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Removal of contaminants using plants: A review

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Abstract

This review lists the environmental benefits from the presence of various plants regarding their application in removing contamination. From the review we concluded that Phytoremediation which is sustainable and inexpensive process, is fast emerging as a viable alternative to conventional remediation methods, and will be most suitable for a developing country like India. Most of the studies have been done in developed countries and knowledge of suitable plants is particularly limited. It is clear from the review that fast growing plants with high biomass and good metal uptake ability are needed. In most of the contaminated sites hardy, tolerant, weed species exist and phytoremediation through these and other non-edible species can restrict the contaminant from being introduced into the food web. Much more work needs to be performed to further confirm: (1) the correlation between transpiration gas and condensate water; (2) soil community contaminant degradation rate; (3) soil flux rate of VOCs; (4) contaminant exposure to the root zone versus sap and condensate water; (5) leaf litter exposure pathway; and (6) microwells to determine the zone of contamination.

Introduction

The Environmental Protection Agencies seek to protect human health and the environment from risks associated with hazardous waste sites, while encouraging development of innovative technologies to more efficiently clean up these sites [1]. Phytoremediation is an emerging technology that uses various plants to degrade, extract and immobilize contaminants from soil and water. This technology has been receiving attention lately as an innovative, cost-effective alternative to the more established treatment methods used at hazardous waste sites [2, 3].

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The word phytoremediation comes from Greek word phyto means "plants" and the latin word remediation means "restore balance". Phytoremediation, the use of green plants to treat and control wastes in water, soil, and air, is an important part of the new field of ecological engineering. *In situ* and *ex situ* [4, 5] applications are governed by site soil and water characteristics, nutrient sustainability, meteorology, hydrology, feasible ecosystems and contaminant characteristics. The plants with their sophisticated metabolic and detoxification mechanism have the ability to accumulate from soil and water, essential as well as non-essential heavy metals.

Where did phytoremediation come from?

Dr. Raskin, a Russian born US educated scientist was the pioneer in the field of phytoremediation. He came to United States in 1976 and in 1989, he joined a company using micro-organisms to degrade and clean up oils and chemicals in soil. He found that micro-organisms were not much suitable to remove heavy metals, where as plants have high capability of accumulating metals from soil. It was then that phytoremediation was born. This led many researchers to find out suitable plants which could act as phytoremediator.

Phytoremediation includes the following processes or methods and they are **useful in treating environmental problems**:

- Rhizofiltration
- Phytostabilization
- Phytoextraction
- Phytovolatization
- Phytodegradation

Rhizofiltration:

Metal pollutants in industrial-process water and in groundwater are most commonly removed by precipitation or flocculation, followed by sedimentation and disposal of the resulting sludge (Ensley, 2000). A promising alternative to this conventional clean-up method is rhizofilration. Rhizofiltration removes contaminants from water and aqueous waste streams, such as agricultural run-off, industrial discharges, and nuclear material processing wastes [6, 7]. Absorption and adsorption by plant roots play a key role in this technique, and consequently large root surface areas are usually required. In research associated with Epcot Centre, closed systems with recirculating nutrients have exhibited the benefits of Rhizofiltration and biofiltration using a variety of species (such as mosses and scented geraniums) [8].

Phytostabilization:

Phytostabilisation, also known as phytorestoration, is a plant based remediation technique that stabilizes wastes and prevents exposure pathway via wind and water erosion; provides hydraulic control, which suppresses the vertical migration of contaminants into groundwater; and physically and chemically immobilizes contaminants by root sorption and by chemical fixation with various soil amendments [9-13].

Erosion and leaching can mobilize soil contaminants resulting in aerial or waterborne pollution of additional sites. In phytostabilization, accumulation by plant roots or precipitation in the soil by root exudates immobilizes and reduces the availability of soil contaminants. Plants growing on polluted sites also stabilize the soil and can serve as a groundcover thereby reducing wind and water erosion and direct contact of the contaminants with animals. Significant phytostabilization projects have been employed in France and the Netherlands [14-16].

