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HARNESSING THE POTENTIALS OF MICRO-ORGANISMS AND PLANTS AS CLEANUP AGENTS FOR PROTECTION AND RESTORATION OF A SUSTAINABLE SOCIETY

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ABSTRACT

The environment has suffered many severe treatments as a result of anthropogenic activities resulting to contaminated environment. Environmental Biotechnology has the potentials of boosting healthy living, societal and economic development of a nation. This study focuses on how some micro-organisms and plants are engineered to cleanup contaminated environment to enhance sustainability of the occupants. Environmental remediation using microbiological and plant intervention in waste water treatment, solid waste treatment; soil treatment and waste gas treatment are examined. It is therefore, recommended that pollution should be prevented in order to provide unprecedented benefits and as well adopts production method that are more economic in energy and resource

Introduction:

Biotechnology is the integration of natural sciences and engineering in order to achieve the application of organisms, cells, parts thereof and molecular analogues for products and services (Van Beuzekom and Arundel, 2006). Biotechnology is versatile and has been assessed a key area which has greatly impacted various technologies based on the application of biological processes in manufacturing, food processing, medicine, agriculture, environmental protection and resources conservation. The new wave of technological changes has enhanced dramatic improvements in various sectors such as production of drugs, steroids, vitamins, *consumption for enhancement of a sustainable society.*

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energy from renewable resources and wastes, genetic engineering applied on animals, plants and humans and as well products of fermentation used as food or drink (Johnson, 2003, Das, 2005; Gavrilescu and Chisti, 2005). Furthermore, Biotechnology can be utilized to develop products and processes that generate less waste and use less non-renewable resources and energy which resulted to reduce cost implication. In this respect biotechnology is well positioned to contribute immensely to the development of a more sustainable society so that the lives of the majority of people will be improved. Unfortunately, the resultant effect of improved life of citizens aggravated their standard of living and higher consumer demand coupled with rapids urbanization, industrialization and other developments amplified pollution of air (with CO_2, NO_x, SO_2, greenhouse gases, particulate matter), water (with chemicals, oil spills, nutrients, leachate), soils (with disposal of hazardous wastes, spreading of pesticides, herbicides) thereby threatened clean environment for healthy habitation.

Therefore mico-organisms and plants are the biological systems that can be used as cleanup agents for protection and restoration of a sustainable society. Micro-organisms can breakdown most compounds for their growth and/or energy needs. These biodegradation processes may be carried out in the presence of air (aerobically) or in its absence (anaerobically). Pollutant molecules can equally be breakdown during this process and when this occurs, it is known as co-metabolism.

Advanced technologies uses living organisms (micro-organisms, plants) to treat waste and degrade pollutants to develop products and processes that generate less waste and preserve the natural non-renewable resources and energy (Gavrilescu and Chisti, 2005; Chisti, 2007).

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Applications of Micro-organisms and Plants in Removing Pollutants from the Environment

All forms of life can be considered as having a potential function in environmental biotechnology. However, micro-organisms such as bacteria or arcaea and eukariotes like yeasts, fungi, protozoa, rotifers and unicellular plants have the ability to degrade some of the most hazardous and recalcitrant chemicals that are unfriendly in the environment. Micro-organisms may live as a free individual or as communities in mixed cultures which are of interest in relevant environmental technologies like activated sludge or biofilms in waste water treatment (Cavrilescu and Macroveanu, 2000).

Waste Water and Industrial Effluents

The use of micro-organisms to remove contaminants from waste water is largely dependent on waste water source and characteristics. Waste water could be from municipal (domestic waste), commercial and industrial and from agricultural farms. The effluent components from these various sources are very diverse, it may be chemical, physical or biological in nature and they can induce an environmental impact that could bring about changes in aquatic habitats and species structure as well as in biodiversity and water quality. Therefore, biological waste water treatment has to be adequate to pollution loading in order to remove non-settleable colloidal solids and to degrade specific pollutants such as organic, nitrogen and phosphorus compounds, heavy metals and chlorine compounds contained in waste water (Bitter, 2005). Biological treatment requires that the effluents be rich in unstable organic pollutants into stable products like CO_2, CO, NH_3, CH_4, H_2S. Biological treatment processes could be aerobic, anaerobic or combination of aerobic and anaerobic.

Aerobic biotreatment: This process is purely used for municipal and industrial waste water treatment. The basic reaction in aerobic treatment plant is represented by the reaction (1, 2):

$$\text{organic material} + O_2 \xrightarrow[\text{Other nutrients}]{\text{Cells}} CO_2 + H_2O + \text{new cells} \quad \text{..... (1)}$$

Microbial cells undergo progressive auto-oxidation of the cell mass.

