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Role of microbes as cleaning degrading industrial wastes for environmental sustainability- A Reveiw.

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Abstract

Public Concern about environment is a very important component necessary for the existence of both man and other biotic organisms. The degree of sustainability of the physical environment is an index of the survival and well-being of the entire components in it. Additionally, it is not sufficient to try disposing toxic/deleterious substances with any known method. The best method of sustaining the environment is such that returns back all the components (wastes) in a recyclable way so that the waste becomes useful and helps the biotic and a biotic relationship to maintain an aesthetic and healthy equilibrium that characterizes an ideal environment. In this review paper we discuss biological method of environmental sustainability which seeks to investigate the various biotechnological tools (biotools) in current use and those undergoing investigations for future use.

Keywords: Environment, Sustainability, Micro-organism, Waste management.

INTRODUCTION

Biotechnology can simply be defined as a technique which uses living or live organisms to make or modify and improve products (Olatunji, 2007). Biotechnology can also be defined as any technological application that uses biological systems, living organisms or derivatives i.e to make or modify products or processes for specific or particular use (UNCBD, 1992). Traditionally, micro-organisms have been widely used to produce beverages and fermented foods (Olatunji, 2007) Environmental biotechnology plays an important role in agroecology in the form of zero waste management in agriculture and most significantly through the operation of over 15 million biogas digesters worldwide (Wikipedia.org; Zylstraa and Kukor, 2005; Vidya, 2005). Hazardous contaminants are harmful to man and other living organisms like cattle, livestock and plants in general. Naturally occured microorganism degrades contaminants through their metabolic processes and this property of microbes has been exploited in bioprocess technology. Micro-organism can also degrade hazardous organic waste such an polycyclic aromatic hydrocarbons (PAH) pesticides, polychlorinated biphenyls (PCBs) metals, nitrogen compounds, halogenated organic solvents and compounds, non-chlorinated pesticides and herbicides, and radio nuclides easily.

Enviornmental Sustainability

Sustainability is the capacity to endure. The word sustainability is derived from the Latin sustinere (tenere, to hold; sus, up). In ecology the word describes how biological systems remain diverse and productive over times. For humans it is the potential for long-term maintenance of well-being, which in turn depends on the well-being of the natural world and the responsible use of natural resources.Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behaviours. An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity.

Enviornment Sustianability Index

This is a composite index tracking 21 elements of environment sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time.

The Environmental Sustainability Index was developed and published between 1999 and 2005 by Yale University's Centre for Environmental Law and Policy in collaboration with Columbia University's Centre for International Earth Science Information Network (CIESIN), and the World Economic Forum. The ESI developed to evaluate environmental sustainability relative to the paths of other countries. Due to a shift in focus by the terms developing the ESI, a new index was developed, the Environmental Performance Index (EPI) that uses the outcome-oriented indicators, then works as a benchmark index that can be more easily used by policy makers, environmental scientists, advocates and the general public.

Challenges Imposed On The Environment By Human Activities

Activities of humans constitute one of the major means of introduction of heavy metals into the environment. One of the major development challenges facing this era is how to achieve a cost effective and environmentally sound strategies to deal with the global waste crisis facing both developed and developing countries (Parker and Corbilt, 1992; Jensen,1990; NEST, 1991; Oyediran,1994; Alloway and Aryes, 1997). different industrial wastes and sewage is constrained by the presence of heavy metals, hazardous organic chemicals, salts, and extreme pH (Cameron et al., 1997). Heavy metal pollution in the environment, even at low levels, and their resulting long term cumulative health effects are among the leading to health concerns all over the world. For example, the bioaccumulation of Pb in human body interferes with the functioning of mitochondria, thereby impairing respiration, constipation, swelling of the brain, paralysis and eventual death (Chang, 1992). The recent population and industrial growth and development has led to increasing production of domestic, municipal and industrial wastes, which are indiscriminately dumped in landfill and water bodies without any pre-treatment. Ogunyemi et al. (2003) reported that the use of farm land as dumpsites is a common practice in urban and rural areas in chattisgarh. these wastes mainly contains heavy metals in various forms and at different levels of contamination. Some of these heavy metals like As, Cd, Hg and Pb are particularly hazardous to all plants, animals and humans (Alloway and Ayres, 1997).Industrial waste contains such heavy metals as As, Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil as the sink when they are leached out from the dump sites. Plants grown on a polluted land with municipal, domestic or industrial wastes the soil absorbs heavy metals in the form of mobile ions present in the soil solution through their roots or through foliar absorption. These absorbed heavy metals get bioaccumulated in the roots, stems, fruits, grains and leaves of plants (Fatoki, 2000).and as a result it causes some chronic disease in humans.

