



Audronė JANKAITĖ

**RESEARCH ON HEAVY METALS IN ROADSIDE
AND EVALUATION OF THEIR INFLUENCE
ON THE ENVIRONMENT**

**Summary of Doctoral Dissertation
Technological Sciences, Environmental Engineering and
Landscape Management (04T)**

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Vilnius  **LEIDYKLA
TECHNIKA 2007**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Scientific Supervisor

Assoc Prof Dr Saulius VASAREVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

Consultants:

Prof Dr Habil Petras VAITIEKŪNAS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T),

Dr Sigita JURKONIENĖ (Institute of Botany, Biomedical Sciences, Botany – 04B).

The dissertation is being defended at the Council of Scientific Field of Environmental Engineering and Landscape Management at Vilnius Gediminas Technical University:

Chairman

Prof Dr Habil Donatas BUTKUS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

Members:

Dr Habil Valentinas BALTRŪNAS (Institute of Geology and Geography, Physical Sciences, Geology – 05P),

Prof Dr Habil Irena EITMINAVIČIŪTĖ (Institute of Ecology of Vilnius University, Biomedical Sciences, Ecology and Environmental Sciences – 03 B),

Assoc Prof Dr Raimondas Leopoldas IDZELIS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T),

Prof Dr Habil Algimantas KAZRAGIS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

Opponents:

Dr Habil Danutė MARČIULIONIENĖ (Institute of Botany, Biomedical Sciences, Botany – 04B),

Assoc Prof Dr Dainius PALIULIS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Environmental Engineering and Landscape Management in the Senate Hall of Vilnius Gediminas Technical University at 1 p. m. on 9 November 2007.

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.

Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;

e-mail: doktor@adm.vgtu.lt

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Audronė JANKAITĖ

**SUNKIŲJŲ METALŲ PAKELĖSE TYRIMAI
IR ĮTAKOS APLINKAI VERTINIMAS**

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Mokslinis vadovas

doc. dr. Saulius VASAREVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

Konsultantai:

prof. habil. dr. Petras VAITIEKŪNAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T),

dr. Sigita JURKONIENĖ (Botanikos institutas, biomedicinos mokslai, botanika – 04 B).

Disertacija ginama Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos ir kraštovarkos mokslo krypties taryboje:

Pirmininkas

prof. habil. dr. Donatas BUTKUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

Nariai:

habil. dr. Valentinas BALTRŪNAS (Geologijos ir geografijos institutas, fiziniai mokslai, geologija – 05P),

prof. habil. dr. Irena EITMINAVIČIŪTĖ (Vilniaus universiteto Ekologijos institutas, biomedicinos mokslai, ekologija ir aplinkotyra – 03B),

doc. dr. Raimondas Leopoldas IDZELIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T),

prof. habil. dr. Algimantas KAZRAGIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

Oponentai:

habil. dr. Danutė MARČIULIONIENĖ (Botanikos institutas, biomedicinos mokslai, botanika – 04 B),

doc. dr. Dainius PALIULIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

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Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.

Tel.: (8 5) 274 4952, (8 5) 274 4956; faksas (8 5) 270 0112;

el. paštas doktor@adm.vgtu.lt

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General characteristic of the dissertation

Topicality of the problem. Soil contamination by heavy metals is one of the major environmental problems all over the world. The interspherical transport and accumulation of chemical elements depends on a range of factors such as meteorological conditions, chemical and mineralogical composition of parent rocks, granulometric composition of soil and pH of its solution, sorption, content of organic matters and other. Soil is contaminated by acid rains, emissions from boiler-houses, and gases contaminated by heavy metals emitted from means of transport. The major part of heavy metals enters the surface of soil together with dust and precipitation, especially at the beginning of rain, both directly and indirectly. This precipitation also contains harmless compounds, however, toxic and harmful compounds, that cause various diseases and mutations, form the biggest part of it. Lead, mercury, cadmium and zinc are considered the most toxic compounds. A considerable amount of heavy metals is found in hard and non-burnt particles such as smut, ashes and slag. The majority of heavy metals, including mercury, lead, cadmium, chromium, copper, nickel, zinc, cobalt, vanadium, molybdenum, beryllium, uranium, strontium, arsenic and others, have all or at least several properties that negatively affect health including carcinogenic, mutagenic, teratogenic, gonadotoxic, embriotoxic, nephrologic and neurotoxic effects. The synergetic effect of heavy metals is especially harmful when values of its separate concentrations do not exceed the normative values. Depending on the soil properties and humidity level these substances may increase acidification or alkalinisation of soil and cause intoxication or diseases to live organisms. Currently many countries carry out ecogeochemical and geohygienic researches in residential and natural environments. As a rule, this is the geochemical analysis of the surface layer of soil showing the total technogenic load of contaminants, including the atmospheric one. Countries where a snow cover remains longer analyze dust and water from melted snow. The findings of such analyses allow us judging about the real structure of contamination and potential possibilities of self-decontamination, as well as help to identify the contaminants and a radius of their influence according to the characteristic spectrum of elements.

Heavy metals in wayside soils make harm to flora and fauna living in this soil. In water cluster stretched near the roads are observed higher concentrations of heavy metals which make harm to fauna living there. Trained territories make harm to human too. Therefore, the contents of heavy metals are measured on a regular basis, and Lithuania as well as other countries look for effective ways of reducing their contents in soil.

Aim and task of the work. The main objectives of this research are the following:

1. With the help of experimental research, to evaluate the growth of perennial ryegrass (*Lolium perenne* L.), meadow-grass (*Poa pratensis* L.) and fescue grass (*Festuca pratensis* Huds.) and their ability to absorb heavy metals (Cu, Cr, Zn, Pb, Mn and Ni) from soil at different concentrations of metals.
2. To evaluate the influence of a mixture of heavy metals (Cu, Cr, Zn, Pb, Mn, Ni) on the physiological processes and morphologic parameters of whitebait of the rainbow trout.
3. To model how heavy metals access perennial ryegrass, meadow-grass and fescue grass and possibilities of soil decontamination based on the findings of the analyses carried out.
4. To present scientifically proved propositions on roadside soil decontamination from heavy metals using a mixture of grassy plants of different compositions.

The tasks are:

1. To carry out experiments on the penetration of heavy metals (Cu, Cr, Zn, Pb, Mn, Ni) into the selected grassy plants (perennial ryegrass, meadow grass, fescue grass) with different concentrations of metals in soil and determine the stage of growth when heavy metals are most effectively absorbed.
2. Based on the research findings, to compose a mixture of grassy plants that absorb heavy metals from soil to the best extent.
3. To examine the influence of the model mixture of heavy metals on the physiological and morphological indices of the rainbow trout.
4. To apply mathematical models of the penetration of heavy metals from soil to vegetation, which help to model the transport of heavy metals from soil to vegetation and evaluate the possibilities of soil decontamination from heavy metals by using the mixture of grassy plants.

