



Agnė KAZLAUSKIENĖ

**RESEARCH AND EVALUATION
OF THE INFLUENCE OF ROAD MAINTENANCE
SALTS ON THE ENVIRONMENT**

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

1427

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2003–2007.

Scientific Supervisors

Prof Dr Habil Pranas BALTRĖNAS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T) (2004–2007),

Prof Dr Habil Donatas BUTKUS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T) (2003–2004).

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 Dmitrijus STYRO (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

Members:

Assoc Prof Dr Valentinas KADŪNAS (Institute of Geology and Geography, Physical Sciences, Geology – 05P),

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

Dr Romas PAKALNIS (Institute of Botany, Biomedical Sciences, Botany – 04B),

Dr Aušra ZIGMONTIENĖ (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering and Landscape Management – 04T).

Opponents:

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

Prof Dr Habil Vytenis Albertas ZABUKAS (Klaipėda 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 7 December 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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Agnė KAZLAUSKIENĖ

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Moksliniai vadovai

prof. habil. dr. Pranas BALTRĖNAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T) (2004–2007),

prof. habil. dr. Donatas BUTKUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T) (2003–2004).

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 – 04B).

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

Pirmininkas

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

Nariai:

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

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

dr. Romas PAKALNIS (Botanikos institutas, biomedicinos mokslai, botanika – 04B),

dr. Aušra ZIGMONTIENĖ (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

Oponentai:

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

prof. habil. dr. Vytenis Albertas ZABUKAS (Klaipėdos 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

The problem

By the density and quality of a road network, Lithuania equals the states of high development level. The roads are used under winter conditions for more than 5 months per year. Thousands of tons of de-icing chemical substances (mainly salts) are applied on Lithuania's roads during the cold period. Out of them, sodium chloride (NaCl) and calcium chloride (CaCl_2) as well as their mixtures and the mixtures of these salts with sand have been most widely applied in our country. The spread rates of these materials depend on the environmental air conditions: ambient temperature, snow layer thickness, traffic intensity and others.

When chlorides are applied for the reduction of road slipperiness and roads are cleaned from snow and ice, first of all chlorides reach the carriageway and roadsides and directly pollute the road environment (coat of snow, soil, surface waters and vegetation). Indirect environment pollution is also possible. This happens when atmospheric precipitation washes out chlorides from the soil of the roads environment to nearby surface and ground waters and when chlorides from soil and water access plants. Chlorides also add to the corrosion cars and of reinforced concrete and destroy street and road paving.

Despite a number of adverse effects caused by de-icing salts, they are used due to their cheapness.

An adverse effect of chlorides on the environment has attracted researchers' attention for several decades already. The issues of chloride-related problems are often analysed during discussions and in national periodicals.

However, the scope of issues in question is bigger than that of related researches carried out. In addition, economically attractive ways of reducing pollution in the road environment have to be developed.

Topicality of the work

In Lithuania, the impact of de-icing salts on the environment has not received much attention from researchers. In Lithuania, one of the first separate researches into chloride pollution were performed at Vilnius Gediminas Technical University (hereinafter – VGTU) Department of Roads in 1996 by determining the amount of chlorides in snow accumulated nearby streets and waste rainwater when the melting of snow started. With the aim to determine the effect of technical salts on ecosystems in the road environment, VGTU Environment Protection Department launched separate researches into the effect of salts on environmental components in 2003. Research into the effect of road maintenance salts on diatom flora in Verkiai pond and Gineitiškiai Lake was carried out.

However, single research cases disclose neither the scope of road environment pollution by salts nor the effect on environmental components. Consequently, it is reasonable to perform systematic complex research under natural conditions as well as laboratory experiments to evaluate the effect of sodium chloride (NaCl), the main salt used in Lithuania, on the road environment, and, when analysing the findings obtained, to propose means for the reduction of pollution in the road environment.

Aim and tasks of the work

To determine and evaluate the effect of road maintenance salt on road environment components by performing research under natural conditions and laboratory experiments.

Tasks of the work

1. To perform research into chloride concentration in the snow cover of roadsides by the roads with heavy traffic in order to determine the scope of pollution of the snow cover and analyse the change of chloride concentration depending on the distance from the carriageway and the distance at which the concentrations are the highest.
2. To perform experimental laboratory research on the sorption of salt elements from water solutions filtered through the zeolite in order to determine the sorption properties of the zeolite.
3. To perform experimental laboratory researches into salt's toxic impact on grassy vegetation by inserting zeolite into soil and without using any zeolite.
4. To perform experimental laboratory research into acute lethal toxic effect of salts on the rainbow trout with the aim to determine the impact of salt on the morphological and haematological parameters of the rainbow trout.
5. To perform mathematical modelling of the growth intensity of grassy vegetation.
6. Based on research findings and analysis, to propose solutions for the prevention and reduction of road environment pollution.

Scientific novelty

The novelty of the paper covers complex natural and experimental laboratory research into the effect of road maintenance salt on the environmental components (cover of snow, grassy vegetation, and hydrobionts). Modelling was performed on the basis of the research. Recommendations and engineering solutions have been presented.

Practical value

A multi-functional engineering installation, an infiltration-grassy ditch, has been developed. It extends the functions of a water take-off ditch by adapting it for complex reduction of adverse effect on the road environment.

The effect of the road maintenance salt LC50 on the rainbow trout was determined by experimental research.

Mathematical modelling was employed to determine the optimum coefficients that help calculate the length of the above-ground part of grass vegetation (perennial ryegrass, fescue grass, meadow-grass) in cm after a certain growth period.

Defended propositions

1. The highest concentrations of chlorides accumulate in the cover of snow in up to 10 metre distance from the carriageway.
2. Perennial ryegrass (*Lolium perenne* L.) has the highest resistance to toxic effect of salt.
3. Sodium chloride has an adverse effect on the haematological and other parameters of the rainbow trout (*Oncorhynchus mykiss*).
4. Due to its unique multi-functional properties, the zeolite can be used for the reduction of pollution in the road environment and improvement of soil quality.