The goal of phytostabilization is not to remove metal contaminants from a site, but rather to stabilize them and reduce the risk to human health and the environment.

Phytoextraction:

Phytoextraction involves the removal of toxins, especially heavy metals and metalloids, by the roots of the plants with subsequent transport to aerial plant organs [6, 17]. Pollutants accumulated in stems and leaves are harvested with accumulating plants and removed from the site. Phytoextraction can be divided into two categories: continuous and induced [6]. Continuous phytoextraction requires the use of plants that accumulate particularly high levels of the toxic contaminants throughout their lifetime. The roots of the established plants absorb metal elements from the soil and translocate them to the above-ground shoots where they accumulate (hyperaccumulators), while induced phytoextraction takes place if metal availability in the soil is not adequate for sufficient plant uptake, chelates or acidifying agents may be used to liberate them into the soil solution [18-20].

Phytovolatization:

Some metal contaminants such as As, Hg, and Se may exist as gaseous species in environment. There are some naturally occurring or genetically modified plants that are capable of absorbing elemental forms of these metals from the soil, biologically converting them to gaseous species within the plant and volatized into the atmosphere through the stomata [21-23].

There are certain members of Brassicaceae which are capable of releasing up to 40 g Se ha^{-1} day^{-1} as various gaseous compounds. Some aquatic plants such as cattail (Typha latifolia l.) are also good for Se phytoremediation. Arabidopsis thaliana L. and tobacco (Nicotiana tabacum L.) have been genetically modified with bacterial organomecurial lyase and mercuric reductase genes. These plants absorb elemental Hg (II) and methyl mercury from the soil and release volatile Hg (0) from the leaves into the atmosphere [24-27].

This remediation method has the added benefits of minimal site disturbance, less erosion, and no need to dispose of contaminated plant material [28].

Phytodegredation:

In phytodegredation, organic pollutants are converted by internal or secreted enzymes into compounds with reduced toxicity [6, 7, 21]. For instance, the major water and soil contaminant trichloroethylene (TCE) was found to be taken up by hybrid poplar trees, *Populus deltoides x nigra*, which breaks down the contaminant into its metabolic components [19]. TCE and other chlorinated solvents can be degraded to form carbon dioxide, chloride ion and water [22].

Biodiversity prospects for phytoremediation of metals in the envitronment

Many hazardous waste sites contain a mixture of contaminant like salts, organics, heavy metals, trace elements, and radioactive compounds [29-31]. The simultaneous clean-up of multiple, mixed contaminants using conventional chemical and thermal methods are both technically difficult and expensive; these methods also destroy the biotic component of soils. Biodiversity prospects offer several opportunities of which the most important is to save as much as possible of the world's immense variety of ecosystems. It would lead to the discovery of wild plants that could clean polluted environments of the world. The desire to capitalize on this new ideas need to provide strong incentives for conserving nature. Aquatic plants in fresh water, marine and estuarine systems act as receptacle for several metals [32-37].

