THE USE OF PHYTOREMEDIATION METHOD IN LATVIA

Kristīne Valujeva
Latvia University of Agriculture, Department of Environment and Water Management
E-mail: kristine.valujeva@gmail.com
Inga Straupe
Latvia University of Agriculture, Department of Forestry
E-mail: inga.straupe@llu.lv
Inga Grīnfelde
Latvia University of Agriculture, Department of Environment and Water Management
E-mail: inga.grinfelde@llu.lv

ABSTRACT

Human activities and a growing economic development have resulted in increased pollution of soil, for instance in Latvia there are more than 2650 territories with historically contaminated soil. There are organic or inorganic pollutants including various heavy metals. This review summarizes phytoremediation process and gives an appropriate list of plants which can be used for phytoremediation under the Latvian climate conditions to remediate petroleum products and heavy metals. Additionally a description and characterization of habitat is given for each plant.

Key words: phytoremediation, pollution, heavy metals, oil pollution

INTRODUCTION

Protractedly science and technologies have allowed human beings to use natural resources. Because of the anthropogenic effect with various chemicals, high-speed progress in manufacturing and artificially made use of raw materials the planet's ecosystem has eroded the ability of self-purification, for its part, the accumulated pollution affects humans' health as well as the whole ecosystem in general (Susarlaa et al., 2002, Kļaviņa un Zaļokšņa red, 2010,).

The term phytoremediation consists of two words: phyto (from Ancient Greek meaning – plant) and remedium (from Latin meaning – restoring balance). Plants have a characteristic feature to imbibe polluted substances and to manage environmental detoxification with diverse mechanisms.

Phytoremediation is the use of plants and related soil microorganisms to decrease the concentration of pollution or toxic consequences in the environment (EPA, 2001; Ashraf et al, 2010). It is comparatively recent technology, and it is considered as advantageous, efficient, original, environmentally friendly and direct solar energy technology. Its research started in the 90s. It is suitable for large polluted areas where other methods of purification are not cost-effective or practical. Compared to different methods of recovery, phytoremediation has low implementation and maintenance costs, for example – less than five percent from alternative purification methods (Ali et al., 2013). In addition, the establishment of vegetation in the polluted areas relieve soil erosion and pollution leaching.

Phytoremediation is a new method, within the framework of which plants are used to remove and convert toxic and chemical substances, which are located in the soil, groundwater, surface water and even in the atmosphere, into less harmful compounds. The aim of research is to develop a list of usable plants for phytoremediation in Latvia.

MATERIALS AND METHODS

The phytoremediation method for the rehabilitation of the soil, polluted with heavy metals and petroleum products has been analysed using the monographic method. To develop a list of plants which can be used for phytoremediation in Latvia, a logical test was developed. It is shown in Figure 1.

As a result of the study, a list of common plants in Latvia, capable of accumulating heavy metals, splitting them into various petroleum products and converting them into less harmful compounds was created. On the basis of the scientific studies on phytoremediation carried out abroad, a list of plants, plant growth conditions and substances, which they can accumulate or split, has been made. The list of plants is divided in five parts: herbaceous native plants in Latvia; herbaceous introduced plants in Latvia; herbaceous cultivated plants in Latvia; scrubs and trees; water and wetland plants.

