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Review Article

Phytoremediation: Using Natural Strength for Curing Nature

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Abstract

Nature is the best source of medicinal constituents [1]. The World Health Organization (WHO) identified 10 chemicals in terms of public concern, of which 7 are associated with soil pollution (Science Communication, 2013). Soil polluting contaminants include: heavy metals (e.g. lead and arsenic), pesticides (e.g. dioxin) and petroleum hydrocarbons (created mainly by chemical manufacturing industry) [2]. Bioremediation is process in which natural degradation of pollutants are simulated with the use of additional nutrient to accelerate their activity (Donlon, 2006). Phytoremediation is one of the Bioremediation approaches, which use plants to transfer pollutants from deep soils and groundwater to surface soils and then to its root and shoot with the help of its root system (Meager 2000). Plants with greater ability to absorb heavy metals and radionuclide are used in this technique. Phytoremediation is natural and relatively cost effective compared to traditional soil pollution treatment. It doesn't require the continuous use of labor and equipment [3]. Main objective of This review is to discuss and identify multiple phytoremediation approaches that is effective to treat various types of pollutants naturally [3].

Keywords: Phytoremediation; Chemical; Bioremediation; Phytoextraction

Introduction

Environmental decontamination is an integral part of sustainable development. In recent years there has been growing interest in using plants for decontamination. On the other hand, water, soil and air are increasingly contaminated. Huge toxic waste has been dispersed in hundreds of contaminated sites and it is spread all over the globe (Prasad, 2015). Among the different contaminants in the environment, Heavy metals (HM) are a unique class of toxicants since they cannot be broken down to non-toxic forms [4]. Toxic metals concentration increased dramatically as a result of industrial revolution [5] thus, health and environment is poisoning since then [6]. The potential threat remains for many years, if ecosystem once contaminated through heavy metals. HM refers to metals and metalloids that cause pollution and toxicity but some of these at low concentrations is required by organisms (Adriano, 2001). Common Heavy Metals are: cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn) [7]. According to the reports published worldwide, Both natural and anthropogenic sources are responsible for release of these metals, specifically, mining, industrial activities, and automobile exhausts. Factors that lead to soil pollution are industrial growth. Thousands of new chemicals are synthesized each year [8]. According to Third World Network reports, 450 million kilograms of toxins in global air and water is releasing. At the same time, in agriculture excessive pesticide use, de-acidifying soils waste leading to soil pollution [9]. HMs contributes a major part in causing hazard to human and animal health because of their long term existence in environment [7,10,11]. Soil pollution due to heavy metals is widespread; on the world scale, it involves about 235 million hectares (Giordani Cecchi and Zanchi, 2005). They travels through underground waters and along with water pathways deposits in the aquifer, or washed away by surface waters run-off, resulting in water as well as soil pollution. Increase in population, industrialization and urbanization causing increase in contamination of Heavy Metal in our surrounding environment [7]. These pollutants mainly come from two main origins. They are: inorganic and organic (Prasad, 2015). Development of innovative and cost-effective solutions to this problem is of today's crying need. Different technique is used by different countries researchers for removing these hazardous elements.

For Remediation of polluted soils many technologies like soil washing and excavation, pneumatic fracturing, chemical reduction, soil flushing, electrophoresis, solidification, verification have been used. But these traditional methods have some limitations in their application to selected areas [7]. Since then, scientists are in search of some eco-friendly, innovative and low cost alternative techniques. Phytoremediation is One of them, which uses plants to clean and cure the environment. These plants absorb, accumulate and detoxify the impurities present in the soil, water and air by using various physical, chemical and biological processes [12]. This review is to find out or discuss Currently used phytoremediation technology used to remove inactive metals and metal pollutants from contaminated soil and water.

What is phytoremediation?

The term Phytoremediation is applied to a group of technologies that uses plants to degrade, immobilize, reduce or remove environmental toxins, mainly of those which are of anthropogenic origin for restoring area sites to a condition useable for any applications [13]. As an invaluable tool phytoremediation works as a solution of various environmental problems. For reducing accumulation of toxic metals in plants various techniques are used. Cultivation of edible crops in contaminated soils is a subject of human health concern if the contaminant concentration in the edible parts of crops plant exceed the permissible level. In such cases non-food crop production viz value chain and value additions appears profitable. Phytoremediation efforts have largely focused on the use of plants to accelerate degradation of organic contaminants, usually in concert with root rhizosphere microorganisms, or remove hazardous heavy metals from soils or water.

