

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Jolita BRADULIENĖ

INVESTIGATION OF EFFICIENCY OF GRAVEL ROADS DUST SUPPRESSANTS AND EVALUATION IN THE ROAD ENVIRONMENT

SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
ENVIRONMENTAL ENGINEERING (04T)



LEIDYKLA
Vilnius TECHNIKA 2011

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2006–2011.

Scientific Supervisor

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

Consultants:

Prof Dr Habil Pranas BALTRĖNAS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),

Assoc Prof Dr Antanas Aloyzas JUŽĖNAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

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

Chairman

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

Members:

Prof Dr Donatas ČYGAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T),

Dr Dainius MARTUZEVIČIUS (Kaunas University of Technology, Technological Sciences, Environmental Engineering – 04T),

Dr Jurga MOTIEJŪNAITĖ (Nature Research Centre, Biomedical Sciences, Botany – 04B),

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

Opponents:

Prof Dr Aloyzas GIRGŽDYS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T),

Assoc Prof Dr Paulius KERPAUSKAS (Lithuanian University of Agriculture, Technological Sciences, Environmental Engineering – 04T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Environmental Engineering in the Senate Hall of Vilnius Gediminas Technical University at 10 a. m. on 3 June 2011.

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@vgtu.lt

The summary of the doctoral dissertation was distributed on 2 May 2011.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

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Jolita BRADULIENĖ

ŽVYRKELIŲ DULKĖTUMĄ
MAŽINANČIŲ MEDŽIAGŲ
EFEKTYVUMO TYRIMAI
IR VERTINIMAS KELIO APLINKOJE

DAKTARO DISERTACIJOS SANTRAUKA

TECHNOLOGIJOS MOKSLAI,
APLINKOS INŽINERIJA IR KRAŠTOTVARKA (04T)



LEIDYKLA
Vilnius TECHNIKA 2011

Disertacija rengta 2006–2011 metais Vilniaus Gedimino technikos universitete.
Mokslinis vadovas

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

Konsultantai:

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

doc. dr. Antanas Aloyzas JUŽENAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

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:

prof. dr. Donatas ČYGAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

dr. Dainius MARTUZEVIČIUS (Kauno technologijos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T),

dr. Jurga MOTIEJŪNAITĖ (Gamtos tyrimų centras, biomedicinos mokslai, botanika – 04B),

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

Oponentai:

prof. dr. Aloyzas GIRGŽDYS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T),

doc. dr. Paulius KERPAUSKAS (Lietuvos žemės ūkio universitetas, technologijos mokslai, aplinkos inžinerija ir kraštovarka – 04T).

Disertacija bus ginama viešame Aplinkos inžinerijos ir kraštovarkos mokslo krypties tarybos posėdyje 2011 m. birželio 3 d. 10 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

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@vgtu.lt

Disertacijos santrauka išsiuntinėta 2011 m. gegužės 2 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva).

VGTU leidyklos „Technika“ 1873-M mokslo literatūros knyga.

Introduction

Topicality of the problem

The most important part of the transport sector in Lithuania is the roads. Currently, the total length of Lithuanian road network is more than 21 thousand kilometers. Under the Law on Roads, the roads are divided into the roads of State and Local importance. According to the data of 1 January 2010, the length of the roads of State importance in Lithuania, with a cover of gravel, is 7604 km.

The greatest negative impact on the environment, traffic safety and quality of life has gravel roads because of the dust and distribution of particulate matter on the roads and roadside areas. Dust forms on gravel roads due to the wear of gravel cover, under the influence of climatic factors and transport. Main goal and objective for the dust reduction on gravel roads are to prevent the formation of a cloud of dust from the small particles resulting from the gravel in the cover and the wearing process of cover.

When reducing road dust on gravel roads, during the summer season, chemical material in the form of solution is sprinkled and sprayed which first enters onto the driveway of the road and roadsides and directly pollutes the land of the protection area nearby the road. Indirect environmental pollution is also possible when atmospheric precipitation washes the chemical material out of the land of the road protection area into the surface and ground water nearby the road, and when chemical material from the soil and water gets into the plants.

Undesirable effects of impact of chemical material on the environment: roadside vegetation and the soil are damaged; surface and ground waters are polluted, which results in negative impact on wildlife and humans.

In summary, the biggest problem of dustiness caused on the gravel roads is the pollution of environmental components (both air and water) by particulate matter, which has direct (get into the airway of living organisms, stop the growth of flora) and indirect (mainly through the trophic chain and water flow) impact on living nature via polluted environmental components.

Currently, there are still a lot of unpaved roads. Effective and inexpensive chemical and technical measures to ensure the traffic safety and comfort during the summer and would not have a negative impact on the environment have not been found or developed yet. The gravel roads dustiness is one of the main causes of ambient air pollution with particulate matter; hence there is a need for the search of measures to reduce the spread of particulate matter. In most studies on material to reduce the dustiness, it was focused on their effectiveness, and there is no information about their environmental impact.

Object of the work – gravel road dust suppressants interaction with gravel roads.

Aim and tasks of the work. **Aim** is to analyze the effectiveness of materials (molasses based and its mixtures with technical salt) used to reduce the dustiness on gravel roads and to find efficient concentration of solution mixture used during the investigation, which would be less detrimental to the environment of gravel road.

To reach the aim set in the thesis, it is necessary to tackle the following **tasks**:

1. To analyze the impact of chemical material used for the reduction of dustiness on gravel roads on the environment and to assess the advantages and disadvantages of various measures used currently for the maintenance of roads during the summer to reduce environmental pollution.
2. To carry out the investigation of gravel roads dustiness through the treatment of gravel roads with the molasses based material and its mixture with technical salt and without their treatment, carrying out the investigations of dustiness in the laboratory and in natural (field) conditions.
3. To determine the optimal concentration of molasses based material and its mixture with technical salt to reduce the dustiness which would be less detrimental to the environmental vegetation of the roads.
4. To carry out the modeling of particulate matter scatter within the environment of gravel roads by determining the coefficients of particulate matter emission under certain environmental conditions according to the solution used for dustiness reduction.

Methodology of research includes particulate matter concentration measurement using mass and optical methods, chlorides concentration in soil measurement using titrimetric chemical analyze method and growth of grass vegetation in polluted soil method.

Scientific novelty

Complex work on the reduction of dustiness on gravel roads, without environmental hazard, through the application of molasses based material and its mixture with technical salt to reduce the dustiness on gravel roads which is previously unused in Lithuania, and the modeling results shall be used for the prognostication of the particulate matter scatter within the protection area of the road.

