The Use of Environmental Biotechnology: A Tool to Progress Towards Sustainable Development Goals

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Abstract

Environmental biotechnology is the use of science and technical knowledge to remediate and rebuild the environment after it has been harmed. Environmental biotechnology grew in significance and breadth in the 1980s, as a result of the establishment of industry guidelines, regulation of conformity, and the introduction of laws for environmental protection. Biotechnology for the environment is not a modern field of research. It has been around for decades, and we are associated with some of the older innovations, such as wastewater treatment and compositing. In addition, novel approaches to harnessing the promise of biotechnological methods continue to gain traction in practice. This chapter examines the state-of-the-art and prospects of environmental biotechnology, as well as the many fields that it encompasses, as well as the challenges and consequences that come with them. The role of some bioprocesses and biosciences for environmental protection, regulation, and health centered on the use of living organisms is examined in light of the numerous issues that describe and expand the field of environmental biotechnology. Innovative new techniques that advance the use of various approaches like molecular ecology, biomarker, etc. will be taken into account. In order to increase their effectiveness, productivity, and versatility, these approaches will enhance the understanding of current biological processes. The contribution of environmental biotechnology to the creation of a more sustainable society is also significant.

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S. Arora et al. (eds.), *Innovations in Environmental Biotechnology*,
https://doi.org/10.1007/978-981-16-4445-0_1

Keywords

Environmental biotechnology · Bioremediation · Sustainable development

1.1 Introduction

The environment can be a complex combination of several factors, such as both the physical and biological surroundings, as well as their relationships. Each organism is affected by environmental issues such as ozone depletion, heating, overpopulation, decrease of natural resources, habitat destruction, and so on. We are vulnerable to floods and tragedies as a result of current environmental issues, both now and in the future. Only by comprehending relationships between different living species as well as physical and chemical phenomena will the threatened status of environmental health be modified. Environment pollution and climate change influence each other through complex interactions on Earth. It is essential to study the relevant areas and contribute new knowledge in the fields of the environment and climate. The major reason for climate change is greenhouse gases. Greenhouse gases emission has increased dramatically in recent years due to human activity and natural factors like volcanic eruptions. These gases accumulate in the atmosphere and causing concentrations to increase within time (Kumar 2020a, b). Environmental biotechnology is frequently regarded as a driving force for integrated environmental conservation that leads to long-term sustainability. Sustainable development is described as change in human well-being that will last for several decades rather than just a few years. In order to integrate environmental policy and growth strategies in a global context, a structure is needed. These fields are broadly divided into two categories: environmental sciences and biotechnology. Environmental biotechnology is sustainable because it has a wide capacity to lead to the reduction, identification, and remediation of environmental contamination and waste depletion. It does so by creating renewable processes and materials that are less toxic and have a lower impact on the environment than their predecessors. Its position is critical in the manufacturing, agroforestry, food, raw material, and mineral sectors when it comes to green technology options. Environmental biotechnology is the branch of biotechnology that addresses environmental problems, like the removal of pollution, renewable energy generation, or biomass production, by exploiting biological processes. Environmental biotechnology is often applied to detect, prevent, and remediate the emission of pollutants into the environment in a number of ways. Replacing chemical materials and processes with biological technologies can reduce environmental damage. The International Society for Environmental Biotechnology defines environmental biotechnology as the event, use, and regulation of biological systems for remediation of contaminated environments (land, air, water) and for environment-friendly processes (green manufacturing technologies and sustainable development).

1.2 Role of Biotechnology in Development and Sustainability

"The introduction of a biological organism, device, or processor to manufacturing and service industries" is how biotechnology is characterized. Biotechnology is described as "the application of science and engineering principles to the production of materials by biological agents to provide products and services" by the Organisation for Economic Co-operation and Development (OECD). Modern biotechnology enables us to fight detrimental and unusual diseases; reduce our environmental impact; feed the poor; use fewer and cleaner resources; and create better, cleaner, and more productive modern production processes.

The responsible use of biotechnology to promote economic, social, and environmental benefits is inherently appealing, and it has resulted in a spectacular evolution in research from traditional fermentation technologies to modern techniques to provide efficient synthesis of low toxicity products, renewable bioenergy, and the need for alternative chemicals and feedstocks fielding new techniques for environmental protection. Figure 1.1 depicts six major biotechnology subfields in relation to these application domains.

