

# A review of applications of biotechnology in the environment

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**ABSTRACT:** Environmental biotechnology refers to the use of microorganisms to improve the *environmental quality* and so far it has focused on the development of technologies to clean up the aquatic, terrestrial and aerial environment. This article is an overview of environmental applications of biotechnology. Environmental remediation, pollution prevention, detection and monitoring with regard to the achievements are among the perspectives in the development of biotechnology. A variety of relevant topics have been chosen to illustrate each of the main areas of environmental biotechnology: wastewater treatment, soil treatment and treatment of gaseous pollutants, using microbiological processes. The distinct role of environmental biotechnology in the future would be to contribute with new solutions and directions in the remediation of polluted environments, to minimize future waste release, and to create pollution prevention alternatives.

**Keywords:** Environmental biotechnology, bioremediation, remediation

## INTRODUCTION

The term "Biotechnology" was first coined by Karl Rekey in 1991 implying the application of biological science and its interactions with man-made technologies. In general, any act of human intelligence in the creation, promotion, and presentation of various animals' products, primarily through its manipulation at the molecular level, are within the realm of biotechnology which is the purest, most economical and most significant technology of the century (Albrecht ., 2006). Environmental biotechnology refers to the application of microorganisms to enhance environmental quality. Main tools used for determining the traits and controlling the environmental biotechnology processes have been around for decades (Daugulis ., 2003). For example, traditional measures of biomass, such as volatile suspended solids have not lost their application. Nevertheless, some tools of molecular biology have provided the possibility of investigating the diversity of microbial communities (Annette ., 2001). This paper reviews the achievements of biotechnology application in environmental protection and future prospects in this field.

### **1. Application of Biotechnology in Environment**

The limited capacity of the biosphere is undeniable. Changes imposed by humans on the planet are so vast that to avoid catastrophic impacts and to prevent future generations facing insurmountable problems, immediate action is required (Cunningham ., 1993). By the use of the superior equipment, science and technology, particularly the technology with no adverse consequences for the environment, sustainable and safe developments for human can be achieved (Fierăscu ., 2009). In summary, the application of biotechnology in environmental remediation can be expressed as follows:

Effective removal of harmful contaminants from the environment using filter-feeder (microorganisms and plants)

Removal of oil pollutants using oil-eating bacteria  
Removal of industrial pollutants such as heavy metals  
Removal of toxic chemicals and pesticide  
Production of biodegradable plastics using vegetable proteins  
Production of environmentally friendly chemicals  
Production of non-fossil fuels  
Reduction of air, soil and water pollution

Detection of indicator organisms for rapid identification and extraction of minerals and pollutants (Kumar ., 2011). In this regard, for the purpose of environmental remediation which is a public duty in general, and the objective and task of environmental specialists in particular, biotechnical methods must be applied committedly, consciously and responsibly so that in addition to minimizing health and environmental impacts, contaminants removal and environmental remediation would be achieved (Kochhar ., 2007).

## **2. Bioremediation**

Remediation of polluted sites necessitates the development of new technologies which emphasize the destruction of pollutants rather than conventional disposal methods. Bioremediation is the most widely used among the new technologies. Bioremediation is a process in which microorganisms, green plants or their enzymes for the remediation of contaminated environments and their high-performance in biodegradation of pollutants, usually take a central role in environmental remediation (Stoltz, 2004). In fact, for the improvement of the remediation process, a deeper understanding of microbial ecology of polluted places is necessary.

### **2.1. Bioremediation techniques**

Bioremediation is not a new technology. Evidence of compost piles dates back to 6000 BC and the first biological sewage treatment plant was constructed in UK in 1891. There are three classifications for environmental remediation:

Biotransformation: transformation and conversion of pollutant molecules to molecules of low risk or no risk  
Biodegradation: a chemical or biological process which breaks organic matter into smaller organic molecules or inorganic (Malik ., 2010). Mineralization: complete biodegradation of organic matter to inorganic compounds such as CO<sub>2</sub> or H<sub>2</sub>O (Boopathy, 2000).

