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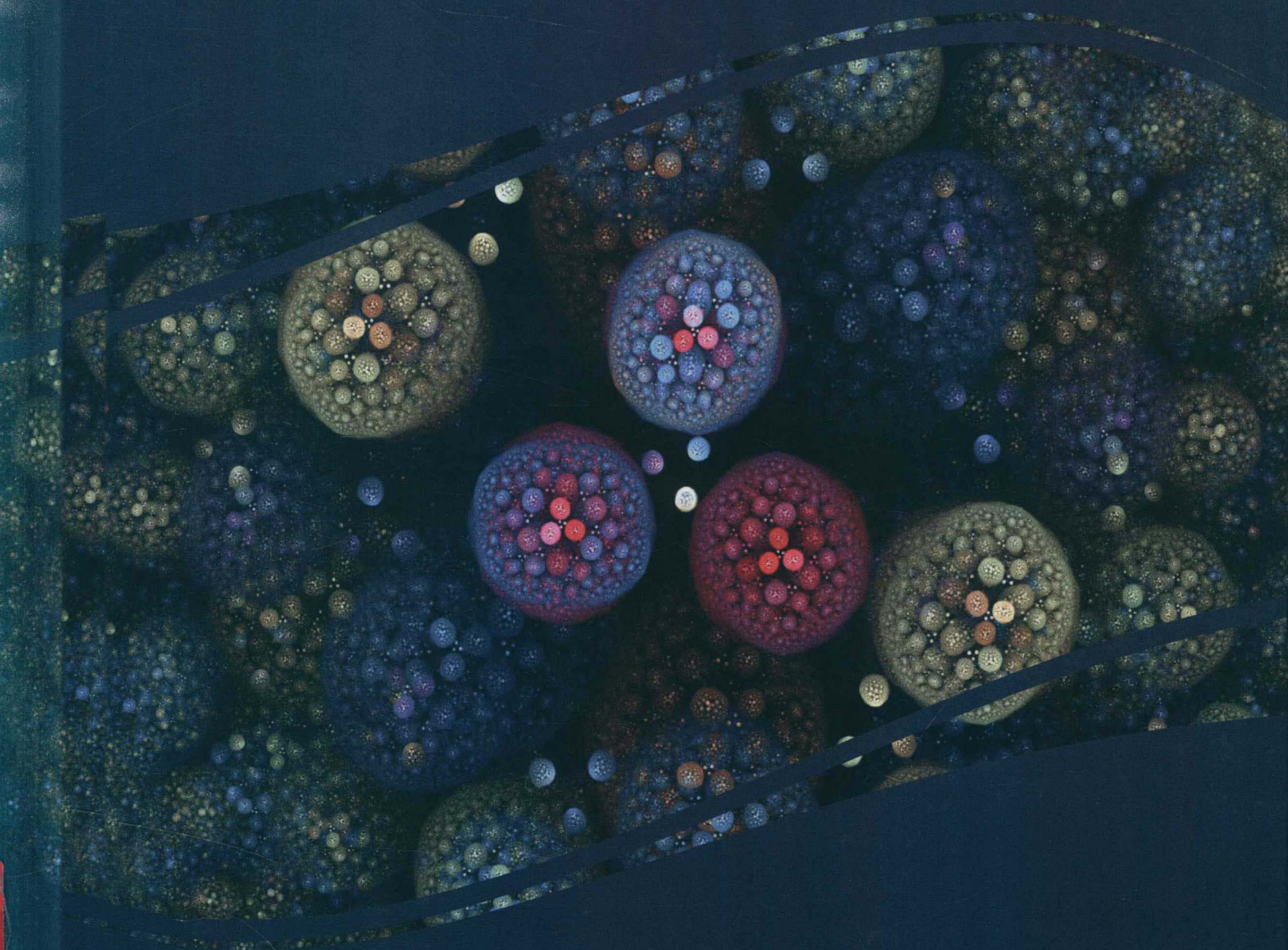
Microbial Biotechnology in Environmental Monitoring and Cleanup



Pankaj and Anita Sharma

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Microbial Biotechnology in Environmental Monitoring and Cleanup

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A volume in the Advances in Environmental Engineering and Green Technologies (AEEGT) Book Series

