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BIOTECHNOLOGY IN ENVIRONMENTAL PROTECTION

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ABSTRACT:

Bio-technology encompasses a wide range of specialized discipline right from age old fermentation process to the latest techniques of genetic engineering. It has received tremendous attention in recent years due to its potentialities and applications in aquaculture, agriculture, immunology, chemical production, industrial processes, pollution control etc. But modern environmental protection is unthinkable without biotechnology. Biotechnological methods are indispensible in fields of soil, waste water and exhaust air purification. Besides, microbial and system biology contribute to increase in efficiency of purification and biowaste recycling plants. These days biotechnology is being put to varied uses. One of the potential uses of it is in the environmental protection and in conserving the natural resources and endangered plants of economic and medicinal uses. Biotechnology not only plays important role in remedying environmental damage but also in detection of environmental damage. But, any advanced technology is often accompanied by benefits to mankind as well as risks to the environment. Therefore, for efficacious and safe utilization of biotechnology, it is essential to select safe and useful genetically engineered microorganisms for applications to waste treatment processes of special environmental significance.

Introduction:

Since the evolution of man on earth, he has always been dependent on nature for all his basic needs. With rapid industrialization, urbanization and economic growth, man has started living in two different worlds. The first and foremost world is natural world of plants, animals, soil, air and water. Gradually as his needs increased, he has created another world of comfort composed of variety of production systems and processes with the use of science and technology and other social and political organizations. Now in 21st century, these two worlds have become the need of life. But this demand for new technological society has created a stress on man's life. His ambition for limitless comfort has led him towards the exploitation of nature's wealth and resources indiscriminately and rapidly. Man's greed for resources and his desires to conquer nature has placed him in front of the environment. Besides, man designed production processes also generate by-products, wastes and effluents which are difficult to biodegrade while many others are non-biodegradable. But what nature gets in return to this – contamination by various human activities that generate pollutants of many kinds.

On the other hand, in spite of anthropogenic activities, one section of people has given a thought to minimize the detrimental effects of his activities on the environment by innovating new technologies. These technologies are generally of two types. One is 'curative' and other is 'preventive' in nature. The first type involves the development of techniques to clean up the pollution generated by other technologies and second type involves the development of efficient production technologies which generate less pollution and are more 'cleaner'. Both these strategies play their role in minimizing the damage to environment and maintaining sustainable environment. The curative techniques that use biological agents in combination with biochemistry, microbiology and engineering sciences in order to achieve technological application, is termed as 'Biotechnology'.

Biotechnology has received tremendous attention in recent years due to its immense potentialities and applications in aquaculture, agriculture, immunology, forestry, chemical production etc. but one of the potential uses of biotechnology is in environmental protection and in conserving the natural resources. Biotechnology is now well positioned to contribute to the development of a more sustainable society, a principle which was advocated in Bruntland Report in 1987 and in Agenda 21 of second Earth Summit in Rio de Janeiro in 1992(that has been widely accepted in meantime). Therefore, protection and conservation have become the dire need of today.

Biotechnology and pollution control

Environmental biotechnology is a very broad field which includes environmental monitoring and safety, waste treatment and recovery, restoration of environmental quality, substitution of non-renewable resource with renewable resources, development of various processes for the benefit of mankind with due regards to socio-economic ,legal and environmental safety considerations. It promotes sustainable use of natural resources like plants, algae and bacteria in industrial processes, generation of useful organic chemicals from bioconversion of biomass, reduction of energy consumption etc. Our biological systems have the capability to absorb and control pollutants like free carbon sources from our environment . Some of these applications have indirect beneficial effects on wider problems such as global warming, acid rain and climatic changes. However, uncontrolled or accidental release of genetically engineered micro-organisms (GEMs) or their hosts derived from recombinant DNA technology into natural environment can be hazardous to natural ecosystems. Hence, care should be taken regarding environmental safety and legal aspects.

Biotechnology also provides solutions for pollution control, for example- Pigs and chicken cannot utilize phosphate from phytate in their feed, which therefore, ends up in their manure. By adding enzyme 'phytase' to their feed, amount of phosphate excreted by these animals can be reduced by more than 30%. Chemical production of 'Indigo' dye which is used for blue zeans takes eight steps, the use of toxic chemicals and special protection measures for process operators and the environment. Biotechnology production of indigo which uses a genetically modified bacteria containing right enzyme takes only three steps proceeds in water, uses simple raw materials like sugar, carbon di oxide and biomass which is biodegradabale.

