Bioremediation of Hydrocarbon Contaminated Soil Using Cow Dung and Poultry Droppings

Ibekwe, Mary James; Ehirim, O. Emmanuel & Umeda, Uchendu
Department of Chemical/PetroChemical Engineering,
Rivers State University, Port Harcourt.
ehirim.emmanuel@ust.edu.ng, mjmail80@yahoo.com,
umexil@yahoo.com

Abstract
Energy related environmental problems, including oil spills, air pollution, flooding and deforestation have become a threat to world's biodiversity and delicate ecosystems. Oil spills are frequent in developing countries such as Nigeria, and have been the cause of severe environmental damage. For example, spills in Ogoni Land and other water bodies in the creeks have caused damages to swamp itself, hurt the local fishing communities, covered beaches with crude and greatly polluted the coastal soils. Bioremediation is process by which organic contaminants are destroyed by the action of soil microorganisms. These microorganisms are capable of obtaining energy by breaking down petroleum hydrocarbon to carbon dioxide and water, as well as incorporating portions of the hydrocarbon for their own growth. The aim of this research is to use cow dung and poultry droppings for the process of bioremediation. The results obtained showed that biodegradation was faster using the nutrient mixture of cow and poultry droppings than individual nutrients. This research established a strong fact that adequate local materials such as cow dung and poultry droppings can provide the necessary nutrients for bioremediation process.

Keywords: *Bioremediation; Cow Dung; Hydrocarbon contaminated soil; & Poultry Droppings*

Introduction

Energy related environmental problems, including oil spills, air pollution, flooding and deforestation have become a threat to world's biodiversity and delicate ecosystems. Oil spills are frequent in developing countries such as Nigeria, and have been the cause of severe environmental damage. For example, spills in Ogoni Land and other water bodies in the creeks have caused damages to swamp itself, hurt the local fishing communities, covered beaches with crude and greatly polluted the coastal soils. Almost all operations of petroleum industries, including exploring, production (extraction), storing, transporting and refining of crude oil and the storing, distribution and handling of products are potential soil contaminates (oily sludge). Accidental spills of crude oil and petroleum products during the handling, storing and transporting operations are the principal causes of formation of oily sludge in large quantities. Oily sludge formation can be minimized by prudent operating practices, sensitive attitudes and suitable control methods.

Soil contamination has become recognized as major concern by regulatory agencies during decades of the 1980s, yet approaches for assessment with respect to evaluation, fate modelling, risk assessment and remediation have presented unusually difficult technical, scientific and regulatory challenges. Many of the petroleum and gasoline hydrocarbons are hydrophobic molecules, and hence possess a low solubility in water. They exhibit a marked tendency toward absorption onto the soil phase of the aquifer, so the conventional removal of pollutants from the contaminated site is largely ineffective.

Bioremediation, a relatively new treatment technology that can be implemented in-situ and /or ex-situ, is process by which organic contaminants are destroyed by the action of soil microorganisms. These microorganisms are capable of obtaining energy by breaking down petroleum hydrocarbon to carbon dioxide and water, as well as incorporating portions of the hydrocarbon for their own growth (Jelena, M.S., Beskoski, V.P. Ilic, M.V. & Ali, S.A.M, 2009). Biodegradation involves increasing the number of these microorganisms in contaminated soil by adding mineral nutrients and oxygen, which they require for growth. During petroleum degradation it is typical for several kinds of bacteria to cooperate in the breakdown of the hydrocarbon (Jorgensen, K.S., Puustinen, J. & Suortti, A.M, 2000). Bioremediation is a popular approach of cleaning up petroleum hydrocarbons because it is simple to maintain, applicable over large areas, cost-effective and leads to the complete destruction of the contaminant. Strategies for inexpensive and clean in situ bioremediation of soil contaminated with petroleum polluted soils include stimulation of the indigenous microorganisms, by introducing nutrients and oxygen into the soil (biostimulation) or through inoculation of an enriched mixed microbial consortium into soil (bioaugmentation). Several variations have been developed such as bioventing, as simple process suitable for volatile and semi-volatile contaminants in unsaturated soil. In bioventing degradable and nondegradable volatile components can be removed. Phytoremediation is a developing process that uses plants –in-situ or ex-situ- to remove, contain or render harmless environmental contaminants.

