garbage to be deposited of properly on land while also protecting fresh water from contamination, odor, pollution control, release of greenhouse gases (GHG), fires, wildlife, and animals, as well as reducing stability problems. In India, dumps must be substituted with proper management constructed graves, which will significantly reduce waste's environmental impact (UNEP, 2021).

Aerobic composting

When Municipal solid waste and organic material undergoes biological transformation, it is composted in a humid, warm atmosphere. Composting produces humus (compost), which contains a substantial amount of nutrients. Composting methods range from tedious to mechanized, with labour intensive composting being used in small towns. Larger cities in India, on the other hand, have composting plants that generate electricity (Behide et al., 2018). For example, mechanized processing facilities were installed in Maharashtra, Karnataka, Kolkata, Meerut, and Baroda, delivering between 200 and 250 tonnes per day (Ambulkar et al., 2019).

Anaerobic digestion

Biomethanation, also referred to as anaerobic waste decomposition, is a treatment method for the biologically degradable component of MSW in subtropical regions. This is a complex phase that stabilizes organic matter and releases biogas containing 55-60 percent methane, that may be transformed into energy grid for generating electricity. The Indian government supports bio- methanation technology, which explains why it is used in many civic establishments, business, and farming. In places like as Bangalore, Delhi, and Lucknow, schemes have been devised to use bio-methanation to the transformation of yard and vegetable market waste (Joardar, 2020).

Thermal treatment

Methods for thermally treating solid waste include incinerating, pyrolyzing, and plasma arc gasification. Because of its water content, high organic elements, 30-60 percent inert content, and MSW 800-1,100 kcal/kg calorific value, combustion is an undesirable MSW treatment option (Jalan et al., 2018). Because incinerating trash with a low calorific value or humidity demands more gasoline, the hospital waste of is burned in compact open burning (Sharholy et al., 2020).

Ex-situ bioremediation techniques

In this method pollutants from contaminated places transferred to somewhere in order to treating them. This process is considered costly as the following factors are considered: the costs of care, pollution depth, the nature of pollutant, the level of contamination and the geographical location of polluted site. Execution models have been characterized, which impact the decision of ex situ bioremediation techniques (Philip et al., 2005) (Table 1).

Bio-pile

To promote bioremediation by boosting microbial activity, bio-pile facilitated bioremediation involves piling contaminated soil above ground, accompanied by nutrients and in some situations by aeration. The components of this technology include a treatment bed, fertilizer and leachate gathering systems, irrigation, and aeration. Because of its advantageous properties, such as cost effectiveness and the capacity to accomplish great biodegradation so under requirement of nutrition, temperature, and oxygenation are all appropriately maintained, the adoption of this specific ex situ method is growing in popularity (Whelan et al., 2015).
Because a temperature controller may be incorporated into the bio-pile design to encourage microbial activity and pollutant availability, speeding up biodegradation, the bio-adaptability piles allow for a shorter remediation period. Warm air can also be included into the bio-pile design to provide both air and heat, improving bioremediation (Aislabie et al., 2006).

Bioreactor

As its name suggests, a bioreactor is a container or vessel where raw materials are transformed into specific products through a series of biological interactions. Different operating modes are used in batches, fed-batch, sequential batch, continuous, and multiple stage bioreactors. The status of the economy and capital expenditures have the most effects on the operational mode choice. The settings of a bioreactor provide ideal growth conditions by mimicking and preserving the natural environment of the cells to encourage normal cell functions. In a bioreactor, materials that have been contaminated can be added as dry mass or as a slur; in both cases, utilizing a bioreactor to treat polluted soil has several benefits over ex situ bioremediation techniques. Good management of biotechnological factors is one of the key benefits of long-term improvements in environmental cleanup (temperature, pH, agitating and oxygenation rates, substrates and inoculation concentrations). It is possible to regulate and alter the processing parameters in a reactor, which suggests that biological reactions can be sped up and lead to a quicker bioremediation process. It is significant to note that bioreactor-based bioremediation can effectively establish controlled bio- augmentation, nutrient addition, increased pollutant accessibility, and mass flow (contact between pollution and bacteria), which are amongst the limiting factors of this process.