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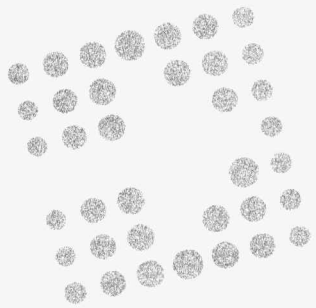

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Evolution is mainly driven by environmental stresses. Among all the living beings, microorganisms have elaborated a wide range of physiological responses to survive in different ecosystems. Variations in the environment allow microorganisms to acquire new gene(s) through different processes and to lose preexisting genes by the processes like mutation or deletion. Our environment is heavily contaminated by indiscriminate and wide spread use of polythene, paints, petroleum products, industrial dyes, toxic chemicals and pesticides etc. Indiscriminate use of these chemicals/polymers adversely affects the environment and ultimately human beings and other living systems. Microbial evolution/ adaptation is the key of formation of a fully functional catabolic pathway enabling them to use toxic compound(s) as a source of carbon and energy. Physical and chemical methods are applicable in a modified matrix or help in converting the pollutants from one phase to another but the microbial degradation process to detoxify the pollutants can be effectively used to overcome the pollution problem.

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Raj Kumar Pandey, G. B. Pant University of Agriculture and Technology, India
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One of the major challenges for society in 21st century is to find a sustainable eco-friendly renewable liquid fuel for replacing petroleum based fossil fuels. Bioethanol is one ofthe most consumable biofuel in the world. Lignocellulosic plant biomass can be an untapped source of fermentable sugars for significant production of bioethanol. But, the polyphenolic lignin of the biomass hinders the digestibility of cellulose,

thus the goal of any pre-treatment technology is to remove this structural component to improve the cellulose accessibility for enzymatic saccharification. A wide range of pretreatment methods and their combinations have been reported for delignification, but recently, the environment friendly approach of microbial pre-treatment has received much attention for enzymatic delignification and saccharificaton of biomass. The extracellular lignin degrading enzymes and cellulase enzyme complex from fungi are now considered for biological delignification and saccharification, respectively.

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Barkha Sharma, Pt. Deen Dayal Upadhay University of Veterinary Science, India

Water is the most important commodity in the world. Over the large parts of world, humans have inadequate access to potable water. Since the inception of industrial revolution different toxic compounds have entered in the water bodies due to leakage, improper disposal or accidents and caused great harms to rivers and various water bodies and imposed major health risks on human beings. Water pollution is measured by variety of physical, biological and chemical methods. Microbiological tests have proven to be indispensable part of environmental contamination detection. The main suggested criteria for selecting a microbial indicator for water potability should be: it should be suitable for the analysis of all types of water, present wherever enteric pathogens are present, survive longer than enteric pathogens, must have easy procedure for detection, should be harmless to humans and the level of indicator bacteria in contaminated water should have direct relationship to the degree of pollution.

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Anjana Srivastava, G. B. Pant University of Agriculture and Technology, India
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In soil, pesticide residues are subjected to various transformations and transportation processes. Leaching is one of the major transportation processes responsible for ground water contamination. Organic amendments used in agriculture are known to improve the physico-chemical properties of soil at low cost and are regarded as one of the most suitable technologies for sustainable agriculture. These amendments play an important role in the retention of pesticides because of increased adsorption of these chemicals on soil. Sorption of pesticides which are weak acids or bases, is influenced by soil pH because they assume a positive or negative charge, or no charge depending on the pH. Leaching of such pesticides to ground water can be prevented to a great extent by mixing of organic amendments to soil because they enhance the ability of pesticide retention on soil and or promote their microbial degradation as well during in situ decomposition of organic amendments in soil.

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Mohammad Raeesh Shekh, National Innovation Foundation (NIF), India
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Table salt is essential for metabolism of human being. These salt crystals are produced in saltpans of high salinity natural reservoirs, affiliated to sea water through evaporation process. Arabian Sea makes its boundary with Goa as its western coast helps in salt production. The pharmaceutical and acid mine drainage generated by nearly located iron mines are continuously destructing the natural reservoirs, agricultural lands, flora and fauna. Local people are affected by the muddy water, passing trucks with mined minerals into their farms or agricultural land and continuously decreasing the fertility of the soil. The aim of this chapter is to focus on the present scenario of the ecosystem, salt pans and flora and fauna in relation to pharmaceutical and mining waste and impact of this pollution on local people. Microbial based monitoring and cleanup strategy of the present polluted bodies, are also discussed in this chapter.