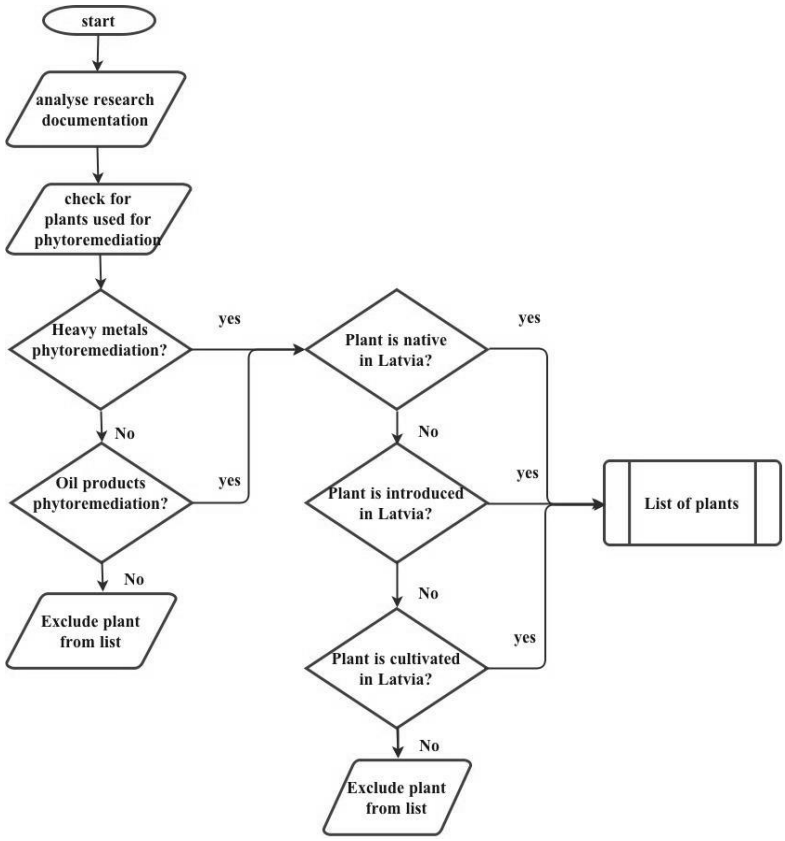

Figure 1. Flowchart of plant selection for the list

RESULTS AND DISCUSSION

Currently the phytoremediation method is used to purify the environment from various polluting substances, among them, petroleum products, chlorinated solvents, pesticides, explosives, heavy metals and radionuclides (Morel et al., 2006). It is known that 80% of the polluted ground extends up to 20 meters deep (Best et al., 1997). Consequently a significant number of polluted areas are potentially suitable for phytoremediation, which has lower costs than traditional methods (Susarlaa et al., 2002).

In recent years there has been a rapid increase in use of phytoremediation in polluted soil and groundwater purification throughout the world. Chang and Corapcioglu (1998) describe that plants can enable environmental rehabilitation in chemical and toxic waste dumps. Recovery can be carried out due to the following plant functions and properties:

1) The ability to change the physical and chemical properties;
2) The ability of the roots to release organic oxygen;
3) The ability to increase the porosity of upper soil area and, thereby, improve soil aeration;
4) The ability to intercept and detain chemical substances, thereby reducing the pollution in the groundwater;
5) The ability to perform chemical degradation by metabolic processes of microorganisms and plant enzymes.

Many environmental restoration projects use phytoremediation after the initial pollution treatment. If the levels of pollution are low, phytoremediation can be a very economical and effective remediation technique (Bell and Failey, 1991). In places where pollution is less toxic, phytoremediation is suitable as a long-term solution to the problem (Susarlaa et al., 2002).

Plant species are selected taking into account their capacity to adapt to climatic conditions and different soils in Latvia. The list includes plant species that grow in wet and damp soils and even those which are suitable for dry and sandy soils. Each species tear down polluted substances by only its inherent plant ongoing biochemical processes. Future studies should be aimed at finding out how each of these species evolve and better adapt to the polluted area, as well as – what kind of phytoremediation methods plants use as a treatment in a polluted place. Plants are divided in 5 tables by the method which is shown in Figure 1. The tables are sorted in alphabetical order by Latin plant names.