During the preparation of the thesis, the following results new for environmental engineering science were obtained:

1. Complex studies of selected mixtures were carried out in order to find out the effectiveness of the proposed mixtures, to reduce the dustiness on gravel roads, the impact of herbaceous plants and chloride concentration in the gravel road cover and the road environment.
2. Mixture for reduction of dustiness on gravel roads was improved.

Practical value. The obtained research results can be applied for the reduction of dustiness on gravel roads under Lithuanian and similar climatic conditions, and the modeling results on the scatter of particulate matter within the road environment will help to protect the road protection area and the greenery in its area from the spread of particulate matter.

Defended propositions

1. The concentration of particulate matter (PM) in ambient air of gravel roads is reducing by using molasses based material (MBM) on the gravel road cover.
2. Molasses based material (MBM) can be adapted for the use of the dustiness reduction on gravel roads under Lithuanian and similar climatic conditions.
3. The length of above-ground part of herbaceous plants is directly proportional to the content of molasses based material (MBM) in the soil.

The scope of the scientific work. The scientific work consists of introduction, 6 chapters, conclusions, list of references, list of author's publications and addendum. The total scope of the dissertation is 156 pages, 69 pictures, 19 tables and 1 addendum.

1. Gravel roads dustiness and dust suppressants

The chapter analyzes the origin of dust particles. Systematic information about the material normally used for dustiness reduction, its use, recommended amounts, as well as general principles on application of material and its effect has been described here. Efficiency and environmental impact of material is analyzed. The investigations related to the reduction of dustiness have been described; the models of scatter of particulate matter commonly used have been given.

After the literary review, it was found that dust emission on gravel roads depends on the cars speed, wheels number, traffic volume, material cover of gravel road, surface moisture of gravel road and climatic conditions. All the investigations on the dustiness analyzed showed that after chemical treating of gravel roads, PM emission decreases from 30 to 80 %. Water is the most secure material for the environment to reduce the dustiness, and oil-based products are the major environmental hazard. Environment impact of most products (e. g., molasses, sugar beet extract, tall oil derivatives, vegetable oils, clay additives) has not been studied so far. Effectiveness of molasses based material (MBM) for the reduction of the dustiness on gravel roads has not been studied in Lithuania yet. Therefore, it is necessary to carry out the investigations on the efficiency of this material and its environmental impact.

2. Laboratory investigation of reduction of particulate matter emission when using different solutions

Molasses based material (MBM) has been selected for the experimental laboratory investigations. Material is of an organic origin; therefore this product belongs to the category of oil-free product of organic material. Molasses is a secondary agricultural product derivable from industrial waste of sugar. It is dark brown in color, odorless, liquid material which can be mixed with all the chlorides and their solutions, but is rarely used alone. MBM has very good anticorrosive properties, is environmentally friendly and decomposes biologically. Calcium chloride (CaCl_2) is also used in investigations.

The experiments described in this chapter were carried out by means of determination of concentrations of particulate matter by mass method.

The aim of these investigations – is to determine gravel fraction using the solution of 36.5 % CaCl_2 for its treatment which is the most suitable for further laboratory experiments, and to carry out the investigations on concentration of particulate matter (PM) after the experiment without treating the samples by dustiness reducing material (control) and using the dustiness reduction measures – MBM and its mixtures with CaCl_2 .

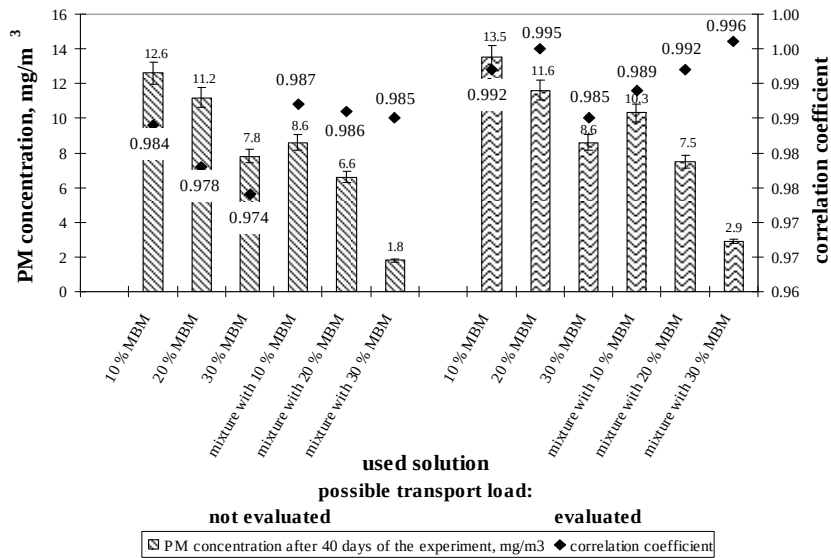


Fig. 1. PM concentration using MBM and its mixtures with CaCl_2 for reducing dustiness, possible transport load not evaluated and evaluated

According to methodological guidelines on the reduction of the dustiness on the roads with gravel cover, concentration of 35.6 % CaCl_2 solution was selected. Gravel was taken from the gravel surface, where the field investigation was carried out later.

The experiment was conducted under the laboratory conditions by carrying out the experiment in PM concentration measuring chamber. After the experiment and evaluation of the correlation coefficient of the results obtained, 0.0–0.4 mm fraction was selected for further studies. The aim of further studies is to determine effectiveness of solutions without evaluating and estimating possible transport load using mixtures of different MBM concentrations (10 %, 20 % and 30 %) and their mixtures with 35.6 % CaCl_2 solution for the treating of gravel samples. The results obtained are presented in Figure 1. Using mixtures of MBM with CaCl_2 , PM concentration is 1.5 to 4.3 times lower than using the MBM only (evaluating–not evaluating possible transport load).

Concentrations of particulate matter (PM) in the chamber for PM concentration measurement directly depend on the temperature: the higher air temperature, the higher PM concentration is. Under laboratory conditions, using mixtures of MBM and CaCl_2 , their effectiveness reaches 100 % immediately after the treating both without evaluating and estimating possible transport load.

3. Investigation of particulate matter emission in experimental road section environment

The experiments described in this chapter were carried out by measuring the concentration of particulate matter under optical method (using a PM concentration analyzer *MicroDust pro*).