- Green biotechnology
- Red biotechnology
- White biotechnology
- Blue biotechnology
- Golden biotechnology
- Grey biotechnology

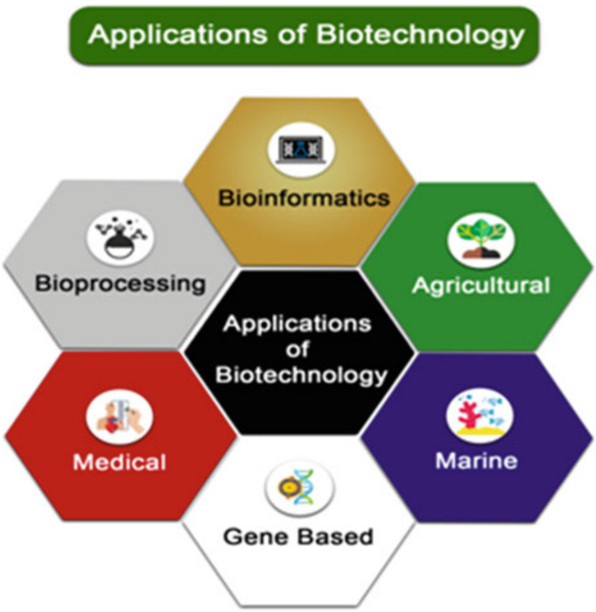

Fig. 1.1 Application of biotechnology in divergent field

This chapter focuses on the developments of biotechnological processes for environmental protection and control, as well as growth expectations and new developments in the field, taking into account the possibilities for environmental biotechnology to contribute with innovative solutions and directions in reclamation and monitoring of contaminated environments, as well as minimizing future waste release and pollution creation.

1.3 Objectives of Environmental Biotechnology (According to Agenda 21)

Environmental biotechnology aims at avoiding, stopping, and restoring environmental degradation by the appropriate use of biotechnology in conjunction with other innovations, while at the same time endorsing protection practices as a key component of the program-relevant goals, which are as follows:

1. Recycling biomass, recovering energy, and minimizing waste generation to implement production methods that allow optimum use of natural resources.
2. Fostering the use of biotechnological methods with an emphasis on bioremediation of land and water, waste treatment, soil conservation, reforestation, afforestation, and land rehabilitation.
3. Applying biotechnological processes and their products to preserve the quality of the ecosystem with a view to long-term environmental protection.

Animals, fungi, bacteria, and other living organisms absorb nutrients to survive and create waste as a by-product. Different types of nutrients are required by various organisms. Some bacteria may tolerate the chemical components of waste materials. Many microorganisms eat substances that are poisonous to others. Recombination research has opened up new avenues for environmental protection and promises to expand bioconversion in the future. Figure 1.2 depicts the different causes of emissions in the area.

1.4 Implementation of Environmental Biotechnology

Protection of the planet is an integral element of sustainable development. Every day, the world is endangered by man's actions. If the use of chemicals, oil, and nonrenewable resources continues to grow as the global population grows, the related environmental concerns are also growing. Despite increasing efforts to avoid the accumulation of waste and encourage recycling, the amount of environmental damage caused by overconsumption is created by the quantity of waste. To some extent, the remedy can be achieved by applying environmental biotechnology techniques which use living organisms in the treatment of hazardous waste and in the control of pollution. A wide variety of uses are covered by environmental biotechnology, such as bioremediation, prevention, identification and tracking, genetic

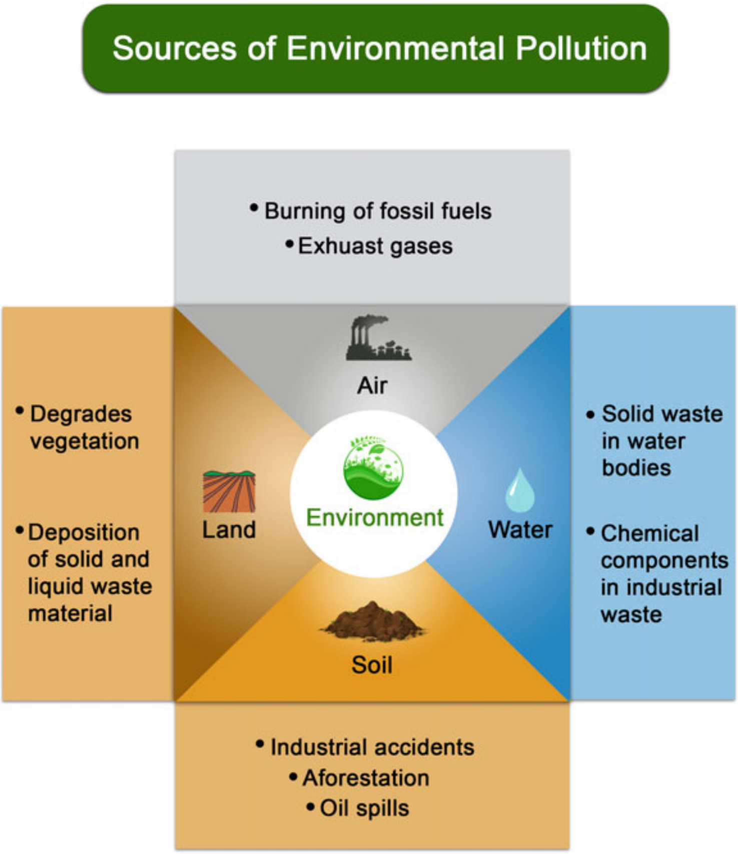

Fig. 1.2 Sources of environmental pollution

modification for sustainable development and enhanced quality of life as shown in Fig. 1.3.