Table 1

Native herbaceous plants usable for phytoremediation in Latvia

Plant species	Habitat's description	Inorganic or organic compound	References
Armeria maritima (Mill.) Willd. Sea Thrift	Different size of groups in dry, salty meadows and in sandy places with thin vegetation. Pollution and fertilization are endangering the species.	Pb	Fiegl et.al., 2003
Artemisia campestris L. Field Wormwood	Often different sizes of groups in dry soils with thin vegetation: in sands, dunes, weedy places, meadows, also in pine forests, on roadsides, along railways, in fallow lands and bushes.	Heavy crude oil	Liužinas et.al., 2003
Calamagrostis epigeios (L.) Roth Wood Small-reed	Often found in dry and rocky places along railways, on roadsides, in dry meadows, forests and in weedy places.	Heavy crude oil	Liužinas et.al., 2003; Madzhugina et.al. 2008.
Carex arenaria L. Sand Sedge	Often found on sea shores or close to them. Form different sizes of groups in thin dry meadows, dunes and dune forests, beach sands.	Heavy crude oil	Liužinas et.al., 2003
Carex hirta L. Hairy Sedge	Often found as individual plants and different sizes of groups in meadows, fallow lands, dry forests and bushes, on roadsides and along railways.	Diesel fuel	Dzhura et.al., 2009; Liužinas et.al., 2003
Cirsium arvense (L.) Scop. Creeping Thistle	Often found as individual plants and different sizes of groups in gardens, fields, near houses, roadsides and along railways and also in weedy places.	Heavy crude oil	Liužinas et.al., 2003
Convolvulus arvensis L. Field Bindweed	Often found, form groups on edges of gardens and roadsides, in weedy places, along railways, in dunes and in bushes by rivers.	Heavy crude oil	Liužinas et.al., 2003
Elytrigia repens (L.) Nevski Common Couch	Often found in different habitats, which have been affected by humans' activities. Weed that is difficult to destroy in gardens and fallow lands, the reason is strong rhizomes.	Heavy crude oil	Liužinas et.al., 2003
Equisetum arvense L. Field Horsetail	Often found in dry fallow lands, meadows, on roadsides and different beds.	Heavy crude oil	Liužinas et.al., 2003
Festuca arundinacea Schreb. Tall Fescue	Often grows in the western part of Latvia in meadows of river valleys, fallow land, roadsides and gravel soils.	Cd, Pb, N, P, K, Zn, PAH , TPH	Christensen-Kirsh, 1996; Byrne-Kelly et.al., 2001; Banks, Schwab, 1998; Flathman, Lanza, 1998; Leewis et.al., 2013; Pivetz, 2001
Festuca ovina L. Sheep's fescue	Different size of groups in dry soils. Found in meadows, fallow land, forests, on roadsides, along railways.	Pb	Fiegl et.al., 2003
Festuca rubra L. Red Fescue	Often found in dry soils in meadows, fallow land, thin forests, bushes, on roadsides, along railways, in deciduous woods. One of the valuable grassland species.	Cs, N, P, K, diesel fuel, crude oil	McCutcheon, Schnoor, 2003; Christensen-Kirsh (1996); Leewis et.al., 2013
Leymus arenarius (L.) Hochst. Lyme - grass	Not infrequently form quite large groups on sandy sea shores and dunes on the sea shore of the Baltic Sea and The Gulf of Riga.	Heavy crude oil	Liužinas et.al., 2003
Lolium multiflorum Lam. Italian Rye-grass	Cultivated species. Form groups on roadsides, along railways, in dry fallow lands and weedy places.	Cs, Sr, PAH	McCutcheon, Schnoor, 2003; Flathman, Lanza, 1998; Leewis et al., 2013
Lolium perenne L. Perennial Rye-grass	Common species, grow in trampled and compatcted soils on roadsides, in quarries, dry fallow lands, cultivated grassland and weedy places.	Ba, Cd, Cu, Pb, P, Al, PAH	Otabbong, 1990; Oyler, 2004; Flathman, Lanza, 1998; Pivetz, 2001; Leewis et.al., 2013
Poa compressa L. Flattened Meadow-grass	Often form thin groups in dry forests, bushes, fallow lands, quarries and roadsides.	Heavy crude oil	Liužinas et.al., 2003
Poa pratensis L. Smooth Meadow-grass	Often found in moderately wet meadows in different Cl. Molinio-Arrhenatheretea communities, in fallow lands, forests, bushes, on	PAH	Leewis et.al., 2013; Bizecki, 2003

