AN OVERVIEW ON BIOREMEDIATION, BIO-STIMULATION, AND BIO-AUGMENTATION

Dr. Pavan kumar Singh*

* Assistant Professor,
Department of Physics, Teerthanker Mahaveer University,
Moradabad, Uttar Pradesh, INDIA
Email id: pavan.engineering@tmu.ac.in

DOI: 10.5958/2249-7137.2021.02511.8

ABSTRACT

To break down pollutants, such as petroleum hydrocarbons, bioremediation employs microbial metabolism in the presence of ideal environmental conditions and adequate nutrition. We looked at bioremediation technologies and found that biotechnological methods to remediation have gotten a lot of interest in recent year. Biostimulation (meaning the adding of limited nutrients to promote microbial growth) or Bioaugmentation (meaning the addition of live cells capable of destruction) research have dominated the literature, and technical evaluations of these technologies are rare if at all accessible. When nutrient delivery alone or with the addition of microorganisms is insufficient for cleanup, a simultaneous strategy is used. Recent research shows that combining the two methods is not only possible, but also advantageous. Evidently, site-specific requirements such as the availability of microorganisms capable of sufficient degradation, nutrient availability to support microorganism's growth and proliferation, as well as climatic variables including such temperature in combination with exposure time all influence technology selection. This study focuses on these technologies, with efforts aimed at eventually manipulating remedial processes in order to make bioremediation technically or economically feasible for the complete treatment of petroleum hydrocarbon-contaminated soils.

KEYWORDS: *Bioremediation, Biostimulation, Bioaugmentation, combined technologies.*

1. INTRODUCTION

There is increasing worry about the present pace of environmental deterioration across the globe, most of it is due to increased production and consumption of fossil fuels. Oil exploration and usage endangers the environment and living things, including people, on all continents. An oil spill occurs when a petroleum hydrocarbon is released into the environment. Releases of crude oil from tankers, offshore platforms, drilling rigs, but instead wells, and also spills of refined petroleum products (such as gasoline, diesel) but also their by-products, heavier fuels used among large ships including such bunker fuel, but rather spills of any oily refuse or waste oil, can all cause oil spills. Natural ecosystems have been harmed by crude oil and refined gasoline spills in Alaska, the Gulf of Mexico, the Galapagos Islands, France, Nigeria's Niger Delta area, and many other locations around the globe. The amount of oil leaked in incidents has varied from a few hundred tons to several hundred thousand tons, although this is just a rough estimate of the damage or effect.

Smaller spills, such as those in the Niger Delta area of Nigeria, have already shown to have a significant effect on ecosystems due to the remoteness of the locations or bottlenecks impeding emergency environmental responses. Oil pollution has far-reaching consequences. Oil seeps into the structure of birds' plumage and animals' fur, decreasing their capacity to insulate and making them more susceptible to temperature changes and less buoyant in water. Due to the powerful smell of the oil, animals that depend on scent to locate their young or moms vanish. This results in infants being rejected or abandoned, causing them to starve and die. Oil may damage a bird's ability to fly, making it impossible for it to forage or flee predators. Birds may swallow the oil covering their feathers when they preen, irritating the digestive system, causing liver dysfunction, and kidney damage. This, along with their reduced foraging ability, may quickly lead to dehydration and metabolic imbalance. Some birds exposed to petroleum suffer alterations in their hormonal balance, including luteinizing protein modifications. Without human assistance, the majority of birds killed by oil spills perish. According to some research, just around 1% of oil-soaked birds survive even after washing **[1].**

An oil spill may result in an immediate fire danger for people. The Kuwaiti oil fires polluted the air, causing respiratory problems. Eleven oil rig employees were killed in the Deepwater Horizon disaster. The fire that erupted as a consequence of the derailment at Lac-Mégantic killed 47 people and destroyed half of the town. A spill at Ikarama, Bayelsa State, Nigeria, resulted in a fire on the work platform, resulting in the deaths of at least fifty people. Drinking water sources may potentially be contaminated by spilled oil. In 2013, for example, two separate oil accidents polluted water sources for 300,000 people in Miri, Malaysia, and 80,000 people in Coca, Ecuador. An oil leak in Clark County, Kentucky, damaged springs in 2000.

