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The technology of using plants to clean up soil

Review article analyzes the recent literature on the phytoremediation of soils contaminated with heavy metals. Provides information about the plants hyperaccumulators of heavy metals for phytoremediation, opportunities of using energy crops and chelating agents in phytoremediation, as well as the advantages and disadvantages of phytoremediation technology.
Keywords: phytoremediation, phytoextraction, hyperaccumulation, heavy metals.

Introduction

Significant areas of soil and water, particularly in the vicinity of large cities and large industrial complexes in Kazakhstan, are contaminated by heavy metals (HM). In particular, the soils of the East Kazakhstan region are mostly contaminated by Zn, Cd, Pb, Cu as a result of prolonged activity of metallurgical factories [1, 2]. To reduce global pollution of anthropogenic pollutants around the world phytoremediation technologies has been successfully used. Phytoremediation is defined as the technology of using plants to clean up contaminated soil, as a cost-effective and safe compared to other physical and chemical methods of treatment [3]. The undisputed leader in the study of plant-hyperaccumulators is The United States Department of Agriculture (USDA). Here, in the laboratory of Prof. R.Chaney, they are conducting research on the study of plants, which are able to accumulate heavy metals in great amounts and improvement of their properties through traditional breeding techniques and genetic engineering. Phytoremediation issues are also studied by scientists in the UK Agriculture and Environment Division IACR-Rothamsted (Prof. S. McGrath, E.Lombi, etc.), Austrian Institute of Soil Science (Prof. W.Wenzel).

Phytoremediation technologies

In compare with the physical and chemical methods phytoremediation is less expensive, more efficient and secure. Phytoremediation technology has a variety of directions. Phytoremediation technology includes phytoextraction, phytovolitalization, rizofiltration and phytostabilization [4, 5].

Phytoextraction – is the technology of soil cleaning, the use of plants that accumulate metals primarily in the aerial parts, and further cleaning of above-ground parts of incineration and recovery of metals from the ashes of plants. The advantage of this method is the ability to extract from the soil a large number of above-ground plant organs-hyperaccumulators of heavy metals. The disadvantage is that plant hyperaccumulators suitable for this kind of phytoremediation usually have small dimensions, low biomass that could affect the efficiency of the method. Therefore, at present researchers are working on the application of traditional methods of plant breeding and bioengineering to create new forms of plants that have a high capacity for metal accumulation and greater biomass.

Phytovolitalization can be used for Hg and Se, and possibly for arsenic (As) [6, 7]. Modified Hg-reductase gene (mercury-reductase) was transferred from bacteria to the plant *Arabidopsis thaliana* L.

The studies toward obtaining transgenic plants using the expression of bacteria genes in higher plants, are able to hydrolyze methyl-Hg and dimethyl-Hg. Organic mercury compounds are the main source of danger, as the lipophylic components accumulate in the body of animals and birds of prey [8]. The disadvantage of this method is the possible contamination of the atmosphere with volatile toxic compounds. Therefore, this method can be applied to areas which are far away from crops and settlements.

Phytostabilization is possible for two elements – lead (Pb) and chromium (Cr). Efficient for this kind of phytoremediation are plant species with long and strong root system. The roots of *Agrostis capillaris* L. (agrostis hairlike) growing in highly contaminated Pb/Zn soil form pyromorphytes of P and Pb, but the mechanism of their formation is not yet known [9].

Although it is believed that the *T. rotundifolium* L. is an accumulator of Pb, *Zea mays* (maize) can accumulate much more lead at low pH and low phosphorus concentrations [10]. Addition of chelating agents (NEDTA, EDTA) increases the solubility and mobility of Pb within the plant, the content of Pb in the aboveground organs can be up to 1%, which allows you to extract a sufficient amount of Pb. Raskin et al. identified methods of using plants for "rhizofiltration" of Pb in contaminated soils [10].

Plants that accumulate Pb in roots, could keep it from leaching down the soil profile. Therefore, inactivation of soil Pb using soil additives (hydroxide Fe, oxides of Mn, phosphates, limestone) and plants to prevent erosion is one of the ways of phytoremediation for Pb-contaminated soil [11, 12].

The disadvantage of this method is that the metals are not recovered fully from the soil surface, and remain bound in the roots of plants. This method is not suitable for soils that can be used later on to grow crops.

Rhizofiltration method can be applied to chromium. Soils containing Cr 10 000 mg /kg as Cr^{3+}, are not a, potential hazard, while the soil in the form of chromium-containingCr^{6+}, is toxic to plants and other organisms.

The roots of the plants could play an important role in the restoration of Cr^{6+} to Cr^{3+} in the soil, allowing the toxic form to immobilize in an inert form, which does not represent a potential risk [13]. The disadvantage of this method is the need for periodic cleaning of contaminated plant parts and recycling it.