Plant species	Habitat's description	Inorganic or organic compound	References
	roadsides and along railways.		
Silene vulgaris (Moench) Garcke Bladder Campion	Often found in meadows, bushes, edges of the forests, weedy places.	Zn, Cd	Oyler, 2004
Trifolium pratense L. Red Clover	Common grassland species in Latvia. Also found in crop lands, pastures, on roadsides, rarely in forests.	Zn	McCutcheon, Schnoor, 2003
Trifolium repens L. White Clover	Often found in meadows, fallow lands, weedy places, grasslands, on roadsides, rarely in bushes and thin forests.	Pb, B, Cu, As, PAH	Speir et al., 1992; McCutcheon, Schnoor, 2003
Tanacetum vulgare L. Tansy	Often found in different size of groups in dry, moderately wet meadows, by riversides, in weedy places, fallow places and along railways.	Heavy crude oil	Dazy, et all. 2009; Liužinas et.al., 2003
Tussilago farfara L. Colt's - foot	Often found from some individual plants to large groups in different meadows, on roadsides, fallow lands and coasts of waterbodies. Usually grows in places with thin vegetation. Typical for new rural areas.	AS; SB Pb; Heavy crude oil	Liužinas et.al., 2003; Robinson et.al., 2008; Vaculík et.al. 2013

Table 2

Introduced herbaceous plants usable for phytoremediation in Latvia

Plant species	Habitat's description	Inorganic or organic compound	References
Amaranthus retroflexus L. Common Amaranth	Individual plants and small groups in weedy places, on roadsides, along railways, in gardens, fields close to houses.	Cd, Cs, Ni, Zn	McCutcheon, Schnoor, 2003
Ambrosia artemisiifolia L. Ragweed	Infrequent along railways and in weedy places.	Pb	McCutcheon, Schnoor, 2003
Avena strigosa Schreb. Bristle Oat	Individual plants and thin groups in cornfields, weedy places, on roadsides and along railways.	Cd	Uraguchi, 2006
Kochia scoparia (L.) Schrad. Summer-cypress	Decorative plant in gardens and green areas. In some places became wild. Individual plants and small groups grow on roadsides and in weedy places.	Se	McCutcheon, Schnoor, 2003
Sorghum halepense (L.) Pers. Sorghum	Individual plants and groups in dry weedy places and along railways.	Al, As, Cs, Cu, Mn, Ni, U, Zn	McCutcheon, Schnoor, 2003

Table 3

Cultivated herbaceous plants usable for phytoremediation in Latvia

Plant species	Habitat's description	Inorganic or organic compound	References
Brassica juncea (L.) Czern. Chinese Mustard	Individual plants and small groups in weedy places and along railways. Rare plant in Latvia.	Cd, Cs, Au, Pb, Ni, Pu, U, Zn	McCutcheon, Schnoor, 2003; Kumar et.al., 1995
Brassica napus L. s.l. Rape	Often cultivated in crop areas. Individual plants in weedy places, on roadsides, along railways and landfills.	Ba, Cu, Pb, Zn	Groom, Halasz et al.,2002; Fiegl et al. 2003; Kumar et al., 1995
Hordeum vulgare L. Common Barley	Often cultivated in crop areas. Individual plants in weedy places, on roadsides, along railways.	Al, Ca	McCutcheon, Schnoor, 2003; Cipollini, Pickering, 1986
Medicago sativa L. Alfalfa	Cultivated in crop fields. In some places have become wild – in meadows, borders of the forest, edges of fields, weedy places, on roadsides and along railways.	Ba, Cs, Pb, Zn, Cu, Cd, Cr, Ni, PAH	McCutcheon, Schnoor, 2003; EPA, 2005; Tiemann et al. 1998; Pradhan et al., 1998; Pivetz, 2001
Pisum sativum L. Garden Pea	Cultivated species in gardens, crop fields, often with oats. Individual plants rarely found in weedy places near locality and in landfills.	PAH	Pivetz, 2001
Triticum aestivum L. Wheat	Cultivated in crop areas. Individual plants in weedy places, on roadsides, along railways.	Ba, Cu, Pb, Zn, Cs	Bell et al., 1988; Fiegl et al., 2003

Vicia faba L. Broad Bean	Often cultivated in gardens and fields. Individual plants in weedy places, near locality and landfills.	Al	McCutcheon, Schnoor, 2003
Zea mays L. Maize	Cultivated in crop areas. Individual species on roadsides, landfills, in weedy places, along railways. Usually do not survive in one place for more than one growing season.	As, Cd, Co, Pb, Ni, Mg, K, Na	Cipollini, Pickering, 1986; Kumar et al., 1995; McCutcheon, Schnoor, 2003