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Tapan Kumar Nailwal, Kumaun University — Nainital, India

At present the many of the man-made compounds released in soil by various ways. These compounds might be pesticides and other hazardous chemicals. Through food chain these compounds increased day by day at particular trophic level and also affect the soil biodiversity. Microbial cultures and associated biotechnology can be helpful to reduce such types of pollution from soil without affecting their natural habitat or niche. In this chapter we will discuss the indigenous microbial flora and their role for the maintenance of the sustainable environment.

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Navneet, Gurukul Kangri University, India
Tara Singh Bisht, Kumaun University — Nainital, India
Anupam Pandey, Kumaun University — Nainital, India

Polymer contamination with the advent of fast industrialization has become one of the serious threat to the natural environment. Due to lack of proper knowledge, poor waste management practice and unavailability of potential microbial strains, preference toward the biodegradable manmade and natural polymers. The prevalent occurrence of synthetic polymers is related to industrialization and domestic practices which affect the marine and terrestrial ecosystems. Scientific approaches exploited for polymer degradation include physical, chemical and biological treatments. Among them, biodegradation serves as eco-friendly approach to remediate polluted environment using living organisms. In this chapter biodegradation of natural (cellulose, hemicelluloses and lignin), synthetic (polyurethane, polyethylene succinate, polycaprolactone, polyvinyl alcohol and polyethylene) polymers and associated factors that influence the polymer biodegradation process have been discussed.

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Arpitha Chikkanna, Indian Institute of Science, India
Devanita Ghosh, Indian Institute of Science, India

Microorganisms play very important role in elemental and mineral chemistry on earth surface. Along with the major biogeochemical cycles such as Carbon, Nitrogen, Sulphur and Phosphorus, which are crucially involved in thermodynamic balances in earth system, microbes are also involved in trace metal cycling. The organic carbon sustaining the indigenous microbial communities critically controls these microbial processes. A large number of the microbial communities are able to form a wide variety minerals, of which many have only biogenic origin and cannot be formed inorganically. Microbes also play a critical role in dissolution of minerals; a process which not only helps in soil formation and the transport of nutrients to higher trophic levels, but can also have many important industrial roles. Thus, in these metabolic activities, microorganisms contribute to the geological phenomenon of the transformation of metals and minerals. This chapter focuses on the role of various microbial metabolic processes that are involved in mineralization and mineral dissolution and the consequences involved with it.

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Green Chemistry: A New Frontier of Challenges and Opportunities for Pollution Abatement 152
Prakash Chandra Mishra, Fakir Mohan University, India
Anil Kumar Giri, Fakir Mohan University, India

Our environment needs to be protected from ever-increasing chemical pollution. Advances in science and technology can address the challenges of global environmental sustainability, which includes the release of persistent organic pollutants, climate change, and bioaccumulation of contaminants, endocrine disruption and ozone depletion. Achieving sustainability requires an intricate balance among resource use, economic growth and environmental impact. Green chemistry is a growing field of research where pollution is reduced by designing and developing chemical products/process addresses. Many of these are concerned by combining the critical elements of environmental improvement, economic competitiveness and social responsibility. In this chapter the scope for the development of green chemistry and the beneficial aspects have been discussed stressing future research.

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Deepika Rajwar, G. B. Pant University of Agriculture and Technology, India
Mamta Bisht, Indian Agricultural Research Institute, India
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In recent years, stringent discharge standards prior to the release of effluent into the water bodies have led to implementation of diverse advanced biological treatment processes in various industries. Biological treatment is a fundamental part of industrial wastewater treatment, contains soluble inorganic/organic pollutants. Being a cost-effective process, biological treatment has an economic advantage over chemical and physical processes. It employs a range of microorganisms which as a community form a microbial

biofilm. Microbial biofilm provides a diverse range of micro-niches to microbial communities and protection from physical agitation to support metabolic potential and functional stability. Currently, biofilms are applied in wastewater treatment, degradation of toxic waste in water and soil and production of various commercial products. Intensive exploration has proved the importance of biofilm as a highly promising biotechnology, especially in wastewater treatment.