Role of Microbes for the Removal of Toxic Chemicals of Industries from the Environment

Micro-organisms have expanded the environment were they live in, by evolving enzymes that allow them to metabolize various man-made chemicals (that is, xenobiotics) (Okpokwasili, 2007). Bioremediation is the use of microorganisms or microbial processes to detoxify and degrade environmental contaminants. Micro-organisms have been used for the routine treatment and transformation of waste products from several years (Okpokwasili, 2007). The fixed-film and activated sludge treatment systems depend on the metabolic activities of micro-organisms which degrade the wastes to enter in the treatment facility.Several waste treatment plants are specialized and contains selected and acclimated microbial populations which are often used to treat industrial effluents (Okpokwasili, 2007). Micro-organisms remove toxic heavy metals from environment by various mechanisms such as adsorption to cell surfaces, complexation of exopolysaccharides, intracellular accumulation, biosynthesis of metallothionins and other proteins that trap metals and transform them to volatile compounds (Bitton and Freichoffer, 1978; Highman et al., 1984; Meissner and Falkinham, 1984; Mullen et al., 1989). A micro-organism (*Micrococcus luteus and Azotobacter sp.)* have been shown to immobilize large quantities of lead from sites containing high concentrations of lead salts, without a detectable effect on viability (Tornabene and Edwards, 1972). Volatization of mercury by *Klebsiella aerogenes* has also been reported (Magos *et al*., 1964) and even some radioactive metals can also be removed (That is, Uranium), copper and cobalt could be removed by polyacrylamideimmobilized cells of *Streptomyces albus*. Microbial processes can also mediate by the precipitation of metals from aqueous solutions. Certain bacterial or extracellular products may interact with free or absorbed metal cations forming insoluble metal precipitates (Okpokwasili, 2007). The major mechanism involved in such precipitation is through the formation of hydrogen sulphide and the immobilization of metal cations as metal sulphides. Certain fungi that produce oxalic acid (oxalates) facilitate the immobilization of metals such as metal oxalate crystals (Okpokwasili, 2007). Microbes can also be catalyzed through range of metal transformations which are useful for waste treatment. These transformations include oxidation, reduction and alkylation reactions. Bacteria, fungi, algae Soetan 113 or protozoa, in the oxidation reactions, can deposit ferrous and manganese ions. *Geobacter metallireducens* remove uranium, a radioactive waste, from drainage waters in mining operations and from contaminated ground waters (Okpokwasili, 2007).

Desulphurization of Fossil Fuels by Microbial Oxidation

The removal of inorganic sulphur from coal is mediated by microbial oxidation of sulphur (Okpokwasili, 2007). In the direct oxidation of inorganic sulphur *Thiobacillus sp.of micro-organism* is used for a membrane-bound reaction and requires direct contact to the substrate with the bacterium. As a result of this, the attachment of the culture to coal particle is the absolute requirement. A variety of mixed and pure cultures of microorganisms (heterotrophic bacteria) can be used to remove organic sulphur from coal and oil (Okpokwasili, 2007). However, sulphur removal micro-organism has also been reported under anaerobic microbial action (Fligwe, 1988).

Role of Microbe in the Bioassay of Environmental Toxicity

Toxic industrial wastes are the major threat for both the biological waste treatment systems and the environment of their ultimate disposal (Okpokwasili, 2007). As a result, bioassays are very necessary and important to generate data that could be used for the prediction of environmental effects of waste and regulation of discharges (Okpokwasili, 2007). The use of microbes (especially bacteria) as bioassay organism is gaining wide acceptance and offers a number of advantages over the standard organisms (Williamson and Johnson, 1981; Wang and Reed, 1983). Bacteria are easily handled and require relatively small space for culturing and/or testing as compared with other bioassays. The simple and rapid technique of bacterial bioassay includes Nitrobacter assay, Microtox tests, the Toxi-chromotest and the Ames/Salmonella test (Ames *et al*, 1975; Williamson and Johnson, 1981; Bullic, 1984; Dutton et al., 1990; Okpokwasili and Odokuma, 1993, 1996a, 1996b). The Nitrobacter bioassay relies on the quantification of Nitrobacter activity which is being determined by measuring the toxicant effect on the rate of nitrite utilization (Okpokwasili, 2007). *Photobacterium phosphoreum* is the basis of the Microtox assay, toxichromotest is based on the inhibition of beta galactosidase biosynthesis in *E. coli* or biosynthesis of enzymes, such as tryptophanse and alpha-glucosidase, under the control of operons other than the Lac operon by environmental pollutants. The Ames/Salmonella assay measures the mutagenic activities of pollutants. It involves the detection of histidine-negative, ampicillinsensitive and ultra-violet (UV) resistant revertants in frame shift and base pair mutations of Salmonella TA 1537, Ta 1538 and TA 98 strains (Ames et al., 1973).