Biotechnological remediation in so called landfarming is an attractive method for oil polluted soils. Landfarming is one of the simplest and cheapest methods for the treatment of excavated soil. During the biotechnological remediation, the soil keeps its structure and can be reused for most remediation of oil-polluted soil. Nowadays (conventional) landfarming is widely applied method for remediation of oil-polluted soil (Hejazi & Husain, 2004). However, the factors that determine the rate and level of aerobic microbiological degradation of pollutants in landfarming systems are poorly controlled. A major drawback of landfarming is the possible emission of volatile compounds, nutrients and leaches to the environment. Time and land requirement can also be expensive. Composting, a method for waste treatment, is one of the newest and most promising ex-situ methods for soil treatment (Jorgensen, K.S., Puustinen, J. & Suortti, A.M. (2000). However, the most volatile components emitted are difficult to treat.

The Nigerian content development center has been advocating for the substitution of the very costly foreign materials with locally made ones. This move encourages both employment and cost effective national economy. Recently, researches have been concentrated in areas where local contents form the primary materials for both laboratory scale and prototype experiment. To demonstrate the potential use of local content for bioremediation in treating soil contaminated with hydrocarbon oil, a combination of cow dungs and poultry droppings was used in a laboratory study with the goal of evaluating the effects of natural attenuation, biostimulation and bioaugmentation on the oil degradation.

Experimental Procedure

10 Kg of soil samples collected from the agricultural farm of Rivers State University, Port Harcourt. The Cow Dung and the Poultry Droppings were also collected from the University abattoir and poultry Farms respectively. Four empty batch reactors were weighed. 2kg of the soil samples were placed in each of the reactors and left for three days. The four reactors were then polluted with 200ml of Bonny light crude oil and allowed to rest for three days after

thorough mixing for homogeneity. Reactor 1, stationed as the Control had no nutrient added to it. Reactor 2 contained the contaminated soil and 1.5kg slurry Cow Dung (CD), Reactor 3 contained the contaminated soil plus1.5kg slurry Poultry Droppings (PD) and Reactor 4 the contaminated soil and 1.5kg slurry of the mixture of the Cow Dung and Poultry Droppings (CD + PD). These were again thoroughly mixed and observed for twenty eight days. Samples were collected from each reactor every seven days for analysis to determine the Total Petroleum Hydrocarbon (TPH).

Determination of Total Petroleum Hydrocarbon

The analysis of the Total Petroleum Hydrocarbon was done using a Gas Chromatography – Flame Ionization Detector Model HP 5890 series II, U.S.A. This analysis was done by Analytical Concept Limited. Total Petroleum Hydrocarbon was obtained using calibrated graph in the software of the equipment as a reference.

Results and Discussion

The results obtained for the four reactors are shown on Figs. 1 through 6 below. The discussions of these figures follow immediately for easy follow up.