Scientific novelty. Through the employment of complex environmental research, i.e. theoretical, experimental and mathematical modelling, to examine the ability of the most common roadside plants to absorb heavy metals from soil in this way decontaminating it, to evaluate the influence of heavy metals on the rainbow trout and prepare recommendations on the bioremediation of soil with the help of roadside plants.

With this aim in view the following has been performed.

- ✓ The ability of grassy plants to absorb heavy metals has been analyzed.
- ✓ The influence of heavy metals on the rainbow trout has been evaluated.
- ✓ Through the employment of mathematical modelling programs, the theoretical model of penetration of heavy metals from soil to the grassy

plants has been designed and it allows us to perform mathematical calculations of possible contaminants' spread and possibilities of soil decontamination.

- ✓ The method of reduction of soil contamination with heavy metals using grassy plants has been proposed.

Methodology of research includes the detection of heavy metals (Cu, Zn, Cr, Ni, Pb) in soil and grassy plants by using an atomic absorption spectrometer (USA) set in flame mode (the substance was mineralized in the Sector of Chemical Analysis of the Institute of Botany, the analysis under AAS method was carried out at the Department of Chemical Analysis of Vilnius University Faculty of Chemistry and at the Norwegian University of Life Sciences).

Practical value. The properties of phytoremediation method (bioremediation) were analyzed, research into grassy plants was carried out and the ability of plants to absorb metals from soil was observed. Based on the findings of the analyses, a mixture of grassy plants that efficiently decontaminated soil from heavy metals was formed.

Proposals on the decontamination of roadside soil by applying the method of phytoremediation and selection of the best grassy plant species under Lithuania's conditions have been worked out.

Part of the dissertation's research was carried out under the international Cost program No. 859 "Phytotechnologies to promote sustainable land use and improve food safety" and the project "Contaminants in the system "soil-plants": contaminants transport, accumulation and soil remediation".

Part of the research, during which concentrations of heavy metals in soil and grassy plants were determined, were carried out during a traineeship at the Norwegian University of Life Sciences.

Defended propositions

1. Part of heavy metals (Cu, Cr, Zn, Pb, Mn, Ni) concentrates in the roots of grassy plants when plants absorb heavy metals from soil, however, the major part of metals (up to 90 %) enter the above-ground part of the plant;
2. The highest concentration of heavy metals in a plant (from 60 % and more) and the most efficient soil cleaning, respectively, was determined in the case of perennial ryegrass, thus, the major part (80 %) of mixture consists of this plant;
3. The mixture of heavy metals has a negative influence on physiological and morphological parameters of the whitebait of the rainbow trout, therefore, the increase of concentrations of heavy metals (up to 0.198–5.12 g/l) is lethal to the rainbow trout and other aquatic animals.

4. The modelling of penetration of heavy metals from soil to the grassy plants demonstrates the possibilities of soil decontamination from heavy metals in a period of 10 years.

The scope of the scientific work. The scientific work consist of the general characteristic of the dissertation, 4 chapters, conclusions, list of literature, list of publications. The total scope of the dissertation – 158 pages, 89 pictures and 7 tables.

Short content of the dissertation

1. The influence of heavy metals on soil, flora and fish

The findings of researches carried out in different countries show that the factors of plants that influence the removal of some contaminants from soil may also be effective in removing other contaminants too. The findings also demonstrate that plant growth in soil contaminated with copper can be controlled by changing the essential “macro chemical” soil properties, for example, pH. Plants can assimilate a small amount of micro and macro elements without being significantly affected by their toxicity. It has been proved that there is a direct relation among nickel concentrations in plants and the worsening of yield as well as the morphological and anatomical consequences in plants. The method of phytoremediation, proposed by scientists, has not received a wide application yet and the possibilities of its application are still under formation. However, this is one of the most prospective methods for soil cleaning due to conditionally low cost and a fairly efficient cleaning of the surface layer of soil.

The analyzed roadside soils differ by their physical and chemical properties, which for the most part predetermines the concentrations of heavy metals in them. Lead, zinc, cadmium and copper tend to accumulate in the upper layer of 0–5 cm and in up to 15–25 m distance off the road in non-arable soil (meadows and pastures). Metals are found in the deeper layers (up to 20 cm) only close to highways in 5 to 15 m off the roadside. Contaminants from means of transport do not always influence the concentrations of heavy metals in plants because soil unevenly absorbs contaminants and their content in plants depends not only on their content in soil but also on the physical and chemical properties of soil and the age of plants.

With the aim to determine the influence of heavy metal concentrations on the morphological, physiological and behavioural parameters of the trout, the analyzed rainbow trout were affected by the mixtures of heavy metals having similar concentrations. The parameters analyzed had different characteristics of

sensitivity. Concentrations of haemoglobin and glucoses were the most sensitive among the haematological rates. Changes of tissue somatic indices were the most sensitive among the morphological parameters. They show the organs – targets and systems of organism that are affected by contaminants to the greatest extent.

2. Research in the application of roadside flora for soil renewal

Perennial ryegrass (*Lolium perenne* L.) is a species of grass that belongs to *Gramineae* family. It grows up to 15–90 cm high and is a valuable perennial feeding plant.

Meadow-grass (*Poa pratensis* L.) is a species of grass that belongs to *Gremineae* family. This is a perennial, rarely annual, grass. It is most common in moderate and cold climate zones and mountains in the tropical zone. Meadow grass grows up to 30–90 cm height. Its leaves are flat and narrow and the panicle is up to 20 cm long.

Fescue grass (*Festuca pratensis* Huds.) is a species of perennial grass that belongs to *Gremineae* family. Its stem reaches the height of 50–100 cm. The leaves are flat and 3–5 mm in width with a roughish upside. The plant is resistant to cold weather, mostly found in humid and fertile areas.

The experiment was carried using pots containing 0.5 kg of uncontaminated soil, each. The composition of clean soil is the following:

- ✓ Ph (CaCl_2) – 5.0–6.0;
- ✓ The amount of salts is 1.5 g/l;
- ✓ Nutritional substances include the following: Nitrogen (N) – 150–300 mg/l, phosphate (P_2O_5) – 150–300 mg/l, kali (K_2O) – 200–300 mg/l.

10 g of seeds of each species was poured into each pot. Clean soil was used for growing control plants. Seeds of each plant were seeded into clean soil, into soil contaminated by heavy metals once, and into soil which was periodically contaminated by heavy metals.

In order the plant could grow and all the necessary physiological processes could take place, plants need humidity, therefore, grassy plants were watered every 5 days. Control plants and those grown in soil contaminated once were watered with 200 ml of distilled water, while plants grown in soil, periodically contaminated by heavy metals were watered with 200 ml of mixture of heavy metals. The sustained temperature was 22–24 °C, the lighting was natural.

The experiment lasted for 3 months. Every two weeks part of meadow-grass, perennial rye-grass and fescue-grass were rooted out, prepared for analysis and then analyzed.