1.1.Bioremediation

George Robinson is credited for helping to popularize the use of microorganisms in contemporary bioremediation. In the late 1960s, a researcher employed microorganisms to eat an oil spill off the coast of Santa Barbara, California. Bioremediation of oil spills and other hazardous pollutants has gotten increasing attention since the 1980s. Microorganisms and their products are used in bioremediation to eliminate pollutants from the soil. Native soil microorganisms, in particular, are important biogeochemical agents in soil bioremediation, converting complex organic chemicals into simple inorganic molecules or their component elements [**2], [3]**. Mineralization is the name for this process. The bacteria are adsorbed to soil particles via the ionic exchange process. Soil particles have a negative charge in general, and soil and bacteria may be held together by a polyvalent cation ionic connection. Microorganisms are used in bioremediation to decrease, remove, contain, or convert harmful pollutants in soils, sediments, water, and air. The employment of microorganisms to eliminate or immobilize waste compounds is referred to as bioremediation. By mineralization, transformation, or modification, this detoxification process targets the toxic compounds. Natural bioremediation has been utilized in wastewater treatment for millennia, but it is only recently that it has been used to reduce hazardous pollutants. Bioremediation entails the generation of energy in microbial cells through a redox reaction. Respiration and other biological processes required for cell maintenance including reproduction are included in these reactions. An energy source (electron donor), an electron acceptor, and nutrients are all needed by most delivery systems. Different kinds of microbial electron acceptor classes, such as oxygen-, nitrate-, manganese-, iron (III)-, sulfate-, or carbon dioxide-reducing, and their associated redox potentials, may be engaged in bioremediation. The relative dominance of the electron acceptor classes is shown by redox potentials **[4], [5].**

Concentrations of contaminants have a direct impact on microbial activity. Contaminants may have harmful effects on the microorganisms present when concentrations are too high. Low contaminant concentrations, on the other hand, may inhibit the stimulation of bacterial degradation enzymes. Contaminant bioavailability is determined by the degree to which pollutants sorb to solids or are sequestered by molecules in contaminated medium, are dispersed in soil or sediment macropores, and other variables such as whether contaminants are present in NAPL form. For pollutants that are more firmly sorbed to solids, contained in matrix of molecules in contaminated media, more extensively dispersed in macropores of soil and sediments, or present in NAPL form, bioavailability for microbial responses is reduced.

Oxidizing or reducing circumstances are indicated by the redox potential and oxygen concentration. The presence of electron acceptors such as nitrate, manganese oxides, iron oxides, and sulfate affects redox potential. Nutrients are required for microbial cell division and growth. Trace nutrients in sufficient quantities for microbial growth are typically present, however nutrients may be supplied in a usable form or through an organic substrate amendment that also acts as an electron donor to boost bioremediation. Moisture content: Microbial development need a high level of water in the surrounding environment. Microorganisms need 12 percent to 25% moisture for optimal development and multiplication.Temperature has a direct impact on microbial metabolism and, as a result, microbial activity in the environment. The rate of biodegradation increases with rising temperature and decreases with lowering temperature.

1.2. Bioremediation kinds :

The placement of pollutants determines the feasibility of bioremediation. Whether the affected soil to be treated remains intact in the ecosystem or excavated for treatment in an offsite facility, the methods for implementing bioremediation vary. If the cleanup takes place on site, the phrase Insitu is appropriate; if it takes place offsite, the term Ex situ is appropriate. This term has been used by certain writers to define the kind of bioremediation. However, it is essential to identify what is done in situ and ex situ, as well as to use the same terminology to describe the various kinds of bioremediation **[6].**

1.2.1. Bio-stimulants:

Many variables, including nutrients, pH, temperature, moisture, oxygen, soil characteristics, and the presence of contaminants, may restrict hydrocarbon biodegradation in soil. Biostimulation entails altering the environment to encourage the growth of microorganisms capable of bioremediation. This may be accomplished by adding limiting nutrients and electron acceptors such as phosphorus, nitrogen, oxygen, or carbon (e.g., in the form of molasses) that are otherwise unavailable in sufficient amounts to restrict microbial activity.