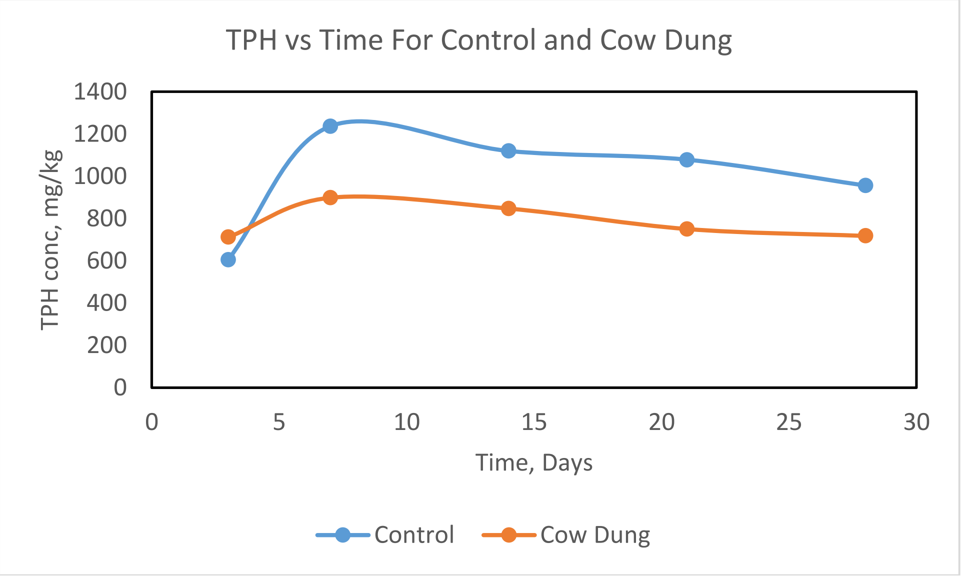

Fig.1: The graph of the Total Petroleum Hydrocarbon Concentration with Time (Control + Cow Dung)

Figure 1 shows the concentration of the total petroleum hydrocarbon for both the control experiment and the contaminated soil plus cow dung. This result shows that biodegradation occurred in both reactors. However the rate of breakdown of complex hydrocarbons is greater on the later due to the action of the nutrients added. The decrease in the total petroleum hydrocarbon in the control experiment could be due to the presence of inherent biodegradation bacteria in the soil itself.

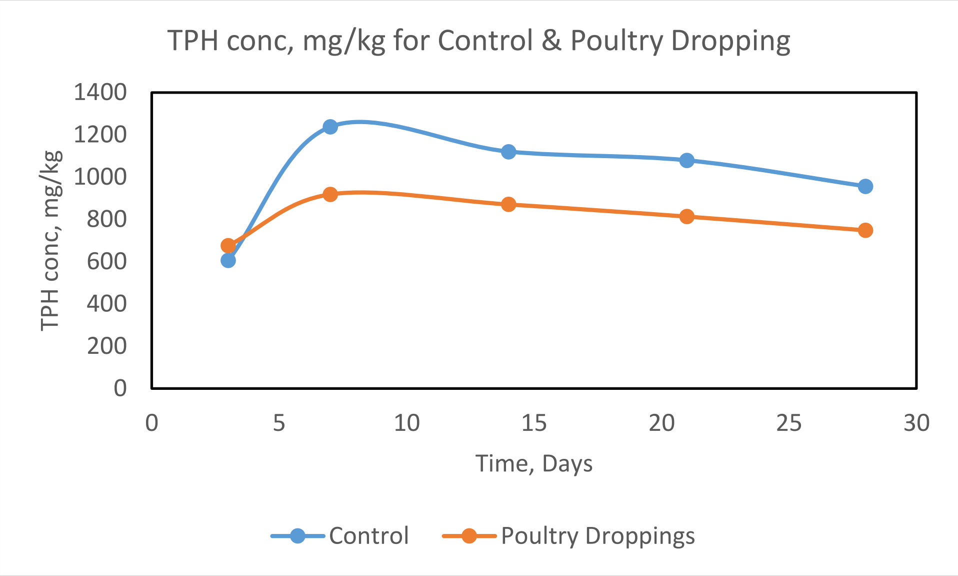

Figure 2. The graph TPH concentration against time for the control experiment and the reactor containing the contaminate soil and poultry droppings. Again, this graph has similar behavior with that shown in Fig.1 above: The concentrations of the TPH decreased with time. The rate of degradation is also greater for the reactor containing the nutrients.

