BIOTECHNOLOGICAL APPROACHES TO MANAGEMENT OF ENVIRONMENTAL POLLUTION

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ABSTRACT

Homo sapiens has, probably, been the most selfish among the living beings. He has, always, been in pursuit of comforts and to achieve this he has been inventing materials that serve his needs and luxuries. Synthetic chemicals are a group of such materials that he invented for various purposes such as improvement of agricultural production, generation of energy, and manufacture of various industrial and healthcare products. His innovative zeal has almost blinded him of the consequences that these xenobiotic chemical compounds would have on the fragile ecosystem. Initially he was either ignorant or negligent about the impact that these man-made chemicals, most of which are toxic and reclacitrant, would make on the environment. He went on synthesizing newer and newer chemicals. According to an estimate, for the last few decades, the production of synthetic chemicals, has been doubling in every 8 years, both numerically and quantitatively. At present, more than 5 million chemical compounds are known and the global production has been estimated to be over 325 million tonnes per annum.

Everincreasing production and indiscriminate use of chemicals have caused irreparable damage to the environment. This continuous and unabated onslaught on the environment has been very severe for the last few decades. However, with the unparallel and remarkable ability of the microbial communities of the terrestrial and aquatic environment to degrade anything thrown to them, the nature could withstand

Kunhi,A.A.M. 1996a. Biotechnological approaches to management of environmental pollution. Invited lecture, **UGC Sponsored Refresher Course for College Teachers**. 7th Nov 1996, Dept of Biosciences, Mangalore University, Mangalore, India

this onslaught to a great extent. These microbial communities evolved continuously to acquire the ability to detoxify and decompose several chemical compounds. The remarkable biochemical versatility of microbes puts them on high pedestal as the major decontaminating agents. However, with the advent of the bulk production of highly substituted hydrocarbons, particularly the halogenated ones, the natural microflora was no longer capable of dissimilating them. Most of these chemicals started getting accumulated in the environment. Several organochlorine pesticides such as BHC (hexachlorocyclohexane) DDT, Heptachlor, endosulflan, aldrin, dieldrin etc, polychlorinated biphenyls (PCBs) such as the Aroclor series, many other chlorinated hydrocarbons are highly reclacitrant and persist in the environment for several years. They get into the food chain and reach human body in bioconcentrated forms.

Traditionally several physical and chemical methods have been followed for treatment of chemical industry wastes. They include incineration, adsorption to charcoal, oxidations by various chemicals such as hydrogen peroxide, ozone, $KMnO_4$ etc. Biological methods including aerated and anaerobic sludge processes, lagooning etc. and bioremediation of soil by growing certain plants and grasses which can take up the pollutant chemicals and accumulate them in large amounts have also been practiced. However, in recent years there has been an increasing awareness about the potentiality of microbiological processes for treatment of industrial effluents and bioremediation of contaminated soils.

In the last 2-3 decades environmental microbiologists have been successful in isolating an array of microorganisms capable of degrading several xenobiotic compounds. However, microbial treatment of hazardous chemicals has not yet been implemented on a wider scale, and the full potentials of biodegradation technology remains untapped. A comparative cost estimate has revealed that biological treatment technologies will be less expensive than the conventional technologies.

A chemical compound is called recalcitrant when it is attacked slowly or not at all by enzymes or microbes. Recalcitrance may be due to (i) high polymerization eg. polystyrene, polypropylene, polyvinyl chloride etc., (ii) introduction of halo-, nitro-, and sulfo-groups or of branched carbon chains eg. pesticides, PCBs, chlorophenols, chlorobenzenes, nitrophenols etc. and/or (iii) increased number of substitutions of a molecule eg. PCBs, pentachlorophenol, hexachlorocyc ohexane (BHC) etc.

Biodegradation of chemcial compounds by microbes may be affected by utilizing the molecule or a part thereof as a source of carbon and energy, or may be co-metabolically through the action of already existing enzymes when the organism may be growing on other analogous or non-analogous molecules.

Several strains of *Pseudomonas*, *Arthrobacter*, *Mycobacterium* etc., are capable of degrading aliphatic hydrocarbons, particularly C_1-C_4 alkanes, which are major components of crude petroleum. C_5-C_9 alkanes are toxic to many microorganisms and alicyclic hydrocarbons are more resistant to microbial attack. Several halogenated aliphalic compounds (nearly 150 are commercially produced) have been detected in soil, water and air as pollutants. However, strains of *Pseudomonas*, *Moraxella*, *Xanthobacter* etc., are capable of degrading several of these compounds at low concentrations.

Aromatic hydrocarbons are the most common pollutants found in nature. Most of the unsubstituted aromatics are easily broken down by natural microflora. Polycyclic aromatics such as naph thalene, anthracene, etc. are more resistant. Chloroaromatics are toxic and persistent. PCBs, polychlorophenols, polychlorobenzoates etc., are notorious examples. However, in recent years several bacterial strains that can degrade many of these compounds have been isolated. Alkyl-substituted aromatics such as xylenes, cresols, xylenols are more amenable to microbial attack. Nitro-substituted aromatics are used in the production of pesticides, dyes, drugs, explosives and industrial solvents. Some of these compounds are highly toxic. Simpler nitroaromatics such as nitroaniline, nitrophenols, nitrobenzoates are degradable at low concentrations.

Pesticides constitute one of the major group of industrial chemicals which can be broadly classified as organophosphorus compounds, carbamates, phenyl ureas, s-triazines, cyclodienes, synthetic pyrethetroids and organochlorine pesticides. Most of these compounds except organochlorine pesticides are generally broken down and detoxified in the environment. DDT analogues, BHC isomers and cyclodiene compounds such as aldrin, dieldrin, endosulfan etc., are highly recalcitrant. However, in recent years, there have been reports of microbial degradation of these compounds. In the authors laboratory also potent microbial strains and consortia have been developed that can completely mineralize DDT, and alpha-,beta-, gamma- and delta-isomers of BHC.

Though several microbial strains have been isolated that can degrade various xenobiotic compounds, most of them have failed when applied in the field. Field conditions, whether it be industrial effluents or contaminated soil are totally different from the laboratory conditions. Even if a microorganism can degrade very high concentrations of a particular compound, it need not do so in the field. On the contrary many of them totally fail. This is mainly due to the chemical as well as microbial heterogeneity of the field conditions ie. presence of different chemicals and different types of natural microflora. Some of the chemicals may be toxic to the applied organism or the metabolites of the chemicals formed due to the action of natural microflora may be incompatible with the applied strain. This is called the biochemical incompatibility. Hence, it is imperative to select and acclimatize microbes or consortia to the field conditions. In many cases acclimatized mixed cultures have been found to be more suitable for treatment of effluents and soils.

Another approach is genetic manipulations of the degrading strains to improve the degrading ability as well as the substrate range. A lot of work has been done in this direction. Recruitment of specific genes encoding enzyme with activity on a broad strectrum of compounds has improved the range of compounds that an organism can degrade.

Judicial selection of microbial strains with abilities to degrade different compounds and formulation of inocula of different strains in suitable ratios are other approaches which have been found successful.

It is also necessary for a microbiologist to have engineering inslights to be successful in developing a waste treatment technology.