soil systems

Review

Phytoremediation of Cadmium Polluted Soils: Current Status and Approaches for Enhancing

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Abstract: Cadmium (Cd) is a heavy metal present in atmosphere, rocks, sediments, and soils without a known role in plants. It is relatively mobile and can easily enter from soil into groundwater and contaminate the food chain. Its presence in food in excess amounts may cause severe conditions in humans, therefore prevention of cadmium entering the food chain and its removal from contaminated soils are important steps in preserving public health. In the last several years, several approaches for Cd remediation have been proposed, such as the use of soil amendments or biological systems for reduction of Cd contamination. One of the approaches is phytoremediation, which involves the use of plants for soil clean-up. In this review we summarized current data on the use of different plants in phytoremediation of Cd as well as information about different approaches which have been used to enhance phytoremediation. This includes data on the increasing metal bioavailability in the soil, plant biomass, and plant accumulation capacity as well as seed priming as a promising novel approach for phytoremediation enhancing.

Keywords: heavy metal tolerance; phytoremediation enhancement; hyperaccumulating plants; metallophytes

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1. Introduction

Cadmium (Cd) is a non-essential metal with an unknown role in plants and toxic effects on plants and animals. It is naturally present in the atmosphere, sedimentary rocks, and soils. Major natural sources of Cd contamination are the result of geological weathering of rocks [1] and anthropogenic sources that include application of agrochemicals, or pollution of soils by disposal or reuse of industrial or urban wastes [2]. Cd may be produced as part of industry processes, such as Zn smelting, and historically, it has found uses in batteries, semiconductors, electroplating, and stabilizers [3]. Phosphatic (P) fertilizers are a major source of Cd in agricultural systems, and increased Cd content in soil was observed in countries where P fertilizer is used extensively [3]. In unpolluted soils, Cd occurs at concentrations of 0.01 to 1 mg/kg with a worldwide mean of 0.36 mg/kg (reviewed by [2]). It is one of the heavy metals with relatively high mobility (depending on many factors) in the environment and may be faster released from the soil into groundwater than other heavy metals [2]. From the soil, it can be relatively easily transferred into vegetative cover entering the food chain [4]. Since 1972, Cd has been recognized as a food contaminant, and if administered in high amounts, it may cause renal failure, bone demineralization and increased cancer risk [5]. At birth, Cd is not present in the human body, but it accumulates with age, mainly in the kidneys and liver [3]. Cd-contaminated food is the main source of Cd exposure in the general population, but some specific groups such as smokers, workers in Cd industries, or people with high industrial or environmental exposure have increased risk for negative impacts of Cd [5].

Pollution of soils and groundwater with Cd is a global problem. Different approaches have been proposed for prevention of Cd contamination or its remediation. Wastewater cleaning, control of Cd levels in landfills and mines, and reduction of the use of Cd-contaminated phosphate fertilizers may help reduce soil and water contamination. Various approaches could be used to remove Cd from the soil and to prevent food chain contamination. One of the proposed approaches is soil washing with chemicals, where different amendments have been proposed for agricultural use [6–8]. In addition, different microbes such as bacteria, fungi, algae, and plants may be potentially useful for removing Cd from soil [9–11]. In this review, we will examine the use of phytoremediation, a plant-based approach that is economically feasible, eco-friendly that has attracted great attention for the past several years [12–15]. In this work, we focused on summarizing the data about current aspects of Cd phytoremediation, which plants have a potential to be used in phytoremediation, and what different approaches can be used to enhance Cd phytoremediation.

2. Behaviour of Cadmium in the Soil and Uptake by Plants

Cd (II) is a highly toxic, soil-persistent, primary heavy metal contaminant [16], relatively easily absorbed by plant roots by which it can contaminate the food chain and consequently bioaccumulate in the human body, expressing its toxic effects. There are several factors that can affect uptake of Cd by plants, pH is one of the most prominent ones since adsorptive capacity of soils for Cd triples for each pH unit increase within the interval 4–7 [17]. Cd is relatively water soluble under acidic conditions, with limited solubility in carbonate forms ($CdCO_3$) and neutral solubility in alkaline soils [18]. Besides pH, other soil factors can also affect Cd solubility, such as organic matter content, cation exchange capacity and concentration of other cations. Organic matter bounds Cd and converts it into an organically bound fraction, reducing its bioavailability [19]. Replacement of structural magnesium cation (Mg) with Cd is an important mechanism in cation sorption, affecting cation exchange capacity (reviewed by [18]).

Cd is a soft Lewis acid promoting formation of strong complex ions with S^{2-}, HS^-, halide ions and organic sulphides and thiols. The presence of inorganic and organic ligands in the soil solution may decrease soil adsorption by formation of dissolved complexes. Cadmium belongs to the group of metals that interact more with low molecular weight organic matter with an order of affinity as follows: $Cu^{2+} > Cd^{2+} > Fe^{2+} > Pb^{2+} > Ni^{2+} > Co^{2+} > Mn^{2+} > Zn^{2+}$ [20]. Organic acids that are dominated by carboxyl groups facilitate complexation of Cd when present in large concentrations, with a magnitude of Cd solubilisation in the following order: fumaric > citric > oxalic > acetic ≈ succinic acid [21]. The presence of some anions in the soils influences sorption behaviour of Cd, e.g., Cl^- and NO^{3-} restrain Cd sorption due to the formation of soluble inorganic complexes, while $H_2PO_4^-$ and HSO_4^- enhance Cd sorption due to surface precipitation [22]. Because of similar geochemical behaviour, Zn is the most efficient Cd competitor for sorption sites, but the limiting pH for Cd mobility is 6.5, higher than that of Zn (5.5–6) and other heavy metals (Ni 5.5; Cu 4.5; Cr 4.0; Pb < 4), reducing the competition between Cd and other minerals [23].

Absorption of Cd from the soil and its (re)distribution between roots and shoots is a highly regulated process where several key players are involved: metal transporters of the root cell plasma membrane, xylem and phloem loading/unloading and leaf/shoot sequestration and detoxification. Plants absorb cadmium through the roots, and there are several factors that can affect availability of cadmium to plants, such as above-mentioned pH, the rhizosphere, and organic acids [24]. In nature, Cd can exist in different forms such as $Cd(OH)_2$, $CdCO_3$, $CdSO_4$ or as a precipitate in the form of arsenates, chromates, sulphides, etc. For plants, Cd uptake can happen at pH 6–7 in forms such as $CdCl^-$, $CdHCO_3^+$, $CdCO_3^+$ and $CdCl_n$ [25].

Generally, uptake of any metal consists of two stages: (1) apoplastic adsorption, a rapid process, where metal ions accumulate in root apoplast due to electrostatic interactions between positively charged metal cations and deprotonated, negatively charged carboxyl groups (dissociation of carboxylic acid due to pH increase) and (2) symplastic uptake which is correlated to metabolic activity and a much slower process (reviewed by [24]). For cadmium to enter the root cells (symplast), it needs to cross the cell membrane, which is facilitated through the presence of various channels and metal transporters. Metal transporters that participate in Cd transport are: ZIP (ZRT and IRT-like proteins) transporter family which can transport metals from extracellular space to cytoplasm; OPT (oligopeptide transporter) family, such as YSL (yellow stripe-like) transporters that transport metal–nicotinamide complexes through the plant cell membrane and can transport Cd complexes; NRAMP (natural resistance-associated macrophage protein), proton-coupled metal ion transporters [26]. There are some reports that Cd could enter the cell also through Ca^{2+} channels [27] and that Cd can block Ca^{2+} channels of the cytoplasmic side of vacuolar membrane [28].

At the level of the plasma membrane within the root cells, H^+ and HCO^{3-} are dissociated from H_2CO_3 in the process of respiration, followed by rapid exchange of H^+ with Cd^{2+} resulting in adsorption of Cd^{2+} on the cell surface preparing Cd for apoplast absorption pathway [29]. Cd then enters the cell through ion channels for Fe^{2+}, Zn^{2+} and Ca^{2+}, additionally plants can secrete low molecular compounds (e.g., mugineic acid, malic acid etc.), enhancing the availability of the ions and forming metal chelates [30] which are subsequently absorbed by the plant.

After Cd crosses the membrane of the root, metal ions are transported from the symplast to xylem and this process is regulated by several factors. Once the metal enters the plant cell, it can be accumulated to a certain level, depending on the plant tolerance, and the rate of accumulation can depend upon the affinity of the chelating molecules (such as nicotianamine, glutathione, and proline), and selectivity and presence of the transporters. Excess Cd is removed from the cytosol to preserve plant activities, and this is achieved by chelation and compartmentalisation in vacuole or plant cell walls [31].

Chelating agents (phytochelatins), vacuolar sequestration and apoplectic barriers, as well as loading activity to the xylem [32,33], where high cation exchange capacity of xylem cell walls controls metal ion transport [24], are major factors that affect Cd xylem loading. In hyperaccumulating plants where high concentration of Cd accumulate in the cells, plants employ different mechanisms of detoxification such as of Cd vacuolar sequestration, Cd chelation (binding Cd to S-containing ligands—phytochelatins, glutathione and metallothionines—cysteine-rich, metal-binding proteins) to alleviate Cd toxicity [34,35]. Phytochelatins are involved in metal inactivation and accumulation mechanisms while metallothionines' role is restrained to cytosol, and they play small or no roles in the accumulation of Cd [24].

If the metal is transported via phloem, it must be ligated to nicotianamine, glutathione (GSH) or phytochelatins (PCs) [36,37], and PCs have high affinity to Cd binding [36]. It is considered that Cd is loaded into the phloem in the form of Cd-thiolate complexes where stability of Cd-S bond minimizes the toxicity [38], and xylem to phloem transfer plays a key role in Cd transport in plants [39]. Movement of metals from the root through xylem is coordinated with sulphur and acetate ligands and ability to load Cd into xylem parenchyma cells is dependent upon the activity of transport proteins. Cd^{2+} uptake from the xylem to shoot symplast is governed by the activity of heavy metal transporters embedded in shoot cell membrane [29]. There are still many aspects of Cd transport and accumulation that remain unclear, especially in plants with different levels of Cd tolerance, resistance and accumulation capacity, further clarification of those mechanisms will lead to more efficient use of hyperaccumulating plants in the processes of phytoremediation.

3. Toxic Effects of Cd on Plants

Toxic effects of Cd are evident in different metabolic and physiological plant processes, with different degrees of severity depending on how resistant the plant is to Cd. Even at low dosages, Cd can cause leaf chlorosis, necrotic lesions, destruction of chloroplast structures, water stress, inhibition of root elongation, impaired gas exchange, wilting, and it can affect uptake of macro- and micronutrients [40]. Once Cd enters plant cells, elicitation of free radicals leads to outbursts of reactive oxygen species (ROS) initiating apoptosis [41]. Plants must counteract these toxic effects by a variety of mechanisms starting from the first point of Cd entrance—the root membrane [42]. Plants transport Cd in the form of metal-organic complexes and in the rhizosphere, Cd often competes with several essential metal ions and Cd absorption can lead to iron deficiency in plants exposed to Cd toxicity [43].

Since root is the first contact point between the plant and Cd it often gets damaged due to oxidation of membrane proteins/thiols, inhibition of protein pumps or simply by altered membrane fluidity reviewed by [42]. Once Cd reaches plant leaves it is sequestered in vacuoles to reduce its toxic effects on photosynthesis and other processes, or it is detoxified by chelating compounds (glutathione, phytochelatins, metallothioneins and other cysteine-rich membrane proteins), reviewed by [42]. In other cases, plants can prevent Cd absorption by excretion of root exudates including carboxylic acid (citric, malic) and histidine [44]. Correlation between synthesis of citric, malic, and oxalic acid and phenolic acids and Cd tolerance has been reported in *Silene sendtneri* [45].

Level of cadmium that is toxic for plants varies among plant species based on ecotypes, cultivars etc. [46]. Some species are sensitive to low Cd concentrations, while other species are highly tolerant and can accumulate high concentrations of Cd in their shoots (>100 mg Cd kg^{-1}) and are considered as Cd hyperaccumulators [47,48]. There are several species classified as Cd hyperaccumulators with high bioconcentration and translocation factors and enhance accumulation of Cd in shoots (>2000 mg Cd kg^{-1}), such as *Arabis gramminifera*, *Chromolaena odorata* [49], *Chara aculeata*, *Nittela opaca* [50] and *Silene sendtneri* [45]. Since hyperaccumulating plants do not show toxic symptoms, such as shoot biomass decrease, plants with high translocation factor (ratio of metal concentration in the shoot to that in the root) are suitable for phytomining (re-extraction of metals form plant biomass) [51].

In contrast, non-accumulating and non-tolerant plant species are susceptible to toxic effects of Cd and severity of toxic symptoms varies in relation to degree of soil contamination, plant species, ecotypes, cultivars, soil composition etc. [24]. Cd can affect plant growth, biomass production, photosynthesis and carbon assimilation, mineral uptake and translocation, development of reproductive tissues, and many other processes in non-tolerant plants.