Phytoremediation of contaminated sites is a relatively inexpensive and aesthetically pleasing to the public compared to alternate remediation strategies involving excavation/removal or chemical in situ stabilization/conversion.

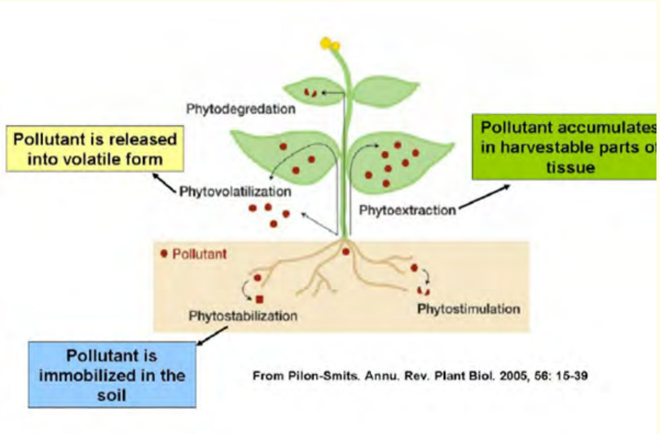

Figure 1: Phytoremediation Process (Source: Pilon., *et al*, 2005).

Many phytoremediation plans have multi-year timetables, but since most sites in need of remediation have been contaminated for more than ten years, as such a ten year remediation plan does not seem excessive. Major aspects of phytoremediation can be subdivided, on the basis of the underlying process and applicability. They are:

I. Phytoextraction,
II. Phytodegradation,
III. Rhizosphere degradation,
IV. Rhizofiltration,
V. Phytostabilization,
VI. Phytovolatization, and
VII. Phytorestoration [13].

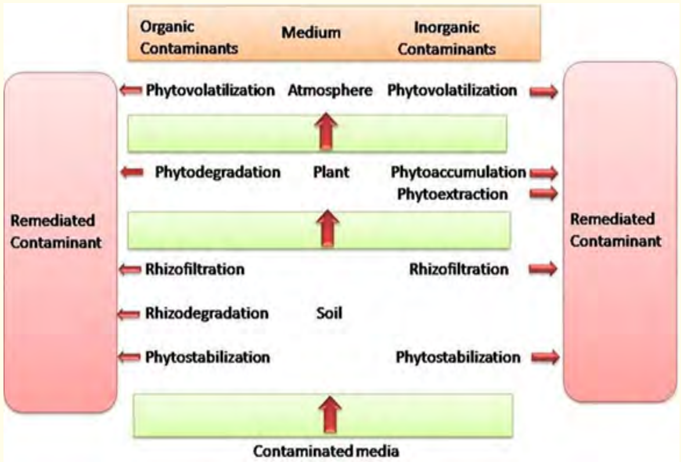

Figure 2: Phytoremediation Technology (ITRC, 2009).

History of phytoremediation

The generic term 'phytoremediation' consists of the Greek prefix phyto (plant), attached to the Latin root remedial (to correct or remove an evil) [14]. Bronze Age (2500-600 BC)- beginnings of significant metal contamination of soil continued with Greek and Roman mining and metal industries 500-300 BC). Exposure to heavy metal concentrations led to proliferation of metal tolerant and hyper accumulating plants. Middle Ages- first use of soil remediation was in the form of crop rotation for the purpose of restoring fertility to the soil 1865- field of genetics founded when Austrian botanist and monk, Gregor Mendel experimented with heredity 1928- F. Griffith discovers genetics transformation with bacteria; first genetically engineered product (insulin) produced 1917- origination of the word "biotechnology" in reference to a mass production of materials from microbes grown in vats 1970's- development of genetic recombination techniques 1986- First genetically engineered plant Modern crop rotation field First methods for field testing phytoremediation developed by Kathy Banks and her husband. Use of poplar trees to remediate soil contaminated with petroleum products is introduced by a team of Purdue University. A scientist in Chernobyl, Ukraine studied Phytoremediation extensively in small-scale through a site-specific demonstration where sunflowers are used to remove radioactive contaminants from a pond water [15].

How does it work?