The main benefit of bio stimulation is that bioremediation will be carried out by previously existing native microorganisms that are well-suited to the subterranean environment and are widely dispersed. The main difficulty is that the distribution of chemicals in such a way that they are easily accessible to subsurface microbes is dependent on the underlying geology. It's difficult to distribute additives across the affected region due to tight, impermeable subsurface lithology. Fractures in the subsurface provide preferred routes for additives to follow, preventing additives from being distributed evenly. The addition of nutrients may encourage the development of heterotrophic bacteria that are not inherent degraders of Total Petroleum Hydrocarbons, resulting in competition amongst the resident microflora **[7].**

1.2.2. Bioaugmentation:

Bioaugmentation, or supplementing indigenous populations with oil-degrading microbes, has been suggested as an alternative method for bioremediation of oil-contaminated settings since the 1970s. The reason for this technique is that native microbial populations may not be capable of decomposing the broad variety of possible substrates found in complex mixes like petroleum, or they may be stressed as a consequence of recent spill exposure. When the original hydrocarbon-degrading community is low, the speed of decontamination is the most essential factor, and seeding may reduce the time it takes to begin the bioremediation process. Bioaugmentation may be considered when the indigenous hydrocarbon-degrading population is low. In order for this approach to be successful in the field, the seed microbes must be able to degrade most petroleum components, preserve genetic stability as well as viability during storage, survive in foreign and hostile environments, compete effectively with indigenous microorganisms, as well as move through the pores of the sediment to the contaminants **[8].**

The assumption or confirmation that indigenous microbes within the impacted site could indeed biodegrade hydrocarbons leads to the introduction of isolated bacteria from the contaminated site, from a historical site, and otherwise carefully selected as well as genetically modified microorganisms to support the remediation of hydrocarbons contaminated sites.

1.3.Types of Bioremediation:

Several research have focused on bioremediation of petroleum-contaminated areas via the addition of nutrients or the introduction of microorganisms. Nutrient additions may be natural or synthetic, organic or inorganic, and enzymes, which can be naturally occurring or manufactured, can be added to accelerate the repair processes in certain instances. Bioaugmentation can take the form of isolating native organisms and ‘mass cultivating' them for reintroduction to contaminated sites, procuring preserved microbial cells and inoculating impacted sites, or, better yet, using genetically modified cells that are specific for the contaminants in question for bioaugmentation processes. In these investigations, a variety of technologies and experimental setup/methodology are used **[9].**

1.3.1. Organic Nutrients for Biostimulation:

Some reports on the use of organic fertilizers for petroleum hydrocarbon stimulation. Organic nutrients may be helpful as stimulating nutrients for bioremediation, according to these research. Atagana used sewage sludge and wood chips compost to treat contaminated soil with more than 38,000mg/kg TPH (2008). Temperature regimes in compost systems, nutrient composition, and moisture content were all important factors in this study.

Inorganic Nutrients for Biostimulation Biostimulation agents have also been used with inorganic fertilizer sources all over the globe. the effectiveness of an inorganic fertilizer (NPK) in promoting microbial decomposition of petroleum hydrocarbons in soil In less than 10 weeks, gas chromatography findings revealed that normal paraffin and isoperoid dropped by 40-60% in all treatment groups. The addition of inorganic fertilizer increased the test setup's CNP ratio, which aided microbial decomposition.

1.3.2. Recent Bioremediation Techniques:

The use of genetically modified microbes to affect their capacity to utilise particular pollutants like hydrocarbons and pesticides is gaining popularity. In the late 1980s and early 1990s, this method was first mentioned. The capacity to 'engineer' microbes to enhance degradative characteristics is based on the ability to investigate microorganism genetic variety and metabolic flexibility. In the chromosomal and extrachromosomal DNA of these microorganisms, the blueprint for gene encoding for biodegradative enzymes is present. By identifying the presence of degradative genes and converting them into appropriate hosts via a suitable vector in a controlled environment, recombinant DNA methods investigate an organism's capacity to metabolize a xenobiotic. Polymerase Chain Reaction (PCR), anti-sense RNA method, site guided mutagenesis, electroporation, and particle bombardment techniques are all explored in this technology **[10].**

2. DISCUSSION

A simultaneous approach is employed when nutrition supply alone or with the inclusion of microbes is inadequate for cleaning. Combining the two techniques is not only feasible, but also beneficial, according to new study. Clearly, site-specific requirements such as that of the availability of microorganisms competent of sufficient degradation, nutrient levels to support microbe growth or proliferation, or climatic variables such as temperature in combination with exposure time all have an impact on technology selection. This research focuses on these methods, with the goal of ultimately modifying remedial processes to make bioremediation technically or economically viable for treating petroleum hydrocarbon-contaminated soils completely. Microbial metabolism may aid in the biodegradation of petroleum hydrocarbons in soils.