In the context of Cd effects on plant growth, most prominent effect is reduction of root length and dry mass which is related to decrease of mitotic activity in root meristems under Cd stress [51,52]. In shoots most prominent effects of Cd toxicity can be seen through changes in leaves such as chlorosis, desiccation, necrosis, and stunting [53]. Cd affects photosynthetic apparatus influencing complex II and two photosystems (PSI and PSII) [54] altering the chloroplast ultrastructure. Cadmium disrupts enzymes involved in the Calvin cycle, decreasing photosynthetic rate. Cd can displace Ca^{2+} ions in oxygen-evolving complexes and Mg^{2+} in chlorophyll pigments and decrease chlorophyll and carotenoid content [54,55].

Cadmium interferes with absorption of minerals such as zinc, iron, calcium, manganese, magnesium, copper, silicon, and potassium [56,57]. It is considered that the effect of Cd on mineral absorption is a result of molecular competition between Cd and other cations in channels for essential metal uptake from soil to root leading to deficiency of essential elements [44]. One of the minerals highly affected is iron, where deficiency of iron is one of the main reasons for toxicity of Cd in leaves [58]. The citrate transporter responsible for xylem loading of iron and its translocation is downregulated by Cd [59], causing Fe deficiency. Other metals using the same transport mechanism such as Cu, Al, Cr and Ni show similar decrease under Cd toxicity. For alkaline earth ions, Mn, and Zn

(Ca-like metals) competitive inhibition of translocation is also present suggesting that Cd can use the same translocation system as Ca [24].

Plants resistance to heavy metals depends on different levels of defence, and the first line of defence is the epidermal layer in the roots with the root tip and root hairs as the most important plant part for the absorbance of Cd^{2+} ions from the soil [29]. In the cell, Cd^{2+} can induce oxidative stress inducing production of reactive oxygen species (ROS) indirectly by blocking cysteine groups in enzymes, by competitive binding to Ca^{2+} binding motifs in calmodulin and water-splitting complex of photosystem II [60]. Cd^{2+} can also induce increased production of oxygen radicals at complex III [61]. Plants respond to increased ROS generation by activation of antioxidant response. In hyperaccumulating plants, this is often regulated by changes in gene expression and related to heavy metal resistance genes presence. Antioxidant is any class of compounds that can protect cells from damage caused by exposure to ROS. Series of antioxidant enzymes comprise enzymatic antioxidant plant system including superoxide dismutase (SOD), catalases (CAT), ascorbate peroxidases (APX) and guaiacol peroxidase (SOD), numerous plant metabolites can also serve as antioxidants in detoxification of heavy metals building a non-enzymatic antioxidant response [62]. The antioxidant role of amino acids has been confirmed, suggesting a different contribution to antioxidant response, e.g., proline in Cd stress reduces formation of free radicals and enhances levels of GSH [63]. Other metabolites, such as organic acid, bind directly to metals and are involved in sequestration of metals. Citrate has high affinity for Cd and Fe, while malate binds to Zn [64]. Confirmations for accumulation of phenolic compounds as a defensive mechanism against heavy metals has been reported for several plants and different metals: maize under aluminium [65] and under Cd exposure [66], *Silene sendtneri* under Cd stress [45].

4. Phytoremediation of Cadmium from Polluted Soils

Phytoremediation is considered an eco-friendly remediation of soil, often called green remediation [67]. Basic mechanism of phytoremediation is based on the use of fast-growing plants to eliminate toxic contaminants in the soil or water [68]. Depending on the mechanism of heavy metal elimination from the soil, phytoremediation can be divided into five types: phytostabilisation, phytostimulation, phytotransformation, phytofiltration and phytoextraction [67,69].

Phytostabilisation refers to the process in which the plant reduces the mobility and bioavailability of heavy metals and reduces their leakage into the ground water consequently decreasing the contamination of the food chain [70]. Process of the metal mobilization reduction includes immobilization of the metal (chemical or physical) by the plant roots and fixation of the metal with different soil amendments [43]. In this method, plants have a role in reduction of water percolation limiting the contact with heavy metals to decrease movement of contaminants [71]. It can be employed for clean-up of Cd from the soil, among other pollutants [72]. For Cd, several species could be used for phytostabilisation such as *Virola surinamensis* [73]; *Miscanthus* x *giganteus* [74], oats, white mustard [75]. Most of the plants that have potential for phytostabilisation are plants that are considered as hypertolerant plants or heavy metal excluders (such as *Commelina communis*, *Thlaspi arvense* and others) (Table 1). This method can reduce the availability of metals to the plant, but the method does not actually remove the metals and it is considered more as a management strategy rather than elimination strategy [76] which is the main disadvantage of this technique [1]. List of plants that have shown potential for the use in phytostabilisation in the past 10 years are listed in Table 1.

Phytostimulation, often called rhizo-degradation, refers to the process of degradation of organic pollutants in rhizosphere with enhanced microbial activity [77]. Root exudes stimulate microbial activity by providing nutrients for their growth and in return microbes convert toxic to non-toxic chemicals. It is not suitable for Cd soil remediation. Phytotransformation or phytodegradation refers to breakdown of organic compounds either in plant metabolism or by plant enzymes and it is not related to microbial community [78]. Plants can degrade organic compounds, Hg and Se and I in this manner and during this process they release volatile compounds into the atmosphere (phytovolatilization) [79].

Phytofiltration exploits plant roots for remediation of soil surface, ground water and wastewater in cases of lower heavy metal contamination [77]. During filtration, contaminants are absorbed or precipitated (due to excretion of root exudates and change in pH) [80], and this method can be used for extraction of Cd, Cr, Cu and Zn. There are reports for several plants with potential of Cd phytofiltration such as *Limnicharis flava* [81], *Arunda donax* [82]. Additionally list of plants that have potential to be used in phytofiltration is given in Table 1. Main disadvantage is that any contaminant below rooting depth is not extracted and it is a time-consuming technique.

Phytoextraction/phytoaccumulation exploits fast growing plants for removal of heavy metals from the contaminated soil or water [66,83] through absorption and accumulation of contaminants in the plant. Heavy metals are removed by roots and transported to upper plant parts [84], harvested subsequently and used for biomining/phytomining (metal recovery) [85]. Phytoextraction includes elimination of heavy metals by absorption, translocation, and accumulation of the metals in hyperaccumulating plants families (Scrophulariaceae, Lamiaceae, Asteraceae, Euphorbiaceae and Brassicaceae). Plants that accumulate more than: 100 mg/kg for Se and Cd; 300 mg/kg for Cr, Co and Cu; 1000 mg/kg for As, Pb and Ni; 10,000 mg/kg for Mn; 3000 mg/kg for Zn are considered as a hyperaccumulating plants [86]. The metal hyperaccumulation should be achieved while maintaining the growth [86] for the plant to be usable in phytoextraction purposes. In cases that there is no suitable plant for the phytoextraction, some chelating agents could be added to the soil (EDTA, citric acid, proline etc.) to increase the solubility and availability of the pollutants and facilitate the phytoextraction process [1].

The technique is best when contamination levels are low to medium, since in highly polluted soils, even hyperaccumulating plants can have severely impaired growth minimising the success rate of phytoextraction [70]. Currently, several plants are identified as Cd hyperaccumulating plants such as: *Celosia argentea* [87], *Cassia alata* [88], *Vigna unguiculata*, *Solanum melonaena*, *Momordica charantia* [89], *Nicotiana tabacum*, *Kummerowia striata* [90], *Swietenia macrophylla* [91], and *Silene sendtneri* [45].

There are several benefits of this method including improvement of the soil for future plant colonisation [92], it is environmentally friendly method, and it is an affordable and cost-effective technique for soil remediation [93]. A main disadvantage is the limitations of plants capacity for accumulation and plants sensitivity to soil contamination levels [94,95]. Plants usually accumulate only one metal and may be highly sensitive to presence of other contaminants [94].

Table 1. The list of the plants which have shown potential for application in phytoremediation and their rate of cadmium accumulation (Table summarizes data for the past 5 years according to the data available on Web of Science (WoS)).

Plant Species	Cd Concentration in the Plant (mg/kg)	Plant Part Where Cd Is Accumulated	Recommended for
Aerva sanguinolenta [95]	186	roots	phytostabilisation
Amaranthus hybridus [96]	242	shoots	phytoextraction
Amaranthus hypochondriacus [87]	217	leaf	phytoextraction
Amaranthus mangostanus [97]	102–604	shoots, roots, leaf	phytoextraction phytostabilisation
Arabidopsis halleri [98,99]	228–5722	shoots, roots	phytoextraction phytostabilisation
Arabis gemmifera [100]	1810	leaf	phytoextraction
Arabis paniculate [101]	1662–8670	leaves, roots	phytoextraction, phytostabilisation
Arabis yokoscense [100]	685	leaves	phytoextraction
Atriplex halimus [102]	217–606	shoot, roots	phytoextraction phytostabilisation

Table 1. *Cont.*

Plant Species	Cd Concentration in the Plant (mg/kg)	Plant Part Where Cd Is Accumulated	Recommended for
Azolla pinnata [103]	740	whole plant	phytoextraction
Beta vulgaris [104]	314.17–4547.9	shoots, roots	phytoextractin phytostabilisation
Bidens pilosa [105]	400	leaf	phytoextraction
Brachiaria mutica [106]	186	shoots	phytoextaction
Brachiaria sp. [95]	137.3–647	shoot, roots	phytoextraction phytostabilisation
Cosmos. bipinnata [107]	112.62	shoots	phytoextrction
Chromolaena. odorata [108]	>100	shoots	phytoextraction
Calendula calypso [109]	165	roots	phytostabilisation
Callisia fragrans [110]	>101	shoots	phytoextraction
Carthamus tinctorius [111]	148.1–236.6	leaves	phytoextraction
Cassia alata [85]	159	roots	phytostabilisation
Celosia Argentea [87,112]	121–236	leaves, roots	phytoextraction phytostabilisation
Chlorophytum comosum [110]	>100	shoots	phytoextraction
Chromolaena odorata [49]	102–1440	leaves, roots	phytoextraction phytostabilisation
Desmostachya bipinnata [106]	312	shoots	phytoextaction
Eucalyptus camaldulensis [113]	10.5	roots	phytostabilisation
Eleusine indica [95]	150	roots	phytostabilisation
Eucalyptus camaldulensis [113]		leaves	phytostabilisation
Eucalyptus globulus [114]	5.11	roots	phytostabilisation
Glycine max [115]	74.8–290	leaves	phytoextraction
Gynura pseudochina [95,116]	457.7	shoots	phytoextraction
Helianthus annuus [117]	65.7	shoots, roots	phytoextraction, phytostabilisation
Helianthus tuberosus [118]	328.77–2167.9	leaves, roots	phytoextraction phytostabilisation
Hydrocotyle sibthorpioides [119]	128.5	shoots	phytoextraction
Impatiens violaeflora [95]	212,3	shoots	phytoextraction
Imperata cylindrica [95]	133,2	roots	phytostabilisation
Iris lacteal	121	shoots	phytoextraction
Iris tectorum	171	shoots	phytoextraction
Justicia procumbens [95]	548	shoots	phytoextraction
Lantana camara [16]	>100	shoots	phytoextraction
Leptochloa fusca [106]	245	shoots	phytoextaction
Lolium multiforum [115]	106.83	leaves	phytoextraction
Lonicera japonica [120]	402.96	shoots	phytoextraction
Lycopersicon esculentum [121]	130–174	shoots	phytoextraction
Microsorum pteropus [122]	>400 mg/kg	root, stem, leaves	phytoextraction
Macleaya cordata [123]	163.39	roots	phytostabilisation
Malva rotundifolia [124]	900	shoots	phytoextraction
Nicotiana sp. [125]	271.5	leaves	phytoextraction
Nicotiana tabacum [90]	314.6	shoots	phytoextraction
Phytolacca acinosa [87]	110	leaves	phytoextraction
Phytolacca americana [126]	188.4	shoots	phytoextraction

Table 1. *Cont.*

Plant Species	Cd Concentration in the Plant (mg/kg)	Plant Part Where Cd Is Accumulated	Recommended for
Picris divaricata [127]	585	shoots	phytoextraction
Pistia stratiotesfe [128]	248	shoots	phytoextraction
Populus nigra [129]	2070	shoots	phytoextraction
Potamogeton pectinatus [130]	422	shoots	phytoextraction
Prosopis laevigata [131]	8176	shoots	phytoextraction
Pteris vittate [132]	216.5	shoots	phytoextraction
Pterocypsela laciniata [133]	207.97	shoots	phytoextraction
Rorippa globosa [134]	150	shoots	phytoextraction
Sedum plumbizincicola [135]	152.93	shoots	phytoextaction
Sida rhombifolia [124]	225.31	roots	phytostabilisation
Sedum alfredii [136]	9000	leaves	phytoextraction
Sedum plumbizincicola [124]	139	shots	phytoextraction
Siegesbeckia orientalis [137]	193	shots	phytoextraction
Silene sendtneri [45]	2156	shots	phytoextraction
Silene vulgaris [138]	203–750	Roots	Phytostabilisation
Solanum lycopersicum [115]	133.45	leaves	phytoextraction
Solanum nigrum [104]	100.6–2021.7	shoots, roots	phytoextraction phytostabilisation
Sphagneticola calendulacea [139]	>100	shoots	phytoextaction
Sporobolus arabicus [106]	171	shoots	phytoextaction
Tagetes. erecta [140]	166.07	shoots	phytoextraction
Tagetes. patula [141]	231.72–601.45	shoots	phytoextraction
Taraxacum ohwianum [142]	181.39	shoots	phytoextraction
Turnip landraces [143]	139.7	leaves	phytoextraction
Vettiveria zizanioides [144,145]	263–2232	Roots	phytostabilisation
Viola baoshanensis [132]	2310	shoot	phytoextraction

5. Approaches for Enhancing Cadmium Phytoremediation

Phytoremediation can be enhanced using different methods and techniques that could be generally grouped in: (1) techniques employed to enhance phytoremediation through amelioration of the soil (mostly used for phytoextraction techniques) and (2) enhancement of plant performance/tolerance/accumulation properties. Some examples of phytoremediation enhancement treatments are shown at Table 2.