Plants are being used in several process to clean up or remediate affected sites. In order to remove contaminants from soil, sediment and/or water, plants act as a filter and break down, degrade or stabilize metal contaminants. Plants uptake contaminants primarily through the root system. Enormous surface area of root system of a plant helps to absorbs and accumulates essential nutrients essential and water and as well as contaminants. Plant roots release inorganic and organic compounds (root exudates) in the rhizosphere and thus it causes change in soil-root interphase.

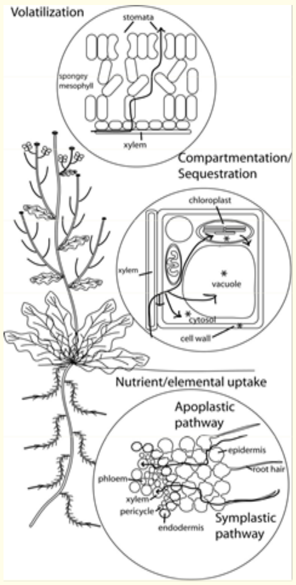

Figure 3: Pathway of metal/nutrient uptake in plants [13].

The process of metal accumulation involves several steps, one or more of which are enhanced in hyperaccumulators. They are:

1. Metal Solubilization from the soil matrix
2. Root system Uptake
3. Transport to the leaves
4. Detoxification/Chelation
5. Sequestration
6. Volatilization

Number and activity of the microorganisms, the aggregation and stability of the soil particles around the root, and the availability of the contaminants depends on root exudates. Either directly or indirectly the availability of the contaminants in the root zone (rhizosphere) of the plant through changes in soil characteristics, changes in chemical composition, release of organic substances. Can be increased (mobilize) or decreased (immobilize) by root exudates [16].

Principles and mechanisms of phytoremediation

The Method or way of phytoremediation depend on the type of contaminant, soil properties and bioavailability (Cunningham and Ow, 1996). Plants uptake contaminants primarily through the root system, in which toxicity preventing principal mechanisms are found. This is because root systems enormous surface area which helps to uptake essential nutrients as well as non-essential contaminants [14,17].

Use of phytoremediation to treat organic contaminants

Organic contaminants like-hydro-carbons that contain carbon and hydrogen atoms are main environmental pollutants. To treat Organic Contaminants through phytoremediation several ways are used like: phytodegradation, rhizo-degradation, and phytovolatilization.

Phytodegradation

Phytodegradation (also known as phyto-transformation), is the breakdown of contaminants through metabolic processes taken up by plants within the plant. Complex organic contaminants are being broken into simpler molecules and are integrated with plant tissues to accelerate plant grow. Plants contain enzymes that catalyze and accelerate chemical reactions, break down and convert ammunition wastes, degrade chlorinated solvents such as trichloroethylene (TCE), and degrade herbicides.

Identification of genes and proteins involved in tolerance and accumulation	o	Genomics and proteomics approaches are being used to study the molecular and biochemical mechanisms of the process of hyperaccumulation.
Genetic bases of tolerance	o o	Genetic studies are being taken in order to determine the genetic bases of tolerance, accumulation; Gene identification studies using genomic and proteomic approaches.
New contaminants	o o	Most common contaminants include radionuclides, heavy metals and nutrients; New contaminants that are subject of research: arsenic, mercury.
		Organic contaminants
Mechanisms of genetic controls – candidate genes	o	Gene identification studies using genomic approaches; - In the xenobiotic's metabolism, specific candidate genes can code for enzymes that are part of the process.
Analysis and identification of enzymes and proteins	o	In the metabolism of xenobiotics, the identification of new enzymes is determined due to proteomic approaches.
Transgenic approaches	o	Transgenic approaches that can modify/improve the enzyme that is responsible for metabolic modification and degradation of xenobiotic molecule.
In vitro studies for implementation	o	Bioassessment studies that use cell cultures are being taken before practical application when it comes to more complex contaminants.

Table 1: Basic mechanisms and principles that are part of phytoremediation technologies (Marmiroli *et al* 2006).

