PHYTOREMEDIATION- AN IDEAL BIOTECHNOLOGICAL METHOD TO IMPROVE ENVIRONMENTAL QUALITY TOWARDS A ZERO POLLUTION PLANET

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ABSTRACT

Environment is the life support system. It is from the environment that all the essential necessities of life are derived. Transitioning towards a pollution-free planet seeks to eliminate the waste, hazardous pollutants, and pollution of air, water and land that emanates from man-made activity and that degrades ecosystems and impacts human health and welfare of living species. There are various ways and means to mitigate the environmental pollution. Afforestation and bioremediation for abatement of pollution and improvement of environmental quality are effective tools and well recognized throughout the world. Since plants are naturally adapted to withstand toxic concentrations of airborne, waterborne, soil, radioactive and heavy metal contaminants, it is logical to employ them to remediate such pollutions. Under stress, plants undergo various physiological, biochemical and molecular changes. This study validates that compared to the process of soil removal, soil disposal, or physical extraction of contaminants; phytoremediation plants are a useful and working alternative that pinpoints toxic materials in the environment.

Key Words: Phytoremediation, Environmental Quality, Pollution free planet, Artificial Intelligence.

INTRODUCTION

Definition of Environment

Etymologically the term, "Environment" connotes surrounding. It is a composite term referring to conditions in which organisms consisting of air, water, food, sunlight etc., live and become living sources for all the living and non-living beings includes temperature, wind, electricity, etc., Environment is the life support system. It is from the Environment that all the essential necessities of life are derived (N.Maheswara Swamy, 1998).

Components of Environment

Environment consists of the following three important components namely:-

1. *Abiotic or non-living component*, which is subdivided into the following three categories, - Lithosphere (Rocks, soil and solid air) Hydrosphere (Water component) Atmosphere (Gaseous envelope) which is in turn divided into four zones, namely:- Troposphere, Stratosphere, Ionosphere and Exosphere. Thus the three basic divisions of physical environment may be termed as Lithospheric environment, Hydrospheric environment and Atmospheric environment.

2. *Biotic or living component* consists of flora and fauna including man as an important factor. Thus the biotic environment may be divided into i) Plants environment and ii) Animals environment.

All the organisms work to form their social groups and organizations at several levels, and form a social environment wherein the organisms work to derive matter from physical environment for their sustenance and development.

3. Energy component, which includes solar energy, geo-chemical energy, thermo-electrical energy, hydro-electrical energy, nuclear atomic energy, energy due to radiation etc., that helps in maintaining the real life of organisms.

Environmental Pollution

According to McLaughtin, “Environmental Pollution” means the introduction by man into any part of the environment, of wastes, water energy or energy or surplus energy which so changes the environment directly or indirectly adversely to effect the opportunity of men to use or enjoy it.

According to Section 2 (c) of the Indian Environment (Protection) Act, 1986, “Environmental Pollution” means the presence in the environment of any environmental pollutant”.

According to Section 2 (b) of the said Indian Act, “Environmental Pollutant” means any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, injurious to environment”.

Environmental Pollution may be classified into

i) *Natural Pollution* – Earthquakes, flood, drought, cyclone.

ii) *Artificial Pollution* – Human activities.

METHODOLOGY

This study focuses on the necessity to improve environmental quality, transitioning towards a pollution free planet and the application of Phytoremediation as an ideal method for noise control and for control of air, water, soil, heavy metal, radionuclide contaminants.

Necessity to improve Environmental Quality

The latest global and regional environmental assessments give an indication of the magnitude of current pollution issues (United Nations Environment Programme 2016a-g; United Nations Environment Programme 2012a). For example, air quality is a problem in nearly all regions; water pollution is a major cause of death of children under five years of age; nutrient over-enrichment of land and water is causing shifts in ecosystems and loss of biodiversity; plastics in the ocean is on the rise and there is still no acceptable “storage or disposal option” for processing of older-generation nuclear fuel. Pollution is even affecting the way in which some major Earth system processes, such as the climate, are functioning (Diamond *et al.*, 2015; Steffen *et al.*, 2015).

