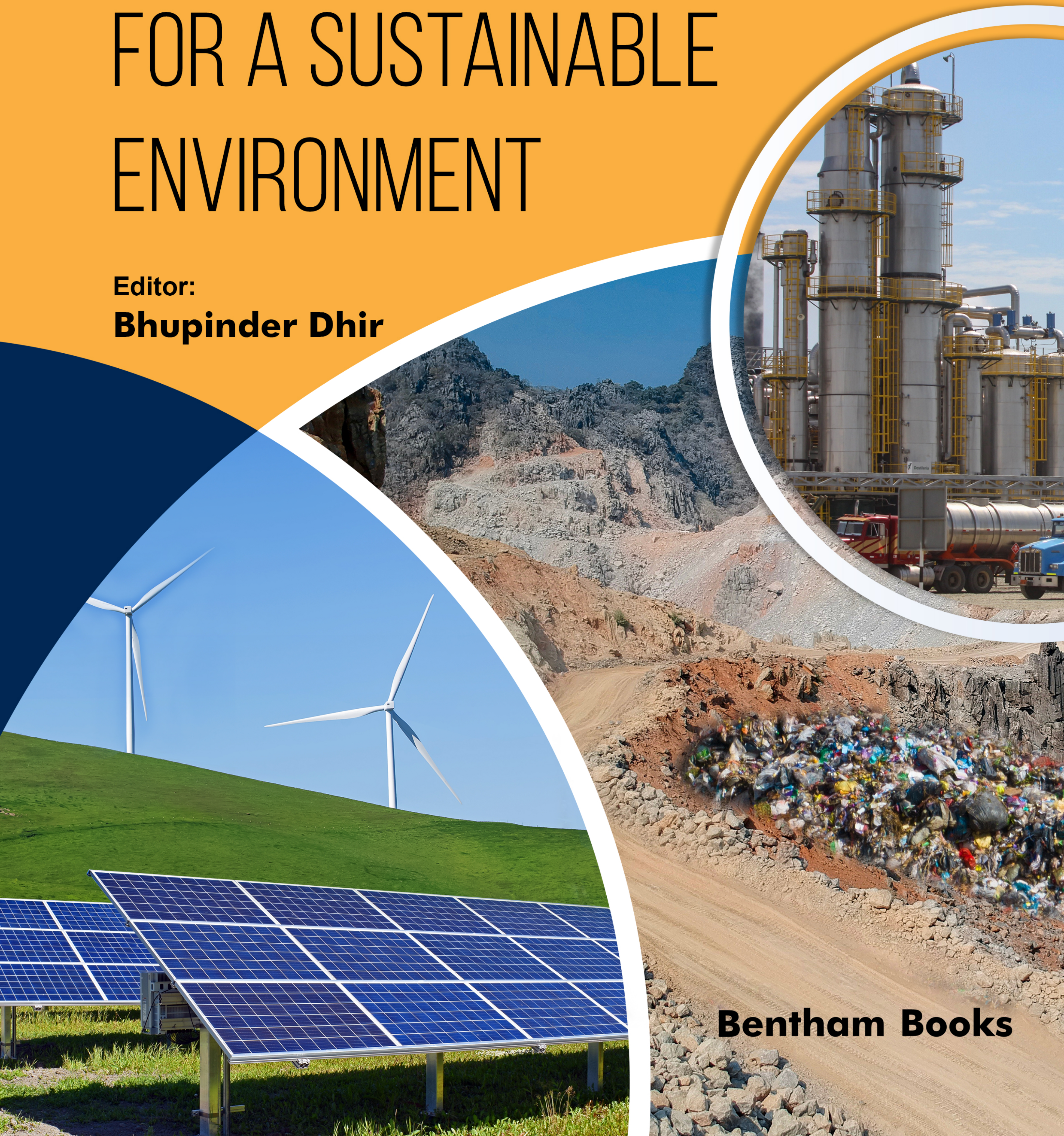
TECHNOLOGY FOR A SUSTAINABLE ENVIRONMENT

Editor:
Bhupinder Dhir



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Technology for a Sustainable Environment

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FOREWORD

Environmental conditions play an important role in the survival of living beings. Clean and safe environmental conditions ensure good health and well-being of living organisms. Rapid industrialization, urbanization and massive population growth have led to the deterioration of the environment. Various components of the environment, *i.e.*, air, water and soil, have shown deterioration in their quality due to increased anthropogenic activities. Therefore, it becomes necessary that appropriate steps are taken to remediate the environment and achieve the goal of creating a sustainable environment. Various technologies have been developed globally in this direction and offer huge potential to accomplish environmental sustainability.

In this book, Dr. Bhupinder Dhir has drawn great attention to an important issue of environmental degradation. She used her expertise to develop a book that can provide readers with updated knowledge about the current environmental scenario. Furthermore, emerging technologies promoting environmental sustainability have been discussed. The chapters in the book deal with some of the modern-day technologies, such as nanotechnology, renewable sources of energy and alternate sources of energy and fuels that contribute to the sustainability of the environment. Recent topics such as the development of green technologies, biodegradable polymers, and plastics have been dealt with in this book in detail. She has also tried to highlight the role of biotechnology in tackling problems related to environmental degradation. These modern-day technologies help in the remediation of environmental pollutants, save non-renewable sources of energy and prevent environmental degradation. This book by Dr. Bhupinder Dhir will undoubtedly contribute significantly to inspiring researchers, students, policymakers and environmentalists working in the related area.

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PREFACE

Rapid population growth and increasing urbanization have posed a threat to natural resources. Soil, air and water are facing degradation in quality due to overexploitation and getting damaged at a higher rate due to an increase in pollution. Researchers and scientists worldwide are engaged in developing strategies and techniques that help us achieve a sustainable environment. Focus has been shifted to new techniques such as bioremediation, nanotechnology and biotechnology. Besides this development of alternate fuels, eco-friendly materials, or the use of non-conventional sources of energy has also been emphasized.

This book presents an overview of various methods and techniques that can be adapted to get a sustainable environment. It provides a detailed study about the role of biotechnology, nanotechnology and other techniques that help in achieving minimum degradation of environment and utilization of natural resources to achieve sustainability in terms of energy, food and water security. The author uncovers the various environmental problems caused by anthropogenic activities. The book suggests various ideas for getting solutions to various environmental problems, whether related to the monitoring of environmental pollutants, their removal from various sectors of the environment, or remediation *via* various techniques.

The book has been divided into three sections. The first section focuses on the use of biotechnological techniques in improving the quality of air, water and soil. The second section discusses the use of nanotechnology in achieving environmental sustainability. Various alternate sources of energy, fuels and other technologies that are eco-friendly and do not harm the environment have been elaborated on in section three of the book. The book provides a comprehensive overview of the key concepts of sustainability and ideas for students. The book is suitable for students having introductory interdisciplinary courses in the fields of environmental science, engineering, biotechnology sociology. The book is of use to researchers, faculty members, policyholders and planners who play a major role in encouraging the development of methods to ensure the long-term sustainability of the planet. The text includes material on environmental sustainability of water, food, and energy that are related to social and economic stability.

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CHAPTER 1

Non-renewable Resources and Environmental Sustainability

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Abstract: Growing need for energy for sustaining increasing population has resulted in overexploitation of natural resources and over use of fossil fuel-based energy sources (coal, oil and gas). The consumption of non–renewable resources such as coal, petroleum and natural gas has increased tremendously resulting in environmental problems and climatic changes. Emission of greenhouse gases and other environmental concerns have increased. The decline in the quantity of non-renewable resources has generated the search of alternate energy sources. Switch to alternate sources of energy and fuel can be a sustainable option to this problem. Solar, tidal, geothermal, wind are some of the renewable sources of energy that are being focused to curtail the energy crisis and ensure sustainability for environment. A framework based on fulfilling the SDGs need to be developed which can contribute for more profitable, responsible path of economic growth and development.

Keywords: Carbon emission, Economic growth, Environmental quality, Non-renewable resources.

INTRODUCTION

Pollution, soil degradation, climatic changes, depletion of natural resources are some of the major environmental problems the world is facing today. The main cause of all these alterations is rapid increase in population, industrialization, burning of fossil fuels and many other anthropogenic activities. Ecosystems irrespective terrestrial, aquatic (freshwater, marine) are get affecting by the rapid

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change in the environmental conditions and the rate of degradation is anticipated to speed up in the coming decades.

CO_2 emissions coming from industrial processes, fossil fuel combustion, power stations, cement producing units and refineries has increased at an alarming rate. Increase in emissions of greenhouse gases has contributed to increase in global mean temperature by about 1.09°C in the last few decades. Wildfires across many regions of the world have also contributed to increase in global temperature. Loss in the forest covers at a rapid rate to meet the demand for more food, shelter and cloth for the growing population and other anthropogenic activities has resulted in increase in levels of carbon dioxide. Events such as La Niña altered rainfall seasons creating drought like conditions in many areas and floods in the other ones world. Drought over large parts of Africa, Asia, and Latin America due to heat waves, severe storms, cyclones and hurricanes in other parts of the world are the some of the major changes noted during the last decade. This has affected the agricultural sector to a great extent. The change in climatic conditions exerts diverse impact on the fauna and flora throughout the globe. The change in temperature has resulted in melting of glaciers and associated increase in the water level in seas and oceans. Ocean warming *via* thermal expansion of sea water has increased threat to aquatic life. Global warming has also lead to decrease in pH of ocean water.

Natural resources are support to any civilization. They are beneficial to humans and were naturally classified as agricultural land, fisheries, mineral resources, fuels. Their classification into renewable and non-renewable resources came into existence quiet late and it was based on their existence. Natural resources have noted depletion at an unprecedented rate. The quality of soil, water, air has shown a significant change over the past few decades. Pollution has declined the quality of natural resources such as water, air or land. Erosion, overgrazing, pollution, monoculture planting, soil compaction, land-use conversion has affected the quality of soil and lead to its deterioration. Depletion in soil quality has affected its productivity thereby threatening the food security at global level. According to an estimate, about 12 million hectares of farmland are getting degraded each year. All these changes have severely affected the survival of the living beings.

Non renewable resources are being utilized by humans in very high quantities resulting in their significant decrease. Environmental degradation is posing as a threat to survival of living beings and leading to extinction of species. A significant loss in biodiversity has been noted every corner of the globe. This has lead to the generation of the concept of sustainability.

Non Renewable Resources

Non-renewable resources such as fossil fuels mainly coal, petroleum, natural gas and oil are limited in amount. They contribute to bout 85% of the energy consumed all over the world. These resources are formed from organic material from plant and animal remains that existed millions of years ago. Since the materials took millions of years to form, they also require millions of years to replenish. They are highly combustible, hence a rich source of energy. Non-renewable resources are affordable as they are cost effective. These resources can be used to form various products. They provide a major source of energy and medium to carry out various anthropogenic activities. These are consumed faster sources and will eventually get depleted. Their amount has become limited to their misuse and over-utilization, therefore it becomes important that they are sustained for use of future generation. Changes in the status of non-renewable material affect the size of the economy [1, 2].

Non-renewable resources are used as major source of energy. Many countries of the world use them for industrial, urban and anthropogenic activities which result to increase in pollution and global warming in the environment [3, 4]. The depletion of natural resources is supposed to increase energy crisis. Over use of fossil fuel results in the emission of greenhouse gases, this is primarily responsible for global warming and climate change. Use of non- renewable energy resources leads to environmental degradation and affect the economic growth of the world. A10% rise in consumption of non- renewable energy resources result in 2.11% rise in GDP [5]. The main reason of de*via*tion from non- renewable resources to renewable energy resources is their environmental effects [6 - 10]. Utilization of energy has both governmental as well as environmental consequences [11 - 14]. With increase in non- renewable energy resources GDP rises.

Non-renewable resources, especially metals, can be expanded by reprocessing. This process involves gathering and processing unused industrial and household products to recover renewable materials including metals and plastics. In oil producing countries, natural gas and petroleum and are the main drivers of economic growth [15, 16]. Non- renewable energy resources such as coal, petroleum and natural gas cannot be replicated once exhausted [17, 18]. Industrial energy supplies are mostly based on the use of non- renewable resources. Use of fossil fuel releases certain amount of residue in the form of solid substances and gases. This residue causes environmental pollution.

Around 300-360 fossil fuels were formed during the time of carboniferous period. About 10 feet of solid vegetation got flattened, heated and created foot of coal.

CHAPTER 2

Role of Biotechnology in Treatment of Solid Waste

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Abstract: Waste management has become a major global concern. The rapid rise in the rate of population has increased the generation of waste at a tremendous pace. Improper disposal of agricultural, household, municipal and industrial wastes can pose a threat to the health of living beings and the environment. Industrial waste, in particular, is highly hazardous as it contains toxic chemicals and metals. Many methods of waste disposal have been adopted, but most of them produce various kinds of after-effects, therefore, biological methods have been adopted because of their eco-friendly and sustainable nature. Sustainable waste management aims to minimize the amount of waste generation. Waste is treated in a proper way, involving the steps such as segregation, recycling and reuse. Biotechnological methods such as composting, biodegradation of xenobiotic compounds and bioremediation have been tried. These methods have proved useful in treating waste in an eco-friendly way. More research studies need to be carried out to standardize the method for the proper treatment of waste so that environmental sustainability can be achieved.

