Using Biotechnology to Address the Problems of the Degradative State of the Physical and Atmospheric Environment

Chigiozie M. Ejikeme,[1] Chukwuma S. Ezeonu, and G. N. Okeke[2]

ABSTRACT

One of our time's great challenges is to create and maintain a sustainable environment. Efforts towards this end must be tackled now and maintained for the sake of future generations. In humanity's quest to produce goods in industries and improve his living conditions, his activities generate gases and chemicals which have a negative impact on the environment. Thus the ozone layer is perforated, acid rain formed, green house gases generated. The recent failure of the Hukushima Nuclear power plant in Japan, caused by a tsunami, contaminated the atmosphere as well as the water bodies, a typical example of the possible negative impact of human technology on the environment. There is therefore great need for checks on certain technological processes and products so as to maintain a sustainable environment. Biotechnology and its products have created some wonderful possibilities, especially in areas of life where humans seem to have their greatest dependence.

1. Department of Chemical Sciences, Godfrey Okoye University, Enugua

A surfactant is a molecule that lowers surface tension, e. g. increasing its wetting properties or assisting the formulation of emulsified liquids

2. Department of Industrial Chemistry, Ebonyi State Universtiy, Abakaliki

Corresponding Author: Ejikeme, C. M. ejiks210@yahoo.com, +2348030980549 Chemical Sciences Department, Godfrey Okoye University, P.M.B 01014, Thinkers Corner, Enugu, Nigeria.

Perhaps biotechnology can be of immense benefit in solving environmental pollution problems if harnessed and applied to human production processes. This paper discusses how this application can be organized and implemented.

Keywords: Biotechnology, Environment, Atmosphere, Ozone, Remediation

INTRODUCTION

Our total environment is summarily made up of living organisms and three components, namely, land, water and air. These components are indispensable to us and, according to the Abrahamic religious traditions, were created purely for our use. The most important of these is air, without which humans cannot survive more than a few minutes (Ademoroti, 1996). For them to survive, there are interactions between them and the three components, and this has led to technologies of material processing and energy conversion. These technologies have in turn led to some disastrous consequences for the environment. On the other hand, technologies have also helped to advance industrial development, hence making life easier for humans. Technologies of material processing and their attendant problems are seen or regarded as man-made. Land, water, air and living things are natural.

The overuse and abuse of natural resources are causing anomalous changes to the environment, such as global warning. These human–induced environmental changes portend that future generations may not enjoy a sustainable environment.

Worldwide, there is a growing appreciation that the management and utilization of natural recourses need to be improved. The amount of waste and pollution generated by human activities must be greatly reduced. There is a realization that making industry more sustainable can provide the means of reducing environmental impacts or even improving the environment while yielding goods and services that can provide jobs, reduce poverty and improve the quality of life for a growing world population (OECD, 2001).

According to the Organization of Economic Co-operation and Industrial Development (OECD), developing a sustainable bio-based economy that uses eco–efficient bio-processes and renewable bio-resources is one of the key strategic challenges for the 21st Century. Improved understanding of biodiversity, ecology, biology and biotechnology is making it possible both to increase sustainably biomass productivity in forestry and agriculture and to utilize that biomass as well as waste organic materials in a highly efficient and sustainable manner. Without such advances in science and technology, the move to a more bio-based economy would result in the rapid depletion of renewable resources and environmental degradation . Also according to OECD (2001) studies, a more bio–based economy offers hope both for developed and developing countries. For developed countries, it presents the opportunity to use their technological capabilities fornational security of their energy and chemical supply. For developing countries, it provides the potential tc leap from at least partially over the age of fossil fuels and petrochemicals to the age of more environment–friendly biofuels and biochemicals that can be produced locally and naturally, thereby improving the economy and quality of life.

THE ENVIRONMENT

Okonkwo and Eboatu (2006) state that the environment is humanity's immediate surrounding which people manipulate for their existence. The environment is made up of land, water, air and living organisms. Humans grow crops on land, build shelter on it and carry out virtually all their activities on it. Their other prime need is water. Apart from domestic uses, water is needed for agricultural practices (cropping, flock watering and fish culturing), for industrial purpose (as a solvent and for cooling, flushing and washing). Air is indispensable to humans; we breathe air in and out whether we are asleep or awake, and this means that we cannot do without air. There are interactions among the three components of the environment land-water, land-air and water–air interactions. For this reason we find water (as moisture) in air, in soil, suspended solids in air, water and dissolved air, particularly oxygen (as dissolved oxygen), in water, dust particles and water vapour in air. Humans stand in the midst of all these interactions, taking interest as part of the system and studying the effects they all have on themselves.

The environment therefore can be defined as the global biological and physical system and endowment on which man depends for existence and well being and which he can only modify with impunity within certain limits (Okonkwo and Eboatu, 2006).

The introduction of contaminants into the environment leads to pollution. Environmental pollution is the contamination of the physical, chemical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected (Kemp 1998). Generally, pollution affects the natural state of human environments, which lead to instability, disorder, harm or discomfort to the physical system or living organisms in the environment (wikipedia. org/wiki/pollution).

CAUSATIVE AGENTS OF ENVIRONMENTAL DEGRADATION

The demands of the modern world have resulted in the generation of vast quantities of by–products as waste that now posses a threat to the environment. The solid and liquid particulate matter that is suspended in the atmosphere comes from various sources. Solid particles are swept up from dry surface of the earth or the sprays. Other sources include volcanoes and fires from burning of fuels, introduction of agricultural and industrial pollutant into the atmosphere. Gases trapped into the atmosphere are emitted through the following:

Greenhouse Gases

There are natural as well as man-made causes of greenhouse effect. The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in the atmosphere warm a planet's lower atmosphere and surface (Ramaswamy, Schwarzkopt and Shine, 1992). The naturally-occurring greenhouse effect is actually beneficial to the earth; it is only when man-made processes increase its speed that problems. Naturally occurring greenhouse gases have a mean warming affect of about 33°C (59°F) (Sparling, 2001), which is not dangerous to the atmosphere. Human activity since the industrial revolution has increased the level of greenhouse gases in the atmosphere, leading to increased radiative forces from carbon dioxide methane, ozone, chlorofluorocarbon, nitrogen oxide and water vapour.