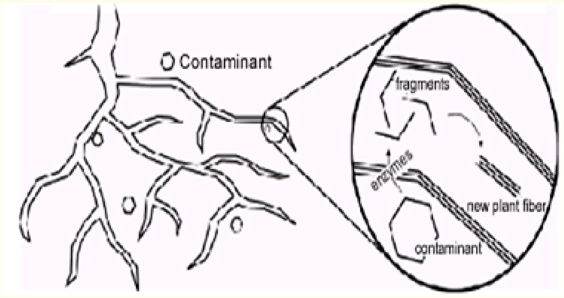

Figure 4: Enzymes in plant roots break down (degarde) organic contaminants. The fragments are incorporated into new plant material.

Advantage

Phytodegradation helps to remove organic contaminants, such as chlorinated solvents, herbicides, and munitions. It can also identify contaminants in soil, sediment as well as in groundwater [2,14].

Rhizodegradation

Rhizodegradation (Also known as phyto-stimulation) refers to the breakdown of contaminants in the rhizosphere through microbial activity. It is a slower process than phytodegradation. Organic substances are consumed by Micro-organisms (yeast, fungi, or bacteria) for nutrition and energy requirement. Certain micro-organisms digest organic substances that is harmful for mankind and break them down into harmless products. Plant roots release natural substances like– sugars, alcohols, and acids which contain organic carbon that provides food for soil microorganisms.

The localized nature of rhizodegradation means that it is primarily useful in contaminated soil, and it has been investigated and found to have at least some successes in treating a wide variety of mostly organic chemicals, including petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), chlorinated solvents, pesticides, polychlorinated biphenyls (PCBs), benzene, toluene, ethylbenzene, and xylenes [2]. It also proceed plant-assisted bioremediation, microbial and fungal degradation acceleration by release of enzymes into the rhizosphere [14].

Phytovolatilisation

Phytovolatilisation refers to the technique that transform contaminants into volatile forms and transpiring them into the atmosphere (USEPA, 2000). It also involves the steps in which first contaminants are taken up into the body of the plant, then the contaminant, as a volatile form is transpired with water vapor from leaves [2]. Poplar trees can volatilize 90% of the TCE they take up [2].

Advantage

The Major benefit is - contaminant, mercuric ion, transformed into a less toxic substance (i.e. elemental Hg).

Disadvantage

Mercury released into the atmosphere is recycled by precipitation and then redeposit back into lakes and oceans and repeat the production of methylmercury by anaerobic bacteria [14].

Use of phytoremediation to treat metal contaminants

Plants can be used at those sites contaminated with metals either to stabilize or to remove the metals from that site through three mechanisms: phytoextraction, rhizofiltration, and phytostabilisation.

Figure 5: Enclosed phytoremediation tests in Canada (Photo: Environment Canada).

Phytoextraction

Phytoextraction, (also known as phytoaccumulation) is the uptake of metals from soil by plant roots into plants ground portion. Hyperaccumulators, absorb large amounts of metals than other plants. These plants are allowed to grow for uptake metals, then they are harvested and decomposed to recycle the metals. Repetition of this procedure is done depending on the level of soil contaminant. Phytoextraction is the best procedure to remove Metals such as nickel, zinc, and copper because approximately 400 plants absorb large amounts of metals that have a high affinity for accumulating these metals. Lead and chromium absorbing plants are currently being studying [18].

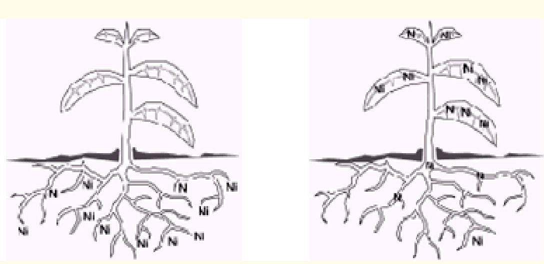

Figure 6: Nickel is removed from soil by moving up into plant roots, stems, and leaves. The plant is then harvested and disposed of and the site replanted until the nickel in the soil is lowered to acceptable levels.

Advantage

There are several advantages of phytoextraction. Phytoextraction is fairly cheap when compared to conventional methods. In this method, contaminants are permanently removed from the soil.

Disadvantage

Hyperaccumulator species growth is slow and shallow root system. As a result, is produces little biomass. Another concern is that. The plant biomass must also be harvested and disposed properly [14,17].