Keywords: Anaerobic degradation, Biogas, Bioremediation, Combustion, Composting, Fermentation, Incineration, Recycle, Reduce, Reuse, Xenobiotic.

INTRODUCTION

Waste released from municipal, domestic and industrial processes is becoming a problem worldwide. Solid waste includes wastes obtained from household, commercial and demolition activities. In the present era, e-waste (electronic) has also become an issue of concern. Besides these, medical waste, radioactive waste and many other forms of waste are generated. Globally, municipal, domestic, industrial, plastic and electronic waste has been discarded at an alarming rate by people worldwide. It is becoming difficult to manage waste generated in huge quantities. Increasing waste is proving a threat to the environment. The main reason for this is rapid industrialization and urbanization-change in the lifestyle of individuals. Recent reports indicated that the rate of waste generation at present is estimated to be about 0.25 to 0.66 kg/person/day [1]. Studies suggest that the rate

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of disposal of municipal solid waste (MSW) all over the world is around one billion metric tons. The amount of waste disposal is expected to reach 2.2 billion by the year 2025. Plastic is one of the major components of MSW. The wastes are both biodegradable (organic waste) and non-biodegradable (Table **1**).

Table 1. Different types of wastes.

Type of waste	Examples
Non-biodegradable waste	
E-waste	Disposed/discarded computers, TV, music cassettes, disks, printer cartridges, electronic items
Liquid waste	Waste from industries, tanneries, distilleries, thermal power plants
Plastic waste	Bags, bottles, cans, packaging *etc*
Metal waste	Metal sheets, metal scraps
Nuclear waste	Waste released from nuclear power plants
Miscellaneous	Foil, wrappings, pouches, sachets, tetra packs, discarded clothing, old/broken furniture, and discarded equipments
Biodegradable or wet waste	
Household waste	Vegetable waste, Fruit peels kitchen waste (cooked and uncooked food items)
Garden waste	Green/dry leaves
Sanitary wastes	Tissue papers, napkins, toilet papers

The wastes are generally disposed of in open dumps, landfills, or subjected to incineration or composting. The practices of disposal of waste in open dumps or incineration affect the various components of the environment, such as soil, land and affect public health *via* the outbreak of diseases. Waste treatment is important before it is released into the environment to prevent ecological imbalance. There is a need to develop technologies so that waste is treated in a manner that does not bring any harm to the environment. Generally direct combustion or crushing of the waste (such as agricultural, household, municipal and certain biomass materials) after sorting has been followed, but these activities release gases such as CO and CO_2 into the atmosphere. If wastes are not treated properly, it emits gases like methane (CH_4) and carbon dioxide (CO_2), which cause air and water pollution [2]. The problem can be mitigated if wastes are treated and processed by adopting environment-friendly technologies before disposal.

Many waste management policies and technologies have been developed, and efforts have been made to tackle waste in an effective manner by public and private agencies. Waste management is an activity that helps in organizing waste from its production to the process of final treatment. Waste management includes processes such as collection, sorting, treatment and recycling of waste materials. Each and every kind of waste needs to be managed in an efficient manner (Fig. **1**). Sustainable waste management strategies aim to reduce the production of waste or follow activities that engross the reuse of waste materials in some or the other way. Less amount of waste generation will prevent contamination and the spread of diseases. Waste management is considered a key element for a sustainable environment [3, 4]. Sustainable waste management reduces the number of products such as plastic along with an increase in means of their recycling at the same time.

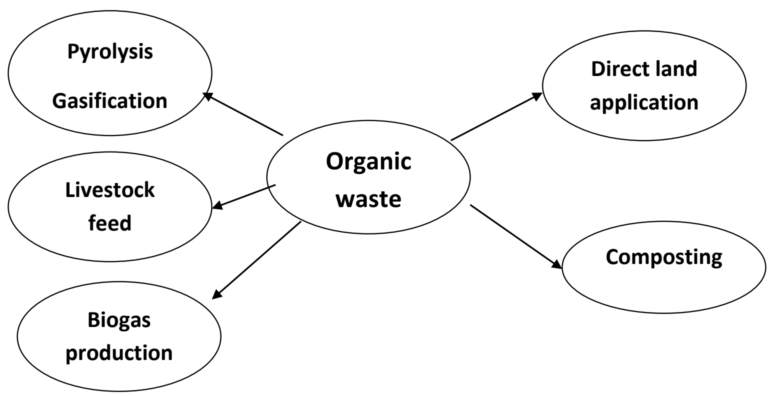

Fig. (1). Various ways in which organic waste can be treated.

Besides the physcio chemical methods, biowaste treatment technologies, including direct land application, animal feed, combustion, physical and chemical treatment processes, temperature treatment (such as pyrolysis, liquefaction, gasification) and biological treatment (composting, vermicomposting, anaerobic digestion, fermentation) have also shown promising results with an aim for achieving waste management [5, 6]. Biowaste treatment reduces threats to human health and environmental deterioration [7. 8]. Conversion of waste-to-energy (WTE) is suggested as another way of handling waste effectively. This technology is supposed to produce a good amount of energy *via* the utilization of waste, thus reducing its quantity and lessening the chances for soil and land pollution. It also suggests a way of safe disposal of waste. The waste-to-energy technique has been adopted by many developed countries. Biotechnology deals with waste management by degrading harmful elements and toxic chemicals with the help of microbes [9]. Biodegradable waste can be effectively treated and converted into useful products using microorganisms. Microbes that possess the potential to metabolize any kind of waste can be engineered *via* molecular techniques.

CHAPTER 3

Role of Biotechnology in Afforestation and Land Rehabilitation

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Abstract: Increased requirements for food and commodities have generated immense pressure on land resources. Landforms and forest areas have been converted to agricultural lands and rehabilitation areas to support the needs of a growing population. Owing to these changes, an urgent need for afforestation and land restoration has been generated. Various methodologies have been tried to restore the degraded land and increase the forest cover. Clonal propagation aiming at rapid multiplication and large-scale production of plants *via* selected clones has been successfully implemented. This approach has proved useful in raising commercial plantations. The use of biotechnological approaches such as molecular markers and advanced breeding programmes proved useful in raising clones for achieving afforestation and land rehabilitation on a large scale. The present chapter provides a detailed account of biotechnological techniques and processes that have played a significant role in afforestation and land rehabilitation.

Keywords: Genetic markers, Micropropagation, Plantation forests, Restoration, Reclamation.

INTRODUCTION

Forests are natural resources that form an important part of the ecosystem because of innumerable goods and services provided by them. Besides providing the oxygen required for the survival of living beings, they offer various materialistic things such as food, timber, paper, medicines, and fuelwood. Ecological roles played by them mainly include providing habitat to fauna, cycling nutrients, protecting watersheds, and regulating climate [1]. According to an estimate, the economic benefits of forests amount to about US$ 130 million per year.

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Forests all over the world are facing a threat due to conversion to other landforms such as croplands, residential areas, industrial setups, and other developmental setups [2]. Studies have shown that about 30% of the Earth's forest cover has been converted for other uses, and about 20% (about two billion hectares) has been degraded. Studies have shown that about 2.3 million km^2 of the forest area has been lost since the year 2000, and around 170 million ha will be lost by 2030 [2, 3]. According to an estimate, about 25% of forests have been cleared in the last 100 years [4 - 6]. The change in the distribution and structure of forests has been caused mainly due to anthropogenic activities. Deforestation, overexploitation, pests, diseases, and pollution have been considered the major causes of the reduction in forest cover. Disturbances such as climate change, flooding, droughts, and fires are some of the other factors responsible for bringing change in forest cover. An increase in the concentration of atmospheric CO_2 and temperature has affected the growth and production of forests across the globe [7]. Climatic changes such as global warming have brought a change in species composition, productivity, and biodiversity of forests in recent years. The change in forest structure and productivity affect biodiversity significantly and results in the loss of vulnerable species.

Land is another important natural resource covering a large part of the earth, including bare soil, vegetation, habitation, and impervious surfaces. Soil erosion, salinization and over-irrigation have resulted in the degradation of land significantly. An increase in the cropland areas in the last 50 years decreased land productivity due to the excessive application of fertilizers. Overloading of nitrogen and phosphorus has been noted in such areas [8]. Extensive mining in many areas has also brought alteration in the characteristics of land and components of soil (soil horizons, structure, soil microbe populations, nutrient cycles) [9 - 12]. The changes in land use and degradation lead to a reduction in soil organic carbon stocks which reduces the productive potential. According to an estimate, the net primary production of the terrestrial area globally has been reduced by 23% [5, 13, 14].

Prevention of land and forest degradation, restoration as well as the resilience of these natural resources is required for sustaining a healthy ecosystem. Various practices have been followed all over the globe to achieve environmental sustainability by preserving land and forest cover [15]. Afforestation programmes have been carried out in various regions of the world [16]. Besides various conventional technologies, such as raising plantations, biotechnological approaches have also been tried to restore degraded land and maintain the forest cover. In recent years, the biotechnological approaches have been proven as a milestone in the recovery of forest areas and degraded lands.

STRATEGIES FOR AFFORESTATION AND LAND REHABILITATION

Remediation and restoration techniques effectively maintain the productivity and biotic function of degraded lands and forest areas. Restoration brings the damaged or degraded area back to its natural state. The reclamation and revegetation mainly include clearing of an area, replacement of species through selection, and re-establishment of vegetation. The process of reclamation helps in restoring the ecological integrity of disturbed areas. These methods help in recreating an ecosystem and establishing a functionally effective and self-sustaining system. Brancalion *et al.* [17] proposed a strategy for the restoration of forests and landscapes. According to this, importance should be given to

- Protection of existing forest area,
- Restoration of native vegetation of an area,
- Restoration of degraded and low-productive lands.

The main prerequisite before the management of land or forest area is an assessment of the condition of an area [18-21].

Various methods have been practiced for a long time to restore degraded forests and lands [22]. Techniques for forest restoration mainly include natural regeneration and afforestation *i.e.*, planting of native tree seedlings, monoculture plantations, and mixed-species plantations. Afforestation converts non-forest land to forests through plantations using seedlings or other plant sources [23]. The technique of afforestation has been adopted by many countries around the world. This is because afforestation helps in preventing drastic climate change, protecting natural forests/vegetation, recovering the loss of trees, and meeting the requirements/products provided by forests [24]. The rate of afforestation has seen a rapid increase in the past decades.

The plantations increased by 277.9 million ha in 2015, which accounts for 6.95% of the global forest area [25]. Studies have shown that plantation forests occupy around 135 million ha of land areas all over the globe. Most (about 75%) of the plantation forests have been established in temperate regions. About 90% of plantation forests have been established on degraded and deforested areas primarily to meet the requirements of timber, fiber, fuelwood for industrial use, and environmental protection.

Plantation forests were established using monocultures and species/interspecific hybrids. Planting of short or long-term species and monocultures proves useful in restoring native forest ecosystem species [26]. Mixed-species plantations increase biodiversity, enhance watershed protection and induce more carbon storage [27,

CHAPTER 4

Remediation of Wastewater Using Biotechnological Techniques

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Abstract: Wastewater contamination is increasing day by day because of increase in industrial operations and anthropogenic activities. Wastewater is a by product of industrial and domestic operations which is directly disposed into the environment and contain large amount of toxic materials harmful for human, animals as well as environment. Wastewater coming from industries is highly contaminated hence its recovery is a major concern. Developing countries and less developed countries generate large amount of wastewater in comparison to developed countries. Biotechnology provides best solution to get rid of this problem. Different technique/methods such as use of activated sludge, trickling filters, biosorption, bio-accumulation, use of nanoparticles play a major role in treatment of water. Role of microorganisms *via* microbial fuel cells and membrane biofilm bioreactors have also been used for removing metals present in wastewater. This chapter aims to provide complete information about biotechnological approaches for wastewater treatment in a cost- effective manner along with complete removal of sludge and toxic compounds.

Keywords: Bio-accumulation, Biosorption. trickling filters, Microbial fuel cells, Membrane biofilm reactors, Wastewater treatment.

INTRODUCTION

Increase in pollution due to anthropogenic activities is one of the biggest environmental problems of the century. Pollutants such as heavy metals, chemicals, dyes, pesticides released from various sources such as municipalities, industry and agriculture have contributed majorly to deterioration of environment. Industrialization and human growth have contributed to development of various environmental toxins and subsequent metal pollution [1]. Human activities have

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lead to release of large amounts of hazardous pollutants and effluents in soil, water, agricultural lands and air [2]. Industrial operations though contribute to change in human society *via* social and economic means but at the same time increase environmental concerns. Tremendous growth in industrial sector seen over the years has contributed to release and accumulation of several toxins such as heavy metals and other chemicals in air, water and land. Managing industrial water pollution due to industry, urbanization, and population growth is one of biggest challenges of today. Rapid urban growth as well industrial activities accelerate water pollution as huge amounts of heavy metals get disposed in the environment. Sewage is one of the major sources of water pollution. At present, water pollution is a global environmental issue as high concentration of toxic waste is getting added in the water bodies and their levels exceed the limits specified by World Health Organization and Environmental Protection agencies. Metals when disposed into environment prove toxic and directly or indirectly impact the human body as they interfere in natural reactions of the body. Excess of heavy metal exposure induces oxidative stress. According to recent reports, about 10-20 million people die every year because of waterborne diseases. It is predicted that billions of people on earth will not have it access to safe drinking water after few decades. The water supply will be reduced to one third of the current supply because the number water resources will decrease. Therefore, it is necessary that an effective wastewater treatment technology is developed. Both public and government need to look for the ways so that wastewater is treated before it is disposed. Water being a necessity for life needs special attention with respect to its use and treatment in way so that its sustainability can be maintained.

