A Review Article- Technology of Bioremediation

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ABSTRACT

Bioremediation of contaminated retaw dna soil is considered more cheap and least harmful way of removing xenobiotics in ecology, also Bioremediation, one of the most safe technology. Microorganisms which live everywhere can be considered as an option way out to solve the problem. Depending on the differences in the nutritional capacity of microorganisms, it can be used as bioremediation for degradation, eradication, immobilization, or detoxification and change contaminants like heavy metal, hydrocarbons, oil, dye’s, pesticides...

This study introduce a summarize to the progress in the technology of bioremediation and the techniques that used in its application (such as phytoremediation, Microorganism and animal remediation...) and the application of these techniques on water pollutants such as eutrophication, petroleum spills, pesticide, heavy metals). The environmental relations between pollutants and microorganisms will be discussed in this review; this study will focus also on major impact, the disadvantage and the advantage of the bioremediation methods and it affect on the contaminants, environment as well as the biology of livings especially its effect on the health of human.

Keywords- ferric iron (Fe⁺³), carbon dioxide (CO₂), sulfates (SO₄²⁻), nitrates (NO₃⁻), Bioremediation.

I. INTRODUCTION

Bioremediation depend on the capability of a specific microorganism to change, adapt and use of poisonous material, and get energy then processed to produce biomass (¹). There is no gather or stock up any contaminants. Bioremediation is a process by which the microbe was obliged to stop working or convert contaminates to lesser toxicity or not-toxic elements or complex form.

Bioremediations including fungus, Bacterial, and microbes are natural driving force used to clear out contaminated districts (²). Usually the Microorganism conducts as important tools to remove contaminants from water, soil and residues, as a biotechnological process involving biodegradation process. Microbes are useful in restore the unique normal surrounds and prevent additional contamination (³). Bioremediation consider low cost and very safe for environments compared with other methods (⁴).

The main goal of this review is to provide a summary about the technology of bioremediation focusing on the aspects and the stuff it depends on and compare the diverse approaches that were reached and adopt by many investigators.

II. FACTORS AFFECTING THE TECHNOLOGY OF BIOREMEDIATION

1- Nutrients

The growth of microorganism depends on existence of elements in the nutrients (nutrients composition) like phosphor, nitrogen (⁵,⁶). The microorganisms enlargement can be prohibited when there is a lack in inorganic, organic complexes for instance ferric iron(Fe⁺³), carbon dioxide (CO₂), sulfates (SO₄²⁻), nitrates (NO₃⁻), vitamins, amino acids, the presence of these compound and ions will achieve and fulfill the microorganism metabolism (⁷), the presence of sufficient quantity of microbes will raise the activity of the metabolism, and hence biodegradation occur due to the presence of water and elements (⁸-¹⁰).

2- PH

PH has ability on the metabolism of microbes and affects its raise or lowers its activity (¹¹). Mostly, microorganisms prefer for degradation process pH values ranged from (6) to (9) (¹², ¹³). High or low pH effects on metabolic processes and bioremediation activity (¹⁴).

3- Temperature

Heat and temperature is major aspects that affect the microorganism survival as well as the hydrocarbon contents and composition (¹⁵). Very low temperature of water can cause freezing to the microbe and eventually damage its cytoplasm, therefore, the microscopic organism that shows affinity toward oil (Oleophilic) are metabolically inactive (¹⁶, ¹⁷). The action of enzyme is to degrade the complexes under certain temperature which play a very important role and affect the progression of degradation due to its effect on activity of microbe and eventually affect its development. The bioremediation can reach utmost under most favorable temperature.

3- Oxygen

Most organisms need oxygen and few others don’t need O₂, but the biodegradation is depend upon availability of this element and will improve and increase
the metabolism of hydrocarbons, since oxygen is a required gas for the majority of existing organisms (17).

4- Moisture

Usually microorganism needs sufficient quantity of water to carry out its development, the percent of humidity in the soil can be an important factor that affects the biodegradation.

5- Metal and elements ions

The presence of elements and metals and its quantities has a significant effect on microbes (fungus, bacteria), and can reduce, slow up or even inhibit the cells metabolism and this will eventually influence the degradation rate.