Benzene, toluene, ethyl benzene, and xylenes are just a few of the VOCs that can be utilized to clean up soil and water (BTEX). Use of various bioreactors in bioremediation process have resulted in the removing of large variety of contaminants. Bioreactor designs are versatile, designed for maximum biodegradation while reducing abiotic losses (Mohan et al., 2004). The operation of a biosensor holding petroleum products soil slurry for a short or long period of time allows for the tracing of changes in bacterial community dynamics, allowing for easy characterization of core bacterial populations engaged in bioremediation (Chikere et al., 2012; Zangi-Kotler et al., 2015).

Table 1: Remediation Techniques for different waste types and their mechanisms

Sr.no	Remediation technique	Waste type	Mechanism	References
1.	Ex situ remediation			
1.1	Biopile	Piling of excavated, contaminated dirt above ground.	In a treatment area with a leachate collecting and aeration system, excavated soils are heaped.	Firmino et al., 2015.

1.2	Windrows	Turning filthy dirt piles on a regular basis.	Enhancing the native hydrocarbonoclastic bacteria's ability to degrade organic matter, which is present in polluted soil, to improve bioremediation.	Barr D., 2002.
1.3	Bioreactor	Crude oil polluted sediment	Remediate soil or water that has been contaminated by volatile organic compounds (VOCs), such as benzene, toluene, and xylenes (BTEX).	Kim, S.,2014.
1.4	Land farming	Excavated or tilled polluted soil.	soil preparation, planting, fertilizer and manure application, irrigation, harvesting, and storage.	Jung J.,2014.
2.	In situ remediation			
2.1	Bioventing	Soil polluted with pesticides and petrochemical waste.	By introducing nutrients and air flow into the unsaturated zone, the activity of the local bacteria is increased.	Henderson AD, et al.,2014.
2.2	Bio-slurping	Hazardous waste, industrial agricultural and animal waste, municipal solid waste, medical waste	Combines soil vapour extraction and vacuum-enhanced pumping to achieve groundwater and soil cleanup by indirect oxygen supply.	Kim J-O, et al., 2014.
2.3	Bio-sparging	Treating aquifers that have been contaminated by petroleum, particularly diesel and kerosene.	Pressured air or gas injection to promote in-situ aerobic biological activity in a polluted area.	Azubike et al., 2016.
2.4	Permeable Reactive Barrier	Polluted ground water	When a permanent or semi-permanent reactive barrier is submerged, pollutants are trapped and subjected to a succession of barriers as water passes through the barrier.	Chikere CB, et al., 2021.

Limitations of Bioremediation:

- Biodegradable compounds are the only ones that make bioremediation possible. Not all chemicals can be broken down to their base forms quickly.
- Some people worry that the byproducts of biodegradation will be more dangerous or persistent than the original molecule.
- It is challenging to extrapolate from laboratory and pilot-scale experiments to effective field operations. There has to be further investigation into bioremediation technologies that are appropriate for locations with complicated combinations of contaminants that are not equally disseminated in the environment. The three different types of contaminants are solids, liquids, and gases.
- Bioremediation is only possible for substances that degrade naturally. Not all substances are capable of complete and quick degradation.
- Bench and pilot-scale research are challenging to translate to full-scale field operations.
- Bioremediation systems that are acceptable for locations with complex combinations of pollutants that are not evenly diffused in the environment must be developed and engineered. There could be contaminants in the form of solids, liquids, or gases.
- Regulatory uncertainty surrounding acceptable performance criteria for bioremediation exists. Bioremediation takes more time than other remediation treatment methods, such as excavation and removal of soil or cremation. Because there is no universally agreement that defines "clean," it's difficult to assess the effectiveness of environmental remediation (Sharma, 2020).

Conclusions

Solid waste generated trash, agricultural residues, industrial garbage from thermal plants and toxic materials are the principal categories of solid waste. In this review we concluded that bioremediation strategies used for solid waste management. These are in-situ and ex-situ techniques. In In-situ techniques, anaerobic digestion, 55-60 percent performed well, and in thermal treatment, 30-60 percent gave their best.

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