Industrial wastewater treatment is a complex process and requires huge set up and input [3, 4]. Pollution caused by industrial operations cause serious health problems. Natural potential of plants and microorganisms can be exploited to remove/treat pollutants present in wastewater. Remediation based on biological means have proved useful in degrading, altering or absorbing high levels of contaminants such as radionuclides, metals, medical waste, organic compounds *viz.* polyaromatic hydrocarbons (PAHs), biphenyls (PCBs). Catabolic functions of microbes have shown potential to degrade/treat pollutants. In bioremediation, different pollutants/toxins present in water are removed by bacteria, fungi, algae [5, 6]. Microbe-based remediation techniques for treatment of environmental pollutants have emerged as the latest technological methods with sustainable approach [7 - 10]. Both living and non-living microalgal biomass has been used as a biosorbent to get removal of metals [11, 12]. Cyanobacteria species such as *Oscillatoria*, *Phormidium*, *Spirogyra* and *Anabaena* have shown high growth even in contaminated water which could be due to their resistance to stress conditions. The microalgae species show specific methods of combating heavy metal toxicity. These include iron reduction, genetic control, isolation, chelation and role of enzymatic and non-enzymatic antioxidants which reduce heavy metals by redox reactions. *Bacillus* sp. showed an excellent capacity in salvation of iron stress. In addition, strains of *Aspergillus* such as *Aspergillus flavus* (FS4) and *Aspergillus fumigatus* (FS6) showed ability to disperse pollutants [13, 14]. Metagenomics are the most advanced tools used in removal of metals from contaminated water involving the microbial community. The technology has shown advancement at a faster pace. Nano-based technology has proved effective in treatment of wastewater to get clean safe drinking water [15].

WASTEWATER GENERATION IN INDIAN INDUSTRIES

Industrialization contributes to social sustainability but at the same time raises major issue such as pollution. Social growth should be done provide environmental sustainability is also focussed [16]. Pulp and paper, diesel and the tanning are some of them fast-growing industries that release wastewater that can pose high environmental risks [13, 17]. Indian tannery, pulp and paper, as well as the distillery industry release about 25,000 liters, 50,000 m^3 and 5-10 million liters of wastewater per day [18 - 20]. Release of such quantity of waste from industry is an issue of major concern for living beings. Being one of the most important natural resources that are important for all aspects of life, water is getting polluted due to rapid increase in population, urbanization as well as industrialization. Leather industry uses chromium-based agents at a large scale to turn raw leather into usable leather. many of the physic-chemical properties such as color, pH, TDS, TSS, BOD, COD, solid (TS), electrical conductivity (EC), heavy metals and metalloids *viz.* Mg, Cu, Zn, Cd, Fe, Cr, As, Pb, and Ni found in used wastewater released from paper and other heating industries are above the permissible levels. Aquatic life gets adversely affected by polluted water. Large areas of agricultural and aquaculture systems are polluted by toxic metals are extracted from glue and paper, tanning leather, and polish industries. About 2.9 billion urban dwellers release approximately 0.64 kg of the municipality solid waste (MSW) daily. Studies suggest that quality has been improved as now each person produces about 1.2 kg municipal solid wastes daily. It is expected that by 2025, 4.3 billion people will be producing about 1.42 billion kg/ capita /day approximately *via* 2.2 billion tons of MSW generated per year.

Heavy Metals Pollution and its Toxicity

Metals such as Ni, Cr, Ur, Hg, Zn, Cd, Se, Au, Ag, and As act as toxicants that pollute the environment. They adversely affect quality of soil, agriculture production and pose a major threat to human health [18, 21]. As a result of human activities, number of heavy metals contaminated water sources increase annually [22]. Heavy metals are toxic and unsafe [23]. The levels of heavy metals in water

CHAPTER 5

Soil Reclamation and Conservation Using Biotechnology Techniques

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Abstract: Pollution and unsustainable use of natural resources such as land and soil has resulted in their destruction. Restoration of degraded land and soil is essential for maintenance of essential ecosystem services such as preservation of biodiversity, nutrient/water cycling and meeting the food requirement for living beings. Bioremediation has appeared as technology with high potential for restoring damaged soil and degraded lands. Biotechnological techniques such as development of efficient microbial consortia with an enhanced capacity to remove various contaminants from soils and improvement in nutrient retention in soil have opened new prospects in bioremediation with an aim to recover productive capacity of soil. The techniques such as bioventing, bioaugumentation, biosparging have also proved useful in restoring degraded and non-productive soils to a great extent. The biotechnological techniques, thus can act as an ecofriendly method for remediation, restoration and reclamation of degraded/damaged soils.

Keywords: Biotechnology, Bioaugmentation, Biostimulation, Biofertilizers, Restoration, Soil.

INTRODUCTION

Soil is an important natural resource that supports basic functions of ecosystem and provides essential services to an ecosystem. It provides habitat to living organisms, plays an important role in cycling of nutrients and breakdown of organic matter. Soil contamination and deterioration has emerged as a major threats due to increase in anthropogenic activtities [1]. Overexploitaton of land resources for agriculture and construction purposes has resulted in decline in fertility of soils and affected their productive potential. According to studies, the productive capacity of about one-fourth of agricultural land throughout the world has been affected due to damage to soil. This has resulted in decline in agricultural production. Predictions suggest that restoration or reclamation of soil

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is very important to increase the agricultural production (by about 50%) to meet the growing demand for food.

The presence of high amounts of heavy metals in soils has been emerged as a major problem related to soil degradation. About 35% of the soils in Europe have been contaminated with metals. Agricultural, mining, metallurgical activities lead to metal(oid) contamination in soil. Organic contaminants get added mainly from the industrial activities. Techniques such as excavation, incineration, chemical washing, and vitrification are some of the physicochemical methods that have been used to treat contaminated soils. Most methods of soil remediation show certain limitations. They are economically infeasible and not environment friendly. Studies have shown that physicochemical methods treat the contaminants effectively but in the process affect the soil processes, functions and biota [2]. Most of these techniques affect the ecological status of the remediated soil. Off late the need for restoration and reclamation of the degraded soils was realized and efforts were made to develop technologies that can help in getting the natural resource (soil/land) restored with an aim to maintain sustainability of the environment. Biological methods have emerged as sustainable remediation technologies that helped in restoring/ reclaming the productivity of the soil without inducing any negative effects on soil biota [3]. These techniques aim at reducing the concentration of soil contaminants and recovering of soil functionality. Biological methods of soil remediation thus provide help in reclamation of degraded soils [4].

The restoration process help in maintaining safe, clean environment and support plant growth. Reclamation process improves soil quality making it suitable for a sustainable use, while conservation process pertains to preservation, protection and planned use of soil [5]. The damaged soils (such as eroded, mined) can be treated in such a way that they return to a condition that occured prior to degradation. Biotechnology has provided a good potential tool that can help us in restoring and conserving the degraded soil [6, 7].

Some processes such as intrinsic bioremediation (bio-attenuation) help in recovering the soil contamination and degradation to a great extent. It is a natural reduction of organic pollutants by micro-organisms present in soil. This type of remediation depends upon potential of microbial population to reduce contaminant levels. It is cost effective than conventional engineered technologies, but remediation requires large time frame to accomplish the task.

The present chapter provides an overview of techniques of biotechnology that help in reclamation and conservation of soil.

VARIOUS TECHNOLOGIES USED IN RESTORATION OF DEGRADED SOILS

Biotechnological techniques have shown immense potential in restoration and retrieval of degraded soil [8].

Removal of Organic Contaminants Using Microbes

Microbes have shown immense potential to degrade organic contaminents present in the soil [9]. Microorganisms degrade organic pollutants under oxic conditions (presence of oxygen) by respiration or under anoxic conditions *via* processes such as denitrification, methanogenesis, and sulfidogenesis. Complete and fast degradation of the pollutants is noted under aerobic conditions. The pollutants present in the soil get trapped into soil pores and/or adsorbed to the soil matrix resulting in their immobilization. The microbial communities present in the soil change with change in the environmental conditions. Only the microbes which are resistant survive and thus play role in cleaning the polluted soil. The remediation of contaminated soil by microbes is regulated by physical factors such as temperature, pH of soil, soil moisture content, soil quality, soil nutrient content and concentration of oxygen. Change in any of these factors can alter the population of microbes affecting the bioremediation potential to a great extent.

Various types of hydrocarbons get degraded by different bacterial genera. Microbes present naturally in the contaminated soil break the complex hydrocarbons into simple form *via* their enzymatic systems. The degradation of hydrocarbons occurs under both aerobic and anaerobic conditions. In anaerobic condition, The bacteria present in the deep parts of the sediments use nitrates, sulfates and iron as electron acceptor to degrade the hydrocarbons under oxygen deprived conditions. Enzyme bacterial dioxygenase integrate oxygen into carbon molecule *via* series of enzyme catalyzed reactions under aerobic conditions. Oxygen gets added to alcohol groups to form aldehyde and further into carboxylic group by the action of other enzymes. This gets degraded to form acetyl co-A *via* beta oxidation. Bacteria such as *Desulfococcus, Thauera, Dechloromonas* and *Azoarcus* show hydrocarbon degradation ability under anaerobic conditons. Some bacteria such as *Alcaligenes, Sphingomonas, Pseudomonas, Bacillus, Nocardia, Acinetobacter, Micrococcus, Achromobacter, Rhodococcus, Alcaligenes, Moraxella, Mycobacterium, Aeromonas, Xanthomonas, Athrobacter, Flavobacterium, Micrococcus, Azospirillum* show ability to degrade crude oil.

Bacteria and fungi show capacity to degrade polyaromatic hydrocarbons (Table **1**). Microorganisms degrade PAHs by bringing oxidation in the aromatic ring of the compound followed by their breakdown to form metabolites [10, 11]. Enzymes such as laccase and manganese peroxidase play an important role in

CHAPTER 6

Remediation of Environmental Contaminants using Nanoparticles

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Abstract: Nanotechnology plays an important role in monitoring, preventing, and remediating environmental pollution. Nanomaterials are used in the detection and removal of contaminants such as heavy metals, organic pollutants (aliphatic and aromatic hydrocarbons), and biological agents such as viruses, bacteria, and parasites. Nanomaterials act as good adsorbents, catalysts, and sensors due to their large specific surface areas and high reactivities. Physicochemical properties, such as large surface area, facilitate easier biodegradation/remediation of environmental contaminants. Carbon nanomaterials, namely carbon nanotubes, graphene, graphene oxide, and zero-valent iron nanoparticles, have shown great potential for the removal of heavy metals and organic contaminants from water and soil. Hence, nanoremediation represents an innovative approach to safe and sustainable remediation of environmental contamination.

Keywords: Carbon nanotubes, Nanomaterials, Nanotechnology, Soil, Water.

INTRODUCTION

Environmental pollution has emerged as one of the major problems all over the world. The major source of pollution is the presence of contaminants that are non-biodegradable in nature. They directly exert toxic effects on living beings but indirectly affect the interactive relationships in ecological communities. Toxic environmental pollutants such as heavy metals and organic compounds (pesticides, dyes) pose risks to human health [1, 2]. The remediation/removal of pollutants from the environment has been done using various methods. Most of the treatment methods employed are difficult, time-consuming, expensive, require pretreatment, and are less effective. Nanotechnology has emerged as a technology with the potential to remediate/treat a wide range of contaminants and hence plays a role in improving the quality of the environment [3, 4]. Major applications of nanotechnology include

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1. Remediation and removal of environmental contaminants,
2. Detection and prevention of pollution.

Nanoparticles (NPs) have been used to remediate various forms of environmental contamination [5, 6]. Nanomaterials have shown the potential to remove/treat various pollutants such as organic compounds, metal ions, and many biological materials from the environment. Carbon nanotubes (CNTs), graphene, graphene oxide, activated carbon, nanoscale zeolites, nanofibers, and titanium dioxide are some of the nanomaterials used in the remediation of environmental contaminants. The properties of nanoparticles, such as big surface area, high surface-to-volume ratio, and reactivity, contribute to their high remediation capacity.

Soil and groundwater contaminated with inorganic pollutants such as heavy metals, organic contaminants, and pharmaceutical and personal care products ion has been successfully treated using nanoremediation [7 - 10]. Remediation of contaminants occurs either by sequestration or degradation. Both i*n situ* (removal of contaminants at their source site) and *ex-situ* (treatment of contaminants at a site different from their source) treatment of contaminants can be done using nanotechnology. *In situ* remediation helps in the treatment of contaminants at the source (such as crevices and aquifers) and eliminates costly operations such as the transport of contaminants. Nanoscience helps in effective remediation for a certain pollutant (such as metal), depending upon their affinity and selectivity.