1. Bioremediation
2. Biomarker
3. Biotransformation
4. Bioenergy
5. Molecular ecology
6. Biosensor

1.4.1 Bioremediation

Bioremediation is the process of using microorganisms to degrade toxins that are harmful to the atmosphere and humans. Bioremediation processes typically involve

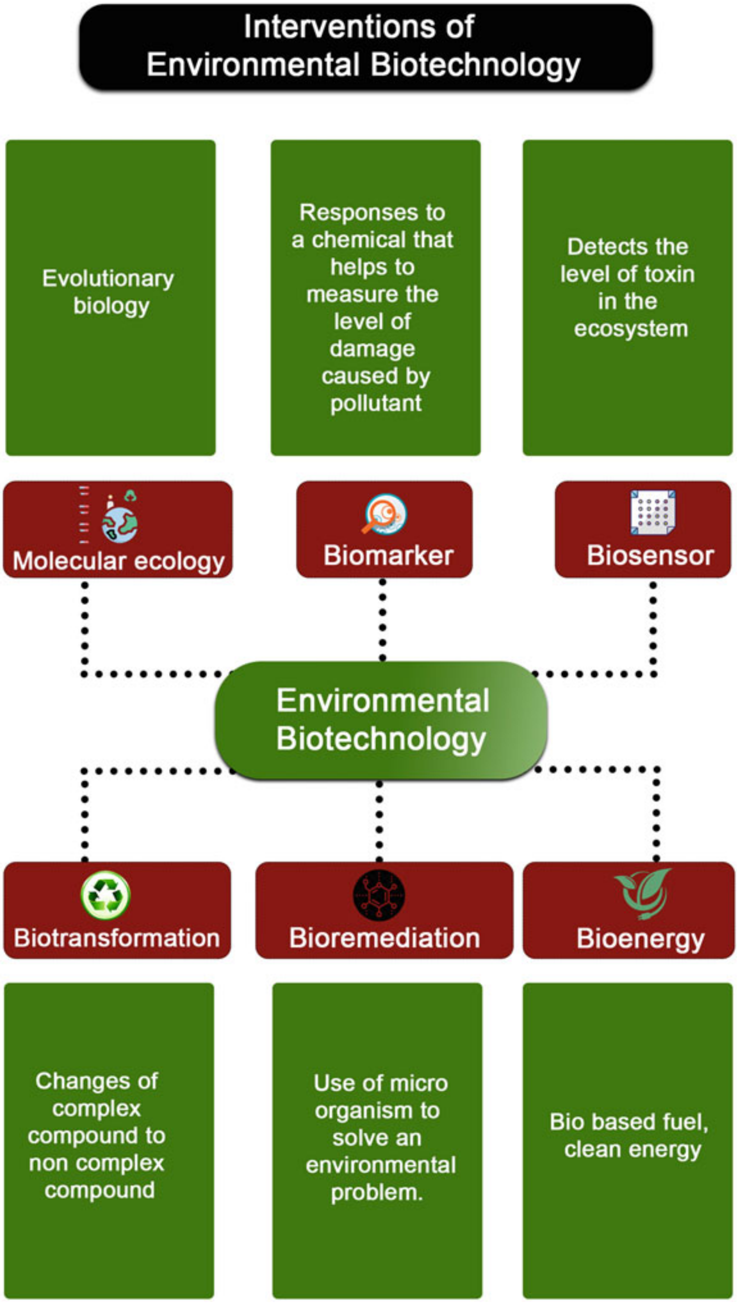

Fig. 1.3 Implementation of environmental biotechnology

the actions of several separate microbes operating in parallel or sequence to complete the degradation process. Both in situ (in place) and ex situ (out of place) remediation techniques are used (removal and treatment in another location). The versatility of microbes to degrade a wide range of contaminants renders bioremediation a technology that can be used to degrade pollutants that face environmental and human risks. Different microbes operating in tandem or sequence are alluded to in bioremediation. Changes in pH, moisture, aeration, or the incorporation of electron donors, electron acceptors, or nutrients may all be used to stimulate biostimulation. Bioaugmentation is a bioremediation technique in which microbes with high oxidation abilities are used to inoculate the polluted site. These two methods are not mutually exclusive; they can both be used at the same time.