5.1. Enhancement of Phytoremediation by Soil Amelioration

The mobility of Cd in the soil can be affected by supplementation of: (a) certain chemicals and surfactants such as ethylenediaminetetraacetic acid (EDTA) [146] alone or in combination with biochar [147], urea [148], ethylenediamine disuccinic acid (EDDS) [149], citric acid [150] or reduction of pH in the soil [151,152] by addition of acids or acid-producing fertilisers [153] and (b) by addition of biological enhancers (bacteria, fungi, intercropping).

The most-known chemical chelator is EDTA, which increases the concentration of water-soluble Cd, promotes its uptake, and facilitates its transfer to shoots [148]. Conversely, EDTA has a complex relationship with pH when small concentrations of EDTA are added to the soil (the number of extracted cations is dependent on pH). Additionally, EDTA efficiency is related to soil type, and in Ca-rich soil EDTA is rapidly consumed by dissolution of calcite [153]. Addition of EDTA can increase the bioavailability of heavy metals, but it also can affect the soil microorganisms, contaminate groundwater and due to slow decomposition, it can cause ground water pollution [154]. Organic acids, due to their biodegradability, can be used as less hazardous chelators with lower possibility of ground water contamination. Citric acid, if added in smaller dosages, can be an efficient mobiliser of Cd facilitating phytoextraction [155], and enhancing effects on the uptake of Cd are probably a result of ameliorative effect of citric acid. Changes in root structure and shape and activation of ATPases in root plasma membrane changing the transport of ions increasing Cd symplastic and apoplastic uptake have been recorded in plants grown in the soil ameliorated with citric acids. Humic acids can be used for enhancement of phytoextraction by soil supplementation. These acids are not water soluble in acidic conditions, but under higher pH, they are extractable and soluble. Their carboxyl and OH functional groups enable them to play a role in the transport, bioavailability, and solubility of heavy metals [156]. In the context of the sustainable increase of bioavailability, acidified manure can be applied to increase phytoextraction efficiency [157].

A widely used enhancement of Cd accumulation is bioaugmentation of soils with cadmium-resistant bacteria. There are many studies reporting the potential of microorganisms for phytoremediation through their effect on Cd bioavailability [158,159]. For phytoremediation, we use bacteria that can transform metals into soluble and bioavailable forms through production of siderophores and these bacteria are classified as plant-growth promoting bacteria (PGPB). Such activity has been recorded for several groups of bacteria: *Pseudomonas* sp., *Microbacterium* sp., *Bacillus* sp., *Rahnella* sp., *Burkholderia* sp. and *Enterobacter* sp. [148,160]. Some of the identified bacteria are resistant to Cd and can be used for improvement of tolerance as well as accumulation capacities of hyperaccumulating plants to further phytoremediation efficiency. *Micrococcus* sp. MU1 and *Klebsiella* sp. BAM1, cadmium-resistant PGPBs promote root elongation of *Helianthus annuus* in cadmium-contaminated soil through stimulation of the indole-3-acetic acid (IAA) synthesis. Increase of Cd accumulation was achieved after adding *Klebsiella* to the soil 4 weeks after plant cultivation in Cd-contaminated soils [161,162]. Change in pH in the rhizosphere was induced by addition of cadmium-resistant *Enterobacter* sp. FM-1 resulting in an increase of cadmium content in aerial parts of *Centella asiatica* up to 160% [163]. Successful increase of cadmium accumulation in roots and shoots of *Zea mays* was achieved by soil augmentation with cadmium-resistant *Micrococcus* sp. TISTR2221 [164]. One problem in bioaugmentation is that some bacteria have growth problems in cadmium polluted soils, in those cases biostimulation which includes addition of mineral nutrients to the soil together with bacteria, can enable the bacterial growth regardless of Cd contamination. Stimulation of phytoextraction of Cd by biostimulated bioaugmentation with *Sphingobium* sp. SA2 was recorded for *Glycine max* [165].

5.2. Enhanced Phytoremediation by Increasing Plant Capacities

One of the simplest approaches of phytoremediation enhancement is to increase plant biomass production and subsequently enhance Cd phytoremediation rates [166], which can be achieved through soil amendments or by plant changes directly. Seed pre-treatments (priming) before sowing can increase seedling vigour and increase biomass production.

Seed priming is a controlled rehydration (imbibition) of seeds for induction of metabolic activity without radicle emergence, followed by seed drying and re-imbibition prior to sowing. It is widely used for improvement of seed vigour, enhancement of germination and achieving germination uniformity, especially under stress conditions. Due to commence of re-hydration, so-called "pre-germinative metabolism" is triggered which includes cellular processes of de novo nucleic acid and protein synthesis, accumulation of phospholipids and sterols, DNA repair and activation of antioxidant mechanisms. The potential of plant priming in abiotic stress tolerance has been extensively investigating using different types of molecules added exogenously to plant organs (roots, leaves etc.) with a result of enhanced tolerance of abiotic stress [167], there are only few papers concerning how seed priming affects tolerance levels, and what is the mechanism of plants memory of "primed" state in seeds. Seed priming with different agents (water, proline, salicylic acid, silicic acid) increased biomass production in *Silene sendtneri* under Cd stress by increasing tolerance levels [45].

One of the most studied molecules in plant priming is plant hormone salicylic acid (SA). This hormone plays a pivotal role in many metabolic processes including antioxidant response under different abiotic stressors [168,169]. It has been recorded that seed priming and plant priming with salicylic acid can affect the plant antioxidant status resulting in increased tolerance levels towards heavy metal exposure [170,171]. Exogenously applied salicylic acid can enhance plant tolerance to heavy metals and increase phytoremediation efficiency [172]. One other molecule that can be used as a priming agent is proline. Proline is considered as a stress marker in plants subjected to abiotic stress [173]. Using proline, seed priming can imprint seeds for defence against various abiotic stressors including heavy metals [45,66]. It is still unknown in which way seed priming induces changes in metabolism that is memorised and transferred to growing plants under heavy metal stress [174]. Main advantage of this method is how easy it is to perform seed priming, the method often uses simple steps such as hydropriming (pre-treatment of seeds with water), and it is considered an eco-friendly method of seed performance improvement. A main disadvantage lays in sensitive timing of priming, since emergence of radicle must be avoided, and time of priming needs to be adjusted to ensure that metabolic processes are initiated but radicle is not emerged.

Genetic engineering of plants can be utilised for production of more advanced, more efficient, more robust hyperaccumulators. Candidate plants for genetic engineering are usually plants with high biomass production and existing capacity for heavy metal accumulation. Genetic engineering can also be employed for induction of gene overexpression such as glutamylcystein syntlitase enhancing heavy metal accumulation [175]. *Brassica juncea* transgenic plant has gshl gene from *Escherichia coli* and it synthesises higher concentrations of phytochelatins, glutathione and nonprotein thiols and displays increased heavy metal tolerance [174]. Incorporation of gene for nicotinamine synthase responsible for synthesis of metal chelating amino acid, HcNAS1 from *Hordeum vulgare* into *Arabidopsis* can stimulate heavy metal accumulation [176]. Similarly, incorporation of the metallothionein gene IlMt2a gene from *Iris lactea* var. *chinensis* incorporated in *Arabidopsis* genome resulted in higher tolerance of Cd [177].

Beside incorporation of new genes into the plant genome, through genetic engineering, overexpression of different genes responsible for enhanced heavy metal, increase in tolerance and accumulation can be achieved. Overexpression of metal transport proteins in plants can induce enhanced metal accumulation in roots (phytostabilisation) or in the shoots (phytoextraction) can be achieved. Additionally, manipulation of genes for phytochelatins (phytochelatin synthetase and c-glutamyl cysteine synthetase) can result with enhanced heavy metal tolerance, such as higher Cd accumulation in transgenic tabaco (*Nicotiana glauca* and *Nicotiana tabacum*) [178]. In the past few years, numerous studies have shown plants overexpressing metallothioneins transgenes with demonstrated improvement of heavy metal tolerance [179]. Overexpression of trans genes responsible for antioxidant plant response (superoxide dismutase, ascorbate peroxidase, catalase, and glutathione *S*-transferase) in some cases impaired the morphological and physiological plant parameters [176].

A newly taken approach in genetic engineering for improvement of heavy metal tolerance is gene silencing. This process includes a process in which small RNA molecules supress gene expression and translation of target mRNA [180]. This technique can be employed in crops to ensure that no heavy metals are accumulated in plants and by silencing phytochelatin synthase gene Cd levels in grains were drastically decreased. Conversely, by silencing gene encoding root-localized Cd-transporter *OsNRAMP5* enhanced Cd translocation to the shoots was achieved [181]. The most prominent disadvantage of gene manipulation and genetic transformation is low acceptance by the public, and there is still fear from GMO plants and the process of introduction of such plants in open fields is long and complex.

Table 2. Some examples of phytoremediation enhancement treatments.

Method		Used Enhancer	Plant Species	Result
Soil supplementation	Chemical chelators	ethylenegluatarotriacetic acid (EDTA); sodium dodecyl sulfate (SDS) [112]	*Calendula officinalis; Althea rosea*	Significant increase of Cd accumulation in *A. rosea*
		SDS EDTA [182]	*Calendula officinalis*	Efficient chemical enhancement of Cd phytoremediation
		Citric acid, ethylenediamine disuccinic acid (EDDS), EDTA [149]	*Ricinus communis*	Low effectiveness great risks due to toxicology and environmental persistence
		[N, N]-bis glutamic acid (GLDA), nitrilotriacetic acid (NTA), [S, S]- EDDS, and citric acid (CA) [183]	*Amaranthus hypochondriacus*	Combination of chelators effective for enhancement of Cd phytoremediation
		EDTA [149]	*Lolium perenne*	Increased heavy metal absorption
		Biochar and EDTA [147]	*Brassica juncea*	Enhanced heavy metal tolerance
		EDTA [184]	*Pelargonium hortoum*	Increased biomass, increased accumulation of heavy metals
		EDTA [185]	*Sedum aizoon* *Suaeda salsa*	Enhanced efficiency of Cd removal
		EDTA [186]	*bamboo*	Increased absorption of heavy metals
		EDTA [187]	*Datura stamonium*	Enhanced phytoremediation of Cd
		EDTA, EDDS [183]	*Amaranthus hypochondriacus*	Enhanced accumulation of heavy metals
	Electro-phytoremediation	Application of low voltage direct current to electrodes in the soil [188]	*Solanum tuberosum.* Var. Kuras	Increase of Cd accumulation in plant roots
		DC electric fields [189]	*Eucalyptus globulus*	Increase of phytoremediation capacity
		DC electric fields [190]	*Eucalyptus globulus*	Increased uptake of heavy metals
	Bioagumentation	*Micrococcus* sp., *Pseudomonas* sp. *Arthrobacter* sp. [191]	*Glycine max*	Increased Cd uptake
		Lactococcus, Raoultella, Bacillus, Acinetobacter, Gluconacetobacter, Dyella [192]	*Phragmites australis*	Enhanced phytoremediation
		Cyanobacteria [193]	*Portulacea oleracea*	Enhanced phytoremediation of heavy metals
		Rhizobacteria [194]	*Scirpus grossus*	Enhanced phytoremediation of pollutants
		Vibrio alginolyticus [195]	*Scirpus grossusThypha angustifolia*	Enhanced removal of heavy metals from soil
		Enterobacter sp. FM-1 [196]	*Polygonum hydropiper Polygonum lapathifolium*	Enhanced Cd phytoextraction

Table 2. *Cont.*

Method		Used Enhancer	Plant Species	Result
Soil supplementation	Bioagumentation	*Kluyvera intermedia, Klebsiella oxytoca, Citrobacter murliniae* [197]	*Sorghum bicolor*	Enhanced phytoremediation
		Simplicillium chinense QD10 [150]	*Phragmites communis*	Significant removal of acid-extractable and reducible metals in soils and the increase of Cd accumulation in *P. communis*
		Funneliformis mosseae and Rhizophagus intraradices, β-cyclodextrin [198]	*Solanum nigrum*	Combination of fungi and surfactant effective enhancement of phytoremediation
Plant enhancement	Plant growth regulators	Indole-3-acetic acid (IAA), gibberellin A3 (GA_3) and 6-Benzylaminopurine (6-BA) [189]	*Brassica juncea*	Significant increase of shoot uptake of Cd after IAA treatment
		IAA, GA_3, 6-BA, 24-epibrassinolide (EBL) [199]	*Brassica juncea*	Enhanced phytoremediation of Cd
		GA_3 [200]	*Luffa acutangular*	Improved phytoremediation of pollutants
		GA_3, IAA, [201]	*Dysphania ambrosioides*	Improved Cd phytoextraction
		Salicylic acid [199]	*Impatiens balsamina*	Enhanced phytoremediation of pollutants
	Seed primingt	Sound waves of frequency 200, 300, 400, 500, and 1000 Hz [202]	*Festuca arundinacea*	Increase od Cd extraction ability in positive correlation with sound frequency
		Proline [66]	*Zea mais*	Increased tolerance of Cd
		Proline, salicylic and silicic acid [45]	*Silene sendtneri*	Increased tolerance and accumulation of Cd in shoots (enhanced phytoremediation)
		Putrescin [203]	*Coriandrum sativum*	Enhanced phytoextraction of Cd

In search of the most effective phytoremediation, there is much work to perform in combining different treatments, supplements, and processes to obtain higher efficiency of hyperaccumulating plants. Often, a combination of plant growth regulators (such as salicylic acid) and bioaugmentation with rhizobacteria is used for enhancement of phytoremediation with promising results [172,204].