The instances above demonstrate that depending only on autochthonous microorganisms is not as effective as other methods, since the percentages of remediation after supplementation (microbes or nutrients) are typically greater than control. It was clear that nutrients (both organic and inorganic) may aid microbial growth and hydrocarbon breakdown. When it was discovered that nutrients such as nitrogen, phosphate, and potassium were lacking, there appeared to be widespread consensus that indigenous microbes needed to be "encouraged" and fed.It was an interesting diversion, since using locally available support material and microbes recovered from previous pollution seems to be a cost-effective and scientifically useful method. Furthermore, effective implementation of a restoration regime required consideration of indigenous biota, nutrient levels, and other environmental variables critical to achieving optimum results. Finally, recovering contaminated soils to fit-for-purpose states would require a combination of technologies that are carefully monitored and given sufficient time.

3. CONCLUSION

Some authors proposed that the presence of hydrocarbons within tolerable ranges for microbial survival was sufficient nutrient for microbial growth, and that a ready-to-use boost of more microbial population tested and trusted (most likely isolated from previously contaminated sites) could be used instead of nutrient addition. It's worth noting that nutrient addition, if not done properly, may be harmful in the sense that it can help heterotrophic populations while unintentionally triggering an antagonistic scenario, slowing down the degradation process. A combined strategy was also explored by several writers in order to maximize the possibilities of a more robust technology. This strategy seemed to combine the benefits of each of the previously mentioned technologies while attempting to overcome the obstacles of nutrient scarcity and petroleum-degrading microbe inadequacy. It proved to be an intriguing detour, as the use of locally accessible support material and microorganisms recovered from past contamination promises to be a cost-effective and scientifically beneficial procedure. In addition, a successful implementation of a remediation regime necessitated taking into account the indigenous biota, nutrient availability, and other environmental factors essential to achieve optimal outcomes. Finally, restoring polluted soils to fit-for-purpose states will need a mix of technologies that are controlled under strict circumstances and given adequate time.

REFERNCES:

1. Kennedy J. et al. Isolation and analysis of bacteria with antimicrobial activities from the marine sponge haliclona simulans collected from irish waters," Mar. Biotechnol., 2009, doi: 10.1007/s10126-008-9154-1.

2. Fouillaud M, Venkatachalam M, Girard-Valenciennes E, Caro Y, Dufossé L. Anthraquinones and derivatives from marine-derived fungi: Structural diversity and selected biological activities. Mar. Drugs, 2016 Mar 25;14(4):64. doi: 10.3390/md14040064.

3. Mandelare P.E, Adpressa DA, Kaweesa EN, Zakharov LN, Loesgen S. Coculture of Two Developmental Stages of a Marine-Derived Aspergillus alliaceus Results in the Production of the Cytotoxic Bianthrone Allianthrone A. J. Nat. Prod., 2018 Apr 27;81(4):1014-1022. doi: 10.1021/acs.jnatprod.8b00024.

4. Lin A, Lu X, Fang Y, Zhu T, Gu Q, Zhu W. Two new 5-hydroxy-2-pyrone derivatives isolated from a marine-derived fungus Aspergillus flavus. J. Antibiot. (Tokyo)., 2008 Apr;61(4):245-9. doi: 10.1038/ja.2008.36.

5. Alexander M. Research needs in bioremediation. Environ. Sci. Technol., 1991.

6. Gomes NM. et al. Antibacterial and antibiofilm activities of tryptoquivalines and meroditerpenes isolated from the marine-derived fungi Neosartorya paulistensis, N. laciniosa, N. tsunodae, and the soil fungi N. fischeri and N. siamensis. Mar. Drugs, 2014 Jan 28;12(2):822-39. doi: 10.3390/md12020822.

7. Bourquin AW, Pedersen TA. Bioremediation engineering. in Bioremediation: Science and Applications, 2015.

8. Sebastianes FLS. et al. 3-Hydroxypropionic acid as an antibacterial agent from endophytic fungi Diaporthe phaseolorum. Curr. Microbiol., 2012;65:622-632. doi: 10.1007/s00284-012-0206-4.

9. Saarinen EM-J, Belfast QU, Aumasson JP. The BLAKE2 Cryptographic Hash and Message Authentication Code (MAC). Constr. Build. Mater., 2015.

10. Luo Y, Mao D. Bioremediation of contaminated environment and its progress. Sect. Title Waste Treat. Dispos., 2003.