

Biotechnology and environment

Jainendra Kumar
Professor & Head
Department of Botany and Biotechnology
College of Commerce, Patna 800 020 (Bihar), India

Abstract

Degeneration of environment is either due to accumulation of non-biodegradable (or scarcely biodegradable) substances, or, due to even common degradable substances that are deposited in more amount than the degrading capacity of the decomposer microorganisms contained at the site. In the latter case, the rate of deposition of polluting substances is higher than the rate of their decomposition. Environmental biotechnology, concerned with conservation and management of environment, mainly employs bioremediation of the degenerating environment through some calculated use of decomposer microorganisms whose ability to degrade pollutants has been enhanced, and, which have been engineered to efficiently degrade even those polluting materials that are normally non-biodegradable. The paper discusses the tools and techniques employed by environmental biotechnology.

Introduction

Over-exploitation of the natural resources is at the root of environmental degeneration and pollution. Cultural evolution of man necessitated the adoption of machinery and automation for fulfilling the demands of better and fast-paced life style. Dependence on automobiles for speed, on industries for desirable products, and on varied artificially developed chemicals (xenobiotics) for enhanced agricultural production, health care, additive substances etc., has caused two-pronged impact on the environment – (a) depletion of natural resources resulting into ecological imbalance, and (b) environmental pollution. Bioremediation calls for judicious exploitation of the capability of the natural decomposer microorganisms of the ecosystem (bacteria, some algae and fungi) through their up-gradation and enhanced activity.

***In situ* bioremediation**

Application of microorganisms to degrade pollutants into harmless chemicals as end products is called *in situ* bioremediation. Mostly, it is applied to saturated soils and groundwater. The technology was developed as a less costly, more effective alternative to the standard pump-and-treat methods used to clean up aquifers and soils contaminated with chlorinated solvents, fuel hydrocarbons, explosives, nitrates, and toxic metals (Bouwer, 1994). Oxygen, sometimes, accompanied by nutrients are pumped under pressure into the soil through wells. The nutrients are spread on the surface to infiltrate into the contaminated area of material or the saturated zone. Advantages of *in situ* bioremediation are -

1. Pollutants are transformed to substances like carbon dioxide, water, ethane, etc.
2. Accelerated *in situ* bioremediation (where substrate or nutrients are added to an aquifer to stimulate the growth of the target group of bacteria) treats both dissolved and adsorbed substances.
3. The time to treat sub-surface pollutants is fast.
4. *In situ* bioremediation costs less.
5. Treatment area is practically larger.

***Ex situ* bioremediation**

Ex situ bioremediation involves taking out the groundwater or polluted soil for remediation. It comprises two processes:

Slurry phase: It involves the mixing of water with the polluted soil followed by degradation in a bioreactor.

Solid phase: It involves transfer of the polluted soil to a bed where it is mixed with nutrients, moisture and oxygen for decomposition to occur.

Genetically modified microorganisms (GMOs)

Bioaugmentation (addition of specific microorganisms) and bio-stimulation (addition of specific compounds to enhance microbial metabolism) are methods that can be applied to accelerate the recovery of polluted sites. In the late 1970s and early 1980s, bacterial genes encoding catabolic enzymes for recalcitrant compounds started to be cloned and characterized. Soon, many microbiologists and molecular biologists realized the potential of genetic engineering for addressing biodegradation. The pioneering work of Gunsalus and Chakrabarty on the genetic basis of degradation of a suite of recalcitrant compounds by *Pseudomonas* strains culminated in 1981 with the granting of a patent for a strain developed by conjugation that could degrade camphor, octane, salicylate, and naphthalene, the first living being to be the subject of an intellectual property case (Cases and Lorenzo, 2005).

Cartwright *et al.* (2002) presented a review of the use of genetically modified organisms (GMOs) for the bioremediation of organic and inorganic pollutants. Genetic modification technology offers a wide variety of applications for use in the bioremediation of pollutants. Three main types of GMOs have been developed e.g. genetically modified microorganisms (GMMs) designed to degrade organic pollutants; genetically modified (GM) plants designed to hyper-accumulate or volatilise metal pollutants; and GMMs used as biosensors to detect the presence and toxicity of particular pollutants on site.

All of the applications of GMOs for bioremediation have used bacteria or plants as the modified organism. Fungi have also the capability to degrade a wide range of compounds, but, they are difficult to manipulate due to their relative complexity compared to bacteria.

Apart from their use in biosensors, the GMMs are used for the degradation of organic pollutants, chiefly chlorinated compounds and hydrocarbons, while, GM plants have been developed mainly for the treatment of metal pollutants. However, GMMs have the potential also to bioremediate metal pollutants, and, GM plants may also degrade organic contaminants.