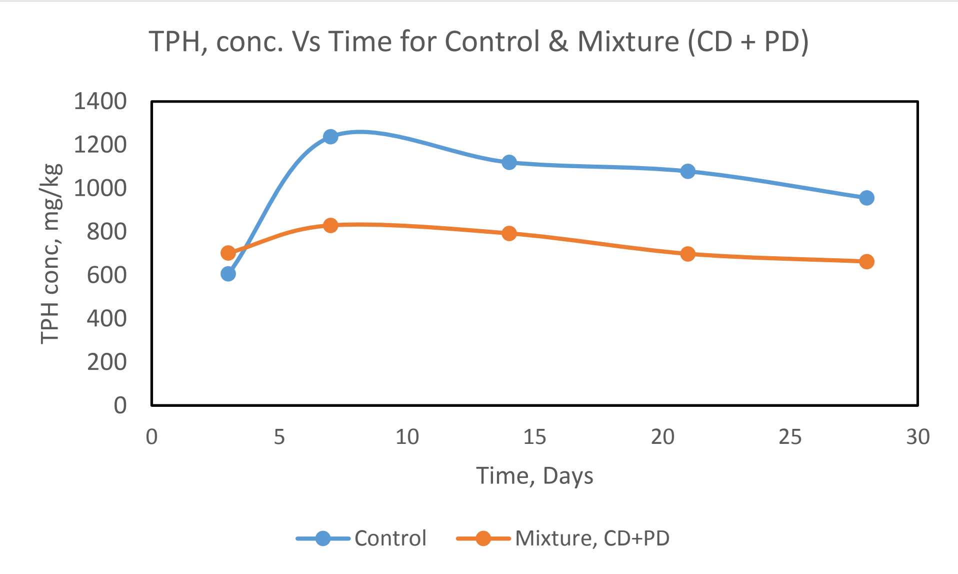

Fig. 3: The graph of TPH against Time for Control and Contaminated soil plus Mixture

Figure 3 illustrates the graph of the Total Petroleum Hydrocarbon concentration for the control experiment and the reactor containing both the cow dung and the poultry droppings. This result shows that a mixture of the cow dung and the poultry droppings worked better than when added individually. This could be as a result of the combined actions of the microorganisms present in these nutrients which accelerated the bioremediation process in the system.

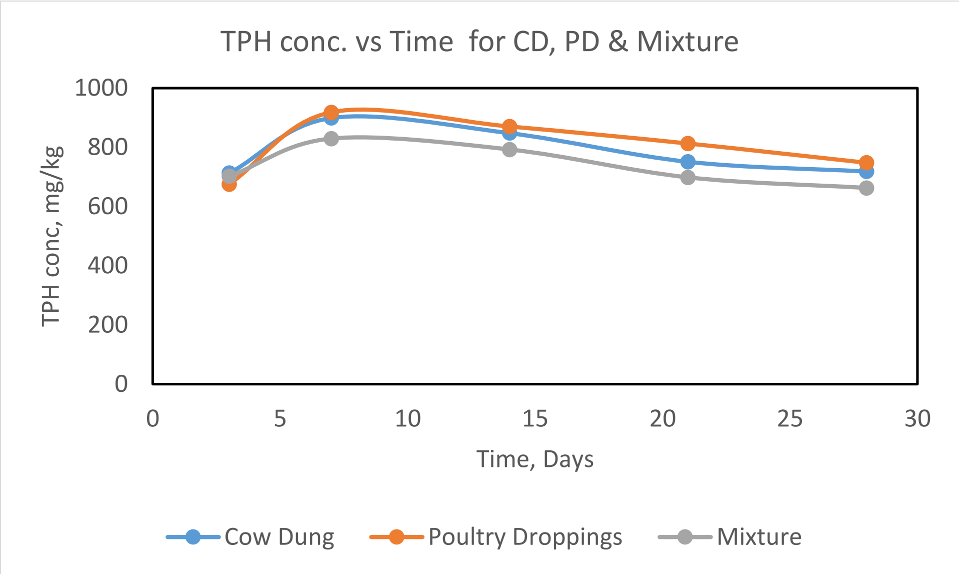

Fig. 4: Graph of the TPH against Time for Cow Dung, Poultry Droppings & Mixture

Figures 4 and 5 show, respectively, the concentrations of the TPH against the three reactors and the control experiment. It can clearly be shown from these figures that the bioremediation is faster in Reactor 4 which contain the mixture of cow dung and poultry droppings. Reactor four would have more of the microorganisms necessary for fast bioremediation process.