The scope of the scientific work

The scientific work consist of the general characteristic of the dissertation, 7 chapters, conclusions and recommendations, lists of literature, list of author's publications and presentations on the subject dissertation in scientific conferences. The total scope of the dissertation is 149 pages, 117 pictures and 29 tables.

Short content of the dissertation

1. Road maintenance salts and pollution caused by them in road environment

To de-ice roads in winter time, a chemical method by using various chemical substances the major part of which consists of salts (chlorides) is applied.

When applied on the carriageway in wintertime, chlorides enter the road environment when the processes of splash out and mist occur, which are reinforced by the wind. Chlorides enter surface and ground waters and reach vegetation. Therefore, the road environment is polluted both directly and indirectly. Undesirable effects of salt impact on the environment include damage to roadside flora and soil, and pollution of surface and ground waters, which results in an adverse effect on fauna and even humans.

Abiotic stresses, such as big fluctuations of temperature, lack of humidity (drought) and heavy metals reinforce the adverse effect of salts on plants.

2. Methodology of research

The dissertation paper involves complex research under national conditions and laboratory experiments. Research into chloride concentrations in the roadsides of Lithuania's main highways was carried out.

Laboratory experiments consisted of 3 parts:

I. determination of the sorption of natural zeolite's (clinoptilolite's) salt elements from saline water solutions by using a column test;

II. research into resistance of grassy vegetation (perennial ryegrass, fescue-grass and meadow-grass) to the toxic effect of sodium chloride by inserting zeolite into soil and without using any zeolite with the aim to determine the seed viability, phytomass and length of an above-ground part of grassy vegetation and establish the optimum required amount of zeolite in soil;

III. research into acute toxicity of saline solutions and long-term toxic effect on the rainbow trout by determining LC50, and changes in morphological and haematological parameters of fish.

After performing experimental research, mathematical modelling of the growth intensity of roadside grassy vegetation, using the software *Phoenix 3.5*, was carried out.

3. The results:

3.1. Findings and analysis of research into chloride concentration in the cover of snow

The highest chloride concentrations were determined in up to 10 metre distance from the carriageway.

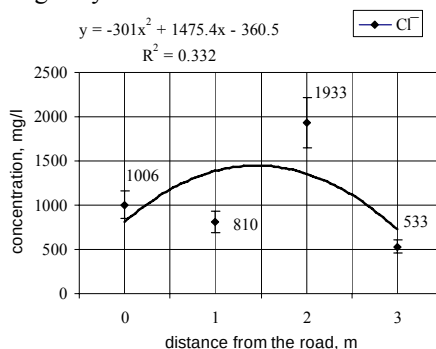


Fig 3.1. Chloride concentrations in snow melt water, in Sītūkūnai

As the distance from the road edge increases according to transverse profile the concentration of chlorides is distributed very unevenly. The highest concentration of Cl^- is detected in 2 m distance from the road edge and it reaches 1933 mg/l (Fig 3.1). This value is even 2 times bigger than the concentration immediately to the road edge and is the highest of all concentrations determined on the highway Vilnius–Kaunas–Klaipėda. Such uneven distribution is predetermined by large flows of passing automobiles that arouse wind flaws and throw salts away from the carriage way. As the distance from the road edge increases Cl^- concentration decreases. A snow melt water sample, that was used to determine Cl^- concentration, had pH equal to 7.54. A snow layer in the sampling place in Sitkūnai was around 18 cm (13/02/2003).

Chloride concentration dependence on the main variables: traffic level, road category, road maintenance level, geographical and climate conditions.

3.2. Findings and analysis of experimental research into the sorption of salt elements from water solutions of salts (NaCl , CaCl_2) and their mixtures filtered via the zeolite charge

The experiment was carried out using a technique developed based on the review of foreign literature. Prepared saline (NaCl , CaCl_2) solutions were filtered via the zeolite charge (a column test). Having passed through the column, filter liquor was collected in single use small containers of 100 ml each. 500 ml of experimental solution was filtered and each 100 ml was collected in a separate small container. In this way, 5 samples, of 100 ml each, were obtained. Na^+ , Ca^{2+} , Cl^- ion concentrations and filtrate's pH were determined in the obtained samples.

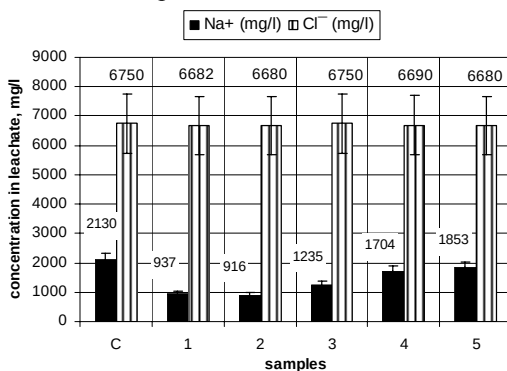


Fig 3.2. Na^+ and Cl^- concentrations in $c=10$ g/l NaCl saline solution, filtered through the zeolite charge

Clinoptilolite does not sorp chlorine ions (Cl^-). The data from 5 samples show that the obtained Cl^- concentrations differ from that of a control sample (6750 mg/l) only within the limits of errors. As Fig 3.2 shows, Na^+ concentration in the 1st sample, 937 mg/l, differs from the control one, $c=2130$ mg/l, 2.27 times. Clinoptilolite sorped Na^+ ions by 33.8 %. In the fourth sample the sorption capacity of clinoptilolite significantly decreased.

Natural zeolite (clinoptilolite) sorps saline cations (Na^+ , Ca^{2+}) from saline solutions but does not sorp anion (Cl^-).

Natural zeolite sorped Na^+ from saline solutions by 30–35 %, and Ca^{2+} – 42–44 %. The results obtained show that the zeolite sorped Ca^{2+} better than Na^+ by 12 %. This tendency was predominant in all saline solutions analysed.

When salts enter the environment they create an alkaline medium. The higher is the concentration of a saline solution the more alkaline is pH of the solution (pH=8.14–8.76).

The zeolite reduces alkaline pH of the saline solution to a weakly acid one.