The aim of these investigations is to determine the dependence of concentration of particulate matter on vehicle speed and distance from the roadway by using the same solutions for the dustiness reduction as during the investigations on reduction of the emission of particulate matter (Section 2): 10 %, 20 % and 30 % MBM and solution mixtures with 35.6 % CaCl_2 .

Also, the studies described in this section were carried out by means of titrimetric chemical analysis on chloride concentrations in soil.

The aim of this investigation is to evaluate the influence of MBM and calcium chloride mixture on the distribution of chloride concentrations in horizontal transverse profiles of the gravel road environment. Since MBM and CaCl_2 mixture was used in the three experimental sections for the reduction of dustiness on the gravel road, it was decided to check what concentration of chloride ions was left in the gravel road cover and how the following concentration distributed within the transverse profile of the road. The samples for investigating chloride concentrations were taken during the performance of experiment on exploratory sectors.

PM concentrations were measured at 0 m, 1 m, 2 m and 3 m distance downwind from the gravel road so that the higher PM concentration would be registered. The car drove at 30 km/h, 40 km/h and 50 km/h speed.

Before starting to measure, the wind direction, wind speed, ambient air temperature, moisture and pressure are determined. Temperature, moisture and wind speed are measured with the device TESTO-400. Atmospheric pressure is measured with the barometer. Wind direction is determined visually. The investigations were conducted in summer of 2007 (experimental sections treated with MBM) and in summer of 2008 (experimental sections treated with mixtures with MBM and CaCl_2). During the experiments (in 2007 and 2008), the parameter values of average prevailing environmental weather conditions were as follows: temperature of 26.51 °C and 21.65 °C, pressure 101.03 kPa and 100.64 kPa, moisture 59.11 % and 47.63 %, wind speed 1.5 m/s and 1.7 m/s

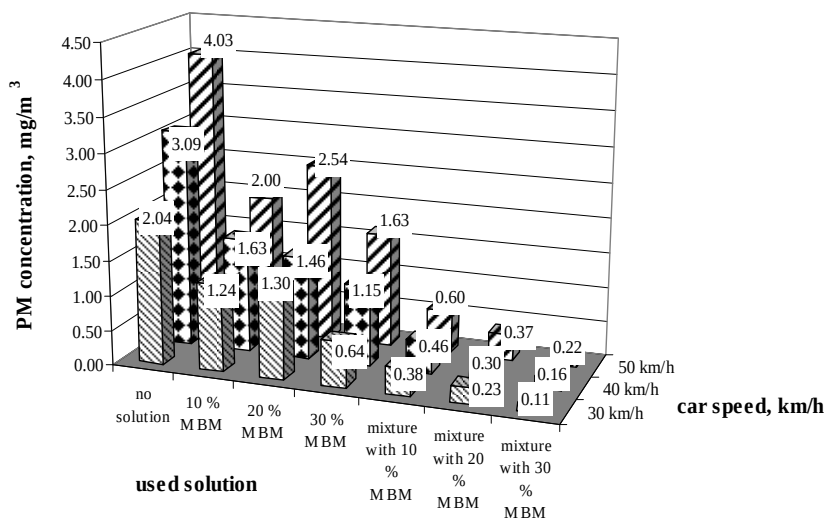


Fig. 2. Decrease of PM concentration for the results evaluated by accordance with the concentration of used solution and car speed

After the experimental measurements, the results obtained were evaluated according to the concentration of solution used and car speed (Fig. 2) and the distance from the roadway (Fig. 3) and both (without results from control section) (Fig. 4).

After treating the sections with solutions containing CaCl_2 , the content of dustiness is apparently less, even when solution contains only 10 % of MBM, and the vehicle goes 50 km/h (Fig. 2). The results obtained are even 3.3 times lower than compared with the control samples.

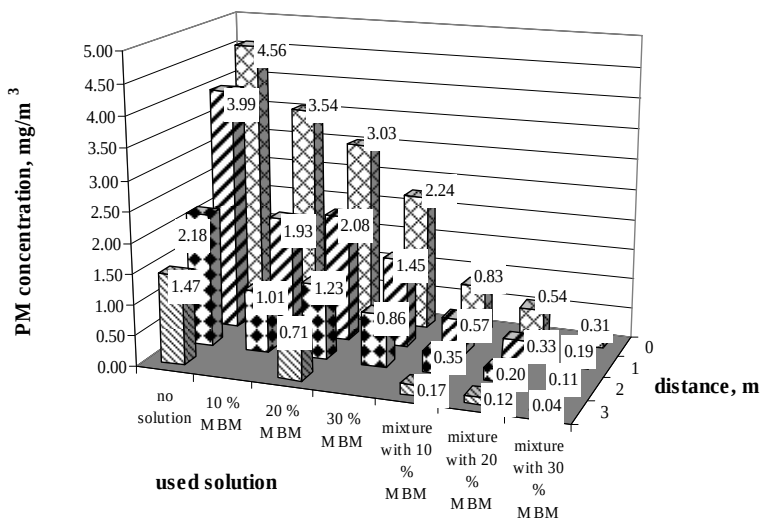


Fig. 3. Decrease of PM concentration for the results evaluated by accordance with the concentration of used solution and distance from the road

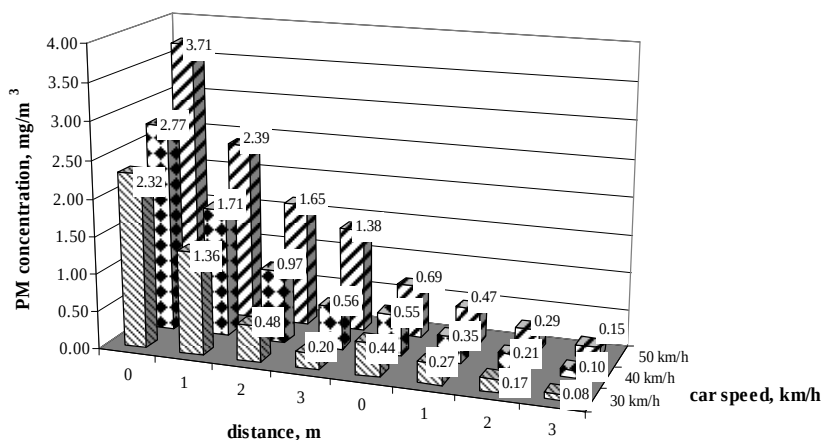


Fig. 4. Decrease of PM concentration for results evaluated by accordance with the distance from the road and car speed

At all distances from the road each summer, a decline of PM (Fig. 3) in air concentrations was determined depending on solution concentration and vehicle speed.