Microorganisms use a series of mechanisms to transform chemicals in their system. In some cases, contaminants function as carbon and energy sources for microbial development, whereas in others pollutants serve as terminal electron acceptors. This is manifested in microbes' diverse ability to transform and degrade poisonous molecules. The phases and explanations of microorganism behavior are described below.

1.4.1.1 Factors Affecting Rates of Biodegradation

Temperature, pH, precipitation, carbon inputs, soil composition, aerobic versus anaerobic environments, the number of substituent, and the pollutant concentration can all affect biodegradation. However, making a broad generalization regarding the best universal conditions for biodegradation is difficult. In aerobic conditions, more substituent means slower degradation, whereas in anaerobic environments more substituent means quicker degradation.

1.4.1.2 Primary Substrate Utilization

Primary substrate usage happens when a microbe both converts and uses a substrate as an energy or carbon source. An electron acceptor is required for these transformations. It can be anaerobic or aerobic, with the presence of oxygen seeming to speed up reactions. This form of biodegradation is known to break down petroleum compounds and certain pesticides.

1.4.1.3 Co-metabolism (Utilization of Secondary Substrates)

Co-metabolism necessitates an organism's fortuitous conversion of a compound where the organism's main source of energy or carbon is a different substance. During the actual reaction that degrades the substance, the organism tends to gain little net carbon or energy production, and can even produce a chemical that is toxic to the cell. Co-metabolism is exemplified by fortuitous metabolism in the oxidation of trichloroethylene.

1.4.1.4 Bioremediation Techniques

The degradation of toxins needs ample evidence for bioremediation to be effective. Bioremediation effectiveness is determined by a combination of abiotic and biotic factors. Current laboratory procedures consider the disappearance of toxins and their

Table 1.1 Types of bioremediation and its mechanism

Technology	Types	Mechanism
In situ	Biostimulating	The alteration of the atmosphere to stimulate existing bacteria capable of bioremediation requires biostimulation
	Biosparging	It is the method of introducing the atmospheric oxygen to site through aquifers
	Bioaugmentation	Introduction of genetically modified organism to the contaminated site to support remediation
	Phytoremediation	Process that uses variety of plants to remove, transfer, stabilize, extract, or destroy contaminant in soil
	Bioventing	It helps with in situ remediation of pollutants by providing enough supply of oxygen to microbes
Ex situ	Biopile	Hybrid of landfarming and composting, used for particularly surface contamination.
	Bioreactor	A container used for the condition of raw material to a specific product through a chain of biological reactions.
	Composting	Compost is organic matter that has been decomposed. This approach recycles different organic materials that are otherwise considered waste products and creates a soil conditioner.
	Windrow	Windrow composting is the processing of compost, such as animal manure and crop residues, by piling organic matter or biodegradable waste

degradation products to legal levels regulated by toxicity tests, which are normally performed on single animals or plants to ensure no caused changes that could result in residual toxicity. The concern with these screening methods is that the measurement of pollutants will result in an inaccurate measure of residual toxicity. Rather, it could be a more detailed residual toxicity measure than a single species to research the microbial community response. There are two forms of remediation: ex situ, which is performed by extracting the polluted soil or water and treating it outside the source, and in situ, which is performed inside the contaminated area. There are several types of treatment that can be either ex situ or in situ, as mentioned in Table 1.1.

1.4.2 Biomarker

Chemical toxins in environmental matrices have accumulated dramatically in recent years as a consequence of anthropogenic activity, creating harmful environments for living organisms, like humans. Contaminants have adverse impacts at different levels of biological organization and on different time scales. First, toxins can have effects on the molecular, cellular, and physiological levels until they have more integrated effects at higher levels. Over longer time scales, ecosystem contamination has significant consequences such as habitat erosion and destruction, habitat loss, and natural resource improvements. Pollution is the leading cause of human illness and death in the world today, accounting for an estimated nine million premature deaths (Landrigan et al. 2018). Air pollution is the leading cause of human disease and death, followed by water pollution and occupational chemical exposure (Landrigan et al. 2018). Because of the increasing concern about the negative effects of chemical pollutants on ecology and human health, early warning methods to detect, assess, and analyze the threats posed to the atmosphere by chemical pollutant discharges are becoming more common. In recent years, it has been identified that chemical evidence alone of pollutant concentrations in environmental matrices (air, water, sediments, and soil) is insufficient to accurately determine the possible risks of exposure to living organisms and human health (Lionetto et al. 2019). Furthermore, a number of factors complicate the risk assessment of chemical contaminants for species and habitats, including (a) the chemical diversity and toxicity of pollutants; (b) the simultaneous presence of a number of pollutants in a mixture that may have additive/synergistic effects on organisms; and (c) the bioavailability of pollutants, which is influenced by a number of environmental factors; (d) the different sensitivity of the organisms to pollutant exposure and effects (Connon et al. 2012).