3.3. Results and analysis of research into the growth of grassy vegetation in soil contaminated by sodium chloride

Three kinds of grass vegetation, most frequently used for planting of waysides in Lithuania, were selected: perennial ryegrass (*darimo* species) – *Lolium perenne* L.; fescue grass (*prana* species) – *Festuca pratensis* Huds.; meadow-grass (*balin* species) – *Poa pratensis* L.

During the research that extended for 4 weeks the biggest height of the above-ground part was achieved by the ryegrass in both the control (19.8 cm) and the experimental (21.3 cm) plant samples, and smallest – by the meadow-grass (7.7 cm and 3.2 cm, respectively) (Fig 3.3). During the research room temperature was 20 °C with insignificant changes (1 °C).

The ryegrass plants of the control group that were growing in the soil not contaminated with NaCl reached the highest growth during the 1st week. The biggest difference in the heights of the above-ground parts of the plants that were growing in soil contaminated with 2 g/kg and 5 g/kg of NaCl was determined after 4 weeks of growth – 5.6 cm, and the smallest – after 2 weeks – 0.9 cm.

The bigger height of the above-ground part of the control group's plants is especially obvious in the 1st and 2nd weeks. But in the 3rd week of research a difference between the control and experimental plants that were growing in soil contaminated with 2 g/kg of NaCl was only 0.8 cm. In the 4th week, the height of plants that were growing in soil contaminated with 2 g/kg of NaCl with 10 % of zeolite inserted was by 1.5 bigger than that of control plants.

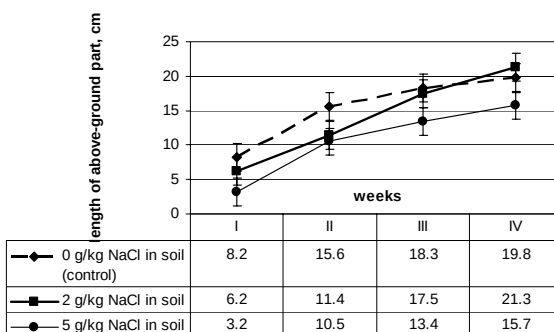


Fig 3.3. The length of the perennial ryegrass' above-ground part in soil contaminated with NaCl and containing 10 % of zeolite

Throughout the research period (4 weeks) the phytomass of perennial ryegrass having grown in soil with 10 % zeolite content was changing consistently, the control plants had the biggest phytomass, and the plants in soil contaminated with 5 g/kg NaCl – the smallest. The biggest difference in phytomass of control (35.37 mg) and experimental (23.82 mg and 20.67 mg) plants was recorded in the 2nd week of the experiment (Fig 3.4).

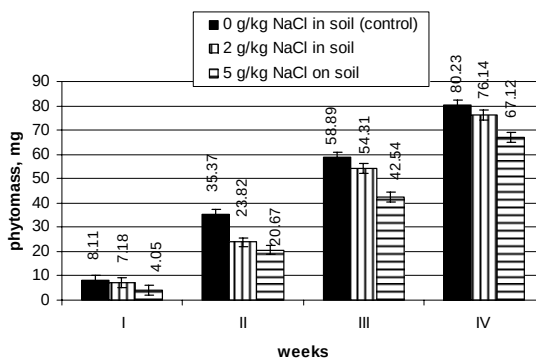


Fig 3.4. The phytomass of perennial ryegrass after 4 weeks of growth in soil contaminated with NaCl and containing 10 % of zeolite

The biggest above-ground parts as well as the biggest phytomass of all the three researched species of grass vegetation (perennial ryegrass, fescue grass and meadow-grass) were determined in those pots where 10 % of zeolite was inserted.

Zeolite retains humidity in soil which was visually seen during the experiments. Zeolite inserted into soil made the greatest influence on the change of above-ground part and phytomass of the fescue grass. The growth process of the researched grass plants was to the greatest extent influence by zeolite during the 1st week of growth.

3.4. Results and analysis of research into acute toxicity and long-term toxic effect on the rainbow trout of road maintenance salt

Toxicity tests were conducted at the Laboratory of Ecology and Physiology of Hydrobiont (Institute of Ecology of Vilnius University). The results of research into acute toxicity showed that the rainbow trout (*Oncorhynchus mykiss*) has different sensitivity to road maintenance salt (RMS) and common salt (CS) (Table 3.1).

Table 3.1. The dynamics of the rainbow trout death in the solutions of technical salt and common salt

Influence	Concentration, g/l				
(hours)	14	16	18	20	22
Road maintenance salt					
24	0	2 (14.28 %)	4 (28.56 %)	8 (57.12 %)	8 (57.12 %)
48	0	2 (14.28 %)	0	0	0
72	0	0	0	0	4 (28.56 %)
96	0	0	0	2 (14.28 %)	2 (14.28 %)
Common salt					
24	0	0	0	0	12(85.68 %)
48	0	0	0	0	0
72	0	0	0	0	0
96	0	0	0	2 (14.28 %)	2 (14.28 %)
Control	0	0	0	0	0

(The Table shows the number of dead fish and in brackets presents the percentage of the total amount of fish analysed (14 fish) in saline solutions of different concentration during different period of time).

Table 3.2. The calculated median lethal 96-hour LC50 of RMS and CS for rainbow trout in acute toxicity tests

Chemicals	LC50, (g/l)	95 % confidence intervals, (g/l)
RMS	18.25	17.40 ÷ 19.13
CS	20.38	19.30 ÷ 20.88

Calculations were made with software *Spearman-Kärber*, the medial lethal concentration (LC50) of 96 hours for the rainbow trout is 18.25 g/l (Table 3.2).

As the findings of research into salt toxicity show, fish has different sensitivity to road maintenance salt (RMS) and common salt (CS) depending on their concentrations.

Haematocrit's digital value expresses a ratio between the volume of red blood cells and the total volume of blood. When blood is in a quiet state, erythrocyte precipitate on the small container's bottom. Erythrocyte sedimentation rate (ESR) has diagnostic importance. Males have a somewhat lower ESR than females. Increased ESR indicates an inflammatory process in the organism (Fig 3.5).