Significant improvements in the measurement of atmospheric precipitation chemistry make it possible to understand how atmospheric pollutants contribute to ecosystem acidification and eutrophication, air pollution and loss of biodiversity (Vet et al. 2014). Similarly there have been great strides in global Earth observation and monitoring systems for air quality, ocean acidification, forest decline, detection of marine oil spills and pollution from mine tailings, as well programmes to track the use of agrochemicals and the occurrence of eutrophication and harmful algal blooms (Group on Earth Observations, 2017; Global Forest Watch, 2017; Global Ocean Acidification Observing Network, 2017). However, significant data gaps continue to prevent us from having a comprehensive picture of the magnitude of pollution across regions.

Transitioning towards a Pollution-free Planet

Transitioning towards a pollution-free planet seeks to eliminate the waste, hazardous pollutants, and pollution of air, water and land that emanates from man-made activity and that degrades ecosystems and impacts human health and welfare of living species. Research on global material flows and material and environmental footprint indicators, indicates that the level of development and well-being in wealthy industrial countries has been achieved largely through highly resource-intensive patterns of consumption and production, which are not sustainable, even less replicable to other parts of the world (International Resource Panel, 2016). Instead, transitioning to a pollution-free planet with development and well-being for all needs innovation, targeted and time-bound action (with focus on the most urgent and 'hard hitting' pollutants' and polluted areas), as well as a longer term system wide shift in the economy to be low carbon, circular and less toxic while reducing the overall use of resources. This transition can only take place if preventive and curative actions are accompanied by system-wide enablers, based on opportunity and innovations (From report of the Executive Director of the United Nations Environment Programme to the 3rd session of the United Nations Environment Assembly "Towards a Pollution-Free Planet"- Agenda 2030).

Significance of Plants in Environmental Pollution Control

There are various ways and means to mitigate the environmental pollution. Afforestation and bioremediation for abatement of pollution and improvement of environmental quality are effective tools and well recognized throughout the world. Plants are an important part of the environment for they help us breathe and give us clean air. More than ten people can be nourished by oxygen from a single tree. Plants act as natural filter to remove harmful particles. Trees serve as wind breakers reducing wind speeds of wind sensitive crops. Less wind makes it easier for insects to pollinate them. Trees are like sponges, catching run off water rather than letting it roll across the surface but they cannot absorb all of it. Water that gets past the roots trickles down into aquifers, replenishing ground water that supplies that are important for drinking, sanitation and irrigation. Plants are habitats for a variety of species. Almost half the species live in forests and deforestation leads to destruction of ecosystem at large. Plants are vital for a balanced ecosystem. A balanced ecosystem is one which sumstains the food chain.

Earlier, the purpose of planting trees in urban areas was purely aesthetic. The incessant increase of urban environmental pollution has necessitated to reconsider the whole approach of urban landscaping and its orientation in order to achieve duel effect i.e. bio-aesthetics and mitigation of pollution. Proper planning and planting scheme depending upon the magnitude and type of pollution, selection of pollution- tolerant and dust scavenging trees and shrubs should be done for bioremediation of urban environmental pollution. Pollution, the major problem in cities, is compounded by the fact that there is no exhaust for the polluted air to escape. Landscape architects can solve the pollution problems related to urban landscape by creating a micro-climate.

Phytoremediation

Phytoremediation is the use of green plants and the associated micro-organisms along with proper soil amendments and agronomic techniques to either contain, remove or render toxic environmental contaminants harmless.

Types of phytoremediation

Different types of phytoremediation are:

1. Phytoextraction: The use of plants to remove pollutants (metals or organics) from the soil by concentrating them in harvestable plant parts.

2. Phytotransformation: Complex organic molecules degradation to a simple one or their incorporation into plant tissues.

3. Phytostimulation: Plant assisted bioremediation, microbial stimulation and fungal degradation by the release of enzymes/exudates into the rhizosphere.