Plants-hyperaccumulators of heavy metals

The term "hyperaccumulator" refers to plant species that accumulate 10-100 times more metal than conventional plants. These plants can be used to extract toxins from the soil and thus may contribute to the restoration of contaminated land fertility. Accumulation of metals by plants in the non-toxic form is one of the strategies used by plants to survive under the severe environmental polluted conditions [3]. For phytoextraction is the most beneficial the use of plant-hyperaccumulators. Hyperaccumulators are of considerable interest from the standpoint of phytoremediation [10] phytomining [14] and biofortification (improvement), of crops [15, 16].

Hyperaccumulators are endemic to the soils that are contaminated with heavy metals and do not compete with other species for uncontaminated soils. To date, well-known plant hyperaccumulators of heavy metals: *Ambrosia artemisiifolia* L. (ragweed), *Thlaspi rotundufolium*L., *Thlaspi* L. *caerulescens* (*Thlaspi)* absorbing a significant amount of Zn, Cd, Pb. *Alyssum* L. belong *Arabidopsis* L. belong to Ni-hyperaccumulators. The latter is considered a suitable object for study because it has a short life cycle and a small number of chromosomes.

Usually plants-hyperaccumulators of HM are mostly scrubby weeds with a low yield. At present there are improved by genetic bioengineering methods, for example *Alpine penycress* L. has a high yield, which can absorb about 500 kg/ha of zinc and 6-8 kg of cadmium per year. Used as phitomeliorants of soils contaminated by Cd and Zn, *T. caerulescens*can accumulate in its organs Zn and Cd 2.5%and 0.2% of dry weight (DW), respectively. With the help of these plants can be extracted 125 kg and 10 kg Zn Cd per hectare (Figure 1). The cost of the metals extracted from plants from 1 hectare will be on the market $ 200 at market price per kilogram for zinc – $ 1.33, cadmium – $ 4.6 [3].

Researchers have identified some of the most characteristic features of hyperaccumulators:

1) Plants should be resistant to high concentrations of the element in the roots and aerial parts. Hypertolerance is a key feature that makes it possible a hyperaccumulation. Hypertolerance is a result of vacuolar compartmentation and chelation [16]. This was demonstrated in vacuoles of isolated protoplasts of tobacco cells which have accumulated high levels of Cd and Zn. Electron microscopic analysis of the leaves of *Thlaspi caerulescens* [16] also showed a vacuolar compartmentation of Zn.

2) The plants will be able to translocate elements from roots to above the ground organs. In the normalplants content of Zn, Cd or Ni in roots of 10 or more times higher than in the aerial parts. The ratio of the metalcontent in the aerial parts to its content in the roots (shoot/root ratio) should be greater than one, indicating a potential ability of hyperaccumulators to redistribute of HM in the aerial parts [15].

R.Kramer et al. found that the ions of Ni, detected in leaf extracts in *Alyssum bertolonii* L., chelated with citrate and malate, and in xylem exudate histidine chelates 40% of Ni. Addition of histidine to the culture medium increased the resistance of Ni and transport it to the aerial organs from in hyperaccumulator *A. montanum* L.

3) Plants should reabsorb large amounts of metals. In *T. caerulescens* content of Zn is 1-4% of DW, while in other plants – less than 0.05% of DW. Studies have shown that Zn-hypertolerant genotypes of *T. caerulescens* require much more Zn (104 times) in the nutrient solution for the normal growth than non-accumulators. Highly efficient compartmentation of metals to reduce the toxicity of Cd and Zn requires the plant to accumulate large quantities of metals for an adequate supply.

At present, it is generally accepted definition R.Brooks (1998) [17], according to which hyperaccumulators of heavy metals are those plants that accumulate in the aerial parts zinc (Zn)> 10,000, lead (Pb) > 1000, cadmium (Cd) > 100 ppm. Non-hyperaccumulators can accumulate in the uncontaminated soil Zn, Pb and Cd <100, <10 and <1 ppm, respectively, in contaminated soil – Zn <1000, Pb<100, and Cd <10 ppm, respectively.

V.Bert found that there is a saturation threshold of the metal concentration (Zn), above which it not rise, and the curve has a plateau. It has also been found for Cd [18]. The authors explain this fact by blocking the flow of metal from the roots to the aerial organs. In this case, the protection mechanism is triggered, which limits the metal uptake by plants at high concentrations in the medium [18].

The authors draw the attention of researchers at some important moments in the study of plant-hyperaccumulators. McGrath (1998) found that when comparing hyperaccumulation ability of plants of various species should be to take into account not only the concentration of metal in plant tissues, as well as the amount of metal extracted by this plant from a certain area [19]. The absolute value of the metal content in plants, based on a certain area will give a more precise picture for evaluation hyperaccumulation activity of plants in a comparative analysis.

Another important point is the attitude of the metal content in the aerial parts of the plants to the content in the soil. Typically, for plants – hyperaccumulatorsthis value is a great (40 or more) [19]. The most precise definition of the hyperaccumulationstatus can be established, according to the authors, only in hydroponic environment where can be shown the ability of plants to survive at high concentrations of metals [20].