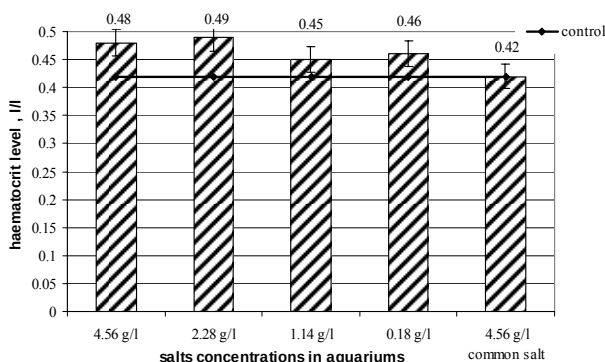


Fig 3.5. Average amount of haematocrit level in the rainbow trout's blood

Long-term research does not show any reliable difference in morphological parameters impacted by RMS (especially those of fish mass) compared to the control sample but RMS affects all haematological parameters of fish.

3.5. Mathematical modelling of the growth intensity of roadside grassy vegetation

Aim of modelling: through the employment of mathematical calculation, to determine the optimum coefficients that would help calculate the length (cm) of the above-ground part of perennial ryegrass, fescue grass and meadow-grass after a certain period of time on the assumption that the concentration of road maintenance salt in soil and the ambient air temperature do not change during research.

The differential equation of change of the plants' above-ground part length in the course of time and its analytical solution are assumed according to the

equation and reading-analytical solution of the library case 711 using the software package *Phoenix* 3.5. They are as follows:

- equation: $\frac{\partial F}{\partial t} = \alpha \cdot e^t - \alpha \cdot F$ (1)

- solution: $F = e^t + \beta \cdot e^{-\gamma \cdot t}$ (2)

α, β, γ – coefficient found by approximation method;

t – number of weeks;

F – analytical solution of differential equation.

However, it was noticed that the expression of the differential equation still lacked a coefficient to evaluate the influence of time (the number of weeks) on the change of above-ground part of the grassy vegetation in question. The following equations were obtained:

$$\frac{\partial F}{\partial t} = A \cdot t + \alpha \cdot e^t - \alpha \cdot F \quad (3)$$

$$A = \frac{\partial F}{\partial t} \cdot t - \frac{\alpha e^t}{t} + \frac{\alpha F}{t} \quad (4)$$

A – coefficient evaluating the factor of time.

After the coefficients α, β and γ are found, the coefficient A is being established. It is different for each species of the plants analysed and evaluates whether soil is contaminated by road maintenance salt or not.

Obtained by mathematical modelling, the coefficient A of the above-ground length calculation equation (4) for perennial ryegrass is 3.0, fescue grass – 2.1, and meadow-grass – 0.7.

When calculating the above-ground part's length (cm) according to the modelled equation, the modelling results of the first week showed the biggest difference from the real length of the above-ground part (up to 83.53 %).

The smallest errors between the real and the calculated lengths of the above-ground part were determined when researching meadow-grass (for control plant – 11.40% and in case of 1 g/kg NaCl concentration in soil – 12.32 %), and the biggest – fescue-grass (for control plant – 26.19 % and in case of 1 g/kg NaCl concentration in soil – 28.10 %).

4. Engineering solutions

The doctoral thesis was started by analysing literature about the impact of road maintenance salts on the environment. Research into contamination of the snow cover by chlorides under natural conditions was performed subsequently. With the aim to have a thorough evaluation of the impact of road maintenance salts on the environment, laboratory experiments were carried out. The

components of the road environment, three species of grassy vegetation along with a representative of hydrobionts, rainbow trout, were selected as research objects. In addition, the natural zeolite (clinoptilolite), was analysed in order to determine its sorption properties with regard to salt elements and with the aim to apply it for the reduction of pollution in the road environment. On this basis, a laboratory stand for experimental research into sorption properties of the zeolite and an improved stand to determine the effect of road maintenance salt on fish were developed. A biotechnical solution for the prevention and reduction of the road environment has been proposed.

An infiltration-grassy ditch (Fig 4.1) belongs to motor road installations that are built and operated at the beds of motor road soil and used for the take-off of surface water. This road ditch extends the functions of the water take-off ditch by applying it for the reduction of a complex adverse effect in the road environment.

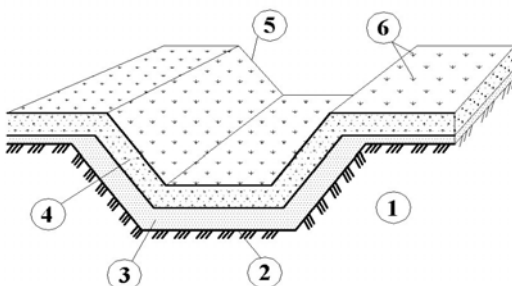


Fig 4.1. Scheme of infiltration-grassy ditch

The infiltration-grassy ditch used for waste water collection from the road surface consist of: soil base (1), ditch bottom in the form of a chute (2), filtering sand layer (3), a layer of fertile soil mixed with 10 % (of the soil volume) of the natural zeolite (clinoptilolite) of 3–5 mm fraction (4) and ditch slopes (5) sown with the mixture of grassy vegetation, i.e. perennial rye-grass (*Lolium perenne* L.) and fescue grass (*Festuca pratensis* Huds.) (6).

Clinoptilolite is used in the installation due to its numerous unique structural and functional properties. When zeolite is used for the preparation of lawns, it conveys the following benefits to soil: reduces soil trampling, deeply aerates soil and plant roots, perfectly transmits water to the root area, holds the optimum amount of water (up to 35 % of the zeolite mass), accumulates in itself toxic substances and does not release them into the environment, significantly reduces washing out of fertilisers into the environment and in this way reduces the pollution of ground waters. Based on plants' needs, the zeolite gradually

renders agro chemically beneficial nutrients to them, such as Na^+ , Ca^{2+} , K^+ , Mg^{2+} and others, that are present in the composition of de-icing substances, as well as water, and ensures a good level of exchange of cations, and encourages the proliferation of useful microorganisms.