4. Phytovolatilization: The use of plants to volatilize metabolites or pollutants.

5. Rhizofiltration: The use of plant roots to adsorb metals, organic pollutants from water and waste streams.

6. Dendroremediation: The use of trees for water evaporation and thus to extract contaminants from the soil.

7. Phytostabilisation: Reduction in the mobility and bioavailability of pollutants in the environment using plants, thus preventing their migration to groundwater or their entry into the food chain.

Phytoremediation is an Ideal Biotechnological Method –

A. For Noise Pollution Control

Noise is not simply a local problem, but global issue that should concern us all. In the European Union over 40% of the population are exposed to noise of motorways to a level, which exceeds 55 dBA during the day and the 20% of the populations to levels that exceed 65 dBA. Sound pollution continues to expand with an increasing number of complaints from the residents. In 1993, the World Health Organization (WHO) recognized the following effects on the health of the population that can emanate from noise: sleep patterns, cardio respiratory and psycho physiological systems, and hearing. It also affects us negatively on intervention in communication, productivity and social behaviour.

Some plants useful for control of noise pollution

Alstonia scholaris; Azadirachta indica; Melia azedarach; Butea monosperma; Grevillea pteridifolia; Grevillea robusta; Tamarindus indica; Terminalia arjuna Calotropis gigantea; Inga dulcis; Saccharum munja; Nyctanthus arbortristics Nerium orodrum; Ipomea sps.

B. For control of Air borne Contaminants

According to Agarwal *et al.*, 2003, air pollution is broad term, which actually covers lots of different types of problems namely, acid rain, domestic and industrial smoke, smog, greenhouse effect, particulates, radionuclides and ozone layer depletion. The five primary criteria pollutants include the gases- Sulphur di oxide (SO_2), Nitrogen oxides(NOx) and Carbon monoxide (CO), solid or liquid particulates (smaller than 10 µm), and particulate lead.

Some Plants for road borders and housing sites as recommended by CPCB
Alstonia scholaris; Lagerstroemia flosreginae; Mimusops elang;
Cassia fistula; Bauhinia purpurea; Grevillea pteridifolia;
Pongamia pinnata; Polyalthia longifolia; Peltoferrum ferrugineum;
Cassia siamea; Melia azedarach; Delonix regia;
Anthocephalus cadamba; Michelia champaca; Cassia siame;

Some Indoor Air Purifying Plants

Plants are efficient enough not only to reduce outdoor air pollution but various studies have reported the effects of some plants on the enhancement of indoor air quality by absorbing air-borne contaminants such as VOCs (Wolverton and Wolverton, 1993; Giese *et al.*, 1994; Agrawal *et al.*, 2003; Kim *et al.*, 2008; Wood *et al.*, 2001; Wood *et al.*, 2002; Orwell *et al.*,2004).Occupational health of the employees working and their productivity were improved by raising indoor plants(Levy *et al.*, 2010; Lu *et al.*, 2007).

The group of plants found potent to remove organic chemicals from indoor air was studied by Wolverton *et al.*, (1989). The studied common indoor plants were determined by joint agreement between the National Aeronautics and Space Administration (NASA) and The Associated Landscape Contractors of America (ALCA).

Plants reported to have efficiency for reducing indoor air pollution and studied therefore, are listed below;

Common Name	*Scientific Name*
Bamboo palm	*Chamaedorea seifritzii*
Chinese evergreen	*Aglaonema modestum*

English

Ivy *Hedera helix* Gerbera
daisy *Gerbera jamesonii* Janet Craig
Dracaena deremensis "Janet
Craig" Marginata *Dracaena marginata* Mass cane/Corn
cane *Dracaena massanqeana* Mother-in-Law's tongue
Sansevieria laure Pot mum
Chrysanthemum morifolium Peace lily
Spathyphyllum "Mauna Loa" Warneckei
Dracaena deremensis "Warneckei" Ficus
Ficus benjamina Heart leaf philodendron
Philodendron oxycardium Elephant ear philodentron
Philodendron domesticum Golden pothos
Scindapsus aureus Green spider plant
Chlorophytum elatum