Having evaluated the distance from the roadway when MBM was used to reduce the dustiness (Fig. 4), and the vehicle speed did not exceed 30 km/h, permissible rate of PM (HN 35:2007) was not exceeded only two times (the distance from the road 2 and 3 meters at a speed of 30 km/h), whereas using the mixture of MBM with CaCl_2 – it exceeded only 2 times (next to the road at speeds of 40 and 50 km/h). After statistical analysis on PM concentrations and parameter of environmental conditions, it was found that the strongest correlation link (correlation coefficient 0.9) was obtained between PM concentration and temperature, PM concentration link with moisture and wind speed varied from weak to strong and showed up either on the roadside or receding from the road, i.e. the same trend to decrease or increase was not observed.

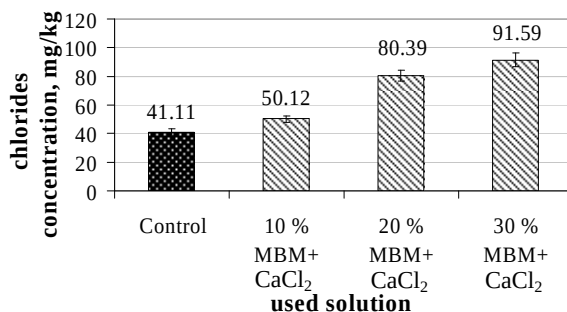


Fig. 5. Chlorides concentration in cover of gravel road

During the studies on chloride concentrations within the road environment, the average chloride concentration of control sector was equal to 41.11 mg/kg. This value has been adopted as a background chloride concentration. Chloride concentration is higher in the places that are treated with the mixtures of higher concentrations of MBM at the same concentration of CaCl_2 (36.5 %): when MBM concentration in the mixture is 10 % – 50.12 mg/kg of chlorides; 20 % – 80.39 mg/kg; 30 % – 91.59 mg/kg (Fig. 5). It can be assumed that MBM traps chloride concentration and increases it in the gravel cover.

4. Laboratory investigation of growth of grass vegetation in polluted soil

The investigations described in this chapter were carried out by means of the method on the growth of grass vegetation in the contaminated soil. The aim of these investigations is to determine the impact of material for the dustiness reduction on the viability of herbaceous vegetation and the length of above-ground part.

Three herbaceous plant species have been selected for the investigations: timothy-grass (*L. Phleum pratense*), white clover (*L. Trifolium repens*) and

crimson clover (*L. Trifolium incarnatum*). These species often grow on the roadsides of gravel roads and are used for the re-cultivation of nearby pastures.

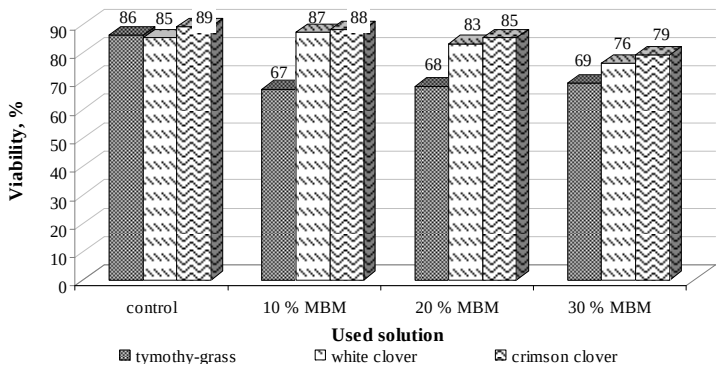


Fig. 6. Viability of timothy-grass, white and crimson clovers in soil

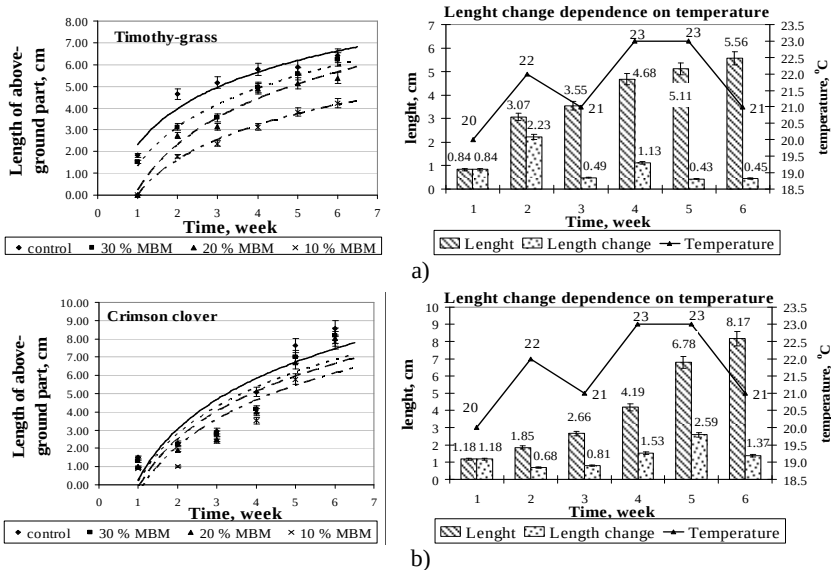


Fig. 7. Length variation of above-ground part of timothy-grass (picture a) and crimson clover (picture b)

The soil was contaminated with the same solutions which were used for the studies of PM concentration (chapters 2 and 3). Viability of selected herbaceous

plants in the soil after six weeks of the study is shown in Figure 6. Only the crimson clover germinated in soil contaminated with 10 % of MBM and CaCl_2 mixture when the soil polluted with MBM and CaCl_2 mixture was used for the studies.

After the investigations, it was determined that the best initial (first week) viability of plants was when using the highest MBM concentration in the soil.

Experimental investigations have shown that changes of length variation of above-ground part depended on change of temperature (Fig. 7). Changes of length variation of above-ground part for both species of clover were similar: the most significant change was observed when the temperature was higher for two weeks.

