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Phytoremediation of heavy metals using Brassica juneca-A Review

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Abstract: Remediation of contaminated sites with toxic and heavy metals is particularly a challenging task. Therefore pre-treatment is needed before the discharge of these effluents. Among all method investigated presently, Phytoremediation is found to be an emerging and most innovative tool for removal of environmental contaminants such as heavy metals, trace elements, radioactive compounds and organic compounds from soil or water. It has been proposed as a cost-effective and environmental friendly technique. It involves the use of either naturally occurring metal hyper accumulator plants or genetically engineered plants. Indian mustard known as *Brassica juncea* is well known hyper accumulator. This paper aims to compile some information about sources of heavy metals and their toxicity. It also reviews deeply about phytoremediation technology, including the heavy metal uptake mechanisms and several case studies associated with Brassica juneca.

Keywords: Brassica; heavy metals; Phytoremediation; Hyperaccumulator.

1. INTRODUCTION

Humans and ecosystem may be exposed to heavy metals such as Pb, Cr, Cu, As, Cd, Ni, Hg, Zn, Cs etc. through the direct consumption of crops and vegetables grown on the contaminated soils or potable water[1]. Enhanced level of heavy metals in soil poses a threat to human, animals. In world all over, awareness about degradation of environment and its impact on human and animals has raised the interest among the researchers in the development of technologies to remediate contaminated sites[2]. In highly populated countries where there are less funds available for environmental restoration, there is a need for low-cost and ecologically sustainable technologies to remediate the lands which are contaminated with heavy metals so as to reduce the risks and make the resource available for agricultural production, enhance food security and for solving scale down land tenure problems. Removal of heavy metal from contaminated sites is particularly challenging task today because there are various metals which do not undergo microbial

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or chemical degradation Theyare toxic and their concentration remain in soil for long period of time after their introduction[3,4]. So it is necessary to make an effective and environmental friendly soil remediation approach. Methods involved in remediation of heavy metal techniques are (i) ex situ (excavation) or in situ (on-site) soil washing/leaching/flushing with chemical agents (ii) chemical immobilization/stabilization method to reduce the solubility of heavy metals by adding some non-toxic materials into the soils (iii) electrokinetics (electromigration) (iv) covering the original polluted soil surface with clean soils (v) dilution method (mixing polluted soils with surface and subsurface clean soils to reduce the concentration of heavy metals) (vi) phytoremediation by plants[5,6]. Phytoremediation is green technology which is being used for the removal of toxicity in soil. Plants can break down, stabilize or degrade organic and inorganic pollutants to detoxify soil, sediment, water and air. Phytoremediation is a low cost, solar energy driven and natural cleanup technique, which are most useful at sites with shallow, low levels of contamination. Phytoremediation harnesses natural processes to assist in the clean-up of pollutants in the environment. The mechanisms by which plants promote the removal of pollutants are varied, including uptake and concentration, transformation of pollutants, stabilization, and rhizosphere degradation, in which plants promote the growth of bacteria underground in the root zone that in turn break down pollutants. Phytoremediation is amenable to a variety of organic and inorganic compounds and may be applied either in situ or ex situ. *In situ* applications decrease soil disturbance and the possibility of contaminant from spreading via air and water, reduce the amount of waste to be land filled (up to 95%) and are low-cost compared with other treatment methods. In addition to this, it is easy to implement and maintain, does not require the use of expensive equipment or highly specialized personnel and is environmentally friendly and aesthetically pleasing to the public.

2. TOXICITY OF HEAVY METALS

The term "heavy metals" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration [7]. "Heavy metals" is a general collective term, which applies to the group of metals and metalloids with atomic density greater than 4 g/cm^3 or 5 times or more, greater than water [8-13]. However, being a heavy metal has little to do with density but concerns chemical properties. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons [14-15] The body has need for approximately 70 friendly trace element heavy metals, but there are another 12 poisonous heavy metals, such as Lead, Mercury, Aluminium, Arsenic, Cadmium, Nickel, etc., that

Table 1: United State Environmental Protection Agency (USEPA) maximum contamination levels[16]