2.1. The evaluation of the contents of heavy metals in soil by using grassy plants

The rye-grass, meadow-grass and fescue-grass selected for the absorption of heavy metals were grown in clean soil, soil contaminated with heavy metals once and soil which was periodically contaminated by heavy metals of different metal concentrations in soil. The results of the analysis show that all the selected grassy plants absorbed those heavy metals which are the most common in roadside soils, i.e. copper, lead, zinc, nickel, manganese and chromium.

The concentrations in soil obtained after contamination with a mixture of heavy metals of low concentrations once: Cu – 0.5 mg/kg; Pb – 3.5 mg/kg; Mn – 25 mg/kg; Zn – 0.88 mg/kg; Ni – 0.63 mg/kg; Cr – 1.81 mg/kg. The concentrations in soil which was periodically contaminated by heavy metals: Cu – 0.75 mg/kg; Pb – 4.38 mg/kg; Mn – 120 mg/kg; Zn – 2.12 mg/kg; Ni – 3.38 mg/kg; Cr – 7.0 mg/kg. The concentrations in soil obtained after contamination once with a mixture of heavy metals of average concentrations: Cu – 20 mg/kg; Pb – 5.0 mg/kg; Mn – 12.4 mg/kg; Zn – 11.5 mg/kg; Ni – 3.0 mg/kg; Cr – 2.3 mg/kg. The concentrations in soil which was periodically contaminated with heavy metals: Cu – 84 mg/kg; Pb – 160 mg/kg; Mn – 162 mg/kg; Zn – 395 mg/kg; Ni – 26 mg/kg; Cr – 45 mg/kg. Soil was contaminated with especially high concentrations of heavy metals during the experimental research was carried out at the Norwegian University of Life Sciences: Cu – 700 mg/kg; Pb – 994.3 mg/kg; Mn – 6.850 mg/kg; Zn – 1.435 mg/kg; Ni – 374.56 mg/kg; Cr – 1.875 mg/kg. Results obtained from the experimental research when soil was contaminated once with concentrations of heavy metals and absorption possibilities observed in grassy plants: Cu – 9.25 mg/kg; Pb – 10.15 mg/kg; Mn – 502.5 mg/kg; Zn – 25 mg/kg; Ni – 4 mg/kg; Cr – 14.5 mg/kg. Concentrations in soil which was periodically contaminated with heavy metals: Cu – 46.5 mg/kg; Pb – 56 mg/kg; Mn – 2751.5 mg/kg; Zn – 176 mg/kg; Ni – 4.65 mg/kg; Cr – 79.5 mg/kg.

The best absorption of heavy metals was noticed in the rye-grass. It removed copper from soil up to 42 %, lead – up to 77 %, manganese – up to 32 %, zinc – up to 50 % and chromium – up to 33 % when soil was contained by low concentrations of heavy metals. Fescue-grass was the most efficient in decontaminating soil from nickel – by up to 64 %. Meadow-grass removed a similar amount of copper as the perennial rye-grass but a lower amount of other metals.

Ryegrass absorbed the major part of heavy metals from soil contaminated with average concentrations of metals. It decontaminated soil from copper by

up to 94 %, lead by up to 40 %, manganese by up to 69 %, zinc by up to 90 % and chromium by up to 80 %. Fescue-grass was more efficient in decontaminating soil from nickel – by up to 85 %. Meadow-grass absorbed similar amounts of heavy metals as fescue-grass except for nickel. Concentration of nickel in soil was significantly lower after the decontamination – 55 % less compared to non-cleaned soil.

Rye-grass was the most efficient in decontaminating soil from high concentrations of heavy metals. It decontaminated soil from copper by up to 48 %, lead by up to 40 %, manganese by up to 50 %, zinc by up to 57 %, nickel by up to 62 % and chromium by up to 75 %. Meadow-grass removed a similar amount of copper and zinc as the ryegrass but removed a lower amount of manganese. Fescue-grass removed a lowest amount of lead from soil – only 4 % compared to non-cleaned soil.

Perennial ryegrass absorbs the major part of heavy metals from soil and soil decontamination was the most efficient when using this grassy plant, thus, the mixture of grassy plants contained 80 % of the ryegrass and 10 % of fescue grass and meadow-grass, each.

2.2. Evaluation of the amounts of heavy metals in soil by using the mixture of grassy plants

The copper concentration of 46.5 mg/kg was determined in soil periodically contaminated. The mixture of plants grown in the periodically contaminated soil contained 30.38 mg/kg of copper. Concentration of copper that remained in soil after the cleaning was 23.75 mg/kg. This concentration was 1.9 times lower than the concentration of copper in non-cleaned soil.

Concentration of lead in soil contaminated periodically was 56 mg/kg. The amount of lead decreased to 25.85 mg/kg after soil was cleaned with the grassy plants. This concentration was 2.1 times lower than the concentration of lead in non-cleaned soil. The mixture of plants grown in the periodically contaminated soil contained 26.3 mg/kg of lead. The obtained results show that this mixture of plants reduced the concentration of lead by up to 50 % compared to the uncleaned soil.

The concentration of manganese amounted 2751.5 mg/kg in the periodically contaminated soil. The concentration of copper in soil decreased almost 9 times, that is up to 308.5 mg/kg when the periodically contaminated soil was cleaned with the mixture of grassy plants. The concentration of manganese amounted 1.562.5 mg/kg in the grassy plants. The results obtained show that up to 88 % of chromium was removed from the periodically

contaminated soil by using the mixture of grassy plants compared to the amount of this metal in the non-cleaned soil (Fig 2.1).

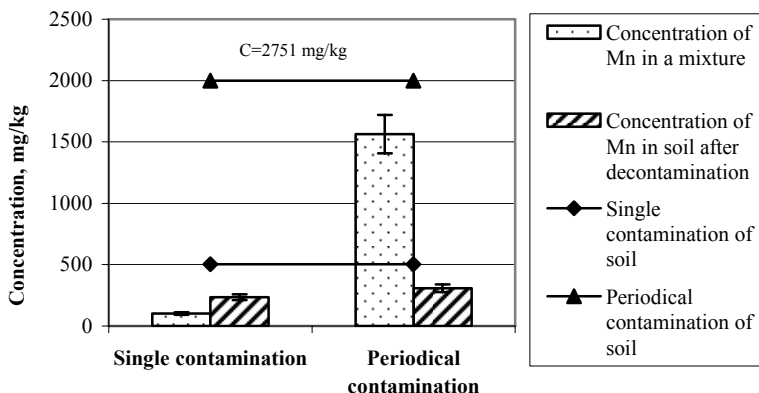


Fig 2.1. Soil decontamination from manganese by using the mixture of grassy plants

The concentration of zinc in soil contaminated periodically was 176 mg/kg. The mixture of plants grown in the periodically contaminated soil contained 104 mg/kg of zinc and the amount of zinc decreased to 95.7 mg/kg in soil where the plants grew. The selected mixture of grassy plants removed up to 54 % of zinc from the periodically contaminated soil compared to the initial contamination of soil.