6. Conclusions

Cadmium is a serious soil contaminant posing a threat to human health through contamination of the food chain since it can be easily absorbed by plants growing on agricultural land that is heavily contaminated by Cd (through application of fertilizers). Unfortunately, current global climate change is making this metal more dangerous, affecting its mobility in soil, and causing cadmium leakage to underground freshwater reservoirs. All this places Cd on top of the list of soil contaminants that need remediation. One of the approaches for Cd remediation is the use of phytoremediation (especially phytoextraction), which represents an eco-friendly, economical, and simple method for heavy metal removal from polluted soils. There is only a relatively small number of plant species that are considered as Cd hyperaccumulators that could be used effectively for this purpose, and there is a constant search for new hyperaccumulating species as well as methods for improvement of phytoremediation. The latest eco-friendly improvement method is seed priming, representing a safe method for enhancement of plant tolerance and accumulation capacities without disrupting soil properties, while increasing the rate of soil clean-up. The next step in the phytoremediation process can be in succeeding of soil clean-up through use of primed plants in intercropping systems, thus cleaning the soil while crops are being grown and ensuring there is no disruption in crop growth. In addition, future research should be focused on finding a solution for more efficient soil clean-up, including investigation of possible inter-cropping systems of hyperaccumulating plants and crops. Such systems would have the benefit of simultaneous soil remediation.

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References

1. Raza, A.; Habib, M.; Kakavand, S.N.; Zahid, Z.; Zahra, N.; Sharif, R.; Hasanuzzaman, M. Phytoremediation of cadmium: Physiological, biochemical, and molecular mechanisms. *Biology* **2020**, *9*, 177. [CrossRef] [PubMed]
2. Kubier, A.; Wilkin, R.T.; Pichler, T. Cadmium in soils and groundwater: A review. *Appl. Geochem.* **2019**, *108*, 104388. [CrossRef] [PubMed]
3. McLaughlin, M.J.; Smolders, E.; Zhao, F.J.; Grant, C.; Montalvo, D. Managing cadmium in agricultural systems. *Adv. Agron.* **2021**, *166*, 1–129.
4. Khan, M.A.; Khan, S.; Khan, A.; Alam, M. Soil contamination with cadmium, consequences and remediation using organic amendments. *Sci. Total Environ.* **2017**, *601–602*, 1591–1605. [CrossRef]
5. Nordberg, G.F.; Alfred Bernard, A.; Diamond, G.L.; Duffus, J.H.; Illing, P.; Nordberg, M.; Bergdahl, I.A.; Jin, T.; Skerfving, S. Risk assessment of effects of cadmium on human health (IUPAC Technical Report). *Pure Appl. Chem.* **2018**, *90*, 755–808. [CrossRef]
6. Makino, T.; Sugahara, K.; Sakura, Y.; Takano, H.; Kamiya, T.; Sasaki, K.; Itou, T.; Sekiya, N. Remediation of cadmium contamination in paddy soils by washing with chemicals: Selection of washing chemicals. *Environ. Pollut.* **2006**, *144*, 2–10. [CrossRef]
7. Qiao, Y.; Wu, J.; Xu, Y.; Fang, Z.; Zheng, L.; Cheng, W.; Zhao, D. Remediation of cadmium in soil by biochar-supported iron phosphate nanoparticles. *Ecol. Eng.* **2017**, *106*, 515–522. [CrossRef]

8. Bashir, S.; Zhu, J.; Fu, Q.; Hu, H. Cadmium mobility, uptake and anti-oxidative response of water spinach (*Ipomoea aquatic*) under rice straw biochar, zeolite and rock phosphate as amendments. *Chemosphere* **2018**, *194*, 579–587. [CrossRef]
9. Abbas, S.Z.; Rafatullah, M.; Hossain, K.; Ismail, N.; Tajarudin, H.A.; Abdul Khalil, H.P.S. A review on mechanism and future perspectives of cadmium-resistant bacteria. *Int. J. Environ. Sci. Technol.* **2017**, *15*, 243–262. [CrossRef]
10. Riaz, U.; Aslam, A.; Zaman, Q.; Javeid, S.; Gul, R.; Iqbal, S.; Javid, S.; Murtaza, G.; Jamil, M. Cadmium contamination, bioavailability, uptake mechanism and remediation strategies in soil-plant-environment system: A critical review. *Curr. Anal. Chem.* **2021**, *17*, 49–60. [CrossRef]
11. Kumar, A.; Subrahmanyam, G.; Mondal, R.; Cabral-Pinto, M.M.S.; Shabnam, A.A.; Jigyasu, D.K.; Malyan, S.K.; Fagodiya, R.K.; Khan, S.A.; Yu, Z.G. Bio-remediation approaches for alleviation of cadmium contamination in natural resources. *Chemosphere* **2021**, *268*, 128855. [CrossRef]
12. Yan, A.; Wang, Y.; Tan, S.N.; Mohd Yusof, M.L.; Ghosh, S.; Chen, Z. Phytoremediation: A promising approach for revegetation of heavy metal-polluted land. *Front. Plant Sci.* **2020**, *11*, 359. [CrossRef] [PubMed]
13. Luo, J.S.; Zhang, Z. Mechanisms of cadmium phytoremediation and detoxification in plants. *Crop J.* **2021**, *9*, 521–529. [CrossRef]
14. Takahashi, R.; Ito, M.; Kawamoto, T. The road to practical application of cadmium phytoremediation using rice. *Plants* **2021**, *10*, 1926. [CrossRef] [PubMed]
15. Nouri, H.; Hashempour, Y. Phytoremediation of Cd and Pb in polluted soil: A systematic review. *Int. J. Environ. Anal. Chem.* **2021**, *in press*. [CrossRef]
16. Liu, S.; Ali, S.; Yang, R.; Tao, J.; Ren, B. A newly discovered Cd-hyperaccumulator *Lantana camara* L. *J. Hazard. Mater.* **2019**, *371*, 233–242. [CrossRef]
17. Ali, U.; Zhong, M.; Shar, T.; Fiaz, S.; Xie, L.; Jiao, G.; Ahmad, S.; Sheng, Z.; Tang, S.; Wei, X.; et al. The influence of pH on cadmium accumulation in seedlings of rice (*Oryza sativa* L.). *J. Plant. Growth Regul.* **2020**, *39*, 930–940. [CrossRef]
18. Shiyu, Q.I.N.; Hongen, L.I.U.; Zhaojun, N.I.E.; Rengel, Z.; Wei, G.A.O.; Chang, L.I.; Peng, Z.H.A.O. Toxicity of cadmium and Shiyuits competition with mineral nutrients for uptake by plants: A review. *Pedosphere* **2020**, *30*, 168–180.
19. Chen, H.S.; Huang, Q.Y.; Liu, L.N.; Cai, P.; Liang, W.; Li, M. Poultry manure compost alleviates the phytotoxicity of soil cadmium: Influence on growth of pakchoi (*Brassica chinensis* L.). *Pedosphere* **2010**, *20*, 63–70. [CrossRef]
20. Bolan, N.S.; Adriano, D.C.; Naidu, R. Role of phosphorus in mobilization and bioavailability of heavy metals in the soil-plant system. *Rev. Environ. Contam. Toxicol.* **2003**, *177*, 1–44.
21. Krishnamurti, G.S.R.; Cieslinski, G.; Huang, P.M.; Van Rees, K.C.J. Kinetics of cadmium release from soils as influenced by organic acids: Implication in cadmium availability. *J. Environ. Qual.* **1997**, *26*, 271–277. [CrossRef]
22. Wang, Z.; Zeng, X.; Yu, X.; Zhang, H.; Li, Z.; Jin, D. Adsorption behaviors of Cd^{2+} on Fe_2O_3/MnO_2 and the effects of coexisting ions under alkaline conditions. *Chin. J. Geochem.* **2010**, *29*, 197–203. [CrossRef]
23. Sipos, P.; Tóth, A.; Kis, V.K.; Balázs, R.; Kovács, I.; Németh, T. Partition of Cd, Cu, Pb and Zn among mineral particles during their sorption in soils. *J. Soils Sediments* **2019**, *19*, 1775–1787. [CrossRef]
24. Ismael, M.A.; Elyamine, A.M.; Moussa, M.G.; Cai, M.; Zhao, X.; Hu, C. Cadmium in plants: Uptake, toxicity, and its interactions with selenium fertilizers. *Metallomics* **2019**, *11*, 255–277. [CrossRef]
25. Smolders, E.; McLaughlin, M.J. Chloride increases cadmium uptake in Swiss chard in a resin-buffered nutrient solution. *Soil Sci. Soc. Am. J.* **1996**, *60*, 1443–1447. [CrossRef]
26. Ishimaru, Y.; Takahashi, R.; Bashir, K.; Shimo, H.; Senoura, T.; Sugimoto, K.; Ono, K.; Yano, M.; Ishikawa, S.; Arao, T. Characterizing the role of rice NRAMP5 in manganese, iron and cadmium transport. *Sci. Rep.* **2012**, *2*, 286. [CrossRef]
27. Perfus-Barbeoch, L.; Leonhardt, N.; Vavasseur, A.; Forestier, C. Heavy metal toxicity: Cadmium permeates through calcium channels and disturbs the plant water status. *Plant J.* **2002**, *32*, 539–548. [CrossRef] [PubMed]
28. White, P.J. Calcium channels in higher plants. *Biochim. Biophys. Acta. Biomembr.* **2000**, *1465*, 171–189. [CrossRef]
29. Song, Y.; Jin, L.; Wang, X. Cadmium absorption and transportation pathways in plants. *Int. J. Phytoremediat.* **2017**, *19*, 133–141. [CrossRef]
30. Curie, C.; Cassin, G.; Couch, D.; Divol, F.; Higuchi, K.; Le Jean, M.; Mari, S. Metal movement within the plant: Contribution of nicotianamine and yellow stripe 1-like transporters. *Ann. Bot.* **2009**, *103*, 1–11. [CrossRef] [PubMed]
31. Viehweger, K. How plants cope with heavy metals. *Bot. Stud.* **2014**, *55*, 1–12. [CrossRef] [PubMed]
32. Clemens, S. Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. *Biochimie* **2006**, *88*, 1707–1719. [CrossRef]
33. Mendoza-Cózatl, D.G.; Jobe, T.O.; Hauser, F.; Schroeder, J.I. Long-distance transport, vacuolar sequestration, tolerance, and transcriptional responses induced by cadmium and arsenic. *Curr. Opin. Plant Biol.* **2011**, *14*, 554–562. [CrossRef]
34. DalCorso, G.; Farinati, S.; Maistri, S.; Furini, A. How plants cope with cadmium: Staking all on metabolism and gene expression. *J. Integr. Plant Biol.* **2008**, *50*, 126S8–1280. [CrossRef]
35. Sigel, A.; Sigel, H.; Sigel, R. *Metallothioneins and Related Chelators, Metal Ions in Life Sciences*; Royal Society of Chemistry Publishing: Cambridge, UK, 2009; Volume 5.
36. Mendoza-Cózatl, D.G.; Butko, E.; Springer, F.; Torpey, J.W.; Komives, E.A.; Kehr, J.; Schroeder, J.I. Identification of high levels of phytochelatins, glutathione and cadmium in the phloem sap of Brassica napus. A role for thiol-peptide in the long-distance transport of cadmium and the effect of cadmium on iron translocation. *Plant J.* **2008**, *54*, 249–259. [CrossRef] [PubMed]