According to the International Panel on Climatic Change, (IPCC), the greatest proportion of greenhouse gases come from the combustion of fossil fuels in cars, factories and electric production facilities. The gas responsible for the most warming is carbon dioxide (CO_2), which is released from fossil fuel, deforestation (resulting in decreasing conversion of CO_2 into oxygen through photosynthesis), road vehicles and forest fires. Methane is released from agricultural activity (especially animal waste), natural decay of vegetation and landfills,; nitrogen oxides from fossil fuels, agriculture and road vehicles; and chlorofluoro carbon gases from their use in refrigerators, aerosol sprays, fire extinguisher chemicals and industrial processes. The continuous release of these greenhouse gases into the atmosphere will increase the atmospheric temperature leading to significant climate and weather changes, affecting cloud cover, precipitation, wind patterns and the duration of seasons. Other effects of greenhouse gases include lower agricultural yields, extinction of living things (eventually including man), and the return of diseases like malaria into areas where they had been eraticated earlier (IPCC, 2007).

Ozone

Ozone is a gas in the atmosphere that protects every living organism on the earth from harmful ultraviolet (UV) rays from the sun. Ozone is a traumatic molecule consisting of three oxygen atoms; it is an allotrope of oxygen that is much less stable than the diatomic allotrope oxygen. Ozone is a by-product of photochemical smog that react with hydrocarbons to form peroxynitrate, which damages sensitive biological tissues.

The Chemistry of Ozone Formation.

According to Finlayson et al., (1999), Fishman (1990), Modronich (1993) and Turco (1996), ozone forms readily in the stratosphere as incoming ultraviolet radiation breaks molecular oxygen (two atoms) into atomic oxygen (a single atom):

$$O_2 + \text{Sunlight} \longrightarrow O + O \text{ ------ (i)}$$

When an electrically excited free oxygen atom encounters an oxygen molecule, they bond to form ozone:

$$O + O_2 \longrightarrow O_3 \text{ -------- (ii)}$$

The destruction of ozone in the stratosphere takes place as quickly as the formation of ozone, because the chemical is reactive. Sunlight can readily split ozone into individual oxygen atoms:

$$O_3 + \text{sunlight} \longrightarrow O_2 + O \text{ ------ (iii)}$$

When an electronically excited oxygen atom encounters an ozone molecule, they may combine to form two molecules of oxygen:

$$O + O_3 \longrightarrow O_2 + O_2 \text{ ------ (iv)}$$

The ozone formation-destruction process in the stratosphere occurs rapidly and constantly, maintaining an ozone layer.

In the troposphere near the earth's surface, ozone forms through the splitting of molecules by sunlight as it does in stratosphere. However, in the troposphere, nitrogen dioxide provides the primary source of the oxygen atom required for ozone formation. Sunlight splits nitrogen dioxide into nitric oxide and oxygen atom:

$$NO_2 + \text{Sunlight} \longrightarrow NO + O \text{ ------- (v)}$$

The single oxygen atom then combines with an oxygen molecule to produce ozone:

$$O + O_2 \longrightarrow O_3 \text{ ------- (vi)}$$

The Ozone then reacts with nitric oxide to yield nitrogen dioxide and oxygen:

$$NO + O_3 \longrightarrow NO_2 + O_2 \text{ ------ (vii)}$$

The process described above results in no net gain in ozone.

Nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds also contribute to ozone formation in the troposphere and they have both natural and industrial sources:

NO_x + VO_c + Sunlight ⟶ O_3 + other product - - - - -

In 1970, Fishman and Crutzen (1970) showed that ozone could be formed from oxidation of methane and carbon monoxide in the troposphere in the processes involving the hydroxyl radical.

$$CH_4 + OH \longrightarrow CH_3 + H_2O$$

$$CH_3 + O_2 + M \longrightarrow CH_3\,O_2 + M$$

$$CO + OH \longrightarrow CO_2 + H$$

$$H + O_2 + M \longrightarrow HO_2 + M$$

M is an uncreative third molecule such as N_2

In the presence of NO:

$$CH_3\,O_2 + NO \longrightarrow CH_3O + NO_2$$

$$CH_3O + O_2 \longrightarrow CH_3\,O + HO_2$$

$$HO_2 + NO \longrightarrow OH + NO_2$$

Thus via reaction of HO_2 and RO_2 (R=alkly), NO is converted to NO_2:

Then: $$NO_2 + hv \longrightarrow NO + O$$

$$O + O_2 + M \longrightarrow O_3 + M$$

The magnitude of this source of Ozone is presently controversial.

In urban areas, there is abundant NO_2 whose photolysis leads to ozone formation. However, fresh emission of NO leads to ozone removal. The full cycle of this reaction is:

$$NO_2 + hv \xrightarrow{K_3} NO + O$$

$$O + O_2 + M \xrightarrow{fi} O_3 + M$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

fi and K_3 are the rate constants for the NO_2, photolysis and O_3 removal reaction respectively.