1.4.2.1 Pollution Biomarker

Pollution biomarkers are quantitative measures of shifts in the biological system in comparison to its natural state as a result of pollution exposure (Dagnino et al. 2008). Contamination at lower levels is generally acknowledged to have a quicker onset than pollution at higher levels (e.g., population effects). Molecular and cellular biomarkers may also offer a subtle early indicator of more integrated toxicological symptoms that could occur in communities in the future (Hook et al. 2014). In addition to the calculation of toxins in environmental matrices, biomarkers offer biologically valuable knowledge on exposure to biologically active pollutants and the potential effects of pollutants on the protection of the exposed organisms. Biomarkers for detecting exposure and adverse biological responses to toxins are meeting the growing need for early warning. This explains the rapid growth of this research area in recent years, both in environmental sciences and in human health surveillance. Biomarkers may be used to determine the type and duration of an exposure, to detect changes in an organism, and to determine underlying susceptibility of an organism. They will aid in the better understanding of the mechanisms by which a chemical is consumed and converted within an organism, as well as the cellular and molecular changes that contribute to toxic effects. Biomarkers are categorized as biomarkers of exposure, biomarkers of impact, and sensitivity based on the particular biological reaction used as a biomarker and the point on the spectrum from exposure to toxicity where the measured biomarker originates.

1.4.2.2 Potential Biomarkers

The biomarkers are listed as follows: biomarkers of exposure and biomarkers of impact. Biomarkers of exposure are the responses of an organism to exposure to a chemical compound or group of chemical compounds at its various levels of structural organization. These biomarkers do not, however, provide any information on the toxicological effects of the studied organism and are instead used as an early warning device in relation to a polluting event. For example, plasma esterase (butyrylcholinesterase (BchE) and carboxylesterase (CbE)) inhibition caused by organophosphorus insecticides is among these biomarkers. No adverse effects on the entire organism are caused by the inhibition of these enzymes. Biomarkers of effects are responses that are associated with both exposure to a contaminant and its toxic impact. For example, the effect of insecticides and carbamates (CBs) from organophosphorus (OPs) activates acetylcholinesterase (AchE) inhibition that causes severe acetylcholinesterase (AchE) inhibition. This causes significant harm to the functioning of many species in the central nervous system. It's also possible to identify biomarkers as general and precise. All those responses of an organism at different levels (genetic, biochemical, cellular, physiological, and behavioral) that are not triggered solely by one class of pollutants are general biomarkers. The stress condition of the species in the environment studied is reflected by these responses. The molecular and biochemical responses observable in species as a consequence of exposure to a given class of pollutants are specific biomarkers.

1.4.2.3 Environmental Biomonitoring

Environmental biomonitoring may use measurements of biomarker responses in vulnerable organisms (sentinel species) as an early warning of population-level modification with the aim of measuring environmental quality and assessing environmental changes.

The use of biomarkers in field surveys of polluted environments has grown substantially in recent years. This is due to the fact that biomarkers can be beneficial for decision-making in a variety of environmental insurance activities, such as ecological system and habitat conservation, or the execution of remediation practices, as instruments for detecting pollutant contamination and impact assessment. In addition to chemical characterization on environmental matrices, relevant molecular and cellular biomarker suites are widely used in this context to measure the impact of environmental chemical stress on bioindicator organisms. A number of biomarker responses have been observed in selected bioindicator organisms, especially in invertebrates (Hagger et al. 2008).

1.4.3 Bioenergy

Bioenergy refers to renewable energy made available from biological materials. In the form of chemical energy, biomass is any organic material which has stored sunlight. As a fuel, a number of agricultural processes can include wood, wood waste, straw, manure, sugarcane, and many other by-products. In order to optimize human well-being in the current framework without undermining the potential of future generations, the value of sustainable development has been greatly established as a way of incorporating the environmental, social, and economic goals of society. Negative natural, social, and economic impacts will ultimately result from growth that is not sustainable. In the latest scenario, biotechnology is globally recognized as a fast-growing and far-reaching technology and is appropriately defined as the technology of hope for its promising food, health, and environmental sustainability. Within the bioenergy sector, biotechnology, especially genetic engineering, has the potential for applications to agricultural output; to optimize the biomass productivity of first and second energy crops; to raise the limit of the potential yield per hectare; to change crops to increase their consumption to fuel; and to transform biomass, for example, through the application of biofuels. However, it remains to be seen if genetic engineering will deliver on its commitments, as well as when and how much the different innovations will cost.