The question “What is more important for the effective phytoremediation: metal accumulation or accumulation of green biomass?” is the subject of debate. It will be cultivated in high-yielding species such as *Zea mays* L. and *Brassica juncea* L. on Zn contaminated soils with a low pH the yield is reduced by 50%. Under normal conditions, the harvest will be 20 tons of dry biomass per hectare. On soils polluted (Zn + Cd) (100 mg Zn:1 mg Cd) plants suffer greatly and reduced yields, when the content of Zn in the aerial parts as high as 500 mg/kg. The toxicity of the soil Zn is the determining factor controlling productivity. By reducing the yield by 50% (10 tons/ha), the biomass will comprise 500 mg/kg of Zn (Zn 500 g per tonne). In this case it will be extracted only 5 kg Zn per hectare per year. *T. caerulescens* initially has low productivity compared to the above mentioned types, but can accumulate up to 25 000 mg Zn per kg (25 kg/t) without reducing yield. Even with a low yield of 5 tons per hectare will be recovery of zinc of 125 kg/ha. Therefore, Chaney et al. believes that the ability to hyperaccumulate of metals and hypertolerant to high concentrations of metal are the most important properties of plants [21].

For 1,000 hectares of Zn- and Cd-contaminated soil the strategy that combines the use of biomass energy used for phytoremediation and the extraction of metals could bring the gross annual income up to $ 400,000 from the sale of electricity production and extraction of metals at market price. Production of electricity and recovery of metals from Ni-contaminated areas exceeds that value. This compares to income from growing wheat on 1,000 hectares of the territory to the United States. According to the literature value of conservative methods (chemical and physical methods) of soil cleaning up to $ 350 per acre, and the cost of cleaning of soils by plants is about $ 160/ha [3]. According to estimates in the literature, the cost of simply removing 50 cm of contaminated soils and disposal by conventional methods is equal to $ 960 000/ha. This does not include the cost of transportation, sorting, revegetation excavated layer. In contrast, treatment of the same soil by biological methods will cost from $ 144,000 to $ 240,000 per hectare (Mining Environmental management, 1995). According to other estimates, the remediation technology as digging or washing the soil is 30 to $ 300 per m^3. Accordingly, the cost of phytoremediation – less than $0.05 per m^3 [22]. Cost of the treatment with plants may be only 5% of the costs necessary for the other physical and chemical methods of ecosystem restoration of polluted soils [23].

For the effective development of phytoremediation, each item must be considered separately. Requires the agronomy approach including physical and chemical properties of the metal, soil and plant genetic properties [3].

"Induced" phytoremediation

The absorption of metals by plants may be limited by the low solubility of metals in the soil. For toxic metals such as Pb in the main limiting factor is the limited solubility of the soil. One of the ways to induce solubility –the lowering the pH. But a strong acidification of soils mobilizes Pb below the root zone. One of the ways of improving of phytoextraction is the use of synthetic chelating agents. These components are associated with the lead and remain soluble metal chelate complexes available for plants and transport within them. Blaylock et al. (1997) noted that the use of chelating agents is also possible for extraction of other metals. EDTA stimulated Cd-, Ni-, Cu-and Zn-phytoextraction by different species. The ability to chelate facilitates a phytoextraction due to their high affinity to metals. Addition of EDTA, HEDTA, EDDS stimulated accumulation of above-ground plant organs [24, 25, 26].

Adding EDTA (ethylene diamintetratsetate) in an amount of 10 mmol/kg of soil stimulated accumulation in plant parts overhead to 1.6% DW. In other studies with Indian mustard, subjected to the effect of lead and EDTA in hydroponic environments, plants accumulated up to 1% of the dry biomass. Synthetic chelators as HEDTA (hydroxymethyl ethylene diamin triacetate) applied at a concentration of 2.0 g/kg soil with Pb concentration 2.5 g/kg in the soil increased accumulation by Indian mustard from 40 to 10 600 g/kg. The accumulation of large amounts of Pb is toxic and can cause a death of plants. Therefore, the authors recommend the use of chelating agents after maximal accumulation of plant biomass. It is necessary immediately remove plants at the optimum time (after 1 week of treatment) for maximum phytoextraction to minimize the loss of biomass from the toxic effect of metal [27].

EGTA (ethylenebis (oxyethylentrinitrilo) tetraacetate) has high affinity for Cd, but does not bind Zn. EDTA, HEDTA, DTPA (diethylenetriamine pentaacetate) is selective for Zn. Binding of Zn DTPA so much that the plant cannot use Zn for its life and caused a zinc deficiency. Application EDTA increased an extraction of Cd up to 1140 mg/kg, and the use of ammonium sulfate does not affect to the phytoextraction [28]. Application NTA (nitrilotriacetate) and elementary sulfur S increases mobility of Zn, Cd, Cu and accumulation in soil metals in aerial plant organs in 2-3 times Addition of chelating agents (0.5 and 2 g/kg of EDTA, 0.5 g/kg of DTPA (diethylentriaminopentaacetate) and 0.5 g/kg of NTA (nitrilotriacetate) for poplar caused an increase in the absorption of Cd. Authors point out that it is necessary to select the optimum chelating agent concentration and the optimal time of removing of plant [29].