All three reactions are rapid and an equilibrium is reached when the rate of ozone formation (equal to the rate of NO_2 photolysis of all oxygen atoms (O) leads to O_3 formation) equals the rate of O_3 removal. Then:

$$fi\,(NO_2) = K_3\,(O_3)\,(NO_3);\text{ and}$$

$$(O_3) = fi(NO_2)\,/\,K_3\,(NO_3)$$

This is termed the photo-stationary state, and thus the ozone concentration is determined by the value of fi, highest at peak sunlight intensity and the ratio of NO_2 to NO.

The ozone layer acts as a filter to absorb some of the potentially harmful UV rays from the sun and to keep them from doing damage to the earth's surface. Studies suggest that this ozone layer is being depleted by some gases produced as by-products of some materials used in industries by interacting with the ozone. The culprits causing ozone depletion are water vapour, carbon, chloride oxides, freons, halons, carbon tetrachloride, trichloroethane, oxides of nitrogen and some un-burnt hydrocarbons injected directly into the ozone layer by aircraft and supersonic transportation (SST) (Okonkwo and Eboatu, 2006).

Ozone depletion leads to a reduction in stratospheric ozone, which in turn allows more solar-ultra-violet (UV-B) radiation to reach the earth's lower atmosphere and surface. This UV-B radiation is the most energetic component of sunlight reaching the surface. It [has a] profound effect on human health, animals, plants, microorga[nisms] and materials, as well as on air quality. The increase in U[V-B] radiation associated with stratospheric ozone depletion ha[s a] substantial impact on human health, leading to such condition[s as] eye disease, skin cancer, sunburn and premature aging of the s[kin.] In moderate amounts, UV radiation has beneficial effects for [life] on earth, including:

1. as a powerful germicide
2. as a triggers for the production of vitamin D in the s[kin] which allows the body to fix the calcium necessary [for] proper bone development (Okonkwo and Eboatu,2006)

Acid Rain

The existence of acid rain was first documented by the Brit[ish] Scientist Robert A. Smith in 1852 (Seinfeld and Pandis, 1998). It [is] only recently, however, that the phenomenon started attract[ing] attention, first in Scandinavia and then worldwide (Seinfeld [and] Pandis, 1998). Acid rain is a popular term referring to the depo[sition] of wet (rain, snow, sleet, smog, cloud water and dew) and d[ry] (acidifying particles and gases) acidic components. Acid rain [is] rain that has absorbed some of the acidic gases formed when sulfu[r] dioxide and nitrogen oxide emitted into the atmosphere react wi[th] water molecules in the atmosphere to produce acids.

According to Okonkwo and Eboatu (2006), the oxidation of [SO_2] and NO_X to form their corresponding acids takes place both in the gas phase and in aqueous reactions, the principal oxidants bein[g] hydrogen peroxide ($H_2 0_2$) and the hydroxyl (OH) radical.

During the daytime OH is the principal Oxidant for [SO_2] conversion to H_2SO_4 thus:

$$SO_2 + OH \longrightarrow HOSO_2$$

$$O_2 + HOSO_2 \longrightarrow HO + SO_3$$

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

In the aqueous phase H_2O_2 is oxidizing agent:

$$SO_2 + H_2O \longrightarrow H+ HSO_3$$

$$HSO_3 + H_2O_2 \longrightarrow HSO_4 + H_20$$

$$HSO_4 + H \longrightarrow H_2SO_4$$

For NOx conversion to HNO_3 only the gas phase is significant. During daylight hours, OH is the oxidant:

$$NO_2 \longrightarrow NO + O$$

$$NO + OH + M \longrightarrow HNO_2 \text{ (nitrous acid)}$$

$$NO_2 + OH + M \longrightarrow HNO_3 \text{ (nitric acid)}$$

where M = is any third body which absorbs energy example nitrogen or oxygen.

At night, O_3 oxidizes NO_2 to N_2O_5 and hence to nitric acid. The overall reaction can be represented as:

$$2NO_2 + O_3 \longrightarrow N_2O_5 + O_2$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

In all, HNO_3, H_2SO_4 and HNO_2 are formed. When these subsequently fall together with rain, they produce acid rain.

The principal sources of acid rain are sulfur and nitrogen compounds from human sources, such as electricity generating plants (especially coal power plants), factories and motor vehicles. The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes. This acid rain increases the acidity of the soil, resulting in crop failure, and leads to the wastage of forests and damage to the fabric of buildings and historic monuments. In addition, the increased acidity of the soil results in aluminum being leached from the soil into rivers, killing fish and other aquatic creatures. The sources of the original emission can be hundreds of kilometers from where the acid rain is deposited (Okonkwo and Eboatu, 2006).

Agricultural Waste

As humans create new technologies for the development and utilization of the resources of the earth through agriculture, there is an increasing interference with nature that results in environmental degradation. Pollutants from agricultural activities can be categorized into those that stay unchanged in the environment i.e. (persistent pollutants), such as certain pesticides and nuclear waste, and those that are easily decomposed once released into the environment (non-persistent pollutants), including farm garbage, rice husks, and animal droppings.

Pollutants from agriculture can be classified on the basis of the environmental element which they affect as air, water and soil pollutants. One source of air pollutant arises from bush-burning to clear the land for planting, thereby pouring an enormous quantity of smoke and other particulate matter into the atmosphere. Gases such as carbon dioxide, and carbon monoxide arising from combustion in factories also have an impact. Fertilizer plants also pour oxides of sulphur and fluorine into the air, as well as oxides of nitrogen and hydrocarbons from nitrogen-based industries that manufacture ammonia, a vital component of most inorganic fertilizers. The run-off from agricultural or cultivated land greatly increases the nutrients on land and in water bodies. Fertilizer rich in nitrates and phosphates is washed into nearby streams or lakes, thereby raising the mineral and salt content of the water. Water that flows on the surface of crop fields where agrochemicals like insecticides and other pesticides are used contributes to soil and soil-to-water pollution. Farmers spray such chemicals as copper sulphate, sodium chlorate and certain arsenic compounds to destroy unwanted plants usually called weed that grow and compete with crop plants for soil nutrients. Such weed killers are poisonous chemicals that, while performing their duties effectively, can be detrimental to beneficial organisms in the soil and wildlife generally.