Table 4

Water and wetland plants usable for phytoremediation in Latvia

Plant species	Habitat's description	Inorganic or organic compound	References
Caltha palustris L. Marsh-marigold	Often found in wet soils and periodically flooded meadows, forests and on the coasts of waterbodies.	U	McCutcheon, Schnoor, 2003
Hydrilla verticillata (L.f.) Royle Hydrilla	Found more than in 20 lakes, where they form groups in sandy and sandy muddy ground usually 1-4 m deep.	Cd, Cr, Pb, Hg	McCutcheon, Schnoor, 2003
Iris pseudacorus L. Yellow Iris	Often found as an ornamental plant in fertile and wet places on the coasts of waterbodies, permanently flooded depressions, edges of bogs and wet deciduous forest.	Cu, Cd	Barbolani et.at., 1986
Juncus articulatus L. Jointed Rush	Often found in wet meadows, on coasts of rivers and lakes, in disappearing sandy depressions, on wet overgrown roads, edges of bogs. Common species on wet edges of waterbodies.	Diesel fuel	Lin, Mendelssohn, 2008
Juncus bufonius L. Toad Rush	Often found. Forms groups in fallow lands with thin plant cover, in fields, wet weedy places and disappearing ditches, on coasts of waterbodies.	Diesel fuel	Lin, Mendelssohn, 2008
Juncus conglomeratus L. Compact Rush	Often found in dense bush in ditches, on wet coasts of waterbodies, in flooding and disappearing meadows and fallow land depressions, on edges of bogs.	Diesel fuel	Lin, Mendelssohn, 2008
Juncus effusus L. Soft - Rush	Often found in different size of groups and individual plants in wet depression of meadows and fallow lands, in bushes, ditches, edges of waterbodies and puddles.	Diesel fuel	Lin, Mendelssohn, 2008
Juncus filiformis L. Thread Rush	Often found, forming different groups in wet, boggy meadows, bogs, on overgrown coasts of waterbodies and ditches.	Diesel fuel	Lin, Mendelssohn, 2008
Lemna minor L. Common Duckweed	Different size of groups found in lakes, ponds, ditches and old rivers. Sometimes cover all water surface.	Cu, Zn, Cd, Cr	Kadlec, Knight, 1996; McCutcheon, Schnoor, 2003
Mentha aquatica L. Water Mint	Not infrequently different size of groups on coasts of waterbodies and overgrown ditches.	Ni	Zurayk et.at., 2002
Scirpus lacustris L. Common Club-rush	Often found in plant communities of reeds and rushes on waterbodies and on the seashore.	Cu, Cr, Mn	Kadlec, Knight, 1996; McCutcheon, Schnoor, 2003
Spirodela polyrrhiza (L.) Schleid. Greater Duckweed	Aquatic plant, found in ponds, ditches and in overgrown lakes.	Al, As, Cd	McCutcheon, Schnoor, 2003
Typha latifolia L. Bulrush	Often found in plant communities of reeds and rushes and in overgrown shallow waterbodies, permanently flooded depressions in meadows, in bushes, rarely in forests.	As, Pb, Pu, Cu, Mn, Cr	Kadlec, Knight, 1996; EPA, 2004

Table 5

Scrubs and trees usable for phytoremediation in Latvia

Plant species	Habitat's description	Inorganic or organic compound	References
Juniperus communis L. Juniper	Bushes in dry forests, dunes, pastures, seldom trees, which form thin forests.	U	McCutcheon, Schnoor, 2003