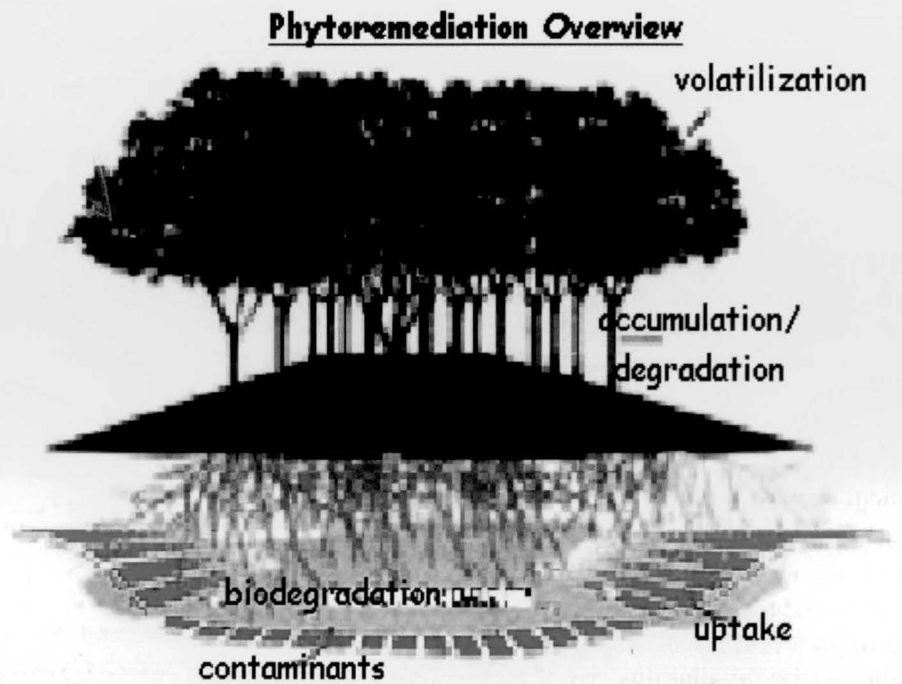
Examples of simpler phytoremediation systems that have been used for years are constructed on engineered wetlands, often using cattails to treat acid mine drainage or municipal sewage. Our work extends to more complicated remediation cases: the phytoremediation of a site contaminated with heavy metals and/or radionuclides involves "farming" the soil with selected plants to "biomine" the inorganic contaminants, which are concentrated in the plant biomass [40-41]

For soils contaminated with toxic organics, the approach is similar, but the plant may take up or assist in the degradation of the organic compounds [30]. Several sequential crops of hyper accumulating plants could possibly reduce soil concentrations of toxic inorganics or organics to the extent that residual concentrations would be environmentally acceptable and no longer considered hazardous. The potential also exists for degrading the hazardous organic component of mixed contamination, thus reducing the waste (which may be sequestered in plant biomass) to a more manageable radioactive one.

For treating contaminated wastewater, the phytoremediation plants are grown in a bed of inert granular substrate, such as sand or pea gravel, using hydroponic or aeroponic techniques. The wastewater, supplemented with nutrients if necessary, trickles through this bed, which is ramified with plant roots that function as a biological filter and a contaminant uptake system. An added advantage of phytoremediation of wastewater is the considerable volume reduction attained through evapotranspiration [42]

Phytoremediation is well suited for applications in low-permeability soils, where most currently used technologies have a low degree of feasibility or success, as well as in combination with more conventional clean up technologies (electromigration, foam migration, etc.). In appropriate situations, phytoremediation can be an alternative to the much harsher remediation technologies of incineration, thermal vaporization, solvent washing, or other soil washing techniques, which essentially destroy the biological component of the soil and can drastically alter its chemical and physical characteristics as well, creating a relatively nonviable solid waste. Phytoremediation actually benefits the soil, leaving an improved, functional, soil ecosystem at costs estimated at approximately one-tenth of those currently adopted technologies.

Phytoremediation is actually a generic term for several ways in which plants can be used to clean up contaminated soils and water. Plants may break down or degrade organic pollutants, or remove and stabilize metal contaminants. This may be done through one of or a combination of the methods. The methods used to phytoremediate metal contaminants are slightly different to those used to remediate sites polluted with organic contaminants.



S. Mukhopadhyay et al. [43] has reported the various type of phytoremediation process like, Phytoextraction, Rhizofiltration, Phytostabilization, Phytovolatization, phytodegredation. The key factor for the success of remediation process depends on characteristics to mine waste, geo climatic conditions, types of amendment used and selection of plants species. Evaluation of the different fraction of bioavailable metals, their mobility in plant parts and growth of the plant species on contaminated side could be helpful for phytoremediation of metallic waste. Data is given in Table No. 1 [43].

