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Review

The role of biotechnology towards attainment of a sustainable and safe global agriculture and environment – A review

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Biotechnology is producing great opportunities for the increase in global agricultural production and for protecting the environment through the reduced use of agro-chemicals like pesticides, fertilizers and rodenticides. Biotechnology has played an important role towards the attainment of environmental sustainability by using environment-friendly crops such as insect-resistant, herbicide-tolerant species and crops that can fix nitrogen leading to purification of the environment. Increasing global food production within existing land area and the use of modern plant breeding methods have enhanced increased production of crops like legumes to improve soil structure, organic matter and fertility. These lead to conservation of bioresources and prevent soil erosion. Some beneficial effects of livestock production on the environment are also discussed. However, fears and concerns about the environmental consequences of biotechnology are also discussed. The overall aim of this review is to emphasize the importance of biotechnology towards attaining a safe and sustainable environment for increased global agricultural production.

Key words: Biotechnology, environmental safety, agricultural production, heavy metal, pollution.

INTRODUCTION

Biotechnology can simply be defined as a technique that uses living 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 thereof to make or modify products or processes for specific use (UNCBD, 1992). Traditionally, micro-organisms have been deliberately used to produce beverages and fermented foods (Olatunji, 2007).

Environmental biotechnology is the application of biotechnology to the study of natural environment. It can also imply trying to harness biological processes for commercial uses and exploitation (Wikipedia.org). The International Society for Environmental Biotechnology defines Environmental Biotechnology as the development, use and regulation of biological systems for remediation of contaminated environments (land, air, water) and for environment-friendly processes (green manufacturing technologies and sustainable development). It can also be described as "the optimal use of nature, in the form of plants, animals, bacteria, fungi and algae, to produce renewable energy, food and nutrients in a synergistic integrated cycle of profit-making processes where the waste of each process becomes the feedstock for another process" (Wikipedia.org).

Environmental biotechnology plays an important role in agroecology in the form of zero waste agriculture and most significantly through the operation of over 15 million biogas digesters worldwide (Wikipedia.org; Zylstraa and Kukor, 2005; Vidya, 2005). Agroecology is the application of ecological principles to the production of food, fuel, fibre and pharmaceuticals. The term encompasses a broad range of approaches and is considered "a science, a movement and a practice" (Wezel et al., 2009).

The roles of biotechnology in improving agricultural productivity and environmental conditions, removal of toxic chemicals and heavy metal pollution from the environment, desulphurization of fossil fuels, ecosystem modeling, control of oil spillage and saving of resources and energy will be discussed. Also, the fears and concerns about biotechnology approach to achieving a safe environment and agriculture will be mentioned in this review.

BIOTECHNOLOGY, AGRICULTURE AND ENVIRONMENTAL POLLUTION

Agriculture is the use of natural resources base for the improvement and increase in production of crops, livestock, fish and trees (Anderson, 1991; Ene-Obong, 2007a). In Agricultural biotechnology, improvement is accelerated and production is increased, using updated knowledge of living organisms including the genetic code. These include well-established conventional techniques as in biological pest control, fermentation, and production of vaccines and biofertilizers as well as modern techniques like tissue culture, genetic engineering (GE) also called genetic modification, recombinant DNA technology (rDNA), crop and animal transformation as a result of transgenesis (Ene-Obong, 2003). The importance of these new technologies like biotechnology in food security, environmental sustainability and economic development was captured at the United Nations General Assembly in 2005 (Ene-Obong, 2007b).

Global industrial explosion which is intended to cater for the needs of the world's increasing population is always associated with environmental pollution (Okpokwasili, 2007). Pollution occurs as a result of improper management of industrial by-products, their accumulation in the environment beyond acceptable limits therefore causes hazard and or nuisance to man. The industrial by-products that are pollutants may be either organic or inorganic compounds (Okpokwasili, 2007). Man's environment is composed of abiotic and biotic components (Okpokwasili, 2007).