Biosensors:

In most cases the series of laws and regulations formulated are hardly implemented due to lack of affordable means of monitoring, survey, surveillance and compliance at least for principle classes of pollutants such as pesticides, heavy metals etc. Environmental protection requires an ever- increasing arsenal of analytical methods to assess the quality of food, soil, water and air. For this, biosensors are the latest tools in environmental monitoring. Microbial biosensors are micro-organisms which produce a reaction upon contact with the substance to be sensed. Usually they produce light but cease to do so upon contact with substance which is toxic to them. Biosensor is an analytical gadget comprising of an amalgamation of biological material (e.g. enzyme, antibody, hormone, nucleic acids, tissue, organ or whole cells of microbes) and physical transducer which analyses biological signals and converts them into an electrical signal. Both naturally occurring light emitting micro-organisms as well as specially developed ones are used. Biosensors are quick, portable and can be directly applied in the field. Fast monitoring of waste water for pesticides, heavy metal and COD or BOD would facilitate quick initiation of treatment process.

Biodegradation of xenobiotic compounds:

These are man made chemicals that are present in the environment at unnaturally high concentrations. These compounds are either not produced naturally or are produced at much lower concentrations than man. Microorganisms have the capability to degrade all the natural as well as xenobiotic compounds. Since xenobiotic compounds consist of a wide variety of compounds, their degradation occurs via a large number of metabolic pathways. Some xenobiotics are degraded by microorganisms, but are not used as energy source by them. The degradation of such compounds is dependent on the presence of other compounds, called co- metabolite that induces the required enzyme production and is also the source of energy. Several other xenobiotics are degraded by an existing pathway and are used by microbes as source of energy. Generally mixed populations of microbes are used for the degradation of xenobiotic compounds.

Microbiological mining:

Microorganisms have been used in mineral leaching and metal concentration processes for many years. With the advent of recent biotechnology of recombinant DNA techniques, it has become possible to manipulate genes and transfer them across genetically unrelated species for increasing efficiency of microorganisms useful in metal recovering processes. The mostly used microbe for leaching of copper and uranium is Thiobacillus ferroxidans. It also affects the solubilisation of cobalt, nickel, zinc and lead. Mostly the bacteria used for metal leaching are autotrophic. As the use of coal as an energy source is increasing, microorganisms may be used to extract sulphur from coal making it less polluting. Heavy metal present in waste water can be concentrated by the use of some microorganisms where either the metals are absorbed un-specifically to the surface or are specifically bound and taken up by the organisms.

The micro-organisms were used in a bio-reactor to treat the uranium containing waste water from a nuclear weapon manufacturing plant. The organisms can be used for waste water treatment in uranium mining.

In South Africa, bacteria are used for isolation of gold from gold ore. These so –called bio-mining saves an enormous amount of smelting energy and generates much less waste making environment more sustainable.

Biological De-Odourisation:

In biological de odourisation, foul smelling compounds are decomposed by exploiting the metabolic process of microorganisms. An exhaust gas treatment system for Hydrogen sulphide and sulphur di oxide based on Thiobacillus ferroxidan bacteria is already in practice in Japan. Bioscrubbing involves scrubbing of waste effluents using microbial methods to detoxify or de –odorize certain constituents in waste effluents, e.g. detoxification of cyanide can be affected by using enzyme Rhodanese of Bacillus sterae othermophillus by converting the toxic cyanide to thiocynate.

Bioremediation:

With rapid industrialization and changes in agricultural practices, heavy metal ions have become an intrinsic component of the present environment. These are persistent and non-biodegradable in nature and accumulate in biological systems. This leads to various ecologically adverse conditions. Industrial operations also generate complex and toxic pollutants which accumulate in natural systems. New technologies are being developed to reduce the concentration of heavy metal ions to environmentally acceptable levels. The toxic wastes thus generated are usually treated by physico-chemical processes. Bioremediation is the microbial clean up approach. Microbes can acclimatize themselves to toxic wastes and new resistant strains develop naturally. Such strains can be used for pollution control and environmental protection. Bioremediation, therefore, is the use of biological system for systems for reduction of pollution from air, from aquatic or terrestrial systems. Micro-organisms and plants play the role of biological system which is generally used. Biodegradation with micro- organisms is most frequently occurring bioremediation option. A complete biodegradation results in detoxification by mineralizing pollutants, carbon di oxide, water and harmless inorganic salts. This process can be used to render or remove hazardous wastes to non- hazardous or less hazardous wastes.

Millions of cars in Junk-yards are posing disposal problem in Germany. The engines breakdown easily but their plastic shells made of duroplastics cannot be destroyed easily. Burning of these emit toxic gases causing air pollution. Micro-organisms which will digest the resin of duroplastics are being developed.

Various strains of bacteria and fungi are being experimented to treat pollutants such as Vinyl Chloride, PCB's, etc. Some fungi, even as dead biomass, were found to trap metallic cations in solution due to their peculiar cell wall composition. Many fermentation industries produce fungal biomass of unwanted byproducts which are utilized for this purpose. Some algae and bacteria can accumulate large quantities of metals. Mixtures of microbes and enzymes are used to clean up chemical wastes such as detergents, pesticides, paper mill wastes, oil etc. Microbial processes were used for removing sulphur from coal. Sulphur present in coal used in thermal power plants is known to contribute to acid rain. Bioremediation using plants is called Phytoremediation. Various applications of bioremediation are- Waste water and industrial effluents: Micro-organisms in sewage treatment plants remove the inorganic common pollutants from waste water before it is discharged into rivers or sea. Heavy metals and sulphur compounds can be removed from waste streams of the galvanization industry by aid of sulphur metabolizing bacteria and reused. Another example is production of animal feed from fungal biomass which remains after the production of penicillin. Most anaerobic waste water treatment system produces useful biogas.