Table no. 1
Phytoremediation process

Mechanism	Process	Media	Contaminants	Plants	References
Phytoextrac-tion	Contaminant extraction and capture	Soil, sediment, sludges	Metals:Ag, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Zn; Radionuclides: ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{234}U, ^{238}U	Indian mustard, sunflowers, hybrid	[3]
	Hyper-accumulation	Soil, sediment, brown fields	Metals: Cd,Cu, Ni, Pb, Zn with EDTA addition of Pb, selenium	Indian mustard, sunflowers, pennycress, Crusifers, Rape seed plants , barley, alyssum	[24]
	Hyper-accumulation	Soil sediments	lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn) with EDTA addition	*Brassica juncea* (Indian mustard) and *Helianthus anuus* (sunflower)	[25,26]
	Hyper-accumulation and Contaminant extraction	Soil, sediment,	Zn, Co, Cu Se , Pb and Cd	*Brassicaceae, Fabaceae, Euphorbiaceae, Asteraceae, Lamiaceae*, and *Scrophulariaceae*	[12]
	Contaminant extraction	Soil	Metals: Ag, Cd, Pb	perennial ryegrass (Lolium perenne)	[27]
Rhizofiltra-tion	Rizosphere accumulation	Ground water , waste water logoons or created wetlands	Metals: Cd,Cu, Ni, Pb, Zn; Radionuclides: 90Sr, 137Cs, 238U	Aquatic plants-emergents (Bullrush,cattail, pondwed, arrow root, duckweed) Sebmergents (algae,,hydrilla,stonewort ,parrotfeather)	[24]
	Contaminant extraction and capture	Ground water and surface water	Metals, radionuclides	Sunflowers, Indian mustard, water hyacinth	[3]
Phytostabili-zation	Contaminant containment	Soil, sediment sludges	As, Cd, Cr, Cu, Hs, Pb, Zn	Indian mustard, hybrid poplars, grasses	[3]
	Complexa-tion	Soil, sediment	Metals: Cd,Cu, Ni, Pb, Zn,Cr,As,Se,U; Hydrophobic Organism	Grasses with fibrous root	[24]
Phytodegra-dation	Contaminant destruction	Soil, sediment sludges	Organic compounds, chlorinated solvents, phenols, herbicides, munitions	Algae, stonewort, hybrid poplar, black willow, bald cypress	[3]

	Degradation in plan	Soil, ground water, land fill leachate la nd application of waste water	Herbisides (atrazine, alachlor) Aromatics (BTEX) Choriated alipatics (TCE), Nutrients (NO_3^-, NH_4^+,PO_3^-), Alnmunition waste TNT, RDX	Phreatophyte trees (Popular willow, cotton wood, grasses rye, Bermuda sorghum fescue) Legumes clover alfalfa, cowpeas	[24]
Phytovolatili zation	Contaminant extraction from media and release to air	Soil, sediment sludges	Chlorinated solvents, some inorganics (Se, Hg, and As)	Poplars, alfalfa black locust, Indian mustard	[3]
	Volatilization by leaves	Soil, sediment, ground water	Se, Hg, and Ti	Poplars, Indian mustard, Canola ,Tobacco plant	[24]
	volatilization to the atmosphere	Soil	Inorganic pollutant Ni,Zn, Cd, As, Se, Cu,Co,Pb,Hg, and Radionuclides	Soil plants	[28]

A comparison of the performance of process phytoextraction has been reported by several scientists such as Mukhopadhyay S. et al. [43] Blaylock et al. [44] and Turgut et al. [45]. They used the various processes to extract the contaminants from the various plants.