General conclusions and recommendations

1. Natural zeolite (clinoptilolite) sorped sodium ions (Na^+) from the road maintenance salt solutions by 30–35 %, and calcium ions (Ca^{2+}) – 42–44 %. The obtained results show that zeolite better sorped Ca^{2+} than Na^+ by ~12 %.
2. Clinoptilolite sorps the elements of road maintenance salts, Na^+ and Ca^{2+} , and can be applied for the prevention and reduction of pollution caused by motor vehicles in the road environment as well as the bettering of soil and vegetation condition.
3. The research findings show that technical NaCl contained in soil has the adverse effect on the growth dynamics of grass vegetation i.e. slows down the increase of the above-ground part and reduces the phytomass.
4. The experiments have proved that is the perennial ryegrass that shows the most rapid germination, the most rapid growth and the highest resistance to the toxic effect of salt.
5. It is not rational to insert more than 10 % of zeolite into soil since researched plants that grew in soils with 20 % zeolite content had by approximately 10 % smaller lengths of above-ground parts as well as phytomass than the grass plants that were grown in soil with 10 % of zeolite.
6. The findings of research into salt toxicity show that fish has different sensitivity to road maintenance salt and common salt depending on their concentrations. Road maintenance salt has an especially adverse effect on fish's haematological parameters.
7. The 96-hour LC50 value of road maintenance salt calculated during research into acute toxicity to young rainbow trout fish was equal to 18.25 g/l.
8. When calculating the above-ground part's length of grass vegetation by modelling and using the equation $A = \frac{\partial F}{\partial t} \cdot t - \frac{\alpha e^t}{t} + \frac{\alpha F}{t}$, the obtained coefficient A for perennial rye-grass was 3.0, that for fescue grass — 2.1, and for meadow-grass – 0.7.
9. The recommendation is to sow roadsides with the mixture of perennial ryegrass, which shows very high resistance to the toxic effect of salt, and fescue-grass (ranked 2nd by resistance to salt) (70:30 %) when building new roads and reconstructing the existing ones. The use of mixture is recommended with the aim to ensure variety of species.

10. The application of the natural substance clinoptilolite on roadsides is recommended for the prevention and reduction of motor vehicle pollution and the improvement of soil and vegetation condition due to its numerous unique properties (in particular, cation exchange).

11. The 96-hour LC50 value of road maintenance salt (RMS) calculated during research into acute toxicity to young rainbow trout fish was equal to 18.25 g/l. Therefore, when performing research into RMS toxicity to other species of fish it is recommended to take into account this concentration of RMS and use it as the maximal concentration.

12. According to the obtained patent of the Republic of Lithuania, the recommendation is to install a multifunctional installation i.e. an infiltration-grassy ditch, on the roadsides of heavy traffic when building new roads or reconstructing and renewing the existing ones.

List of published works on the topic of the dissertation

In the scientific periodical publications included ISI Master List

1. BALTRĖNAS, P.; KAZLAUSKIENĖ, A. Grass vegetation dynamics in soil contaminated with salt. *Ekologija*, 2007, Nr. 3, p. 58–63. ISSN 0235-7224.

2. BALTRĖNAS, P.; VOSYLIENĖ, M. Z.; KAZLAUSKIENĖ, A. Toxicity of road maintenance salts to rainbow trout *Oncorhynchus mykiss*. *Ekologija*, 2006, Nr. 2, p. 15–20. ISSN 0235-7224.

In the conference proceedings included in ISI Proceedings List

3. BRANNVALL, E.; KAZLAUSKIENE, A. Experimental research on sorption of Pb^{2+} , Zn^{2+} , Cu^{2+} , Mn^{2+} , Ni^{2+} , Na^{+} , Ca^{2+} and Cl from solutions on clinoptilolite. In *Proceedings of 6th International Conference Environmental Engineering held in 26–27 May 2005 in Lithuania*. Vol. 1. Vilnius: Technika, 2005, p. 49–53. ISBN 9986-05-850-3.

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4. BALTRĖNAS, P.; ZAVECKYTĖ, J.; KAZLAUSKIENĖ, A.; ŠČUPAK-AS, D. Mathematical modelling of growth intensity of roadside plants. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika, 2006, Vol XIV, No 4, p. 215–224 (in Lithuanian). ISSN 1648-6897.

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Journal of Environmental Engineering and Landscape Management. Vilnius: Technika, 2006, Vol XIV, No 2, p. 83–88. ISSN 1648-6897.

6. STORPIRŠTYTĖ, I.; KAZLAUSKIENĖ, A.; ŠČUPAKAS, D. Investigations of chloride concentration in snow cover on roadsides of Lithuanian roads with intensive traffic. *Journal of Environmental Engineering and Landscape Management*. Vilnius: Technika, 2004, Vol XII, Supplement 2, p. 60–66 (in Lithuanian). ISSN 1648-6897.

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7. BALTRĖNAS, P.; KAZLAUSKIENĖ, A. Research on chloride concentrations in snow melt water in the roadside of highway Vilnius – Kaunas – Klaipėda. *Геоэкология, инженерная геология, гидрогеология, геокриология*. Москва, 2005, № 1, с. 18–24 (in Russian). УДК 550.42:556.124.

8. BALTRĖNAS, P.; KAZLAUSKIENĖ, A. Investigations of chlorides concentrations in thawing snow water on roads with intensive traffic. *Экология и промышленность России*. Москва, 2003, № 11, с. 28–32 (in Russian). Индекс 72146 / Индекс 45220.

9. BALTRĖNAS, P.; KAZLAUSKIENĖ, A. Chloride and sodium concentrations in snow cover on roadsides of highway Panevėžys – Šiauliai in Lithuania. In *Sustainable Development in the Baltic and Beyond*. Edited by Walter Leal Filho/Arnolds Ubelis/Dina Berzina (eds.). 2006. Vol. 23, p. 467–472. ISSN 1434-3819, ISBN 3-631-55282-3.

10. KAZLAUSKIENĖ, A.; BALTRĖNAS, P. Research on chloride concentrations in snow melt water in the roadside of highway Vilnius – Kaunas – Klaipėda. In *Proceedings of Sixth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe and the Commonwealth of Independent States, organized in 1–4 September 2003 in Czech Republic* (in CD). ISBN 0-9748192-0-4.