NANOMATERIALS USED IN ENVIRONMENTAL REMEDIATION

Nanomaterials have been used successfully for remediating contaminants present in water and land areas of hazardous waste sites [10]. The use of nanomaterials in environmental remediation has proved better than conventional techniques. Nanosorbents, nanoclays, nano-aerogels, nano-iron oxides, nanoscale zerovalent iron (nZVI), nano-metal oxides, dendrimers and nanofibres are some of the materials that have shown great potential to remove/treat contaminants Table (**1**). Major nanomaterials that have been exploited in the removal of contaminants include carbon-based nanomaterials, dendrimers, ferritin and metallopor phyrinogens. Treatment of surface water, groundwater, wastewater, soil and sediments contaminated with heavy metals, microorganisms, and organic and inorganic solutes has been done using nanoscale particles [11 - 13].

Oxide-based Nanoparticles

Oxide-based nano-particles include inorganic nanoparticles prepared by using non-metals and metals. These include titanium oxides, titanium oxide/dendrimers composites, zinc oxides, magnesium oxide, manganese oxides, and ferric oxides. They help in removing hazardous pollutants from wastewater.

Table 1. Nanomaterials used in the remediation of pollutants.

Type of Nanomaterial	Pollutant	Area of application
Amphiphilic polyurethane nanoparticles	Phenanthrene	Soil
Nanoscale zero-valent iron	Heavy metals, hydrocarbons, oil	Water
Nanocellulose	Heavy metals, dyes	Water
Polymer nanocomposites	Hydrocarbons, heavy metals	Water and soil
Carbon nanotubes	Ethylbenzene, copper, nickel ions, cationic dye, oil	Water
Dendrimer nanoparticle composite	Organic pollutants, metal ions	Water
Titanium dioxide	Organic pollutants	Water, Soil
Bimetallic nanoparticles	Polybrominated diphenyl ethers, chlorine	Water, Soil
Magnetic nanoparticles	Heavy metals	Water, Soil
Graphene-based nanomaterials	Cationic compounds	Water, Air
Plasmonic-based nanomaterials	Organic pollutants, pathogenic microorganisms	Water

Manganese oxide (MnO), Magnesium oxide (MgO) and iron-based nano-particles such as Fe_2O_3 have been successfully used in the removal of heavy metals from wastewater. Their high surface area and polymorphic structure contribute to their adsorption capacity [14]. Nano-adsorbents such as nano assemblies, nanoplates, nano-sheets, and ZnO nano-rods are used in the removal of heavy metals from wastewater [15, 16]. High removal of heavy metals such as Pb and Cd (II), from wastewater using mesoporous hierarchical ZnO nano-rods, has been reported [16].

Factors such as pH, temperature, adsorbent dose, and incubation time regulate the adsorption of heavy metals [17]. Research showed that modification of the surface of MnOs increased the adsorption capacity of Fe_2O_3 [18]. The affinity for the removal of different pollutants such as Cr, Co, Ni, Cu, Cd, Pb, and As from wastewater increased when the surface of nano-adsorbents was modified [17].

Zero-Valent Iron Nanoparticles

Nanoscale iron particles remediate and transform a variety of environmental contaminants. These nanoparticles have been proven useful in treating environmental contaminants such as toxic metals, and organic and inorganic compounds. These nanoparticles exhibit high reactivity in remediating compounds from aqueous media [19]. These particles effectively remove

CHAPTER 7

Application of Nanoparticles in Environmental Monitoring

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Abstract: The planet is dealing with a major problem of environmental pollution. Year after year, this problem worsens, causing harm to our planet. To combat the major environmental issues, various technologies have been developed over the years. The use of nanomaterials in environmental management is becoming more common. Nanomaterials are increasingly being used to clean the air, purify water, decontaminate soil, and detect pollution. Nanotechnology has emerged as a technique for cleaning up pollution and monitoring degradation of environmental sectors such as air, water and soil. Hence nanotechnology can contribute to the sustainability of the environment. This chapter discusses the use of nanomaterials in the monitoring of air pollutants, organic contaminants and other environmental pollutants, as well as the various methods involved in the production of nanoparticles.

Keywords: Environmental monitoring, Nanomaterials, Nanoparticles, Pollutants.

INTRODUCTION

Environmental contamination and energy deficiency are two major problems recognized all over the world. The advancement of nanotechnology in the last twenty years has focused on improving interaction in the plan, disclosure, creation, and novel use of counterfeit nanoscale materials. A variety of nano materials like iron, titanium dioxide, silica, zinc oxide, carbon nanotube, dendrimers, polymers, and have been constantly used to make the air clean, to refine water, and to purify soil [1].

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Interesting and conceivably valuable properties of nanomaterials include expanded surface zones and reactivity, improved strength-weight proportions, expanded electrical conductivity, and changes in shading and mistiness. Materials with these properties found their application in a various areas such as medication and environmental insurance [2]. Nanoscale materials discover use in a variety of various territories, like electronic, attractive and optoelectronic, biomedical, drug, corrective, energy, environmental, reactant, and materials applications. Nanomaterials and nanotechnology give an incredible technique for recognition and treatment of toxins found in the environment. Small sized particles have been utilized for achieving various tasks by humanity and there has been a new resurgence because of its capacity to combine and control such materials. In view of the capability of this innovation, there has been an overall expansion in interest in nanotechnology innovative work [3].

The subject of nanoparticles applications is extremely expansive. Nanotechnology has acquired a ton of consideration in the previous a very long time because of the one of a kind actual property of nanoscale materials. Nanomaterials present upgraded reactivity and in this way better *via*bility when contrasted with their bulkier partners because of their higher surface-to volume proportion. Nanotechnology is additionally being utilized to make sustainable power less expensive and more efficient. The utilization of nanotechnology in agribusiness area will lessen the aimless utilization of agrochemicals and in this manner will diminish the heap of substance toxin [3].The utilization of nanoparticles in environmental applications will definitely prompt the arrival of nanoparticles into the climate. Surveying their dangers in the climate requires a comprehension of their portability, bioavailability, harmfulness, and constancy. Though air-borne particles and inward breath of nanoparticles have pulled in a great deal of consideration significantly less is thought about the conceivable openness of amphibian and earth bound life to nanoparticles in water and soils. A growing body of evidence demonstrates that nanoparticles can be taken up by a wide variety of mammalian cell types, cross the cell membrane, and become disguised. Nanoparticles are also toxic to amphibian species, both unicellular and multicellular (e.g. microscopic organisms or protozoa) and creatures (e.g. *Daphnia* or fish) [4].

These outcomes from considers show that certain nanoparticles will have impacts on creatures, on the environment, at any rate at raised focuses. Nanomaterials present improved reactivity and in this way better *via*bility when contrasted with their bulkier partners because of their higher surface-to volume proportion. The following stage towards an appraisal of the dangers of nanoparticles in the environment will, in this way, be to gauge the openness to the diverse nanoparticles benefits are augmented while limiting the probability of accidental unfavorable results [4].

These outcomes from contemplates show that certain nanoparticles will have consequences for living beings and the environment, in any event at raised focuses. It is significant that the materials utilized for the remediation of contamination are not another toxin themselves after they have been utilized. The subsequent stage towards an evaluation of the dangers of nanoparticles to the environment, consequently, be to gauge the openness to the distinctive nanoparticles [4].

CLASSIFICATION OF NANOPARTICLES

Based on their physical and chemical features, nanoparticles are classified into different types Fig. (**1**). The major classes of NPs are briefly defined in the following section [5].

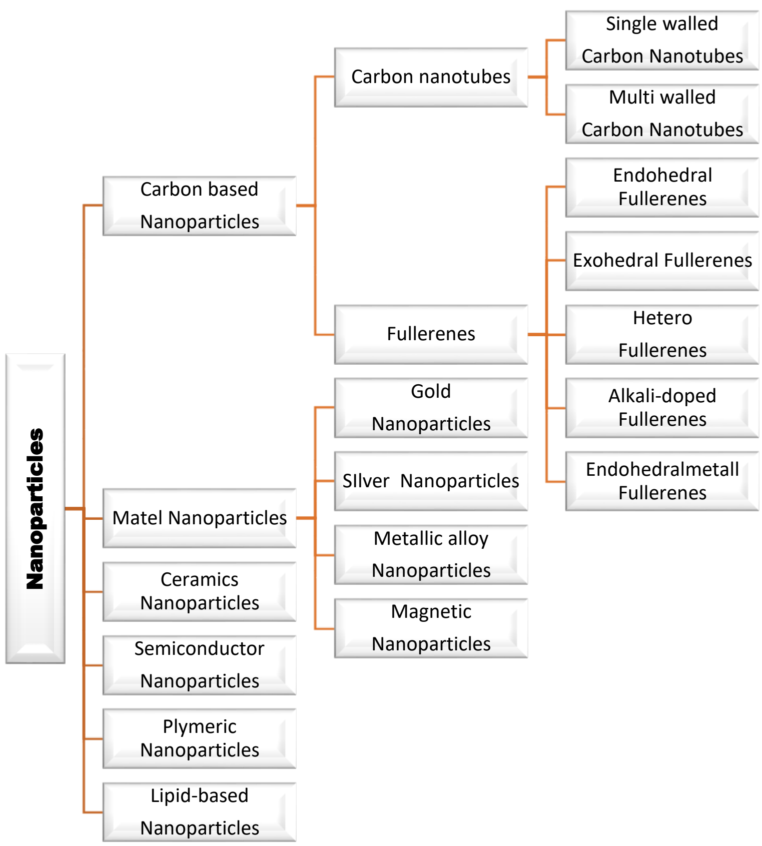

Fig. (1). Classification of Nanoparticles.

CHAPTER 8

Removal of Micropollutants and Pathogens from Water using Nanomaterials

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Abstract: Presence of micro pollutants and pathogens in water has become a concern worldwide. Micropollutants such as pharmaceutically active compounds, personal care products, organic compounds and pathogens/microbes (viral, bacterial and protozoa) pose a threat to humans. Nanotechnology has proved effective in developing strategies for the treatment of contaminated water. Nanomaterials have found application in the removal of different categories of pollutants, from water. The properties such as high reactivity and effectiveness establish nanomaterials as ideal materials suitable for treatment of contaminated water/wastewater. Nanomaterials such as carbon nanotubes, graphene-based composites and metal oxides, have shown potential to remove dyes, pathogens from wastewater. Research efforts are required to develop an eco-friendly, economic and sustainable technology for the removal of micropollutants and biological agents such as microbes using nanomaterials.

Keywords: Carbon tubes, Composites, Graphene, Metal oxides, Microorganisms, Nanomaterials, Nanotechnology, Nanoadsorbents, Pharmaceuticals.

INTRODUCTION

Micropollutants are trace levels of synthetic organic substances/molecules that contaminate ground and surface water. The micropollutants released from household activities and industries mainly include pharmaceutical compounds and personal care products (PCPs) such as cosmetics, detergents, toxic chemicals, dyes, fertilizers, and endocrine disruptive compounds (EDCs). Other sources of micropollutants include runoff from agriculture and livestock areas, leakage from landfills, septic tanks and industrial sources. Micropollutants are usually present at trace levels (from ng/L to µg/L) in water, thus their detection and quantification

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are difficult. These pollutants need to be treated properly; otherwise, they enter the food chain and affect living beings in a negative way. The presence of micropollutants in water proves toxic to aquatic organisms and produces a detrimental effect on the health of humans *via* disruption of the endocrine-system [1 - 4].

Most of these micropollutants and their metabolites are non-biodegradable and do not get removed easily after treatment procedures. Various physico-chemical techniques used for the removal of organic pollutants from water include precipitation, membrane filtration, coagulation, ion exchange, adsorption and chemical oxidation [5]. Other conventional treatment techniques include ozonation and reverse osmosis [6]. The physical and chemical methods adopted for the removal of micropollutants involve operational setup and energy input, hence eco-friendly and cost-effective alternate techniques were explored. Nanotechnology has emerged as one of the promising technologies that play a role in areas of biomedical, health care, mechanics, environment and energy. Properties such as high specific surface area (fast dissolution, high reactivity, strong sorption), excellent mechanical properties, superparamagnetism, low cost and energy requirements, high chemical reactivity, recyclability, ease of fabrication, and functionalization establish nanomaterials such as ideal materials to be used in the removal of contaminants from wastewater. Nanotechnology benefits the existing environmental technologies with effective performance and less consumption of energy and materials. Nanobased characteristics allow the development of novel high-tech materials, namely membranes, adsorption materials, nanocatalysts, functionalized surfaces, coatings, and reagents for use in water treatment processes. Water and wastewater treatment using nanosized materials have been tried in the last few decades. The application of nanomaterials ranging from 1 nm to about 100 nm in environmental monitoring, remediation and efficiency for avoiding environmental contamination has been explored. Nanotechnologies offered proved useful in developing innovative methods to treat contaminated water [7].

Different nanoscale materials that have shown immense potential in environmental applications include nanoscale zeolites, metal oxides and titanium dioxide, carbon nanotubes and fibers and enzymes. Nanoengineered materials adsorb and/or degrade various pollutants such as metal ions, dyes, pesticides, pharmaceuticals, other organic pollutants and waterborne microbes (bacteria, viruses, protozoa, *etc*.). Some commercially available nanomaterials are carbon nanotubes, graphitic carbon nitride (CNT/g-C_3N_4) composites, graphene-based composites and metal oxides. Iron oxide nanoparticles (IONPs), magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3) and hematite (α-Fe_2O_3) particles are non-toxic, hence considered safe for their application in the area of removing contaminants from water. Nanotechnology can be used directly or indirectly in the treatment of surface water, groundwater and wastewater polluted with toxic metal ions, organic/inorganic compounds and microorganisms [8, 9].