Phytoextraction involves the removal of toxins, especially heavy metals and metalloids, by the roots of the plants with subsequent transport to aerial plant organs [6, 12]. Pollutants accumulated in stems and leaves are harvested with accumulating plants and removed from the site. In the case of heavy metals, chelators like EDTA assist in mobilization and subsequent accumulation of soil contaminants such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn) in *Brassica juncea* (Indian mustard) and *Helianthus anuus* (sunflower) [44-45]. The ability of other metal chelators such as CDTA, DTPA, EGTA, EDDHA, and NTA to enhance metal accumulation has also been assessed in various plant species [48-49]. However, there may be risks associated with using certain chelators considering the high water solubility of some chelator- toxin complexes which could result in movement of the complexes to deeper soil layers [12, 50] and potential ground water and estuarian contamination. Their data is also given in Table no. 1

G. M Pierzynski [52] explained the Applicable Contaminants/Constituents amenable to phytoextraction include Metals, (Ag, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Zn.), Metalloids (As, Se), Radionuclides, (^{90}Sr, ^{137}Cs, ^{239}Pu, ^{238}U, ^{234}U),

Nonmetals (B) and Organics contaminants the accumulation of organics and subsequent removal of biomass generally has not been examined as a remedial strategy.

The relative degree of uptake of different metals will vary. Experimentally-determined phytoextraction coefficients [ratio of g metal/g dry weight (DW) of shoot to g metal/g DW of soil] for *B. juncea* [52] indicate, for example, that lead was much more difficult to take up than cadmium: (Table No. 2)

Table No.2
Determined phytoextraction coefficients

Metal	Phytoextraction Coefficient
Cr^{6+}	58
Cd^{2+}	**52**
Ni^{2+}	31
Cu^{2+}	**7**
Pb^{2+}	1.7
Cr^{3+}	0.1
Zn^{2+}	17

Contaminated soil concentrations used in research studies or found in field investigations are given below in Table no.3 [52-56]. These are total metal concentrations; the mobile or available concentrations would be less.

Table no. 3.
Contaminated soil concentrations

Metal	Soil Concentration	Reference
As	1,250 mg/kg	[33]
Cd	9.4 mg/kg	[33]
	11 mg/kg	[34]
	13.6 mg/kg	[35]
Cd uptake in vegetables	2000 mg/kg	[36]
Pb	110 mg/kg	[34]
	625 mg/kg	[32]
Zn	444 mg/kg	[35]
	1,165 mg/kg	[34].
Se	40 mg/kg	[37]

J. I. Nirmal Kumar et al has focused their study on assessment of heavy metal accumulation in certain aquatic macrophytes used as biomonitors, in comparison with water and sediments (abiotic monitors) for phytoremediation. Roots, stems and leaves of native aquatic plants (biomonitors) represented by seven species: *Ipomoea aquatica* Forsk, *Eichhornia crassipes*, (Mart.) Solms, *Typha angustata* Bory & Chaub, *Echinochloa colonum* (L.) Link Hydrilla *verticillata* (L.f.) Royle, *Nelumbo nucifera* Gaerth. And *Vallisneria spiralis* L. along with surface sediments and water were analyzed for Cd, Co, Cu, Ni, Pb and Zn contamination [57].

The greater accumulation of heavy metals was observed in *Nelumbo nucifera* and the poor content in *Echinochloa colonum*. Based on the concentration and toxicity status observed in the lake's vegetation, the six heavy metals are arranged in the following descending order: Zn > Cu > Pb >Ni > Co > Cd compared with the standard, normal and critical toxicity range in plants. The detected values of Cd and Pb fall within normal range, while that of Co and Ni were within the critical range. However, Zn and Cu showed the highest accumulation with alarming toxicity levels, which are considered as one of the most hazardous pollutants in Pariyej reservoir. Species like *Typha angustata* and *Ipomoea aquatica* are also proposed as bioremediants, which are the two most useful plant species in phytoremediation studies due to their ability to accumulate heavy metals in high concentration in the roots. The results showed the significant differences in accumulation of metals like Zn, Cu and Pb in different plant organs, in roots than that of stems and leaves [57]. Data is given in Table no.4.