Another approach – the use of humic acids (HA).HA – high-dark-colored substances whose structure is not fully established. The structure of HA is defined by the presence light condensated and substituted aromatic rings linked within by non-aromatic sections. The molecules containcarboxylic and carbonylic groups, alcoholic and phenolic hydroxyls and sometimes methoxyl groups [30].

It was found that cadmium ions mainly associated with low molecular weight HA (<1000 D) fractions, whereas the lead ions bind to the high molecular weight fraction (up to10000 D), and these complexes have a high stability constant. The low molecular weight substances are more easily transported across cell membranes than high-molecular substances that can cause greater bioavailability of cadmium in the presence of humic acids [31].

Thus, to improve the phytoextraction processs could be optimized an agronomic practices used in phytoremediation technology. The use of fertilizers is necessary for the greatest accumulation of plant biomass, respectively, to increase the amount of extractable metals.

The use of energy crops for phytoremediation of contaminated soils

Using the "energy" crops («energy crops») as phytoremediants will reduce the level of pollution on the one hand and on the other hand increases the productive value of contaminated soils. The best candidates are the sunflower plants (*Helianthus annus* L.), castor bean (*Ricinus communis* L.), white mustard (*Sinapis alba* L.). High productivity oil plant species have a high potential for extracting large quantities of trace metals by aboveground biomass, if a sufficient concentration in their tissues will be achieved. The results showed that. *H. annuus* is the best candidate for use as a hyperaccumulator has the potential to be used for remediation of contaminated soils [32]. Adding EDTA or citric acid increased the concentration of heavy metals in plant tissues. The concentration in the tissues increased and increased the removal of heavy metals by plant biomass [33]. Sunflower can also be used for phytoextraction of arsenic. Arsenic oxidation status may be different. Pentavalent arsenate (AsO^{4-})is a most stable and dominated in well-aerated soils, so the arsenic contamination of soil is a big problem. Arsenates and phosphate (PO^{4-}) are chemically similar and thus competing for space in the soil. Therefore, the addition of phosphate may increase the content of arsenate in the soil solution by substituting arsenate on specific anion-exchange sites. This increases the bioavailability of arsenic by plant roots. Phosphate fertilizers directly increase the accumulation of As in plants by stimulation of phosphate-absorbing mechanism. Studies have shown that sunflower (*Helianthus annuus* L.) may be a candidate for phytoextraction adding phosphorus arsenic as a mobilizing agent [34]. Among the species *Brassica juncea*L., *Brassica nigra* L., *Raphanus sativus* L., *Helianthus annuus* L. and *Ipomea triloba* L. found that sunflower accumulated lead in great greater extent [35].

Another type of oil plants, from which castor oil is extracted, known as the castor bean (*Ricinus communis* L.), the researchers also determined as hyperaccumulator. Growing castor (*Ricinus communis* L.) in hydroponic environment with lead concentration of 0, 100, 200 and 400 pmol / L it revealed a hyperaccumulation capacity.

Runch weed according to the literature also has the potential to accumulate heavy metals. In studying the phytoextraction potential of 14 species in the presence of 5 mmol / kg soil EDTA increased the proportion of phytoavailable Pb, Zn and Cd. Their absorbance increased 48 times from white mustard (*Sinapis alba*), 4.6 times in radish (*Raphanus sativus oleiformis*), and 3.3 fold in amaranth (*Amaranthus* spp.), respectively. In mustard Pb concentration was equal to 479,71; Zn – 524,68, Cd – 7,93 mg/kg, respectively. Technical, "energy" plants having high potential a phytoextraction potential can be used to produce biofuels [36]. The scheme of bio-energy production from energy-value crops used for phytoremediation, is shown in Figure 1 [37].

Thus the need for the development of phytoremediation technology using energy-value crops due to the following circumstances:

1. These species accumulate greater biomass.
2. The use of chelating agents enhance phytoextraction of metals which have a low bioavailability and increase their translocation in their aerial organs.
3. Disadvantage of phytoremediation technology, as the duration of the process, can be used economically if we will grow plants from which may be obtained biofuel or biodiesel, especially in seeds which accumulate the least of HM.

Utilization of biomass

Phytoextraction is a repeated process of planting plants-hyperaccumulators in the contaminated soils, until the concentration of the metal reaches an acceptable level. One obstacle to the commercialization of phytoextraction – the removal of the contaminated plant material. After the cycle of development of plants, plant biomass is removed from the field, which leads to the accumulation of large quantities of hazardous waste.