The concentration of nickel was 4.65 mg/kg in soil, which was contaminated periodically. After the experiment the amount of nickel decreased to 2.31 mg/kg in soil and 3.94 mg/kg of zinc was found in the mixture of grassy plants.

The concentration of chromium decreased almost 10 times, i.e. 7.8 mg/kg in the periodically contaminated soil which was cleaned with the selected mixture of plants. The concentration of chromium amounted 26.63 mg/kg in the grassy plants. According to the results obtained, up to 89 % of chromium was removed from the periodically contaminated soil by using the mixture of grassy plants compared to the amount of this metal in the non-cleaned soil.

3. The influence of heavy metals on the rainbow trout

The main goal of applying biologic tests is to operatively determine the degree of toxicity of contaminants, natural and sewage waters and bottom sediments in order the lowest possible amount of contaminants enters the

environment, try to strengthen the control of contamination and to ensure the efficiency of sewage treatment to maintain the present quality of the natural water sources.

$0.84 \pm 0.02 \cdot 10^6$ l was the highest amount of red blood cells determined in blood of the whitebait of the rainbow trout which lived in water contaminated with 5.7 ml of mixture of heavy metals. This red count was the most similar to the red count of control fish, while the red count of fish in other aquariums was lower than that of the control fish.

The amount of haematocrit in the blood of the control rainbow trout's whitebait reached 0.42 ± 0.002 l/l. The highest amount of haematocrit was found in the blood of fish which lived in the water contaminated with 5.7 ml of mixture of heavy metals, i.e. 0.48 ± 0.0017 l/l, while 0.38 ± 0.007 l/l was the least amount of haematocrit found in the blood of the rainbow trout whitebait which lived in the water contaminated with 26 ml of heavy metals.

The determined amount of leucocytes in the blood of all the rainbow trout whitebait which lived in the contaminated water was higher than that of the control fish. The average amount of leucocytes in the blood of the control fish was $22.1 \pm 1.79 \cdot 10^3$ l, the highest amount of leucocytes was found in the blood of the fish which lived in the water contaminated with 5.7 ml of heavy metals and reached $36.0 \pm 0.036 \cdot 10^3$ l (Fig 3.1).

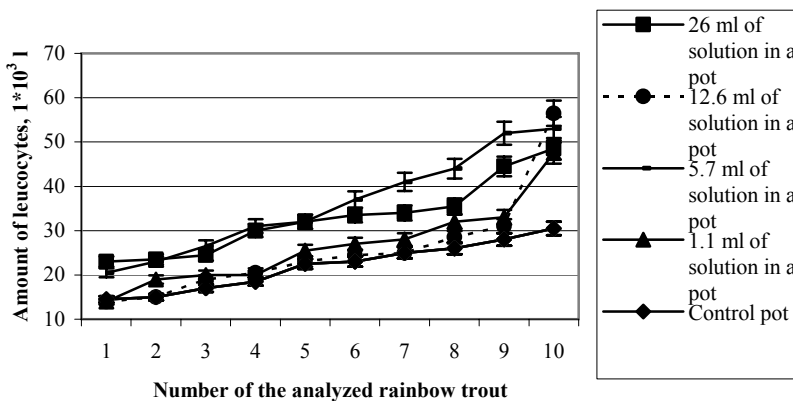


Fig 3.1. The average amount of leucocytes in the blood of the rainbow trout

The mass of the whitebait of the rainbow trout was similar. The mass of the fish in the control aquarium was 22.26 ± 0.68 g. The highest mass of the rainbow trout was determined in the aquarium with 12.6 ml of solution of heavy

metals, that is 3.23 ± 0.81 g. 22.02 ± 0.7 g was the lowest mass of the fish which lived in the water contaminated with 5.7 ml of heavy metals.

The length of all the observed fish was similar. The average length of the control rainbow trout was 11.76 ± 0.19 cm. Fish that lived in the aquarium contaminated with a 12.6 ml solution of heavy metals were the longest, i.e. 11.95 ± 0.16 cm, while fish that lived in the water with a 12.6 ml solution of heavy metals were the shortest 11.62 ± 0.17 cm.

The mass of liver of the whitebait which lived in a control aquarium reached 0.383 ± 0.02 g. Fish that lived in the water contaminated with a 5.7 ml solution of heavy metals had the biggest liver, i.e. 0.40 ± 0.01 g, while fish that lived in the water contaminated with a 26 ml solution of heavy metals had the smallest liver, i.e. 0.32 ± 0.01 .

1.60 ± 0.09 was the lowest somatic parameter of liver determined in fish that lived in the water contaminated with a 26 ml solution of heavy metals. 2.05 ± 0.07 was the highest somatic parameter of liver determined in the fish that lived in the water contaminated with a 5.7 ml solution of heavy metals. The somatic parameter of liver of fish that lived in the control aquarium was 1.92 ± 0.08 .

4. Mathematical modelling of penetration of heavy metals from soil into plants

The program of the mathematic modelling REC (Risk Reduction, Environmental Merit and Cost) is based on a comparison of alternative cleaning technologies for cleaning the contaminated area. The aim of the REC program is to apply effective and efficient technologies of soil cleaning. The application of the mathematical modelling program REC v4_rural is used to model a period of time during which heavy metals may be totally removed from soil by using the mixture of grassy plants. The chosen period of decontamination is 10 years. In this period soil was not contaminated additionally.

The set initial concentrations of heavy metals (copper, lead, manganese, zinc, nickel and chromium) during the program were concentrations used during the experimental analysis when the efficiency of remediation of soil quality was examined using the mixture of the grassy plants.

Practically, within the period of 10 years soil would be decontaminated from copper and lead. The most significant decontamination from both metals occurs in the first 6 years by using the mixture of the grassy plants when higher concentrations of these metals are determined in soil (Fig 4.1). Higher concentrations are also found in the mixture of the grassy plants.

Manganese and zinc are fully removed from soil faster than in 10 years. In the case of manganese, the zero concentration in soil is reached after 8 years, that of zinc – after 9 years of cleaning soil with the mixture of the grassy plants and without additional contamination of soil.

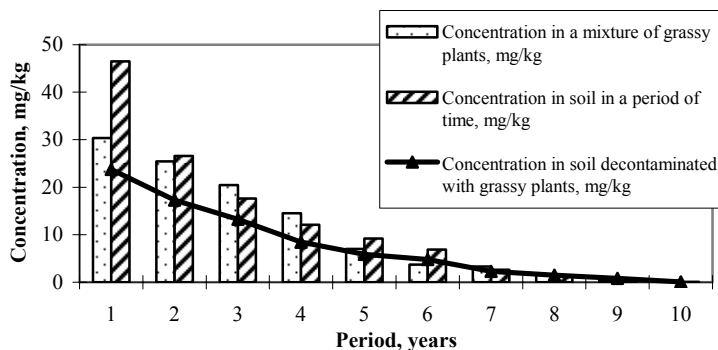


Fig 4.1. Soil decontamination from copper in the course of time

The quickest soil decontamination is reached with regard to nickel – 6 years. Chromium would be totally removed from soil in 7 years when its initial concentration is 79.5 mg/kg (Fig 4.2).