Heavy metal	Max conc. In air (mg/m_3)	Max. Conc. In sludge(soil) (mg/Kg or ppm)	Max. Conc. In drinking water(mg/l)	Max conc. In H_2O supporting aquatic life(mg/l or ppm)
Cd	0.1-0.2	85	0.005	0.008
Pb	--	420	0.01	0.0058
Zn2	1,5	7500	5.00	0.0766
Hg	--	<1	0.002	0.05
Ca	5	Tolerable	50	Tolerable>50
Ag	0.01	--	0.0	0.1
As	--	--	0.01	--

act as poisonous interference to the enzyme systems and metabolism of the body. No matter how many good health supplements or procedures one takes, heavy metal overload will be a detriment to the natural healing functions of the body. The tolerance limits of some heavy metals are shown in Table 1 for heavy metal concentration in air, soil and water [16].

Heavy metals enter the surroundings by natural means and through human activities. Various sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops, and many others [17]. Figure 3 shows the global production and consumption of selected toxic metals during 1850–1990 [11].

There are documented cases of many different metals causing toxicity issues. According to a report released by a U.S. environmental action group [18], the heavy metal toxicity threaten the health of more than 10 million people at contaminated sites in many countries. The coal region of Chinese city of Linfen, is as an example of the severe heavy metal pollution faced by many Chinese cities;, Dominican Republic city Haina is the site of a former automobile battery recycling smelter where residents suffer from widespread lead poisoning; Kyrgyzstan, uranium plant and severely contaminated with radioactive uranium mine wastes; Ranipet (India), where some 3.5 million people are affected by tannery waste, contains hexavalent chromium and azodyes ; the Russian industrial city of Norilsk, which houses the world's largest heavy metals smelting complex is where more than 4 million tons of Cu, Cd, Ni, As, Se, Zn released annually, the Far East towns of Dalnegorsk and Rudnaya

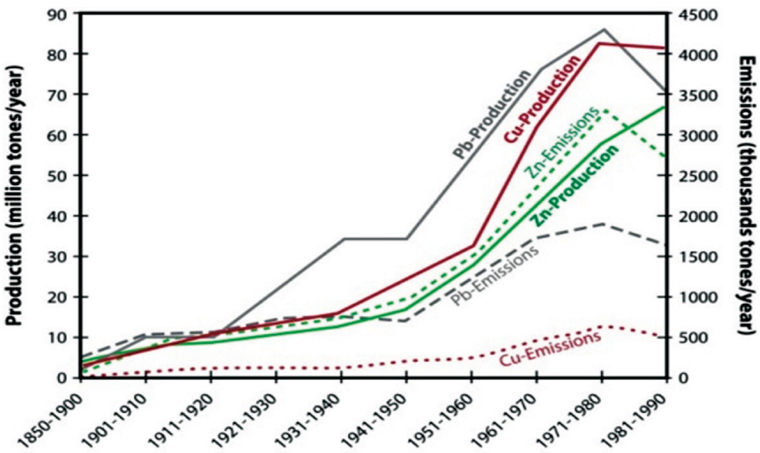

Fig 1: The global production and consumption of selected toxic metals during 1850–1990 [11].

