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Bioremediation

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Bioremediation uses microbial metabolism in the presence of optimum environmental conditions and sufficient nutrients to breakdown contaminants. We reviewed technologies for carrying out bioremediation and observed that biotechnological approaches that are designed to carry out remediation have received a great deal of attention in recent years. At times, nutrient application alone or augmenting with microbes is not sufficient enough for remediation leading to a simultaneous approach. Recent studies show that a combination of both approaches is equally feasible but not explicitly more beneficial. Evidently, selection of a technology hinges on site specific requirements such as availability of microorganisms capable of degradation in sufficient quantities, nutrient availability to support microbial growth and proliferation as well as environmental parameters such as temperature in combination with duration of exposure. This review focuses on these technologies and efforts are directed towards eventual manipulation of the processes of remediation all geared towards making bioremediation technically and economically viable for comprehensive treatment of contaminated soils.

Keywords: Bioremediation, Microbial metabolism.

The human population size has grown enormously over the last hundred years. This means increase in demand for food, water, home, electricity, roads, automobiles and numerous other commodities[1]. These demands are exerting tremendous pressure on our natural resources and are also contributing to pollution of air, water and soil. It has changed the physical, chemical and biological characteristics of air, water and soil. Though, pollution at times occurs naturally due to volcanic eruptions, forest fires, etc. All these environmental degradation issues are mainly anthropogenic due to the enormous growth of population size globally[1]. All of these deteriorating process, they have created havoc in biosphere and "The mother Earth" is facing so many evils like Global warming, ozone depletion, loss of biodiversity, biological magnification, desertification, cultural eutrophication, over exploitation, deforestation and many more. And it also influenced the hydrological cycles very drastically; floods and draughts increased over the past decades worldwide.

Deforestation is the conversion of forested areas to non-forested ones. According to an estimate, almost 40% forests have been lost in the tropics. The present scenario of deforestation is particularly grim in India. At the beginning of twentieth century, forests covered about 30% of the land of India. By the end of century, it shrunk

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to 19.4%, whereas the National Forest Policy (1988) of India has recommended 33% forest cover for the plains and 67% for the hills[2].

Deforestation causes loss of biodiversity due to habitat destruction, disturbs hydrological cycles, causes soil erosion and may lead to desertification in extreme cases. The most dramatic example of habitat loss comes from tropical rain forests. Once covering more than 14% of the earth's land surface, theses rain forests now cover no more than 6%. They are being destroyed very fast. In fact by the time you finish reading this article, 1000 more hectares of rain forests would have been lost[1].

The Amazon rain forest it is so huge that it is called the "lungs of the planet" harboring probably millions of species which is being cut and cleared for cultivation of *soya beans* or for conversion to grasslands for raising beef cattle[2]. Co-extinctions are also a major threat - It is when a species becomes extinct, the plant and the animals species associated with it in an obligatory way also become extinct. The colonisation of tropical Pacific Islands by human beings has led to the extinction of more than 2000 species of native birds. International union for conservation of nature (IUCN) Red list 2004 documents the extinction of 784 species in the last 500 years that include 359 invertebrates, 338 vertebrates and 87 plants. 27 species have become extinct in the last twenty years alone. Due to uncontrolled and excess emission of greenhouse gases from fossil fuels burning and industries created Global warming. Carbon dioxide, nitrous oxide, chlorofluorocarbons and methane are mainly responsible for it. Earth's surface emits heat in the form of infrared radiations to the space, but most of it is absorbed by these gases. During the past century, the temperature of the earth has increased by 0.6%, most of it during the last three decades and the average global temperature may increase by 1.4-5.8p C by the year 2100[1].

Environmentalists believe that the rise in temperature is leading to deleterious changes in the environment and resulting in odd climatic changes (e.g El Nino effect), thus leading to increased melting of polar ice caps as well as of other places like the Himalayan snow caps. Over many years, this will result in a rise in sea level that can submerge many coastal areas as well as mortality rate of many organisms species increase. Many compound are resistant to the aquatic environments which are very harmful and toxic for the lives in the sea as well as human simultaneously. Recently it is widely recognized as a threat , various significant contaminated sites have been put into consideration to enable to remake or rebuild the condition of that area. This has created an inevitable threat to the lives of each and every species on our planet including "THE GREAT HUMANS" who are the sole architect of this "Dark house" which we are living in. So it is now a serious alarm to "wake up" which cannot be snoozed at any cost. The global society in the 21st century is facing various changes in order to improve the quality of air, water, soil contents to maintain the ecological balance. As India ranks 10th in the industrialized world so it is so obvious to fall under the endangered situation. We have to save Our Mother's biodiversity in narrowly utilitarian approach, broadly utilitarian approach and ethical reasons. And in order to save that , we have to reduce the evil of pollution and effects without damaging environment. We should need not to worry because we have elucidated this problematic phenomenon after the introduction of a scientific, innovating and eco-friendly process called bioremediation[2].