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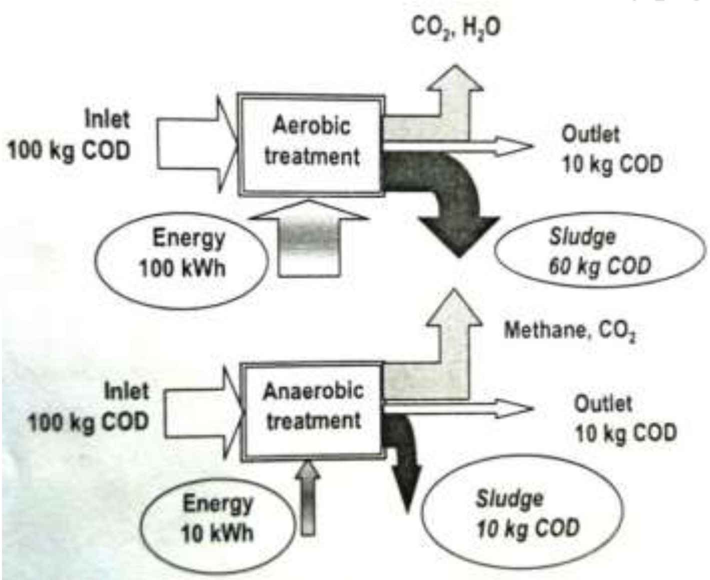
$$\text{cells} + O_2 \longrightarrow CO_2 + H_2O + NH_3 \quad \text{..... (2)}$$

The processes can be exploited as suspended in active sludge or attached growth in film fixed systems. Aeration tanks used for the activated sludge processes allows suspended growth of bacterial biomass waste treatment while trickling filters support attached growth of biomass (Gavrilescu and Ungureanu, 2002; Gallert and Winter, 2005). Domestic waste waters are usually treated by aerobic activated sludge process since they are composed mainly of protein (40 – 60%), carbohydrates (25 – 50%), fats and oils (10%), urea (Bitton, 2005).

Anaerobic biotreatment: This is often considered a pre-treatment process to minimize amount of oxygen demand and excessive formation of sludge. Anaerobic treatment generates low quantities of biological excess sludge with a high treatment efficiency, low capital cost, no oxygen requirements, methane production, low nutrient requirement (Fig. 1).



The use of non sulphur metabolising bacteria, a sort of photosynthetic bacteria under light and anaerobic condition to produce a large amount of useful biomass with little carbon (iv) oxide (Fig. 2).

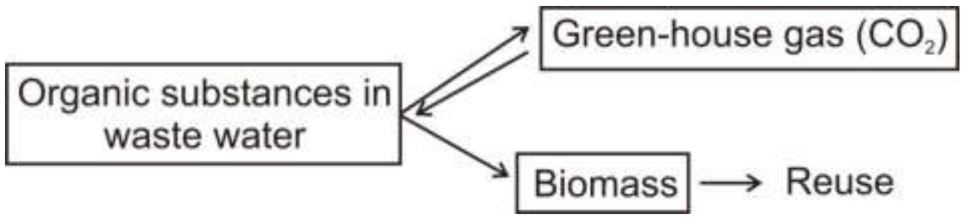


Fig. 2: Wastewater Treatment by Photosynthetic Bacteria (Adapted from Gavrilescu, 2010.)

The biomass of these bacteria can be utilized for agricultural and industrial purposes such as feed for fish and animals, fertilizers. Useful biogas is also produced from anaerobic waste water treatment. All these immense benefits bring about reduction in the cost of waste water treatment.

Removal of Heavy Metals from Waste Water

Heavy metals that are toxic are discharged into waste water treatment plants from industrial discharges and storm water. These metals may damage the biological treatment process. However, non-living immobilized bacteria, fungi, algae are able to remove heavy metals from waste water. The mechanisms involved include complexation and solubilization of metals, absorption to cell surface, volatilization, precipitation and use of recombinant bacteria. For instance Cd^{2f} can be accumulated by bacteria such as *Entamoeba coli*, *B. cepeus* and by *fungi* like *Aspergillus niger*. Also Enterobacter cloacae strain can reduce hexavalent chromium (Cr^{6+}) to trivalent chromium (Cr^{3+}). The metabolic activity of Aeromonas and flavobacterium can be used to transform selenium to volatile alkylselenide, as a result of methylation (Bitton, 2005).

Solid Waste Bioremediation

Domestic solid wastes constitutes major problem in our society. Their elimination is costly and also warrants constant surveillance in terms of air pollution and ground water, although they composed of readily biodegradable organics. Certain processes have been developed for the treatment and disposal of wastes to meet the following objectives:

1. to improve the efficiency of utilization of raw materials to reduce cost and conserve resource;

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2. to recycle waste streams within a given facility and to minimize the need for effluent disposal;
3. to reduce the quantity and maximize the quality of effluent waste streams that are created during production of goods; and
4. to transform wastes into marketable products (Gavrilescu & Nicu, 2005; Banks & Stentiford, 2007).

These processes include composting or anaerobic digestion of organic waste composting:

Solid waste which is categorized as nuisance in the environment can be transformed into valuable products through composting. This is initiated by bacteria, actinomyctes and fungi. The end product which is humus like in nature can be used as fertilizer, soil conditioner, biofilter material or fuel. Composting enhance waste stabilization, volume and mass reduction, drying, elimination of phytotoxic substances end undesired seeds and plant parts, sanitation of environment and restoration of contaminated soil.