6- Salinity

Many recent studies showed that increasing the temperature and the salinity will slow down the metabolism rate as well as the yield and it grown (18).

7- Toxic compounds

Increasing the presence of pollutants that have toxicity will defiantly the decontamination of the microorganism, it percent and the exposure time of these toxic compounds and materials consider as an important factor on how and the level of its work (19).

III. PRINCIPLES OR BIOREMEDIATION

- Bioremediation is defining as degradation or detoxifying of organic waste under certain restriction and following a certain procedure and method, it is usually occurred using natural plant or fungi, and bacteria.
- Enzymes were possessed to decompose the wastes and pollutants in order to enable them to be used as environmental food.
- The goal of bioremediation is to provide best level of nutrients as well as other essential chemical compounds for the metabolism so as to be degraded or detoxified materials and be not hazard environmentally.
- Application of bioremediation usually involved with the conduction of environmental factors to permit the growing of microbes to insure a rapid process of degradation (20).
- Three essential procedures concerned in this process. Biotransformation (alteration of pollutants from toxic to non toxic or less hazard materials), biodegradation (transfer the products from biotransformation to a simple compounds), and mineralization (transferring organic molecules to inorganic molecules such as water H2O, or carbon dioxide CO2) (21).
- Every process could take place at pollutant in-situ (at site), or ex-situ (relocated to different site), it can also occurs aerobic or anaerobic (with or without oxygen) (22-24).
- However, bioremediation is limited, a few pollutants can resist microbes (like aromatic or chlorinated organic compounds), which affect the degradation process and make it slowly or not possible.
- Bioremediation is economically better than other techniques like incineration.

IV. BIOREMEDIATION METHODS

Three main techniques of in situ bioremediation with microbes: natural attenuation, bioaugmentation and biostimulation (25-27).

Natural attenuation is associated with the degrade activity of the microorganism. This process does not damage the habitation, and permit the slip back of the ecosystem to the unique state and allows the toxic materials to detoxified (26-30).

The contaminants removed through the normal shrinking that usually take time for the reason that the presence of microorganisms in the soil is only around 10% which reflected to the degradation process and make it slow. The increases in the efficiency of bioremediation in situ can understand in the bioaugmentation method, where certain degradation takes place in the soil (31, 32). This technique is useful when the original microfloras are not capable to decompose contaminates, or when the inhabitants of the microorganisms able to degraded pollutants weren’t adequately huge.

To create a successful bioaugmentation processes, the introduction of the microorganism to the contaminated area like a free or powerless inoculums and must has ability to achieve degradation to a certain pollutants and stay alive in a strange environment, be genetically constant and feasible, and shifted via soil pores.

It is possible to a chive a previous isolation and propagation to the microorganisms from a pollutant soil, or enhancing its functional capability in lab. Non-indigenous strain or genetically modified microorganisms (GMM) can also be included in the soil remediation (33-35).

On the other hand, the bioaugmentation results rely on the interface among inner and outer inhabitants of microorganisms as a result of the rivalry, mostly the nutrients (32). To speed up the process of bioremediation that occurs in the location (in situ), and to adapt the physio-chemical properties of the soil, it is recommended to apply bio-initiation (biostimulation). For this reason, it is recommended to set up certain ingredients to the soil like (manure, biogas slurry, straw rice, corncob, mushroom, etc) or even inorganic metals such as (C, N, O2, and P) (35-36).

Since the location (in situ) progression were uncontrollable, it is hard to expect the level of remediate in the place of polluted soil (29), while the outer process (ex-situ) permit additional efficiency to remove the contaminants, due to the ability to control the chemical and the physical properties, which may decrease the recovery time. Although the outer process (ex situ) has some benefits and in spite of its importance, still it has few weakness and disadvantage like the extra costs, and association threats, as well as opportunity of pollution spreading throughout transportation. At some point in the
outer (ex situ) methods, the medium of extracted pollutes needs to be transferred to the location of the process. Fluids can be cleaned in the location of the designed wetland, but in the bioreactor slurry for the solid and semi-solid waste. The solid pollutes were biodegraded when using it in land farming, or as a composite, as well as bio-accumulates (biopiles) (37, 38).