Table No.4
Heavy metal concentration in sediments and water and ratios between the concentration in the sediments and that in the water

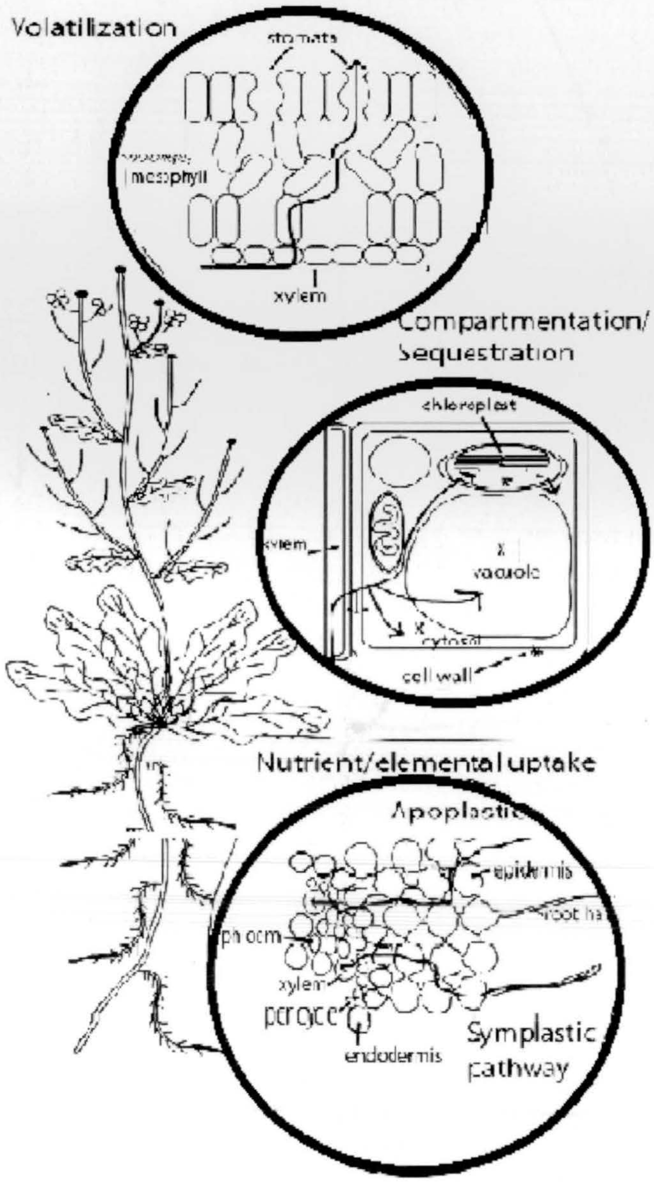
Metal	Sediment (ppm)	Water (ppm)	Sediment / Water
Cd	1.27	0.74	1.70
Co	34.88	1.76	19.81
Cu	105.78	19.67	5.38
Ni	58.08	10.13	5.73
Pb	9.47	6.11	1.55
Zn	2114.82	160.70	13.16

P. McGrath et al. [47] explained that three main strategies currently exist to phytoextraction inorganic substances from soils using plants:(1) use of natural hyperaccumulators; (2) enhancement of element uptake of high biomass species by chemical additions to soil and plants; and (3) phytovolatization of elements, which often involves alteration of their chemical form within the plant prior to volatilization to the atmosphere. Concentrating on the techniques that potentially remove inorganic pollutants such as Ni, Zn, Cd, Cu, Co, Pb, Hg, As, Se, and radionuclides, we review the progress in the understanding of the processes involved and the development of the technology.(Table No.1)

