BIOREMEDIATION THROUGH OILZAPPER AND OILIVOROUS-S TECHNOLOGIES: A REVIEW

MANISH RANDHAWA, DR. JYOTSNA KAUSHAL

Abstract: Oil spills and oily sludge generated by oil refineries pose a serious threat to the environment. Dumping oily sludge into specifically constructed pits (the traditional method) is fraught with many problems. Moreover there is a limited availability of land in India and many other nations for constructing such pits. Thus requirement of the oil degrading pits in large numbers; possibility of seepage through soil layers; high cost in constructing seepage free pits call for alternative solutions for eradication of oily sludge. Bioremediation through the use of Carrier based Oil zapper is used nowadays for cleanup of crude oil spills and treatment of oily sludge. TERI has developed an Oil zapper, a consortium of crude oil and oily sludge degrading bacteria (Patented) deriving from various bacterial cultures existing in the natural environment that eats up all four layers of crude-waxy element or saturated hydrocarbons, aromatic component or benzene compounds, NSO (compounds of nitrogen and sulphur) and asphaltene or tar and converts them into harmless CO_2 and water. Oil zapper can work in temperatures ranging from 8 to 40 degree Celsius. By the use of Oil zapper/ Oilivorous-S technologies bioremediation is 30-40% cheaper than the conventional physico-chemical treatments. Both Oil zapper and Oilivorous-S can be used in situ, thereby eliminating the need to transfer large quantities of contaminated waste from the site and the clean up process is complete in itself as contaminants are not merely transferred from one environmental medium to another (from water to air or land) but destroyed.

Keywords: Bioremediation, Consortium, Oil zapper, Seepage.

Introduction: Oil spills are releasing large volumes of liquid petroleum hydrocarbon into the environment due to human activities such as accidental leakage of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil. Oil spills can also take place on the land as a result of leakage from terrestrial pipelines and pilferage activities. Oil spills on land pose a three-fold menace: fire hazards, groundwater pollution due to percolation, and air pollution due to evaporation. Oil refineries (the major source) unavoidably generate huge quantity of oil sludge during refining of crude oil. Since crude oil is lighter than water, it floats on the sea surface and results in a swift-spreading fire. Oily sludge is a hazardous hydrocarbon waste, which constitute a major task of sludge management. Traditional way to handle this type of waste is dump the sludge into pits, but possible seepage of the oily sludge from the pits over a period of time cannot be ruled out, therefore, environment-friendly technologies are increasing in demand by petroleum industry to manage oily sludge. Crude oil is a major source of energy and feedstock for petrochemicals. Oily sludge, bio-sludge and chemical sludge are the major sludges generated from the processes and effluent treatment plants of the refineries engaged in crude oil refining operations. Refineries in India generate about 28,220 tons of sludge per annum. Various types of pollutants like phenols, heavy metals, etc. are present in the sludges and they are treated as hazardous waste Bhattacharyya, J. K.; Shekdar, A. V. (2003). The problem is common to all oil-producing countries. The situation with sludge accumulation in Russia presents an opportunity for American oil reclamation companies. Russia's vast territories and its seemingly inexhaustible natural resources have produced significant environmental problems for the country. In a less-than-wise regime of environmental protection and resources conservation, large open spaces and easily accessible raw materials made the situation perverse on a national scale. An efficiently engineered biological treatment will always be environment friendly and economically feasible. One such application is the Bioremediation technology. Based on this technology India has developed a product "Oil zapper", as an environment-friendly remedy for oil spills at sea and land. Oil zapper is carrier based (powdered corncob) efficient crude oil and oily sludge degrading bacterial consortia which can degrade petroleum sludge and treat crude oil spills Narang R. K. (2007), Fulekar M. H. (2010) and Mishra S., Lal B., Jyot J., Rajan S., Khanna S. (1999). It has been proved that treating the waste by using eco-friendly process is not only beneficial for the industries but also for sustaining the natural wherewithal of the environment.