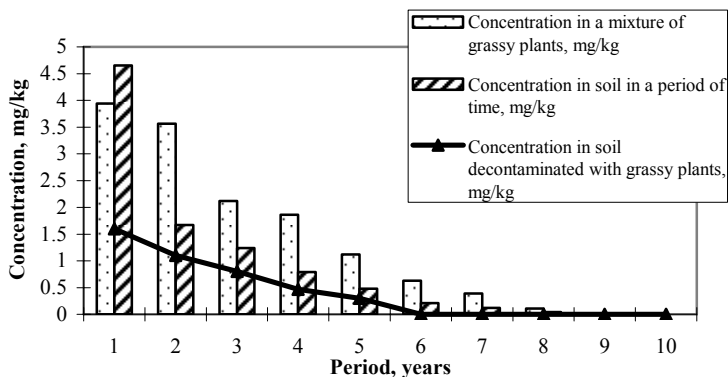


Fig 4.2. Soil decontamination from nickel in the course of time

Based on the results obtained, it can be stated that the quality of soil remediation is efficient enough when using the mixture of the grassy plants for cleaning soil from heavy metals.

Conclusions and recommendations

1. The analysis of the current methods of soil cleaning from heavy metals leads to conclusions that phytoremediation, i.e. soil decontamination by using plants, is one of the best methods. Although this method has not received a wide application yet and possibilities of its application are still being analysed, it is one of the most prospective soil cleaning methods due to low cost and a rather efficient cleaning of the upper surface of soil.
2. The results of experiments show that the selected grassy plants (perennial ryegrass, meadow-grass and fescue-grass) efficiently clean soil from heavy metals (copper, lead, manganese, zinc, nickel and chromium) when soil contains both low (0.5–120 mg/kg) and high (up to 6,850 mg/kg) concentrations of these metals. Since the perennial ryegrass absorbs the highest amount of heavy metals, the highest efficiency of soil cleaning is achieved using this plant, therefore, 80 % of the mixture of grassy plants was formed of the perennial ryegrass and 10 % of fescue-grass and meadow-grass, each.
3. The results of experimental research demonstrate that the perennial ryegrass is able to remediate soil and remove the average amount of heavy metals, that is up to 52 % of copper, up to 52 % of lead, 50 % of manganese, 66 % of zinc, 42 % of nickel, and 62 % of chromium. When soil is cleaned with fescue-grass, the process of soil decontamination is slower compared to soil cleaning with the perennial ryegrass; an exception is nickel, which is removed from soil by up to 66 % in comparison with the primary contamination of soil. Fescue-grass removes up to 35 % of copper, up to 33 % of lead, up to 35 % of manganese, up to 36 % of zinc and up to 46 % of chromium.
4. Based on the experimental research it was established that meadow-grass removed the lower amount of metals compared to the perennial ryegrass, however, higher concentrations (up to 6,850 mg/kg) of heavy metals were efficiently removed from soil by the meadow-grass: soil was decontaminated by up to 33 % of copper, up to 34 % of lead, up to 33 % of manganese, up to 47 % of zinc, up to 41 % of nickel and up to 44 % of chromium compared to concentrations of heavy metals in uncleaned soil.
5. The experiments with the mixture of grassy plants demonstrated that the mixture removed up to 50 % of copper, lead and nickel, up to 54 % of zinc

and up to 88 % of manganese and chromium in comparison with concentrations of metals in the uncleaned soil.

6. The experiments were carried out in order to find out how concentrations of heavy metals have a negative impact on hydrobionts; it was established that the increase of concentrations of metals (up to 0,198–5,12 g/l) is lethal to the rainbow trout and other water animals as well.
7. The results of experiments with the rainbow trout showed that fish which lived in water contaminated with a 5.7 ml mixture of heavy metals had an increased amount of red blood cells, white blood cells and haematocrit, which is caused by heavy metals. The mass of liver of the fish, which lived in this water, was the biggest compared with the fish, which lived in a control aquarium.
8. Results obtained with the program of mathematical modelling REC show that when the method of phytoremediation is applied, 10 years, i.e. the entire period analysed, would be necessary to clean soil from copper and lead to the lowest concentrations. Manganese is totally removed from soil after 8 years, while zinc is removed after 9 years when soil is cleaned with the mixture of grassy plants and is not additionally contaminated. Nickel is the metal which is removed from soil in the shortest period, i.e. 6 years. The concentration of chromium in soil reaches zero after 7 years.
9. The research findings show that the mixture of the grassy plants (80 % of perennial rye-grass, 10 % of meadow-grass and 10 % of fescue grass) is effective in cleaning soil from heavy metals most frequently encountered in roadside soil. Thus, the recommendation is to seed this mixture along the roadsides of highways and roads.
10. It was established that the highest efficiency of grassy plants was achieved during the growth of plants. Therefore, roadsides where these plants grow are recommended to be mowed down every 2 months, and in this way a bigger content of heavy metals together with nutritious substances is transferred from roots to the above-ground part of plants when biochemical processes take place.
11. The recommendation is to collect mowed down mixture of grassy plants and have it burnt in special burning facilities where emissions are cleaned of solid particles. This will prevent heavy metals from accessing the environment.

List of published works on the topic of the dissertation

In the scientific periodical publications included ISI Master List

1. VOSYLIENĖ, M. Z.; JANKAITĖ, A. Effect of heavy metal model mixture on rainbow trout biological parameters. *Ekologija*, 2006, Nr. 4, p. 12–17.

In the reviewed scientific periodical publications

2. Baltrėnas, P.; Jankaitė, A. Research of distribution of heavy metals in soil of National park of Lithuania. *Геоэкология. Инженерная геология. Гидрогеология, геоэкология*. 2006, №. 4, с. 371–374 (in Russian).
3. Baltrėnas, P.; Jankaitė, A. Research of impurity by heavy metals of soil along highway Via Baltica. *Экология и промышленность России (ЭКПП)*. Москва, 2003, Август, с. 41–44 (in Russian).
4. JANKAITĖ, A.; VASAREVIČIUS, S. Remediation technologies for soils contaminated with heavy metals. *Journal of Environmental Engineering and Landscape Management*, 2005, Vol XIII, No 2, p. 109a – 113a.
5. BALTRĖNAS, P.; KLIAUGIENĖ, E.; JANKAITĖ, A. Soil pollution with heavy metals near Via Baltica highway and Klaipėda ringabout. *Journal of Environmental Engineering and Landscape Management*, 2003, XI t., supplement 1, p. 3–10 (in Lithuanian).