Deforestation

A forest is a piece of land covered with large plants either planted by man or grown wildly. Forests are the greatest life supporting element in nature; they account for over 50% of the plants of the world and are home to nearly all living organisms. Deforestation is the removal of a forest or stand of trees in order to convert the land to a non-forest use for human habitation or for industrial establishments or agricultural purposes (www.wikipedia.org/wiki/deforestation). Deforestation increases the amount of carbon-dioxide in the atmosphere by eliminating trees, so that photosynthesis can not take place. It also exposes the land to both wind and water erosion. Deforestation is rampant today due to the increase in human population and activity. The rate of deforestation has increased by about nine percent in recent times. Also, burning of wood causes it to oxidize, therefore releasing more carbon-dioxide into the atmosphere. This adds to the greenhouse effect.

Water and Land Pollution: Oil Spillages

Water pollution is the contamination of water bodies by hazardous pollutants from domestic, commercial and industrial sources, such as oil spills, waste and liquid discharges from industrial plants, sewage and discharge from sewage treatment works and acid rain.

These pollutants contaminate the surface and groundwater often used for drinking and which supports aquatic life. The presence of pollutants in water leads to the contamination of surface and underground water, destruction of aquatic life, silting of water bodies and interference with the aesthetic environment (Okonkwo and Eboatu, 2006).

In the Niger Delta of Nigeria, oil spillage is the major cause of land and water pollution. Spills of crude oil, as well as the disposal of used or exhausted lubricants and waste oil, have a detrimental effect not only on the environment but also on life forms within the environment. Oil spills occur as a result of either equipment failure or, human errors\ and are especially frequent during transfer operations, as between ship or shore. Whenever an oil spill occurs, nature tries to adjust in a number of ways, including evaporation of the lighter and more volatile components into the atmosphere. Heavier components tend to sink to the bottom of the sea. The compounds in crude oil or petroleum are known as organic because they are mainly made of carbon. The elemental composition of typical petroleum is carbon, hydrogen, sulphur, oxygen and nitrogen. Thus crude oil consists primarily of hydrocarbons, with minute amounts of such inorganic compounds as furans, thiophenes, acids, meceptants and some inorganic substances. Whenever an oil spill occurs, the immediate victims are the animals living in water. Apart from animal life, marine plants are adversely affected, whole farm crops are destroyed and soil fertility is degraded as some of the oil soaking into the soil gets into the roots of plants and poisons microbes that are responsible for soil fertility. Land animals for examples flies, ants and other crawling insects, even snakes and rodents, are not spared.

Oil spillages can also lead to community unrest stunted growth in vegetation, disrupted recreational activity and sometimes fire outbreaks. Land can also be contaminated by chemicals allowed to drain into the ground or where disposal is by indiscriminate burying. Other sources of contamination are acid rain, agrochemicals and refuse dumps. Land pollution exposes the people to health hazards, stunts growth in plant, reduces land use and causes a public nuisance (Okonkwo and Eboatu 2006).

Fossil Fuel

Fossil fuels are fuel formed by natural processes like the anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuel is typically millions of years and sometimes exceeds 650 million years (Paul et al, 2009). The fossil fuels which contain high percentage of carbon include coal, petroleum and natural gas. Fossil fuels range from volatile materials with a low carbon: hydrogen ratio, like methane, to liquid petroleum and further to non-volatile materials composed of almost pure carbon, such as anthracite coal. The burning of fossil fuels produces around 21.3 billion tons of carbon dioxide per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tones of atmospheric carbon dioxide a year (http://www/britannic.com/ebc/particle). Carbon dioxide is one of the greenhouse gases that enhance radiative forcing and contribute to global warming.

Photochemical Smog: Air Pollution

Photochemical smog is the resulting photochemical reactions which occur among the primary pollutions in the presence of sunlight. Both natural and anthropogenic primary pollutants can increase their concentration to harmful levels. Examples include NOx, SOx, COx, particulate matter and hydrocarbons (Okonkwo and Eboatu, 2006). Photochemical smog occurs when strong sunlight acts upon a mixture of nitrogen oxides released from vehicle emission which combine with oxygen in the air to form ozone.

In the presence of hydrocarbons again from vehicle emissions, a number of complex substances are formed which condense into minute droplets and create the characteristic haze. The Smog tends to be most intense in the afternoon when the sunlight is most intense. It frequently occurs when high level of vehicle emissions combine with strong sunlight and little wind to disperse the gases. Photochemical health effects can include irritation of the eyes and breathing problems.

Air Pollution

Every year millions of people die or suffer serious health effects from air pollution, (including respiratory diseases like asthma and chronic obstructive pulmonary disease), cardiovascular diseases and even cancer of the lung, which is on the increase due to industrial activities. Many studies consistently show the direct link between mortality rates and daily ambient concentrations of suspended particulate matter, produced mainly by industries.

Indoor exposure to particulate matter suspended in the air increases the risk of acute respiratory infections, one of the leading causes of infant and child mortality in developing countries. In Asia such exposure accounts for between half and one million excess deaths every year. In sub-Saharan Africa, the estimate is 300,000 to 500,000 excess deaths (Tayeye, 2002). In some populations, around 30% to 40% of cases of asthma and 20% to 30% of all respiratory diseases can be linked to air. In adult non–smokers, chronic exposure to environmental tobacco smoke increases mortality from lung cancer by between 20% and 30%.