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Mukesh Samant, Kumaun University — Nainital, India
Satish Chandra Pandey, Kumaun University — Nainital, India
Anupam Pandey, Kumaun University — Nainital, India

Hazardous waste has emerged as an issue of major concern that has negative impact both on human health as well as on the environment. Hazardous and infectious agents are handled in daily routine in biomedical laboratories. Their effects are increasing continuously in the environment. Hazardous waste includes solid, liquid, sharp and pathological waste. Workers in hospitals and health care, agricultural and fishing occupations are at particular risk of exposure to hazardous biological agents. Recently, more systematic and strict steps have taken by the Indian government regarding the public concern to prevent the proliferation of hazardous waste and its improper disposal. However, management of waste are still not well promoted. So, to intercept the build-up of biohazards into the environment, waste from biohazardous operations must be disposed or treated appropriately in a special way and it also intends to create awareness amongst the personnel involved in these sectors to develop and implement hazardous waste management and mitigation strategies.

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Rajeev Kumar, G. B. Pant University of Agriculture and Technology, India
Anita Sharma, G. B. Pant University of Agriculture and Technology, India

Agriculture is one of the major determining forces for the economy of India. The burgeoning population also puts more pressure of the agriculture system. To meet the requirement for future population with little arable land and limited agricultural production, doubling of crop yields is required. Development of such production systems which depend on renewable resources is an urgent requirement for sustainable agriculture. New technologies are also required to be tested and tried for the improvement of the crop production system. Nanotechnology in agriculture system is the recent hope to make sustainable agriculture a success. A high proportion of the atoms in a nanoparticle are present on the surface of a nanoparticle which accounts for higher reactivity compared with particles of macrosize. On the other side, toxicity is also a considerable concern, but using nontoxic nanoparticles like nanozeolite, nanochitosan, and nanoclay is safe. These nanocompounds show advantages in crop production without harming the soil system.

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Rakesh Bhatt, Graphic Era Hill University — Bhimtal, India
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Nano particles are particles that exist on a nanometer scale. Nanoparticles exist in our surrounding either naturally or created by human activities. A nano-object needs only one of its characteristic dimensions to be in the range of 1-100nm to be classed as a nanoparticle even if its other dimensions are outside that range. Nanoparticles have revolutionized the world through the introduction of a unique class of material and consumer products in many fields due to production of innovative materials and devices. Despite their unique benefits and utility in daily activities, this could result in undesirable changes in the environment and affect the workplace. Carbon-based nanoparticles, oxides of metals, and natural inorganic compounds can have biological effects on the environment and human health. This chapter deals with the nanoparticles and their mode of action in the environment.

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Yadukrishnan P., Indian Institute of Science Education and Research Bhopal, India
Nitin Kumar, G. B. Pant University of Agriculture and Technology, India

Nanoparticles are being formed continuously in processes like mineralization, natural calamities, and geological recycling of matter and present naturally in the environment. In the recent past, nanoparticles and their applications have become an extensive topic of research. Application of nanomaterials in different industries will surely enhance the chances of discharge of nanoparticles into the environment. So, a number of studies have been performed to explore the mode of action of nanoparticles on living organisms and their surroundings. The most reported modes of action of nanoparticles are antimicrobial activity, ROS-induced cytotoxicity, genotoxicity, plant growth promotion, etc. It has been successfully demonstrated that actions of nanoparticles are governed by their size, shape, dose, and concentration. However, a complete mechanism of action of nanoparticles has not been known. The present chapter focuses on the highlights of the mechanisms behind the mode of action of nanoparticles in plants and microorganisms.

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Aparna Baban Gunjal, Haribhai V. Desai College, India
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Neha N. Patil, Annasaheb Magar Mahavidyalaya, India
Balasaheb P. Kapadnis, Savitribai Phule Pune University, India

This chapter discusses the endophytic bacteria and their role in agriculture. The endophytes help in the plant growth by various mechanisms and also help in disease control. The capability of colonizing internal host tissues of plant has made endophytic bacteria valuable for agriculture to improve crop performance.

Various endophytic diazotrophic bacteria colonize primarily the root interior of graminaceous plants. The review also discusses the role of endophytes in phytoremediation and induced systemic resistance. Endophytes have found important role in the production of many bioactive compounds, which have various applications (e.g., antibiotics, antimicrobial compounds). The contributions of this research field will have economic and environmental impacts.