Rhizofiltration

Rhizofiltration is the technique of adsorption or precipitation of contaminants from surrounding solution onto plant roots. Rhizofiltration is quite as the same of phytoextraction, but in this process plants are used to clean up contaminated groundwater rather than soil (as in the case of phytoextraction). In this process used plants are raised in greenhouses with their roots in water. Then contaminated water is either collected from a waste site or the plants are planted in a contaminated area. As the plant's roots become saturated with contaminants, they are removed from the contaminated site. For example, at Chernobyl, Ukraine, sunflowers were used to remove radioactive contaminants from pond water [18]. Sunflower, Indian mustard, tobacco, rye, spinach, and corn have ability to remove lead from water. Specially sunflowers reduced lead concentrations significantly [14,17].

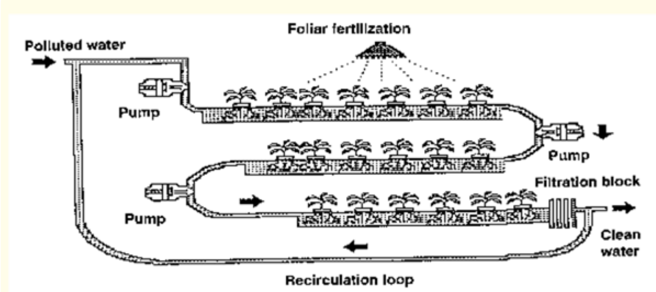

Figure 7: Engineered rhizofiltration system. Source: Phytoremediation: using plant to remove pollutants from the environment (Source: http//www.aspp.org/pubaff/phytorem.htm).

Advantage

Ability to use both terrestrial and aquatic plants both for in situ or ex situ applications. Rhizofiltration can be used primarily for removal of Pb, Cd, Cu, Ni, Zn, and Cr (USEPA, 2000). And a major fact of this process is that contaminants do not translocate to the shoots [17].

Disadvantage

This process to proceed successfully needs constantly adjusted pH. Plants need to be grown in a greenhouse or nursery first. The plant also needs periodic harvesting and disposal. The tank must be well designed. A good understanding of the chemical speciation is also needed. The cost of rhizofiltration is very high (estimated to be $2-$6 per 1000 gallons of water) [14].

Phytostabilisation

Phytostabilisation refers to the use of plant species to immobilize contaminants through absorption and accumulation by roots in the soil and groundwater. This process immobilizes the contaminant and prevents migration to the groundwater, soil and air. It also reduces risk of entrance of contaminants into food chain by reducing its bioavailability. It is also used to re-establish a vegetative cover at sites where high metal concentrations restricts natural vegetation. Metal-tolerant species decreases the potential migration of contamination through wind erosion and leaching of soil contamination to groundwater [18].

Figure 8: Harvesting in the experimental crops exposed to toxic metals in Poland (Photo: IETU).

Advantages

In this technique disposal of hazardous material/biomass is not required. It is very effective when rapid immobilization is required to preserve surface as well as surface waters (Zhang., *et al.* 2009). Plants also reduces soil erosion and decreases water available (USEPA, 2000). It also effective for treatment of lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn).

Disadvantage

This clean-up technology like others also has several major disadvantages. In this process contaminant remain in soil. Application of extensive fertilization or soil amendments is required, this could be expensive [14].

Use of phytoremediation for hydraulic control of contaminants

When roots of plants reach down toward the water table, it works as hydraulic pumps and establish a dense root mass that helps to takes up water. Poplar trees can transpire 50 to 300 gallons of water/day. Ability of surface contaminants to move towards groundwater and drinking water is decreased as plants water consumption decrease. Hydraulic control can be defined as the technique of using plant to rapidly uptake large volume of water to control the migration of subsurface water. Hydraulic control is used to identify contaminants in groundwater, soil and sediment [2]. Several applications are used for this purpose, such as riparian corridors/buffer strips and vegetative caps.

Riparian corridors

The term 'riparian' means 'located on the bank of a river Riparian corridors are use of phytoremediation that may also involve technique of phytodegradation, phytovolatilisation, and rhizodegradation to control, intercept, or remediate contamination in a river or groundwater plume. These systems restrict contamination from spreading into surface water as well as in groundwater.

Vegetative cover

Vegetative cover is most ancient and a long-term technique for soil and plants growing in a waste landfill. This is alternative to composite clay or plastic layer caps. Thus, in that landfill Plants restricts erosion and minimize seepage of water that can percolate through the landfill and may form contaminated leachates.