Bioremediation

Bioremediation comes from two words bios means life and remediate means to decipher an issue.

The degradation of noxious waste from the environment using microorganisms like bacteria, fungi, algae etc is called as bioremediation. Microorganisms that carry out bioremediation are called bioremediators. According to United Staes EPA, bioremediation is a "treatment that uses naturally occurring organisms to breakdown hazardous substances into less toxic or non toxic substances"[1].

Bioremediation techniques are used to degrade highly toxic metals, chemicals, effluent from home and factories, oil spills and pollutants from the environment. Test have also shown that it can be beneficial when attempting to remove the harmful toxins found in diesel-contaminated soil. More recently, the advances in the field of genetic engineering have allowed scientists to attempt to create artificial strains of microorganisms, specifically designed to breakdown and remove

the toxic parts of highly radioactive wastes. Though still in its infancy, such a breakthrough could prove to be potentially ground- breaking in bioremediation strategies to eradicate theses harmful fatal substances from environments. Heavy metals from tanneries if not degraded by algae produce toxic oxides. Theses oxides produce lung cancer, asthma, paralysis, brain damage, memory loss etc. If theses heavy metals are accumulated in to water they cause the death of fishes and marine, algal blooms that lower downs the BOD of water and responsible for killing the plants also in the aquatic system. This also makes the water unusable and unfit for drinking as the algal blooms give colour and bad odour to the water. Processes like incineration requires a lot of energy whereas bioremediation is energy independent process thus saving a large amount of energy as well as refraining us from global warming, which causes melting of glaciers and creates floods[3].

Three steps are involved in remediation are immobility, mobility and removal of obnoxious pollutants from the environment

If pollutants are non-biodegradable, soil becomes highly disturbed and makes the soil useless for the cultivation of crops. The nutrient content of the soil is greatly reduced and hence infertile but with the help of bioremediation, the microorganisms clean the soil and protect it from further contamination and enhance its fertility. Microorganism can be aerobic and anaerobic which breakdown waste products and use this breakdown as an energy source for their metabolism. (This in turn help in reducing waste and contribute energy to locals.)

In the soil, chemicals and metals spills may occur from industries are cleaned by using a particular archael microbes. At the same time, many factors can hinder like nutrient availability, temperature, moisture content. Oil degrading bacteria are cheap and friendlier. Several organism help eating up the oil using it as their food. These microorganism help in degradation of petroleum oil and other ships that cover the water affecting the aquatic life. With the increase in population more production of food is in demand in which pesticides are distributed more than required in the agricultural fields. Xenobiotics can be replaced by using microbes agent instead.

Bioremediation can easily be observed by keeping a check on the

- Redox potential
- pH
- Temperature
- oxygen content
- Residues from catabolism etc.
- Bioremediation is also beneficial to eradicate these such as :-

→ Domestic sewage constituted of suspended solids (sand, silt, clay etc.), colloidal materials (faecal matter, bacteria, paper fibres, cloth fibres) and dissolved materials (nitrates, ammonium salts, sodium salts, calcium salts)

→ Agricultural runoff i.e.
—Pesticides &
—Fertilizers products

→ Industrial wastes which are
— Chemical pollutants (organic compounds such as polychlorinated biphenyls, biocides and inorganic compounds like heavy metals Pb, Cd, Hg, Cu and physical pollutants e.g thermal waste water and oil)

→ Fly ash - Thermal power plants generate fly ash, which is composed of oxides of silica, iron and aluminium and low concentrations of toxic metals.

→ Hospital wastes

→ Electronic wastes (e-wastes) - It is mainly generated in developed countries and are sent to under developing countries. Then recycling is done manually and the workers are exposed to the toxic substances and they get lethal diseases.