11. KAZLAUSKIENĖ, A.; BALTRĖNAS, P. Short-term investigations of road maintenance salt solution acute toxicity rainbow trout (*Oncorhynchus Mykiss*). In *Environmental Protection Engineering. Reports from 10th Lithuanian Conference of Junior Researchers „Science – future of Lithuania“*. Vilnius: Technika, 2007, p. 108–112 (in Lithuanian). ISBN 978-9955-28-162-7.

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13. KAZLAUSKIENĖ, A.; BALTRĖNAS, P. Alternation of pH in deicing salt solutions passed through zeolite. In *Environmental Protection Engineering. Reports from 8th Lithuanian Conference of Junior Researchers „Lithuania without Science – Lithuania without future“*. Vilnius: Technika, 2005, p. 331–337 (in Lithuanian). ISBN 9986-05-876-7.

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15. KAZLAUSKIENĖ, A. Usage and spread norm of chemical materials for maintenance of roads in winter. In *Environmental Protection Engineering. Reports from 6th Lithuanian Conference of Junior Researchers „Lithuania without Science – Lithuania without future“*. Vilnius: Technika, 2003, p. 359–365 (in Lithuanian). ISBN 9986-05-645-4.

Patent

BALTRĖNAS, P.; KAZLAUSKIENĖ, A. *Seepage – grassy trench*. Int. Cl. (2006): E01F 5/00. Lithuanian patent Nr. 5446 obtained in November 2007.

About the author

Agnė Kazlauskienė was born on 20 August 1978 in Vilnius. She acquired the Bachelor's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 2000, and Master's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 2002. In the period of 2002–2007, she was employed at the Institute of Environment Protection; in the period of 2003–2007 was a doctoral student at Vilnius Gediminas Technical University. Presently, Agnė Kazlauskienė is employed in the position of junior research fellow with Vilnius Gediminas Technical University Institute of Environment Protection.

KELIŲ PRIEŽIŪRAI NAUDOJAMŲ DRUSKŲ ĮTAKOS APLINKAI TYRIMAI IR VERTINIMAS

Problema

Kelių tinklo tankiu bei jo tobulumu Lietuva prilygsta aukšto plėtros lygio valstybėms. Žiemos sąlygomis keliai eksploatuojami daugiau nei penkis mėnesius per metus. Šaltuoju periodu Lietuvos keliuose išberiami tūkstančiai

tonų slidumą mažinančių cheminių medžiagų (daugiausiai druskų). Plačiausiai mūsų šalyje naudojamas natrio chloridas (NaCl) ir kalcio chloridas (CaCl₂), jų mišiniai bei šių druskų mišiniai su smėliu.

Barstant chloridus slidumo mažinimui bei valant kelius nuo sniego ir ledo, jie pirmiausiai patenka ant važiuojamosios kelio dalies bei jos kelkraščių ir tiesiogiai teršia kelio aplinką (sniego dangą, dirvožemį, paviršinius vandenis, augaliją). Galima ir netiesioginė aplinkos tarša, kai atmosferos krituliai chloridus išplauna iš kelio aplinkos dirvožemio į netoliese esančius paviršinius ir gruntinius vandenis bei kai chloridai iš dirvožemio ir vandens patenka į augalus. Slidumui mažinti skirtos druskos, nepaisant daugelio jų sukeltų neigiamų padarinių, naudojamos dėl jų pigumo.

Neigiamo chloridų poveikio aplinkai pasekmės jau kelis dešimtmečius domina mokslininkus. Apie chloridų sukeltas problemas dažnai diskutuojama ir keliama klausimai periodiniuose šalies leidiniuose. Tačiau iškeltų klausimų yra daugiau nei atliktų mokslinių tyrimų.

Darbo aktualumas

Lietuvoje kelių druskų poveikis aplinkai yra mažai tyrinėtas. Lietuvoje vieni iš pirmųjų pavienių chloridų taršos tyrimų buvo atlikti 1996 metais VGTU Kelių katedroje, nustatant chloridų kiekį sniego dangoje šalia gatvių susikaupusiame sniege bei lietaus kanalizacijos vandenyje, prasidėjus sniego tirpimui. Siekiant nustatyti techninių druskų neigiamą poveikį kelio aplinkoje esančioms ekosistemoms, 2003-iais metais VGTU Aplinkos apsaugos katedroje buvo pradėti vykdyti pavieniai druskų poveikio aplinkos komponentams tyrimai. Atlikti kelių priežiūrai naudojamų druskų įtakos titnaginių dumblių įvairovei tyrimai Verkių tvenkinyje bei Gineitiškių ežere.

Tačiau pavieniai tyrimai neatskleidžia kelio aplinkos užtaršos druskomis masto bei poveikio aplinkos komponentams. Todėl tikslinga atlikti sisteminius kompleksinius natūrinius tyrimus ir laboratorinius eksperimentus, siekiant įvertinti pagrindinės Lietuvoje naudojamos druskos – natrio chlorido (NaCl) druskos įtaką kelių aplinkai. Analizuojant gautus rezultatus, rekomenduoti priemonės taršai kelio aplinkoje mažinti.

Darbo tikslas

Atliekant natūrinius tyrimus ir laboratorinius eksperimentus, nustatyti ir įvertinti kelių priežiūros druskų įtaką kelio aplinkos komponentams.

Darbo uždaviniai

1. Atlikti chloridų koncentracijos tyrimus sniego dangoje intensyvaus eismo kelių pakelėse, norint nustatyti sniego dangos užtaršos mastą nei išanalizuoti, kaip kinta chloridų koncentracija tolstant nuo važiuojamosios kelio dalies ir koku atstumu jų susikaupia daugiausia.

2. Atlikti druskų elementų sorbcijos iš druskų vandeninių tirpalų, perfiltruotų per ceolitą eksperimentinius laboratorinius tyrimus, siekiant nustatyti ceolito sorbcines savybes.
3. Atlikti toksinio druskos poveikio žolinei augalijai eksperimentinius laboratorinius tyrimus į dirvožemį įterpiant ceolitą bei nesant ceolito.
4. Įvykdyti druskų ūminio letalaus toksiško poveikio vaivorykštiniam upėtakiui eksperimentinius laboratorinius tyrimus, siekiant nustatyti druskos poveikį vaivorykštinio upėtakio morfologiniams ir hematologiniams rodikliams.
5. Atlikti pakelės žolinės augalijos augimo intensyvumo matematinį modeliavimą.
6. Remiantis tyrimų rezultatais ir analize, pasiūlyti sprendimus kelio aplinkos taršos prevencijai bei mažinimui.