Plant species	Habitat's description	Inorganic or organic compound	References
Larix decidua Mill. European Larch	Cultivated in dry mineral soils in forest stands and in green areas.	Cs	McCutcheon, Schnoor, 2003
Picea abies (L.) Karst. Norway Spruce	Boreal coniferous forest species. Constitute a fifth of Latvian total forest area. Grows in unmixed forests or mixed forests in moderately fertile soils and in wet soils mainly in mineral soils.	Cs	McCutcheon, Schnoor, 2003
Pinus sylvestris L. Scots Pine	Main tree species in Latvian forests. Grows in unmixed forests and mixed forests. The dominant species in dry and wet mineral soil and marsh soil in different pine forests.	Diesel fuel	Palmroth et.al., 2002
Populus deltoides x Wettstein; Populus x canadensis Hybrid Aspen	Selectively for forestry needs. Cultivated in hybrid aspen plantations.	BTEX, PAH	ITRC, 2009
Quercus robur L. Pedunculate Oak	Often found in European broadleaf forests by riversides, in glens and individual plants in agricultural land.	U	McCutcheon, Schnoor, 2003
Salix schwerinii x viminalis Hybrid Willow, Tora	Selectively for forestry needs. Cultivated in willow plantations.	Heavy crude oil	Pivetz, 2001
Salix viminalis L. Osier	Quite often as individual plants and groups by waterbodies, in overgrown ditches and sand dunes.	Cd, Cr, Cu, Pb, K, Ag, Sr, U, Zn, As	Hinchman et al., 1997; Schmidt, 2003; McCutcheon & Schnoor, 2003

CONCLUSIONS

The phytoremediation research method is at an early stage in the world and also in Latvia, and it opens up a wide range of opportunities for further research. Currently, most studies have been performed in laboratories under experimental conditions and temporarily, therefore it is necessary to extend field studies about the effectiveness of pollution purifying plant species from the above mentioned in the climatic conditions in Latvia. Since the plant movement is limited, many species have developed unique biochemical systems for feeding process security, as a result of which they determine and affect the local geochemical soil conditions and play a significant role in reducing the pollution in the soil.

REFERENCES

Ali H., Khan E., Sajad M.A., (2013). *Phytoremediation of heavy metals—Concepts and applications*. 91(7), 869-881. DOI: 10.1016/j.chemosphere.2013.01.075

Ashraf, M., Ozturk, M., Ahmad, M. S. A., (2010). *Plant Adaptation and Phytoremediation*. Springer (pp. 481).

Banks K., Schwab P., (1998). *Phytoremediation in the Field: Craney Island Site*. 3rd Annual International Conference on Phytoremediation, Houston

Barbolani E.; Pantani F.; Gellini R.; Clauser M., (1986). *Residual heavy metal (Cu and Cd) removal by Iris pseudacorus*. Water, Air & Soil Pollution, 28(3-4), 277-282.

Bell J. N. B., Minski M. J., Grogan H. A., (1988). *Plant Uptake of Radionuclides*. Soil Use Management, 4, 76–84.

Bell R.M., Failey R.A., (1991). *Plant uptake of organic pollutants*. In Organic contaminants in the environment. Ed. K.C. Jones. Elsevier Applied Science, Essex, U.K., pp 189-206.

Best P.H., Zappi M.E., Fredrickson H.L., Sprecher S.L., Larson S.L., Ochman M., (1997). *Screening of aquatic and wetland plant species for phytoremediation of explosives-contaminated groundwater for the Iowa Army Ammuntion Plant*. Annals of the New York Academy Sciences, 829, 179-194. DOI: 10.1111/j.1749-6632.1997.tb48574.x

Bizecki D., (2003). *Phytoremediation of hydrocarbon-contaminated soil using plants adapted to the western canadian climate*. Soil Science, University of Saskatchewan, pp 235.

Byrne-Kelly D., Cornish J., Gordon R., Licis I., (2001). *Revegetation of Mining Waste Using Organic Soil Amendments and Evaluation of the Potential for Creating Attractive Nusiances for Wildlife*. Abstract. 2001. Proceedings of the 2001 Conference on Environmental Research, pp 119-147.

Chang Y., Corapcioglu M.Y., (1998). *Plant-enhanced subsurface bioremediation of nonvolatile hydrocarbons*. Journal of Environmental Engineering, 124(1), 162-169.

Christensen-Kirsh, K.M (1996). *Phytoremediation and wastewater effluent disposal: Guidelines for landscape planners and designers*. Master's Project, Department of Landscape Architecture. University of Oregon.

Cipollini M. L., Pickering J. L., (1986). *Determination of the Phytotoxicity of Barium in Leach-Field Disposal of Gas Well Brines*. Plant and Soil, 92, 159–69.