1.4.3.1 Bioenergy and Biofuels

The cornerstone of the bio-based sector is a plentiful supply of biomass. Biofuels are oils produced from biomass. The most widely used liquid biofuels are bioethanol and biodiesel. Ethanol is an alcohol that can be used straight in cars built to run on ethanol or blended with gasoline to make “gasohol.” Ethanol can be used as an octane-raising, pollution-reducing substitute in unleaded oil, eliminating chemicals like methyl tertiary-butyl ether (MTBE). Biodiesel is a synthetic fuel that resembles gasoline. It may be used as a standalone fuel or in combination with petroleum diesel. Though biofuels for transportation receive a lot of attention, the use of biofuels for cooking is a potentially huge global use, particularly in rural areas of developing countries. Cooking with biofuels will produce far less toxins than solid-fuel cooking. As a result, biofuels have the potential to improve the health of billions of people. Biofuels are primarily divided into two categories: “first generation” and “second generation” oils. The feedstock is the main distinction between these terms, despite the lack of strict technical meanings. A first-generation fuel is one made from sugars, grains, or seeds; it uses only a portion (often edible) of the biomass supplied by a plant above ground; and it is produced using a relatively simple process. First-generation fuels are currently being produced in significant commercial quantities in a number of countries. The second generation of fuels is traditionally made from nonedible lignocellulosic materials, such as nonedible food crop residues (e.g., corn stalks or rice husks) or nonedible biomass production (e.g., grasses or trees grown specifically for energy use). The conversion of lignocellulosic biomass to fuel is a complicated procedure. Enzymatic hydrolysis (which produces so-called biological second-generation biofuels) and gasification (which produces so-called thermo-chemical second-generation biofuels) are the two methods for processing second-generation biofuels. A biofuel derived by a biological method is cellulosic ethanol.

1.4.3.2 Type of Biological Resources for Bioenergy

Microalgae Biomass

Microalgae are single-cell, complex plant biomasses of varying capacity for liquid transportation fuel processing. Microalgal species can be grown in freshwater and saturated saline (or both) with a higher contribution to global carbon fixation if CO_2 from our atmosphere is used productively (up to 40%). These algal biomass can be generated very rapidly (double cycles 6–24 h), depending on the genus or species normally capable of generating energy-rich oils in their overall dry cell biomass. Spp. *Botryococcus* has stored up to 50% of the dry cell mass of long chain hydrocarbons oil. Scientists have various choices for distinguishing new microalgae strains with their genetic information for biosynthesis due to the possible existence of millions of variants in algal organisms. The reduction of nitrates and phosphates as effluents before reuse of municipal wastewater treatment has the ability to exclude microalgal species from sewage systems. The biosynthesis ability of algal biofuels would reduce the usage of fertile lands in comparison to biofuel biosynthetic pathway from higher terrestrial plants. These microalgae activities have provided an acceptable platform with greater potential for the production of biofuels at a lower cost (Hannon et al. 2010).

Since microalgae require less arable land than plant-based feedstocks, microalgal oils are another appealing choice for biodiesel production. Microalgae are being seen as a viable option for the long-term processing of edible oils. Microalgae contain plentiful polyunsaturated fatty acids (PUFA) and have high photosynthetic activity and oil productivity, making them superior to terrestrial oleaginous crops in terms of edible oil production. Since microalgae are grown in water, oil extraction methods for microalgae must account for the effects of water.

Agricultural Crop

Agricultural wastes are left in the farm sector, which helps to mitigate soil degradation by recycling nutrients back into the soil. Biomass residues from crops have been used to synthesize energy compounds thereby preserving soil fertility. Another source of sustainable material residue is milk whey sugar (leftover from cheese manufacturing industries) and manure organic compounds (synthesized from livestock operations centers), which have yielded the most benefits from bioenergy processing through lowering disposal costs and reducing emission speed effective use of biogenic by-products compounds, leftover bits, and waste material has provided alternate carbon sources for renewable energy sources. From conversion technologies through synthesis of final-used energy bioproducts, biomethane, liquid nature biofuels compounds, electric power, and heat energy synthesis has been documented. Energy shortages can be avoided by developing alternative energy supplies and optimizing the energy market system, resulting in energy savings and a decrease in GHG emissions.

Biotechnology applied to the energy sector will provide opportunities for both developed and developing nations if an adequate regulatory system is in place and cautious strategies are developed. It allows the former to use their technological capabilities to ensure national energy stability and avoid major social and economic disruptions caused by changes in fossil fuel supplies and prices. A growing number of countries will be able to reduce their dependence on oil imports, is less vulnerable to oil price fluctuations, and reduce the environmental consequences of fossil fuel combustion.