Mokslinis naujumas

Darbo naująmą sudaro kompleksiniai natūriniai ir eksperimentiniai laboratoriniai kelių priežiūros druskos įtakos kelio aplinkos komponentams (sniego dangai, žolinei augalijai, hidrobiontams) tyrimai. Jų pagrindu atliktas modeliavimas. Pateiktos rekomendacijos bei inžineriniai sprendimai.

Praktinė vertė

Sukurtas daugiafunkcinis inžinerinis įrenginys – Infiltracinis – žolinis griovys, kuris išplečia vandens nuvedimo griovio funkcijas, pritaikant jį kompleksiniam neigiamam poveikiui kelio aplinkoje mažinti.

Eksperimentiniais tyrimais nustatyta kelių priežiūros druskos LC50 vaivorykštiniam upėtakiui.

Matematinio modeliavimu nustatyti optimalūs koeficientai, kuriuos naudojant būtų galima apskaičiuoti, koks bus žolinės augalijos (daugiametės svidrės, tikrojo eraičino, pievinės miglės) antžeminės dalies ilgis po tam tikro augimo laiko.

Ginamieji teiginiai

1. Didžiausios chloridų koncentracijos sniego dangoje susikaupia iki 10 metrų atstumu nuo važiuojamosios kelio dalies.
2. Atspariausia toksiniam druskos poveikiui yra daugiametė svidrė (*Lolium perenne L.*).
3. Natrio chlorido druska neigiamai veikia vaivorykštinio upėtakio (*Oncorhynchus mykiss*) hematologinius ir kt. rodiklius.
4. Ceolitas dėl savo unikalių daugiafunkcinių savybių, gali būti taikomas taršos kelio aplinkoje mažinimui bei dirvožemio kokybės gerinimui.

Darbo apimtis

Darbą sudaro bendra darbo charakteristika, 7 skyriai, išvados, rekomendacijos, inžineriniai sprendimai, literatūros sąrašas, autorės publikacijų sąrašas. Bendra disertacijos apimtis – 149 puslapiai, 117 paveikslų 29 lentelės.

Pirmame disertacijos skyriuje apžvelgiamos kelių priežiūrai žiemos metu naudojamos druskos, nagrinėjama jų įtaka gyvėjai ir negyvėjai gamtai. Analizuojami pasaulyje atlikti tyrimai, nustatant druskų neigiamą poveikį aplinkos komponentams. Antrame skyriuje nagrinėjami kelio aplinkoje atlikti chloridų koncentracijos natūriniai tyrimai. Trečiame skyriuje pateikiami druskų elementų sorbcijos iš druskų vandeninių tirpalų, perfiltruotų per ceolitą eksperimentiniai laboratoriniai tyrimai. Ketvirtame skyriuje analizuojami ir vertinami toksinio kelių priežiūros druskos poveikio žolinei augalijai eksperimentinių laboratorinių tyrimų rezultatai. Penktame skyriuje pateikti druskų letalaus toksiško poveikio vaivorykštiniam upėtakiui eksperimentinių tyrimų rezultatai ir analizė. Šeštasis skyrius skirtas žolinės augalijos augimo intensyvumo matematiniam modeliavimui. Septintame skyriuje pateikti trys inžineriniai sprendimai: laboratorinis stendas ceolito sorbcinių savybių eksperimentiniams tyrimams; stendas, skirtas kelių priežiūrai naudojamos druskos įtakai žuvims nustatyti; biotechninis įrenginys kelio aplinkos taršos prevencijai bei mažinimui.

Rezultatų apibūdinimas

Darbo rezultatai paskelbti 15-koje mokslinių publikacijų: 2 moksliniai straipsniai žurnaluose, įtrauktuose į Mokslinės informacijos instituto (MII) duomenų bazės pagrindinį sąrašą (ISI Master Journal List); 1 – konferencijos pranešimų medžiagoje, referuotoje Mokslinės informacijos instituto (MII) duomenų bazėje (ISI Proceedings); 3 moksliniai straipsniai kitose tarptautinėse duomenų bazėse referuojamuose užsienio mokslo žurnaluose; 2 recenzuojamuose mokslo žurnaluose; 3 kituose recenzuojamuose leidiniuose; 4 nerecenzuojamoje Lietuvos konferencijos pranešimų medžiagoje. Gautas Lietuvos respublikos patentas Nr. 5446.

Bendrosios išvados

1. Atlikus natūrinius tyrimus nustatyta, kad chloridų koncentracijų pasiskirstymas sniego dangoje priklauso nuo kelio priežiūros lygio, geomorfologinių aplinkos sąlygų (ar kelias nutiestas iškasoje ar sankasoje; kelio griovių nuolydis), klimatinių sąlygų (temperatūra ir jos kaita, sniego dangos storis, vėjo kryptis ir kryptis, klimatinė zona), eismo intensyvumo (eismo sukeliamo oro gūsių turbulentiškumo).
2. Tyrimų metu nustatyta, kad chloridų koncentracijos sniego dangoje kinta nuo 1868 mg/l (prie važiuojamosios kelio dalies) iki 115 mg/l (10 metrų atstumu nuo važiuojamosios kelio dalies).
3. Gamtinis ceolitas (klinoptilolitas) natrio jonus (Na^+) iš kelių priežiūros druskų tirpalų sorbavo 30–35 %, o kalcio jonus (Ca^{2+}) – 42–44 %. Pagal gautus rezultatus matyti, kad ceolitas Ca^{2+} sorbavo geriau nei Na^+ ~12 %.