Dazy, M., Béraud, E., Cotelle, S., Grévilliot, F., Férard, J.-F., Masfaraud, J.-F. Changes in plant communities along soil pollution gradients: Responses of leaf antioxidant enzyme activities and phytochelatin contents (2009) Chemosphere, 77 (3), 376-383.

Dzhura N.M., Romanyuk O.I., Oshchapovsky I.V., Gasior J., Tsvilynyuk O.M., Terek O.I. (2009). *Using plants for recultivation of oil polluted soils*.

Fiegl J. L., McDonnell B. P., Kostel J. A., Finster M. E., Gray K. (2003). *A Resource Guide: The Phytoremediation of Lead to Urban, Residential Soils*. New Jersey, John Wiley & Sons.

Flathman P. E, Lanza G. R., (1998). *Phytoremediation: Current Views on an Emerging Green Technology*. Journal of Soil Contamination, 7, 415–32.

Groom, Halasz C.A, A., Paquet L., Morris N., Olivier L., Dubois C. and Hawari J. (2002). *Accumulation of HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) in Indigenous and Agricultural Plants Grown in HMX- Contaminated Anti-Tank Firing-Range Soil*. Environmental Science & Technology, 36(1), 112-118. DOI: 10.1021/es0110729

Hinchman, R. R., Negri M. C., Gatliff E. G., (1997). *Phytoremediation: Using Green Plants to Clean Up Contaminated Soil, Groundwater, and Wastewater*. Submitted to the U.S. Department of Energy, Assistant Secretary for Energy Efficient and Renewable Energy under Contract W-31-109-Eng-38.

Interstate Technology & Regulatory Council (ITRC), (2009). *Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised*. PHYTO-3. Washington, D.C.: Interstate Technology & Regulatory Council, Phytotechnologies Team, Tech Reg Update.

Kadlec, R. H., Knight R. L.. (1996). *Treatment Wetlands*. Boca Raton, Fla.: CRC Press, Lewis Publishers.

Kļaviņa M., Zaļokšņa J. redakcija (2010). *Vide un ilgtspējīga attīstība*. (97. – 116. lpp). Rīga: LU akadēmiskais apgāds.

Kumar P. B. A. N., Dushenkov V., Motto H., Raskin I., (1995). *Phytoextraction: The Use of Plants to Remove Heavy Metals from Soils*. Environmental Science and Technology. 29:1232–38

Kumar P. B. A. N., Dushenkov V., Motto H., Raskin I., (1995). *Phytoextraction: The Use of Plants to Remove Heavy Metals from Soils.* Environmental Science and Technology. 29:1232–38

Leewis M.C., Reynolds C.M., Leigh B.M., (2013). *Long-term effects of nutrient addition and phytoremediation on diesel and crude oil contaminates soils in subarctic Alaska*. ScienceDirect, Cold Regions Science and Technology, 96, 129-137. DOI: 10.1016/j.coldregions.2013.08.011

Lin Q., Mendelssohn I.A., (2008). *Potential of restoration and phytoremediation with Juncus roemerianus for diesel-contaminated coastal wetlands*. ScienceDirect, Ecological Engineering, 35(1), 85-91. DOI: 10.1016/j.ecoleng.2008.09.010

Liužinas R., Jankevičius K., Šalkauskas M., Rašomavičius V., Gudžinskas Z., Sinkevičiene Z., (2003). *Phytoremediation of polluted soil at sites in the district of Klaidepa (Lithuania)*, pp 12.

Madzhugina, Yu.G., Kuznetsov, Vl.V., Shevyakova, N.I. Plants inhabiting polygons for megapolis waste as promising species for phytoremediation. (2008) Russian Journal of Plant Physiology, 55 (3), pp. 410-419.

McCutcheon S.C., Schnoor I.L., (2003). *Phytoremediation: Transformation and Control of Contaminants*. Hoboken, New Jersey: Wiley-Interscience, Inc.

Morel J.L., Echevarria G., Goncharova N., (eds.), (2006). *Phytoremediation of Metal-Contaminated Soils*. NATO Science Series. IV. Earth and Environmental Sciences (pp 345).