Development Of Oilzapper: Tata Energy Research Institute, (TERI), New Delhi, initiated the research on crude oil and oil sludge degrading bacterial consortium in the year 1997 and after seven years of

research work, they were successful in developing an efficient bacterial consortium that degrades crude oil and oily sludge very fast. This bacterial consortium was developed by mixing five bacterial strains, which could degrade aliphatic, aromatic, asphaltene, and NSO (nitrogen, sulphur, and oxygen compounds) fractions of crude oil and oily sludge. Oil zapper was produced in bulk and immobilized on to a carrier material (organic powder material such as powdered corncob etc.) Mishra S, Lal B, Jyot J, Rajan S, Khanna S. (1999). The research and development wing of Indian Oil Corporation Ltd, in association with TERI, had also developed few other bacterial consortiums named "Oilivorous-S" which would completely biodegrade all the fractions of oily sludge, including the sulphur compounds Piemonte V., De alco M. and Basile A.(2013) and "Oilivorous-A" that was found to be effective against highly acidic oily sludge Lal (2000). Oil zapper, Oilivorous-S and Oilivorous-A has the natural ability to degrade hydrocarbon compounds in crude oil and oil sludge and convert them into harmless CO_2 and water. These bacterial consortiums are very effective, are of low cost, leaves behind no harmful side effects or residues and are quite easy in application. Oil zapper can be used in both marine and terrestrial environments. Zapper is specifically used on land, the new concoction developed by TERI and the University of Adelaide can do the oil eating job at sea. It's a new product conceived by Dr Banwari Lal (Director, Environmental and Industrial Biotechnology Division, TERI), who developed the zapper a decade ago and perfected the technology over the years.

Biodegradation Of Crude Oil By Bacteria: A microbial consortium was developed from five different bacterial strains that are immobilized and mixed with a carrier material such as powdered corncob. These isolates were obtained from hydrocarbon-contaminated sites using enrichment methods. The immobilized culture was put into sterile polythene bags and sealed aseptically and transported to the place of requirement. This immobilized bacterial consortium was named Oil zapper. The shelf life of the product is three months at ambient temperature Mishra S, Lal B, Jyot J, Rajan S, Khanna S. (1999). A feasibility study on the bioremediation of soil contaminated with crude oil/oily sludge was carried out at the Mathura oil refinery (India) with six different treatments in a 25 square metre land area contaminated with crude oil/oily sludge prior to full scale bioremediation. The indigenous crude oil/oily sludge degrading bacterial population were only 104 c fu/g soil in the feasibility study. Of the six treatments, the application of bacterial consortium and nutrients gave maximum response, which resulted in 48.5% biodegradation of TPH (total petroleum hydrocarbons) in four months as compared to only 17% biodegradation of TPH in soil treated with nutrients alone. Based on the feasibility study, the treatment consisting of the application of bacterial consortium and nutrients was selected for full-scale bioremediation. The site was tilled thoroughly to mix the oily sludge uniformly with the soil and oil zapper was applied onto it. The land was tilled again and watered to maintain proper aeration and moisture levels. The land was tilled at regular intervals to facilitate faster degradation. The problem of heterogeneous distribution of the oily sludge was solved by extensive tilling prior to the application of the oil zapper Willey N. (2007). The success of Oilzapper and Oilivorous-S can be gauged by the tremendous response received from various oil refineries. At present, TERI and IOC R&D centre are working on the bioremediation of oil spill sites and the treatment of oily sludge at various oil refineries and oil exploration sites. more than 5000 hectares of cropland contaminated with crude oil spills has already been reclaimed in different parts of India and more than 26 000 tonnes of oily sludge successfully treated with Oilzapper. Many oil-slick contaminated lakes in the north-eastern parts of India have also been cleaned up in two years. The table below provides details of the amount of oily sludge treated in India.