Developing countries are faced with the challenge of rapidly increasing agricultural productivity to help feed their growing populations without depleting the natural resource base (Rege, 1996). In many African countries, agriculture is still subsistent and primitive and this raises concerns on food security, deforestation, rapid population growth, environmental protection, poor soils, stressed environments, unfavourable climatic conditions and improved crops and livestock (Ene-Obong, 2007a).

For instance, an environment in which pollution of a particular type is maximum. The effluents of a starch industry mixing up with a local water body like a lake or pond. These cause huge deposits of starch which are not easily degraded by micro-organisms except for a few exceptions. Through genetic engineering, a few micro-organisms were isolated from the polluted site and scanned for any significant changes in their genome like evolutions or mutations. The modified genes were then identified because the isolate would have adapted itself to utilize/degrade the starch better than other microbes of the same genus. As a result, the resultant genes are cloned onto industrially significant micro- organisms which are used for economically significant processes like fermentation and it can also be applied in pharmaceutical industries (Wikipedia.org).

Another case study is the incidence of oil spills in the oceans which require cleanup, microbes isolated from oil rich environments like oil transfer pipelines, oil wells etc have been discovered to have the potential to degrade or use it as an energy source and thus serve as a remedy to oil spills. Still another case study is the case of microbes isolated from pesticide rich soils. These microbes have the potential to utilize the pesticides as a source of energy and so when mixed along with bio-fertilizers, they would serve as a good insurance against increased pesticide-toxicity levels in agricultural processes (Wikipedia.org).

However, there are counter arguments that the newly introduced micro-organisms used for cleanup of oil spillage could create an imbalance in the natural environment concerned. There are also concerns that the mutual harmony in which the organisms in that particular environment existed may be altered and extreme caution should be taken so as not to disturb the mutual relationships that already existed in the environment to which these newly discovered and cloned micro-organisms are introduced. This leads to a suggestion that the positive and negative environmental consequences of environmental and agricultural biotechnology needs to be promptly addressed.

CHALLENGES IMPOSED ON THE ENVIRONMENT BY HUMAN ACTIVITIES

Human activities constitute one of the major means of introduction of heavy metals into the environment. One of the major development challenges facing this decade is how to achieve a cost effective and environmentally sound strategies to deal with the global waste crisis facing both the developed and developing countries (Parker and Corbilt, 1992; Jensen,1990; NEST, 1991; Oyediran,1994; Alloway and Aryes, 1997). The crisis has threatened the assimilative and carrying capacity of the earth, which is our life support system. Although the nutrient content of wastes makes them attractive as fertilizers, land application of many 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 of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world. For example, the bioaccumulation of Pb in human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes constipation, swelling of the brain, paralysis and eventual death (Chang, 1992). This problem is even more pronounced in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stake holders. Heavy metals concentration in the environment cannot be attributed to geological factors alone, but human activities do modify considerably the mineral composition of soils, crops and water. The recent population and industrial growth has led to increasing production of domestic, municipal and industrial wastes, which are indiscriminately dumped in landfill and water bodies without treatment. Ogunyemi et al. (2003) reported that the use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility and these wastes often contain heavy metals in various forms and at different contamination levels. Some of these heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans (Alloway and Ayres, 1997).