This contaminated biomass to bury or dispose of them appropriately so that it did not present any risk to the environment. Biomass comprises carbon, hydrogen and oxygen. The main components of the biomass are any lignin, hemicellulose, cellulose, minerals and ash. It possesses high moisture and volatile components, low bulk density. The amount of these components varies from species to species. Dry weight of *Brassica juncea* plants for induced phytoextractionis equal to up to 6 tons / ha with 10,000 to 15,000 mg/kg of lead in dry weight [38]. Processing a large number of plants is a problem and hence there is a need to reduce the amount of biomass [39]. Therefore, after removing the biomass needed in composting and sealing. In the composting process it is formed the soluble organic compound that enhances the solubility of metals (Pb). Research showed that composting can significantly reduce the amount of harvested biomass, but contaminated metals plant biomass will continue to be in need of treatment. One of the traditional and emerging ways of using biomass for phytoremediation is a thermochemical conversion process. If accompanied by phytoextraction high biomass production, it is advantageous to use commercially as a source of energy and ash formed after combustion can be used as bio-ore [40] This is the basic principle of the process phytomining [41] Phytomining process can bring huge profits by extracting of heavy metals. The process of combustion and gasification are the most important components for production of electricity and heat. Energy production from biomass during combustion or gasification can help make the process more cost-effective phytoextraction.

Thermochemical conversion of energy use contributes to its best advantage, because it cannot be used as animal feed and fertilizer. Combustion (biomass burning process) should occur in a controlled environment, the volume should be reduced with up to 2-5%, and the ash can be disposed of properly [42]

Gasification – the process by which the biomass undergoes a series of chemical changes to the production of pure and combustible gas. This mixture of gases is called pyrolysis, which can be burned to produce heat electricity. The gasification process of biomass in the gasifier is a complex phenomenon which involves drying, combustion, thermal decomposition (pyrolysis) and gasification [43] Perhaps biomass co-firing with coal [44]. This reduces the mass incineration of lead-contaminated plant material more than 90%. This makes it possible to recover lead from ash [45].

Future experiments will focus on the development of combustion systems and methods for processing a variety of metals from the ash. This process destroys organic matter, metals recovered in the form of oxides. Considering other technologies for recycling this method is environmentally friendly.

Pyrolysis – processing method of municipal waste [46] may also be used for contaminated plant material. Pyrolysis material decomposes under anaerobic conditions, with no emissions into the atmosphere. The final product – the liquid pyrolysis oil and coke; Heavy metals remain in the coke, from which the metals can be recovered.

Advantages and disadvantages of the technology of phytoremediation

The question of the chemical interaction of metals with the soil matrix is central to phytoremediation. Binding to soil particles reduces the activity of metals in the system.

The larger the cation-exchange capacity of the soil, the greater the absorption and immobilization of metals. In acidic soils, desorption from the soil solution is stimulated competition of H^+ protons for binding sites. Acidity (pH) soils affects not only the bioavailability but also the absorption of metals plant roots. This effect is specific for each metal [47] For example, the absorption of Zn *Thlaspi caerulescens* showed weak dependence on the pH of the soil, while Mn and Cd absorption greatly depend on the acidity of the soil.

In soil metals associated with the following fractions: 1) the soil solution as free ions or soluble complexes, and 2) with inorganic soil components, 3) the organic matter in the soil, and 4) in the form of oxides, hydroxides, carbonates introduced into the structure of silicate minerals. For phytoextraction polluters should be bioavailable. Bioavailability depends on the stability of metal in the soil solution [48].

Only the metals associated with the first two abovementioned fractions are accessible to plants. Some metals such as Zn and Cd are in the bioavailable form. Other metals such as Pb, are not in the available form. The literature describes the factors limiting phytoremediation process.

Almost a profitable opportunity to use the plant-hyperaccumulators determined by the rate of accumulation of metals (g metal in plant tissue), multiplied by the rate of accumulation of biomass (kg of biomass per hectare per year). But even when such cleaning pollutant removal rate may take 15-20 years, depending on the initial concentration of the metal layer and the depth of the contaminated soil. In some species, toxic metals inhibit the accumulation of biomass.

Based on theoretical calculations based on the rate of accumulation of zinc *Thlaspi* plants (125 kg / ha year), the recovery of a typical plot may take 16 years. These terms are too large for practical use of technology, and aimed to change the properties of plants using molecular genetics [48].

Due to the presence of metal ions does not charge can pass freely through the cell membranes, which have a lipophylic structure. Therefore, transport within the cell membrane carriers is known as transporters. Transmembrane transporters include sites that bind ions and transmembrane structures which binds intracellular and extracellular spaces. These conveyors are characterized by certain kinetic parameters as the ability to transport (Vmax) and the affinity to the ion (Km). Vmax value determines the maximum level of ion transport through the cell membrane, Km transporter affinity measures to specific ions and the concentration of ion in the external solution when the level of transport which is Vmax / 2. The low value of Km, high affinity means that the level of ion transport through the membrane is high in spite of low ion concentration in the external solution. By studying the kinetic parameters Km and Vmax, are the specificity and selectivity of the transport system [49].