NANOADSORBENTS

Nanoadsorbents are adsorbents having nanoscale pores and show high selectivity, surface area, permeability and good mechanical and thermal stability. Nanoadsorbents mainly include nanotubes, nanomesh, nano-filtration membranes, nanofibrous alumina filters, magnetic nanoparticles, nanoporous ceramics and clays, cyclodextrin nanoporous polymer, polypyrrole–carbon nanotube composite, *etc* [9, 10].

1. Nanomaterials have been classified into four types.
2. Carbon-based nanoadsorbents [carbon nanotubes (CNTs)]
3. Metal-based nanoadsorbents
4. Polymeric nanoadsorbents
5. Zeolites

Carbon-based nanoadsorbents are composed mostly of carbon and available in various shapes, such as the sphere, ellipsoid or tube. Spherical and ellipsoidal carbon nanomaterials are known as fullerenes, while cylindrical ones are called nanotubes. CNTs are categorized as single-walled nanotubes and multi-walled nanotubes. Carbon nanotubes have large specific surface area that makes them ideal adsorbents for removal of various organic pollutants and metal ions. Carbon nanotubes establish π-π electrostatic interactions and can easily be modified by chemical treatment to increase the adsorption capacity. The smooth interior of the nanotubes provides faster flow rates. This helps in saving the energy required to push the water through the tubes. They can be used for the adsorption of persistent contaminants as well as to preconcentrate and detect contaminants. Metal ions get adsorbed by CNTs through electrostatic attraction and chemical bonding. CNTs exhibit antimicrobial properties by causing oxidative stress in bacteria and destroying the cell membranes. As a result of chemical oxidation, no toxic byproducts are produced, hence can prove useful in disinfection processes like chlorination and ozonation [11, 12].

Metal-based nanomaterials include quantum dots, nanogold, nanosilver, and metal oxides, such as titanium dioxide. Nanoscale metal oxides act as effective adsorbents and help in the removal of heavy metals and radionuclides. They possess a high specific surface area. The nanoscale metal oxides such as nanomaghemite and nanomagnetite are superparamagnetic, and facilitate separation by a low-gradient magnetic field. They can be employed for adsorptive

CHAPTER 9

The Potential of Magnetic Nanoparticles in Environmental Remediation

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Abstract: Magnetic nanoparticles (MNPs) possess inherent properties that help them in improving the quality of the environment *via* the detection, remediation, and removal of pollutants and contaminants. The properties such as high reactivity, high surface-to-volume ratios, superparamagnetism, large surface area and biocompatibility are responsible for the extensive use of magnetic nanoparticles in environmental remediation. MNPs act as adsorbents or catalysts and help in the removal of contaminants from environmental matrices. High pollutant removal efficiency of magnetic nanoparticles can be exploited in framing low-cost-effective technologies for environmental remediation.

Keywords: Chlorinated solvents, Environment, Magnetic nanoparticles, Organic compounds.

INTRODUCTION

Nanotechnology has been used in various areas such as the environment, industrial, medical, material science, and engineering [1, 2]. It has emerged as a promising alternative to high-cost environmental remediation technologies [3, 4]. Nanoscale materials are being developed for potential use to adsorb or remove contaminants under *in situ* or *ex-situ* conditions [5, 6]. Different kinds of nanomaterials, including magnetic nanomaterials (MNMs), are being used in various areas of the environment, such as sensing and monitoring environmental contaminants [7]. Magnetic nanomaterials such as nano zero-valent iron (nZVI), magnetite and maghemite nanoparticles, Fe_3O_4 and g-Fe_2O_3 have found their use in the treatment of contaminated water. Nanomaterials possess good potentials in remediating the environment, such as the removal of pollutants and reduction of toxicity.

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Magnetic nanoparticles possess properties such as high contaminant removal capacity and fast reaction rate. High surface-area-to-volume ratio and availability of a large number of active sites for the reaction are some of the properties of magnetic nanoparticles that support the removal/remediation of contaminants from the environment. Small particle size, high surface-area-to-volume ratio and property of magnetism support the larger rate of contaminant removal, fast kinetics and high reactivity of magnetic nanoparticles. The capacity for removal of contaminants and reactivity of magnetic nanoparticles depends on the surface area and surface properties. The capacity for the removal of contaminants increases with a decrease in particle size [8, 9]. When the particle size was reduced from 500 to 100nm, the reactivity of ZVI ranged between 50 to 90 times higher [10]. Iron oxide magnetic nanoparticles (IONPs), in particular, show a high surface area-to-volume ratio, fast kinetics, strong adsorption capacities, high reactivity and magnetism [9].

ZVI is classified into two types: (1) Nanoscale ZVI (nZVI) and (2) Reactive nanoscale iron product (RNIP). nZVI particles possess a diameter of 100–200 nm and are formed of iron (Fe) with zero valency, whereas RNIP particles are made up of 50% Fe and 50% Fe_3O_4. The contaminant removal capacity of Fe_3O_4 nanoparticles (8 nm) is much higher (about seven times) than coarse-grained counterparts (50 mm) [11].

ENVIRONMENTAL APPLICATIONS OF MAGNETIC NANO MATERIALS

Nanoscale materials have been used for applications in the field environment for the last few years [3, 12]. Remediation of contaminated soil and groundwater at hazardous sites has been achieved using nanoscale materials [13, 14]. The small size and high surface area of magnetite nanoparticles contribute to their high adsorption capacity. Iron oxide nanoparticles separate adsorbents from the system *via* magnetic property. Magnetic nanoparticles remove contaminants mainly *via* electrostatic interaction [15 - 19]. Ion exchange is another way by which cont aminants are removed.

Iron is a strong reducing agent, hence this property of nZVI is used in the degradation of a wide range of organic and inorganic pollutants.

A charged nanoparticle surface is preferred for the removal of charged contaminants. Environmental conditions that can affect the performance of magnetic nanoparticles include background ions, humic substances and pH. The chemistry and composition of groundwater vary from site to site. When magnetic nanoparticles are used in wastewater treatment, high ionic strength and extreme pH are usually a concern.

The reduction of nZVI and adsorption performance of Fe_3O_4 and Fe_2O_3 nanoparticles was affected by factors such as pH value. The surface property of magnetic nanoparticles gets changed by coating with organic surfactants or polymers [20 - 23]. Hu *et al.* [24] suggested a way to use the surface property of magnetic nanoparticles to remove contaminants from the environment. Heavy metals can be separated and recovered with the help of magnetic nanoparticles by changing pH values.

Adsorption is the process by which organic and inorganic contaminants get removed from water and wastewater. Small size, higher surface area, more sorption sites and the surface chemistry of iron oxide nanoparticles (IONPs) contribute to enhanced selectivity.

REMOVAL OF HEAVY METALS

Anions like arsenic, fluoride and chromium, and cations like copper, nickel and mercury get removed from water and wastewater with the help of MNPs. Magnetic nanoparticles act as good sorbents and help in the removal of metals. Iron oxide-based nanomaterials are very effective in removing heavy metals from water [25, 26]. Small size, high surface area and magnetic properties contribute to heavy metal removal. Nano zero-valent iron showed a capacity to remove arsenic, chromium and organic pollutants like chlorinated solvents. Functionalized sorbents remove heavy metals *via* affinity or selective removal from complicated matrices. Iron oxide/hydroxide shell is formed when nZVI comes in contact with air or water. Heavy metal removal occurs *via* surface sorption and co-precipitation [27, 28]. Coating the surface with a thin layer of Fe_3O_4, silica or polymers reduces contact with oxygen, thereby retaining the reactivity of nZVI [29 - 31]. Heavy metals diffuse on the active surface of Fe_3O_4 nanoparticles.

Nanoadsorbents prepared from iron oxide nanoparticles such as magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3), and hematite (α-Fe_2O_3 remove heavy metals from water/wastewater. Contaminants get adsorbed on the surface of magnetic nanoparticles. Efficiency of nanoparticles for adsorption decreases after aggregation. Magnetic nanoparticles, therefore, play a role in the sustainable water treatment process [26].

Improvement in the surface of iron oxide nanoparticles can help in retaining their activity. Carboxylic acids, phosphoric acid, silanol, thio and amine are functional groups besides other small organic molecules, biomolecules, polymers and other metal nanoparticles that modify the surface of iron oxide nanoparticles. The removal of arsenic [As(III) and As(V)] from an aqueous solution occurs *via* adsorption. Flower-like magnetic adsorbent showed a maximum adsorption capacity of 51 and 30 mg/g for As(V) and Cr(V), respectively. Hollow nest-like

CHAPTER 10

Role of Nanotechnology in Water Treatment

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Abstract: Nanotechnology has emerged as an alternative to conventional water treatment methods that involve high costs and processes. Nanomaterials offer great potential for cleaning wastewater. Various nanomaterials have shown the potential to remove pollutants such as organic and inorganic content, and toxic heavy metal ions from wastewater. Nanoparticles with nanofibers and carbon nanotubes form an important part of ultrafiltration membrane, osmosis, sorption, advanced oxidation process, water remediation as well as disinfection processes. The rate of removal of contaminants from wastewater depends upon the physical and chemical characteristics of the nanomaterial, the contaminant, and wastewater.

Keywords: Nanoparticles, Nanotechnology, Pollution, Purification.

INTRODUCTION

Industrialization and urbanization have increased tremendously in recent years. This involve activities such as manufacturing, transportation, construction, petroleum refining, mining, depletion of natural resources and production of hazardous wastes. These activities cause pollution and threaten human health and the environment [1]. The wastes include atmospheric pollutants such as toxic gases (ozone, nitrogen oxides, sulfur oxides, carbon oxides) and suspended airborne particles, while soil and water pollutants comprise organic substances (pesticides, insecticides, phenols, hydrocarbons, volatile organic compounds), heavy metals (lead, cadmium, arsenic, mercury) and microbial pathogens. These environmental pollutants adversely influence human health [2, 3]. They enter the human body either *via* inhalation, ingestion or absorption. It is necessary to save the environment to build better ecosystems.

The entry of pollutants into water contaminates it. Thermal treatment, chemical oxidation and surface solvent flushing are some techniques used for cleaning water. The conventional methods of water treatment are lengthy, expensive and not very effective. The development of sustainable, efficient, and low-cost techno-

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logies that assist in the treatment of toxic environmental pollutants is required. These technologies help in reducing or optimizing the use of natural resources. Nanotechnology has emerged as an alternative to conventional technologies.

ROLE OF NANOTECHNOLOGY FOR THE SUSTAINABLE ENVIRONMENT

Nanotechnology has found its applications at a wide scale in developing innovative methods to form new products, substitute existing ones, reform new materials with less energy consumption, reduce harm caused to the environment, and assist in environmental remediation. Nanotechnology is one of the most promising approaches that have proved useful in environmental remediation. Nanotechnology can be applied in many fields and is considered a sustainable technology. Nanotechnology involves the use of nanoparticles (particle size of less than 100 nm range) to produce materials, devices, and systems that can find their use in various applications [4, 5] Fig (**1**). Nanotechnology has found its application in fields like the cosmetics industry, agricultural industry, medicine, food industry, energy, and control/treatment of pollution [6 - 14]. Nanotechnology represents the ‘’key technology” of the present century and is expected to bring improvement in the environmental zone considerably. The chemical and physical properties of nanomaterials make them suitable for numerous applications in the field of the environment [15]. The research conducted by various researchers proved that nanotechnology can be used in environmental sectors such as saving raw materials, treatment of wastewater and contaminated soil, and hazardous waste management [16].

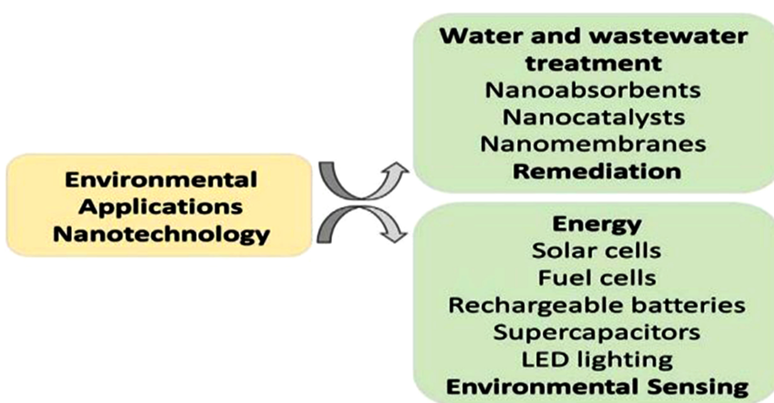

Fig. (1). Nanotechnology used for the environmental application (adopted from Pathakoti *et al.* [18]).

Nanotechnology can contribute to resolving different environmental issues like the cleaning of drinking water and the transformation/detoxification of contaminants (PCBs, heavy metals, organochlorine pesticides, and solvents) [17]. Environmental applications of nanotechnology can address the issues related to existing environmental problems and can provide preventive measures for future problems.

Nanotechnology has been used in increasing the yield and quality of agricultural products, improving cosmetic products and direct delivery of medicines and sensor applications. Innovations have led to the development of nanosensors that can easily recognize disease-causing elements, toxins and elements in environmental samples, and food nutrients. The main focus of nanotechnology in the past few decades has been on the use of nanoparticles in various sectors, and this resulted in its unrestricted development [9].