In the other editions

6. JANKAITĖ, A.; VASAREVIČIUS, S. Fescue grass ability to absorb heavy metals from soil. In *Proceedings of Diffpolmine Conference, which took place on 12-14 December*, in Montpellier, France, 2006, p. 1–7.
7. JANKAITĖ, A.; VASAREVIČIUS, S. Grassy vegetation ability to accumulate manganese from soil. In *Environmental Protection Engineering. Reports from 10th Lithuanian Conference of Junior Researchers „Science – future of Lithuania“*. Vilnius: Technika, 2007, p. 101–107 (in Lithuanian).
8. JANKAITĖ, A.; VASAREVIČIUS, S. Investigation of heavy metals uptake by bluegrass (*Poa pratensis* L.) from soil. In *Environmental Protection Engineering. Reports from 10th Lithuanian Conference of Junior Researchers „Science – future of Lithuania“*. Vilnius: Technika, 2006, p. 318–323 (in Lithuanian).
9. JANKAITĖ, A.; VASAREVIČIUS, S. Test of seeds growth ecological factors. In *Environmental Protection Engineering. Reports from 8th Lithuanian Conference of Junior Researchers „Lithuania without Science – Lithuania without future“*. Vilnius: Technika, 2005, p. 200–204 (in Lithuanian).
10. JANKAITĖ, A.; VASAREVIČIUS, S. Heavy metals in Lithuanian roadsides soils and vegetation. In *Environmental Protection Engineering. Reports from 7th Lithuanian Conference of Junior Researchers „Lithuania without Science – Lithuania without future“*. Vilnius: Technika, 2004, p. 381–388 (in Lithuanian).
11. JANKAITĖ, A.; VASAREVIČIUS, S. Motor transport influence for the soil pollution over Via Baltica and Vilnius – Panevėžys highways. In *Environmental Protection Engineering. Reports from 6th Lithuanian*

Conference of Junior Researchers „Lithuania without Science – Lithuania without future“. Vilnius: Technika, 2003, p. 352–358 (in Lithuanian).

About the author

Audronė Jankaitė was born on 1 June 1979 in Kėdainiai.

She acquired the Bachelor's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 2001, and Master's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 2003. In the period of 2002–2003, she was employed at the Institute of Environment Protection, in the period of 2003–2007 was a doctoral student at Vilnius Gediminas Technical University. Audronė Jankaitė was on a traineeship at the Norwegian University of Life Sciences. Presently, Audronė Jankaitė is employed in the position of Assistant at Vilnius Gediminas Technical University Department of Environment Protection.

SUNKIŲJŲ METALŲ PAKELĖSE TYRIMAI IR ĮTAKOS APLINKAI VERTINIMAS

Mokslo problemos aktualumas. Tarša sunkiaisiais metalais yra viena svarbiausių ekologinių problemų visame pasaulyje. Tarpsferinė cheminių elementų migracija ir akumuliacija priklauso nuo gausybės aplinkos veiksnių, tokių kaip meteorologinės sąlygos, dirvodarinių uolienų cheminės ir mineraloginės sudėties, dirvožemio granulometrinės sudėties, jos tirpalo pH, sorbcijos, organinių medžiagų kiekio ir kt. Dirvožemį teršia rūgštūs lietūs, katilinių emisijos, autotransporto išmetamos dujos su sunkiaisiais metalais. Žymi dalis sunkiųjų metalų, dažniausiai su dulkėmis, o taip pat ir su krituliais, ypač lietaus pradžioje, patenka ant dirvožemio dangos tiek tiesiogiai, tiek ir netiesiogiai. Šiose iškritose yra ir nekenksmingų junginių, tačiau nemažą dalį sudaro toksiški ir pavojingi junginiai, sukeliantys įvairias ligas bei mutacijas. Toksiškiausiems junginiams priklauso švinas, gyvsidabris, kadmis ir cinkas. Gana daug sunkiųjų metalų yra kietose, nesudegusiose dalelėse, tokiose kaip smėliai, pelenai, šlakas. Dauguma sunkiųjų metalų – gyvsidabris, švinas, kadmis, chromas, varis, nikelis, cinkas, kobaltas, vanadis, molibdenas, berilis, uranas, stroncis, arsenas ir daugelis kitų – pasižymi visomis arba bent keliomis neigiamo poveikio sveikatai savybėmis. Jie veikia kancerogeniškai, mutageniškai, teratogeniškai, taip pat gonadotoksiškai, embriotoksiškai, nefrotoksiškai, neurotoksiškai. Ypač pavojingas bendras, sinergetinis metalų poveikis, kai žala realizuojama atskiroms jų koncentracijoms esant ne didesnėms už normatyvines reikšmes. Priklausomai nuo dirvožemio savybių ir

drėgmės režimo šios medžiagos gali sukelti dirvožemio parūgštėjimą arba pašarmėjimą, tapti įvairių gyvųjų organizmų apsinuodijimų arba ligų priežastimi. Šiuo metu daugelyje pasaulio šalių yra vykdomi gyvenamosios ir gamtinės aplinkos ekogeocheminiai ir geohigieniniai tyrimai. Dažniausiai tai dirvožemio paviršinio sluoksnio, atspindinčio bendrą technogeninę teršalų apkrovą, įskaitant ir atmosferinę, geocheminę analizę. O tose šalyse, kur ilgiau išsilaiko susiformavusi sniego danga – surinktų iš jos dulkių ir sniego tirpimo vandens tyrimai. Iš jų rezultatų galima ne tik spręsti apie realią užterštumo struktūrą ir potencines savivalos galimybes, bet ir identifikuoti pagal būdingą elementų spektrą potencialius teršėjus bei jų įtakos spindulį.

Magistralinių bei rajoninių kelių pakelių dirvožemyje kaupiasi sunkieji metalai, kurie kenkia tiek augalijai, tiek pedobiontams. Vandens telkiniuose, esančiuose šalia pakelių taip pat pastebimi didesni sunkiųjų metalų kiekiai, kenkiantys hidrobiontams. Užterštos teritorijos kelia pavojų žmonių sveikatai, riboja galimą žemės nuosavybės naudojimą. Būtent dėl šių priežasčių sunkiųjų metalų kiekiai yra nuolat matuojami ir bandoma ieškoti būdų, kaip kuo efektyviau sumažinti jų kiekius mus supančioje aplinkoje ne tik Lietuvoje, bet ir visame pasaulyje.

Darbo tikslai

1. Atliekant eksperimentinius tyrimus įvertinti žolinės augalijos – daugiametės svidrės (*Lolium perenne L.*), pievinės miglės (*Poa pratensis L.*) ir tikrojo eraičio (*Festuca pratensis Huds.*) augimą ir gebėjimą sorbuoti sunkiuosius metalus Cu, Cr, Zn, Pb, Mn ir Ni iš dirvožemio esant skirtingoms jų koncentracijoms.
2. Įvertinti sunkiųjų metalų mišinio (Cu, Cr, Zn, Pb, Mn, Ni) įtaką vaivorykštinio upėtakio jaunikių fiziologiniams procesams ir morfologiniams rodikliams.
3. Remiantis atliktų tyrimų rezultatais sumodeliuoti sunkiųjų metalų patekimą į žolinės augalijos (svidrės, miglės ir eraičio) mišinį bei dirvožemio išvalymo galimybes.
4. Remiantis atliktais tyrimais paruošti moksliskai pagrįstus pasiūlymus pakelių dirvožemio valymui nuo sunkiųjų metalų naudojant įvairios sudėties žolinės augalijos mišinį.

