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Investigation of particulate matter and chloride concentrations in the environment of gravelled roads

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The main problem related to gravelled roads is their dustability during the warm season of the year. The formation of dust is mainly predetermined by traffic intensity, climatic factors and the quality of gravel applied. A large variety of treatment materials and methods are applied to deal with the problem of dustiness. Bituminous emulsion and calcium chloride are among the most popular and widespread materials used to reduce dustiness in Lithuania. The article presents the findings obtained from the investigation of gravelled-road sections treated and untreated with different materials reducing dustiness in different regions of Lithuania. According to these findings, when inserted in the paving of gravelled roads, bituminous emulsion is most effective in reducing dustiness: its effectiveness reaches up to 95%. When impacted by precipitation, calcium chloride is leached out of the top layer of the treated gravelled road paving, and its efficiency in binding particulate matters reaches 17–25%.

Key words: particulate matter, gravelled roads, dustiness reduction, bituminous emulsion, calcium chloride, roadside soil

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INTRODUCTION

The dustiness of gravelled roads worsens traffic conditions, road practicability and capacity, and poses threat to traffic safety (VĮ transporto..., 2006; Žilionienė et al., 2007). Large quantities of particulate matters have a negative effect on the environment (Baltrėnas et al., 2008). The maximum road capacity drops by half where the length of a dust cloud is up to 40 m and 7 times at the length of the dust cloud 150–200 m. In consequence of worsened visibility, the speed of vehicles passing each other falls to 15–20 km/h. A perfect correlation between a gravelled road and the environment can be achieved only by means of reconstructing the road or laying asphalt paving over it, whereas the pollution of the environment with dust can be reduced by applying various means intended for dustiness reduction, which will ensure good road paving conditions suitable for traffic, as well as the road environment (Bolander, Yamada, 1999; Žvyrkelių dulkėjimo..., 2007).

In Lithuania, asphalt is constantly laid over the surface of gravelled roads according to various state programs. There were 8,416 km of gravelled roads in Lithuania in 2006 versus 8,091.92 km in 2008 (Kelių dangos..., 2008).

Trial works to reduce dustiness of gravelled roads were started in Lithuania in 1999. The scope of these works was enlarged in all the regions by using various measures intended for dustiness reduction and fitting up trial sections in 2003; 51.7 km and 95.9 km of gravelled roads were treated with dustiness reducing materials in 2003 and 2004, respectively. In 2003, operations of dustiness reduction on gravelled roads were carried out in 29 road sections with the total length of 51.7 km. In 2004, 27 out of 29 road sections were repeatedly treated for dustiness (the total length of 27 gravelled road sections was 50.3 km). 24 new sections were additionally fitted up in 2004. Bituminous emulsion was applied on the major part of the road sections to reduce dustability. In 2003, the number of such sections was 15 with the total length of 25.5 km, and in 2004 it was 28 with the total length

of 48.5 km. On 14 road sections, out of the total of 28, bituminous emulsion was applied to reduce dustability for the second year in turn. The mentioned road sections are located in all regions of Lithuania except Kaunas. From 2004, six sections were fitted up in Kaunas, Panevėžys, Telšiai, Utena, and Alytus regions (with the total length of 13.0 km) where calcium lignosulphonate was applied to reduce dustability. In 2004, the number of such sections increased to 13 with the total length of 25.9 km.

Calcium chloride is also being applied to reduce the dustability of gravelled roads. Eight and 12 trial sections were fitted up in the roads of Alytus, Panevėžys, and Šiauliai regions in 2003 and 2004, respectively. The total length of these sections was 13.2 km and 21.5 km in 2003 and 2004, respectively. In 2004, calcium chloride was repeatedly inserted in gravelled roads with the total length of 12.6 km (7 road sections).

In 2007, 15 gravelled road sections were treated with dustiness-reducing materials: 2 in Alytus, 4 in Panevėžys, 4 in Šiauliai, 1 in Utena and 4 in Vilnius regions. The treatment covered the total of 27.88 km of gravelled roads. The major part (15) of gravelled road sections were treated with calcium chloride and 5 with bituminous emulsion (www.lra.lt).

The impact of dustiness-reducing agents on the environment can manifest itself in many ways such as atmospheric transports, surface leakage, absorption by plants, ingestion by animals, when humans eat meat containing dustiness-reducing agents, when dustiness-reducing agents are infiltrated into a water area and groundwater during transportation, during water evaporation from the soil, during spraying operations skin or mouth contacts or inhalation are possible, danger to the ecosystems of the soil because of substances contained therein, transportation of dustiness-reducing particles to unexpected areas because of wind erosion,; leakage of substances from roadsides and during transportation of solvents; when consuming contaminated groundwater, spatter leakage downwind during application of dustiness-reducing agents, ingestion by humans of the components of dustiness-reducing agents (Foley et al., 1996; Žilionienė et al., 2007; Potential Environmental..., 2002).