37. Vogel-Mikuš, K.; Arčon, I.; Kodre, A. Complexation of cadmium in seeds and vegetative tissues of the cadmium hyperaccumulator *Thlaspi praecox* as studied by X-ray absorption spectroscopy. *Plant Soil.* **2010**, *331*, 439–451. [CrossRef]
38. Küpper, H.; Mijovilovich, A.; Meyer-Klaucke and Kroneck, W.P.M. Tissue-and age-dependent differences in the complexation of cadmium and zinc in the cadmium/zinc hyperaccumulator *Thlaspi caerulescens* (Ganges ecotype) revealed by X-ray absorption spectroscopy. *Plant Physiol.* **2004**, *134*, 748–757. [CrossRef]
39. Wong, C.K.E.; Cobbett, C.S. HMA P-type ATPases are the major mechanism for root-to-shoot Cd translocation in *Arabidopsis thaliana*. *New Phytol.* **2009**, *181*, 71–78. [CrossRef]
40. Rochayati, S.; Du Laing, G.; Rinklebe, J.; Meissner, R.; Verloo, M. Use of reactive phosphate rocks as fertilizer on acid upland soils in Indonesia: Accumulation of cadmium and zinc in soils and shoots of maize plants. *J. Plant Nutr. Soil Sci.* **2011**, *174*, 186–194. [CrossRef]
41. Keunen, E.; Remans, T.; Bohler, S.; Vangronsveld, J.; Cuypers, A. Metal-induced oxidative stress and plant mitochondria. *Int. J. Mol. Sci.* **2011**, *12*, 6894–6918. [CrossRef] [PubMed]
42. Irfan, M.; Hayat, S.; Ahmad, A.; Alyemeni, M.N. Soil cadmium enrichment: Allocation and plant physiological manifestations. *Saudi J. Biol. Sci.* **2013**, *20*, 1–10. [CrossRef] [PubMed]
43. Wuana, R.A.; Okieimen, F.E. Heavy metals in contaminated soils: A review of sources, chemistry, risks, and best available strategies for remediation. *ISRN Ecol.* **2011**, *2011*, 402647. [CrossRef]
44. Clemens, S.; Schroeder, J.I.; Degenkolb, T. *Caenorhabdites elegans* expresses a functional phytochelatin synthase. *Eur. J. Biochem.* **2001**, *268*, 3640–3643. [CrossRef]
45. Karalija, E.; Selović, A.; Dahija, S.; Demir, A.; Samardžić, J.; Vrobel, O.; Zeljković, S.Ć.; Parić, A. Use of seed priming to improve Cd accumulation and tolerance in *Silene sendtneri*, novel Cd hyper-accumulator. *Ecotoxicol. Environ. Saf.* **2021**, *210*, 111882. [CrossRef]
46. He, S.; He, Z.; Yang, X.; Stoffella, P.J.; Baligar, V.C. *Advances in Agronomy*; Elsevier: Amsterdam, The Netherlands, 2015; Volume 134, pp. 135–225.
47. McGrath, S.P.; Zhao, F.J. Phytoextraction of metals and metalloids from contaminated soils. *Curr. Opin. Biotechnol.* **2003**, *14*, 277–282. [CrossRef]
48. Krämer, U. Metal hyperaccumulation in plants. *Annu. Rev. Plant Biol.* **2010**, *61*, 517–534. [CrossRef]
49. Tanhan, P.; Kruatrachue, M.; Pokethitiyook, P.; Chaiyarat, R. Uptake and accumulation of cadmium, lead and zinc by Siam weed [*Chromolaena odorata* (L.) King & Robinson]. *Chemosphere* **2007**, *68*, 323–329.
50. Sooksawat, N.; Meetam, M.; Kruatrachue, M.; Pokethitiyook, P.; Nathalang, K. Phytoremediation potential of charophytes: Bioaccumulation and toxicity studies of cadmium, lead and zinc. *J. Environ. Sci.* **2013**, *25*, 596–604. [CrossRef]
51. Xue, Z.C.; Gao, H.Y.; Zhang, L.T. Effects of cadmium on growth, photosynthetic rate and chlorophyll content in leaves of soybean seedlings. *Biol. Plant.* **2013**, *57*, 587–590. [CrossRef]
52. Wei, S.; Zhou, Q.; Wang, X.; Zhang, K.; Guo, G.; Ma, L.Q. A newly-discovered Cd-hyperaccumulator *Solatium nigrum* L. *Chin. Sci. Bull.* **2005**, *50*, 33–38. [CrossRef]
53. Solís-Domínguez, F.; González-Chávez, M.; Carrillo-González, R.; Rodríguez-Vázquez, R. Accumulation and localization of cadmium in *Echinochloa polystachya* grown within a hydroponic system. *J. Hazard. Mater.* **2007**, *141*, 630–636. [CrossRef] [PubMed]
54. Küpper, H.; Parameswaran, A.; Leitenmaier, B.; Trtílek, M.; Šetlík, I. Cadmium-induced inhibition of photosynthesis and long-term acclimation to cadmium stress in the hyperaccumulator *Thlaspi caerulescens*. *New Phytol.* **2007**, *175*, 655–674. [CrossRef] [PubMed]
55. Pagliano, C.; Raviolo, M.; Dalla Vecchia, F.; Gabbrielli, R.; Gonnelli, C.; Rascio, N.; La Rocca, N. Evidence for PSII donor-side damage and photoinhibition induced by cadmium treatment on rice (*Oryza sativa* L.). *J. Photochem. Photobiol. B* **2006**, *84*, 70–78. [CrossRef]
56. Jinadasa, N.; Collins, D.; Holford, P.; Milham, P.J.; Conroy, J.P. Reactions to cadmium stress in a cadmiumtolerant variety of cabbage (*Brassica oleracea* L.): Is cadmium tolerance necessarily desirable in food crops? *Environ. Sci. Pollut. Res.* **2016**, *23*, 5296–5306. [CrossRef] [PubMed]
57. Bertoli, A.C.; Cannata, M.G.; Carvalho, R.; Bastos, A.R.R.; Freitas, M.P.; dos Santos, A.A. *Lycopersicon esculentum* submitted to Cd-stressful conditions in nutrition solution: Nutrient contents and translocation. *Ecotoxicol. Environ. Saf.* **2012**, *86*, 176–181. [CrossRef]
58. Fodor, F.; Gáspár, L.; Morales, F.; Gogorcena, Y.; Lucena, J.J.; Cseh, E.; Kröpfl, K.; Abadía, J.; Sárvári, E. Effects of two iron sources on iron and cadmium allocation in poplar (*Populus alba*) plants exposed to cadmium. *Tree Physiol.* **2005**, *25*, 1173–1180. [CrossRef] [PubMed]
59. Yamaguchi, H.; Fukuoka, H.; Arao, T.; Ohyama, A.; Nunome, T.; Miyatake, K.; Negoro, S. Gene expression analysis in cadmium-stressed roots of a low cadmium-accumulating solanaceous plant, *Solanum torvum*. *J. Exp. Bot.* **2009**, *61*, 423–437. [CrossRef]
60. Heyno, E.; Klose, C.; Krieger-Liszkay, A. Origin of cadmium-induced reactive oxygen species production: Mitochondrial electron transfer versus plasma membrane NADPH oxidase. *New Phytol.* **2008**, *179*, 687–699. [CrossRef]
61. Wang, Y.; Fang, J.; Leonard, S.S.; Rao, K.M. Cadmium inhibits the electron transfer chain and induces reactive oxygen species. *Free Radic. Biol. Med.* **2004**, *36*, 1434–1443. [CrossRef] [PubMed]
62. Singh, S.; Parihar, P.; Singh, R.; Singh, V.P.; Prasad, S.M. Heavy metal tolerance in plants: Role of transcriptomics, proteomics, metabolomics, and ionomics. *Front. Plant Sci.* **2016**, *6*, 1143. [CrossRef] [PubMed]

63. Siripornadulsil, S.; Traina, S.; Verma, D.P.S.; Sayre, R.T. Of proline-mediated tolerance to toxic heavy metals in transgenic microalgae. *Plant Cell* **2002**, *14*, 2837–2847. [CrossRef] [PubMed]
64. Shah, V.; Daverey, A. Phytoremediation: A multidisciplinary approach to clean up heavy metal contaminated soil. *Environ. Technol. Innov.* **2020**, *18*, 100774. [CrossRef]
65. Winkel-Shirley, B. Biosynthesis of flavonoids and effects of stress. *Curr. Opin. Plant Biol.* **2002**, *5*, 218–223. [CrossRef]
66. Karalija, E.; Selović, A. The effect of hydro and proline seed priming on growth, proline and sugar content, and antioxidant activity of maize under cadmium stress. *Environ. Sci. Pollut. Res.* **2018**, *25*, 33370–33380. [CrossRef] [PubMed]
67. Ashraf, S.; Ali, Q.; Zahir, Z.A.; Ashraf, S.; Asghar, H.N. Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. *Ecotoxicol. Environ. Saf.* **2019**, *174*, 714–727. [CrossRef]
68. Mahar, A.; Wang, P.; Ali, A.; Awasthi, M.K.; Lahori, A.H.; Wang, Q.; Li, R.; Zhang, Z. Challenges and opportunities in the phytoremediation of heavy metals contaminated soils: A review. *Ecotoxicol. Environ. Saf.* **2016**, *126*, 111–121. [CrossRef]
69. Ramanjaneyulu, A.V.; Neelima, T.L.; Madhavi, A.; Ramprakash, T. Phytoremediation: An overview. In *Applied Botany*; Humberto, R.M., Ashok, G.R., Thakur, K., Sarkar, N.C., Eds.; American Academic Press: Cambridge, MA, USA, 2017; pp. 42–84.
70. Khalid, S.; Shahid, M.; Niazi, N.K.; Murtaza, B.; Bibi, I.; Dumat, C. A comparison of technologies for remediation of heavy metal contaminated soils. *J. Geochem. Explor.* **2017**, *182*, 247–268. [CrossRef]
71. Akhtar, M.S.; Chali, B.; Azam, T. Bioremediation of arsenic and lead by plants and microbes from contaminated soil. *Res. Plant Sci.* **2013**, *1*, 68–73.
72. De Mello-Farias, P.C.; Chaves, A.L.S.; Lencina, C.L. Transgenic plants for enhanced phytoremediation–physiological studies. In *Genetic Transformation*; Alvarez, M., Ed.; IntechOpen: London, UK, 2011; pp. 305–328.
73. Andrade Júnior, W.V.; de Oliveira Neto, C.F.; Santos Filho, B.G.D.; do Amarante, C.B.; Cruz, E.D.; Okumura, R.S.; Barbosa, A.V.C.; de Sousa, D.J.P.; Teixeira, J.S.S.; Botelho, A.D.S. Effect of cadmium on young plants of *Virola surinamensis*. *AoB Plants* **2019**, *11*, plz022. [CrossRef]
74. Zgorelec, Z.; Bilandzija, N.; Knez, K.; Galic, M.; Zuzul, S. Cadmium and Mercury phytostabilization from soil using *Miscanthus* x *giganteus*. *Sci. Rep.* **2020**, *10*, 1–10.
75. Boros-Lajszner, E.; Wyszkowska, J.; Kucharski, J. Application of whitemustard and oats in the phytostabilisation of soil contaminated with cadmium with the addition of cellulose and urea. *J. Soil Sediment.* **2020**, *20*, 931–942. [CrossRef]
76. Vangronsveld, J.; Herzig, R.; Weyens, N.; Boulet, J.; Adriaensen, J.; Ruttens, A.; Thewys, T.; Vassilev, A.; Meers, E.; Nehnevajova, E.; et al. Phytoremediation of contaminated soils and groundwater: Lessons from the field. *Environ. Sci. Pollut. Res.* **2009**, *16*, 765–794. [CrossRef]
77. Mukhopadhyay, S.; Maiti, S.K. Phytoremediation of metal enriched mine waste: A review. *Glob. J. Environ. Res.* **2010**, *4*, 135–150.
78. Kumar, V.; Shahi, S.K.; Singh, S. Bioremediation: An eco-sustainable approach for restoration of contaminated sites. In *Microbial Bioprospecting for Sustainable Development*; Singh, J., Sharma, D., Kumar, G., Sharma, N.R., Eds.; Springer: Singapore, 2018; pp. 115–136.
79. Kumar, P.S.; Gunasundari, E. Bioremediation of heavy metals. In *Bioremediation: Applications for Environmental Protection and Management*; Springer: Singapore, 2018; pp. 165–195.
80. Javed, M.T.; Tanwir, K.; Akram, M.S.; Shahid, M.; Niazi, N.K.; Lindberg, S. Phytoremediation of cadmium-polluted water/sediment by aquatic macrophytes: Role of plant-induced pH changes. In *Cadmium Toxicity and Tolerance in Plants*; Academic Press: Cambridge, MA, USA, 2019; pp. 495–529.
81. Abhilash, P.; Pandey, V.C.; Srivastava, P.; Rakesh, P.; Chandran, S.; Singh, N.; Thomas, A. Phytofiltration of cadmium from water by *Limnocharis flava* (L.) Buchenau grown in free-floating culture system. *J. Hazard. Mater.* **2009**, *170*, 791–797. [CrossRef] [PubMed]
82. Dürešová, Z.; Šúnovská, A.; Horník, M.; Pipíška, M.; Gubišová, M.; Gubiš, J.; Hostin, S. Rhizofiltration potential of *Arundo donax* for cadmium and zinc removal from contaminated wastewater. *Chem. Pap.* **2014**, *68*, 1452–1462. [CrossRef]
83. Pajević, S.; Borišev, M.; Nikolić, N.; Arsenov, D.D.; Orlović, S.; Župunski, M. Phytoextraction of heavy metals by fast-growing trees: A review. *Phytoremediation* **2016**, *11*, 29–64.
84. Jadia, C.D.; Fulekar, H.M. Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant. *Environ. Eng. Manag. J.* **2008**, *7*, 547–558.
85. Singh, V.; Bhargava, M. Phytomining: Principles and Applications. In *Biotechnology: Recent Trends and Emerging Dimensions*; Bhargava, A., Srivastava, S., Eds.; CRC Press: Boca Raton, FL, USA, 2017; pp. 141–159.
86. Van der Ent, A.; Baker, A.J.; Reeves, R.D.; Pollard, A.J.; Schat, H. Hyperaccumulators of metal and metalloid trace elements: Facts and fiction. *Plant Soil* **2013**, *362*, 319–334. [CrossRef]
87. Yu, G.; Liu, J.; Long, Y.; Chen, Z.; Sunahara, G.I.; Jiang, P.; You, S.; Lin, H.; Xiao, H. Phytoextraction of cadmium-contaminated soils: Comparison of plant species and low molecular weight organic acids. *Int. J. Phytoremediat.* **2019**, *22*, 383–391. [CrossRef] [PubMed]
88. Silva, J.; Fernandes, A.; Junior, M.S.; Santos, C.; Lobato, A. Tolerance mechanisms in *Cassia alata* exposed to cadmium toxicity–potential use for phytoremediation. *Photosynthetica* **2018**, *56*, 495–504. [CrossRef]
89. Ali, S.Y.; Banerjee, S.N.; Chaudhury, S. Phytoextraction of cadmium and lead by three vegetable-crop plants. *Plant Sci. Today* **2016**, *3*, 298–303. [CrossRef]