5. Modeling of particulate matter scatter in road environmental

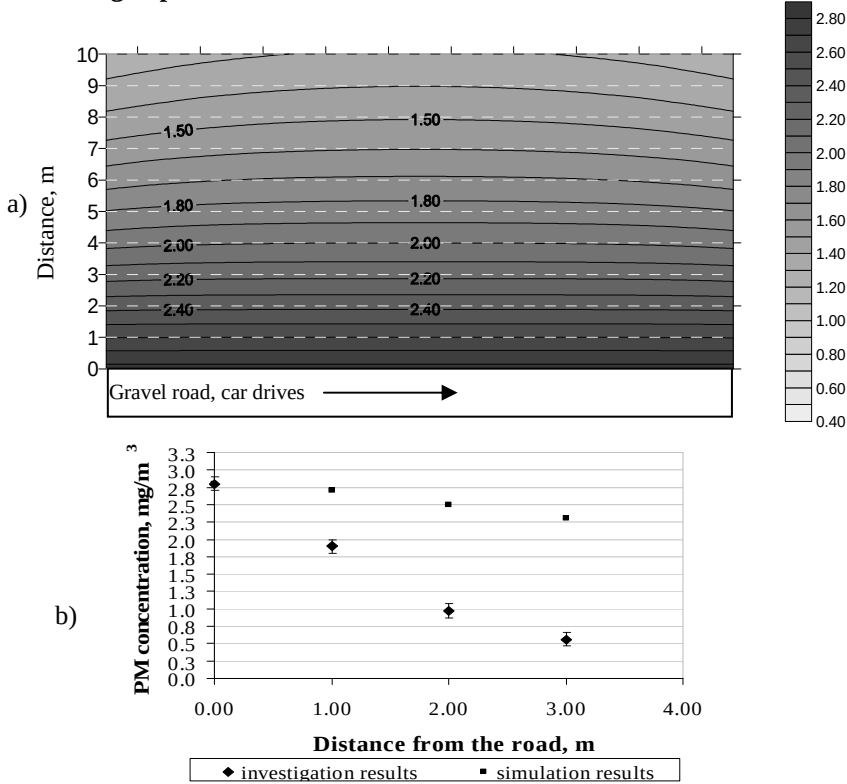


Fig. 8. Comparison of simulation and investigation results in road section, treated with 20 % MBM, car speed 40 km/h, wind direction north: a) simulation results; b) disagreement

The aim of modeling is to get the concentration values of particulate matter at the far distance from the road than it was measured during the study (chapter 3) by using the program ADMS 4.2, i.e. more than 3 m onward from the roadside, and to compare the model results derived with the investigation results. To obtain the most accurate results of modeling, the coefficients of emission content is recalculated in accordance with the PM concentration received during the studies on the roadside. Modeling results obtained are compared with the investigation results.

PM concentration results presented by the modeling program and their comparison with the investigation results are shown in Figures 8 and 9 (the most variable (Fig. 8) and coincide (Fig. 9) results of the model and investigations).

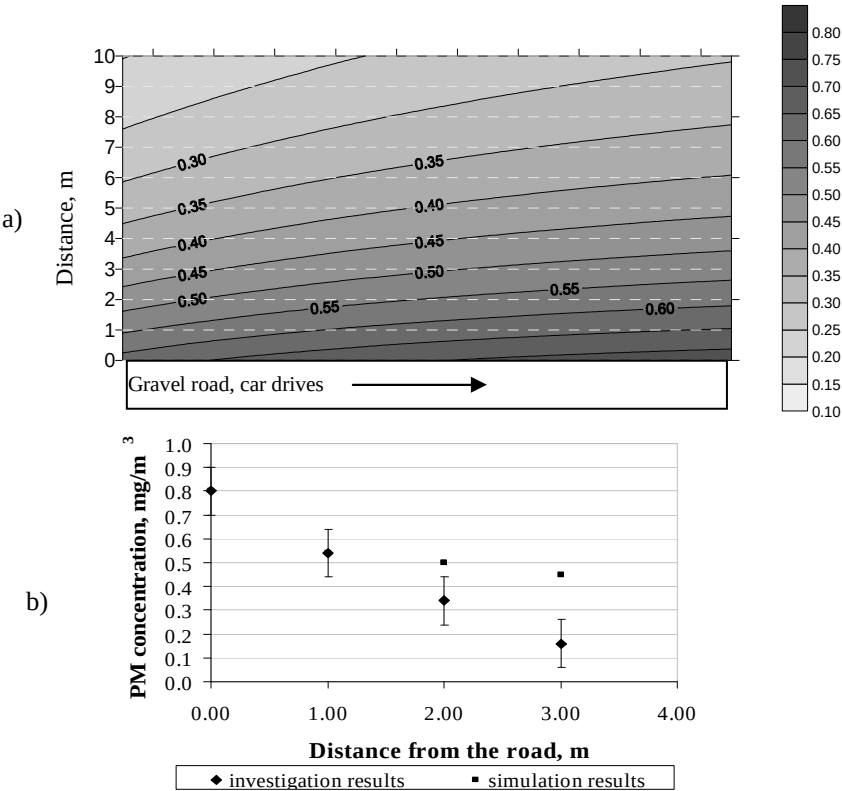


Fig. 9. Comparison of simulation and investigation results in road section, treated with mixture of 10 % MBM and 35.6 % CaCl_2 , car speed 40 km/h, wind direction North West: a) simulation results; b) disagreement

The modeling showed that having chosen the direction of the wind perpendicular to the road, higher PM concentrations have been calculated according to the model receding from the road. In order to get the values closer to real conditions, the direction of the wind perpendicular to the road should not be chosen during the modeling.

6. The developed methodology and suggested environmental consideration

This chapter presents the calculation on concentrations of pollutants in the soil (gravel cover) which is based on the calculations and accomplished study results proposed by various authors.

The aim of these calculations suggested is to simplify the calculations on amount of possible pollutants (chloride) in the soil.

Also, on the grounds of the material presented in this chapter, an application to obtain the Lithuanian patent has been prepared for the Lithuanian Patent Office.

The advantage of the new mixture for the reduction of the dustiness on gravel roads proposed is that after insertion of molasses based material into the calcium chloride, not only the dustiness on gravel roads is reduced, but there is also less damage to the roadside vegetation. The components of proposed material are as follows: calcium chloride, molasses based material and water. The aim of the invention is the development of material mixture for the reduction of the dustiness on the gravel roads which would be the less detrimental to the roadside vegetation.

General conclusions

1. The analysis of the literature showed that the material commonly used for the dustiness reduction on gravel roads are harmful to components of the environment of gravel roads (soil, vegetation). Up to now, Lithuania does not have any means for effective reduction of the dust which would have a minimal impact on the environment.
2. Experimental investigations have shown that suitable material for dustiness reduction on gravel roads is the molasses based material (MBM) but it is efficient most when first applied and during non-rainy days. It was found that 10 % of MBM reduces the concentration of particulate matter about two times under laboratory conditions immediately after the application; and under the field conditions – even about three times when the car was going 50 km/h on the average.