4. Tyrimų metu gauta, kad kelių priežiūros druska, patekusi į dirvožemį, neigiamai įtakoja žolinės augalijos augimo dinamiką, tai yra mažina antžeminės dalies ilgį, fitomasę bei sėklų daigumą. Tirtų augalų antžeminės dalies ilgis bei fitomasė vidutiniškai 22 % buvo mažesni, lyginant su kontroliniais augalais. Dėl druskų toksinio poveikio, daugiametės svidrės daigumas, lyginant su kontroliniu, buvo mažesnis 11 %, tikrojo eraičino – 12 %, pievinės miglės – 40 %.

5. Eksperimentų metu nustatyta, kad greičiausiai sudygstanti ir atspariausia toksiniam kelių priežiūros druskos poveikiui yra daugiametė svidrė (*Lolium perenne* L.). Tyrimų metu šio žolinio augalo, augusio NaCl užterštame dirvožemyje, antžeminės dalies ilgis (23,4 cm) bei fitomasė (35,2 mg) buvo didžiausi.

6. Atlikus eksperimentus įvertinta, jog į dirvožemį tikslinga įterpti ne daugiau nei 10 % ceolito nuo dirvožemio tūrio, žolinės augalijos būklės pagrindinių parametrų gerinimui.

7. Druskų toksiškumo tyrimų rezultatai parodė skirtingą žuvų jautrumą kelių priežiūros druskai (KPD) bei valgomajai druskai, priklausomai nuo jų koncentracijų. Kelių priežiūros druska ypač neigiamai veikia hematologinius žuvų rodiklius. Eritrocitų skaičius mažiausias buvo 4,56 g/l KPD koncentracijoje – 0,6 T/l, kai kontrolėje – 0,84 T/l. Hemoglobino koncentracija taipogi mažiausia buvo 4,56 g/l KPD koncentracijoje – 72,8 g/l, kai kontrolėje – 81,6 g/l. Leukocitų kiekis – 15,9 G/l, kai kontrolėje – 22,1 G/l.

8. Ūminio toksiškumo tyrimo metu, apskaičiuota 96 val. LC50 KPD vertė vaivorykštiniam upėtakiui yra 18,25 g/l.

9. Žolinės augalijos antžeminės dalies aukščio skaičiavimo lygties

$$A = \frac{\partial F}{\partial t} \cdot t - \frac{\alpha e^t}{t} + \frac{\alpha F}{t}$$

modeliavimo būdu koeficientas A daugiametei

svidrei gautas 3,0; tikrajam eraičiniui – 2,1; pievinei miglei – 0,7. Turint šiuos koeficientus galima modeliuoti žolinės augalijos antžeminės dalies ilgį per tam tikrą jos augimo laiką, priimanč, kad kelių priežiūros druskos koncentracija dirvožemyje ir aplinkos oro temperatūra yra nekintanti tyrimo metu.

10. Vykdam kompleksinius kelių priežiūros druskos įtakos kelio aplinkai tyrimus, nustatytas toksinis jos poveikis žolinės augalijos parametrams bei vaivorykštinio upėtakio hematologiniams rodikliams. Tiesiant naujus kelius ar rekonstruojant esamus, taršos kelio aplinkoje prevencijai bei mažinimui siūloma įrengti biotechninį įrenginį – Infiltracinį-žolinį griovį.

Rekomendacijos

1. Tiesiant naujus kelius ar rekonstruojant esamus, pakeles rekomenduojama apsėti daugiametės svidrės, kuri yra itin atspari toksiniam druskos poveikiui, ir

tikrojo eraičino (II vieta pagal atsparumą druskai) sėklų mišiniu (70:30 %). Rekomenduojama naudoti mišinį, siekiant užtikrinti rūšinę įvairovę.

2. Gamtinę medžiagą – ceolitą (klinoptilolitą), dėl daugelio jo unikalių savybių (ypač katijonų mainų) rekomenduojama naudoti pakelėse autotransporto taršos prevencijai ir mažinimui. Taipogi ceolitas gali būti naudojamas dirvožemio bei žolinės augalijos būklės gerinimui.

3. Ūminio toksiškumo tyrimų metu, apskaičiuota 96 val. LC50 kelių priežiūros druskos (KPD) vertė vaivorykštinio upėtakio jaunikliams yra 18,25 g/l. Todėl vykdant KPD toksiškumo kitų rūšių žuvims tyrimus, rekomenduojama vadovautis šia KPD koncentracija, kaip maksimalia naudotina koncentracija.

4. Siūloma įrengti daugiafunkcinės paskirties įrenginį – Infiltracinį – žolinį griovį. Infiltracinį – žolinį griovį rekomenduojama įrengti intensyvaus eismo pakelėse, tiesiant naujus kelius ar rekonstruojant bei atnaujinant esamus. Šis griovys išplečia vandens nuvedimo griovio funkcijas ir yra skirtas kompleksiniam neigiamam poveikiui kelio aplinkoje mažinti. Biotechniniam įrenginiui gautas Lietuvos respublikos patentas.

Trumpos žinios apie autorę

Agnė Kazlauskienė gimė 1978 m. rugpjūčio 20 d. Vilniuje. 2000 m. įgijo Aplinkos inžinerijos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2002 m. įgijo Aplinkos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. Nuo 2002 m. dirba Aplinkos apsaugos institute. 2003–2007 m. – Vilniaus Gedimino technikos universiteto doktorantė. Šiuo metu Agnė Kazlauskienė dirba jaunesniąja mokslo darbuotoja Vilniaus Gedimino technikos universiteto Aplinkos apsaugos institute.

Agnė Kazlauskienė

**RESEARCH AND EVALUATION OF THE INFLUENCE
OF ROAD MAINTENANCE SALTS ON THE ENVIRONMENT**

Summary of Doctoral Dissertation

Technological Sciences,

Environmental Engineering and Landscape Management (04T)

Agnė Kazlauskienė

**KELIŲ PRIEŽIŪRAI NAUDOJAMŲ DRUSKŲ ĮTAKOS
APLINKAI TYRIMAI IR VERTINIMAS**

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Vilniaus Gedimino technikos universiteto

leidykla „Technika“, Saulėtekio al. 11, LT-10223 Vilnius, <http://leidykla.vgtu.lt>

Spausdino UAB „Baltijos kopija“, Kalvarijų g. 16A, LT-09109 Vilnius

www.kopija.lt