The build wet-land is utilized successfully in treating the waste water that come from different sources and activities such as, agriculture, various industries, and the general domestic activities which required phyto, and bio treatment due to the presence of the microorganisms (39). It is useful to use plants for transferring, removing, and stabilizing the pollutes via metabolic process due to soil and roots interferences and its effects in gathering, hold and extracted the pollutions (37). In slurry, the biological treatment (bioremediation) process in slurry bioreactors can be carried out with or without air (29). The naturally occurring strains and microorganisms possess a certain capable metabolism to adapt toxicity of the compounds (39). The slurry bioreactor cannot be consider as the best method and technology to remove the pollutions from the soil since it is carried out in a restricted condition, it allow the improvement of the activities of the microorganisms (40, 41).

Farming of the lands considered as main and wide techniques for bioremediation to the soil, by which the extracted pollut soil and spreads to slim layers on the exterior. The initiation and stimulation of the aerobic microbes were activated by ventilation and by the addition of ingredients, nutrients and minerals as well as by increasing the moist of the soil (42, 43), it is a moderately easy process, it is a cheap and efficient to degraded the low quantities of pollutions (42-44). Compost considered as an agriculture, and municipal treatment to the waste of soils and sewages sludge respectively, these restricted biological processes are carried out by the uses of a certain microorganism under certain temperature and air, this process can minimize the landfills and residue (29, 37).

V. BIOREMEDIATION ADVANTAGES

a. Natural process, it does not take long time (short time), it is a suitable method to treat waste of polluted compounds and materials. When microbial degradation process take place to the pollutant, the inhabitant number will be increased while the process declined the biodegraded inhabitant. The outcome residue is not hazard.

b. A low effort is required and can be achieved on location, with no disturbance to the regular activities, beside that there is no need to transfer the waste away from the location.

c. The cost also is lower than other usual techniques that designed to crackdown harmful wastes (45).

d. This method is helpful to destroy the contaminants, by which the hazara materials were changed and transferred to safe compounds.

e. The method doesn’t apply hazardous materials, composts are applied to grow microbes which used in gardens and lawns this will eventually leads to the decomposition and destruction of hazardous materials and turn it to gas and water (46).

f. Easy, few concentrated work is required, it is also not expensive because of the natural impact on the location.

g. It is a sustained and friendly to the environment (Eco-friend technique) (47).

VI. DISADVANTAGE OF BIOREMEDIATION

a. Limited compounds are biodegradable, but other materials are liable to quick and inclusive degradation.

b. Biodegradation outcomes could be more stable or poisonous than the original materials.

c. A precise and specific biological process occurs. A certain location and site condition are necessary to be insuring the accomplishment, this includes existence of microbes that can achieve metabolism, also there must be appropriate environment, and a suitable attitude of pollutants and nutrients.

d. Requires many skilled human power.

REFERENCES

[1] Tang, C. Y., Fu, Q. S., Criddle, C. S., & Leckie, J. O. (2007). Effect of Flux (Transmembrane Pressure) and Membrane Properties on Fouling and Rejection of Reverse Osmosis and Nanofiltration Membranes Treating Perfluorooctane Sulfonate Containing Wastewater. Environmental Science & Technology, 41(6), 2008–2014. https://doi.org/10.1021/es062052f

[2] Strong, P. J., & Burgess, J. E. (2008). Treatment Methods for Wine-Related and Distillery Wastewaters: A Review. Bioremediation Journal, 12(2), 70–87. https://doi.org/10.1080/10889860802060063

[3] Demnerová, K., Mackova, M., Špěváková, V., Beranova, K., Kochánková, L., Lovecká, P., Ryslavá, E., & Macek, T. (2005). Two approaches to biological decontamination of groundwater and soil polluted by aromatics-characterization of microbial populations. International Microbiology: The Official Journal of the Spanish Society for Microbiology, 8(3), 205–211.