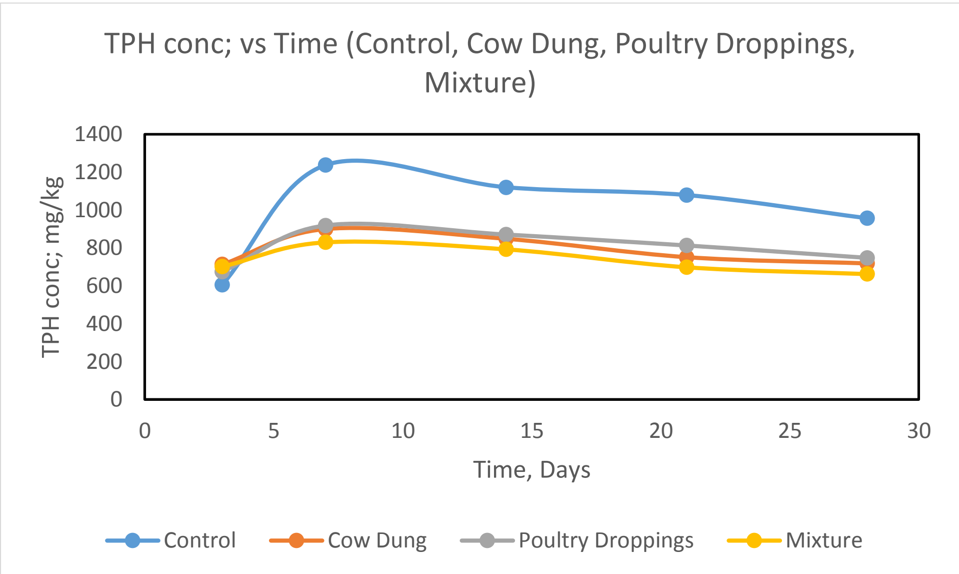

Fig. 5: Graph of the TPH concentration against Time for the four Reactors.

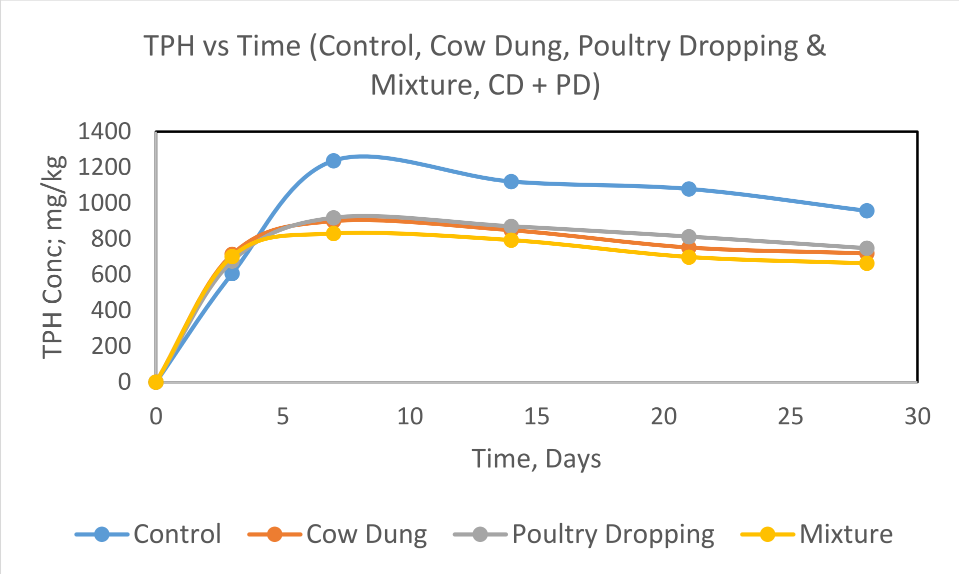

Figure 6. Graph of TPH concentrations against Time for the control and three reactors.