C. For control of Water borne Contaminants

Water is an essential element for life and is considered as most important and beneficial natural resource. According to an estimate, about 70% of the earth's surface is covered by water, approximately 97.5% of that amount is in the oceans and generally not available for daily use.
Major portion of the remaining 2.5% is found in icecaps present in the Polar Regions or mountain peak and is similarly unavailable. Less than 1% of the earth's water is fresh water on the land surface, as groundwater.

It has been reported by the press release of UNO Secretary General on World Water Day 2002 that about 1.1 billion people lack access to safe drinking water, 2.5 billion people have no access to proper sanitation, and more than 5 million people die each year from water-related diseases.

There are so many factors which are responsible for water pollution, but it is most often due to human activities. Increasing population, geological factors, rapid urbanization, agricultural developments, global markets, industrial development, industrialization and poor wastewater regulation have affected the quantity and the quality of water (Saleem, 2001; Farooq *et al.*, 2006).

Besides the indiscriminate disposal of industrial, municipal and domestic wastes in water channels, rivers, streams and lakes etc. are regarded as the documented source of water pollution (Kahlown and Majeed, 2003).

Aquatic plants for example, duckweed and pennywort, also Brassica and sunflower remove contaminants like metals, radionuclides, hydrophobic organics from groundwater. The cultivation of *Dalbergia sissoo* as woody species may be extended to industrial and urban areas where industrial and municipal wastewater is the only source of irrigation (Farooq et al., 2006). On the other hand, Poplar and Willow trees remove inorganic, nutrients, and other chlorinated solvents present in the groundwater (Schooner, 2002). A special characteristic of Willow, which makes it a very suitable tree for use in phytoremediation, is that it can be frequently harvested by coppicing, yielding as much as 10 to 15 dry t ha-1 year1 (Riddell-Black, 1993; Punshon et al., 1995; Pulford and Watson, 2003). The concentration of heavy metal pollutants in the bark and wood of 20 different Willow varieties were determined by Pulford et al. (2002). Wetland plants generally are not "hyperaccumulator", they store metals in the below ground organ than above ground organ (Weis and Weis, 2004).

Some plants useful for phytoremediation of water borne contaminants

Hydrilla verticillata; *Spirodela polyrrhiza; Bacopa monnierii; Phragmites karka; Scirpus lacustris; Eichhornia crassipes* (Water hyacinth); *Hydrocotyle umbellate* (Pennywarth); *Lemna minor* (Duck weed); *Azolla pinnata* (Water velvet)

D. For control of Soil borne Contaminants

By definition, any substance in the soil that exceeds naturally-occurring levels and poses human health risks is a soil contaminant.

Soil pollutants can be included into two main groups, the organic pollutants (OPs) and the inorganic pollutants (IPs).

Some of the main toxic substances in waste are inorganic constituents such as heavy metals, including cadmium, chromium, lead, mercury, nickel, zinc, amongst others. The two main culprits responsible for the transfer of heavy metals to land are smelting and mining activities and the spreading of metal-laden sewage sludge on land.

Organic based pollutants, such as PCBs (polychlorobiphenols), PAHs (polyaromatic hydrocarbons), pesticides, pathogens, are mainly associated with various industrial outputs and the chemicals used by the industries. The sites of special concern include Industrial/manufacturing sites, landfills, junkyards, waste disposal sites, highway corridors, parking lots, areas of heavy traffic, household sites, former farmland with build-up of contaminants.