Air pollution also damages plants and animals alike and contaminates water sources, threatening economic and social welfare as well as health. Lives around industrially populated areas are especially at risk. The effect of air pollution depends on levels of exposure and susceptibility of the exposed population. Air pollution also affects the workforce, and indoor air pollution is the primary cause in as many as 50 million cases of occupational chronic respiratory disease each year, a third of all occupational illness (Tayeye, 2002). These are widespread and debilitating conditions and affect people in their social and economic primes of life.

Photochemical Smog

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Thanks to biotechnology, the environmental effects of photochemical smog can be minimized, if not eventually eliminated, by using such alternative fuels as biofuel in vehicles to reduce the health problem affecting both developed and developing countries. Smog comes from sources of dust, gases and smoke generated mainly by human activity. When inhaled, air pollutants affect the lungs and respiratory tract but can also be taken up by the skin and, when absorbed, transported by the blood stream. Through deposit in the environment, air pollutants can also contaminate food and water.

APPLICATION OF BIOTECHNOLOGY IN ADDRESSING ENVIRONMENTAL CHALLENGES

According to studies by OECD (2001), biotechnology provides tools for adapting and modifying the biological organisms, products, processes and systems found in nature to develop processes that are eco-efficient and products that are not only more profitable but also more environmental friendly. It also provides an increasing range of tools for industry to continue improving cost and environmental performance beyond what could normally be achieved using conventional chemical technologies (OECD 2001).

Biotechnology has proved its worth as a technology that can contribute to environmental sustainability and sustainable industrial development. The organization for Economic – Co-operation and Development (OECD) has analyzed case studies of the application of biotechnology into such diverse sectors as chemicals, plastics, food processing, textiles, pulp and paper, mining, metal refining and energy. The case study results reveal that biotechnology can not only reduce cost but also reduce the environmental footprint for a given level of production. In some cases, capital and operating costs decreased by 10%-50% and energy and water use decrease by 10%-80%. Use of petrochemical solvents was reduced by 90% or eliminated completely. In a number of cases, biotechnology enabled the development of new products whose properties, cost and environmental performance could not be achieved using conventional chemical processes or petroleum as a raw material (OECD 2001).

The ability to "evolve" bioprocesses and bioproduction systems allows for major improvements in both economic and environmental performance and thus permits a manufacturing facility to increase its profitability and capacity while maintaining, or even reducing its environmental footprint (OECD 2001). Some biotechnological applications for solving atmospheric and physical environmental deterioration are as given hereafter.

The Use of Biotechnology to Reduce Depletion of The Ozone Layer

The ozone layer is an environmental protective mechanism that helps to shield the earth's Surface from excessive ultra-violet (UV) radiation of the sun. However, industrial pollutants like chloroflourocarbon (CFC) emissions from petrochemicals seem to be the worst enemies to this earth shield. According to the Asian and Pacific Center for the Transfer of Technology, chlorine peroxide has long been thought to trigger ozone destruction when the molecule absorbs sunlight and breaks into two chlorine atoms and an oxygen molecule, a process known as photolysis. The larger the absorption cross-section of chlorine peroxide, the faster chlorine peroxide absorbs sunlight and the faster chlorine atoms are generated, depleting the ozone layer at a rapid pace.

In a bid to avoid the depletion of the ozone layer some innovative biotechnological findings that are alternatives to CFC has been discovered. Some of these new CFC-free initiatives are as follows:

1. Daimler Industries, a leading manufacturer and distributor of commercial cleaning products based in the United States, offers Eco-Green® GreaseTrap Degreaser and treatment, a

plant-based grease trap cleaner that prevents nasty clogs without hazardous chemical solvents. The formulation is created for hospitality, healthcare and other industries that use grease traps. Daimer's Eco-Green® green chemicals line, which includes about 100 formulations, consists mainly of plant and vegetable components without ozone depleting substances or dangerous volatile organic compounds (VOCs). Eco-Green® solutions biodegrade around 50 per cent faster than most competitors.

2. Industrial Urethanes, South Africa, following its development of environment-friendly rigid polyurethane (PU) foam blowing agent, has set its sights on the production of "green polyols" derived from natural unsaturated oil sources such as palm, soya, sunflower, rapeseed and Jatropha. It plans to convert up to 50 per cent of its PU production from using petroleum-based polyether and polyester to polyols derived from natural sources that have zero ozone depletion potential, zero global-warming potential and zero volatile organic content. By modifying natural oils in certain ways they hope to arrive at polyols that ensure there is no reactive product to dispose of. Reaction times are also significantly reduced, and a third benefit is the fact that natural oils give off significantly lower odour levels when polyols are extracted. The company is also examining the recycling of PET bottles, which can be granulated and chemically broken down into "green" polyols that can then be used to manufacture PU, producing propylene oxide rather than glycerine, and ultimately PU compounds that have exceptional fire retardant properties. The major international motor vehicle manufacturer Ford has already specified its requirements for natural-based PU products, and others are bound to follow suit because both rigid and flexible PU have many uses in motor vehicle from seats to air filters. In the United States,

commercial quantities of natural oil-based polyols have been available for the past two years, initially from soybean oil. Many other natural oil options are also being investigated (www.pu2pu.com).