Factors affecting heavy metal extraction by phytoremediation

Hyperaccumulator plants works as a solar-driven pump and it can extract and concentrate some elements from a contaminated site. There are a lot of factors that affect uptake of heavy metals in the plants. The success of phytoremediation depends on correct and positive combination of these factors when it comes to the implementation of phytoremediation projects.

Figure 9: Phytoremediation experimental sunflower plantation in Silesia, Poland. Heavy metals are directly applied on the top soil by dispenser designed at the Institute for Ecology of Industrial Areas - Kotowice, Poland (Photo: IETU) [18].

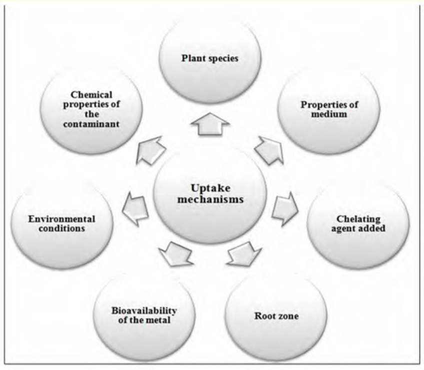

Figure 9: Factors that affect the uptake of heavy metals (Tangahu., *et al.* 2001).

Hyperaccumulator plants

A hyperaccumulator plant is capable of growing in a contaminated soil with very high concentrations of metals. These plants absorbs these metals through their roots. High levels of metals concentration are found in their tissues. The concentrated levels are toxic to closely related species. Hyperaccumulators root extract contaminants from the soil at a higher rate compared to a normal plant, transfer it to their shoots, and store it in their leaves and roots.

Plant species	Metal	Metal accumulation (mg kg^{-1})	Reference
Alyssum bertolonii	Ni	10 900	Li., *et al.* (2003)
Alyssum caricum	Ni	12 500	Li., *et al.* (2003)
Alyssum corsicum	Ni	18 100	Li., *et al.* (2003)
Alyssum heldreichii	Ni	11 800	Bani., *et al.* (2010)
Alyssum markgrafii	Ni	19 100	Bani., *et al.* (2010)
Alyssum murale	Ni	4730–20 100	Bani., *et al.* (2010)
		15 000	Li., *et al.* (2003)
Alyssum pterocarpum	Ni	13 500	Li., *et al.* (2003)
Alyssum serpyllifolium	Ni	10 000	Prasad (2005)
Azolla pinnata	Cd	740	Rai (2008)
Berkheya coddii	Ni	18 000	Mesjasz-Przybylowicz., *et al.* (2004)
Corrigiola telephiifolia	As	2110	(Garcia-Salgado., *et al.*, 2012)
Eleocharis acicularis	Cu	20 200	Sakakibara., *et al.* (2011)
	Zn		
	Cd	11 200 239 1470	
	As		
Euphorbia cheiradenia	Pb	1138	Chehregani and Malayeri (2007)
Isatis pinnatiloba	Ni	1441	Altinozlu., *et al.* (2012)
Pteris biaurita	As	~2000	Srivastava., *et al.* (2006)
Pteris cretica	As	~1800	Srivastava., *et al.* (2006)
		2200–3030	Zhao., *et al.* (2002)
Pteris quadriaurita	As	~2900	Srivastava., *et al.* (2006)
Pteris ryukyuensis	As	3647	Srivastava., *et al.* (2006)
Pteris vittata	As	8331	Kalve., *et al.* (2011)
		~1000	Baldwin and Butcher (2007)
	Cr	20 675	Kalve., *et al.* (2011)
Rorippa globosa	Cd	> 100	Weiet al. (2008)
Schima superba	Mn	62412.3	Yang., *et al.* (2008)
Solanum photeinocarpum	Cd	158	Zhang., *et al.* (2011)
Thlaspi caerulescens	Cd	263	Lombi., *et al.* (2001)

Table 2: List of some hyper accumulator plants with their accumulation potential.

(Source: ENVIS_635108876410284841_Anthropogenic sources of specific heavy metals in the environment).