Pristan of Russia, suffer from serious lead poisoning from the local lead mining site; and in the city of Kabwe, Zambia, mining and smelting operations have led to widespread lead and cadmium contamination. Tannery runoff in India is polluting the water supply of some 3.5 million people [18]. Arsenic is one of the most important heavy metals causing disquiet from both ecological and individual health standpoints [19]. Drinking water may get contaminated by use of arsenical pesticides, natural mineral deposits or inappropriate disposal of arsenical chemicals. Arsenic toxicity can be either acute or chronic and chronic arsenic toxicity is termed as arsenicosis. Most of the reports of chronic arsenic toxicity in man focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic arsenic toxicity [20]. Lead is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. Lead is a bright silvery metal, slightly bluish in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds, depending on the given conditions [14]. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death [20].Cadmium is the seventh most toxic heavy metal as per ATSDR ranking. It is a by-product of zinc production which humans or animals may get exposed to at work or in the environment. Once this metal gets absorbed by humans, it will accumulate inside the body throughout life[14].Cadmium is a highly toxic nonessential heavy metal that is well recognized for its adverse influence on the enzymatic systems of cells, oxidative stress and for inducing nutritional deficiency in plants [21]. Cadmium interacts with essential nutrients through which it causes its toxicity effects. Experimental analysis in animals has shown that 50% of cadmium gets absorbed in the lungs and less in the gastrointestinal tract. Mercury is considered the most toxic heavy metal in the environment. Mercury poisoning is referred to as acrodynia or pink disease. Mercury is released into the environment by the activities of various industries such as pharmaceuticals, paper and pulp preservatives, agriculture industry, and chlorine and caustic soda production industry [17]. Mercury has the ability to combine with other elements and form organic and inorganic mercury. Exposure to elevated levels of metallic, organic and inorganic mercury can damage the brain, kidneys and the developing foetus [22]. Symptoms of organic mercury poisoning include depression, memory problems, tremors, fatigue, headache, hair loss, *etc.* Since these symptoms are common also in other conditions, it may be difficult to diagnose such cases [20].Chromium is present in rocks, soil, animals and plants. It can be solid, liquid, and in the form of gas. Chromium compounds are very much persistent in water sediments. They can occur in many different states such as divalent, four-valent, five-valent and hexavalent state. Cr (VI) and Cr (III) are the most stable forms and only their relation to human exposure is of high interest [23]. Chromium (VI) compounds, such as calcium chromate, zinc chromates, strontium chromate and lead chromates, are highly toxic and carcinogenic in nature [14]. Exposure to chromium compounds can result in the formation of ulcers, which will persist for months and heal very slowly. Ulcers on the nasal septum are very common in case of chromate workers. Exposure to higher amounts of chromium compounds in humans can lead to the inhibition of erythrocyte glutathione reductase, which in turn lowers the capacity to reduce methaemoglobin to hemoglobin [24]. These toxic substances are released into the environment and contribute to a variety of toxic effects on living organisms by food chain [25]. Heavy metals, such as cadmium, copper, lead; chromium, zinc and nickel are important environmental pollutants, particularly in areas with high anthropogenic pressure [26]. According to their chemical properties and biological function, heavy metals form a heterogeneous group; toxicity varies by metals and concentrations. Many of them (Hg, Cd, Ni, Pb, Cu, Zn, Cr, Co) are highly toxic both in elemental and soluble salt forms. Their presence in the atmosphere, soil and water, even in traces can cause serious problems to organisms. Heavy metals bioaccumulation in the food chain especially can be highly dangerous to human health. The most common route of human exposure to heavy metals is through ingestion from both food and water sources. So, soil and water contaminated with metals pose a major environmental and human health problem that is still in need of an effective and affordable technological solution.

3. PHYTOREMEDIATION AND ITS MECHANISM

The generic term 'phytoremediation' consists of the Greek prefix *phyto* (plant), attached to the Latin root *remedium* (to correct or remove an evil) [27]. Phytoremediation is an *in situ* remediation technology that utilizes the inherent abilities of living plants. It is also an ecologically friendly, solar-energy driven clean-up technology, based on the concept of using nature to cleanse nature. Plants can help clean up many kinds of pollution including metals, pesticides, explosives, and oil. The plants also help prevent wind, rain, and groundwater from carrying pollutants away from sites to other areas. The mechanisms and efficiency of phytoremediation depend on the type of contaminant, bioavailability and soil properties [28]. There are several ways by which plants clean up or remediate contaminated sites. The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found. The root system provides an enormous surface area that absorbs and accumulates water and nutrients essential for growth along with other non-essential contaminants [29]. Basic mechanism involved in Phytoremediation is shown in figure 2.