These estimates assume 5 tons / ha of crop biomass and electricity costs 2 cents per kilowatt-hour, which is accepted in the national energy system in many countries. In the USDA / ARS (U.S.) are grown hyperaccumulators that accumulate biomass of 10 tons / ha. The usual crop of *Thlaspi*- 5-10 t / ha (dry biomass). The energy content of the biomass – 17,5 MJ / kg. If we take the rate of 5 tons / ha and conversion efficiency of 40% of the heat from the combustion of biomass in electricity, each hectare can produce about 9,700 kilowatt-hours. Sale of energy provides gross income 194,000 $ 1,000 hectares of contaminated sites [48].

For the effective development of phytoremediation, each item must be considered separately. Requires agronomy approach including physical and chemical properties of the metal, the genetic properties of the soil and plants. For the remediation of contaminated surface soils are necessary plants with short root system, a deeper contaminated soils used plant with a long root system.

Some elements can be absorbed by plant roots and turn into a volatile form, as dimethyl selenid or mercury. Although many plants are able to volatilize dimethyl selenid, added pollution and salinization of sulfates Se-contaminated soils inhibit this process. Hence, it is necessary to improve soil conditions with additives to achieve the best effect of phytoremediation.

The level of extraction of heavy metals from the soil depends on the biomass and concentration of metals in the aerial part. The main problem in phytoremediationis that hyperaccumu-lators have small biomass of leaves and small dimensions. Chaney et al. (1998) investigated the acidification of soils for phytoextraction of Zn and Cd, and suggested the use of $(NH_4)_2SO_4$ as a soil additive that provides nitrogen and sulfur plant to produce high yield and acidifies soil for greater availability of elements for plants. There is a negative effect, which can occur in metal leaching and gets into the ground water.

Phosphorus – the main battery and the plants are responsible for its use more biomass accumulation. But the addition of phosphorus fertilizer can inhibit the absorption of Pb by the formation of pyromorphite and chloro-pyromorphite. But phosphorus fertilizer can be applied to other extraction plants metals. This highlights the importance of finding new approaches to the use of fertilizers. An alternative approach would be to use leaves as the phosphorus source. This method leads to increase in phosphorus status without inhibiting mobility Pb [48].

Conclusion

One of the aspects of incoming metal plant to which increased interest in recent years, – possibility to use clarification plants capable metals accumulate in significant quantities in the environment as cleaners. To date, phytoremediation is recognized around the world as the most cost-effective and environmentally friendly technology. Plant hyperaccumulators widely studied in the world for the development of biotechnology contaminated soil and wastewater. Based on the analysis of the recent literature the following stages of phytoremediation technology:

a) assessment of the degree of contamination of soils and plants of heavy metals;

b) screening for resistance of plants and accumulation of heavy metals in the laboratory;

c) testing the selected species under field conditions in the contaminated soil to evaluate the removal of heavy metals plant organs.

Phytoremediation technology also includes agricultural practices as the use of fertilizers to increase crop and chelating agents to enhance the removal of metal overhead authorities. Using these methods to increase the yield and efficiency of the removal of heavy metals above-ground organs can increase the level of phytoextraction of selected species.

References

1 Panin MS The influence of anthropogenic factors and human activities on the agrochemical content and migration of heavy metals in the "soil-plant" // Proceedings of the scientific-technical. Conf. "The state and the rational use of soil of the republic of Kazakhstan." – Almaty, 1998. – P. 76-79 (In Russian).

2 Tasekeev M. Bioremediation of toxic industrial waste / / Industry of Kazakhstan. – 2004. – № 5 (26). – Pp. 59-63. (In Russian).

3 Chaney R.L., Li Y. M., Scott J.A. Improving metal hyperaccumu¬lator wild plants to develop commercial phytoextraction systems: Approaches and Progress. – New York, 1998. – 37 p.

4 Wenzel W., Adriano D., Salt D., Smith R. Phytoremediation: A plant-Microbe-based remediation system // Bioremediation of Contaminated Soils. Agronomy Monograph no 37. – 2000. – 508 p.

5 Ghosh M., Singh S.P. A review on phytoremediation of heavy metals and utilization of its by products // Applied ecology and environmental research. – 2005. –Vol. 3(1). – P. 1-18.

6 Terry N., Carlson C., Raab T.K., Zayed A.M. Rates of selenium volatilization among crop species // J. Environ. Qual. – 1992. – № 21. – P. 341-344.

7 Terry N., Zayed A.M. Selenium volatilization in plants. // Selenium in the Environment (Ed. Frankenberger Jr.W., Benson S.) – New York, 1994. – P. 343-367.