Common name	Scientific name	Source
Reed	*Phragmites australis*, *Phragmites karka*	Rai 2009a
Water fern, water velvet	*Azolla caroliniana*,*Azolla pinnata*	Rai 2007b, 2008c, 2010a, b
Water bloom/algal bloom	*Microcystis* sp.	Rai and Tripathi 2007a
Balrush/cattail	*Typha latifolia*, *Typha angustata*, *Typha domingensis*	Rai 2008a, 2009a
Poplar trees	*Populus deltoids*	Rai 2008a
Pond weed/curly leaf pond weed	*Potamogeton natans*, *Potamogeton crispus*	Rai 2008a
Parrot's feather	*Myriophyllum spicatum*	Rai 2008a
Umbrella plant	*Cyperus alternifolius*	Rai 2009b
Duckweed	*Lemna minor*	Rai 2007a
Water hyacinth	*Eichhornia crassipes*	Rai 2008a
Smart weed	*Polygonum hydropiper*	Rai 2008a
Smooth cordgrass	*Spartina alterniflora*	Rai 2008a
Water zinnia	*Wedelia trilobata*	Rai 2008a
Water lettuce	*Pistia stratiotes*	Rai 2008a
Irish-leaved rush	*Juncus xihoides*	Rai 2009a
Fuzzy water clover	*Marsilea dromondii*	Rai 2009a
Reed canarygrass	*Phalaris arundinacea*	Rai 2009a
Salt marsh bulrush	*Scirpus robustus*	Rai 2009a
Rabbitfoot grass	*Polypogon monspeliensis*	Rai 2008a
Zebra rush	*Scirpus tabernaemontani*	Rai 2009a

Figure 10: Commonly used hyperaccumulator plants. (Source: https://en.wikipedia.org/ wiki/Hyperaccumulator).

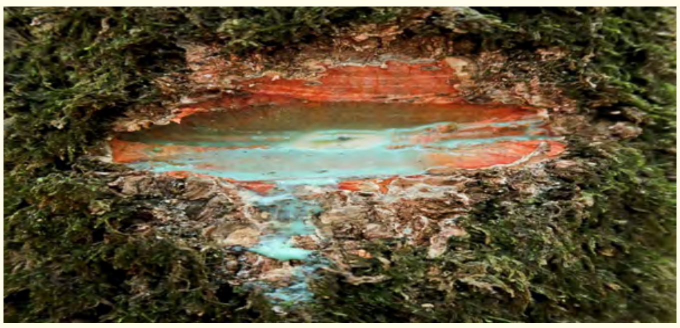

Figure 11: The famous blue latex of the New Caledonian tree Pycnandra acuminata that contains 25% nickel. (Source:https://www.newphytologist.org/blog/heavy-metal-hyperaccumulators-plants-that-lean-up/).

Limitations and Concerns

Contaminants that extracted and stored in the leaves and shoots of the plant may release when the leaves fall and when firewood or mulch from the trees is used. Disposal of such plants can create serious environmental problem if they contain extreme levels of heavy metals. If the depth of the contaminants high such treatment doesn't work effectively for those case. The treatment zone depends on plant root depth. Phytoremediation is limited for some areas like- lower contaminant concentrations, contamination in shallow soils, streams, and groundwater. However, research is on to use phytoremediation for deeper treatment of contamination. Another limitation of phytoremediation is that its effectiveness depends on season or specific location and Climatic factors also influence its effectiveness. Introduction of new plant species in any ecosystem can have widespread ecological malfunction. Additionally, the establishment of new plants species may require several efforts to establish in terms of seasons of irrigation. Extra mobilization of contaminants in the soil and groundwater may create during the start-up period and can cause serious side effect. Some hyperaccumulator plants transfers contaminants across media (e.g. from soil to air). Phytoremediation is not effective for strongly contaminated area which is contaminated with contaminants like-polychlorinated biphenyls (PCBs).Large surface area of land is wasted for this technique of remediation [19].

Application

Phytoremediation is used with an aid to extract contaminants which include -metals, radionuclides, pesticides, explosives, fuels, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Research is underway to make role phytoremediation to work more effectively to remediate perchlorate, a contaminant that is persistent in surface and groundwater systems.