Figure 6 shows the Total Petroleum Hydrocarbons with time for all the reactors, beginning from day zero of the experiment to day 28. These figures show clearly that the system behavior followed the experimental trend as seem in the literature (Ayotamuno &Agunwamba). That is to say that this behavior is in agreement with the Monod Kinetics that describes the kinetics of bioremediation process.

Conclusion

1. Local materials such as cow dung and poultry droppings can effectively provide the necessary nutrients to initiate bioremediation process. Lands polluted with petroleum hydrocarbons (crude oil) can be remediated back to its natural agricultural benefits.
2. The rate of biodegradation of petroleum contaminated soil using cow dung is faster than that of poultry droppings.
3. The mixture of cow dung and poultry droppings was more effective in remediating the petroleum contaminated soil.

References

Aggarwal, P.K., Means, J.L., Hinchee, R.E., Headington, G.L. & Gavaskar, A.R.(1990). Methods to select chemicals for in-situ biodegradation of fuel hydrocarbon.*Florida tyndal AFB, Air force Engineering and Service Center.*

Andreoni, V. & Gianfreda, L., (2007). Bioremediation and Monitoring of aromatic- polluted habitats. *Applied Microbiology*, 76, 287-303

Antizar –Ladisoloa, B., Lopez- Real, J. & Beck, A.J.(2005). Laboratory studies of the remediation of polycyclic aromatic hydrocarbon contaminated soil by in – vessel compositing. Journal of Waste Management, 25, 281-289

Amellal, N., Portal, J.M. & Berthelin, J. (2001).Effect of soil structure on the bioavailability of polycyclic aromatic hydrocarbons within aggregates of a contaminated soil. *Applied Geochemistry*, 16, 1611-1619

Atlas, R. M. & Philip, J. (2005) Bioremediation.Applied microbial solution for real- world environmental clean-up.*ASM Press*

Ayotamuno, M.J., Kogbara, R.B. & Agunwamba, J.C. (2006).Bioremediation of a petroleum hydrocarbon polluted agricultural soil at various level of soil tillage in Port Harcourt.

Nigeria Journal of Technology, 25, 44-51

Bentos, F.M., Carmago, F. A. O., Okeke, B.C. & Frankenberger, W.T.(2005). Comparative bioremediation of soil contaminated with diesel oil by natural attenuation, bio-stimulation and bio-augmentation. *Bio-resources Technology*, 96, 1049-1055

Bhupathiraju, K., Krauter, P., Holman, H Y.N., Conrad, M.E., Dalay, P.F., Templetion, A.S., Hunt, J.R., Herandez, M. & Alvarez-Cohen N.(2002). Assessment of in-situ bioremediation at a refinery waste contaminated site and an aviation gasoline contaminated site. *Biodegradation*, 13, 79- 90

Bundy, J.G., Paton, G.I. & Campbell, C.D. (2004). Microbial communities in different soil type do not converge after diesel contamination. *Journal of Applied Microbiology*, 92, 276-288.

Challan, S.K. & Tazaki, K. (2005). How kaolinite play an essential role in remediating oil polluted seawater. *Clay Mineral*, 40: 481-491.

Delille, D., Coulon, F. & Pelletetier, E.(2004). Effect of Temperature warming during a biodegradation study of natural and nutrient amended hydrocarbon- contaminated sub-Antarctic soil. *Cold Region Science Technology*, 40, 61-70

Devinny, J.S. & Islander, R.L. (1998).Hazard. Waste Hazard Material, 61: 421

Diplock, E. E., Mardlin, D.P., Killham, K.S. & Paton, G.I. (2009).Predicting bioremediation of hydrocarbons: Laboratory to field scale. Environmental Pollution, 157, 1831-1840

Durant, N.D., Jonkers, C.A.A. & Bouwer, E.J. (1997).Spatial variability in the naphthalene mineralization response to oxygen, nitrate, and orthophosphate amendments in M.G.P aquifer sediment.*Biodegradation*, 8: 77-86.