Anaerobic Digestion of Organic Wastes

This is a natural decomposition of organic material without oxygen. This process maintains the pH, temperature and moisture content close to their optimum values. It also permits the recovery of substantial amounts of high-value bio-gas (CH_4) which can be used to produce heat and/or electricity. Advantages of anaerobic digestion process include: production of low excess sludge, consume less energy and maintain enclose of odour.

Soil and Land Bioremediation

Living organisms are used to degrade soil pollutants, either above the ground (ex situ) or in the ground (in situ). It also includes solid piles, biotreatment cells and prepared treatment beds (Khan, Satoh, Katayanna, Kurisn, & Mino 2004; Gavrilescu, 2006). Ex situ treatment involves removing the soil and ground water and treating it above ground. The soil may be treated as compost, in soil banks or in specialized slurry bioreactors. Ground water is treated in bioreactors and consequently pumped back into the ground or drained into the surface water. In situ treatment involves introduction of micro-organisms (bio augmentation), ventilation and/or addition of nutrient solutions (Bio-stimulation).

Effective bioremediation of soil depends on micro-organisms ability to enzymatically attack the pollutants and convert them to harmless products. In addition environmental perimeters must be manipulated to allow microbial growth and degradation to proceed at a faster rate.

Plants can be used to remove metals from contaminated soil and ground water (Phytoremediation). Toxic metal such as lead, mercury and arsenic that found in polluted soil and water could be absorbed by certain plants. Some phytoremediation mechanisms and applications are shown in table 1.

Table 1: Overview of phytoremediation applications.

Technique	Plant Mechanism	Surface Medium
Phytoextraction	Uptake and concentration of metal via direct uptake into the plant tissue with subsequent removal of the plants	Soils
Phytotransformation	Plant uptake and degradation of organic compounds	Surface water, groundwater
Phytostabilization	Root exudates cause metal to precipitate and become less available	Soils, groundwater, mine tailing
Phytodegradation	Enhances microbial degradation in rhizosphere	Soils, groundwater within rhizosphere
Rhizofiltration	Uptake of metals into plant roots	Surface water and water pumped

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Phytovolatilization	Plants evapotranspirate selenium, mercury, and volatile hydrocarbons	Soils and groundwater
Vegetative cap	Rainwater is evapotranspirated by plants to prevent leaching contaminants from disposal sites	Soils

Adapted from Gavrilescu 2010

Bioremediation of polluted soil and land using combination of plants and bacteria is also possible. Certain bacteria live closely associated with the roots of plants and depends on substances excreted by the roots. Such rhizobacteria may be genetically modified to breakdown pollutants in the soil.

Biotreatment of Air and Waste Gases

Odorous emissions into the environment constitute a nuisance to residents. Hence effective and efficient method of purifying environment include bioscrubbers in which pollutants are washed out using a cell suspension and biotrickling filters in which the pollutants are degraded by micro-organisms which are more efficient at metabolizing pollutants; which enhanced better air and gas purifying biofilters which work at normal operating conditions of temperature and pressure. They are relatively cheap with high efficiency (Gavrilescu et al 2005; Andres, Dumont, LeCloiree & Ramirez Lopez, 2006).

The combinations of biofilters and bioscrubbers constitute an efficient system to treat odorous off-gases from composting processes. A typical example is the removal of nitrogen and sulphur oxides from the flue gas of blast furnaces by bioscrubber based system as an alternative to the classical limestone gypsum process and the elimination of styrene from the waste gas of polystyrene processing industries by a biofilter containing fungi.

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The Role of Environmental Technology in Prevention of Pollution

More industrial companies are developing processes with reduced environmental impact and pervading trend towards less harmful products. The application of biotechnology as an environmentally friendly alternative in conventional manufacturing proves to be very useful for pollution prevention through source reduction, waste minimization, recycling and reuse. This results in lower production costs, less pollution and resource conservation. Also, biotechnology has succeeded in substituting multistep chemical processes with a one-step biological process using genetically modified organism (GMO$_s$).

Biopesticides that are manufactured from natural materials (animal, plants, bacteria, minerals) have replaced chemical pesticides. Their immense benefits results from their low toxicity to non target organism, low potential to contaminate environmental components and resources and as well low risk to human health.

Conclusion

Environmental biotechnology has proved to have a large potential to contribute to the detection, prevention and remediation of environmental pollution using micro-organisms and some plants. It is a sustainable way to develop clean processes and products, less harmful, with reduced environmental impact than their forerunners. Economic and environmental benefits derived from biotechnology are tools for the development of a more sustainable society in spite of increasing population, urbanization and industrialization.

Recommendations

1. Application of biotechnology in various fields should be encouraged for economic and environmental benefit.
2. Pollution prevention practices should be adopted.
3. Process innovation should be encouraged in the industry for efficiency and improvement of their public image.

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