90. Liu, L.; Li, Y.; Tang, J.; Hu, L.; Chen, X. Plant coexistence can enhance phytoextraction of cadmium by tobacco (*Nicotiana tabacum* L.) in contaminated soil. *J. Environ. Sci.* **2011**, *23*, 453–460. [CrossRef]
91. Fan, K.C.; His, H.C.; Chen, C.W.; Lee, H.L.; Hseu, Z.Y. Cadmium accumulation and tolerance of mahogany (*Swietenia macrophylla*) seedlings for phytoextraction applications. *J. Environ. Manag.* **2011**, *92*, 2818–2822. [CrossRef] [PubMed]
92. Anderson, C.; Brooks, R.; Stewart, R.; Simcock, R.; Robinson, B. The phytoremediation and phytomining of heavy metals. In Proceedings of the Pacrim International Congress on Earth Science, Exploration and Mining Around Pacific Rim, Bali, Indonesia, 10–13 October 1999; pp. 127–135.
93. Ranieri, E.; Moustakas, K.; Barbafieri, M.; Ranieri, A.C.; Herrera-Melián, J.A.; Petrella, A.; Tommasi, F. Phytoextraction technologies for mercury-and chromium-contaminated soil: A review. *J. Chem. Technol. Biotechnol.* **2020**, *95*, 317–327. [CrossRef]
94. Ernst, W.H. Phytoextraction of mine wastes—Options and impossibilities. *Geochemistry* **2005**, *65*, 29–42. [CrossRef]
95. Phaenark, C.; Pokethitiyook, P.; Kruatrachue, M. Cd and Zn accumulation in plants from the Padaeng zinc mine area. *Int. J. Phytoremediat.* **2014**, *11*, 37–41. [CrossRef]
96. Zhang, X.; Zhang, S.; Xu, X.; Li, T.; Gong, G.; Jia, Y. Tolerance and accumulation characteristics of cadmium in *Amaranthus hybridus* L. *J. Hazard. Mater.* **2010**, *180*, 303–308. [CrossRef] [PubMed]
97. Hong-li, F.A.N.; Wei, Z. Screening of Amaranth Cultivars (*Amaranthus mangostanus* L.) for Cadmium Hyperaccumulation. *Agric. Sci. China* **2009**, *8*, 342–351.
98. Küpper, H.; Lombi, E.; Zhao, F.J.; McGrath, S.P. Cellular compartmentation of cadmium and zinc in relation to other elements in the hyperaccumulator *Arabidopsis halleri*. *Planta* **2000**, *212*, 75–84. [CrossRef]
99. Zhao, F.J.; Jiang, R.F.; Dunham, S.J.; McGrath, S.P. Cadmium uptake, translocation and tolerance in the hyperaccumulator *Arabidopsis halleri*. *New Phytol.* **2006**, *172*, 646–654. [CrossRef]
100. Kubota, H.; Takenaka, C. Field Note: *Arabis gemmifera* is a hyperaccumulator of Cd and Zn. *Int. J. Phytoremediat.* **2003**, *5*, 197–201. [CrossRef] [PubMed]
101. Qju, R.L.; Zhao, X.; Tang, Y.T.; Yu, F.M.; Hu, P. Antioxidative response to Cd in a newly discovered cadmium hyperaccumulator. *Chemosphere* **2008**, *74*, 6–12.
102. Nedjimi, B.; Daoud, Y. Cadmium accumulation in *Atriplex halimus* subsp. *schweinfurthii* and its influence on growth, proline, root hydraulic conductivity and nutrient uptake. *Flora: Morphol. Distrib. Funct. Ecol. Plants* **2009**, *204*, 316–324.
103. Rai, P.K. Phytoremediation of Hg and Cd from industrial effluents using an aquatic free floating macrophyte *Azolla pinnata*. *Int. J. Phytoremediat.* **2008**, *10*, 430–439. [CrossRef]
104. Li, Y.; Hu, X.; Song, X.; Hou, Y.; Sun, L. Phytoextraction Potential of *Solanum nigrum* L. and *Beta Vulgaris* L. Var. *cicla* L. in Cd-Contaminated Water. *Pol. J. Environ. Stud.* **2015**, *24*, 1683–1687.
105. Dai, H.; Wei, S.; Twardowska, I.; Han, R.; Xu, L. Hyperaccumulating potential of *Bidens pilosa* L. for Cd and elucidation of its translocation behavior based on cell membrane permeability. *Environ. Sci. Pollut. Res.* **2017**, *24*, 23161–23167. [CrossRef]
106. Ullah, S.; Mahmood, T.; Iqbal, Z.; Naeem, A.; Ali, R.; Mahmood, S. Phytoremediative potential of salt-tolerant grass species for cadmium and lead under contaminated nutrient solution. *Int. J. Phytoremediat.* **2019**, *21*, 1012–1018. [CrossRef]
107. Huang, J.; Yang, Z.; Li, J.; Liao, M.A.; Lin, L.; Wang, J.; Yang, Y.; Liang, D.; Xia, H.; Wang, X.; et al. Cadmium accumulation characteristics of floricultural plant *Cosmos bipinnata*. *Chem. Ecol.* **2017**, *33*, 807–816. [CrossRef]
108. Wei, T.; Lv, X.; Jia, H.; Hua, L.; Xu, H.; Zhou, R.; Zhao, J.; Ren, X.; Guo, J. Effects of salicylic acid, Fe (II) and plant growth-promoting bacteria on Cd accumulation and toxicity alleviation of Cd tolerant and sensitive tomato genotypes. *J. Environ. Manag.* **2018**, *214*, 164–171. [CrossRef]
109. Farooq, A.; Nadeem, M.; Abbas, G.; Shabbir, A.; Khalid, M.S.; Javeed, H.M.R.; Saeed, M.F.; Akram, A.; Younis, A.; Akhtar, G. Cadmium partitioning, physiological and oxidative stress responses in Marigold (*Calendula calypso*) grown on contaminated soil: Implications for phytoremediation. *Bull. Environ. Contam. Toxicol.* **2020**, *105*, 270–276. [CrossRef]
110. Simek, J.; Kovalikova, Z.; Dohnal, V.; Tuma, J. Accumulation of cadmium in potential hyperaccumulators *Chlorophytum comosum* and *Callisia fragrans* and role of organic acids under stress conditions. *Environ. Sci. Pollut. Res.* **2018**, *25*, 28129–28139. [CrossRef] [PubMed]
111. Angelova, V.R.; Perifanova-Nemska, M.N.; Uzunova, G.P.; Kolentsova, E.N. Accumulation of heavy metals in safflower (*Carthamus tinctorius* L.). *Int. J. Biol. Biomol. Agric. Food Biotechnol. Eng.* **2016**, *10*, 410–415.
112. Liu, J.N.; Zhou, Q.X.; Sun, T.; Ma, L.Q.; Wang, S. Identification and chemical enhancement of two ornamental plants for phytoremediation. *Bull. Environ. Contam. Toxicol.* **2008**, *80*, 260–265. [CrossRef] [PubMed]
113. Madejon, P.; Maranon, T.; Navarro-Fernandez, C.M.; Dominguez, M.T.; Alegre, J.M.; Robinson, B.; Murillo, J.M. Potential of *Eucalyptus camaldulensis* for phytostabilization and biomonitoring of trace-element contaminated soils. *PLoS ONE* **2017**, *12*, e0180240. [CrossRef] [PubMed]
114. Luo, J.; Qi, S.; Peng, L.; Wang, J. Phytoremediation efficiency of Cd by *Eucalyptus globulus* transplanted from polluted and unpolluted sites. *Int. J. Phytoremediat.* **2016**, *18*, 308–314. [CrossRef] [PubMed]
115. Guo, J.K.; Zhao, J.; Ren, X.H.; Jia, H.L.; Muhammad, H.; Lv, X.; Wei, T.; Hua, L. Effects of Burkholderia sp. D54 on growth and cadmium uptake of tomato, ryegrass and soybean plants. *Int. J. Environ. Sci. Technol.* **2020**, *17*, 1149–1158. [CrossRef]
116. Murakami, M.; Ae, N.; Ishikawa, S. Phytoextraction of cadmium by rice (*Oryza sativa* L.), soybean (*Glycine max* (L.) Merr.), and maize (*Zea mays* L.). *Environ. Pollut.* **2007**, *145*, 96–103. [CrossRef]