Municipal 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. Soil is a vital resource for sustaining two human needs of quality food supply and quality environment (Wild, 1995). Plants grown on a land polluted with municipal, domestic or industrial wastes can absorb heavy metals in the form of mobile ions present in the soil solution through their roots or through foliar absorption. These absorbed metals get bioaccumulated in the roots, stems, fruits, grains and leaves of plants (Fatoki, 2000). Plants are known to take up and accumulate heavy metals from contaminated soils (Madejon et al., 2003). The consumption of such plants could particularly be hazardous because the accumulated metals in edible plants may end up in human food chain with the attendant adverse effects on human and animal health. A promising cost-effective plant-based technology for the cleanup of heavy metal pollution is phytoremediation. Lombi et al. (2001) stated that this technology has attracted attention in recent years because of the low cost of implementation and is particularly attractive in the tropics, where normal climatic conditions favour plant growth and microbial activity. Plants that sprout and grow in metal laden soils are tolerant to metal pollution in soil and are ‘candidates’ for remediation strategies and management for heavy metals contaminated soils. Fulekar (2004) reported that in recent decades, the mangrove forests have been affected mainly by human developmental activities, pollution discharge from industrial and domestic waste resulting into impact on the mangrove forests and coastal aquatic ecosystem. The potential environmental and public health impacts of biotechnology approach to livestock production have been reviewed by Soetan and Oluwayelu (2011).

CONTRIBUTIONS OF BIOTECHNOLOGY TO IMPROVED AGRICULTURAL PRODUCTIVITY

Biotechnology is regarded as a means to the rapid increase in agricultural production through addressing the production constraints of small-scale or resource-poor farmers who contribute more than 70% of the food produced in developing countries (Rege, 1996). Biotechnology is applicable to all areas and fields of human endeavours. The dynamic and ubiquitous nature of biotechnology has been reviewed by Soetan (2008a). Agricultural biotechnology as the solution to the problem of global food insecurity has also been reviewed by Soetan (2008b). Agricultural biotechnology has the potential to address some of the problems of developing countries like food insecurity, unfavourable environmental and climatic conditions etc mentioned above and also improve agricultural productivity. Agricultural biotechnology has provided animal agriculture with safer, more efficacious vaccines against pseudo rabies, enteric collibacilosis and foot-and-mouth disease (FMD) (Stenholm and Waggoner, 1992). Disease detection in crops and animals are more efficiently and rapidly done using DNA probes. Biotechnology as a key tool to breakthrough in medical and veterinary research has been reviewed by Soetan and Abatan, (2008).

Crops are now routinely genetically modified for insect and pest resistance, delayed ripening, herbicide tolerance and maximal production under stressed environments. Molecular mapping of crops and farm animals has markedly cut down breeding time and enhanced man’s understanding and manipulation of genes (Ene-Obong, 2007b). Application of modern technology to agriculture as a catalyst to sustainable food production and industrial growth in Nigeria has been reviewed (Soetan, 2008c).

Nutrition is one of the most serious limitations to livestock production in developing countries, especially in the tropics (Rege, 1996). Plants generally contain anti-nutrients acquired from fertilizers, pesticides and several naturally-occuring chemicals (Igile, 1996). Some of these chemicals are known as secondary metabolites and they have been shown to be highly biologically active (Zenk, 1991). Examples of these secondary plant metabolites are saponins, tannins, flavonoids, alkaloids, oxalates, phytates, trypsin (protease) inhibitors, cyanogenic glycosides etc. Some of these chemicals have been shown to be deleterious to health or evidently advantageous to human and animal health if consumed at appropriate amounts (Kersten et al., 1991; Sugano et al., 1993). These antinutritional factors affect the overall nutritional value of human foods and animal feeds (Osagie, 1998). Some of these plant components have the potential to precipitate adverse effects on the productivity of farm livestock (D’Mello, 2000). Conventional plant breeding methods has been used to reduce and in some cases, eliminate such antinutritive factors (ANF) (Rege, 1996). An example is the introduction of cultivars of oilseed rape which are low in or free from erucic acid and glucosinolates.

A combination of genetic engineering and conventional plant breeding methods could lead to substantial reduction or removal of the major antinutritive factors in plant species of importance in animal feeds (Rege, 1996). Transgenic rumen microbes could also play a role in the detoxification of plant poisons or inactivation of antinutritional factors (Rege, 1996). Successful introduction of a caprine rumen inoculum obtained in Hawaii into the bovine rumen in Australia to detoxify 3 hydroxy 4(IH)pyridine (3,4 DHP), a breakdown product of the non-protein amino acid mimosine found in Leucaena forage.