Pagrindiniai darbo uždaviniai

1. Atlikti sunkiųjų metalų (Cu, Cr, Zn, Pb, Mn, Ni) skverbimosi į pasirinktą žolinę augaliją (svidrę, miglę, eraičią) eksperimentinius tyrimus esant skirtingoms metalų koncentracijoms dirvožemyje bei nustatyti, kurioje augalo vystymosi stadijoje geriausiai sorbuojami sunkieji metalai.
2. Pagal gautus tyrimo rezultatus sudaryti efektyviausiai sunkiuosius metalus iš dirvožemio sorbuojančios žolinės augalijos mišinį.

3. Naudojant sunkiųjų metalų modelinį mišinį, ištirti jo įtaką vaivorykštinio upėtakio fiziologiniams ir morfologiniams rodikliams.
4. Pritaikyti sunkiųjų metalų skverbimosi iš dirvožemio į augaliją matematinius modelius, leidžiančius modeliuoti sunkiųjų metalų migraciją iš dirvožemio į augaliją bei įvertinti dirvožemio išvalymo nuo sunkiųjų metalų, naudojant žolinės augalijos mišinį, galimybes

Mokslinis naujumas. Taikant kompleksinius aplinkosauginius tyrimus: teorinius, eksperimentinius ir matematinį modeliavimą, ištirti pakelėse dažniausiai naudojamos žolinės augalijos gebėjimą sorbuoti sunkiuosius metalus iš dirvožemio tokiu būdu vykdant dirvožemio valymą nuo jų, įvertinti sunkiųjų metalų įtaką vaivorykštiniam upėtakiui bei paruošti rekomendacijas dirvožemio biologiniam atstatymui naudojant pakelių augmeniją.

Tuo tikslu atlikta:

- ✓ ištirtas žolinės augmenijos gebėjimas sorbuoti sunkiuosius metalus;
- ✓ įvertintas sunkiųjų metalų poveikis vaivorykštiniam upėtakiui;
- ✓ naudojant matematinio modeliavimo programas parengtas teorinius sunkiųjų metalų skvarbos iš dirvožemio į augaliją modelis, leidžiantis matematiškai apskaičiuoti galimus teršalų išplitimo mastus bei dirvožemio išvalymo galimybes;
- ✓ pasiūlytas dirvožemio taršos sunkiaisiais metalais mažinimo būdas naudojant žolinę augaliją.

Tyrimų metodika apima sunkiųjų metalų (Cu, Zn, Cr, Ni, Pb) nustatymą atominės absorbcijos spektrometru (JAV) liepsnos režimu dirvožemyje ir žolinėje augalijoje (medžiaga mineralizuojama Botanikos instituto Cheminių analizių sektoriuje, analizavimas AAS metodu atliekamas VU Chemijos fakulteto Cheminės analizės katedroje bei Norvegijos gamtos mokslų universitete).

Praktinė vertė. Išnagrinėtos fitoremediacijos (biologinio atstatymo) metodo ypatybės, atlikti tyrimai su žoline augalija, kurių metu buvo stebimas žolinės augalijos gebėjimas sorbuoti metalus iš dirvožemio. Pagal gautus tyrimų rezultatus sudarytas žolinės augalijos mišinys, efektyviai valantis dirvožemį nuo sunkiųjų metalų.

Paruošti pasiūlymai pakelių dirvožemio valymui taikant fitoremediacijos metodą bei parenkant geriausias Lietuvos sąlygomis tam tinkančias žolinės augalijos rūšis.

Dalis disertacijos mokslinių tyrimų atlikti dalyvaujant tarptautinės *Cost programos Nr. 859 „Fitotechnologijos, siekiant vystyti darnų žemės naudojimą ir gerinti maisto saugumą“* veikloje, bei vykdant projektą „*Teršalai sistemoje „dirvožemis – augalai“: teršalų migracija, kaupimasis, dirvožemio atstatymas*“

Dalis tyrimų, kurių metu buvo nustatytos sunkiųjų metalų dirvožemyje ir žolinėje augalijoje koncentracijos, atlikti stažuotės Norvegijos gamtos mokslų universitete metu.

Ginamieji darbo teiginiai

1. Augalijai sorbuojant sunkiuosius metalus iš dirvožemio dalis šių metalų (Cu, Cr, Zn, Pb, Mn, Ni) koncentruojasi žolinės augalijos šaknyse, tačiau didžioji dalis ten susikaupiančių metalų (iki 90 %) pereina į antžeminę augalo dalį.
2. Didžiausios sunkiųjų metalų koncentracijos augale (iki 60 % daugiau) ir atitinkamai efektyviausias dirvožemio valymas nustatytas svidrės atveju, todėl sudarant mišinį didžiąją dalį (80 %) jame sudaro svidrė.
3. Sunkiųjų metalų mišinys daro neigiamą įtaką vaivorykštinio upėtakio jauniklių fiziologiniams ir morfologiniams rodikliams, todėl didinant sunkiųjų metalų mišinio koncentracijas (iki 0,198–5,12 g/l) jos tampa letalinėmis vaivorykštiniam upėtakiams, tuo pačiu ir kitiems vandens gyvūnams.
4. Modeliuojant sunkiųjų metalų skvarbą iš dirvožemio į žolinę augaliją gautieji rezultatai parodo dirvožemio išvalymo nuo sunkiųjų metalų galimybes per 10 metų.

Darbo apimtis – darbą sudaro bendra darbo charakteristika, 4 skyriai, išvados ir rekomendacijos, literatūros sąrašas, publikacijų sąrašas. Bendra disertacijos apimtis – 158 puslapiai, 89 iliustracijos, 7 lentelės.

Pirmame disertacijos skyriuje analizuojami pasaulyje vykdomi tyrimai dirvožemio atstatymo srityje, apžvelgiamos pagrindinės dirvožemio valymo technologijos, sunkiųjų metalų mobilumas, jų poveikis vaivorykštiniam upėtakiui, sunkiųjų metalų koncentracijos Lietuvos pakelių dirvožemiuose.

Antrame skyriuje pateikiama eksperimentinių tyrimų su žoline augalija metodika, dirvožemio išvalymo nuo sunkiųjų metalų galimybės naudojant tiek pavienes pasirinktos žolinės augalijos rūšis, tiek sudarytą procentinį mišinį iš tirtos žolinės augalijos.

Trečiame disertacijos skyriuje aptariami eksperimentiniai tyrimai, susiję su sunkiųjų metalų mišinio poveikiu test-organizmams – vaivorykštiniam upėtakiams.

Ketvirtame skyriuje pateikiamos dirvožemio išvalymo galimybės nuo sunkiųjų metalų laiko bėgyje taikant matematinį modeliavimą.