Otabbong E., (1990). *Chemistry of Cr in Some Swedish Soils*. Plant and Soil 123, 89–93.

Oyler, J., (2004). *Blue Mountain Superfund Remediation Project*. Palmerton, PA, ITRC Phytotechnologies conference.

Palmroth M.R.T., Pichtel J., Puhakka J.A., (2002). *Phytoremediation of subarctic soil contaminated with diesel fuel*. Bioresource Technology, 84(3), 221-228. DOI: 10.1016/S0960-8524(02)00055-X

Pivetz B.E., (2001). *Phytoremediation of Contaminates Soil and Ground Water at Hazardous Waste Sites*. U.S. Environmental Protection Agency (EPA), Office of Research and Development, Office of Solid Waste and Emergency Response, Washington, DC.

Pradhan S. P., Conrad J. R., Paterek J. R., Srinistava V. J., (1998). *Potential of Phytoremediation for Treatment of PAHs in Soil at MGP Sites*. Journal of Soil Contamination, 7, 467–80.

Robinson, B.H., Bischofberger, S., Stoll, A., Schroer, D., Furrer, G., Roulier, S., Gruenwald, A., Attinger, W., Schulin, R. Plant uptake of trace elements on a Swiss military shooting range: Uptake pathways and land management implications (2008) Environmental Pollution, 153 (3), pp. 668-676.

Salt, D. E., Blaylock M., Kumar P. B. A. N., Dushenkov V., Ensley B. D., Chet I., Raskin I., (1995). *Phytoremediation: A Novel Strategy for the Removal of Toxic Metals from the Environment Using Plants*. Biotechnology 13: 468–74.

Schmidt U., (2003). *Enhancing Phytoextraction: The Effect of Chemical Soil Manipulation on Mobility, Plant Accumulation, and Leaching of Heavy Metals* (pp. 1939-1954). Journal of Environmental Quality.

Speir, T. W., August J. A., Feltham C. W., (1992). *Assessment of the Feasibility of Using CCA (Copper, Chromium and Arsenic)–Treated and Boric Acid–Treated Sawdust as Soil Amendments, I. Plant Growth and Element Uptake*. Plant and Soil, 142, 235–48.

Susarlaa S, Medinab V. F., McCutcheon S. C., (2002). *Phytoremediation: An ecological solution to organic chemical contamination*. Ecological Engineering. 18(5), 647-658. DOI: 10.1016/S0925-8574(02)00026-5

Tiemann, K. J., Gardea-Torresdey J. L, Gamez G., Dokken K.. (1998). *Interference Studies for Multi-Metal Binding by Medicago sativa (Alfalfa)*, p. 42 (Abstract 67) in Proceedings, Conference on Hazardous Waste Research, Snow Bird, Utah.

U. S. Environmental Protection Agency (EPA), (2005). *Road Map to Understanding Innovative Technology Options for Brownfield's Investigation and Cleanup*. (Fourth ed.). Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation.

U.S Environmental Protection Agency (EPA), (2004). *Phytoremediation field studies database for chlorinated solvents, pesticides, explosives, and metals*. Office of Superfund Remediation and Technology Innovation, Washington, DC.

U.S. Environmental Protection Agency (EPA), (2001). *Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup*. Office of Solid Waste and Emergency Response, Washington, DC.

Uraguchi S., Watanabe I., Yoshitomi A., Kiyono M., Kuno K., (2006). *Characteristics of cadmium accumulation and tolerance in novel Cd accumulating crops, Avena strigosa and Crotalaria juncea*. Journal on Experimental Botany, 57(12), 2955-2965.

Vaculík, M., Jurkovič, A., Matejkovič, P., Molnárová, M., Lux, A. Potential risk of arsenic and antimony accumulation by medicinal plants naturally growing on old mining sites (2013) Water, Air, and Soil Pollution, 224 (5), art. no. 1546

Zurayk R., Sukkariyah B., Baalbaki R., Ghanem D. A., (2002). *Ni Phytoaccumulation in Mentha aquatica L. and Mentha sylvestris L. American University of Beirut, Water Air and Soil Pollution*, 139(1-4), 355-364.