3. Experimental investigations have shown that MBM mixed with calcium chloride when first applied; PM concentration is 0 mg/m^3 . After the evaluation of the distance from the roadway when MBM and CaCl_2 mixture was used to reduce the dustiness, the maximum allowable onetime concentration of particulate matter in living ambient air under HN 35:2007 was exceeded only on the roadside (0 m), when the average vehicle speed was 40–50 km/h.
4. During experimental investigations, when solutions of different concentration were used for dustiness reduction on gravel roads, the strongest correlation was found between PM concentration and air temperature (correlation coefficient 0.9). Statistically significant relationship between PM concentrations and air moisture and PM concentration and wind speed has not been established.
5. Experimental investigations have shown that using MBM and CaCl_2 solution mixtures for the dustiness reduction on the gravel roads, chloride concentration was higher (till 2 times) within the places of gravel road cover which were treated with mixtures of increased MBM concentration (the same calcium chloride concentration – 35.6 %). It can be assumed that MBM keeps chloride concentration within the cover, but the studies should be carried out to determine the distribution of chloride concentrations in the deeper (20–40 cm) layers of the soil.
6. Experimental investigations have shown that higher amount of molasses based material (MBM) in the soil affects the length of above-ground part of selected species of grass plants (timothy-grass, white clover and crimson clover). Increasing trend of the length of above-ground part of plants has been established when MBM concentration in the soil was increasing, too, but the length of above-ground part of the plants in the soil contaminated with 10 % of MBM was 1.28 times lower, 20 % of MBM – 1.07 times lower, 30 % of MBM – 1.04 times lower than the plants grown in the soil unpolluted with MBM.
7. Experimental investigations have shown that crimson clover is the most resistant to the impact of CaCl_2 because it was the only one which germinated in the soil polluted with 10 % MBM and 35.6 % of CaCl_2 mixture.
8. It was determined that when using the program ADMS 4.2, the best coincidence of PM concentration results of experimental investigations and modeling (difference was 1.1–2.8 times at 3 m distance from the gravel road) was when the wind direction was not perpendicular ($\neq 90^\circ$; 270°) to the road and this is the best case for the pollutants modeling.

Recommendations

1. In order not to exceed the maximum allowable onetime concentration of particulate matter in living ambient air, it is recommended to use molasses based material of concentration of 30 % for the dustiness reduction on the gravel roads for a short period, and for a longer period – the solution of calcium chloride of 36.5 % and the molasses based material of 10 %.
2. It is appropriate to sow the meadows and pastures nearby gravel roads with crimson clover.

List of published works on the topic of the dissertation In the reviewed scientific journals

Bradulienė, J.; Vasarevičius, S. 2011. The impact on grass vegetation of materials reducing gravel road dustiness, *The Baltic Journal of Road and Bridge Engineering*. ISSN 1822-427X print, ISSN 1822-4288 online. IF=2,056. (Thomson ISI Web of Science). (in print).

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In the other editions

Bradulienė, J.; Vasarevičius, S. 2010b. Chloridų koncentracijos žvyrkelio aplinkos dirvožemyje tyrimai [Investigation of concentration of chlorides in soil of gravel road environmental], *Aplinkos apsaugos inžinerija, 13-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ straipsnių rinkinys (2010 m. kovo 25 d.)* [Environmental Engineering Proceedings of the XIII Conference of Lithuanian Young Scientists „Science – the future of Lithuania“, held in Vilnius on 25 March, 2010]. Vilnius: Technika: 43–48 (in Lithuanian). ISSN 2029-5456. (Index Copernicus).

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About the author

Jolita Bradulienė was born in Vilnius, on 26 of April 1982.

First degree in Environmental Engineering, Faculty of Environmental Engineering, Vilnius Gediminas Technical University, 2004. Master of Science in Environmental Engineering, Faculty of Environmental Engineering, Vilnius Gediminas Technical University, 2006. In 2006–2011 – PhD student of Vilnius Gediminas Technical University. Since 2006 Jolita Bradulienė works as Assistant in Environment Protection Department of Vilnius Gediminas Technical University.

ŽVYRKELIŲ DULKĖTUMĄ MAŽINANČIŲ MEDŽIAGŲ EFEKTYVUMO TYRIMAI IR VERTINIMAS KELIO APLINKOJE

Mokslo problemos aktualumas

Svarbi transporto infrastruktūros dalis Lietuvoje yra automobilių keliai. Šiuo metu bendras Lietuvos kelių tinklo ilgis siekia daugiau kaip 21 tūkstantį kilometrų. Pagal kelių įstatymą keliai skirstomi į valstybinės ir vietinės reikšmės kelius. 2010 m. sausio 1 d. duomenimis Valstybinės reikšmės kelių, kurių danga yra žvyras, ilgis Lietuvoje yra 7604 km.

Pakankamai didelę neigiamą įtaką aplinkai, eismo saugumui ir žmonių gyvenimo kokybei daro žvyrkeliai dėl jų dulkėjimo ir kietųjų dalelių sklaidos keliuose bei pakelės zonose. Žvyrkeliuose dulės susidaro dėl žvyro dangos dėvėjimosi, veikiant klimato veiksniams ir transportui. Pagrindinis žvyrkelių dulkėjimo mažinimo uždavinys ir tikslas yra neleisti susidaryti dulkių debesiai iš žvyro dangoje esančių ir dangos dėvėjimo procese atsirandančių smulkiųjų dalelių.

Dulkėtumą įtakojantys veiksniai: automobilių greitis, automobilių ratų skaičius, eismo intensyvumas, žvyrkelio dangos paviršiaus medžiaga, paviršiaus drėgmė, klimatas.

Mažinant kelių dulkėtumą žvyrkeliuose vasaros sezono metu barstoma ir purškiama cheminė medžiaga, kuri pirmiausiai patenka ant važiuojamosios kelio dalies bei jos kelkraščių ir tiesiogiai teršia šalia kelio esančią kelio apsaugos zonos žemę. Galima ir netiesioginė aplinkos tarša, kai atmosferos krituliai cheminę medžiagą išplauna iš kelio apsauginės zonos žemės į netoliese kelio esančius paviršinius ir gruntinius vandenius bei kai cheminė medžiaga iš dirvožemio ir vandens patenka į augalus.

Saugaus ir komfortiško eismo kaina – ženkliai padidėjusi automobilių metalinių dalių, gelžbetoninių konstrukcijų korozija, didėjanti neigiama įtaka aplinkai. Ilgalais cheminės medžiagos, skirtų dulkėtumo mažinimui, poveikis įtakoja transporto priemonių koroziją.