### **2.2. Phytoremediation**

Phytoremediation refers to the natural ability of plants to maintain, demolish or dismantle the toxic chemicals and pollutants from soil (Abhilash ., 2009). These plants also help to prevent pollution carried by wind, rain and groundwater from one area to another (Ahmadpour ., 2012). Phytoremediation of organic compounds and metal pollutants in contaminated areas is performed through one of the following methods:

#### **2.2.1. Rhizofiltration**

This method is applicable to the removal of pollutants from surface water and groundwater. In this process, the root absorbs pollutants directly from the environment. It is used in artificial wetlands for wastewater treatment and cemetery drainage (Fierascu ., 2013).

#### **2.2.2. Phytotransformation**

In this process, plants absorb soil and ground water pollutants and break down chemicals through the metabolic processes (Garvillesco, 2010).

#### **2.2.3. Phytostabilization**

In this method, plants maintain soil and water pollutants or they reduce the movement of the pollutants in the soil environment. This is done by surface adsorption or absorption through the roots (Chen ., 2005).

#### **2.2.4. Phytoremediation**

It includes pollutants absorption by roots and their accumulation in the shoots. These plants are mostly harvested and destroyed as herbaceous biomass. The inner parts of the plants are not broke down and deformed (Sanchez ., 2008).

### **2.2.5. Phytovolatilization**

It is the absorption of pollutants by plant roots, transferring them to the leaves and their evaporation through stomata (Diebel ., 2012).

### **2.2.6. Rhizosphere Bioremediation**

In this method, plants act as stimulus for the growth of microorganisms that are spherically around the roots. Microorganisms such as yeast, fungi and bacteria – break down the pollutants through metabolic processes (Rosegrant ., 2008).

## **3. Removing pollutants from polluted environments**

Environmental pollution, the large volume of garbage and non-degradable waste materials, heavy air pollution, progressive destruction of the ozone layer, and serious climate change are all adverse consequences that the existing science and technology has brought to us due to neglect and improper use (Abhilash ., 2009). Biotechnology could be considered as the most ideal environmental protection technology due to its multifunctional nature of and its widespread ness (Arienzo ., 2004). Opposition between bioengineering science and biotechnology in the major reduction of pollution in the aquatic, terrestrial and aerial environment could demonstrate the ability of modern science in sustainable development which is briefly explained in this paper (Lee, 2013).

### **3.1. Wastewater**

Water is the most basic and most essential compound of all living processes in our water planet (Min ., 2012). Despite many attempts to stop the destruction and pollution of water resources, humans' impact on the natural cycle of water make irreparable risks in this area and it requires a consideration on the necessity of the use of new methods to prevent contamination of water resources (Delplanque ., 2013). Wastewater compounds may be physical, chemical or biological, and cause environmental impacts including changes in aquatic habitat and its special structure, and the change in biodiversity and water quality (Aleem ., 2003). Three basic groups of biological processes in aquatic environments include aerobic processes, anaerobic processes or a combination of both of them (Nicks ., 1994). The main objectives of wastewater treatment processes can include: Reduction of biodegradable organic content (BOD5) Removal of toxic and heavy metals, removal or reduction of nitrogen and phosphorus-containing compounds Removal or reduction of nitrogen and phosphorus-containing compounds Removal or inactivation of pathogenic microorganisms and particles (Ghosh ., 2005).

#### **3.1.1. Activated sludge process**

It was invented by Arden and Lockett in England in 1914. Since then, it has been consistently used as a biological treatment process for domestic wastewater treatment. In this method, wastewater is placed in ponds and artificially exposed to air so that the oxygen gets dissolved in the wastewater and leads to the growth and reproduction of bacteria. After receiving the oxygen in aerated ponds and reduction of BOD5, wastewater gets into sedimentation ponds (Guo ., 2012). The particulates on which are located the aerobic bacteria form clots, and finally they are settled as activated sludge in the final settling pond. These organisms treat the wastewater by consuming the contents of the wastewater as food (Elekes, 2011).