8 Raskin I. Plant genetic engineering way help with environmental cleanup // Proc. Nat. Acad.Sci. USA. 1996. – № 93. – P. 3164-3166.

9 Raskin, I., Smith R.D. and D.E. Salt. Phytoremediation of metals: Using plants to remove pollutants from the environment. – Curr. Opin. Biotechnol. -1997- 8(2). – P. 221-226.

10 Huang J.W., Cunningham S.D. Lead phytoextraction: Species variation in lead uptake and translocation // New Phytol. – 1996. – №.134. – Pp. 335-342.

11 Chaney R.L., Ryan J.A. Risk based standarts for arsenic, lead and cadmium in urban soils. DECHEMA, Frankfurt // New Phytol. – 1994. – №.103. – P. 1305-1309.

12 Sarret G., Saumitou-Laprade P., Bert V., Proux O., Hazemann J.-L., Traverse A., Matthew A. Forms of zinc accumulated in the hyperaccumulator Arabidopsis halleri // Plant Physiol. – 2002. – Vol. 130. – P.1815-1826.

13 Ernst W. Physiology of metal resistance in plants // Proc. Int.Conf. on Heavy Metals in the environment. – Toronto, Canada, 1975. – Vol. 11. – P. 121-136.

14 Li Y.M., Chaney R., Brewer E., Roserberg R., Angle J.S., Baker A., Reeves R., Nelkin J. Development of a technology for commercial phytoextraction of nickel – economic and technical conciderations // Plant and Soil. – 2003.- Vol. 249. – P. 107-115.

15 Vazquez M.D., Poschenreider C., Barcelo J., Baker A.J., Hatton P., Cope G.H. Compartmentation of zinc in roots and leaves of the zinc hyperaccumulator Thlaspi caerulescens // Bot. Acta. – 1994. – № 107. – P. 243-250.

16 Lombi E., Zhao F.J., Dunham S.J., McGrath S. Cadmium accumulation in populations of Thlaspi caerulescens and Thlaspi goesingense // New Phyt. – 2000. – № 145. – P. 11-20.

17 Brooks R.R. Plants that hyperaccumulate heavy metals // Wallingford, UK:CAB International, 1998. – 53 p.

18 Hamon R.E., Holm P.E., Lorenz S.E., McGrath S.P. Metal uptake by plants from sludge-amended soils: caution is required in the plateu interpretation // Plant and Soil. – 1999. – № 216. – P. 53-64.

19 Lasat M.M., Fuhrman M., Ebbs S.D. Phytoextraction of radiocesium-contaminated soil: Evaluation of cesium-137 bioaccumulation in the shoots of three plant species // J. Environ. Qual. – 2003. – № 27. – P. 165-169.

20 Baker A.J., McGrath S.P., Reeves R.D. Metal hyperaccumulator plants: a review of the ecology

and physiology of a biochemical resource for phytoremediation of metal polluted soils // Contaminated soil and water. – Boca-Raton, Fl., USA: Lewis Publishers, 2000. – P. 85-107.

21 Chaney, R.L, Malik M., Li Y.M., Brown S.L., Brewer E.P., Angle J.S., Baker A.J.M. Phytoremediation of soil metals // Curr. Opin. Biotech. – 1997. – N 8. – P. 279 284.

22 Lai H, Chen Z. Multi-dose applying EDTA to decrease the potential groundwater contamination using rainbow pink (Dianthus chinensis) for enhanced phytoextraction // Desalination. – 2007.- 210, 236-247

23 MN Prasad The practical use of plants for the recovery of the ecosystems, contaminated by metals / / Plant Physiol. – 2003. – T.50, № 5. – C. 764-780.

24 Koopmans G.F, Schenkeveld W.D.C, Song J., Luo Y., Japenga J., Temminghoff E.J.M. Influence of EDDS on metal speciation in soil extracts: measurement and mechanistic multicomponent modeling // Environmental Science Technology. – 2008. – 42 (4). – Pp. 1123-1130.

25 Borggaard O.K, Hansen H.C.B., Holm P.E., Jensen J.K., Rasmussen S.B., Sabiene N., Steponkaite L., Strobel B.W. () Experimental assessment of using soluble humic substances for remediation of heavy metal polluted soils // Soil and Sediment Contamination: An International Journal – 2009. – http://www.informaworld.com/smpp/title~db=all~content=t713401148~tab=issueslist~branches=18 - v1818 (3). – Pp. 369 – 382.

26 Purakayastha T.J., Chhonkar P.K. Phytoremediation of heavy metal contaminated soils // Soil Biology. – 2010. -19. – Pp. 389-429.

27 Kvesitadze GI Khatisashvili GA, Sadunishvili TA, Evstigneeva ZG The metabolism of anthropogenic toxicants in higher plants. – Moscow: Nauka. 2005. – 197 p.