3. Asian and soil solarization – preparing planting beds by covering them with clear plastic sheets for several weeks during the summer to trap heat – destroys weeds, nematodes and fungi, says an expert from the University of Florida (UF), the United States. The study published in the *International Journal of Pest Management* showed solarization effectively prepared planting beds for snapdragons, in some cases as well as the soil fumigant methyl bromide (www.news.ufl.edu). In the United States, researchers from the Horticultural Research Laboratory of the United States Department of Agriculture Agricultural Research Service (ARS) and the University of California Santa Cruz have evaluated anaerobic soil disinfestation (ASD) as an alternative to methyl bromide (MeBr) fumigation in a bell pepper-eggplant double crop system. ASD combines brief periods of soil saturation with soil solarization, allowing reducing conditions to develop in concert with increased soil temperatures. This technology is being widely investigated as alternative to chemical soil fumigation for control of soil-borne pathogens, plant-pathogenic nematodes and weeds in response to the global phase-out of MeBr, and as an option for organic and transitional growers (www.pctonline.com).

The Use of Biotechnology To Solve The Climate Change Problem

A report by the European Association for Bioindustries (2009) stated that reducing the impact on the world's climate is a key element in sustainable development and of particular importance for industry. Industrial or white biotechnology is one of the most promising new approaches to pollution prevention, resource conservation and cost reduction. Applications of white biotechnology can contribute to meet the EU's environmental objective to reduce greenhouse gas (GHG) emissions by 20% in 2020. Mankind and the environment benefit daily from industrial biotechnology without being aware of it, for example while doing a load of laundry. Enzymes have been used in detergents since the 1960s and since then have helped to reduce the amount of detergent released into the environment as well as decreasing the energy needed to do laundry. In fact detergent enzymes represent one of the largest and most successful applications of modern industrial biotechnology (www.europabio.org).

Plastics

Plastics in general are important materials contributing significantly to environmental protection: due to their tailor-made properties (e.g. light weight, excellent insulation ability, tunable properties for optimum food protection, etc.) they have already reduced energy use by 26% and greenhouse gas (GHG) emissions by 56% across a variety of applications when compared to alternatives. Besides crude oil, natural gas and coal, biomass is an additional raw material source for plastics. Today, biotech processes allow for the production of bio-based plastics from renewable resources. Even though bio-based plastics currently make up only a small portion of all plastics produced, they contribute to a reduction of dependency on fossil fuel in some specific sectors. In many cases, the production of bio-based polymers has a great potential to reduce greenhouse gases. Using biotechnology processes to produce plastics, less energy may be expended, few resources are consumed and global greenhouse gas

(GHG) emissions are reduced, as shown in the graphs below (www.europabio.org).

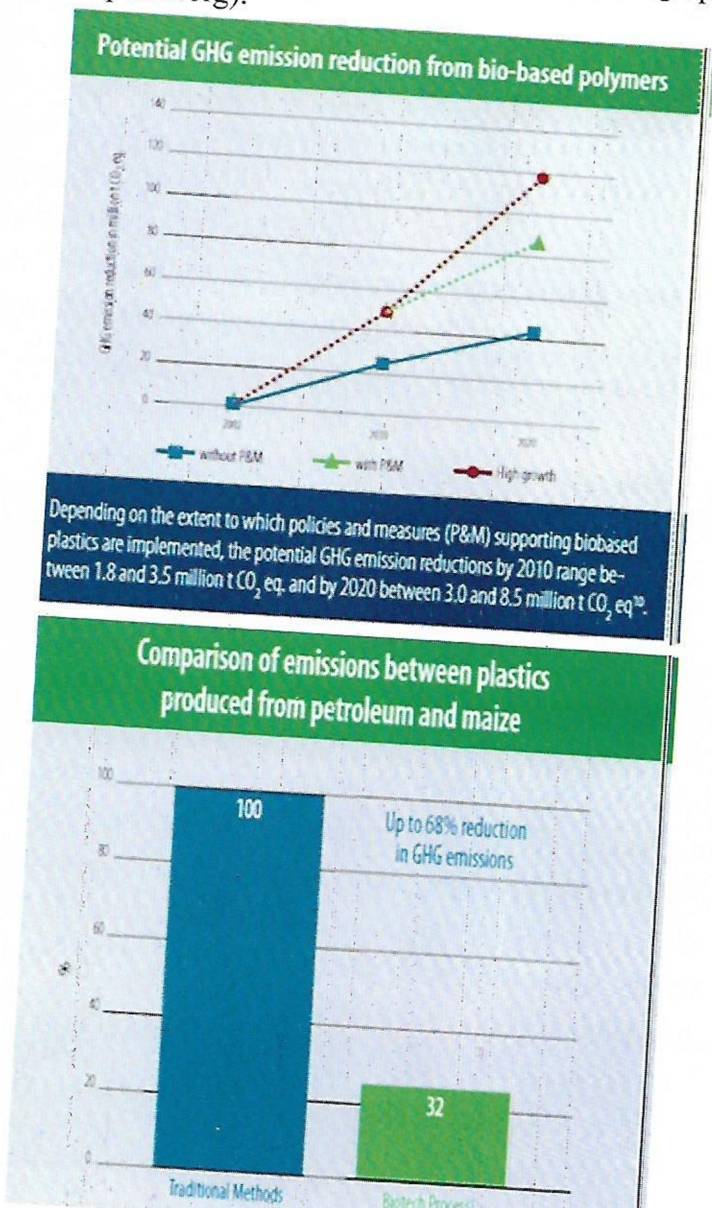

Figure 1: *Source: www.europabio.org*

Tanning

Enzymes have been used in the tanning industry for centuries because they are efficient in degrading protein and fat. In early times, the enzymes were derived from animal excrement and later on from the pancreases of cattle. Today, the enzymes are almost entirely produced by microbial fermentation. Soaking enzymes reduce the required soaking time by producing the surfactant* and soda required during the tanning process. Reduced soaking time leads to electricity savings in turning the drum where the hides rest. Enzymes that remove hair during the tanning process reduce the sulfide requirements for the process. The environmental impacts of producing and delivering the enzymes to the tannery on the one hand and the savings in chemicals and electricity on the other have been evaluated via a life cycle analysis (LCA) 23 study. This comparison of conventional and enzyme-assisted bovine soaking and de-hairing/liming processes indicates that the application of enzymes in the tanning industry is justified by considerable energy savings and considerable reductions in the processes' contribution to global warming. Assuming that the environmental improvements made by switching from conventional to enzyme-assisted soaking and de-hairing/liming are applicable worldwide, the global saving potential is in the order of 8 million GJ of energy and 0.7 million tonnes of CO_2 per year (www.europabio.org).