#### **3.2. Bioremediation of contaminated soil**

According to published reports, more than 20% of the Earth's lands are vulnerable to contamination by chemicals. Bioremediation is one of the world's most significant and up to date technologies to remediate contaminated soil. In this method, the soil is cleaned up by insemination and reproduction of microorganisms which are effective in the decomposition a particular type of contaminant. According to the metabolic diversity of microorganisms and their use of environmental pollutants, they could be beneficial for the absorption, emission, reduction and complete elimination of various pollutants by making a proper choice (Bouwman ., 2005). There are two main ways to remediate contaminated soil: Remediation of contaminated site: soil remediation takes place in the actual location (in situ remediation). Off-site remediation of contaminated soil: contaminated soil is excavated to a specified volume and then it is taken away from the area, and finally it gets remediated in another place (Barrows ., 2014).

#### **3.3. Clearing the air**

However ever-increasing expansion of urban industrial areas has led to relative prosperity of human society, it has brought many problems such as air pollution for the community (Grommen ., 2002). Odor dispersion is currently

a serious problem which might influence several kilometers away due to climatic conditions and topography of the area (Brooks, 1998). Most common minerals which have unpleasant odor are hydrogen sulfide and ammonia and the most common volatile organic compounds with low molecular weight are mercaptans (Kazuya, 2001). The emission of pollutants in the atmosphere causes problems such as depletion of the ozone layer, ozone creation in the Earth's atmosphere, the greenhouse effect, photochemical reactions, and harmful impacts on humans, plants, animals and ecosystems (Banerjee ., 2013). In the presence of sunlight and nitrogen oxides, it turns to ozone through a complex set of photochemical reactions which is a key combination in the creation of smog in urban areas. Conventional methods for chemical and physical control of gaseous pollutants mainly include incineration, thermal and catalytic oxidation, surface or deep absorption, and condensation (Bidar ., 2007). These methods generally have high costs and in some of them, primary pollutants produce dangerous secondary pollutants during the process (Kummerer, 2004). Recently, biological methods attracted much attention since they do not produce secondary pollutants and they also don't need much energy. Bioreactors are the equipment for biological treatment of pollutants. They are of various types which among them, bio filters and trickling filters are the most popular (Lezcano ., 2011). Bio filters are one of the main biological systems which are used at normal operating conditions of temperature and pressure. In general, filters are considered as the most ideal method for biological treatment of gaseous pollutants (Marchiol ., 2004). However, these bio filters are usually only effective in low concentrations of organic contaminants. Bio filters are column reactors which are filled with porous material inside and microbial populations for analysis of volatile organic compounds in the air flow have developed inside it (Marchand ., 2010). Porous materials have the ability of gaseous components absorption and biological growth. The most commonly used fillers are substances such as coal, a mixture of organic nutrients, wood chips and soil (Macek ., 2000).

#### **4. Other applications of biotechnology**

The wide range of environmental biotechnology which is a result of the Green Revolution presents an adequate economic, social and environmental issue toward the development and this by itself is an indicator of the necessity of considering the efficiency of biotechnological environmental in the current society (Arundel, 1991). Application of Environmental Biotechnology is not just about remediation processes. Productions of useful materials in various fields as well as energy generation are of other applications of this science (Mesjasz ., 2004).

##### **4.1. Bioleaching**

The future of sustainable development requires measures to reduce dependence on renewable raw materials and demand for basic needs. New sources of metals must be developed with the help of technology (Nixdorf ., 2001). Biotechnology is a modern science which has solutions for many human problems, and it has provided great services to the human society (Mishra ., 2010). The application of bioleaching process in extracting minerals is among significant advantages of this science. In fact, bioleaching is the interaction between metals and microbes with the aim of converting insoluble metal sulfides into soluble metal sulfides (Hoque ., 2011). Bioleaching process is generally used for extraction of useful elements from their ores by bacteria and to dissolve them. Leaching efficiency is dependent on soil micro flora (Dumitrescu, 2002).