Pakilusios dulės gali būti nešiojamos iki šimto metrų atstumu, prasiskverbti į gyvenamuosius namus, padengti pasėlius, dėl to jų augimas gali sulėtėti. Nusėdusios smulkios žvyro dalelės didina vandenų drumstumą. Dulės yra viena iš alergijų priežasčių bei gali pernešti ligas. Smulkios žvyro dalelės gali būti abrazyvios ir todėl pagreitėja judančių autotransporto priemonių dalių nusidėvėjimas. Smulkios dalelės pakyla į orą ir nupučiamos, todėl prarandama žvyrkelio dangos medžiaga. Dulės mažina matomumą ir kelia pavojų eismo saugumui.

Be to, žvyrkelio dangos medžiaga gali būti nusviedžiama nuo kelio paviršiaus. Kai tai nutinka, kelias pradeda irti ir formuojasi nelygumai, skatinantys brangų taisymą.

Nepageidaujamos cheminių medžiagų poveikio pasekmės aplinkai: kenkiama pakelių augmenijai, dirvožemiui, užteršiami paviršiniai ir gruntiniai vandenys, o dėl to atsiranda neigiamas poveikis gyvūnijai ir žmonėms.

Apibendrinant galima teigti, kad didžiausia žvyrkeliuose sukkelto dulketumo problema yra aplinkos komponentų (tiek oro, tiek vandens) tarša kietosiomis dalelėmis, kurios per užterštus aplinkos komponentus tiesiogiai (patenka į gyvųjų organizmų kvėpavimo takus, stabdo floros augimą) ir netiesiogiai (daugiausiai per mitybos grandines bei vandens nuotėkį) kenkia gyvajai gamtai.

Šiuo metu yra vis dar daug neasfaltuotų kelių. Iki šiol nėra surasta ar sukurta tokių efektyvių ir nebrangių cheminių ar techninių priemonių, kurios užtikrintų eismo saugumą ir komfortą vasarą bei kartu neturėtų neigiamo poveikio aplinkai. Žvyrkelių dulkejimas yra pagrindinė kelio aplinkos oro taršos kietosiomis dalelėmis priežastis, todėl būtina ieškoti priemonių, mažinančių kietųjų dalelių sklidimą. Atliekant daugumą dulketumą mažinančių medžiagų tyrimų susitelkta ties jų efektyvumu, o informacijos apie jų poveikį aplinkai nėra.

Tyrimų objektas – žvyrkelių dulketumą mažinančių medžiagų sąveika su žvyrkeliais.

Darbo tikslas ir uždaviniai. **Tikslas** – ištirti žvyrkelių dulketumui mažinti naudojamų medžiagų (melasos pagrindu ir jos mišinių su technine druska) efektyvumą ir surasti efektyvią tyrimų metu naudojamų tirpalų mišinio koncentraciją, kuo mažiau kenkiančią žvyrkelio aplinkai.

Darbo tikslui pasiekti darbe reikia spręsti šiuos **uždavinius**:

1. Išanalizuoti žvyrkelių dulketumo mažinimui naudojamų cheminių medžiagų poveikį aplinkai bei įvertinti šiuo metu kelių priežiūrai vasaros metu naudojamų įvairių priemonių privalumus ir trūkumus, siekiant sumažinti aplinkos taršą.
2. Atlikti žvyrkelių dulketumo tyrimus, apdorojant žvyrkelius medžiaga melasos pagrindu bei jos mišiniu su technine druska ir neapdorojant jų, dulketumo tyrimus atliekant laboratorinėmis ir natūraliomis (lauko) sąlygomis.
3. Nustatyti optimalią dulketumui mažinti medžiagos melasos pagrindu ir jos mišinio su technine druska koncentraciją, kuo mažiau kenkiančią kelių aplinkos augalijai.

4. Atlikti kietųjų dalelių sklaidos žvyrkelių aplinkoje modeliavimą, nustatant kietųjų dalelių emisijos koeficientus tam tikromis aplinkos sąlygomis pagal dulkėtumui mažinti naudojamus tirpalus.

Tyrimų metodika apima kietųjų dalelių koncentracijos svorinio ir optinio nustatymo metodus, chloridų koncentracijos dirvožemyje titrimetrinį cheminės analizės metodą bei žolinių augalų augimo užterštame dirvožemyje metodą.

Mokslinis naujumas

Ši disertacija yra kompleksinis darbas, kuriame tyrinėjamos žvyrkelių dulkėtumo mažinimo galimybės, kartu nekeliant pavojaus aplinkai, taikant iki šiol žvyrkelių dulkėtumui mažinti nenaudotą medžiagą melasos pagrindu ir jos mišinius su technine druska, o modeliavimo rezultatus panaudojant kietųjų dalelių sklaidos į kelio apsaugos zoną prognozavimui.

Rengiant disertaciją buvo gauti šie aplinkos inžinerijos ir kraštotvarkos mokslui nauji rezultatai:

1. Atlikti pasirinktų mišinių kompleksiniai tyrimai, norint sužinoti siūlomų mišinių efektyvumą, mažinant žvyrkelių dulkėtumą, poveikį žoliniams augalams ir chloridų koncentraciją žvyrkelio dangoje bei kelio aplinkoje.
2. Patobulintas mišinys žvyrkelių dulkėtumui mažinti.

Praktinė reikšmė. Darbo rezultatai gali būti pritaikyti Lietuvos bei panašių klimato sąlygų šalių žvyrkelių dulkėtumo mažinimui, o kietųjų dalelių sklaidos kelio aplinkoje modeliavimo rezultatai padės geriau apsaugoti kelio apsaugos zoną ir joje esančius želdinius nuo kietųjų dalelių sklaidimo.

Ginamieji teiginiai

1. Laistant žvyrkelius medžiaga melasos pagrindu mažinama kietųjų dalelių koncentracija žvyrkelių aplinkos ore.
2. Medžiaga melasos pagrindu gali būti pritaikyta naudoti Lietuvos ir panašių klimato sąlygų šalių žvyrkelių dulkėtumui mažinti.
3. Žolinių augalų antžeminės dalies aukštis tiesiogiai proporcingas medžiagos melasos pagrindu kiekiui dirvožemyje.

Darbo apimtis. Darbą sudaro įvadas, 6 skyriai, išvados, literatūros sąrašas, publikacijų sąrašas ir priedas. Bendra disertacijos apimtis – 156 puslapiai, 69 iliustracijos, 19 lentelių ir 1 priedas.