Applications/Benefits: Presently there are 22 refineries in India and in order to prevent the contamination of environment with the toxic waste generated by them, construction of polymer-lined pits with a special leachate collection system (a system that gathers leachate and pumps it to the surface for treatment) is done thereby preventing the dumped sludge from leaking into the earth and groundwater. A pit costs about Rs 10 million and each refinery needs several such pits. With more refineries being set up, space is always a constraint. A pit gets filled up in three to four years whereas with Oil zapper, one just needs 200 tonnes of environment-friendly bacteria to clean up 20,000 tonnes of oily waste. By the use of Oil zapper or Oilivorous-S technologies bioremediation is 30-40% cheaper than the conventional physico-chemical treatments Narang R. K. (2007). Oil zapper's uniqueness lies in the bio-friendly manner in which it detoxifies oil sludges and cleans up oil slicks. Cleanup of an oil slick using bacteria is called 'bioremediation' and is practiced in many parts of the world. It is naturally occurring and non-pathogenic and can be used in both marine and terrestrial environments. The continuing success story of Oilzapper was triggered off with the field trial in a small site at the Indian Oil Refinery in Mathura, UP Willey N. (2007). The highly encouraging results prompted another trial at a much

larger site (two-and-a half acres) of the same refinery, resulting in complete reclamation of the land. Indian formulation of Oil zapper is unique as it eats up all four layers of crude-waxy element or saturated hydrocarbons, aromatic component or benzene compounds, NSO (compounds of nitrogen and sulphur) and asphaltene or tar. Oilzapper can work in temperatures ranging from 8 to 40 degree Celsius. Both Oilzapper and Oilivorous-S can be used in situ, thereby eliminating the need to transfer large quantities of contaminated waste from the site, a process that poses more threats to the environment. The clean up process is complete in itself as contaminants are not merely transferred from one environmental medium to another (from water to air or land) but destroyed.

Figure 1 Pre-bioremediation: a site in Mehsana, Gujarat

Figure 2 Post-bioremediation: the same site after 2 months

With the application of Oil zapper, crude oil contaminated agricultural lands were cleaned up in the north-eastern and western parts of India. The end-users of Oilzapper and Oilivorous-S technologies are:

-Indian Oil Corporation Ltd, India
-Bharat Petroleum Corporation Ltd, India
-Hindustan Petroleum Corporation Ltd, India
-Oil and Natural Gas Corporation Ltd, India
-Oil India Ltd, India
-Indian Petrochemicals Corporation Ltd, India
-Reliance Industries Ltd, India
-Abu Dhabi National Oil Company, Abu Dhabi
-Kuwait Oil Company, Kuwait

The Oil zapper has not just snapped up wasted oil but also several eminent scientific awards in India and outside, including the All India Biotech Association Award 2001 given by the All India Biotech Association, New Delhi; the biotech Product and Process Development for commercialization Award 2002 by the DBT; the Jawaharlal Nehru Memorial National Gold Medal Award 2002 for excellence in Environmental Biotechnology Research by the International Greenland Society, Hyderabad; the best oral presentation award in the 5th International Petrotech 2003 (a petroleum conference and exhibition organized by the ONGC); the National Petroleum Management Programme Award 2002/03 for creativity and Innovation in the R&D category by the Ministry of Petroleum and Natural Gas, Government of India; and more recently, the National Bioscience Award for the career Development, 2004/05, by the DBT among others. A cheap and quick solution to one of the most menacing environmental issues sure deserves these accolades.

Conclusion: Bioremediation is a process that uses naturally occurring microorganisms to transform harmful substances to nontoxic compounds. Bioremediation exploits this natural process by promoting the growth of microbes that can effectively degrade specific contaminants. Thus Oil zapper technology utilizes the bioremediation potential of specific microbes that degrades the toxic hydrocarbon compounds leaving behind non hazardous end products or metabolites and hence no harmful effects. Not only this technique is environmental friendly but also highly cost effective when compared to storage of oily waste/oily sludge in sludge pits and removing and transporting oil contaminated soil from the affected site due to accidental leakage of effluent water or crude oil. Further, the technique is ecologically sound, natural process; existing microorganisms can increase in numbers when oily sludge and waste water effluent sludge (the contaminants) is present. When the contaminants are degraded, the microbial population naturally declines. The residues from the biological treatment are usually harmless products (such as carbon dioxide, water and fatty acids) and hence, bioremediation technique could greatly help in solving the problem of soil contamination, oil sludge and waste water management problems of oil industries and controlling environmental and ground water pollution and also providing access to recharge of ground water system to the great extent at places where layer of oil contaminated soil formed restricting water percolation.