Bendrosios išvados ir rekomendacijos

1. Išanalizavus šiuo metu dirvožemio valymui nuo sunkiųjų metalų naudojamus metodus, galima daryti išvadą, kad vienas iš tinkamiausių

metodų yra fitoremediacija, t. y. dirvožemio valymas nuo teršalų panaudojant augalus. Šis metodas dar nėra plačiai taikomas ir jo taikymo galimybės dar tik tiriamos tačiau, tai vienas iš perspektyviausių dirvožemio valymo metodų dėl sąlyginai mažos kainos ir pakankamai efektyvaus paviršinio dirvožemio sluoksnio išvalymo.

2. Atliktų eksperimentinių tyrimų rezultatai parodė, kad pasirinkta žolinė augalija – daugiametė svidrė, pievinė miglė ir tikrasis eraičinas efektyviai valo dirvožemį nuo sunkiųjų metalų (vario, švino, mangano, cinko, nikelio, chromo) tiek esant mažoms (0,5–120 mg/kg), tiek didelėms (iki 6850 mg/kg) jų koncentracijoms dirvožemyje. Kadangi daugiausiai sunkiųjų metalų iš dirvožemio sorbuoja svidrė, tai dirvožemio valymo efektyvumas naudojant šią žolinės augalijos rūšį yra efektyviausias ir sudarant žolinės augalijos mišinį 80 % sudarė svidrė ir po 10 % eraičinas bei miglė.
3. Remiantis atliktų eksperimentinių tyrimų rezultatais galima teigti, kad dirvožemio atstatymui naudojant daugiametę svidrę dirvožemį nuo sunkiųjų metalų vidutiniškai galima išvalyti nuo vario iki 52 %, nuo švino – iki 52 %, nuo mangano – 50 %, nuo cinko – 66 %, nikelio – 42 %, chromo – 62 %. Naudojant tikrąjį eraičiną dirvožemio valymas nuo visų minėtų metalų vyksta silpniau nei naudojant svidrę, išskyrus nikelį – eraičinas nuo šio metalo dirvožemį išvalo iki 66 % lyginant su pradiniu dirvožemio užteršimu. Nuo vario eraičino pagalba dirvožemis vidutiniškai išvalomas iki 35 %, nuo švino – 33 %, nuo mangano – 35 %, nuo cinko – 36 %, nuo chromo – iki 46 %.
4. Remiantis eksperimentiniais tyrimais nustatyta, kad miglė sunkiuosius metalus valo blogiau nei svidrė, tačiau esant didelėms (iki 6850 mg/kg) jų koncentracijoms dirvožemyje panaudojus miglę sunkieji metalai iš dirvožemio šalinami pakankamai efektyviai: dirvožemis nuo vario vidutiniškai išvalomas iki 33 %, nuo švino – iki 34 %, nuo mangano – iki 33 %, nuo cinko – 47 %, nuo nikelio – 41 %, nuo chromo – 44 % palyginus su nevalytame dirvožemyje esančiomis sunkiųjų metalų koncentracijomis.
5. Atlikus eksperimentus su žolinės augalijos mišiniu nustatyta, kad žolinės augalijos mišinys užterštą dirvožemį nuo vario, švino ir nikelio išvalo iki 50 %, nuo cinko – 54 %, nuo mangano ir chromo – iki 88 % lyginant su nevalytame dirvožemyje esančiomis sunkiųjų metalų koncentracijomis.
6. Eksperimentų metu tirta, kaip sunkiųjų metalų mišinio koncentracijos kenkia hidrobiontams ir nustatyta, kad didinat sunkiųjų metalų mišinio koncentracijas (iki 0,198–5,12 g/l) jos tampa letalinėmis vaivorykštiniam upėtakiui, tuo pačiu ir kitiems vandens gyvūnams.
7. Pagal tyrimų su vaivorykštiniais upėtakis rezultatus nustatyta, kad stebimų upėtakių, gyvenusių akvariume, užterštame 5,7 ml sunkiųjų metalų mišinio

tirpalu, kraujyje nustatytas padidėjęs eritrocitų, leukocitų ir hematokrito kiekis, kurį sukelia tirpale esantys sunkieji metalai. Šiame akvariume stebimų žuvų kepenų masė didžiausia lyginant su kontroliniame inde gyvenusiomis žuvimis.

8. Taikant matematinio modeliavimo programą REC nustatyta, kad naudojant fitoremediacijos metodą dirvožemis nuo vario ir švino iki sąlyginai nulinių koncentracijų turi būti valomas per visą nagrinėtą laikotarpį – 10 metų. Mangano atvejų nulinė koncentracija dirvožemyje pasiekama po 8 metų, cinko – po 9 metų valant dirvožemį su žolinės augalijos mišiniu ir neesant papildomam teršimui. Greičiausiai dirvožemis išvalomas nuo nikelio – per 6 metus. Nuo chromo dirvožemis iki nulinės koncentracijos būtų išvalytas per 7 metus.
9. Pagal gautus tyrimų rezultatus matyti, kad žolinės augalijos mišinys (80 % daugiametės svidrės, 10 % pievinės miglės ir 10 % tikrojo eraičio) efektyviai valo dirvožemį nuo sunkiųjų metalų, dažniausiai sutinkamų pakelių dirvožemiuose. Todėl rekomenduojama tokios sudėties mišiniu apsėti magistralinių bei krašto kelių pakeles.
10. Tyrimų metu nustatyta, kad efektyviausias dirvožemio valymas vyksta žolinei augalijai augant, todėl rekomenduojama mišiniu apsėtas pakeles šienauti kas 2 mėnesius – tokiu būdu vykstant biocheminiams procesams iš šaknų į antžeminę augalo dalį kartu su maistingomis medžiagomis pateks daugiau sunkiųjų metalų ir dirvožemio valymas bus efektyvesnis.
11. Nušienautą žolinės augalijos mišinį rekomenduojama surinkti ir išvežti deginimui į specialias vietas, kuriose deginant atliekas oras yra valomas nuo teršalų. Tokiu būdu atgal į dirvožemį nebepateks jau minėti sunkieji metalai.

Trumpos žinios apie autorę

Audronė Jankaitė gimė 1979 m. birželio 1 d. Kėdainiuose.

2001 m. įgijo Aplinkos inžinerijos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2003 m. įgijo Aplinkos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2002–2003 m. dirbo Aplinkos apsaugos institute. 2003–2007 m. – Vilniaus Gedimino technikos universiteto doktorantė. Audronė Jankaitė 2006 m. stažavosi Norvegijoje, Norvegijos gamtos mokslų universitete. Šiuo metu Audronė Jankaitė dirba asistente Vilniaus Gedimino technikos universiteto Aplinkos apsaugos katedroje.

Audronė Jankaitė

**RESEARCH ON HEAVY METALS IN ROADSIDE AND EVALUATION
OF THEIR INFLUENCE ON THE ENVIRONMENT**

Summary of Doctoral Dissertation

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