According to Wendy Ann. et al. [58] the best example of volatilization is the volatilization of mercury (Hg) by conversion to the elemental form in transgenic *Arabidopsis* and yellow poplars containing bacterial mercuric reductase [58-59] (fig 2). In a study where the movement of volatile organics was monitored by Fourier transform infrared spectrometry (FT-IR) in hybrid poplars (*Populus deltoides x nigra*), *Tamarix parviflora* (saltcedar), and *Medicago sativa* (alfalfa), chlorinated hydrocarbons were found to move readily through the plants, but less polar compounds like gasoline constituents did not [15]. However, amounts of the contaminant transpired are in proportion to water flow and are relatively low, especially in the field [61]. It was found that poplar saplings can concentrate (100 ppb) and transpire methyl tertiary-butyl ether (MTBE), a compound added to gasoline which is commonly found as a groundwater pollutant. In a one week time period, they observed a 30% reduction in MTBE mass in hydroponic solution by saplings at both high (1600 ppb) and low (300 ppb) MTBE concentrations, which suggested that these plants could be successful in the phytoremediation of this toxin from groundwater [61]. Selenium (Se) is a special case of a metal that is taken up by plants and volatilized. Se can also be volatilized following conversion to dimethylselenide by microbes and algae [62]

Applicable Contaminants to the phytovolatization include the organic contaminants such as Chlorinated solvents include TCE, 1,1,1-trichloroethane (TCA) and carbon tetrachloride [62-63]. And the inorganic contaminants Se and Hg, along with As, can form volatile methylated species [52].

Fig 2.



Poplars have also been shown to take up the ammunition wastes 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5 triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7 tetrazocine (HMX) and partially transform them [64-65]. Root exudates from *Datura innoxia* and *Lycopersicon peruvianum* containing peroxidase, laccase, and nitrilase have been shown to degrade soil pollutants [9,66] and nitroreductase and laccase together can break down TNT, RDX, and HMX [7] . The plants are then able to incorporate the broken ring structures into new plant material or organic soil components that are thought to be non-hazardous.

Organic compounds are the main category of contaminants subject to Phytodegradation. In general, organic compounds with a log k_{ow} between 0.5 and 3.0 can be subject to Phytodegradation within the plant. Inorganic nutrients are also remediated through plant uptake and metabolism. Phytodegradation outside the plant does not depend on log k_{ow} and plant uptake.

L. A. Newman et al [67] demonstrate the applicable Contaminants amenable to Phytodegradation. They include Organic contaminants Phenols, Munitions. The example of Organic contaminants is Chlorinated solvents. TCE was metabolized to trichloroethanol, trichloroacetic acid, and dichloroacetic acid within hybrid poplar trees. In a similar study, hybrid poplar trees were exposed to water containing about 50 ppm TCE and metabolized the TCE within the tree. L. A Licht et al [68] explained the Inorganics contaminants, Nutrients: Nitrate will be taken up by plants and transformed to proteins and nitrogen gas.

Bruce M. Greenberg et al [69] developed a multi-process phytoremediation system (MPPS) that utilizes plant/PGPR (plant growth promoting rhizobacteria) interactions to mitigate stress ethylene effects, thereby greatly increasing plant biomass, particularly in the rhizosphere. The MPPS degrades a variety of organic contaminants in soils with accelerated remediation kinetics. Over the last two years at a petroleum impacted site in Sarnia, ON, a decrease of ~ 50 % in CCME fractions 3 and 4 was observed. At a site in Turner Valley, AB, 30 % remediation of total petroleum hydrocarbons was achieved in 3.5 months. Recently, we tested the MPPS in salt-impacted soils in greenhouse experiments, with promising preliminary results.

Dushenkov S. et al. [70] have developed the subsets - phytoextration, which is based on using high biomass crop plants in combination with a system of soil amendments to extract heavy metals from soil, and rhizofiltration, a technology which employs plants to remove contaminants from aqueous streams.