For the benefit of the environment, nanotechnology has been involved in the development of products, *i.e.*, nanomaterials or products that can clean hazardous waste sites directly, desalinate water, treat pollutants, and monitor environmental pollutants. Lightweight nanocomposites developed for automobiles and transp ortation help in saving fuel. Nanotechnology-based fuel cells and LED (light-emitting diodes) lighting aim to reduce environmental pollution, and help in energy generation. The conservation of fossil fuels reduces the use of materials for production. A nanoscale self-cleaning (surface coatings) material reduces/eliminates the use of many chemicals that may harm the environment. Nanotechnology also improved battery life, resulting in less use of material and less waste production (Fig. **1**) [18].

Nanotechnology for Environmental Remediation

Abatement of pollution and environmental protection are the two major concerns that need special attention throughout the world. The numbers of landfills, military setups, oil fields, manufacturing units and industrial operations are mainly responsible for the contamination of the environment. Techniques that use biological systems such as bioremediation, phytoremediation and rhizoremediation have been successfully tried to eliminate environmental pollution and restore contaminated sites. Recently nanotechnology has been applied to remediate environmental contamination, and it was termed nanoremediation, which provides an effective solution for environmental clean-up. Nanoremediation plays a significant role detection, prevention, monitoring and remediation of pollution [19]. Nanoremediation that involves the use of nanoscale particles or nanomaterials has helped in the remediation of affected sites and improved the efficiency of the remediation processes in a cost-effective manner. Contaminated

CHAPTER 11

Use of Biodegradable Polymers and Plastics- A Suitable Alternate to Prevent Environmental Contamination

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Abstract: Bioplastics are plastics that are manufactured from biomass. These polymers have become increasingly popular as a means of conserving fossil fuels, lowering CO_2 emissions and minimising plastic waste. The biodegradability of bioplastics has been highly promoted, and the demand for packaging among merchants and the food industry is fast rising. It also has a lot of potential applications in the biological and automobile industries. The plastic on the market is extremely dangerous because it is non-biodegradable and harmful to the environment. As a result, the production and usage of biodegradable polymers are becoming increasingly popular. Some of the more recent formulations, partially as a result of third-party certifications, are more compliant than the initial generation of degradable plastics, which failed to achieve marketing claims. Many "degradable" plastics, on the other hand, do not degrade quickly, and it is unclear whether their use will lead to significant reductions in a litter. Biodegradable polymers, such as poly(lactic acid), are seen as *via*ble replacements for commodity plastics. In seawater, however, poly(lactic acid) is practically non-degradable. Other biodegradable polymers' degradation rates are further influenced by the habitats they wind up in, such as soil or marine water, or when utilised in healthcare equipment. All of these aspects are discussed in detail in this chapter, including bioplastic types, applications, production, degradation, problems in landfills and sea water, fermentation, synthesis, and sustainability. This chapter, taken as a whole, is intended to help evaluate the possibilities of biodegradable polymers as alternative materials to commercial plastics.

Keywords: Applications, Biopolymers, Poly hydroxybutyrate, Poly lactic acid.

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Bhupinder Dhir (Ed.)

INTRODUCTION

Plastics have substantially replaced traditional packaging materials because of their superior physical properties, particularly strength and toughness, lightness, and barrier properties. Their capacity to keep perishable goods from rotting at a low cost has resulted in a revolution in food delivery, to the point where they are now considered necessary in modern retailing. Compared to conventional materials, plastics are also more energy efficient [1]. Paper requires double the weight of polyethylene to successfully protect goods, and if all polymers currently used in packaging were to be replaced with paper, the environmental consequences would be disastrous in terms of forest loss, increased energy consumption, and environmental harm [2, 3].

The volume of plastics, synthetic fibres, and rubber that end up in landfills is becoming a severe concern for trash management. Domestic and industrial garbage was once inexpensively disposed of in holes in the ground on the outskirts of towns and cities. The decrease in the number of such sites, along with the huge volumes of the waste, has resulted in an unacceptably high cost of transporting packaging wastes to available dump sites. There is also a growing awareness that waste should be treated as a resource that may be re-used by recycling it into usable items rather than burying it. Plastic trash is also a direct threat to wildlife, with many different species having been identified as being harmed by it. For most animals, the main risks connected with plastic materials are entanglement in and ingestion of those items [4]. Plastic waste entangles juvenile organisms in particular, causing serious harm as the animal matures [5, 6]. It restricts their movement, preventing animals from adequately feeding and breathing [7].

Biodegradable polymers provide a possible solution to this problem. As biodegradable polymers are generally obtained from natural sources, they are usually referred to as "biopolymers" (Fig **1**) [8]. Biodegradable biopolymers are few and far between on the list of biopolymers. Plastics like PLA, PHA, and starch are the most often utilised biopolymers that have little to no impact on the environment's rising carbon footprint.

TYPES OF BIOPOLYMERS

The most common and widely available biopolymers can be divided into four groups Fig. (**2**).

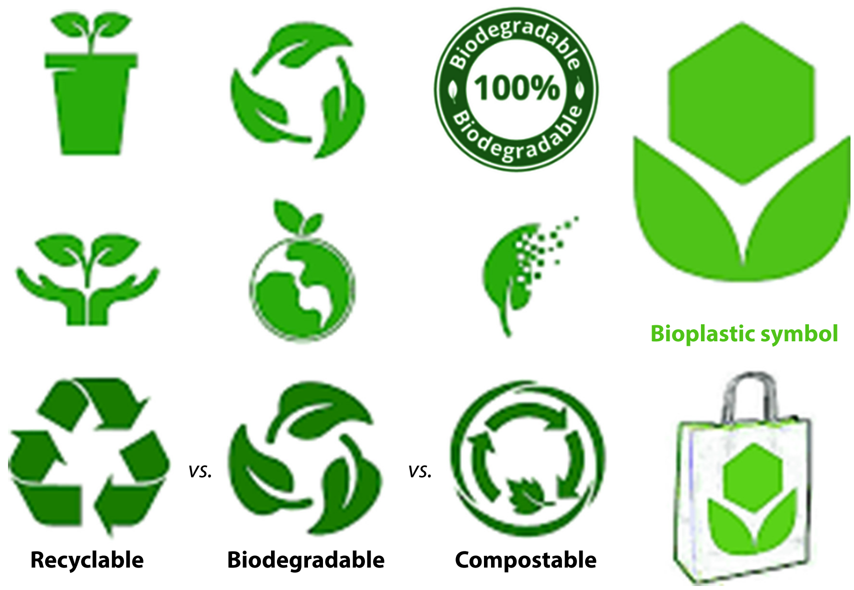

Fig. (1). Bioplastic symbol.

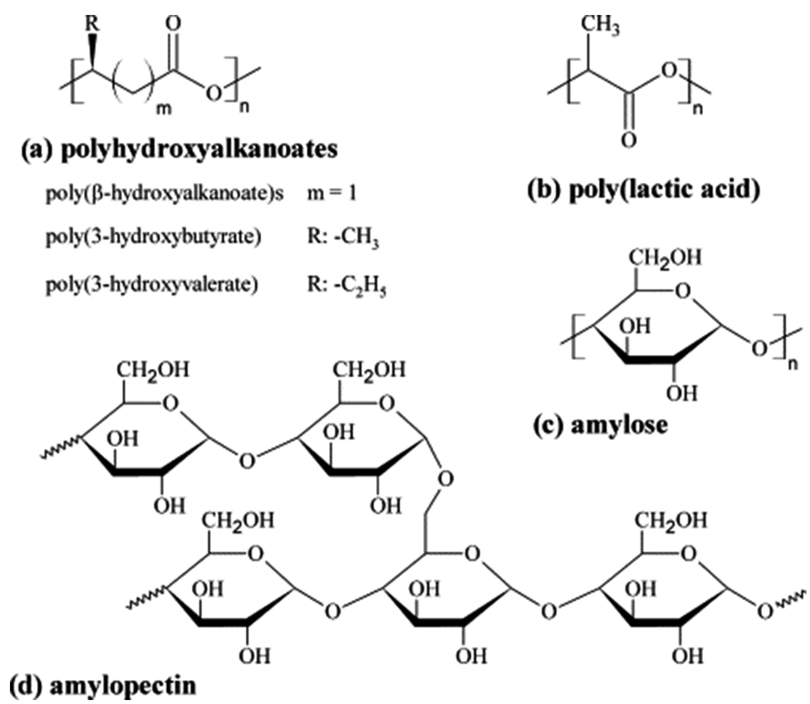

Fig. (2). Biopolymers.

CHAPTER 12

Role of Alternate Fuels (Bioethanol and Biodiesel) in Preventing Environmental Degradation

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Abstract: The diminishing quantity of fossil fuels and environmental degradation lead to the search for renewable and environmentally friendly fuels that can substitute petroleum. The burning of petroleum products releases gases that pollute the environment, hence need for alternate fuels was realized. Biofuels such as biodiesel and bioethanol derived from food crops, biomass, algae, vegetable oil, animal fats, or lignocellulosic materials are renewable, biodegradable and non-toxic. They possess low quantities of sulfur, polycyclic aromatic hydrocarbons, and metals and are considered eco-friendly. Biotechnological methods have been adapted to increase the production of crop plants that are used in the production of biofuels. Genes encoding for enzymes that degrade lignin, an important component of food crops,have also been inserted in food crops so that processing can be made easier for getting increased production of biofuels.

Keywords: Biodiesel, Bioethanol, Biofuels, Biotechnology, Eco-friendly, Lignin.

INTRODUCTION

Depleting reserves of fossil fuels due to the rise in population has generated interest in the search for alternate renewable sources of fuels. Liquid or gaseous fuel is derived from renewable feedstocks, and biomass is referred to as biofuel. Biofuels mainly include bioethanol, biodiesel, alkanes, and various other hydrocarbon mixtures. These fuels are environmentally friendly and are expected to reduce dependency on fossil fuels such as petroleum. Biofuels reduce the effect of global warming as they do not produce greenhouse gas emissions hence protecting the environment. Hence biofuels have emerged as a safe, clean, eco-friendly, sustainable solution to energy. Biofuels offer sustainable alternatives to petroleum [1].

Biodiesel and bioethanol are the primary biofuels [2, 3]. Biodiesel acts as an alternate fuel to diesel while bioethanol can be used instead of petrol. Corn

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ethanol and biodiesel are referred to as first-generation biofuels. They are largely made from food crops such as cereals, sugar crops, and oil seeds [4]. To overcome limitations such as environmental and social concerns, “next-generation,” *i.e.*, second- and third-generation biofuels are being developed from non-edible lignocellulosic materials [5]. Woody biomass, wood wastes, crop residues, municipal wastes, and energy crops such as switchgrass and algae are some of the lignocellulosic feedstocks. Agricultural, forestry residues, municipal solid wastes, industrial wastes, and terrestrial and aquatic crops grown solely for energy purposes form the major resources for biomass.

Biodiesel

Biodiesel is a fuel obtained from vegetable oils and animal fats. Some of the oilseed crops used in biodiesel production include rape, sunflower, palm and soybean [6, 7]. Algae and cyanobacteria as also used as a source of biodiesel. Feedstocks from waste animal fats, rapeseed oil, sunflower oil and palm oil are also used in biodiesel production [8]. Biodiesel (B100) is composed of mono-alkyl esters of long-chain fatty acids. Transesterification of oils or fats obtained from plants/animals or alcohols such as methanol, ethanol derived from vegetable oils or animal fats produces biodiesel. Fuel made up of 100% esters of fatty acids is called pure biodiesel (B100). Esters of fatty acids when mixed with diesel in the ratio of 20% form B20 (*i.e.*, 20% B100 and 80% diesel). Similarly, B5 (5% B100) and B2 (2% B 100) can also be formed.

Biodiesel is produced *via* the transesterification of oils along with alcohols (such as methanol or ethanol) or by the esterification of fatty acids. A chemical process called transesterification helps in the production of biodiesel. A catalyst such as an alkali or acid helps in transesterification, and glycerol is formed as a byproduct. The process of transesterification converts fats and oils, *i.e.*, triglycerides, to their corresponding fatty acid methyl esters (FAME) or methyl esters in a very short time. The process of transesterification is used for the production of biodiesel on a commercial scale [9].

Vegetable oils are the main feedstocks used for biodiesel production in the United States of America. Feedstocks such as raw vegetable oils, used cooking oils, yellow grease and animal fats are also used for transesterification. About 2.6 billion gallons of biodiesel were produced by the US in 2018. Oilseed rape is used as the main source of biodiesel in UK. Biofuels make up to 5% of petroleum blends in UK. The United States produced about 1.7 billion gallons of B100 in 2019. Europe is also one of the biggest producers of biodiesel. Fleet vehicles in the European Union and the United States currently use E-diesels (blends of ethanol in diesel) as fuel. In E-diesel, ethanol is immiscible in diesel over a wide range of temperatures, becoming its major drawback.