Dyer, M., Heiningen, E.V. & Gerritse, J. (2003).A field trial for in-situ bioremediation of 1, 2 DCA.*Engineering Geology*, 70, 315-320.

Farhadian, M., Vachelard, C., Duchez, D. & Larroche, C. (2008). In-situ bioremediation of mono-aromatic pollutants in groundwater: A review. Bio-resources Technology, 99, 5296 – 5308.

Frutosa, F.T.G., Pereza, R., Escolano, O., Rubiob, A., Gimenob, A., Fernandezc, M.D. & Lagunad, J.(2012). Remediation trials for hydrocarbon contaminated sludge from a soil washing process. Evaluation of bioremediation technology. Journal of Hazardous Material, 200,262-271

Ghazali, F.M., Abdulrahaman,R.N.Z., Salleh, A.B. & Basri, M. (2007). Biodegradation of hydrocarbons in soil by microbial consortium.*International Bio-deterioration and Biodegradation*, 56, 61-67.

Harayamo, S. (1997).Polycyclic aromatic hydrocarbon bioremediation design.*Current option in Biotechnology*, 8, 268-273.

Hejazi, R.F. & Husain, T. (2004). Land farm performance under arid conditions.,Evaluation of parameters. *Environmental Science Technology*, 38, 2457-2469.

Ijah, U.J.J. & Antai, S. P. (2003). Removal of Nigerian Light Crude oil over a 12 – month period. *International Bio-deterioration and Biodegradation*, 51, 93-99.

Jelena, M.S., Beskoski, V.P. Ilic, M.V. & Ali, S.A.M. (2009). Bioremediation of soil heavy contaminated with crude oil and its products. Composition of the microbial consortium.*Journal of the Serbian Chemical Society*, 74, 455-460.

Jorgensen, K.S. & Puustinen, J.S. (1995). Bioremediation of petroleum hydrocarbon-contaminated soil by compositing in biopiles. *Environmental pollution*, 107, 245-254

Jorgensen, K.S., Puustinen, J. & Suortti, A.M. (2000). Bioremediation of petroleum Hydrocarbon contaminated soil by composting in biopiles. *Environmental Pollution*, 107, 245–254,

Kermanshashi, A.P., Karamaner, D. & Margantis, A. (2005). Biodegradation of petroleum hydrocarbons in an immobilized cell airlift bioreactor. *Water Resources*, 39, 3704 –