Mechanism	Contaminant	Media	Plant	Reference
Phytoextraction	Zn, Cd, and As	Soil	*Datura stramonium* and *Chenopodium murale*	Varun., *et al.* (2012)
Phytodegradation	Pb, Cd	Soil	*Jatropha curcas* L.	Mangkoedihardjo and Surahmaida (2008)
Phytostabilisation	Cd	Soil	Sunflower	Zadeh., *et al.* (2008)
Extraction-concentration in shoot and root	Cd, Co, Cu, Ni, Pb and Zn	Wetlands	*Ipomoea aquatica* Forsk, *Eichhornia crassipes*, (Mart.) Solms, *Typha angustata* Bory and Chaub, *Echinochloa colonum* (L.) Link, *Hydrilla verticillata* (L.f.) Royle, *Nelumbo nucifera* Gaerth. and *Vallisneria spiralis* L.	Kumar., *et al.* (2008)
Phytodegradation	Total petroleum hydrocarbons (TPH)	Soil	*Anogeissus latifolia*, *Terminalia arjuna*, *Tacomella undulata,*	Mathur., *et al.* (2 010)
Phytodegradation	Zn and Cd	Soil	*Vetiveria*, *Sesbania*, *Viola*, *Sedum*, *Rumex*	Mukhopadhyay and Maiti, 2010)
Phytodegradation	As	Soil	*Cassia fistula*	Preeti., *et al.* (2011)
Phytoextraction	Cr	Soil	*Anogeissus latifolia*	Mathur., *et al.* (2010)
Phytoextraction	137Cs	Soil	*Catharanthus roseus*	Fulekar., *et al.* (2010)
Phytodegradation	U	Soil	*Brassica juncea*	Huhle., *et al.* (2008)
Phytoextraction	Uranium and Thorium	Soil	*Nyssa sylvatica, Liquidambar styraciflua*	Saritz (2005)
Phytostabilisation	Mn	Soil	*Cousinia bijarensis, Chondrila juncea, Chenopodium botrys*	Cheraghi., *et al.* (2011)

Table 3: Details of application of Phytoremediation.

It may be used to cleanup contaminants found in soil and groundwater. For radioactive substances, chelating agents are sometimes used to make the contaminants amenable to plant uptake [19-21].

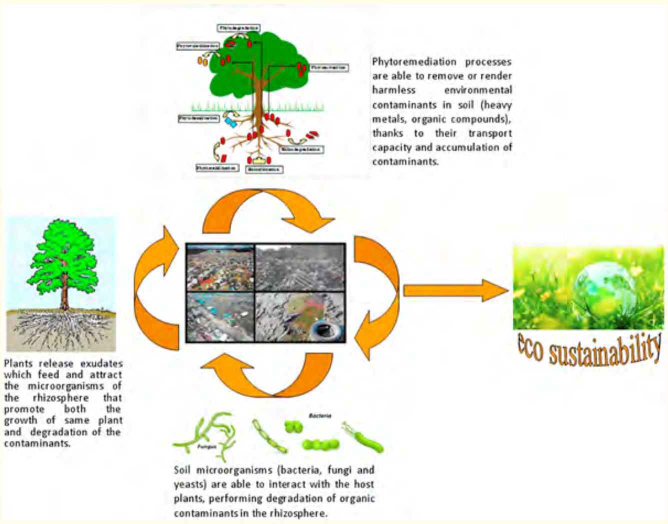

Figure 12: Phytoremediation and Eco sustainability (Source: https://doi.org/10.1016/j. eti .2017.08. 002.

Conclusions

Environmental pollution problems have spread unprecedentedly in many parts of the world. Many methods and processes of preventing and removing pollutants from environments is being used from its identification and in addition with that correcting the negative effects of pollutants released into the environments is also using, but their application is not free of side effect. It cleans up a medium of environment, it affects other medium of environment. This is mainly because most of the technique is not natural. Phytoremediation is a natural technology with great potential. The underlying mechanisms of hyper accumulation can be applied to many different technologies. Phytomining with hyperaccumulating plants selected to uptake high levels of valuable metals, such as gold and Ni, would eliminate the need for traditional mining technologies which have heavy metal contamination as a byproduct. Phytoremediation is a natural cleanup technique which is cost efficient, solar energy driven and which are most effective at sites of shallow depth and has low levels of contamination. They are useful for treating environmental contaminants using natures strength and are effective than mechanical cleanup methods in terms of side effects. It is also environmentally friendly and aesthetically pleasing for the public. Phytoremediation is a harnesses natural processes and researchers are working to extract pollutants quite permanently from the environment through this method. In addition to this, Necessary focus must be given nationally as well as globally on it to make it available and easier to native farmers to implement and maintain properly.

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