Figure 2: *The dye and tanning industries*
Source: www.europabio.org

Thanks to the production of dyes through more environmentally friendly processes, as well as through wastewater treatment, enzymes can help to reduce the potential environmental impact of dye manufacturing. Bioprocesses to produce bio-based colorants have been developed and recently patented as an alternative to traditional chemical synthesis. While the creation of chemical-based dyes requires temperatures up to 70°-90°C in harsh conditions, the enzymatic synthesis of these colorants can be obtained at ambient temperature, under mild conditions. A life cycle analysis has shown that on an industrial scale, enzymatic processes could help to reduce CO_2 emissions and toxicity towards the environment (www.europabio.org).

An Alternative Energy Source: Bio-Energy

Biofuels (www.uneptie.org) like ethanol and methane are commonly produced from plants grown and harvested for this purpose and from waste plant **biomass**, including wood or agricultural residues. These sources of energy are renewable and relatively clean, and can be produced in most regions where plants can be grown. Brazil, for example has produced fuel alcohol for years from fermented sugar cane. Fuel-making factories are built in areas where the cane is grown, minimizing the need for transport. Cane debris left behind after the fermentable juice is squeezed out is used as boiler fuel, supplying steam for stills, sterilization of equipment, and local electrical production. Since no other fuel is required for these operations, the fuel alcohol produced is a net gain.

The greatest part of the carbohydrate content in plants is not in the form of either starch or sugars but in cellulose – the material making up the structural cell walls of stems, leaves, hulls, husks, cobs, etc. Lignocellulose (a mixture of cellulose, hemicellulose, and lignin) in wood and paper wastes makes a vast, cheap, widespread and largely untapped renewable source of biomass that can be converted to fuel. However, lignocellulose is very difficult to break down and convert into sugars and alcohol. The breakdown of cellulose alone releases a mixture of sugars, including glucose, xylose, mannose, galactose and arabinose. Work is now being done to determine the best enzymes for rapidly and efficiently metabolize all of these sugars into ethanol. With the right microbes feeding on the sugar residues found in waste paper and other biomass, significant quantities of ethanol could be produced each year.

Forestry and Agriculture

Forests are reservoirs of biodiversity. Preservation of their unique genetic characteristics is vital to the development of improved drugs, pesticides, foods and materials. To sustain renewable tree harvesting into the future, forest managers need to replace what they cut. Where forests have grown undisturbed for centuries, they are often impossible to replace. An important alternative therefore is to sustain the diversity of tree species through forest plantations. However, forest plantations can impact the environment through excessive use of chemical fertilizers, pesticides and herbicides. If, in the long term, they deplete the soil, these plantations become unsustainable (www.uneptie.org). These potential impacts can be addressed in a number of ways, including:

- adding leguminous species to plantations to improve soil fertility and keep down weeds, reducing the need for both fertilizers and herbicides,
- leaving chipped logging residue and bark in the field to reduce nutrient loss and act as a mulch, which also decreases weed growth and the need for burning to prepare sites for subsequent plantings,
- using biological control instead of herbicides to combat insect pests

Adapted from Life Sciences Biotechnology and Food Security (2011).
Source: www.biotechandfoodsecurity.com.

Climate also has a significant impact on the growth and viability of forests. A steady increase in average temperatures from global warming could dramatically alter today's pattern of tree distribution, thereby putting certain species under stress and encouraging the spread of other species.

Plant Selection

Native, non-agricultural plants are generally preferred for phytotechnology applications. In most applications, plants that are adapted to local conditions will have better chances of success than non-adapted plants. The use of mixed species of vegetation can also lead to greater chances of success than the use of monocultures. Care should be taken not to introduce species of plants that are invasive or a nuisance. In cases where the spread of a plant is undesirable, the plants should be selected to prevent reproduction. The long term establishment of vegetation at a site is dependent on the project goals and the future intended use of the site. For phytotechnology applications involving little or no maintenance at a given site, it is likely that there will be a succession of plants. If so, this succession should be planned when considering types and timing of vegetation. Plant rotation could be important when short-lived vegetation is used that does not meet overall objectives or for vegetation that should not be replanted in the same place (www.uneptie.org).

THE USE OF BIOTECHNOLOGY FOR BIOREMEDIATION

Many microorganisms can degrade various kinds of environmental pollutants into relatively harmless materials before the death of the microorganisms. This property could also be used in overcoming the environmental hazards of DDT, lead and other environmental pollutants like toxic wastes globally (Soetan, 2008c).

Microorganisms can now be genetically engineered for use in 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, microorganisms with the property of enhanced leaching ability could be designed.

Research is already being carried out to improve the naturally-occurring bacteria that can 'eat oil.' for use following an oil spill. By applying bacteria to oil covered beaches, the complex oil molecules would be broken down into harmless sugars (Su, 1998). Strains of bacteria which can degrade fuel hydrocarbons have been designed and the use of genetically engineered microorganisms to clean up oil spillages or treat sewages has been proposed and is undergoing production/manufacturing.