117. Alaboudi, K.A.; Ahmed, B.; Brodie, G. Phytoremediation of Pb and Cd contaminated soils by using sunflower (*Helianthus annuus*) plant. *Ann. Agric. Sci.* **2018**, *63*, 123–127. [CrossRef]
118. Chen, L.; Long, X.H.; Zhang, Z.H.; Zheng, X.T.; Rengel, Z.; Liu, Z.P. Cadmium accumulation and translocation in two Jerusalem artichoke (*Helianthus tuberosus* L.) cultivars. *Pedosphere* **2011**, *21*, 573–580. [CrossRef]
119. Pan, P.; Lei, M.; Qiao, P.; Zhou, G.; Wan, X.; Chen, T. Potential of indigenous plant species for phytoremediation of metal (loid)-contaminated soil in the Baoshan mining area, China. *Environ. Sci. Pollut. Res.* **2019**, *26*, 23583–23592. [CrossRef]
120. Liu, Z.; He, X.; Chen, W.; Yuan, F.; Yan, K.; Tao, D. Accumulation and tolerance characteristics of cadmium in a potential hyperaccumulator—*Lonicera japonica* Thunb. *J. Hazard. Mater.* **2009**, *169*, 170–175. [CrossRef]
121. He, L.Y.; Chen, Z.J.; Ren, G.D.; Zhang, Y.F.; Qian, M.; Sheng, X.F. Increased cadmium and lead uptake of a cadmium hyperaccumulator tomato by cadmium-resistant bacteria. *Ecotoxicol. Environ. Saf.* **2009**, *72*, 1343–1348. [CrossRef] [PubMed]
122. Lan, X.Y.; Yan, Y.Y.; Yang, B.; Li, X.Y.; Xu, F.L. Subcellular distribution of cadmium in a novel potential aquatic hyperaccumulator–*Microsorum pteropus*. *Environ. Pollut.* **2019**, *248*, 1020–1027. [CrossRef]
123. Nie, J.; Liu, Y.; Zeng, G.; Zheng, B.; Tan, X. Cadmium accumulation and tolerance of *Macleaya cordata*: A newly potential plant for sustainable phytoremediation in Cd-contaminated soil. *Environ. Sci. Pollut. Res.* **2016**, *23*, 10189–10199. [CrossRef] [PubMed]
124. Wu, M.; Luo, Q.; Liu, S.; Zhao, Y.; Long, Y.; Pan, Y. Screening ornamental plants to identify potential Cd hyperaccumulators for bioremediation. *Ecotoxicol. Environ. Saf.* **2018**, *162*, 35–41. [CrossRef] [PubMed]
125. Yang, Y.; Ge, Y.; Zeng, H.; Zhou, X.; Peng, L.; Zeng, Q. Phytoextraction of cadmium-contaminated soil and potential of regenerated tobacco biomass for recovery of cadmium. *Sci. Rep.* **2017**, *7*, 1–10. [CrossRef]
126. Liu, X.; Peng, K.; Wang, A.; Lian, C.; Shen, Z. Chemosphere Cadmium accumulation and distribution in populations of *Phytolacca americana* L. and the role of transpiration. *Chemosphere* **2010**, *78*, 1136–1141. [CrossRef] [PubMed]
127. Tang, Y.; Qiu, R.; Zeng, X.; Fang, X.; Yu, F.; Zhou, X.; Wu, Y. Zn and Cd hyperaccumulating characteristics of *Picris divaricata* Vant. *Int. J. Environ. Pollut.* **2009**, *38*, 26–38. [CrossRef]
128. Das, S.; Goswami, S.; Talukdar, A.D. A study on cadmium phytoremediation potential of water lettuce, *Pistia stratiotes* L. *Bull. Environ. Contam. Toxicol.* **2014**, *92*, 169–174. [CrossRef]
129. Akkus Ozen, S.; Yaman, M. Examination of correlation between histidine, sulphur, cadmium, and cobalt absorption by Morus L., *Robinia pseudoacacia* L., and *Populus nigra* L. *Commun. Soil Sci. Plant Anal.* **2017**, *48*, 1212–1220. [CrossRef]
130. Lu, G.; Wang, B.; Zhang, C.; Li, S.; Wen, J.; Lu, G.; Zhu, C.; Zhou, Y. Heavy metals contamination and accumulation in submerged macrophytes in an urban river in China. *Int. J. Phytoremediat.* **2018**, *20*, 839–846. [CrossRef]
131. Buendía-González, L.; Orozco-Villafuerte, J.; Cruz-Sosa, F.; Barrera-Díaz, C.E.; Vernon-Carter, E.J. *Prosopis laevigata* a potential chromium (VI) and cadmium (II) hyperaccumulator desert plant. *Bioresour. Technol.* **2010**, *101*, 5862–5867. [CrossRef]
132. Wan, X.; Lei, M.; Yang, J. Two potential multi-metal hyperaccumulators found in four mining sites in Hunan Province, China. *Catena* **2017**, *148*, 67–73. [CrossRef]
133. Zhong, L.; Lin, L.; Liao, M.A.; Wang, J.; Tang, Y.; Sun, G.; Liang, D.; Xia, H.; Wang, X.; Zhang, H.; et al. Phytoremediation potential of *Pterocypsela laciniata* as a cadmium hyperaccumulator. *Environ. Sci. Pollut. Res.* **2019**, *26*, 13311–13319. [CrossRef]
134. Wei, S.; Zhou, Q.X. Phytoremediation of cadmium-contaminated soils by *Rorippa globosa* using two-phase planting (5 pp). *Environ. Sci. Pollut. Res.* **2006**, *13*, 151–155. [CrossRef]
135. Huang, R.; Dong, M.; Mao, P.; Zhuang, P.; Paz-Ferreiro, J.; Li, Y.; Li, Y.; Hu, X.; Netherway, P.; Li, Z. Evaluation of phytoremediation potential of five Cd (hyper) accumulators in two Cd contaminated soils. *Sci. Total Environ.* **2020**, *721*, 137581. [CrossRef]
136. Yang, X.E.; Long, X.X.; Ye, H.B.; He, Z.L.; Calvert, D.V.; Stoffella, P.J. Cadmium tolerance and hyperaccumulation in a new Zn-hyperaccumulating plant species (*Sedum alfredii* Hance). *Plant Soil* **2004**, *259*, 181–189. [CrossRef]
137. Zhang, S.; Lin, H.; Deng, L.; Gong, G.; Jia, Y.; Xu, X.; Li, T.; Li, Y.; Chen, H. Cadmium tolerance and accumulation characteristics of *Siegesbeckia orientalis* L. *Ecol. Eng.* **2013**, *51*, 133–139. [CrossRef]
138. Miras-Moreno, B.; Almagro, L.; Pedreño, M.A.; Ferrer, M.Á. Accumulation and tolerance of cadmium in a non-metallicolous ecotype of *Silene vulgaris* Garcke (Moench). *Anales de Biología* **2014**, *36*, 55–60. [CrossRef]
139. Lu, R.R.; Hu, Z.H.; Zhang, Q.L.; Li, Y.Q.; Lin, M.; Wang, X.L.; Wu, X.N.; Yang, J.T.; Zhang, L.Q.; Jing, Y.X.; et al. The effect of *Funneliformis mosseae* on the plant growth, Cd translocation and accumulation in the new Cd-hyperaccumulator *Sphagneticola calendulacea*. *Ecotoxicol. Environ. Saf.* **2020**, *203*, 110988. [CrossRef]
140. Liu, Z.; Chen, W.; He, X. Evaluation of hyperaccumulation potentials to cadmium (Cd) in six ornamental species (Compositae). *Int. J. Phytoremediat.* **2018**, *20*, 1464–1469. [CrossRef] [PubMed]
141. Wang, Y.; Xu, Y.; Qin, X.; Liang, X.; Huang, Q.; Peng, Y. Effects of EDDS on the Cd uptake and growth of *Tagetes patula* L. and *Phytolacca americana* L. in Cd-contaminated alkaline soil in northern China. *Environ. Sci. Pollut. Res.* **2020**, *27*, 25248–25260. [CrossRef]
142. Cheng, H.; Liu, Q.; Ma, M.; Liu, Y.; Wang, W.; Ning, W. Cadmium tolerance, distribution, and accumulation in *Taraxacum ohwianum* Kitam. As a potential Cd-hyperaccumulator. *Int. J. Phytoremediat.* **2019**, *21*, 541–549. [CrossRef]
143. Li, X.; Zhang, X.; Yang, Y.; Li, B.; Wu, Y.; Sun, H.; Yang, Y. Cadmium accumulation characteristics in turnip landraces from China and assessment of their phytoremediation potential for contaminated soils. *Front. Plant Sci.* **2016**, *7*, 1862. [CrossRef] [PubMed]
144. Aibibu, N.; Liu, Y.; Zeng, G.; Wang, X.; Chen, B.; Song, H.; Xu, L. Cadmium accumulation in *Vetiveria zizanioides* and its effects on growth, physiological and biochemical characters. *Bioresour. Technol.* **2010**, *101*, 6297–6303. [CrossRef] [PubMed]

145. Lai, H.Y.; Chen, Z.S. Effects of EDTA on solubility of cadmium, zinc, and lead and their uptake by rainbow pink and vetiver grass. *Chemosphere* **2004**, *55*, 421–430. [CrossRef]
146. Turgut, C.; Pepe, M.K.; Cutright, T.J. The effect of EDTA and citric acid on phytoremediation of Cd, Cr, and Ni from soil using *Helianthus annuus*. *Environ. Pollut.* **2004**, *131*, 147–154. [CrossRef]
147. Rathika, R.; Srinivasan, P.; Alkahtani, J.; Al-Humaid, L.A.; Alwahibi, M.S.; Mythili, R.; Selvankumar, T. Influence of biochar and EDTA on enhanced phytoremediation of lead contaminated soil by *Brassica juncea*. *Chemosphere* **2021**, *271*, 129513. [CrossRef] [PubMed]
148. Li, F.L.; Qiu, Y.; Xu, X.; Yang, F.; Wang, Z.; Feng, J.; Wang, J. EDTA-enhanced phytoremediation of heavy metals from sludge soil by Italian ryegrass (*Lolium perenne* L.). *Ecotoxicol. Environ. Saf.* **2020**, *191*, 110185. [CrossRef]
149. Zhang, H.; Guo, Q.; Yang, J.; Ma, J.; Chen, G.; Chen, T.; Shao, C. Comparison of chelates for enhancing *Ricinus communis* L. phytoremediation of Cd and Pb contaminated soil. *Ecotoxicol. Environ. Saf.* **2016**, *133*, 57–62. [CrossRef]
150. Jin, Z.; Deng, S.; Wen, Y.; Jin, Y.; Pan, L.; Zhang, Y.; Zhang, D. Application of *Simplicillium chinense* for Cd and Pb biosorption and enhancing heavy metal phytoremediation of soils. *Sci. Total Environ. Environ.* **2019**, *697*, 134148. [CrossRef] [PubMed]
151. Beiyuan, J.; Awad, Y.M.; Beckers, F.; Tsang, D.C.; Ok, Y.S.; Rinklebe, J. Mobility and phytoavailability of As and Pb in a contaminated soil using pine sawdust biochar under systematic change of redox conditions. *Chemosphere* **2017**, *178*, 110–118. [CrossRef] [PubMed]
152. Agrawal, M.; Singh, A. Reduction in metal toxicity by applying different soil amendments in agricultural field and its consequent effects on characteristics of radish plants (*Raphanus sativus* L.). *J. Agric. Sci. Technol.* **2018**, *15*, 1553–1564.
153. Wu, L.H.; Luo, Y.M.; Xing, X.R.; Christie, P. EDTA-enhanced phytoremediation of heavy metal contaminated soil with Indian mustard and associated potential leaching risk. *Agric. Ecosyst. Environ.* **2004**, *102*, 307–318. [CrossRef]
154. Postigo, C.; Martinez, D.E.; Grondona, S.; Miglioranza, K.S.B. *Groundwater Pollution: Sources, Mechanisms, and Prevention*; Reference Module in Earth Systems and Environmental Sciences; Elsevier: New York, NY, USA, 2017; pp. 143–162.
155. Sinhal, V.K.; Srivastava, A.; Singh, V.P. EDTA and citric acid mediated phytoextraction of Zn, Cu, Pb and Cd through marigold (*Tagetes erecta*). *J. Environ. Biol.* **2010**, *31*, 255–259.
156. Lagier, T.; Feuillade, G.; Matejka, G. Interactions between copper and organic macromolecules: Determination of conditional complexation constants. *Agronomie* **2000**, *20*, 537–546. [CrossRef]
157. Ashraf, S. Phytoextraction of Lead and Cadmium by Grasses from Contaminated Soil Amended with Acidulated Cow Dung Slurry/Extract and Bioaugmented with Sulphur Oxidizing Bacteria. Ph.D. Thesis, University of Agriculture Faisalabad, Faisalabad, Pakistan, 2017.
158. Khonsue, N.; Kittisuwan, K.; Kumsopa, A.; Tawinteung, N.; Prapagdee, B. Inoculation of soil with cadmium-resistant bacteria enhances cadmium phytoextraction by *Vetiveria nemoralis* and *Ocimum gratissimum*. *Water Air Soil Pollut.* **2013**, *224*, 1696. [CrossRef]
159. Bolan, N.; Kunhikrishnan, A.; Thangarajan, R.; Kumpiene, J.; Park, J.; Makino, T.; Kirkham, M.B.; Scheckel, K. Remediation of heavy metal(loid)s contaminated soils—To mobilize or to immobilize? *J. Hazard. Mater.* **2014**, *266*, 141–166. [CrossRef]
160. Jing, Y.X.; Yan, J.L.; He, H.D.; Yang, D.J.; Xiao, L.; Zhong, T.; Yuan, M.; Cai, X.D.; Li, S.B. Characterization of bacteria in the rhizosphere soils of *Polygonum pubescens* and their potential in promoting growth and Cd, Pb, Zn uptake by *Brassica napus*. *Int. J. Phytoremediat.* **2014**, *16*, 321–333. [CrossRef]
161. Ma, Y.; Rajkumar, M.; Zhang, C.; Freitas, H. Beneficial role of bacterial endophytes in heavy metal phytoremediation. *J. Environ. Manag.* **2016**, *174*, 14–25. [CrossRef]
162. Prapagdee, B.; Chanprasert, M.; Mongkolsuk, S. Bioaugmentation with cadmium-resistant plant growth-promoting rhizobacteria to assist cadmium phytoextraction by *Helianthus annuus*. *Chemosphere* **2013**, *92*, 659–666. [CrossRef] [PubMed]
163. Li, Y.; Liu, K.; Wang, Y.; Zhou, Z.; Chen, C.; Ye, P.; Yu, F. Improvement of cadmium phytoremediation by *Centella asiatica* L. after soil inoculation with cadmium-resistant *Enterobacter* sp. FM-1. *Chemosphere* **2018**, *202*, 280–288. [CrossRef]
164. Sangthong, C.; Setkit, K.; Prapagdee, B. Improvement of cadmium phytoremediation after soil inoculation with a cadmium-resistant *Micrococcus* sp. *Environ. Sci. Pollut. Res.* **2016**, *23*, 756–764. [CrossRef] [PubMed]
165. Mahbub, K.R.; Krishnan, K.; Megharaj, M.; Naidu, R. Bioremediation potential of a highly mercury resistant bacterial strain *Sphingobium* SA2 isolated from contaminated soil. *Chemosphere* **2016**, *144*, 330–337. [CrossRef]
166. Chirakkara, R.A.; Reddy, K.R. Biomass and chemical amendments for enhanced phytoremediation of mixed contaminated soils. *Ecol. Eng.* **2015**, *85*, 265–274. [CrossRef]
167. Antoniou, C.; Rafaella, X.; Giannis, C.; Anastasis, C.; Khosrow, K.; Vasileios, F. Exploring the potential of nitric oxide and hydrogen sulfide (NOSH)-releasing synthetic compounds as novel priming agents against drought stress in *Medicago sativa* plants. *Biomolecules* **2020**, *10*, 120. [CrossRef]
168. Heydari, M.; Zanfardino, A.; Taleei, A.; Shahnejat Bushehri, A.A.; Hadian, J.; Maresca, V.; Sorbo, S.; Di Napoli, M.; Varcamonti, M.; Basile, A.; et al. Effect of heat stress on yield, monoterpene content and antibacterial activity of essential oils of *Mentha* x *piperita* var. *mitcham* and *Mentha arvensis* var. *piperascens*. *Molecules* **2018**, *23*, 1903. [CrossRef]
169. Sharma, A.; Sidhu, G.P.S.; Araniti, F.; Bali, A.S.; Shahzad, B.; Tripathi, D.K.; Brestic, M.; Skalicky, M.; Landi, M. The role of salicylic acid in plants exposed to heavy metals. *Molecules* **2020**, *25*, 540. [CrossRef] [PubMed]