28 Vassil A., Kapulnik Y., Raskin I., Salt D.E. The role of EDTA in lead transport and accumulaation by Indian mustard // Plant Physiol. – 1998. – Vol.117. – P. 447-453.

29 Kayser A.K., Wenger A., Keller W. Enchancement of phytoextraction of Zn, Cd and Cu from calcareous soil: the use of NTA and sulfur amendmebts. //Environ. Sci. Technol. – N34. – P. 1178-1783.

30 Platonov V, Proskuryakov VA, VE Savchenko Humic acid, etc. – effective sorbents of heavy metals. – 2006.

31 Grzybowsky W. Comparison between stability constants of cadmium and lesd complexes with humic substances of DL. Erent molecular weight isolated from Baltic Sea water // Oceanologia. – 2000. – Vol. 42(4). – P. 473–482.

32 Boonyapookana, B., Parkpian, P., Techapinyawat, S., DeLaune, R. D., Jugsujinda, A. Phytoaccumulation of lead by sunflower (Helianthus annuus), tobacco (Nicotiana tabacum), and vetiver (Vetiveria zizanioides) // Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering. – 2005. – Vol. 40, N. 1. – P.117-137.

33 Lesage E., Meers E., Vervaeke P., Lamsal S., Hopgood M., Tack F.M Enhanced phytoextraction: II. Effect of EDTA and citric acid on heavy metal uptake by Helianthus annuus from a calcareous soil // Int. J. Phytoremediation.- 2005. – Vol. 7(2). – P.143-52.35.

34 Gulz P.A., Gupta S.K., Schulin R. P-Enhanced Phytoextraction of Arsenic from contaminated Soil using Sunflower // Proceedings of the 7th International Conference on the Biogeochemistry of Trace Elements (7th ICOBTE), 15-19 June 2003, Uppsala, Sweden. Book of Abstracts. – 2003. – Vol I-II. – P. 148-149.

35 Begonia B. Comparative lead uptake and responses of some plants grown on lead contaminated soils. Department of Biology, Jackson State University, Jackson, MS 39217. http://www.msstate.edu/org/MAS/ejour3.html

36 Kos B., Grčman H., Leštan D.. Phytoextraction of lead, zinc and cadmium from soil by selected plants // Plant Soil Environ. – 2003. – Vol. 49. – P. 548–553.

37 Ginneken L.V., Meers E., Guisson. R., Ruttens A., Elst K., Tack F.M.G., Vangronsveld J., Diels L., Dejonghe W. Phytoremediation for heavy metal contaminated soils combined with bioenergy production // Journal of environmental engineering and landscape management. – 2007. – Vol XV, N4. – P. 227–236.

38 Ow D.W. Heavy metal tolerance genes-prospective tools for bioremediation. – Res. Conserv. Recycling. 1996. – V. 18. – Pp. 135–149.

39 Blaylock M.J., Huang J.W. Phytoextraction of metals. In: Raskin I., Ensley B.D. (Eds.) Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment. – John Wiley and Sons, New York, 2000. – Pp. 53–70.

40 Kumar, P. B. A. N., Dushenkov, V., Motto, H. and Raskin, I. (1995): Phytoextraction: the use of plants to remove heavy metals from soils. – Environ.Sci. Technol. 29. – Pp. 1232-1238.

41 Nicks L., Chambers M.F. (1994): Nickel farm. – Discover. September. –P.19

42 Kramer U., Cotter-Howels J.D., Charnock J.M., Baker A.J., Smith J.A.C. Free histidine as a metal chelator in plants that accumulate nickel // Nature (London). – 1996. – Vol. 379. – P. 635-638.

43 Iyer, P.V.R., Rao, T.R., Grover, P.D. (2002): Biomass Thermochemical characterization. Third edition, – 38 p.

44 Hetland, M.D., Gallagher, J.R., Daly, D.J., Hassett, D.J., Heebink, L.V. Processing of plants used to phytoremediate lead-contaminated sites. In: Leeson, A., Foote, E.A., Banks, M.K., Magar, V.S. (Eds.), Phytoremediation, Wetlands, and Sediments, – The Sixth International in situ and on-site Bioremediation Symposium, San Diego, California, 2001, 4–7 June. Battelle Press, Columbus, Richland; pp. 129–136.

45 Raskin I., Smith R.D., Salt D.E. Phytoremediation of metals: using plants to remove pollutants from the environment // Curr. Opin. Biotech. – 1997. – Vol. 8. – P. 221-226.

46 Blaylock M.J., Salt D.E. Dushenkov S., Zakharova O., Gussman C. Enchanced accumulation of Pb in Indian mustard by soil-applied chelating agents // Environ Sci Technol. – 1997. – Vol. 31. – P. 860-865.

48 Lasat M.M. The use of plants for the removal of toxic metals from contaminated soils // Environmetal protection agency, New York, 2001. – 33 p.