Jones and Megarrity (1986) demonstrate the possibilities. However, the pharmacological and other beneficial effects of these anti-nutritional factors in plants have been reviewed by Soetan (2008d).

In animal production, biotechnology techniques applied include gene cloning, embryo transfer, artificial insemination, milk modification etc. In animal health, biotechnology techniques are used for the fast and accurate diagnosis and treatment of diseases. Gene therapy, vaccine production, production of recombinant pharmaceuticals etc are examples (Soetan and Abatan, 2008; Soetan, 2009). According to Ene-Obong (2007b), biotechnology can help promote sustainable and safe agriculture and environment respectively globally in two ways:

1. By increasing food production within existing land area under plough, making it unnecessary to use marginal land or environmentally-sensitive methods and areas. This leads to conservation of bioresources thereby avoiding soil erosion.
2. Using environment-friendly crops such as insect-resistant, herbicide tolerant species, as well as crops that can fix nitrogen lead to purification of the environment. Consequently, less chemicals like pesticides, herbicides and synthetic nitrogen fertilizers are used.

Agricultural biotechnology has long been a source of innovation in the production and processing of agricultural products and has profound impact on the livestock sector (Jutzi et al., 2003). Improved agricultural technology as the catalyst to sustainable food production and industrial growth in Nigeria has been reviewed by Soetan (2008a). Globally, if hunger and malnutrition, is to be reduced drastically, agriculture must be tailored to meet the future demands of increased population. The increase in human population increase the demand for land, space and available resources and primitive agricultural practices cause desertification, environmental pollution and produces resultant effects on climate, ecosystems, biogeochemical cycles and human health (Ene-Obong, 2007b). Sustainable agricultural practices targeted towards improved agricultural productivity, under clean, safe and environment- friendly conditions must be introduced into the global agricultural system, in order to reduce the adverse effects of environmental pollution on human health and the climate (global warming) (Soetan, 2008c). The new techniques of biotechnology provide innovations that complement the weaknesses of conventional agricultural practices and should be adopted for increased food production (Ene-Obong, 2003; 2005; 2007a).

BIOTECHNOLOGY AND LIVESTOCK PRODUCTION IN THE IMPROVEMENT OF ENVIRONMENTAL CONDITIONS

Livestock recycle nutrients on the farm, produce valuable output from land that is not suitable for sustained crop production and provide energy and capital for successful farm operations (Delgado et al., 1999). Livestock can also help maintain soil fertility in soils lacking adequate organic content or nutrients (Ehui et al., 1998). Adding animal manure to the soil increases the nutrient retention capacity (or cation-exchange capacity), improves the soil's physical condition by increasing its water-holding capacity and improves soil structure (Delgado et al., 1999). Animal manure also helps maintain or create a better climate for micro- flora and fauna in soils. Grazing animals improve soil cover by dispersing seeds, controlling shrub growth, breaking up soil crusts and removing biomass that otherwise might be fuel for bush fires (Delgado et al., 1999). These activities stimulate grass tilling and improve seed germination and thus improve land quality and vegetation growth. Livestock production also enables farmers to allocate plant nutrients across time and space by way of grazing to produce manure, land that cannot sustain crop production. This makes other land more productive (Delgado et al., 1999). Grazing livestock can also accelerate transformation of nutrients in crop by-products to fertilizer, thus speeding up the process of land recovery between crops. As disease constraints are also removed, large breeds of livestock can be integrated into crop operations for providing farm power and manure (Delgado et al., 1999). Biotechnology has enhanced increased animal production through Artificial insemination (AI) and also improved animal health and disease control through the production of DNA recombinant vaccines (Soetan and Abatan, 2008).