OBJECTS AND METHODS

Determination of the fractional composition of gravelled road paving

To analyse the paving of a gravelled road by fractions, a sample is taken from the road in question; 1 kg of the sample is weighed and sieved with the AS200 Digital 70 analytical unit with the sieving amplitude of 3 min. The granulometric composition, i.e. the percentage of every fraction of a different size in the total composition of the paving of the gravelled road in question is determined. Fraction sizes are as follows: >5 mm; 5–4 mm; 4–2.5 mm; 2.5–2 mm; 2–1.6 mm; 1.6–1 mm; 1–0.9 mm; 0.9–0.6 mm; 0.6–0.4 mm; 0.4–0.3 mm; 0.3–0.2 mm; 0.2–0.1 mm; 0.1–0.05 mm; <0.05 mm (Žvyrkelių dulkėjimo..., 2007; Zaveckytė, Vasarevičius, 2008).

Determination of meteorological parameters

When performing research on the dustiness of gravelled roads, meteorological conditions were determined: the speed and direction of the wind, ambient air temperature and humidity. Temperature, air humidity and wind speed were measured with the TESTO-350 microclimate analyser. Wind direction was determined visually. The observations of the nature of precipitation, ambient air temperature and humidity were started at least 3 days before making measurements of solid particle concentrations in the air. These measurements can be started when there is no rain and the average ambient air temperature is no lower than 18 °C for at least 3 days (Žvyrkelių dulkėjimo..., 2007).

Determination of solid particles concentrations in the air

The aim of the research was to determine the concentrations of dust particles in the air by making transverse profiles on the sides of the gravelled roads treated with different agents reducing dustiness. Measurements of dustiness were made downwind by making the transverse profile of 5 points at a distance of 1 m, 2 m, 5 m, 10 m and 25 m from the roadway. Control measurements of dust concentration in the air were performed in a road section not treated with any agent reducing dustiness. In the gravelled road section in question, the measurements of solid particle concentrations were performed at the beginning, at the end and in the middle of the road section every kilometre.

The measurements of particulate concentrations in the ambient air were made with the Micro Dust *pro* dust monitor with the measuring range 0.001 to 2500 mg/m^3. This instrument measures particulate concentrations using the near-forward-angle light scattering technique. Infrared light (wave length 880 nm) is projected through the sensing volume where a contact with particles causes the light to scatter.

At the points of measuring particulate concentrations, the analyser is held at a height of one meter from the road paving. Air samples are taken every 2 min as long as a cloud of dust is settling down as observed visually.

Experiments were performed according to the proposed method based on methods used by other researchers (Baltrėnas, Kvasauskas, 2005; Baltrėnas, Morkūnienė, 2006; Giummarra et al., 1997; Järvinen et al., 1993).

Chloride concentrations in roadside soil

The aim of research was to measure chloride concentrations on the gravelled road roadsides.

Chemical analysis: soil samples collected from roadsides of the gravelled road No. 3106 were dried up, sieved through a 2 mm sieve and divided into 100 g portions. The soil samples prepared in the said manner were placed in glass vessels, topped with 200 ml of 5% HNO_3 solution and placed in a shaker for an hour. The settled samples were taken out of the shaker, filtered through filter paper and poured into a 250 ml conical flask in 100 ml portions. 1 ml of 10% K_2CrO_4 was poured into each sample and titrated with 0.02 mol/l

$AgNO_3$ solution until a sample colour turned from yellowish to orange.

The chloride concentrations established by the titrimetric analysis are expressed and presented in mg/kg, when analysing the distribution of chlorides with the distance from the roadway, increasing according to a transverse profile. To record chloride concentrations, soil samples were taken on both sides of the road. The difference in the results was statistically verified, and therefore the article presents results from one side of the highway. An error of 15%, shown in the diagrams, is possible when measuring chloride concentrations by the titrimetric method of chemical analysis (Lietuvos standartas…, 2003; Kazlauskienė et al., 2008).

Gravelled roads under study

Two gravelled roads located in different regions were selected for the investigation. These gravelled roads were treated with materials dustiness-reducing (bituminous emulsion and calcium chloride).

The road Bagaslaviškis–Neveronys–Mikalajūnai (Neveronys residential area) is a road of regional significance (No. 4310). Its length is 10.95 km. The road is maintained by the "Vilniaus regiono keliai" state enterprise.