1.4.4 Use of Synthetic Biology in Biofuel Production

Synthetic biology aims to construct increasingly complex biological systems out of standard interchangeable components. The perfect microorganism for biofuel production will produce a single fermentation product with high substratum utilization and processing capacities. In addition to fast and deregulated sugar transport pathways, some microorganisms have good resistance to inhibitors and products with high metabolic flow rates. Recent findings that heterologous hosts can reestablish plant metabolic processes and that crop plant metabolites can be tailored to increase biofuel productivity have brought molecular biological approaches to enhancing food and biofuel products new hope.

1.4.4.1 Biotransformation

The oxidation of naturally occurring or industrially manufactured organic compounds is one of the most essential functions of microorganisms in nature. Both living species are subject to a large number of xenobiotics, many of which are potentially toxic. The presence of xenobiotics in a living organism will disturb the living body by suppressing its development or interacting with one or more components or chemical reactions on which it relies. The number of mechanisms by which a xenobiotic (pesticide) is subjected to chemical modifications in living organisms is known as biotransformation. Biotransformation reactions (phase I or phase II) are needed to understand the metabolism of endogenous (endobiotic) or exogenous (xenobiotic) molecules, and their role is to increase the defensive mechanisms produced in relation to cells or biological fluids. The toxicity of a cell, tissue, or organism is determined by the equilibrium between the concentrations of parent pesticides, intermediate bio-transformers, and conjugates.

1.4.4.2 Enzymatic Stages of Biotransformation

Biotransformations, including enzymes and whole microbial cells, have been used to make foods and drinks for decades. However, methods for understanding and optimizing the stability and efficacy of biocatalysts have only been established in the last decade. Enzyme innovation and guided evolution have improved enzyme function and expanded the number of biotransformation products available. The use of microbial cells in nonaqueous biocatalytic systems has also enabled researchers to better understand how cells respond to their surroundings. The enzymatically driven biotransformation of organic xenobiotics still proceeds through the measures outlined below. In phase I reactions, the molecule is normally oxidized to increase polarity and provide more reactive groups for further transformation. If the material is highly lipophilic, phase I can entail several oxidative steps. This is the case for the oxidation of polycyclic aromatic hydrocarbons (PAHs). The restricting reaction for the ultimate removal process is the first oxidation of organo-halogenated substances.

1.4.4.3 In Situ and Ex Situ Methods

For both polluted soil and water, biotransformation processes may be used as a cleanup tool and the applications of this technology fall into two different categories:

in situ or ex situ. In situ biodegradation processes treat the polluted soil or groundwater at the site where it has been detected, whereas ex situ biodegradation processes need contaminated soil excavation or groundwater pumping before they can be treated. In situ biotransformation is used where the pollutants cannot be fully eliminated through physical and chemical remediation techniques, leaving residual amounts that are beyond regulatory guidelines.

The applications for biotransformation fall under two broad categories: (1) in situ or (2) ex situ. Processes of in situ biotransformation are used to treat the polluted soil or groundwater in the place where it is located. Until they can be treated, ex situ biotransformation processes involve excavation of polluted soil or pumping of groundwater. In situ techniques do not require polluted soil excavation, so they may be less costly, produce less dust, and cause less contaminant release than ex situ techniques. Often, a huge amount of soil can be handled at once. However, in situ techniques can be slower than ex situ techniques, difficult to handle, and are most successful at permeable soil sites. The natural biodegradation processes that take place in the water-soaked underground area below the water table are intensified by the in situ biotransformation process applied to groundwater. One disadvantage of this technology is that differences in layering and density of underground soil which cause some preferred flow paths to be followed by reinjected conditioned groundwater. On the other hand, ex situ techniques can be quicker, easier to monitor and used than in situ techniques to handle a broader variety of pollutants and soil types.

1.4.5 Biosensors

Biosensors have an excellent analytical method for measuring environmental contaminants with high precision and sensitivity. They are a cheap and enticing alternative to traditional analytical approaches that are capable of providing online tracking in real time. Varieties of biosensors have been developed and are still in development because of the complex effects of these contaminants on the biological system. The main issue is the identification of heavy metals, phenolic compounds, mercury, organophosphorus, and carbamate pesticides among toxic compounds, considering their significant contribution to elevated levels of contaminants. In contrary to direct monitoring, indirect monitoring of pollutants is gaining popularity due to its high vulnerability and hence rapid growth of its market. Due to their accuracy, rapid response times, low cost, portability, ease of use, and continuous real-time signal, biosensors can provide distinct advantages in some situations. Because of their biological foundation, they are ideal for toxicological measurements in safety and health applications. Over the last 3–4 years, the number of publications on biosensors for remote sensing has increased, especially in the field of pesticide analysis.