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

THE USE OF BIOTECHNOLOGY TO PRODUCE CLEANER PRODUCTS

Plastics and other polymers

Occurrence of biodegradable plastics such as poly-hydroxyalkanoic acids (PHA) in bacteria has been known since the 1920s. The expense of producing bioplastics and the availability of versatile low-cost petrochemicals-derived plastics led to bioplastics being ignored for a long time. Concern over the persistence of petrochemical plastics in the environment is a renewing interest in biologically derived polymers (Kim et al., 2000; Stevens, 2002). The Japan Institute of Physics and Chemical Research engineered a microorganism to produce up to 96% of its dry weight as biodegradable plastic (Lenz, 1995). Many diverse plastic and non-plastic biopolymers are now available. Even though they remain relatively expensive, their production and use are environmentally sustainable. Substantial effort is underway to develop improved production of polyhydroxyalkanoates (PHAs) and other biodegradable, renewable, biopolymers (Tamer et al., 1998a, b; Grothe et al., 1999; Grothe and Chisti, 2000; Stevens, 2002; Salehizadeh and Van Loosdrecht, 2004). Biopolymers with enhanced properties and microbial strains for producing them are being developed. More efficient fermentation and product recovery processes are being investigated (Tamer et al., 1998a, b; Grothe et al., 1999; Grothe and Chisti, 2000; Salehizadeh and Van Loosdrecht, 2004). The use of mixed cultures and inexpensive substrates can substantially reduce the production costs of PHAs (Salehizadeh and Van Loosdrecht, 2004). The conversion of acrylonitrile to acrylic acid for the production of anionic polyacrylamides is an example of a large-scale biotransformation with significant commercial and environmental benefits. Ciba Specialty Chemicals (*www.cibasc.com*) manufactures a range of polymers based on acrylamide and acrylic acid using biological technologies. The conventional method for producing acrylic acid was a hazardous, multi-step, energy-intensive process that required high concentrations of toxic acrylonitrile, operated at an elevated temperature. It also produced hazardous emissions. Ciba's biotransformation route is claimed to have the following benefits: a simple, one-step process that is cost-effective and provides a product of good quality; production at ambient temperature and atmospheric pressure; a low concentration of hazardous acrylonitrile throughout manufacture; few by-products; and near-quantitative conversion.

Biopesticides

Pesticides are used in crop protection, management of weeds, control of insects, treatment of seeds, control of algae in swimming pools and preservation of wood and textiles (Waxman, 1998). A biopesticide is any microscopic biological agent or product derived from microorganisms, for use in controlling insects, weeds and rodent pests. Packaging, handling, storage and methods of application of biopesticides are similar to those for traditional pesticides. Biopesticides have had some spectacular successes, but there have been concerns related to their effectiveness (Auld and Morin, 1995). Approximately US$160 million worth of biopesticides were sold in 2000. Of this, over 90% represented sales relating to Bt (*Bacillus thoringensis*) products (Vega, 1999). At present, biopesticides capture less than 2% of the global pesticides market, but this is expected to increase significantly in the future. Biopesticides generally tend to be highly target specific, do not leave toxic residues, reduce the risk of resistance development in the target species (Pimentel, 2002) and produce a lesser overall impact on the environment than conventional chemical pesticides. Biofungicides have been used in both the phylloplane and rhizosphere to suppress fungal infection in plants. Species of *Bacillus* and *Pseudomonas* have been successfully used as seed dressings to control certain soilborne plant diseases (Johnsson *et al.*, 1998).

The variety of biopesticides is already large and increasing (Hall and Menn, 1999; Koul and Dhaliwal, 2002). In addition to biologically produced chemicals, pest pathogenic bacteria, fungi, viruses and parasitic nematodes are being developed or used for managing various pests. Both spore-forming and non-sporulating bacterial entomopathogens are being used or assessed for biopesticidal use. Nonspore-forming species in the *Pseudomonaceae* and the *Enterobacteriaceae* families are potential biocontrol agents. The spore formers *Bacillus popilliae* and *Bacillus thuringiensis* (Bt) are already well established insecticides.

Biofertilizers and soil inoculants.

Biofertilizers and soil inoculants are attracting attention as inexpensive and safe alternatives to chemical fertilizers that are used to deliver nitrogen, phosphorus, potassium, sulfur and certain other inorganic nutrients required for crop growth (Subba Rao, 1982). The first generation of biological fertilizers was based on nitrogen fixing rhizobial bacteria found naturally in the root nodules of legumes. These bacteria fix nitrogen from the air, to provide the plant with assimilable nitrogen. Microbial inoculants may be used to complement conventional fertilizers, by enhancing their absorption by plants. Enhanced use of biofertilizers is expected to contribute significantly to reducing pollution and the energy and resource consumption associated with the use of conventional fertilizers (Gavrilescu, and Chisti, 2005).

Efforts are under way to engineer non-leguminous plants with symbiotic rhizobial root nodules so that, like the legumes, they can be grown without the need for added nitrogen fertilizers. In addition, biofertilizer research is focusing on enhancing the consistency and reliability of the performance of products; developing stable formulations and effective delivery systems; demonstration of effectiveness under a range of field conditions; and elucidation of mechanisms of action. Work is underway on producing mycorhizal soil inoculants for enhancing the effectiveness of plant root systems (Gavrilescu, and Chisti, 2)

CONCLUSION

God is undoubtedly the great creator and super-technologist who gave humanity the authority to pro-create. Biotechnology is therefore the direct adherence of man to the Divine command of pro-creating and subduing the world. This same act of pro-creation via bio-technology and its products has created some amazing possibility especially in areas of life where humans seem to have their greatest dependence.

Developing sustainable industries implies constantly assessing and improving industrial performance. The aim is to uncouple economic growth from environmental degradation so that industries will be more profitable and simultaneously, environmental quality will also improve. Economic growth provides jobs and income, goods and services and opportunities to improve the standard of living for an increasing world population.

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