BIOTECHNOLOGY AND THE REMOVAL OF TOXIC CHEMICALS FROM THE ENVIRONMENT

Micro-organisms have broadened the environments they live in by evolving enzymes that allow them to metabolize numerous man-made chemicals (that is, xenobiotics) (Okpokwasili, 2007). Bioremediation is the use of micro-organisms or microbial processes to detoxify and degrade environmental contaminants. Micro-organisms have been used for the routine treatment and transformation of waste products for several decades (Okpokwasili, 2007). The fixed-film and activated sludge treatment systems depend on the metabolic activities of micro-organisms which degrade the wastes entering the treatment facility. Specialized waste treatment plant containing selected and acclimated microbial populations are often used to treat industrial effluents (Okpokwasili, 2007). The innovation in bioremediation has been applied to the remediation of soils, groundwater and similar environmental media (Okpokwasili, 2006 a, b).

Bioremediation techniques depend on having the right micro-organisms in the right place with the right environmental condition for degradation to occur. The right micro organisms are those bacteria and fungi which possess the physiological and metabolic capability to degrade the contaminants (Okpokwasili, 2007). Already, bacteria with natural abilities to digest certain chemicals are being used to clean up industrial sites (Su, 1998). By means of genetic engineering, biotechnology has brought about the rapid production of bacteria.

BIOTECHNOLOGY AND THE REMOVAL OF HEAVY METAL POLLUTION FROM THE ENVIRONMENT

Basically, the heavy metals of environmental interest include mercury, vanadium, nickel, cobalt, lead, cadmium, chromium, tin etc (Okpokwasili, 2007). Some harmful compounds that cause serious environmental pollutions and disaster like Dichlorodiphenyltrichloroethane (DDT) and lead (Pb) could be safely removed by means of genetic engineering of bacteria manufactured for that purpose. The ability of micro-organisms to accumulate metals and their potential use in the decontamination of environments impacted by toxic metals has been reported by (Kelly et al. (1979) and Aiking et al. (1985).

Micro-organisms remove toxic metals 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). *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). Uranium, copper and cobalt could be removed by polyacrylamide-immobilized cells of *Streptomyces albus*. Microbial processes can also mediate the precipitation of metals from aqueous solutions. Certain bacteria 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 catalyze a range of metal transformations which are useful for waste treatment. These transformations include oxidation, reduction and alkylation reactions. Bacteria, fungi, algae 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).

BIOTECHNOLOGY AND DESULPHURIZATION OF FOSSIL FUELS

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 particle is the absolute requirement. Mixed and pure cultures of a variety of micro-organisms (heterotrophic bacteria) can be used to remove organic sulphur from coal and oil (Okpokwasili, 2007). However, sulphur removal has also been reported under anaerobic microbial action (Fligwe, 1988).

BIOTECHNOLOGY AND ECOSYSTEM MODELLING

An ecosystem consists of producers, consumers, decomposers and detritivores and their physical environment, all interacting through energy flow and materials recycling (Starr and Taggart, 1995). A food web is a network of crossing, interlinked food chains involving primary producers, consumers and decomposers (Starr and Taggart, 1995).

Disturbances to one part of an ecosystem can have unexpected effects on other, seemingly unrelated parts (Starr and Taggart, 1995). Ecosystem modeling is an approach to predict unforeseen effects. By this method, researchers identify crucial bits of information about different ecosystem components. They use computer programs and models to combine the information and then use the resulting data to predict the outcome of the next disturbance. Biotechnology techniques like bioinformatics are useful in ecosystem modeling.

Bioinformatics deals in gene database management, gene mapping, coding, sequence alignment etc (Abd-Elsalam, 2003; Olukosi, 2006).

MICROBIAL BIOTECHNOLOGY IN THE MONITORING OF ENVIRONMENTAL POLLUTION

A number of microbial parameters are used for the detection and monitoring of pollutants, especially in water bodies (Okpokwasili, 2007). Some micro-organisms serve as indicators of organic pollution while others serve as indicators of inorganic pollution.