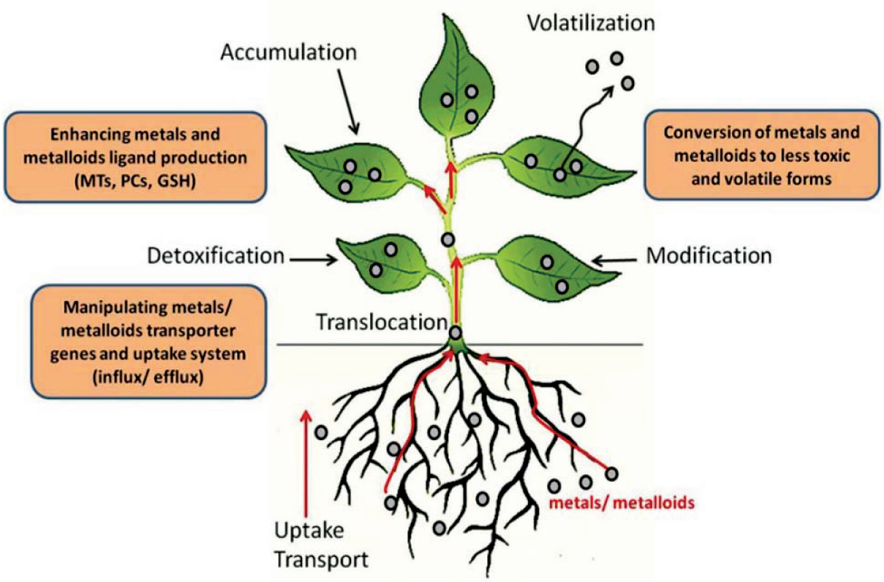

Fig 2: Mechanism involved in Phytoremediation [30]

Phytoextraction (Phytoaccumulation)

The uptake and translocation of metal in the soil by plant roots into the above portions of the plants. To extract metals from the soil, plants uses to absorb, concentrate, and precipitate toxic metals from soils into the shoots, leaves etc. through roots (Fig. 2). It uses hyperaccumulator plants species for the removal of heavy metals. Hyperaccumulators are able to extract and store extreamely high concentration of metallic elements [32]. Discovery of metal hyperaccumulator species demonstrates that plants have the potential to remove metals from contaminated soils [33]. A hyperaccumulator is a plant species capable of accumulating 100 times more metal than a common non-accumulating plant [26]. Metals such as nickel, zinc and copper are the best candidates for removal by phytoextraction because it has been shown that they are preferred by a majority of plants (approximately 400) that uptake and absorb unusually large amounts of metals. Indian mustard is considered as the most viable hyperaccumulator for the phytoextraction of number of metals such as cadmium, chromium, cesium, lead, nickel, zinc [34-36]. *Brassica juneca* has ability to accumulate high level of metal and tolerance to elevated heavy metal concentration which make this plant as ideal hyperaccumulator for phytoremediation.

Rhizofiltration

On the same grounds of phytoextraction, rhizofiltration meant for cleaning contaminated ground water rather than soil. In greenhouses, plants are grown up for their dense root system which filter the contaminants from water. When the roots become saturated with contaminants, they are harvested. Sunflower, Indian mustard, tobacco, rye, spinach, and corn have been studied for their ability to remove lead from water. Figure 3 showed an engineered rhizofiltration system for removal of heavy metal by Brassica juneca.

Fig 3: Rhizofiltration by Brassica [31]

Phytovolatilization

It involves the use of plants to take up pollutants from the soil and transforming them into volatile forms and expel them into the atmosphere into less toxic forms [26]. Phytovolatilization also involve the diffusion of pollutants from the roots to stems or other plant parts [29]. Phytovoltalization has also been found to occur with as well as inorganic and organic chemicals that have volatile forms such as TCE, TNT, Se, Hg and As [18].

Phytostabilization

In phytostablization, plants are used to stabilize the contaminants in the soil and ground water through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone of plants [26]. This process reduces the mobility of the contaminant and prevents bio magnification. It is useful for the treatment of lead (Pb) as well as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn) through the sorption, precipitation, complexation, or metal valence reduction onto the plant roots [18].

Phytodegradation

It is also referred to as phytotransformation. In phytodegradation, complex organic molecules degraded into simple molecules[37]. Phytodegradation helps in remediation of some organic pollutants such as chlorinated solvents, herbicides etc[18].