170. Choudhary, S.; Zehra, A.; Mukarram, M.; Wani, K.I.; Naeem, M.; Khan, M.M.A.; Aftab, T. Salicylic acid-mediated alleviation of soil boron toxicity in *Mentha arvensis* and *Cymbopogon flexuosus*: Growth, antioxidant responses, essential oil contents and components. *Chemosphere* **2021**, *276*, 130153. [CrossRef]
171. Hediji, H.; Kharbech, O.; Massoud, M.B.; Boukari, N.; Debez, A.; Chaibi, W.; Chaoui, A.; Djebali, W. Salicylic acid mitigates cadmium toxicity in bean (*Phaseolus vulgaris* L.) seedlings by modulating cellular redox status. *Environ. Exp. Bot.* **2021**, *186*, 104432.
172. Khan, N.; Bano, A. Effects of exogenously applied salicylic acid and putrescine alone and in combination with rhizobacteria on the phytoremediation of heavy metals and chickpea growth in sandy soil. *Int. J. Phytoremediat.* **2018**, *20*, 405–414. [CrossRef] [PubMed]
173. Marín Velázquez, J.A.; Andreu Puyal, P.; Carrasco, A.; Arbeloa Matute, A. *Determination of Proline Concentration, an Abiotic Stress Marker, in Root Exudates of Excised Root Cultures of Fruit Tree Rootstocks under Salt Stress*; Actes du 3ème Meeting International: Jerba, Tunisie, 2010.
174. Mladenov, V.; Fotopoulos, V.; Kaiserli, E.; Karalija, E.; Maury, S.; Baranek, M.; Segal, N.; Testillano, P.S.; Vassileva, V.; Pinto, G.; et al. Deciphering the epigenetic alphabet involved in transgenerational stress memory in crops. *Int. J. Mol. Sci.* **2021**, *22*, 7118. [CrossRef]
175. Fulekar, M.H.; Singh, A.; Bhaduri, A.M. Genetic engineering strategies for enhancing phytoremediation of heavy metals. *Afr. J. Biotechnol.* **2008**, *8*, 529–535.
176. Koźmińska, A.; Wiszniewska, A.; Hanus-Fajerska, E.; Muszyńska, E. Recent strategies of increasing metal tolerance and phytoremediation potential using genetic transformation of plants. *Plant Biotechnol. Rep.* **2018**, *12*, 1–14. [CrossRef]
177. Gu, C.S.; Liu, L.Q.; Zhao, Y.H.; Deng, Y.M.; Zhu, X.D.; Huang, S.Z. Overexpression of *Iris lactea* var. *chinensis* metallothionein llMT2a enhances cadmium tolerance in *Arabidopsis thaliana*. *Ecotoxicol. Environ. Saf.* **2014**, *105*, 22–28.
178. Chen, Y.; Liu, Y.; Ding, Y.; Wang, X.; Xu, J. Overexpression of PtPCS enhances cadmium tolerance and cadmium accumulation in tobacco. *Plant Cell Tissue Organ Cult.* **2015**, *121*, 389–396. [CrossRef]
179. Banerjee, A.; Roychoudhury, A. Metallothionein-assisted phytoremediation of inorganic pollutants. In *Handbook of Bioremediation*; Academic Press: Cambridge, MA, USA, 2021; pp. 81–90.
180. Saurabh, S.; Vidyarthi, A.S.; Prasad, D. RNA interference: Concept to reality in crop improvement. *Planta* **2014**, *239*, 543–564. [CrossRef]
181. Takahashi, R.; Ishimaru, Y.; Shimo, H.; Bashir, K.; Senoura, T.; Sugimoto, K.; Ono, K.; Suzui, N.; Kawachi, N.; Ishii, S.; et al. From laboratory to field: *OsNRAMP5*-knockdown rice is a promising candidate for Cd phytoremediation in paddy fields. *PLoS ONE* **2014**, *9*, e98816. [CrossRef]
182. Liu, J.; Zhou, Q.; Wang, S. Evaluation of chemical enhancement on phytoremediation effect of Cd-contaminated soils with *Calendula officinalis* L. *Int. J. Phytoremediat.* **2010**, *12*, 503–515. [CrossRef]
183. Wang, K.; Liu, Y.; Song, Z.; Wang, D.; Qiu, W. Chelator complexes enhanced *Amaranthus hypochondriacus* L. phytoremediation efficiency in Cd-contaminated soils. *Chemosphere* **2019**, *237*, 124480. [CrossRef]
184. Gul, I.; Manzoor, M.; Kallerhoff, J.; Arshad, M. Enhanced phytoremediation of lead by soil applied organic and inorganic amendments: Pb phytoavailability, accumulation and metal recovery. *Chemosphere* **2020**, *258*, 127405. [CrossRef] [PubMed]
185. Wang, Y.; Chen, D.; Jiang, Z.; Nie, W.; Zhang, J. Phytoremediation of the soil contaminated by Pb, Cd and secondary salinization with the enhancement of EDTA. *J. Agro-Environ. Sci.* **2018**, *37*, 1866–1874.
186. Jiang, M.; Liu, S.; Li, Y.; Li, X.; Luo, Z.; Song, H.; Chen, Q. EDTA-facilitated toxic tolerance, absorption and translocation and phytoremediation of lead by dwarf bamboos. *Ecotoxicol. Environ. Saf.* **2019**, *170*, 502–512. [CrossRef] [PubMed]
187. Shirkhani, Z.; Rad, A.C.; Gholami, M.; Mohsenzadeh, F. Phytoremediation of Cd-contaminated Soils by *Datura stramonium* L. *J. Toxicol. Environ.* **2018**, *10*, 168–178. [CrossRef]
188. Aboughalma, H.; Bi, R.; Schlaak, M. Electrokinetic enhancement on phytoremediation in Zn, Pb, Cu and Cd contaminated soil using potato plants. *J. Environ. Sci. Health A* **2008**, *43*, 926–933. [CrossRef]
189. Luo, J.; Cai, L.; Qi, S.; Wu, J.; Gu, X.S. The interactive effects between chelator and electric fields on the leaching risk of metals and the phytoremediation efficiency of *Eucalyptus globulus*. *J. Clean. Prod.* **2018**, *202*, 830–837. [CrossRef]
190. Cameselle, C.; Gouveia, S.; Urréjola, S. Benefits of phytoremediation amended with DC electric field. Application to soils contaminated with heavy metals. *Chemosphere* **2019**, *229*, 481–488. [CrossRef]
191. Rojjanateeranaj, P.; Sangthong, C.; Prapagdee, B. Enhanced cadmium phytoremediation of *Glycine max* L. through bioaugmentation of cadmium-resistant bacteria assisted by biostimulation. *Chemosphere* **2017**, *185*, 764–771. [CrossRef]
192. Almeida, C.M.R.; Oliveira, T.; Reis, I.; Gomes, C.R.; Mucha, A.P. Bacterial community dynamic associated with autochthonous bioaugmentation for enhanced Cu phytoremediation of salt-marsh sediments. *Mar. Environ. Res.* **2017**, *132*, 68–78. [CrossRef]
193. Zanganeh, F.; Heidari, A.; Sepehr, A.; Rohani, A. Bioaugmentation and bioaugmentation–assisted phytoremediation of heavy metals contaminated soil by a synergistic effect of cyanobacteria inoculation, biochar, and purslane (*Purtolaca Oleracea* L.). *Environ. Sci. Pollut. Res.* **2021**, *in press*. [CrossRef]
194. Al-Baldawi, I.A.; Abdullah, S.S.; Anuar, N.; Mushrifah, I. Bioaugmentation for the enhancement of hydrocarbon phytoremediation by rhizobacteria consortium in pilot horizontal subsurface flow constructed wetlands. *Int. J. Environ. Sci. Technol.* **2017**, *14*, 75–84. [CrossRef]
195. Purwanti, I.F.; Obenu, A.; Tangahu, B.V.; Kurniawan, S.B.; Imron, M.F.; Abdullah, S.R.S. Bioaugmentation of *Vibrio alginolyticus* in phytoremediation of aluminium-contaminated soil using *Scirpus grossus* and *Thypa angustifolia*. *Heliyon* **2020**, *6*, e05004. [CrossRef]

196. Li, Y.; Lin, J.; Huang, Y.; Yao, Y.; Wang, X.; Liu, C.; Liang, Y.; Liu, K.; Yu, F. Bioaugmentation-assisted phytoremediation of manganese and cadmium co-contaminated soil by Polygonaceae plants (*Polygonum hydropiper* L. and *Polygonum lapathifolium* L.) and *Enterobacter* sp. FM-1. *Plant Soil* **2020**, *448*, 439–453. [CrossRef]
197. Boechat, C.L.; Carlos, F.S.; Nascimento, C.W.A.D.; Quadros, P.D.D.; Sá, E.L.S.D.; Camargo, F.A.D.O. Bioaugmentation-assisted phytoremediation of As, Cd, and Pb using Sorghum bicolor in a contaminated soil of an abandoned gold ore processing plant. *Rev. Bras. Cienc. Solo* **2020**, *44*, e0200081. [CrossRef]
198. Li, H.; Li, X.; Xiang, L.; Zhao, H.M.; Li, Y.W.; Cai, Q.Y.; Zhu, L.; Mo, C.H.; Wong, M.H. Phytoremediation of soil co-contaminated with Cd and BDE-209 using hyperaccumulator enhanced by AM fungi and surfactant. *Sci. Total Environ.* **2018**, *613*, 447–455. [CrossRef]
199. Chen, L.; Long, C.; Wang, D.; Yang, J. Phytoremediation of cadmium (Cd) and uranium (U) contaminated soils by *Brassica juncea* L. enhanced with exogenous application of plant growth regulators. *Chemosphere* **2020**, *242*, 125112. [CrossRef] [PubMed]
200. Somtrakoon, K.; Chouychai, W. Gibberellic acid treatment improved pyrene phytoremediation efficiency of ridge gourd (*Luffa acutangula* (L.) Roxb.) in soil. *Soil Sediment Contam. Int. J.* **2021**. *online ahead of print*. [CrossRef]
201. Jan, A.U.; Hadi, F.; Shah, A.; Ditta, A.; Nawaz, M.A.; Tariq, M. Plant growth regulators and EDTA improve phytoremediation potential and antioxidant response of *Dysphania ambrosioides* (L.) Mosyakin & Clemants in a Cd-spiked soil. *Environ. Sci. Pollut. Res.* **2021**, *28*, 43417–43430.
202. Gu, X.; Zhang, Q.; Jia, Y.; Cao, M.; Zhang, W.; Luo, J. Enhancement of the Cd phytoremediation efficiency of *Festuca arundinacea* by sonic seed treatment. *Chemosphere* **2021**, *287*, 132158. [CrossRef] [PubMed]
203. Sardar, R.; Ahmed, S.; Yasin, N.A. Role of exogenously applied putrescine in amelioration of cadmium stress in *Coriandrum sativum* by modulating antioxidant system. *Int. J. Phytoremediat.* **2021**. *online ahead of print*. [CrossRef]
204. Wei, H.; Huang, M.; Quan, G.; Zhang, J.; Liu, Z.; Ma, R. Turn bane into a boon: Application of invasive plant species to remedy soil cadmium contamination. *Chemosphere* **2018**, *210*, 1013–1020. [CrossRef] [PubMed]