Some of the parameters used for the monitoring of organic pollution are heterotrophic bacteria, total and faecal coliforms and faecal streptococci. Parameters used for monitoring inorganic pollution include nitrifying bacteria, sulphur oxidizing bacteria, sulphate reducing bacteria (SRB), iron bacteria etc (HTC, 1993; Odokuma and Okpokwasili, 1997). The presence of faecal coliforms in numbers above the World Health Organization (WHO) standard for portable water is indicative of faecal contamination of human origin (Okpokwasili, 2007).

Heterotrophic micro-organisms are organisms that derive their energy from the oxidation of organic molecules. Their presence in large numbers in aquatic systems is indicative of organic pollution. The presence of biodegradable carbon sources supports the proliferation of heterotrophs in aquatic systems. In the case of xenobiotics, the few species that can degrade them may produce by-products during metabolism that may support other microbial species (Okpokwasili, 2007). Thus, a high heterotrophic microbial count is suggestive of high level of organics in aquatic system while low count is suggestive of either a low level of organic pollution or the presence of persistent organic matter within the aquatic system (Okpokwasili, 2007).

MICROBIAL BIOTECHNOLOGY IN THE BIOASSAY OF ENVIRONMENTAL TOXICITY

Toxic industrial wastes are a threat to both the biological waste treatment systems and the environment of their ultimate disposal (Okpokwasili, 2007). As a result, bioassays are very necessary to generate data that could be used for the prediction of environmental effects of waste and regulation of discharges (Okpokwasili, 2007). Although fishes have been the most popular test organisms, standard organisms for aquatic bioassays also include phytoplankton, zooplankton, molluscs, insects and crustaceans (Wang and Reed, 1983; APHA, 1998). 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, compared with other bioassays.

Moreover the short life cycle means fast experimental results, thus enabling the laboratory to process more samples (Okpokwasili, 2007). The simple and rapid bacteria bioassay techniques include 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 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, ampicillin-sensitive 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).

BIOTECHNOLOGY AND CONTROL OF OIL SPILLAGE

Micro-organisms 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, micro-organisms with the property of enhanced leaching ability could be designed. Micro-organisms can bind metals to their surfaces and concentrate them internally. As a result of this, genetically improved strains can be used to recover valuable metals or remove polluting metals from dilute solution as in industrial waste (Daini, 2000). 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).

Many micro-organisms can degrade various kinds of environmental pollutants into relatively harmless materials before the death of the micro-organisms. This property could also be used in overcoming the environmental hazards of DDT, lead and other environmental pollutants like toxic wastes globally (Soetan, 2008c). 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 has been proposed and is undergoing production/manufacturing.

BIOTECHNOLOGY AND THE SAVING OF RESOURCES AND ENERGY

Breeding of insect and pest–resistant crop strains help promote a safe environment, saves money and conserve resources (Su, 1998). Industrial processes are very complex and chemists make use of inorganic catalysts which speed up the rate of reaction when making new chemicals (Su, 1998). These catalysts often need high temperatures, and acid or alkaline conditions, in order to work efficiently. In future, genetically engineered organisms may be able to work effectively at lower temperatures, and require less extreme conditions. This will save money and resources, and will also produce fewer

fewer hazardous by-products (Su, 1998). For example in paper-making, the wood pulp has to be treated with chemicals which break up the fibres and remove the lignin (the substance that makes up the wood). The pulp is bleached so that the finished paper is white. This process produces a large volume of chemical waste that has to be treated before it is ready for disposal (Su, 1998). Enzymes have been discovered in fungi which may be suitable for use as biological alternatives to some of these chemicals (Su, 1998). In the near future, using the modern plant breeding techniques, it may be possible to breed trees which have less lignin, and so require fewer chemicals and less energy to produce the pulp. Plastic is made from oil and its manufacture uses a lot of energy and produces a lot of polluting by-products (Su, 1998). There is now hope that some forms of plastic will be made by living organisms. One biodegradable plastic, called Biopol (trade name) is made by bacteria (Su, 1998). One way to make larger quantities of this plastic at lower cost might be to insert the gene into potatoes. This would save energy, and reduce both cost and pollution.