Some applications of phytoremediation for soil contamination

In 1980, R.L. Chaney published a paper on the subject of what makes good soil and how to establish it through the use of phytoremediation plants. Plants such as mustard and canola thrive in contaminated soils, absorbing and therefore reducing the level of toxic accumulation. A native phytoremediation plant for cleaner soil, known as Indian Grass, has the ability to detoxify common agrochemical residues such as pesticides and herbicides. Indian Grass is one of nine members of grasses that assist in phytoremediation plants. When planted on farmland, the reduction of pesticides and herbicides is significant. This list also includes Buffalo grass and Western wheatgrass, both capable of absorbing hydrocarbons from the land.

For any plant used in Phytoremediaton to be able to tolerate any toxin it absorbs, researcher David W. O., has been investigating which genes were the key to increased plant tolerance. When identified, these genes can then be moved to other plant species to absorb high levels of certain metals. More research proves genetic movement. During testing into the nutritional value of broccoli, it was found that the plant worked well to deplete the soil of several metals. In California, some farmers who had been irrigating with recycled water discovered that their soil became overloaded with either selenium or boron.

Other plants used in phytoremediation for cleaner soil include species that reduce levels of organic compounds found in coal and tar, which are present in pitch, creosote, and asphalt. These include the very popular sunflower, which has the ability to absorb heavy metals, such as lead. Homesteaders, farmers, and agriculturalists have been practicing "intercropping" for several years. By simply employing the intercropping method, the above-mentioned plants can be effectively used as excellent choices. For example, sunflower plants were demonstrated to have removed 95 per cent of uranium from a contaminated area in a 24-hour period. This highly successful crop is a powerful tool for the environment because of its ability to remove radioactive metals from superficial groundwater.

The willow is being used as a phytoremediation plant for cleaner soil. It not only beautifies the landscape but the roots have the capability of accumulating heavy metals in sites polluted with diesel fuel. A tree that is being studied for use as phytoremediation for cleaner soil is the poplar tree. Poplar trees have a root system that absorbs large quantities of water. Carbon tetrachloride, a well-known carcinogen, is easily absorbed by poplar tree roots. They can also degrade petroleum hydrocarbons like benzene or paint thinners that have accidentally spilled onto the soil.

E. For control of Heavy Metal Contaminants

Heavy metals are extremely persistent in the environment because they are not biodegradable and may not be broken down by chemical oxidation or through thermal processes, as a result their accumulation readily reaches to toxic levels (Riddell-Black, 1993), (Bohn H.L. *et.al.*, 1985). Human activities such as metal smelting, electroplating and mining are sources through which heavy metals enter the environment.

The level of heavy and toxic metals (Pb, Cr, Hg, etc.) in the environment can be reduced from contaminated sites or media using a number of aquatic and terrestrial plants. Metals are taken up in solution by the root system of plants and transported to the stems and leaves without showing toxicity syndromes and this have been supported by many studies (Cardwell *et al.*, 2002), (Chatterjee *et al.*, 2000). As a developing technology (He Z.L. *et al.*,2007), phytoremediation, particularly phytoextraction have been applied to metals contaminations containing (e.g. Ag, Cr, Fe, Cu, Hg, Mn, Mo Ni, Pb, Zn),metalloids (e.g. As, Se), radionuclides (e.g. ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U) and non-metals (Salt D.E. *et al.*,1995), (Cornish J. *et al.*,!997),. Phytoextraction employs plants to transport and accumulate high quantities of metals from soil into the harvestable parts of roots and above ground shoots (Chaney R.L., 1993) (Chaney R.L *et al.*, 1997), and has emerged as a cost effective, environmentally friendly clean up alternative (Zayed *et al.*, 1998). The phytoextraction or hyperaccumulation of metals in various plant species have been extensively investigated and substantial progress has been made. The potential of duck weed was investigated for the removal of Cd, Cr, and Cu from nutrient-added solution and the results indicated that duck weed is a good accumulator for Cd and Cu, but his result was unable to establish potential plant for abstracting Cr from the soil(Zayed *et al.*, 1998). The uptake of Cr from soil by the use of some plants including Indian mustard (*Brassica juncea*) was investigated and validated (Brooks et al., 1998). He indicated that there is no evidence of Cr hyperaccumulation by any vascular plants. Robinson et al. (Robinson B.H., 1998) investigated the potential of *Berkheya Coddii* to phytoextract Co from artificial metalliferrous media. Although, Co was readily taken up by the plant, cobalt was toxic to the plant above a certain limit. Although, a majority of phytoextraction investigations have focused on Cd, Pb and Zn ((Huang J.W *et al.*, 1995), Fe contamination is a more prominent problem in many soils particularly where iron extraction is common.