Control over Oil Spillage through Use of Microbes

Micro-organisms can now also be genetically engineered by r-DNA technique for the oil recovery, pollution control, mineral leaching and recovery (Daini, 2000). In the petroleum industry, micro organisms can also be genetically engineered to produce chemicals useful for enhanced oil recovery (Daini, 2000). Cleaning up oil spills could in the future be left to genetically- engineered bacteria (Su, 1998). In the mining industries, micro-organisms with the property of enhanced leaching ability could be designed. Micro-organisms can bind metals to their surfaces and concentrate them internally. (Daini, 2000). Research is already being carried out to improve the naturally-occurring bacteria that can 'eat or digest oil', for use following an oil spill. By applying bacteria to oil covered beaches, the complex molecules of oil would be broken down into harmless sugars (Su, 1998). Some strains of bacteria which can degrade fuel hydrocarbons have been designed and the use of genetically engineered micro-organisms to clean up oil spillages or treat sewages and effluents has been proposed and is undergoing production/manufacturing.

Various Other Methods for the Degradation of Industrial Waste:
Bioremediation

Bioremediation is the use of microorganisms and plants to degrade contaminants in sewage, domestic, agricultural and industrial effluents to reduce toxicity of toxic and non-toxic materials by natural biological processes (ELC, 2008).

Methods of Bioremediation

The methods of bioremediation include: Mycoremediation, Phytoremediation and Bacteria Bioremediation.

1. Mycoremediation-In this method fungi is used to remove chemical contaminants from the soil. It is one of the most modern methods. In this method, the fungus makes use of certain enzymes and acids that it naturally secretes to decompose the hazardous chemicals into less or non toxic compounds (Barry et al., 1994)

2. Phytoremediation- This method uses plants to control and remove pollutants from the soil, air, and water. Organic and inorganic waste such as metals, sewage, sludge, salts, leachates, metalloids and xenobiotic contaminants can be removed by this method (Eneh et al., 2008).

Bacteria Bioremediation

This method makes use of bacteria to clean up environmental contaminants such as oil spills, mine effluents and even human waste through its natural metabolic process.

Bioreactor

A slurry or sludge of the contaminated soil is placed with microorganisms in a vessel. The bioreactor provides a controlled, optimal environment for metabolic activity and degradation of contaminants.

Land Farming

This involves spreading of contaminated soil over an area and apply specialized bacteria or allowing indigenous bacteria to metabolize the contaminants (US EPA, 2006)

Biocell Treatment

This method of treatment is similar to land farming except that the contaminated soil is placed in a pile with alternates vent layers to provide oxygen needed for bacteria growth.

Composting

Here the contaminated soil is mixed with other organic materials and left in a pile for the microorganism to act on the contaminant.

Biostimulation

Involves the management of a naturally occurring microbial population to monitor or provide an environment that optimizes the growth and activity of microbes. Methods of biostmulation include biorenting, air sparging, nutrient addition and oxygenation.

Bioaugmentation

This involves the introduction of specific microorganisms that targets specific chemical compounds or a range of compounds. The microbe has been developed or desined to biodegrade common organic contaminate such polychlorinated biphenyls (Pbp), solvents and petroleum (Ojum et al., 2005).

Biological Treatments

1. Trickling bed filter-Spread wastewater over microorganism and made of coke (carbonized coal), limestone chips or specially fabricated plastic media, therefore Optimize their thickness by insect or worm grazing.
2. Activated sludge-mixed community of microorganisms. Both aerobic and anaerobic bacteria may exist & Biological floc is formed.

This method is used when indigenous microbe cannot metabolize the contaminant or where the contaminants are toxic to the naturally occurring bacteria.

CONCLUSION

Sometimes, concentrations of compounds can be so high that the environment is toxic to microbial populations. Therefore, the bioengineer must either use a method other than bioremediation or modify the environment (e.g., dilution, change of pH, pumped Oxygen, adding organic matter, etc.) to make it habitable. An important modification is the removal of non-aqueous-phase liquids (NAPLs) since the microbes' biofilm and other mechanisms usually work best when the microbe is attached to a particle; thus, most of the NAPLs need to be removed, by vapour extraction [A. D. Vallero, 2010]. Thus, low permeability soils, like clays, are difficult to treat, since liquids (water, solutes, and nutrients) are difficult to pump through these systems. Usually bioremediation works best in soils that are relatively sandy, allowing mobility and greater likelihood of contact between the microbes and the contaminant. Therefore, an understanding of the environmental conditions sets the stage for problem formulation (i.e., identification of the factors at work and the resulting threats to health and environmental quality) and risk management (i.e., what the various options available to address these factors are and how difficult it will be to overcome obstacles or to enhance those factors; that make remediation successful). In other words, bioremediation is a process of optimization by selecting options among a number of biological, chemical and physical factors these include correctly matching the degrading microbes to conditions, understanding and controlling the movement of the contaminant (microbial food) so as to come into contact with microbes, and characterizing the abiotic conditions controlling both of these factors [A. D. Vallero, 2010]. Optimization can vary among options, such as artificially adding microbial populations known to break down the compounds of concern. Only a few species can break down certain organic compounds [A. D. Vallero, 2010]. Two major limiting factors of any biodegradation process are toxicity to the microbial population and inherent biodegradability of the compound. Numerous bioremediation projects include in situ (field treatment) and ex situ (sample/laboratory treatment) waste treatment using biosystems

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