References:

1. Alexander M. (1999). Biodegradation and Bioremediation, 2nd Edition, Academic Press: New York.
2. Arthur E. L. and Coats J. R. (1998). Phytoremediation. In: Pesticide remediation in soil and water. Kearney P. C. and T. Roberts (Eds.), Wiley, New York.
3. Bhattacharyya, J. K.; Shekdar, A. V. (2003). Treatment and disposal of refinery sludges-Indian scenario. Waste Management & Research. 21(3): 249-261, E.
4. Fulekar M. H (2010). Bioremediation Technology: Recent advances, First Edition, Springer Publications, 31-33.
5. Ghose T. K. and Ghosh P. (2003). Biotechnology in India I, Springer- Verlag Berlin Heidelberg New York, 1-48.
6. Jackson M. L. (1973). Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi.
7. Khanna S., Lal B., Chandra R., Rajan, Bajpai U. (1998). Enzymes and Bioremediation In Enzyme Chemistry: impact and applications, pp. 249-285, edited by J S Colin, A Pint and C Gibson. Third Edition. Hampshire, UK: Chapman & Hall Limited.
8. Lal B. and Khanna S. (1996). Degradation of crude oil by ***Acinetobacter calcoaceticus*** and ***Alcaligenes odorans***, Journal of Applied Bacteriology 81: 355-362.
9. Lal B. and Khanna S. (1996). Mineralization of [14C] octacosane by ***Acinetobacter calcoaceticus***, Canadian Journal of Microbiology 42: 1225-1231.
10. Mishra S., Jyot J., Kuhad R. C., Lal B. (2001). Evaluation of Inoculum addition to stimulate in situ bioremediation of oily sludge contaminated soil, Applied and Environmental Microbiology 67:1675-1681
11. Mishra S., Jyot J., Kuhad R. C., Lal B. (2001). In situ bioremediation potential of an oily sludge degrading bacterial consortium, Current Microbiology 43.
12. Mishra S., Lal B., Jyot J., Rajan S., Khanna S. (1999). Field study: In situ bioremediation of oily sludge contaminated land using oilzapper, In Proceedings of Hazardous and Industrial Wastes, pp. 177-186, edited by D Bishop, Pennsylvania, USA: Technomic Publishing Co. Inc.
13. Mishra S., Sharma P. M., and Lal B. (2004). Crude oil degradation efficiency recombinant lux tagged ***Acinetobacter baumannii*** strain and its survival in crude oil contaminated soil microcosm FEMS Microbiology Letters 235:323–331.
14. Mishra S., Jyot J. and Lal B. (2000). Oil zapper: an oily sludge degrading bacterial consortium for in situ bio-degradation of oily sludge. *In Proceedings of the 40th Annual Meet of Association of Microbiologists of India, edited by S Ayyappan and S P Adhikary*.
15. Narang R. K. (2007). Cleaner is cheaper-case studies of corporate environmental excellence, The Energy and Resources Institute Vol. 5, 43-48.
16. Piemonte V., De alco M. and Basile A. (2013). Sustainable development in Chemical Engineering: Innovative technologies, John Wiley and Sons Ltd, UK.
17. Sharma P. M., Bhattacharya D., Krishnan S., Lal B. (2004).Degradation of polycyclic aromatic hydrocarbon by a newly discovered enteric bacterium, ***Leclercia adecarboxylata*** Applied and Environmental Microbiology 70: 3163–3166.
18. Sharma P. M., Bhtacharya D., Krishnan S., Lal B. (2004). Assessment of intraspecies diversity among strains of ***Acinetobacter baumannii*** isolated from sites contaminated with petroleum hydrocarbons, Canadian Journal of Microbiology 50: 405–414.
19. Udiwal K.H. and Patel V.M (2010). International Journal of Chemical, Environmental and Pharmaceutical Research Vol. 1, No. 1, 17-26.
20. Willey N. (2007). Phytoremediation: Methods and Reviews, Humana Press, New Jersey, 445-449.

***

Assistant Professor, Dy Dean
School of Applied Sciences, Chitkara University, Himachal Pradesh, India,
manish.randhawa@chitkarauniversity.edu.in
jyotsna.kaushal@chitkara.edu.in