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V. P. Sharma, ICAR-DMR, India
Mahantesh Shirur, ICAR-DMR, India
Sunny Banyal, ICAR-DMR, India

The environment is a life support system and it significantly influences the living organisms and their genes. Decomposers and microorganisms play a major role in maintaining the sustainability of the environment by converting toxic products into a mineralized form and maintaining the nutrient cycle. It is estimated that 62% of the 22 million tons of surplus rice straw is burnt in the field every year and contributes significantly to the black carbon emission from biomass burning. This alarming situation calls for a sustainable approach in crop residue management. Mushroom cultivation offers one such approach. Mushroom farms can act as disposal sites of agriculture residue and at the same time produce quality protein to meet the increasing protein demand. The macro fungi can play a major role in synthesis of non-toxic metal nano-particles from their salts and degradation of diverse crop residues through various enzymes present in them such as ligninases, cellulases, and laccases. Their role also extends to degrading the pesticides and persisting chemicals. This chapter explains the recent advances in mushrooms for effective crop residue utilization.

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Kijpokin Kasemsap, Suan Sunandha Rajabhat University, Thailand

This chapter explains the overview of bioremediation; soil remediation and Polycyclic Aromatic Hydrocarbon (PAH); bioremediation and ecosystem services; oil-contaminated soil, motor oil-contaminated soil, and petroleum-contaminated soil during bioremediation process; the overview of phytoremediation; the strategies and issues of phytoremediation; and phytoremediation and Plant Growth Promoting Bacteria (PGPB). Bioremediation is one of the safest methods to effectively manage contaminated waste. Without chemicals, bioremediation allows the contaminated waste to be recycled in environmental settings. Phytoremediation applies many types of plants to remove, stabilize, and destroy the contaminants in the soil and groundwater. The chapter argues that bioremediation and phytoremediation are the green technologies that can help remove contaminants from natural resources and are effective on the remediation of contaminated sites.

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Phytoremediation: Exploitation of Plants for Environmental Cleanup 286
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Environmental pollution with xenobiotics is a global problem and development of inventive remediation technologies for the decontamination of impacted sites are therefore of paramount importance. Phytoremediation capitalizes on plant systems for removal of pollutants from the environment. Phytoremediation is a low maintenance remediation strategy and less destructive than physical or chemical remediation. Phytoremediation may occur directly through uptake, translocation into plant shoots and metabolism (phytodegradation) or volatilization (phytovolatilization) or indirectly through plant-microbe-contaminant interactions within plant root zones (rhizospheres). In recent years, researchers have engineered plants with genes that can bestow superior degradation abilities. Thus, phytoremediation can be more explored, demonstrated, and/or implemented for the cleanup of metal contaminants, inorganic pollutants, and organic contaminants.

Chapter 19
Metal Hyperaccumulator Plants and Environmental Pollution 305
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During evolutionary history of life on Earth, different life forms have undergone harsh environmental conditions. Plants have evolved multiple life forms and some of the specialist pioneer plants have the ability to colonize in hostile environmental conditions. Some plant taxa have the ability to accumulate high concentrations of potentially toxic trace elements (Ni, Zn, Cd, Se, As, Mn, Co, Cu, Pb, Sb, Tl) in their biomass. In some of these, taxa concentration of trace elements exceeds the concentration of macronutrients (e.g., Ca, K). Furthermore, metal hyperaccumulation is strongly associated with enhanced ability of these plants to detoxify the accumulated metal in the tissues. Such hyperaccumulation property has been reported in a total of approximately 500 Angiosperm species. This ability of the plants can be used for pollutant stabilization, extraction, degradation, or volatilization. The present chapter discusses heavy metals uptake mechanisms by plants and the potential of phytoremediation technique on treating heavy metal contaminated sides.

Chapter 20
Plant Growth Promoting Bacteria: A Gateway to Sustainable Agriculture 318
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Conventional agriculture plays a substantial role in meeting the food demands of a growing human population, which has led to an increased reliance on chemical fertilizers and pesticides. Chemical fertilizers are industrially manipulated substances and composed of known amount of nitrogen, phosphorus and potassium. In appropriate and misuse use of chemical fertilizers causes air and ground water pollution by eutrophication of water bodies and causing health problem in human. Therefore, the aim of this chapter is to emphasize the importance and use of plant growth promoting bacteria (PGPB) as a gateway to sustainable agriculture that could ensure plant productivity and quality agricultural practices in an