3714
Landmeyer, J.E. & Bradley, P.M. (2003). Effect of hydrologic and geochemical condition on oxygen enhanced bioremediation in a gasoline contaminated aquifer. *Bioremediation Journal*, 7, 165 – 177.
Kermanshashi, A.P., Karamaner, D. & Margantis, A. (2005). Biodegradation of petroleum hydrocarbons in an immobilized cell airlift bioreactor. *Water Resources,* 39, 3704 – 3714
Gargouri, B., Karry, F., Mhiri, N., Aloui, F. & Sayadi, S. (2011).Application of continuously Stirred tank bioreactor (CSTR) for bioremediation of hydrocarbon-rich industrial waste water effluents.*Journal of Hazardous Materials.* 189: 427-434.
Guerin, T.F. (2000). Long- term performance of land treatment facility for the bioremediation of non- volatile oily wastes.*Reserve Conservation Recycling*, 28, 105-120.
Margesin, R., Zimmerbaner, A. & Schinner, F. (2000).Monitoring of bioremediation by soil biological activities.*Chemosphere*, 40, 339 – 346.
Margesin, R. & Schinner, F. (2001).Biodegradation and bioremediation of hydrocarbons, inextreme environments, *Applied Microbial Biotechnology*, 56, 650 – 663.
Nakles, D. & Ray, L. (2002).Overview of Bioremediation Research of Texas and Gas Research Institute. Presentation of DOE/PERF Bioremediation workshop.
Nester, E.W., Denise, G. A.C., Evans, R.J., Nancy, N.P. & Martha, T.N. (2001). *Microbiology: A human perspective*, 3rd Ed. New York: Mc Graw- Hill.
Obire, O. & Nwanbete, O. (2001). Bioremediation of Refined Petroleum Hydrocarbon in soil. *Journal of Applied Science and Environmental Management*, 1, 43 – 46
Okoh, A.I. (2006). Biodegradation alternative in the clean -up of petroleum hydrocarbon pollutant.*Biotechnology and Molecular Biology Review*, 2, 38 – 50.
Perfumo, A., Banat, I.M., Marchant, R. & Vezzuli, L. (2007). Thermally enhanced approaches for remediation of hydrocarbon – contaminated soil. *Chemosphere,* 66, 179 – 184.
Radwan, S. S. Al- Mailem, D., El-Nemr, I. & Salamah, S. (2000). Enhanced remediation of hydrocarbon contaminated desert soil fertilized with organic carbons. *International Bio-deterioration and Biodegradation*, 46, 129- 132.
Rowland, A.P., Lindley, D.K., Hall, G.H., Rossal, M.J., Wilson, D.R., Benhan, D.G.,Harrison,A.F. & Daniels, R.E., (2000). Effects of beach and sand properties, temperature and rainfall on the degradation rates of oil buried in oil/beach sand mixtures, *Environmental Pollution*, 109,109-118.
Rhykerd R L., Crews B. & MeInnes K J.(1999). Impact of bulking agents, forced aeration, and tillage on remediation of oil-contaminated soil. *Bio-resources Technology*, 67: 279-283
Scherr, K., Aichberger, H., Braun, R. & Loibner, A.P. (2007). Influence of soil fraction on microbial degradation behavior of mineral hydrocarbon. *European Journal of soil Biology*, 43, 341 – 350.
Si-Zhong, Y., Hui-Jun, J., Zhi, W., Rui-Xia, H., Yan-Jun, J., Xiu-Mei, L. & Shao-Peng, Y. (2009).Bioremediation of Spills in Cold Environment.A Review.*Pedosphere, 3,* 371-381
Sorhkoh, N.A., AL Hasan , R., Radwan, S. & Hopner T. H. (1992). Self- cleaning of the Gulf *Nature* (*London*), 359, 109
Stotzky, G. & Rem, L.T. (1996). Influence of clay minerals on microorganisms. I.Montinorillonite and kaolinite on bacteria.*Canadian Journal microbiology*, 12, 547-563
Trindade, P.V.O., Sobral, L.G., Rizzo, A. C.L., Leite, S .G. F. & Soriano, A. U. (2005).Bioremediation of a weathered and a recently oil- contaminated soil from Brazil, a comparison study.*Chemosphere*, 5, 515-522.
United State Environmental Protection Agency (USEPA) Bioventing (2006).

Van Hamme, J.D., Singh, A. & Ward, O.P. (2003). Recent advances in petroleum microbiology. *Microbial Molecular Biology Review*, 67, 503-549.

Vasudevan, N. & Rajaram, P. (2001). Bioremediation of oil sludge- contaminated soil. *Environment International*, 26, 409-411.

Wang, X. & Bartha, R. (1990).Effect of bioremediation on residues, activity and toxicity in soil contaminated by fuel spills.*Soil Biology and Biochemistry*, 22, 501-505.

Wolicka, D., Suszek, A., Borkowski, A. & Bieleaka, A. (2009).Application of aerobic microorganism in bioremediation in-situ of soil contaminated by petroleum product.*Bio-resources Technology*, 100, 3221-3227.

Yang, X., Beckmann, D., Fiorenza, S. & Niedermeier, C. (2005). Field study of pulsed air sparging for remediation of petroleum hydrocarbon contaminated soil and ground water. *Environmental science Technology*, 39, 7279 - 7286.

Zucchi, M., Argiolini, L., Borin, S., Brusetti, L., Dietrich, N., Gigliotti, C., Barbieri, P. Sorlini, C. & Daffonchio, D. (2003). Response of bacterial community during bioremediation of an oil- polluted soil. *Journal of applied microbiology.* 94, 248 – 257