The method of action of GMOs comprises two approaches. They either mineralise the pollutant, or, they modify the catabolic pathway which tends to prevent the biodegradation of the compound by the natural flora and fauna. Metals cannot be biodegraded, and, hence their bioremediation requires the sequestration and accumulation of the metal by the organism. GM plants can accumulate metal pollutants that can ultimately be removed. They have been developed by the modification of plants with bacterial genes such as *merA* and *merB* (to bioremediate mercury polluted area), and, by the modification of some fast growing and high biomass plants with genes isolated from other metal-accumulating plant species.

The application of GMMs in the bioremediation of hydrocarbons, other than PAHs, is mainly based on the genetic modification of microorganisms most suited to the target environment, rather than just the design of microorganisms able to degrade the hydrocarbon. The reasons for this may be due to the relative ease by which many hydrocarbons (other than PAHs) may be degraded by microorganisms, and also, the relatively good level of understanding of the genetic basis of the biodegradation of many hydrocarbons by microorganisms (Johri *et al.*, 1999; Staples *et al.*, 1997).

Biosensors

The term 'biosensor' is mostly used to denote sensor devices that can determine the concentration of substances and other biological parameters existing at any place. International Union of Pure and Applied Chemistry (IUPAC) defines biosensors as a subgroup of chemical sensors in which a biologically based mechanism is used for analyte detection (Bertie and Vo-Dinh, 1996).

However, the area of biosensors takes inputs from biochemistry, bioreactor science, physical chemistry, electrochemistry, electronics and software engineering. In context of environment, biosensors are powerful tools aimed at providing selective identification of toxic chemical compounds even at minute level in environmental samples. They can measure the interaction of pollutants with biological systems due to their bio-molecular recognition capability. A biosensor has a biological sensing element attached to a signal transducer. The sensing element may be an enzyme, antibodies, DNA, or microorganisms. The transducer is either electrochemical, optical, or acoustic. Electrochemical transducers measure changes in current or voltage. Optical transducers measure changes in fluorescence, absorbance or reflectance. Acoustic transducers measure changes in frequency resulting from small changes in mass bound to their surface.

BOD sensors have been field tested in Japan (Karube et al.,1995; Tanaka et al., 1994) and Europe (Szweda et al., 1994). The short response time and high sensitivity of these microorganism-based sensors make them desirable for atmospheric and water monitoring. Japanese studies indicate that a biosensor using immobilized *Trichosporon cutaneum* in combination with a dissolved oxygen electrode can be used to measure BOD values in industrial wastewater in as little as 15 minutes. Traditional BOD measurements take five days. The BOD biosensor has been useful in process control applications for wastewater treatment in which rapid analyses are required.

References

- Bertie, J. E.; Vo-Dinh, T. *Appl. Spectrosc.* 1996, 50 (4), 12A-20A.
- Bouwer, E.J. 1994. "Bioremediation of Chlorinated Solvents Using Alternate Electron Acceptors." In: *Handbook of Bioremediation*, R.D. Norris, R.E. Hincbee, R. Brown, P.L. McCarty, L. Semprini, J.T. Wilson, D.H. Kampbell, M. Reinhard, E.J. Bouwer, R.C. Borden, T.M. Vogel, J.M. Thomas, and C.H. Ward eds. Lewis Publishers, Boca Raton, FL. pp. 149-175.
- Cartwright, C., Folkard-Ward, H., Thompson, I., Barclay, M. Bailey, M. and Smith, A. 2002 *Genetically Modified Organisms for the Bioremediation of Organic and Inorganic Pollutants* (Final report). WS Atkins Environment. Woodcote Grove, Ashley Road, Epsom, Surrey KT18 5BW.
- Cases, I. and Lorenzo, V. 2005. Genetically modified organisms for the environment: stories of success and failure and what we have learned from them. *International microbiology* 8:213-222.
- Johri AK, Dua M, Singh A, Sethunathan N and Legge R. L. 1999 Characterization and regulation of catabolic genes. *Critical Reviews in Microbiology*, 25(4): 245-273.
- Karube, I.; Nomora, Y; Arikawa, Y. 1995 *Trends Anal. Chem* 14: 295-99.
- Staples CA, Peterson DR, Parkerton TF and Adams W. J. 1997 The environmental fate of phthalate esters: a literature review. *Chemosphere*, 35: 667-749.
- Szweda, R.; Renneberg, R. 1994 *Biosens. Bioelectron* 9(1): ix-x.
- Tanaka, H. et al. 1994 *Water Sci. Tech* 30: 215-27.

.....