As the supply of fossil fuels (oil, gas and coal) dwindles as a result of the global financial crisis, genetically engineered organisms may be manufactured to produce far more materials like plastics at less energy, reduced cost and minimal environmental pollution.

FEARS AND CONCERNS ABOUT BIOTECHNOLOGY APPROACH TO ACHIEVING A SAFE ENVIRONMENT AND AGRICULTURE

There are some fears and concerns about biotechnology and safe environment and agriculture. For instance, plant breeding, an agricultural biotechnology approach has some concerns. Genetically engineered organisms are living things and so are much less predictable than artificial materials and chemicals (Su, 1998). They can reproduce, move and even mutate. Developments in genetic engineering take place in carefully controlled laboratory conditions. However, once a new or modified organism has been developed, it is likely to be grown outside and once released into the environment, it cannot be recalled. The organism could change or interbreed with others, creating new specie. Geneticists should therefore be cautious and assess the possible risks involved so that genetically engineered plants cause no more harm than the chemicals they are replacing (Su, 1998). It has been found that genetic alteration of plants to resist viruses can stimulate the virus to mutate into a more virulent form, one that might even attack other plant species (Su, 1998). If the genes for insect- and weed-killer resistance, introduced into crop plants, find their way into weeds, this could result in development of super-weeds which would be impossible to kill using traditional weed killers. There are also concerns that the genetically engineered soyabeans poses an unacceptable risk to human health and the environment (Su, 1998). There are many questions about this soyabeans, some of which are:

1. Will the new bean force out other plants?
2. Will it enter other ecosystems?
3. Will it genetically contaminate wild relatives or traditional strains?
4. Will it change in the long term due to its resistance to toxic substances?

Some scientists think that genetically engineered plants and animals will threaten the survival of other species and reduce diversity (the number of different plant and animal species) (Su, 1998). The genetically engineered plants, which may be more resistant to disease and pests, when grown around the world, may cross to the wild species. The wild population would be contaminated which could affect local habitats and the species that grow there. For example, oilseed rape cross-breeds easily with wild relatives. This may mean that genetically engineered oilseed rape would breed with related plants, and the new gene for resistance to weed killer could spread into the wild population. Some scientists predict that, within just one year, a large percentage of weeds growing near the crop would have acquired this gene (Su, 1998). There is no way of stopping genetically engineered crops from breeding with wild plants.

FEARS AND CONCERNS ABOUT ENVIRONMENTAL IMPACT OF BIOREMEDIATION

Bioremediation is the use of micro-organisms or microbial processes to detoxify and degrade environmental contaminants (Okpokwasili, 2007). Micro-organisms have been used for the routine treatment and transformation of waste products for several decades. Although bioremediation represents a promising and largely untapped environmental biotechnology, it has some disadvantages. Additives added to enhance the functioning of one particular group of micro-organisms during *in situ* bioremediation, may be disruptive to other organisms inhabiting that same environment. Also, stimulated microbial population or genetically-modified micro-organisms introduced into the environment after a certain point of time may become difficult to remove. Bioremediation is generally very costly and labour- intensive, and can take several months for the remediation to reach acceptable levels (Okpokwasili and Oton, 2006).

CONCLUSION

The way these fears and concerns about application of biotechnology to achieving a safe environment and agriculture are addressed will have a remarkable impact on the future of biotechnology. A detailed analysis of both the advantages and the disadvantages would assist in directing the future of environmental and agricultural biotechnology, since the overall goal is to achieve a safe environment and improved agricultural productivity.

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