4. PHYTOREMEDIATION BY BRASSICA JUNECA

The technology based on the use of metal-accumulating plants to remove toxic metals, including radionuclides, from soil and water. Phytoremediation has recently become a subject of intense public and scientific interest and a topic of many recent reviews. This results into research of plants for phytoremediation, with properties: (i) tolerance to the high metal concentrations in soils; (ii) fast growth and high accumulating biomass (iii) ability to accumulate the heavy metals in the aboveground parts (iv) easy to grow as an agricultural crop and easily harvestable [38]. Hence, depending upon the heavy metal concentration in the contaminated soil and the target values sought for inthe remediated soil, phytoextraction may involve repeated cropping of the plant until the metal concentration drops to acceptable levels [39]. In spite of its cost-effectiveness and eco-friendliness, field applications of phytoremediation have only been reported in developed countries. It is yet to become a commercially available technology in most developing countries. Although over 400 taxa of plant hyperaccumulators of heavy metals have been identified, most are exotic species and are low biomass producers. There's, thus, the need to supplement the list of plants available for phytoremediation. High heavy metal accumulating ability has been reported for edible crops such as Mustarrd (Brassica juneca),maize (*Zea mays* L.), sorghum (*Sorghum bicolor*), alfalfa (*Medicago sativa* L.) [40]. Moreover, the demand for water for irrigation in fields has been fulfilled by the use of industrial treated waste waters mostly in fields but it may contain different contaminants including heavy metals. Some recent reports have been published on the dangers of using treated waste waters of industries for the irrigation purposes as these crops including Brassica juneca can be used for human consumption [41]. The objective of this study was to evaluate the potential of the brassica crop in the phytoextraction of heavy metals from moderately contaminated soils. Phytoremediation by Brassica juneca .*Brassica* belongs to the Cruciferae (Brassicaceae) plant family, commonly known as the mustard family. The name crucifer is derived from the shape of the flowers that have four diagonally opposed petals in the form of a cross. *B. juncea* (fig 4) has pale green foliage, with a few hairs on the first leaves and leaf blades that terminate well up the petiole. Mature *B. juncea* plants grow to a height of one to two meters. The lower leaves are deeply lobed, while the upper leaves are narrow and entire. *B. juncea* is distinct from its close relatives *B. napus* and *B. rapa* in that the upper leaves of *B. juncea* are not clasping. The inflorescence is an elongated raceme and the flowers are pale yellow and open progressively upwards from the base of the raceme. The seed pods are slightly appressed and 2.5 to 5 cm in length exclusive of the beak. The beak is 0.5 to 1 cm long. Seeds are round and can be yellow or brown.There are both vegetable and oilseed varieties of *B. juncea* that possibly have different origins [42]. Both types are considered to be natural amphidiploids (AABB genome, 2n=36) of *B. rapa* (AA genome, 2n=20) by *B.nigra* (BB genome, 2n=16) crosses. Axelsson *et al.* have shown by molecular analysis that *B. juncea* contains conserved genomes of the progenitor species[43].Phytoremediation studies of heavy metals with *Brassica* species have mainly on Cd, Cu, Zn and Pb. *B. juncea* is widely regarded as a hyperaccumulator plant for phytoremediation purposes and most studies have focused on this species. Studies reported on Brassica have been reported are performed under controlled conditions usually in pots, and few in field conditions. A few experiments are performed in hydroponic solution, others in soils spiked with heavy metals and other in naturally contaminated soils [44]. Mhalappa N. Jagtap et al. studied that metal accumulation in this plant increased with increase in initial metal concentration as shown in in table 2. The translocation factor(TF) of heavy metals relative to *Brassica juncea* is shown in Table 3 [45]. From this data, it has been concluded that Brassica have shown highest TF value for chromium followed by nickel and cadmium.

Table 2: Accumulation of metals [45]

Plant Part	**Metal uptake(µg/g) at initial metal concentration(mg/kg)**											
	Cu		**Cr**		**Cd**		**Pb**		**Zn**		**Ni**	
	10	25	10	25	10	25	10	25	10	25	10	25
Leaf	15.27a	29.28	24.62	26.32	13.11	27.13	32.11	38.11	19.88	36.12	16.13	28.10
Stem	37.18	33.15	18.20	32.09	21.17	35.71	41.13	80.31	16.68	21.44	13.71	26.08
Root	43.12	47.12	19.25	18.13	18.78	21.97	58.10	101.13	26.57	57.49	11.14	22.72

Table 3 : Translocation factor for ***Brassica juncea*** when grown in presence of metals [45]

Metal	Concentration(mg/kg)	TF
Cu	10	0.61
	25	0.66
Cr	10	1.11
	25	1.61
Cd	10	0.91
	25	1.43
Pb	10	0.63
	25	0.59
Zn	10	0.69
	25	0.50