Biodiesel is a renewable, safe, biodegradable and nontoxic fuel. It leads to less pollution in comparison to conventional petroleum or diesel. The use of biodiesel reduces the emission of gases, such as CO_2, carbon monoxide, nitrogen oxides (NO_x), particulate matter and other chemicals such as hydrocarbons, aromatic hydrocarbons, alkenes, aldehydes and ketones. Hence proves very useful in environmental protection. It also reduces the emission of SO_2 because it is low in sulfur content. A reduction in the release of exhaust emissions by about 45% has been noted after the use of a 20% blend of biodiesel, *i.e.*, B20. A significant reduction in greenhouse gases (~ 86 percent), hydrocarbon emissions (~67 percent), particulate matter (~47 percent) and smog has been noted after the use of biodiesel [10]. Biodiesel can be used in any engine without modification. It acts as an alternative to fuel additives such as methyl tertiary butyl ether (MTBE). Advantages such as good economic potential, low emissions and high efficiency make biodiesel a good option for the replacement of fossil fuels.

Bioethanol

Bioethanol is an environmentally friendly alternative petrol additive/substitute. It is produced from starch, feedstocks based on sugar crops (such as corn, and sugar cane) or cellulosic feedstocks (wood, straw, and even household wastes). It is produced from sucrose or simple sugars *via* the process of alcoholic fermentation [11]. Starch-rich plant material gets converted to sugars and fermented to produce bioethanol. In another method, cellulose from the cell walls of stems or leaves gets converted into sugars, and fermented to produce bioethanol (Fig **1**) [9]. At present, bioethanol is being produced by the fermentation of sugar by microbes. Microbes use sugar as a source of food and convert it to ethanol [12, 13]. Hence bioethanol is derived mainly from biological feedstocks that contain a good amount of sugars that easily get fermented. The plant material is treated with sulphuric acid and heated to convert cellulose into sugars, or cellulose is treated with enzymes. Lignocellulosic materials are subjected to biochemical and thermochemical treatment that breakdown biomass into cellulose and other polymers, which undergo hydrolysis and fermentation [14, 15].

A pretreatment step of chemical or enzymatic hydrolysis is done to the lignocellulosic feedstock to remove the lignin present within it [16]. In the method of chemical hydrolysis, acid is used to break sugar molecules of the feedstock, whereas, in enzymatic hydrolysis, enzymes help in the breakdown of lignocelluloses of cellulose. The process of chemical pretreatment is fast, and con-

CHAPTER 13

Remediation of Heavy Metals Using Biochar and its Modified Forms

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Abstract: Heavy metal contamination has affected various life forms on earth due to their toxic, carcinogenic and bio-assimilative nature. Heavy metals are rapidly transported by various water bodies in our environment. Thus, the remediation of heavy metals in water bodies is essential for sustaining our ecosystems. The treatment technologies available for treating the heavy metals undergoing dynamic biochemical transformations in the environment are a challenge as well as an opportunity for developing alternate cost-effective technologies. Adsorption has emerged as an environment-friendly and cost-effective technology. Biochar, a sustainable and low-cost adsorbent, has shown encouraging results for the remediation of these environmental contaminants. It stands out as a promising adsorbent due to chelating functional moieties apart from high surface area and porosity. These physicochemical attributes of biochar can be modulated using various physicochemical treatments to achieve higher heavy metal removal efficiencies. Biochar is a carbon-neutral material, which can be regenerated and disposed-off easily in an adsorption-based remediation process. This chapter brings out the modifications characteristic of biochar, a comparative statement of properties *vis-a-vis* biochar and their use in the adsorption of heavy metals, and various mechanisms accounting for their removal.

Keywords: Adsorption, Biochar-modifications, Heavy metals, Remediation.

INTRODUCTION

Heavy metal contamination has now spread to almost every part of the ecosphere, affecting various biotic and abiotic components. The main sources of these contaminants include anthropogenic sources, such as industry, mining, pesticide application, metal processing and natural sources. Due to their widespread use, heavy metals can easily enter aquatic systems, soil and atmosphere, thereby impacting human health. These pollutants are toxic, non-biodegradable and have a

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tendency to bioaccumulate in nature, thus are placed in the category of extremely dangerous contaminants. Various technologies are available for the environmental treatment/remediation of heavy metals. Some of these include adsorption, chemical precipitation, membrane techniques, ion exchange, reverse osmosis and electrochemical methods [1, 2]. However, these methods have many drawbacks and restrictions, such as high cost, production of secondary pollutants, sludge production and disposal problems, skilled labour requirements, and excessive use of chemicals. Of these processes, adsorption offers advantages over high operational costs and environmental risks posed by other technologies. It is highly effective, easy to operate and an efficient process. Flexibility in design makes it one of the most used processes for heavy metal removal. By definition, adsorption is a physicochemical process used for the removal of organic and inorganic pollutants from water and wastewater with the help of a substance called 'adsorbent'. Various adsorbents like zeolites, clay, activated carbon and biomass have been used to remove contaminants. Activated carbon is frequently used for adsorption. It is considered an ideal adsorbent, but its high cost restricts its usage for large-scale applications. So, the focus has shifted to low-cost and renewable materials derived from biomass. Biochar is one such material that has gained worldwide attention among researchers. It is an effective and cheap adsorbent. Properties like well-developed pore structure, abundant functional groups and large surface area make it a favorable material for the adsorption of water-based contaminants [3, 4].

BIOCHAR

The concept of 'biochar' is supposed to have come into existence around 2500 years back with the discovery of Terra Preta in the Amazon basin. These are dark-coloured, carbon-rich, and highly fertile soils of anthropogenic origin found at a depth of two meters. It is believed that civilizations that inhabited the Amazon basin used to smolder the biomass in deep earthen pits instead of burning it, which gave rise to Terra Preta soils. This technique eventually led the way to the production of biochar.

Research on these soils highlighted the benefits of biochar on soil systems [5], and gradually, it emerged as an environment management tool [6]. In modern science, biochar is produced by the thermal degradation of biomass under oxygen-limited conditions with temperatures ranging from 300-700°C and is a highly aromatic, carbon-rich and stable product [7].

Biochar can be produced from a variety of lignocellulosic materials like straw, leaves, wood chips, grass, roots and kitchen and garden waste using various biomass conversion technologies like pyrolysis, hydrothermal carbonization, torrefaction and gasification. Among these methods, pyrolysis is a relatively simpler and most common technique which yields solid product (char), condensable vapours (bio-oil), and non-condensable gaseous fraction. The process involves heating biomass in the absence of oxygen. The pyrolysis process is mainly of two types- fast and slow pyrolysis.

Fast pyrolysis operates at higher temperatures (~500°C) and high heating rates (100-1000°C/s) followed by fast cooling to allow rapid quenching of the vapours formed during the process so as to minimize secondary reactions that can form additional products [8]. The main product of fast pyrolysis is a viscous liquid called bio-oil which consists of organics and water (20-25 wt %). However, biochar production from fast pyrolysis is not preferred as it leads to a larger fraction of biomass converted to bio-oil resulting in poor yield of biochar.

Slow pyrolysis works at low temperatures (400-700°C), longer residence time (>1hr) and heating rates between 5-7 °C/min. Around half of the total carbon present in the feedstock is retained in biochar produced *via* slow pyrolysis [9]. The process also yields bio-oil and gases like H_2, CO_2, CO, and CH_4. Slow pyrolysis can be carried out in reactors like kilns, retorts and converters [10]. Reactors based on heat pipe technology have been used recently for pyrolysis [11, 12]. Constant temperature at any point in the heat pipe makes it better technology than other existing technologies. Depending upon the different pyrolysis conditions like heating rate, residence time, and temperature, the final desired product can be obtained.

The quality and yield of biochar depend upon feedstock type and pyrolysis temperature. Researchers emphasized the influence of both these parameters on biochar, particularly for their application in adsorption studies [13, 14]. Lignocellulosic biomass is mainly composed of lignin, cellulose and hemicellulose. A higher yield of biochar is obtained from biomass with higher lignin content, like wood, as compared to herbaceous biomass. On the other hand, the surface area of wood biochars is higher (62 to 240 m^2/g) and contains lesser functional groups compared to crop residue biochars (0.17 to 68.5 m^2/g) when pyrolyzed at the same pyrolysis temperature [15]. Among crop residues, straw-derived biochars have high ash content due to the high inorganic content in feedstock. It is further observed that the inorganic content of the biochar, particularly alkali and alkaline metals, catalyzes biochar formation [16]. The moisture content of biomass also has an effect on its production, as biomass with higher moisture content yields a higher proportion of biochar under high-pressure conditions [17]. Another property that varies depending on feedstock is pH, which is higher for crop residue-derived biochars than wood biochars because of the higher concentration of alkali and alkaline metals in their precursors [15].

CHAPTER 14

Contribution of Green Technologies in Getting Sustainable Environment

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Abstract: Green technologies provide an eco-friendly and sustainable alternative to conventional technologies. Conventional technologies used for combating pollution show certain limitations and drawbacks. Green technologies have been accepted worldwide for their advantages, such as easy availability, less environmental harm and sustainability. In recent years, solar, wind, geothermal energy, and alternate fuels, such as biogas and biodiesel, have emerged as eco-friendly alternatives to conventional energy sources and fuels. Green technologies, such as developing eco-friendly and recyclable products, have restricted the release of greenhouse gases, generation of waste, and exploitation of natural resources to a great extent. Green technologies thus provide a sustainable option to prevent environmental degradation and over-exploitation of natural resources. Carbon-neutral alternatives have the potential to meet the needs of present and future generations. The production of clean energy is one of the major approaches to get a sustainable environment. Developing clean and environmentally friendly carbon-neutral alternatives can prove useful in meeting the needs of the fuels of present and future generations.

Keywords: Biodiesel, Biofuels, Geothermal energy, Green products, Solar energy, Wind energy.

INTRODUCTION

Scientific and technological innovations, though, have improved the standard of living but have resulted in the over-exploitation of natural resources and environmental degradation. Global warming, climate change, and frequent occurrence of natural disasters have affected environmental sustainability. Therefore, an urgent need to develop sustainable and eco-friendly technologies was realized. Green technologies have emerged as eco-friendly alternatives to conventional technologies.

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A technology that aims at conserving natural resources and the environment is referred to as Green technology (GT). In other words, it is defined as the technology that aims at fulfilling the needs of society by developing products, equipment, and systems that help to conserve the environment and resources without compromising the needs of future generations [1]. The uses of green technologies help us reduce the use of fossil fuels, waste and pollution, conserve natural resources and play an important role in protecting the environment. Green technologies also help monitor, assess, remedy, and restore the environment. Green technology is also known as sustainable technology.

Some green technologies include bio-fuel, eco-forestry, alternative energy sources such as renewable energy, green products, recyclable products (eco-friendly), cleaner fuels, and solid waste management. Green technology aims to minimize resource use, generate waste, conserve natural resources, and reduce human involvement.

The affordability of this technology is the main reason behind wider acceptance, especially in developing nations. Technological innovations possess great potential to maintain environmental sustainability [2].

GREEN TECHNOLOGIES

Some of the major green technologies have been discussed below.

Green Products or Green Manufacturing

Green products are developed to reduce waste and maximize resource efficiency. They are manufactured using toxic-free ingredients and environmentally-friendly procedures. Common examples of green products include solar panels and thermal heating discs. Solar panels heat the sun to generate electricity and can be installed in homes, apartments, and commercial buildings. Thermal heating discs work on the principle of trapping the rays of the sun. Green products provide an alternative to minimizing fossil fuel use [2].

Green chemicals form an important part of green technology. These products do not contain toxic chemicals and reduce water pollution, hence are eco-friendly. Some of the characteristics of green products are that they

- Do not produce toxic chemicals and within hygienic conditions
- Can be recycled, reused and is biodegradable
- Are produced without the use of fewer resources
- Possess less or zero carbon footprint
- Possess less or zero plastic footprint

Examples of such products include cleaning agents and green laundry detergent made of coconut and glycerin, insecticides made from orange or peppermint oil, reusable water bottle development, and microemulsions (aqueous) as cleaning agents for (an alternative to VOCs). Wooden cutlery made with bamboo fiber and handmade watches made from wood is other green products.

Eco-Friendly Products

Eco-friendly products have been developed to maintain sustainable use of materials and save energy. Some of them have been described below.

An E-reader has been developed for people who buy new books frequently. We can reduce the paper that is used in the printing of books. The use of an E-reader helps in reducing the cutting of trees. Rocket book Everlast Reusable Smart Notebook, developed in the US can be used to write and reused many times after wiping and cleaning. Eco Tool's air hairdryer, made from bamboo, recycled aluminum, and plastic, helps dry hair faster (40%) and causes less heat damage. The 100% tree-free packaging paper is also used worldwide. Chic-made bags made from recycled materials also come in the eco-friendly products category. Biodegradable trash bags are normally easy to compost and hence safe for the environment. They are 100% compostable and are BPI certified. Bamboo-made washcloths and makeup removers are now an eco-friendly alternative in houses and parlors. They do not harm sensitive skin and are hypoallergenic and antimicrobial. Reusable makeup remover pads made from organic bamboo fibers are getting more popular daily. Toothbrushes made from bamboo are stronger and cheaper than plastic. LED light bulbs convert 95% of energy into light, and only 5% is wasted as heat. They also use less energy, saving money. Biodegradable Garden Pots made from recycled material decompose easily. They help in reducing the use of plastic and rubber that cause pollution. Recycled Floor Mats made from natural, reclaimed, or recycled rubber material. Ballpoint pens made from recycled plastic bottles. The B2P (Bottle-2-Pen) pens are retractable and refillable. Reusable coffee cups and lids help reduce a significant amount of single-use plastic waste. Eco-friendly phone cases made up of sustainable bioplastics that are completely (100%) compostable. Eco-friendly dishwasher reduces the usage of energy and water to half the amount. This green product benefits the environment and helps consumers save a lot. A programmable thermostat is a green technology product that can set a schedule and automatically adjust the temperature to save energy.