Drinking and process water: A very important aspect of biotechnology is its potential for reclamation and purification of waste water for reuse. By this, high level of nitrates can be removed from processed water before it is delivered to customers.

Air and waste gases: A bioscrubber based system for simultaneous removal of nitrogen and sulphur oxides from flue gas of blast furnaces which has been developed as an alternative to classical limestone gypsum process and the elimination of stylene from waste gas of polystyrene processing industries by a biofilter containing fungi.

Soil and land treatment: For clean up of soil and associated ground water, in –situ (in its original place) include introduction of micro-organisms (bioaugmentation) ventilation and/or adding nutrient solutions (biostimulation). Ex-situ (somewhere else) treatment involves removing soil and ground water and treating it above ground.

Soil may be treated as compost, in soil banks or in specialized slurry bioreactors. Ground water is pumped back into the ground or drained into surface water.

Solid waste: Domestic solid waste is a major problem in our consumption society. Biowaste can be converted to a valuable resource by composting or anaerobic digestion.

Biofertilisers and biopesticides:

Biofertilisers and biopesticides are being developed and used to reduce the damaging effects of chemical pesticides and fertilizers. Biofertilisers are biologically active products or microbial inoculants of bacteria, algae and fungi either individually or in combination which may help biological nitrogen fixation for the benefit of plants. Biofertilisers are the products containing living microorganisms that have the ability to mobilize nutritionally important elements from non usable to usable through biological systems. Rhizobium symbiotic nitrogen fixers, blue green algae, mycorrhizae, phosphate solubilizing bacteria are generally used as biofertilisers.

Azospirllum and Azotobacter biofertilisers in addition to supplying nitrogen to soil also secretes antibiotics which act as pesticides. Hence, biofertilisers' use will definitely boost the agricultural output, augment the economic growth of the nation and also help to preserve the environment for the generations to come.

Microbiology in oil recovery:

Conventional oil extractions processes can recover only about half of the sub terrainean oil reserves. The use of microbes and their products could be used for recovery of trapped oil from rocks. It is called microbial enhanced oil recovery. Oil spills from the oil tankers on land and water surfaces are a major environmental hazard. Spilled oil destroys the aquatic life as well as health problems for local residents causing long term damage to the environment. Chemical treatment causes pollution problems due to their toxic nature. So, micro-organisms are used to degrade oil facilitating slow removal of oil from water as well as environment. Many oil- utilizing microorganisms produce surface active compounds that emulsify oil in water and aid in removal of oil. These emulsifiers are non toxic and biodegradable e.g. Pseudomonas aeruginosa which produce a glycolipid emulsifier which reduces oil- water interface surface tension and helps in removal of oil from water.

Bioinformatics:

Biotechnology, which was once considered as the science of future has now become the technology of the present. The various biomolecules sequence data-bases are available in India with Bio-technology Information System (BITS) established by department of biotechnology. Various data bases on nucleic acid sequences, molecular structure, genetic information, vectors, microbial strains, genetic maps and probes etc. are available to support the applied research to be useful for environmental protection.

Biotechnology and biodiversity conservation:

Biotechnology tools are being employed for conservation of endangered plant species of economic and medicinal importance controlling environmental pollution, restoring environmental quality, developing cleaner technology. Tissue culture techniques have been developed for endangered plants found in southern coastal ecosystems. Germ plasm of rare desert plants has been collected for conservation.

Some major achievements have been made in conservation of environment and biodiversity. Various projects for ex-situ conservation, micro- propagation, in vitro conservation of rare and endangered plants of medicinal importance, ethnobotanical plants and microbial diversity of North Eastern region have been supported. Major projects on biosystematics and conservation studies of liverworts, genetic diversity of ferns, lichen and their use as indicators of pollution have also been supported.

Conclusion:

Biotechnology is a multi- disciplinary field of far reaching consequences. As we move forward into the 21st century, biotechnology will become even more vitally important, as populations, urbanization and industrialization will continue to climb. Modern environmental protection is unthinkable without biotechnology. It utilizes the biochemical potential of microorganisms and plants for the preservation and restoration of the environment and also helps to prevent environmental pollution, save energy and resources in numerous production processes – an effective and state- of – art way to protect the environment. The novel technologies like biotechnology are accompanied by benefits to the mankind as well as often risks to the environment. Some of the environmental problems may cause environmental imbalance. Therefore, it is necessary to select safe and useful genetically engineered micro-organisms for application to specific waste treatment processes for safer and protected environment.

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