F. For control of Radionuclide Contaminants

Radioactive pollution, like any other pollution is something that is unwanted and exploits the ecosystem. Radiation from the radionuclides can mutate the DNA, cause abnormalities, birth defects and cancer (George C. *et al.*, 1986). Radiation stays in the environment for billions of years and diminishes very slowly. The leading causes of radioactive pollution are human activities involving production of nuclear weapons, mining of radioactive ore, waste from the medical surgeries and treatments, and production of nuclear energy. A variety of biomaterials viz. algae, fungi, bacteria, plant biomass, etc. have been reported for radionuclide remediation with encouraging results. This paper reviews the achievements and current status of radionuclide remediation through bio absorption which will provide insights into this research.

Some plants useful for phytoremediation of radionuclide contaminants

Phragmites australis, *Macleaya cordata*, and *Azolla imbircata* were studied as the ideal candidates for phytoremediation of uranium-contaminated soil, *Phragmites australis* was studied as the ideal candidate for phytoremediation of thorium-contaminated soil, and *Pteris multifida* was studied as the candidate for phytoremediation of ^{226}Ra-contaminated soil (Nan Hu *et al.*, 2014).

Accumulation of ^{90}Sr and ^{137} Cs was higher in roots compared to shoots in *Calotropis gigantea* plants. When two months old plants were in incubated in low level nuclear wase, 99% of activity disappeared at the end of 15 days (Susan Eapen *et al.*, 2006).

Artificial Intelligence Support System

Artificial Intelligence Support Systems let us accurately, unobtrusively, and inexpensively collect wildlife data, which could help catalyse the transformation of many fields of ecology, wildlife biology, zoology, conservation biology, and animal behaviour into 'big data' sciences," reported Jeff Clune, the Harris Associate Professor at the University of Wyoming and a Senior Research Manager at Uber's Artificial Intelligence Labs.

Fourth Industrial Revolution technologies combine with AI include robot labour (such as Ecobots, Agrobots, Core Intelligence chatbots, etc.,), drones, synthetic biology and advanced materials. Machine and deep learning will also work in tandem with the Internet of Things and with drones. Sensors measuring conditions such as crop moisture, temperature and soil composition gives AI the data needed to automatically optimize production and trigger important actions such as adding moisture. Drones are increasingly being used to monitor conditions and communicate with sensors and AI-enabled systems (Anderson C., MIT Technological Review).

CONCLUSION

Since plants are naturally adapted to withstand toxic concentrations of airborne, waterborne, soil, radionuclide and heavy metal contaminants, it is logical to employ them to remediate such pollutions. Under stress, plants undergo various physiological, biochemical and molecular changes. Various phyto-constituents play an important role in the toxic uptake and its compartmentalization in plants. The functional parameters of these phytocompounds decide its efficiency and specificity to bind with the chemical contaminants. If promising phytocompounds are available, then it could be used in phytoremediation technology. With ongoing research and new toxin-absorbing plant life being discovered each year, we can expect phytoremediaton choices for pollutant cleanup projects to increase. The process appears simple, but the research is slow, complicated and painstaking. But, compared to the process of soil removal, soil disposal, or physical extraction of contaminants, phytoremediation plants are a useful and working alternative that pinpoints toxic materials in the environment and thus validates our study that Phytoremediation is an ideal method for the improvement of environmental quality towards a pollution free planet.

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