[4] Macek, T., & Mackova, M. (2011). Potential of Biosorption Technology. In P. Kotrba, M. Mackova, & T. Macek (Eds.), Microbial Biosorption of Metals (pp. 7–17). Springer Netherlands. https://doi.org/10.1007/978-94-007-0443-5_2

[5] Macek, T., Kotrba, P., Svatos, A., Novakova, M., Demnerova, K., & Mackova, M. (2008). Novel roles for genetically modified plants in environmental protection. Trends in Biotechnology, 26(3), 146–152. https://doi.org/10.1016/j.tibtech.2007.11.009

[6] Muyzer, G., & Stams, A. J. M. (2008). The ecology and biotechnology of sulphate-reducing bacteria. Nature
Comparative analysis of different soil remediation from heavy metals. In: Environmental Deterioration and Human Health. Springer 215-227.

Couto, N., Fritt-Rasmussen, J., Jensen, P. E., Højrup, M., Rodrigo, A. P., & Ribeiro, A. B. (2014). Suitability of oil bioremediation in an Artic soil using surplus heating from an incineration facility. Environmental Science and Pollution Research, 21(9), 6221–6227. https://doi.org/10.1007/s11356-013-2466-3

Phulia V, Jamwal A, Saxena N, et al. (2013). Technologies in aquatic bioremediation. Kumar P, Zaki BMSA, Chauhan A, editors. Freshwater ecosystem and xenobiotics. Discovery Publishing House Pvt. Ltd.: India. pp. 65-91.

Thavasi, R., Jayalakshmi, S., & Banat, I. M. (2011). Application of biosurfactant produced from peanut oil cake by Lactobacillus delbrueckii in biodegradation of crude oil. Bioresource Technology, 102(3), 3366–3372. https://doi.org/10.1016/j.biortech.2010.11.071

Asira, E. E. (2013). Factors that Determine Bioremediation of Organic Compounds in the Soil. Academic Journal of Interdisciplinary Studies. https://doi.org/10.5901/ajis.2013.v2n13p125

Davis, T. A., Volesky, B., & Mucci, A. (2003). A review of the biochemistry of heavy metal biosorption by brown algae. Water Research, 37(18), 4311–4330. https://doi.org/10.1016/S0043-1354(03)00293-8

Neethu, C. S., Mujeeb Rahman, K. M., Saramma, A. V., & Mohamed Hatha, A. A. (2015). Heavy-metal resistance in Gram-negative bacteria isolated from Kongsfjord, Arctic. Canadian Journal of Microbiology, 61(6), 429–435. https://doi.org/10.1139/cjm-2014-0803

Wang, Q., Zhang, S., Li, Y., & Klassen, W. (2011). Potential Approaches to Improving Biodegradation of Hydrocarbons for Bioremediation of Crude Oil Pollution. Journal of Environmental Protection, 02(01), 47–55. https://doi.org/10.4236/jep.2011.21005

Das, N., & Chandran, P. (2011). Microbial Degradation of Petroleum Hydrocarbon Contaminants: An Overview. Biotechnology Research International, 2011, 1–13. https://doi.org/10.4061/2011/941810

Macaulay BM. (2015). Understanding the behaviour of oil-degrading micro-organisms to enhance the microbial remediation of spilled petroleum. Applied Ecology and Environment Research, 13(1), 247-262. https://doi.org/10.15666/aer/1301_247262

Yang, S.-Z., Jin, H.-J., Wei, Z., He, R.-X., Ji, Y.-J., Li, X.-M., & Yu, S.-P. (2009). Bioremediation of Oil Spills in Cold Environments: A Review. Pedosphere, 19(3), 371–381. https://doi.org/10.1016/S1002-0160(09)60128-4

Gallizia, I., McClean, S., & Banat, I. M. (2003). Bacterial biodegradation of phenol and 2,4-dichlorophenol. Journal of Chemical Technology & Biotechnology, 78(9), 959–963.

https://doi.org/10.1002/jctb.890

Madhavi GN, Mohini DD. (2012). Review paper on – parameters affecting bioremediation. International Journal of Life Science and Pharma Research, 2(3), 77–80.

Kumar A, Bisht BS, JoshiVD, et al. (2011). Review on Bioremediation of Polluted Environment: A Management Tool. International Journal of Environmental Sciences, 1(6), 1079-1093.

Leung M. (2004). Bioremediation: techniques for cleaning up a mess. J. Biotechnol, 2, 18–22.