Arunima Singh et al proposed that As can be efficiently taken out at all concentrations using high biomass producing plant B. juncea grown in hydroponic solution and also resulted that increase in accumulation of As in biomass with increase in each selected concentration as well as time concept of Accumulation of As in the roots and shoots of Brassica juncea [46].Similar observations were found in the investigation where Brassica juncea was used for the removal of copper from soil [47]. More or less similar results have been reported in the accumulation pattern of heavy metals in Amarantus [48].Experiments were performed for the removal of heavy metal as from the solution which was spiked with 5 ppm, 10 ppm, 20 ppm and 50 ppm, respectively. From the table 4 it is clear that roots of B. juncea at 5 ppm to 50 ppm accumulation of As was 3045 µg/gm and 26650 µg/gm, respectively. Similarly at this concentration the amount accumulated in shoot was 1075 µg/gm and 5462 µg/gm of the dry biomass of the stem. At 10 and 20 ppm the accumulation heavy metal As in roots was 4165 µg/gm and 20,850 µg/gm, respectively.

R. Kathal et al showed efficient uptake of Pb and Ni by B. juncea from polluted soil taken from Delhi University nursery which establishes it as a hyperaccumulator plant [49]. This study also showed the utility of Brassica juncea for crop rotation with the food crops to control biomagnification of toxic metals in the food chain.

Table 4: Dry biomass of B. juncea after 21 days of exposure to the different concentrations of As supplemented Hoagland solution [46].

As Concentration (ppm)	Dry weight (g)	
	Roots	Shoots
0	0.034±0.008	0.128±0.012
5	0.028±0.004	0.068±0.014
10	0.016±0.006	0.078±0.016
25	0.021±0.005	0.098±0.027
50	0.036±0.012	0.107±0.016

R.A. Wuana et al compared the effects of poultry droppings on the phytoremediation of soil contaminated with chromated copper arsenate (initial metal concentration, As = 32.09mg kg^{-1} , Cr = 265.84mg kg^{-1} , Cu = 155.82mg kg^{-1}) using B.juncea and recently demonstrated [51] that after 20-day pot trials, 5.87mg kg^{-1} of As; 4.89mg kg^{-1} of Cr and 20.04mg kg^{-1} of Cu corresponding respectively to 18.30%, 1.84% and 12.86% soil-to-brassica metal transferability were recorded for the unamended soil[50]. Metal uptake increased with percent amendment and at 20% amendment, the level of relative advantage in brassica uptake was As 2.3%, Cr 0.16% and Cu 4.24% over the control. Experiments were conducted by [52] in a glasshouse to characterize soil-plant interactions of the main sludge borne metals (Pb, Cd, Zn, Cu) in two sludges (low metal and high metal) to different soil types (clayey, loamy and sandy) on brassica seedlings. The low metal sludge treatment showed the highest yield for brassica seedlings when compared to controls (soil unamended and inorganic fertilizer added). No negative effects of heavy metal contamination in plant parts of brassica were evident. Results showed that application of sludge to different soils could be useful in order to increase crop growth over a 28-day period in the glasshouse. Once in the plant, most metals are too insoluble to move freely in the vascular system so they usually form carbonates, sulphates and phosphate precipitate immobilizing them in apoplastic (extracellular) and symplastic (intracellular) compartments [29].

5. HEAVY METAL CHELATION AND BRASSICA JUNECEA

The factors are responsible for heavy metal uptake are listed in figure 4[53]. Among these factors the most important for heavy metal uptake is chelation. In order to increase the uptake of heavy metals by plants and the transferring it from roots to shoots but without affecting plant growth, various chemical chelating agents have been proposed [54]. Chelate assisted phytoremediation is effective for heavy metals such as lead or cadmium as they are insoluble in a

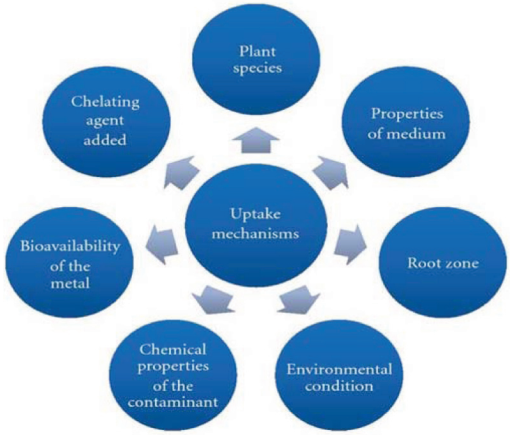

Fig 4: Factors which are affecting the uptake mechanisms of heavy metals [53].