Rhizofiltration was also shown to be useful in the San Francisco Bay study directed by Norman Terry

(University of California, Berkely) and supported by Chevron [71]. A wetland constructed next to the bay was shown to remove 89% of the Se from selenite contaminated wastewater released from various oil refineries. The water flowing into the wetland was measured to have 20–30 $\mu g\ L^{-1}$selenite, while the outflow from the wetland had less than 5 $\mu g\ L^{-1}$ selenite [71]. In a study of Se removal from agricultural subsoil drainage in the San Joaquin Valley [72], a flow-through wetland system was constructed with cells containing either a single species, or a combination of species [e.g. *Schoenoplectus robustus* (sturdy bulrush), *Juncus balticus* (baltic rush), *Spartina alterniflora* (smooth cordgrass), *Polypogon monspeliensis* (rabbit's foot grass), *Distichlis spicata* (saltgrass), *Typha latifolia* (cattail), *Schoenoplectus acutus* (Tule grass), and *Ruppia maritima* (widgeon grass)]. Four years after planting, comprehensive analysis showed that 59% of the Se remained in the wetland, mostly in the organic detrital layer and surface sediment, 35% in the outflow, 4% in seepage and 2% to volatilization. Wetland plant uptake of Se varies with species type, and parrot's feather (*Myriophyllum aquaticum*), iris-leaved rush (*Juncus xiphioides*), cattail, and sturdy bulrush were particularly noted for high Se uptake potential [72]

V. Dushenkov et al [73-75] explain the applicable Contaminants/ Concentrations Constituents amenable to phytoremediation include the Metals such as Lead (Pb^{2+}), Cadmium (Cd^{2+}) Chromium ($Cr^{6+)}$ Copper ($Cu^{2+)}$ Nickel ($Ni^{2+)}$ Zinc ($Zn^{2+)}$ and Radionuclides such as Uranium (U), Cesium (Ce), Strontium (Sr)

Contaminated water concentrations used in research studies or found in field investigations are given below in Table no.5.

In the above table [73-75] we explained that different plants contain different metals in varying concentration. Sometimes these metals are useful for environment and some time these are very hazardous. So by using Rhizofiltration techniques we are able to extract these metals from various plants. Rhizofiltration is the recent using technique, which is gaining popularity in the field of phytoremediation. Many scientists have worked over this, with different concentration of water we are able to extract these metals and then processed these for future use.

A 2005-2010 superfund basic research program [58] is developing a phytostabilization revegetation strategy to remediate mine tailings in arid and semi-arid ecosystems. The researchers will monitor the bioavailability of metals for the native metal- and droughttolerant plant species used, and determine the permanence of expected toxicity reductions. Plants with high transpiration rates, such as grasses, sedges, forage plants, and reeds are useful for phytostabilization by decreasing the amount of ground water migrating away from the site carrying contaminants [47]. Combining these plants with hardy, perennial, dense rooted or deep rooting trees (poplar, cottonwoods) can be an effective combination [59].

Phytostabilization has not generally been examined in terms of organic contaminants. The following is a discussion of metals and metal concentrations, with implications Arsenic: As (as arsenate), Cadmium: Cd, Chromium: Cr, Copper: Cu, Mercury: Hg

Conclusion

This study concluded that Phytoremediation plays an important role in stabilisation and remediation of some contamination sites. The main factor driving the implementation of phytoremediation projects are low costs with significant improvements in site aesthetics and the potential for ecosystem restoration.

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Table No. 5
Contaminated water concentrations found in field investigations

Plant	Metal (water concentration)						Ref-No.
	Pb^{2+}	Cd^{2+}	Cu^{2+}	Ni^{2+}	Zn^{2+}	Cr^{6+}	
Indian mustard roots	2mg/L	2mg/L	6mg/L	10mg/L	100mg/L	4mg/L	[54]
Brassica juncea	20 to 2000 g/L	20 to 2000 g/L	----	20 to 2000 g/L	-----	20 to 2000 g/L	[55]
Myriophyllum spicatum	1 to 16 mg/L	1 to 16 mg/L	1 to 16 mg/L	1 to 16 mg/L	1 to 16 mg/L	-----	[56]

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