Chapter 9

Bioremediation Approaches for Recalcitrant Pollutants: Potentiality, Successes and Limitation

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ABSTRACT

The different chemical pollutants discharged by the industries to the environment can upset the delicate balance of the ecosystem. Bioremediation, the use of microorganisms and plants to remediate polluted environments, is a promising and growing area of environmental biotechnology. Bioremediation options encompass diverse types of biotechnological mechanisms that may lead to a target pollutant’s mineralization, partial transformation, humification, or altered redox state. The use of extra cellular and/or cell-free enzymes has been also proposed as an innovative remediation technique. Perspectives and limitations to evolve and use this technology are critically discussed in this chapter with respect to the complexity of mixtures of xenobiotics often found in practice. Whereas the potential of bioremediation is substantial, its application has important limitations that are apparent from many examples and the authors feel that these limitations can be overcome only when adequate attention is directed to fundamental microbiological, chemical and engineering issues.

1. INTRODUCTION

Environmental contamination due to anthropogenic and natural sources is increasing day by day because of increase in human population, industrialization and urbanization. The paradox for the public, scientists, academicians and politicians is how to tackle the contaminants that jeopardize the environment. Human activities to a greater extent and natural processes to some extent cause serious issues of polluting soil and aquatic environments by releasing a large number of organic chemical substances such as petroleum hydrocarbons, phenolic compounds, halogenated and nitroaromatic compounds, phthalate esters, solvents and pesticides, endocrine disrupting chemicals, toxic heavy metals etc. Organic pollutants
comprise a potential group of chemicals which can be dreadfully hazardous to human health. Many of
these are recalcitrant. As they persist in the environment, they are capable of long range transportation,
bioaccumulation, in human and animals, and biomagnifications in food chain (Nair et al., 2008).Most
of the compounds belong to groups that are widespread and are generally persistent and/or toxic. The
term “bioremediation” has been used to describe the process of using microorganisms to degrade or
remove hazardous components of the wastes from the environment. Biodegradation and its application
in bioremediation of organic pollutants have benefited from the biochemical and molecular studies of
microbial processes. Biodegradation is defined as the biologically catalyzed reduction in complexity of
chemical compounds. It is based on two processes: growth and co-metabolism. In growth, an organic
pollutant is used as sole source of carbon and energy and it results in the complete degradation of the
pollutant molecules. Co-metabolism can be defined as the transformation of a pollutant by a microorgan-
ism incapable of using the pollutant as a sole source of energy or of one of its constituent elements in
the presence of a growth substrate that is used as primary carbon and energy source (Basak et al, 2014).
Biotransformation of organic contaminants in the natural environment, which is defined as transforma-
tion of recalcitrant toxic organic pollutant into the lesser one, has been extensively studied to understand
microbial ecology, physiology and evolution for their potential in bioremediation. Bioremediation has
considerable strength and certain limitations too. Remediation, achieved whether by biological, chemical
or a combination of both means, is the only option as the problem of pollution is to be solved without
transferring to the future. As the knowledge mandate and complexities vary for different bioremediation
treatments, a better understanding of the principles together with the limitations of bioremediation aids
in maximizing the benefits and minimizing the cost of treatments. In this chapter we shall be critically
reviewing (i) the potentiality, (ii) successes, the advances made thus far and the requisite foci of research
on maximizing the biodegradation of pollutants, and (iii) limitations of bioremediation techniques in
removing toxic pollutants from the environments.

2. BACKGROUND

Relative to the pre-industrialization era, industrialization and intensive use of chemical substances such
as petroleum oil, hydrocarbons (e.g., aliphatic, aromatic, polycyclic aromatic hydrocarbons (PAHs),
BTEX(benzene, toluene, ethylbenzene, and xylene), chlorinated hydrocarbons like polychlorinated
biphenyls (PCBs), trichloroethylene(TCE), and perchloroethylene, nitroaromatic compounds, organophos-
phorus compounds) solvents, pesticides, and heavy metals are contributing to environmental pollution
(Megharaj et al., 2011). Large-scale pollution due to man-made chemical substances and to some extent
by natural substances is of global concern now. Seepage and run-offs due to the mobility, and continuous
cycling of volatilization and condensation of many organic chemicals such as pesticides have even led
to their presence in rain, fog and snow (Dubus et al., 2000). Remediation of these polluted sites following
the conventional engineering approaches based on physicochemical methods is both technically and
economically challenging. Bioremediation employs the capabilities of microorganisms in the removal
of pollutants. With advances in biotechnology, bioremediation has become one of the most rapidly de-
veloping fields of environmental restoration, utilizing microorganisms to reduce the concentration and
toxicity of various chemical pollutants. Although, this novel technology has a multidisciplinary approach,
its central drive depends on microbiology. This technology includes biostimulation (stimulating viable
native microbial population), bioaugmentation (artificial introduction of viable Microbial population),
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