Pirmasis skyrius skirtas literatūros šaltinių analizei. Jame analizuojama informacija apie dulkių dalelių atsiradimą ir dinamiką, dulkėtumą mažinančias

medžiagas, jų naudojimą, bendruosius taikymo principus ir veikimą, naudojamus kiekius, efektyvumą bei poveikį aplinkai, pasaulio šalyse naudojamas medžiagas, kietųjų dalelių sklaidos modeliavimą. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai. Antrajame skyriuje pateikiama kietųjų dalelių emisijos mažinimo laboratorinių tyrimų metodikos, rezultatų analizė bei išvados. Trečiajame skyriuje pateikiamos eksperimentinio kelio ruožo aplinkoje tyrimų metodikos, rezultatų analizė bei išvados. Ketvirtajame skyriuje pateikiamos žolinių augalų augimo užterštame dirvožemyje tyrimų metodikos, gautų rezultatų analizė, gautų tyrimų rezultatų išvados. Penktajame skyriuje pateikiama modeliavimo metodika bei gautų modeliavimo rezultatų palyginimas su tyrimų metu gautais rezultatais bei pateikiamos išvados. Šeštajame skyriuje aprašomas aplinkosauginis sprendimas.

Bendrosios išvados

1. Išanalizavus literatūrą nustatyta, kad žvyrkelių dulktumo mažinimui dažniausiai naudojamos medžiagos kenkia žvyrkelių aplinkos komponentams (dirvožemiui, augalijai). Iki šiol Lietuvoje nėra efektyviai dulktumą sumažinančios ir pasižyminčios minimaliu poveikiu aplinkai medžiagos.
2. Eksperimentinių tyrimų metu nustatyta, kad žvyrkelių dulktumui mažinti tinkama medžiaga melasos pagrindu (MMP), tačiau jos efektyvumas didžiausias taikymo pradžioje ir nelietingomis dienomis. Nustatyta, kad 10 % MMP iškart po taikymo kietųjų dalelių koncentraciją laboratorinėmis sąlygomis sumažina iki 2 kartų, o lauko – net iki 3 kartų, kai automobilis važiavo vidutiniu 50 km/h greičiu.
3. Eksperimentinių tyrimų metu nustatyta, kad MMP maišant kartu su kalcio chloridu taikymo pradžioje kietųjų dalelių (KD) koncentracija lygi 0 mg/m³. Įvertinus atstumą nuo važiuojamosios kelio dalies, kai dulktumui mažinti naudotas MMP ir CaCl₂ mišinys, didžiausia leidžiama vienkartinė kietųjų dalelių koncentracija gyvenamosios aplinkos ore pagal HN 35:2007 viršyta tik kelkraštyje (0 m), kai automobilio vidutinis greitis buvo 40–50 km/h.
4. Eksperimentinių tyrimų metu, žvyrkelių dulktumui mažinti naudojant įvairios koncentracijos tirpalus, stipriausias koreliacinis ryšys nustatytas tarp KD koncentracijos ir oro temperatūros (koreliacijos koeficientas 0,9). KD koncentracijos ir oro drėgmės bei KD koncentracijos ir vėjo greičio statistiškai patikimas ryšys nenustatytas.
5. Eksperimentinių tyrimų metu nustatyta, kad žvyrkelių dulktumui mažinti naudojant MMP ir CaCl₂ tirpalų mišinius, chloridų koncentracija buvo didesnė (iki 2 kartų) tose žvyrkelio dangos vietose, kurios buvo

- padengtos mišiniais su didesne nei 10 % MMP koncentracija (kalcio chlorido koncentracija vienoda – 35,6 %). Galima daryti prielaidą, kad MMP sulauko chloridus kelio dangos paviršiuje ir neleidžia jiems sklisti į kelio aplinką. Tačiau reiktų atlikti papildomus chloridų koncentracijos pasiskirstymo gilesniuose (20–40 cm) grunto sluoksniuose tyrimus.
6. Eksperimentinių tyrimų metu nustatyta, kad didesnis medžiagos melasos pagrindu (MMP) kiekis dirvožemyje įtakoja pasirinktų žolinių augalų rūšių (pašarinio motiejuko, baltojo ir purpurinio dobilų) antžeminės dalies aukštį. Nustatyta augalų antžeminės dalies aukščio didėjimo tendencija didėjant MMP koncentracijai dirvožemyje, tačiau 10 % MMP užterštame dirvožemyje augalų antžeminės dalies aukštis buvo 1,28 karto mažesnis, 20 % MMP – 1,07 karto mažesnis, 30 % MMP – 1,04 karto mažesnis nei augalų, augintų neužterštame MMP dirvožemyje.
 7. Eksperimentinių tyrimų metu nustatyta, kad CaCl_2 poveikiui atspariausias purpurinis dobilas, kadangi jis vienintelis sudygo dirvožemyje, užterštame 10 % MMP ir 35,6 % CaCl_2 mišiniu.
 8. Modeliavimui naudojant programą ADMS 4.2 nustatyta, kad geriausiai eksperimentinių tyrimų ir modeliavimo rezultatai sutampa (skirtumas 1,1–2,8 karto 3 m atstume), kai vėjo bei kelio kryptys yra ne vienodos ir tarpusavyje sudaro kampą, nelygų 90° (270°) ir tokiu atveju geriausia taikyti modeliavimo programą.

Rekomendacijos

1. Siekiant neviršyti didžiausios leidžiamos vienkartinės kietųjų dalelių koncentracijos gyvenamosios aplinkos ore, rekomenduojama žvyrkelių dulkėtumui mažinti naudoti tokius tirpalus: trumpam laikotarpiui 30 % koncentracijos medžiagą melasos pagrindu, o ilgesniam laikui – 36,5 % kalcio chlorido ir 10 % koncentracijos medžiagos melasos pagrindu mišinį.
2. Greta žvyrkelių esančias pievas ir ganyklas tikslinga apsėti purpuriniais dobilais.

Trumpos žinios apie autorių

Jolita Bradulienė gimė 1982 m. balandžio 26 d. Vilniuje.

2004 m. įgijo aplinkos inžinerijos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2006 m. įgijo aplinkos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2006–2011 m. – Vilniaus Gedimino technikos universiteto doktorantė. Nuo 2006 m. dirba asistente Vilniaus Gedimino technikos universiteto Aplinkos apsaugos katedroje.