conventional soil environment. Heavy metal accumulation ability in plants can be increased by the addition of chelating agents. Soil can absorb 0.01-0.06% lead in dry weight without chelating agent, while with the addition of chelating agent soil can absorb more than 1% lead dry weight [35, 55-56]

The chelating of heavy metals seems to be one of the most important mechanisms for the tolerance of Brassica species. Many researchers have worked with Brassica species, with different chelating agents [57]. In order to remove Cd, Quartacci et al. and Irtelli and Navari-Izzo found that adding of citric acid and sodium nitrilotriacetate (NTA) to contaminated soil, in B. juncea plants gives more better and efficient result[58-59]. As per their results, the plants were able to accumulate more Cd with the addition of NTA while for citric acid the differences in relation to the control were very small. They concluded that (S,S)-ethylenediamine-N,N′-disuccinic acid (EDDS) was even more effective than NTA in the phytoremediation of contaminated soil with B. carinata species. There is another strategy to improve soil-contamination is the use of organic products to remove the presence of heavy metals and also to improve plant growth. Clemente et al. found that plant growth and metal uptake was highly dependent on soil pH, although the added amendments improved plant growth [60]. They also concluded that between a minimum of 1150 years for Cu and a maximum of 360,000 years for Pb would be necessary for the effective result using B. juncea obviously making this technique completely unsuitable. Other researchers confirm that it would take hundreds or thousands of years for the complete clean-up of sites which are contaminated with heavy metals [61]. Inoculation of plants with certain bacteria and amendments is included with the desire to have the growth of the plant in a contaminated medium and thus improving uptake capacity of heavy metals) in order to improve the process of phytoremediation using Brassica species. Irtelli and Navari-Izzo found that with increase in total organic acids in response to Cd toxicity in B. juncea plants which confirms the role of organic compounds in uptake mechanism of heavy metal[59]. The same results were reported by Ghnaya et al. that citrate tolerance to Pb and its role in lead translocation and shoot accumulation as its levels increased both in xylem sap and in shoots of Brassica juneca [62]. Gasic and Korban engineered a transgenic B. juncea with an Arabidopsis thaliana AtPCS1 gene. Authors observed that B. juncea showed increased tolerance to Cd and Zn at low AtPCS1-expressing lines but did not improve the accumulation of these metals [63]. Nouairi et al. conclude that decrease in GSH hormonal levels in B. juncea plants in presence of Cd results into increased levels of PC synthesis which was observed only for B. juncea [64]. Gadapi and Macfie also detailed a comparison report on Cd effects on B. juncea and B. napus according to it, B. napus had more in the leaves whie B. juncea accumulated more PCs in the roots[65]. From this study, the authors concluded that along with PC concentrations some other factors must exist which are responsible for metal uptake by brassica plant. In another study, an increase in GSH contents for lower concentrations of Cd in B. juncea plants was reported by [41].

6. CONCLUSION

Increasing concentration of heavy metals by industrial and natural processes is a major concern of pollution, so heavy metals need to be eradicated. Phytoremediation is a low cost, environmental friendly approach to eradicate the heavy metals. This review showed that Brassica juncea have remediatory effects on removal from contaminated soil. The ability of Brassica juncea being hyperaccumulators, to bioaccumulate heavy metal like Pb, Cd, Cu, Cr etc. can be used to eradicate metallic contaminants in the soil. There has been a large effort in the research of plants suitable for phytoremediation processes. As we restrict our study to only Brassica juneca, we observe there is variation in the published data regarding metal uptake and the mechanisms adopted by the plant. In context to chelation, citrate to a contaminated medium not only improves the uptake of heavy metals but also improves plant tolerance. Phytochelatins are also widely considered to be very important in the resistance of certain Brassica juneca to heavy metal toxicity. The role of heavy metal transporters seems to be very important in the tolerance of Brassica juneca to different heavy metals. Damage to Brassica plants is due to direct heavy metal effects or to induced oxidative stress. Frequently reported observations include stunted growth, reduced root growth and affected root morphology, affected photosynthetic activity and chlorosis, reduced uptake of water and of certain essential elements. But there is still a long way ahead to enable the establishment of a clear picture of the tolerance and defense mechanisms used in Brassica juneca.

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