1.4.5.1 Biosensors for Monitoring Biochemical Oxygen Demand

The requirement for biochemical oxygen (BOD) is the amount of oxygen absorbed by microorganisms during the decomposition of organic matter at a certain temperature under aerobic (oxygen-rich) conditions. The biochemical oxygen requirement test is one of the most widely used and accepted methods for calculating organic pollutants (BOD). Classical BOD tests require lengthy incubation times of up to 5 days. Biosensors have had a significant commercial impact on environmental surveillance in this region. Many commercial BOD biosensors with short reaction times and automatic sampling have emerged as a result of research that began in the 1970s in Japan and Germany.

1.4.5.2 Biosensors for Monitoring Pesticides

Pesticides have become valuable tools in the agricultural sector, as soil is the foundation. Grass, mosquito, and fungal management that is effective and does not damaging crops. Pesticide bioactive compounds are reported in over 600 different ways in the United States alone, with a worldwide demand of more than $20 billion. Insecticides, fungicides, and herbicides may all be divided into three classes. Insecticides are typically organophosphorus (such as parathion), organochlorine (such as DDT), or carbamate (such as carbofuran) substances. Fungicides are made up of sulfur, zinc, or chemical-based compounds, whereas herbicides are made up of organic or inorganic compounds. Pesticides may be applied as a vapor, as dust or granules, or more often as, or in the presence of, liquid (usually water or oil).

1.4.5.3 Biosensors for Monitoring Phenols

Pesticides, pharmaceuticals, plasticizers, bombs, and surfactants are only a few of the things that are processed with phenols. The phenol itself is one of the most essential. Chemicals that are widely used account for about 1.56 million tons of annual US supply and have been identified as a significant organic chemical with the ability to pollute the atmosphere. Biosensors have been successfully used to detect phenols using quinone reduction.

1.4.6 Molecular Ecology

Instead of being propagated as a monoculture in an optimized, controlled environment with nutrients in excess, the recombinant organism is introduced into a community of diverse organisms where it must establish itself interact with other members of the community in unknown ways, and face a multitude of poorly controllable external factors, some of which place it under considerable stress. Some environmental situations, such as those encountered in bioremediation, are patently hostile for the recombinant organism. Thus, whereas contained applications are mainly based on a few well-characterized microorganisms, such as *Escherichia coli*, *Bacillus subtilis*, *Saccharomyces cerevisiae*, and some cell lines which perform well in bioreactors, open applications are based on a more diverse range of organisms able to survive and perform in natural communities in the environment, such as Pseudomonas, Rhizobium, Salmonella, etc. Microbial ecosystems that provide society with services are regulated by environmental biotechnology.

Prominent and emerging services include the removal of water, wastewater, sludge, sediment, or soil pollutants; the processing of useful goods from renewable resources (e.g., biomass), in particular from energy carriers, but also from nutrients, metals, and water; the identification of contaminants or pathogens in the atmosphere or, maybe, in humans; and the protection of the public from harmful exposure to pathogens. In order for modern human society to be clean, prosperous, and stable, these services are necessary. Properly controlled, microbiological communities can provide such services efficiently, continuously, economically, and without creating any other hazards. The new name reflects that environmental biotechnology, as well as other developments in science and technology, is adapting and benefiting from modern molecular biology methods. Based on the plethora of new molecular tools and conceptual insights, environmental biotechnology and molecular ecology should come to terms and evolve approaches that allow transparent and effective management. Molecular ecology is the theoretical bedrock of environmental biotechnology. This will help society to understand the multitude of services rendered by microorganisms to the quality of our world in particular and to our "environmental spectrum" in particular.

1.5 Conclusion

To achieve the objectives of sustainability, a major role will have to be played in the food production fields, green raw resources, biofuel, waste reduction, and bioremediation, along with a wide variety of technologies with the potential to biotechnology. Clean processes and products are a sustainable way to evolve, less harmful, and have a lower impact on the environment, as environmental biotechnology has proven to have a tremendous opportunity to enhance to the reduction, identification, and awareness of environmental waste remediation and depletion. This role is demonstrated with regard to industrial, agroforestry, renewable energy options, food, raw materials, and minerals industries. In terms of genetics, since certain modern approaches require use of changed species, regulation to ensure the safe use of fresh or modified species in the field is essential. Biological methods of all kinds are still in use. However, new technologies are designed to track emission incidents and to continuously control pollutants. The environmental and economic advantages of biotechnology in processing control and waste disposal, as well as technical and economic management, are in line with issues that still need to be resolved. All is being done in a way that has less-negative impacts on the environment and is more sustainable. It has the potential to contribute to the aforementioned primary goal areas and serve as a valuable tool for assessing environmental sustainability.

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