##### **4.2. Bioenergetics**

Given the human's increasing need for energy resources and limitations of the use of fossil fuels due to the reduction of existing reserves as well as the environmental impact caused by it, numerous efforts have been made towards achieving renewable energy sources. Biofuels are the major source to replace fossil fuels (Sivrikaya ., 2011). Biofuels are fuels that are derived from biomass sources and nowadays they have allocated 11\_14% of the world's total energy consumption (Megharaj ., 2011). Generally, the primary sources of biofuels are wood waste, agricultural waste, sugar cane, corn, herbal and vegetable oil, oil residues (such as chicken fat and cooking oil used in restaurants), fresh vegetable oil (such as soybean oil) and non-food products (such as algal oil). The fuels which come from residual products such as kitchen oil or ethanol are produced from grass or wood chips (Won ., 2013). They have the most compatibility with the environment. Liquid ethanol, methanol, biodiesel and diesel fuels such as hydrogen and methane gas are among many varieties of biofuels (Hassen ., 1998).

##### **4.3. Bio plastic**

Productions of plastics from synthetic polymers derived from renewable resources have brought many bioenvironmental problems including their non-biodegradability (Kikuchi ., 2012). Production of new materials such as bio plastics using sugars, fats, proteins, fibers and other natural ingredients extracted from plants would prevent the use of renewable resources such as fossil fuels and it will lead to less energy, more limited resources and

reduction of greenhouse gas emissions (Costea ., 2013). Germs can produce necessary enzymes to convert plant material into structural materials for the biodegradable plastics (Keller ., 2005).

#### 4.4. Biological Fertilizer

Today, with increased agricultural production to meet the needs of the growing population expansion, concerns have been grown about the future food supplies for humans (Rojas ., 2001). Water, soil, and air contamination, soil erosion, pest resistance to pesticides and increase in chemical fertilizers has led to going back to the past and considering industrial cultures in order to maintain supplies. Although it produces low agricultural yields, future human health is guaranteed. In this regard, most attention is directed towards sustainable agriculture (Tan ., 2011). The biological fertilizer contains living cells and different types of microorganisms which have the ability to convert chemical food complexes into simpler forms through chemical processes, and to prepare them for absorption by plants (Costea ., 2013).

## RESULTS AND DISCUSSION

### Results

In general, biotechnology is considered as one of the main axes of development in many countries and serious attention has been paid to it in adjusting national strategies and plans (Kang ., 2010). Today, the ability of creating biotechnology is one of the basics in the development of countries. Biotechnology is mainly applied in areas of the world where modern knowledge is achieved. Continuing advances in biotechnology procedures, identifying cellular structure of organisms and using their metabolism products has led to changes in the basic research in recent years (Kunito ., 2001). Population growth and reduction of up-to-date resources, problems arising from the use of physical and chemical technologies and health problems caused by environmental degradation has caused the policymakers to focus their attention on biotechnology and consequently it brings hopeful promises for the development (Caggiano ., 2005). Since this branch of technology is still new, the faster application of it will reduce the gap between our country and developed countries and help the ease of access possibilities to achieve high added value of products and raise the right to patent biotechnology rather than any other technology as the perfect choice for our country (Hoque ., 2011). The high and remarkable ability of biotechnology in environmental protection is of other advantages of this method (Leung, 2004). Although biotechnology and genetic engineering have played an enormous role in the advancement of human health and life, but the potential risks that may be due to not applying biosafety principles should not be overlooked (Kabata, 2010). Therefore, while emphasizing the importance of developing biotechnology activities in all aspects, it is necessary to prepare and conduct principles for the safety of these activities so that monitoring and control could be performed properly based on them (Zahran, 2001). This short article was a review of the process of biotechnology and its impact on the environment. I hope we will have a clean and contaminant-free environment one day using biotechnology.

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