Ecofriendly vehicles that do not emit gases have also been developed. They help in reducing the gases such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), sulphur dioxide and hydrocarbon compounds (HC) in the

CHAPTER 15

Techniques in Prevention, Detection and Monitoring of Environmental Contaminants

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Abstract: Pollution in various sectors of the environment has produced a threat to human health and aquatic ecosystems. Biosensors play an important role in the detection of toxicants such as heavy metals. Efforts have been made to develop sensitive and efficient sensors for monitoring the presence of contaminants in the environment using nanotechnology and bioengineering techniques. Biosensors, in particular, help in monitoring the presence of pollutants in the environment, protecting our environment. Enzyme, DNA, imuno and whole cell-based biosensors have been developed and work depending on the reaction type, transduction signal, or analytical performance. Advantages such as specificity, low cost, ease of use, and portability establish biosensors as an efficient technique that can be used to detect the presence of various inorganic and organic contaminants.

Keywords: Biosensors, Heavy metals, Electrochemical sensors, Enzymes.

INTRODUCTION

Toxic compounds and contaminants present in soil and water cause threats to ecology and human health [1-3]. Therefore, one needs to develop precise methods for their detection and quantitation. Inorganic, organic and radioactive compounds present in the environment need to be monitored/ traced so that they can be treated effectively and living beings and the environment can be protected from damage and their harmful effects [4 - 7]. Monitoring of air, water and soil (major environmental components) is important to find out the current status of environmental damage/deterioration [8]. Environmental monitoring helps us in assessing the impact of human activities on the environment, and thus enables us to protect the environment.

High-performance liquid chromatography (HPLC), gas chromatography (GC), mass spectroscopy (MS), atomic absorption spectroscopy (AAS), emission spectr-

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oscopy, inductively coupled plasma mass spectroscopy, and various chromatographic techniques are some of the analytical methods that have been used in a routine manner to check the presence of toxicants in the environment. These methods are accurate, sensitive and reliable. Sophisticated instrumentation, sample preparation, pretreatment (pre-concentration), and long measuring time of analysis are required for their work. These methods need to be carried out by trained people. Most of these methods cannot assess the cumulative effect of various toxicants present in a sample, therefore need for the development of sensors with high specificity was realized.

Many research studies have been conducted to investigate and develop technologies that aim to reduce or detect the impact of hazardous compounds on the environment. Sensors for the rapid detection of environmental pollutants have been developed [9 - 11]. Ion-selective electrodes, biosensors and voltammetric techniques are some electrochemical methods that are used as an alternative to classical methods. These methods require less instrumentation and take less time for measurement. Biosensors have emerged as a good alternative to conventional techniques [12 - 14]. They do not require any pre-treatment of the sample, hence the analysis carried out by them is very rapid and highly sensitive. They provide real-time, high-frequency monitoring, which is very specific and accurate. Easy portability, low cost, simplicity and selectivity are some of the other advantages reported in biosensors. According to the Environmental protection Agency (EPA), bio-monitoring of pollution using biosensors is important for the implementation of preventive and remedial measures.

A device that provides quantitative or semi-quantitative information about a component using a biological recognition element is termed a biosensor. It performs specific biochemical reactions or interactions with its surrounding environment. Biosensors consist of a recognition element (enzyme, antibody, DNA), a signal-transducing structure (electrical, optical, or thermal), and an amplification/processing element. This analytical device combines information obtained by a biological sensing element, such as an enzyme or an antibody with a physical (optical, mass, or electrochemical) transducer. The target and the bio-recognition molecules interact with each other, and a measurable electrical signal is generated [15]. The biological component is used as a recognition element [16]. The interaction of the target analyte with the biological sensing element, generates a signal in the transducer which gives information related to the concentration of the analyte. The amplification of the signal is displayed by a signal processor.

The detection of an analyte takes place with the help of a recognition component of a sensor. The signal gets converted using a transducer. Various contaminants are monitored according to analytes which include trace metals, radioisotopes, volatile organic compounds, and biological pathogens. Biosensors help in the rapid and accurate detection of hazardous components.

The detection of heavy metals such as lead, cadmium, mercury, and arsenic is done using electrochemical biosensors. The heavy metal ions can also be analysed with biosensors using protein-based (enzyme, metal binding proteins and antibody) and whole cell-based approaches (genetically engineered microorganisms).

BIOSENSORS

Sensors are categorized into different types depending on the type of sensor that is used and environmental factors which are analysed. The classification of biosensors into various groups depends upon signal transduction or recognition principles. Biosensors are categorized as electrochemical (amperometric, and impedance biosensors), optical (optical fibre and surface plasmon resonance biosensors), piezoelectric (quartz crystal microbalance biosensors), or thermal sensors on the basis of the transducing component. Biosensors are classified as immunosensors, apt sensors, genosensors, and enzymatic biosensors (when antibodies, aptamers, nucleic acids, and enzymes are used). This classification is based on the type of their recognition element.

The biosensors mainly used in environmental monitoring are immunosensors and enzymatic biosensors. Apt sensors which have been developed recently, show characteristics such as thermal stability, *in vitro* synthesis, structure designing, easy modification, and capacity to distinguish targets with different functional groups. These features establish them as ideal candidates for environmental monitoring.

Optical biosensors are based on the principle of absorption of light, fluorescence, luminescence, reflectance, Raman scattering and refractive index. These sensors have found many applications in the area of environmental monitoring, food safety, drug development, biomedical research, diagnosis and control of environmental pollution [17, 18]. Enzyme-based biosensors having optical transducers represent autonomous devices that help in environmental monitoring.

Principle of Biosensors

Molecular recognition occurs when the substance that needs to be measured diffuses through the bioactive material. The process of recognition is followed by a biological reaction. The transducer converts the information obtained into a quantitative electrical signal. The signal later gets amplified, and the concentration of the substance is measured.

CHAPTER 16

Utility of Biofertilizers for Soil Sustainability

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Abstract: Modern agriculture is almost entirely reliant on the supply and utilization of agrochemicals, such as fertilizers, pesticides, and insecticides, to maintain and boost agriculture productivity. Heavy use of chemical fertilizers has resulted in numerous adverse effects on the environment and human health. Biofertilizers have emerged as an eco-friendly, inexpensive, and renewable alternative to restore, enhance, and maintain soil fertility, soil health, and crop yield. Biofertilizers are beneficial microbes, including plant growth-promoting rhizobacteria, mycorrhizal fungi, cyanobacteria, and their symbionts. Hence, the importance of biofertilizers in soil management practices for soil and crop sustainability needs to be highlighted in light of their multiple benefits, including augmenting nutrient availability in the rhizosphere, increasing nutrient uptake and recycling, supplementing soil water holding capacity, production of plant growth regulators, and soil reclamation. The challenges regarding the large-scale utilization of biofertilizers need to be emphasized to achieve sustainability in agricultural soils.

Keywords: Biofertilizers, Biotechnology, Nutrient, Phosphorus, Soil he, Sustainable agriculture.

INTRODUCTION

Currently, the global population is still increasing and it is estimated that around 2050 it will reach approximately 9.7 billion people in the world [1].With the increasing human population, food demand grows exponentially, and to cope with this problem, we have major challenges like maintaining sustainable agriculture to create a balance in the ecosystem. The unconscious application of agrochemicals and lack of knowledge regarding biodegradation ability lead to soil chelation with toxic molecules, which disturbs the soil structure, fertility, and water-holding capacity [2]. Over usage of synthetic fertilizers has been directly linked to the eutrophication of water resources [3 - 5] and the toxic build-up of heavy metals

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such as arsenic, cadmium, and plumbum [6]. The rapid growth in the world population has been the key factor in the explosion of intensive industrialization, urbanization, and agricultural production. The nutritional requirements of the present world population cannot be achieved by traditional agriculture practices, and these methods are incapable of making the countries self-sufficient [7 - 9]. Conventional agricultural practices based on the extensive application of synthetic fertilizers and pesticides are applied to enhance crop productivity and make the crop disease resistant [10]. Unfortunately, both these methods directly or indirectly consist of a high risk to the environment as they expose the water table, air, and soil stratum to these toxic chemicals [11]. The unconscious application of agrochemicals and lack of knowledge regarding biodegradation ability lead to soil chelation with toxic molecules, which disturbs the soil structure, fertility, and water-holding capacity [2]. Over usage of synthetic fertilizers has been directly linked to the eutrophication of water resources [3 - 5] and the toxic build-up of heavy metals such as arsenic, cadmium, and plumbum [6]. The rapid growth in the world population has been the key factor in the explosion of intensive industrialization, urbanization, and agricultural production. The nutritional requirements of the present world population cannot be achieved by traditional agriculture practices, and these methods are incapable of making the countries self-sufficient [7 - 9]. Conventional agricultural practices based on the extensive application of synthetic fertilizers and pesticides are applied to enhance crop productivity and make the crop disease resistant [10]. Unfortunately, both these methods directly or indirectly consist of a high risk to the environment as they expose the water table, air, and soil stratum to these toxic chemicals [11].

Eco-friendly practices like organic farming are a promising method over conventional agriculture, which can reduce the dependence on toxic chemicals and can enable chemical-free food production in addition to maintaining the high quality and biodiversity of soils [12]. Present-day agriculture is shifting more towards organic agriculture, and a considerable amount of growth from 11 million hectares (1999) to 57.8 million hectares (2016) has been recorded in the area of organic agriculture [13, 14]. Biofertilizers seem to be a promising approach in order to attain sustainable agriculture, and it utilizes live microorganisms such as microbial strains to enhance plant growth and development. Microbial strains employed a plethora of mechanisms such as nitrogen fixation, potassium, and phosphorus solubilization, flushing of excess phytohormones, beneficial plant-pathogen interactions, alle*via*ting abiotic and biotic stresses, and sequestration of soil soluble pollutants to enhance soil fertility and crop yield. Present-day agriculture practices involve heavy usage of chemical fertilizers and pesticides, which has created a disorder in the ecological cycle. Microbial inoculants are a promising and non-toxic way to overcome these potent biological hazards.

Biofertilizer application has been showing promising outcomes as it utilizes the strains of microorganisms having beneficial properties to reduce the problems arising from the use of mineral fertilization [15]. These microbial strains have the potential to make agricultural practices sustainable as they enhance plant growth and development by enriching native nutrient (N,P, K, S, Zn) concentrations and bioavailability (Fig **1**) [16]. Moreover, it also minimizes the mycotoxins contamination as these strains pose antibacterial and/or antifungal activity [16]. Previous reports have been suggesting the crucial role of biofertilizers in sustainable agriculture as they enhance the activity of indigenous microorganisms present in the soil [17], activate the plant growth stimulants, induce abiotic and biotic stress tolerance mechanisms, maintain the soil pH, metabolize complex chemical compounds into simple assimilate forms [18] and sequester soil pollutants such as heavy metals [19], atrazine [20] or pesticide mixtures [21]. Various other properties and roles of biofertilizers are represented in Fig. (**1**).

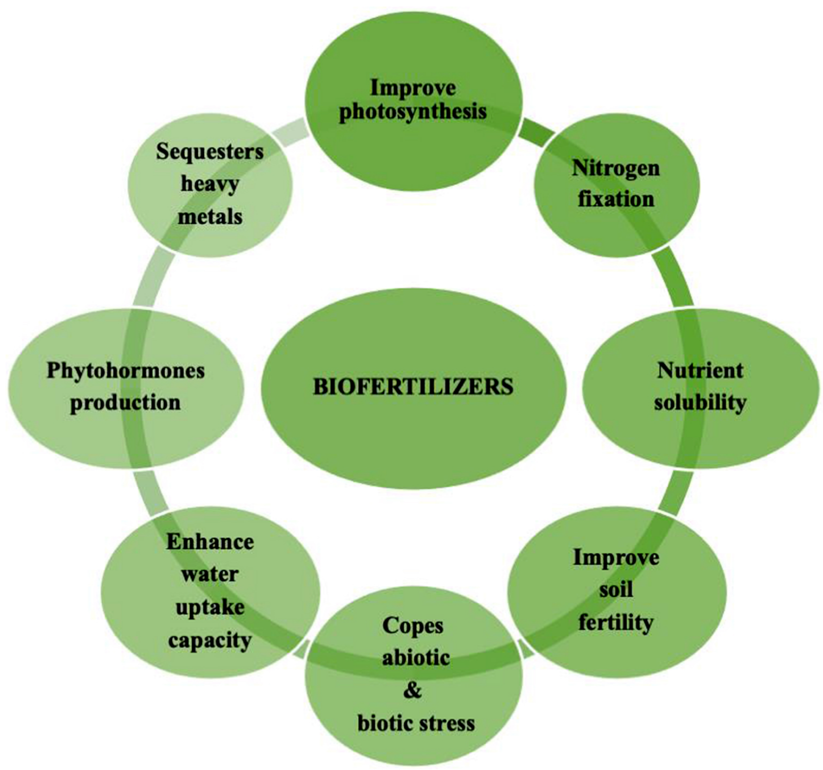

Fig. (1). Diagrammatic overview of various roles and properties of biofertilizers for soil sustainability and sustainable crop production.

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