Mary Kensa V. (2011). Bioremediation - An overview. J. Ind. Pollut. Control, 27, 161–168.

Ubani, O., Atagana, I. H., & Thantsha, S. M. (2013). Biological degradation of oil sludge: A review of the current state of development. African Journal of Biotechnology, 12(47), 6544–6567. https://doi.org/10.5897/AJB11.1139

Yuniati, M. D. (2018, February). Bioremediation of petroleum-contaminated soil: A Review. In IOP Conference Series: Earth and Environmental Science (Vol. 118, No. 012063, pp. 1755-1315).

Garbisu C, Alkorta I. (2003). Basic concepts on heavy metal soil bioremediation. Eur. J. Miner Process Environ Prot, 3, 58–66. Available at: http://www.ejmepe.com/garbisu_and_alkorta.pdf.

Perelo, L. W. (2010). Review: In situ and bioremediation of organic pollutants in aquatic sediments. Journal of Hazardous Materials, 177(1–3), 81–89. https://doi.org/10.1016/j.jhazmat.2009.12.090

Kulik, N., Goi, A., Trapido, M., & Tuahkan, T. (2006). Degradation of polycyclic aromatic hydrocarbons by a combination of chemical pre-oxidation and bioremediation in creosote contaminated soil. Journal of Environmental Management, 78(4), 382–391. https://doi.org/10.1016/j.jenvman.2005.05.005

Xu, Y., & Lu, M. (2010). Bioremediation of crude oil-contaminated soil: Comparison of different biostimulation and bioaugmentation treatments. Journal of Hazardous Materials, 183(1–3), 395–401. https://doi.org/10.1016/j.jhazmat.2010.07.038

Mosca Angelucci, D., & Tomei, M. C. (2016). Ex situ bioremediation of chlorophenol contaminated soil: Comparison of slurry and solid-phase bioreactors with the two-step polymer extraction-bioregeneration process: Ex situ soil remediation: comparative analysis of different solutions. Journal of Chemical Technology & Biotechnology, 91(6), 1577–1584. https://doi.org/10.1002/jctb.4882

Tomei, M. C., & Daugulis, A. J. (2013). Ex Situ Bioremediation of Contaminated Soils: An Overview of Conventional and Innovative Technologies. Critical Reviews in Environmental Science and Technology, 43(20), 2107–2139. https://doi.org/10.1080/10643389.2012.672056

Suja, F., Rahim, F., Taha, M. R., Hambali, N., Rizal Razali, M., Khalid, A., & Hamzah, A. (2014). Effects of local microbial bioaugmentation and biostimulation on.
the bioremediation of total petroleum hydrocarbons (TPH) in crude oil contaminated soil based on laboratory and field observations. International Biodeterioration & Biodegradation, 90, 115–122. https://doi.org/10.1016/j.ibiod.2014.03.006

[32] Pimmata, P., Reungsaeng, A., & Plangklang, P. (2013). Comparative bioremediation of carbofuran contaminated soil by natural attenuation, bioaugmentation and biostimulation. International Biodeterioration & Biodegradation, 85, 196–204. https://doi.org/10.1016/j.ibiod.2013.07.009

[33] Hamdi, H., Benzarti, S., Manusadzianas, L., Aoyama, I., & Jedidi, N. (2007). Bioaugmentation and biostimulation effects on PAH dissipation and soil ecotoxicity under controlled conditions. Soil Biology and Biochemistry, 39(8), 1926–1935. https://doi.org/10.1016/j.soilbio.2007.02.008

[34] Alisi, C., Musella, R., Tasso, F., Ubaldi, C., Manzo, S., Cremisini, C., & Sprocati, A. R. (2009). Bioremediation of diesel oil in a co-contaminated soil by bioaugmentation with a microbial formula tailored with native strains selected for heavy metals resistance. Science of The Total Environment, 407(8), 3024–3032. https://doi.org/10.1016/j.scitotenv.2009.01.011

[35] Ueno, A., Ito, Y., Yumoto, I., & Okuyama, H. (2007). Isolation and characterization of bacteria from soil contaminated with diesel oil and the possible use of these in autochthonous bioaugmentation. World Journal of Microbiology and Biotechnology, 23(12), 1739–1745. https://doi.org/10.1007/s11274-007-9423-6

