Chapter 1
Role of Biotechnology in Bioremediation

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ABSTRACT

The global environment is now facing a highly critical situation due to rapid urbanization and industrialization as well as increasing population in the limited natural resources. The population growth reflects the drastic changes of the life style of the people that created anthropogenic stress on the environment. There is requirement of highly developed environmental management systems and search of biotechnological technology to remove the contaminated materials and reestablish the natural resources Bioremediation is now considered as the most useful alternative method for eradicate the contaminated material from the nature for sustainable waste management. Now with recent advancement of the genetic approach multiplies the bioremediation process for protection of the natural environment by recycling the waste materials. This chapter covers detail notes on the use of most advanced technology to boost up the bioremediation process.

INTRODUCTION

Environmental pollutants are now the major global concern due their undesirable recalcitrant and xenobiotic compounds. A variety of polycyclic aromatic hydrocarbons (PAHs), chlorinated and nitro-aromatic compounds and xenobiotics, were depicted to be highly toxic, mutagenic and carcinogenic for all living organisms in the earth. A number of microorganisms are considered to be the best suitable candidates among all living organisms to remediate most of the environmental contaminants into the natural biogeochemical cycle due to their diversity, versatility and adaptability in adverse conditions. These microorganisms exhibit a remarkable range of contaminant degradable capacity that can profi-

ciently restore the natural environmental conditions. However, some contaminants have been shown to be uncommonly recalcitrant, i.e. microorganisms neither metabolize nor transform them into certain other nontoxic metabolites. As a result, it may be more productive to discover new catabolic pathways that might lead towards complete mineralization of these toxic pollutants. Due to complexity of microbial physiology which allows response and adaptability to various internal and external stimuli, the perfect knowledge of mechanisms of microbial degradation pathways is quite incomplete. (Fulekar, 2007).

Bioremediation, a biological process mediated by microorganisms, is now considered to be one of the most sustainable approaches to degrade and detoxify environmental contaminants. Though bioremediation approach has been used at varying degrees for more than 60 years, for example petroleum land farming, it historically has been implemented as a very 'black box' engineering solution where amendments are added and the pollutants are degraded (Chakraborty, Wu, & Hazen, 2012). This approach is often successful but practically admiration of less result as desirable, i.e., instead of degradation of the contaminant, even production of more toxic daughter products is found. The key to successful bioremediation is to trap up the naturally occurring catabolic potential of microorganisms to effectively catalyze transformations of environmental pollutants. Small scale experiments using distinct microbial consortia in the laboratory is an immense starting point in providing crucial initial indication of the bioremediation process within definite control condition. However *In situ* bioremediation in real execution is a complex phenomenon involving more than one contaminant and simultaneously mediated by different microorganisms involving different metabolic pathways, across geochemical gradients, geophysical and hydrological complexities (Purohit, 2003).

Recently, modern tools of "omics" such as metagenomic, transcriptomics, proteomics, metabolomics, have been applied to explore biological phenomena of microbial communities. Bioremediation also offers many interesting possibilities from a bioinformatics point of view which is gradually going to be explored. This discipline requires the integration of huge amounts of data from various sources: sequence, structure and function of proteins, chemical structure and interaction of organic compounds; comparative genomics; environmental microbiology etc. Development of biosensor is also another milestone to integrate in remediation process. Biosensors are analytical tools, which use the biological signals in sensing the target molecule. Different types of reporter systems have been described and as well as their application in tracking of levels of pollutants, nitrogen, phosphorus, dissolved oxygen in different habitats and toxic compounds. Systems biology is an integrated research approach to study complex biological systems, by systematic searching of interactions and networks at the molecular, cellular, community, and ecosystem levels. Combination of the results from the various 'omics' tools and approach has provided decisive insights into the survival, metabolism and interaction of microorganisms in their native environments together with groundwater and marine systems (Benndorf, Balcke, Harms, & von Bergen, 2007; Hemme et al., 2010; Edward, 1997; DeLong, 2005), extreme milieus (Baker & Banfield, 2003), deep-sea sediments and vents (Harmsen, Prieur, & Jeanthon, 1997; Hu et al., 2010), and animal microbiomes (Gill et al., 2006). A systems biology approach is being adopted to unravel key processes to understand, optimize, predict and evaluate microbial function and survival strategies in the ecosystem. However, successful application of this approach requires over coming several challenges, including the high cost, materials and reagents, large amount of samples,, the need for skilled personnel to process the samples, massive amount of data generated, and the time consuming nature in integration and synthesis of the data (Chakraborty et al., 2012).

This book chapter describes in detail all the possible application of biotechnological processes for effective bioremediation.

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