→ Radioactive wastes

Classification of bioremediation

Bioremediation techniques can generally be divided into two categories. They are

(i) *In situ*

(ii) *ex situ*

In situ bioremediation involves treating the contaminated material at the site where these are present.

ex situ bioremediation involves removal of the contaminated materials to be treated elsewhere [1]. Some examples of bioremediation related technologies are :-

Phytoremediation

It refers to the technologies that use living plants to clean up soil, air, and water contaminated with hazardous chemicals. It is a cost-effective plant-based approach of remediation that

takes advantage of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues. It refers to the natural ability of certain plants called hyperaccumulators to bioaccumulate, degrade, or render harmless contaminants in soil, water and air.

Target

Toxic heavy metals and organic pollutants are major targets for phytoremediation.

It may be applied wherever the soil or static water environments has become polluted or is suffering from chronic pollution. It is useful to clean the mine workings and sites where polychlorinated biphenyls have been dumped, pesticides solvents, explosives and crude oil and derivatives. Many plants such as mustard plants, alpine pennycress, hemp and pigweed are used[4].

Bioventings

It is an *in situ* remediation that uses microorganisms to biodegrade organic constituents in the ground water system. Bioventing enhances the activity of indigenous bacteria and archaea and stimulates the natural *in situ* biodegradation of hydrocarbons by inducing air or oxygen flow into the unsaturated zone and, if necessary, by adding nutrients. It primarily assists in the degradation of adsorbed fuel residuals, but also assists in the degradation of volatile organic compounds as vapours move slowly through biologically active soil[5].

Bioleaching

It is the extraction of metals from their ores through the use of living organisms. This is much cleaner than the traditionalheap leaching using cyanide. It is one of the several applications within biohydrometallurgy and several methods are used to recover copper, zinc, lead, arsenic, antimony, nickel, molybdenum, gold, silver and cobalt[6].

Landfarming

It is an ex situ waste treatment process that is performed in the upper soil zone or in biotreatment cells. Contaminated soils, sediments or sludge are transported to the landfarming site, incorporated into the soil surface and periodically turned over to aerate the mixture. It is commonly uses a clay or composite liner to intercept leaching contaminants and prevent groundwater pollution. This technique has been used for years in the management and disposal of drill cuttings, oily sludge and other petroleum refinery wastes[7'8].

Bioreactor

It is an engineered device or system that supports a biologically active environment. A bioreactor is a vessel in which chemical process is carried out which involves organisms or biochemically active substances derived from such organisms. This process can either be aerobic or anaerobic. Immobilization is useful for continuously operated processes, since the organisms will not be removed with the reactor effluent, but is limited in scale because the microbes are only present on the surfaces of the vessels[9].

Composting

Compost is an organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming. It requires making a heap of wetted organic matter known as green waste including leaves, food waste etc. and waiting for the materials to breakdown into humus after a period of weeks or months. Worms and fungi further break up the material. Aerobic bacteria requiring oxygen to function and fungi manage the chemical process by converting the inputs into heat, carbon dioxide and ammonia. Compost is rich in nutrients. It is used in gardens, landscaping, horticulture and agriculture. It acts as natural pesticide for soil[10,11].

Biological augmentation

The introduction of strains which are known to have decompositional properties into a contaminated area, with the aim of increasing enzyme concentration and radioactive degradation as a result. It develops the biological material in order to smoothly breakdown certain compounds. When microbes are added to the contaminated area, they are able to improve the biological material's capability to behave in a manner as to breakdown up before. It is commonly used in municipal wastewater treatment to restart activated sludge bioreactors. Microorganisms commonly used are B. *licheniformis, B. thuringiensis, P. polymyxa*, streptomyces, Triphoderma etc[5].

Rhizofiltartion

It is a form of phytoremediation that involves filtering water through a mass of roots to remove toxic substances or excess nutrients. This process is very similar to phytoextraction in that it removes contaminants by trapping them into

harvestable plant biomass[12]. Both phytoextraction and rhizofiltration follow the same basic path to remediation. Plants are put in contact with the contamination. They absorb contamination through their root systems and store them in root biomass and/or they transport them up into the stems and/or leaves. The plant continue to absorb contaminants until they are harvested. The major difference between rhizofiltration and phytoextraction is that rhizofiltration is used for treatment in aquatic environments while phytoextraction deals with soil remediation.