[36] Kauppi, S., Sinkkonen, A., & Romantschuk, M. (2011). Enhancing bioremediation of diesel-fuel-contaminated soil in a boreal climate: Comparison of biostimulation and bioaugmentation. International Biodeterioration & Biodegradation, 65(2), 359–368. https://doi.org/10.1016/j.ibiod.2010.10.011

[37] Georgieva, S., Godjievargova, T., Mitu, D. G., Diano, N., Menale, C., Nicolucci, C., Carratelli, C. R., Mitu, L., & Golovinsky, E. (2010). Non-isothermal bioremediation of waters polluted by phenol and some of its derivatives by laccase covalently immobilized on polypropylene membranes. Journal of Molecular Catalysis B: Enzymatic, 66(1–2), 210–218. https://doi.org/10.1016/j.molcatb.2010.05.011

[38] EPA. (2006). In situ and ex situ biodegradation technologies for remediation of contaminant sites. Engineering issue, EPA/625/R-06/015. http://clu-in.org/download/contaminantfocus/dnapl/Treatment_Technologies/epa_2006_engineer_issue_bio.pdf.

[39] Chen, J., Wei, X.-D., Liu, Y.-S., Ying, G.-G., Liu, S.-S., He, L.-Y., Su, H.-C., Hu, L.-X., Chen, F.-R., & Yang, Y.-Q. (2016). Removal of antibiotics and antibiotic resistance genes from domestic sewage by constructed wetlands: Optimization of wetland substrates and hydraulic loading. Science of the Total Environment, 565, 240–248. https://doi.org/10.1016/j.scitotenv.2016.04.176

[40] Venkata Mohan, S., Purushotham Reddy, B., & Sarma, P. N. (2009). Ex situ slurry phase bioremediation of chrysene contaminated soil with the function of metabolic function: Process evaluation by data enveloping analysis (DEA) and Taguchi design of experimental methodology (DOE). Bioresource Technology, 100(1), 164–172. https://doi.org/10.1016/j.biortech.2008.06.020

[41] Prasanna, D., Venkata Mohan, S., Purushotham Reddy, B., & Sarma, P. N. (2008). Bioremediation of anthracene contaminated soil in bio-slurry phase reactor operated in periodic discontinuous batch mode. Journal of Hazardous Materials, 153(1–2), 244–251. https://doi.org/10.1016/j.jhazmat.2007.08.063

[42] Silva-Castro, G. A., Uad, I., Rodríguez-Calvo, A., González-López, J., & Calvo, C. (2015). Response of autochthonous microbiota of diesel polluted soils to landfarming treatments. Environmental Research, 137, 49–58. https://doi.org/10.1016/j.envres.2014.11.009

[43] Paudyn, K., Rutter, A., Kerry Rowe, R., & Poland, J. S. (2008). Remediation of hydrocarbon contaminated soils in the Canadian Arctic by landfarming. Cold Regions Science and Technology, 53(1), 102–114. https://doi.org/10.1016/j.coldregions.2007.07.006

[44] Maila, M. P., & Cloete, T. E. (2004). Bioremediation of petroleum hydrocarbons through landfarming: Are simplicity and cost-effectiveness the only advantages? Reviews in Environmental Science and Bio/Technology, 3(4), 349–360. https://doi.org/10.1007/s11157-004-6653-z

[45] Montagnolli, R. N., Lopes, P. R. M., & Bidoia, E. D. (2015). Assessing Bacillus subtilis biosurfactant effects on the biodegradation of petroleum products. Environmental Monitoring and Assessment, 187(1), 4116. https://doi.org/10.1007/s10661-014-4116-8

[46] Sharma S. (2012). Bioremediation: Features, Strategies and applications. Asian Journal of Pharmacy and Life Science, 2(2), 202–213.

[47] Dell’Anno, A., Beolchini, F., Rocchetti, L., Luna, G. M., & Danovaro, R. (2012). High bacterial biodiversity increases degradation performance of hydrocarbons during bioremediation of contaminated harbor marine sediments. Environmental Pollution, 167, 85–92. https://doi.org/10.1016/j.envpol.2012.03.043