Biostimulation

It involves the modification of the environment to stimulate existing bacteria capable of bioremediation. This can be done by addition of various forms of rate limiting nutrients and electron acceptors, such as phosphorus, nitrogen or carbon in the form of molasses. Also, remediation of halogenated contaminants in anaerobic environments may be stimulated by adding electron donors. So it allows indigenous microorganisms to use the halogenated contaminants as electron acceptors. It is also potentially useful for the treatment of less frequently encountered contaminant spill such as pesticides, specifically herbicides[13].

World health organisation estimated data

25th march 2014 I Geneva- WHO reports that in 2012 around 7 million people died as result of air pollution exposure- one in eight total global deaths[16].

In particular, the new data reveal a stronger link between both indoor and outdoor air pollution exposure and cardiovascular diseases such as strokes and ischaemic heart diseases, as well as between air pollution and cancer.

Outdoor air pollution- caused deaths breakdown by diseases :

- 40% - ischaemic heart diseases
- 40% - stroke
- 11% - chronic obstructive pulmonary disease (COPD)
- 6% - lung cancer; and
- 3% - acute lower respiratory infection in children[14]

Indoor air pollution- caused deaths - breaking by disease:

- 34% - stroke
- 26% - ischaemic heart disease
- 22% - COPD
- 12% - acute lower respiratory infections in children
- 6% - lung cancer

Other relevant data:

- 2.2 million deaths annually in African Regions
- 8,47,000 deaths annually in Regions of the Americas
- 8,54,000 deaths annually in Eastern Mediterranean Region
- 1.4 million deaths annually in European Region
- 3.8 million deaths annually in South-East Asia Region
- 3.5 million deaths annually in Western Pacific Region
- An estimated 70% of industrial waste dumped into surrounding water courses. The world generates 1.3 billion tonnes of wastes every year and the majority of which is stored in landfills or dumped into the oceans.
- Around 2.6 billion people lack any sanitation with over 200 million tonnes of human waste untreated every year.
- Diarrhoeal diseases - 8,46,000 deaths annually
- Respiratory infections - 5,67,000 deaths annually
- Neonatal condition - 2,70,000 deaths annually
- Malaria - 2,59,000 deaths annually[15]

Cases of radioactive waste

- Thyroid cancer- In Belarus, the Russia Federation and Ukraine nearly 5,000 cases of thyroid cancer have been diagnosed till date among children who were aged up to 18 years at the time of the Chernobyl accident.
- Leukaemia and non-thyroid solid cancer - Latest investigations showed a doubling of the incidence of leukaemia among the survivors.The expert Group concluded that there may be up to 4000 additional cancer deaths the three highest exposed groups over their lifetime (2,40,000 liquidators; 1,16,000 evacuees and the 2,70,000 residents of the SCZs). Since more than 1,20,000 people in thses three groups may eventually die of cancer, the additional cancer deaths from radiation exposure corresponds to 3-4% above the normal incidence of cancers from all causes.
- Cataract
- Cardiovascular diseases
- Mental health and psychological effects.
- Reproductive health and hereditary effects and children's health [16].

CONCLUSION

The challenges to overcome these evil scenarios in the management of contaminated

environment are multifaceted, there are no easy solutions. So we must look towards it as a team of universal members as well as an integral member of this whole global environment not as the OWNERS of "Mother Nature". It is a need of the hour to use a more clean, eco-friendly and innovative way to deal with it. Bio-remediation is a natural help strategy to a huge amount of expense by using natural products existence in the world. This technique enhances to clean up the pollution in land, air and water. Microorganisms primarily bacteria and fungi are recyclers since ages/since the beginning of life. Bioremediation help in changing the synthetic and natural chemicals into environment friendly constituents as manures for useful products. genetically engineered technology can help in improving of remediation by producing more and more organism which are at par with the usefulness of pollution control.

There are a number of cost/efficiency advantages to bioremediation which can be employed in areas that are inaccessible without excavation. Low cost of treatment per unit volume of soil or groundwater compared to other remediation technologies. Low technology equipments are required. It does not require any consumption of energy in most of its techniques. It is totally eco-friendly and efficient. It requires less manual supervision. Also, toxic chemicals are destroyed or removed from environment and not just merely separated. Bioremediation is perceived positively by the public public because it is a natural process.

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