To reduce dustiness on road No. 4310, the paving of the 5.07–5.85 km section was repeatedly treated with bituminous emulsion on 23 April 2007. Dustiness was measured by organising three expeditions. The first expedition was held on 20 July 2007, i. e. after three months from road paving treatment with bituminous emulsion, the second on 3 August 2007, i. e. 3 months and 3 weeks after the road paving treatment, and the third on 20 September 2007, i. e. 5 months after the treatment. The road paving was repeatedly treated with bituminous emulsion on 30 April 2008. Dustiness was again measured three times: on 30 May 2008 (1 month after road paving treatment), on 11 July 2008 (2 months and 2 weeks after road paving treatment), and on 8 September 2008 (4 months and 1 week after road paving treatment). A control investigation of the dust concentration was performed at kilometre 6 of the road No. 4310.

The second road in question, Krinčinas–Žvirgždė–Šukionys–Meiliūnai, is a road of regional significance (No. 3106). Its length is 16.3 km. The road is maintained by the "Panevėžio regiono keliai" state enterprise. On 4 May 2007, a 12.5–16.3 km section without asphalt paving of the road No. 3106 was treated with calcium chloride ($CaCl_2$) to reduce dustiness for the third year in turn. Dustiness in the 12.5–16.3 km section was measured by organising three expeditions: on 17 July 2007, i. e. 2 months and 2 weeks after the road paving treatment with calcium chloride, on 3 August 2007, i. e. 3 months after the treatment, and on 14 September 2007, i. e. 4 months and 1 week after the road paving treatment.

The mentioned road section was repeatedly treated with calcium chloride in 2008. The first expedition was organised on 28 May 2008, i. e. 1 month after the road paving treatment with calcium chloride, the second expedition was held on 24 July 2008, i. e. 2 months and 2 weeks after the treatment, and the third on 16 September 2008, i. e. 4 months and 2 weeks after the treatment. A control measurement of the dust concentration was done at kilometre 11.5 of the road Krinčinas–Žvirgždė–Šukionys–Meiliūnai.

RESULTS AND DISCUSSION

Fractional composition of gravelled road paving

As described in Objects and Methods, the fractional composition of the paving of gravelled roads in question was analysed. Upon weighing 1 kg of the surface paving of a gravelled road, its fractional composition was obtained (Fig. 1).

As Fig. 1 shows, by mass, medium-sized (0.9–4.00 mm) fractions account for the major part of a road paving sample of 1 kg. Dustiness is caused by fine fractions of a road paving, which remain suspended in the air longest and are transferred by airflows. Such fractions are 0.1 mm and smaller in diameter. By mass, such fractions account for around 3.5% in a road paving.

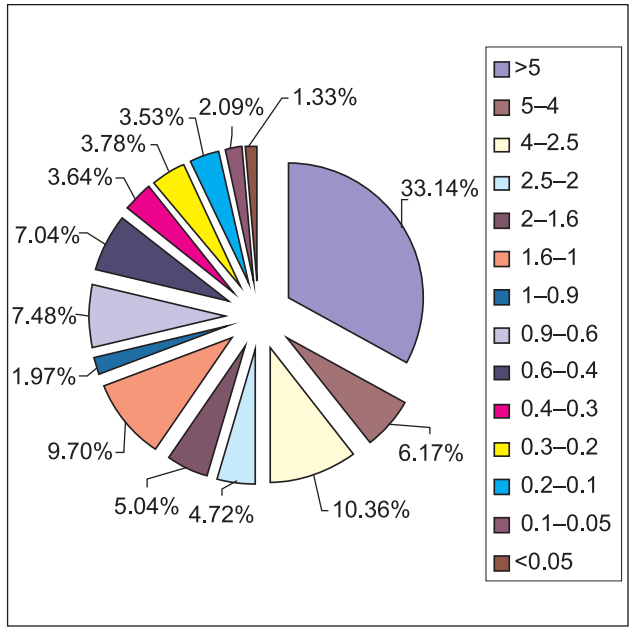

Fig. 1. Paving fraction percentage for road No. 4315
1 pav. Kelio Nr. 4315 dangos frakcinė sudėtis (%)

As Fig. 2 shows, the largest fraction >5 mm (183.32 g, i. e. 18.33%) makes the biggest and the gravel fraction with the diameter <0.05 mm (8.85 g, i. e. 0.89%) the smallest part in the paving of the road Krinčinas–Ličiūnai–Mieliūnai. The gravel fraction 0.6–0.4 mm accounts for 15.2% (151.99 g).

A comparison of the paving fractional composition of both roads shows that fine fractions are better bound when road is treated with bituminous emulsion than in the case of calcium chloride. This may predetermine a higher dustiness of gravelled roads treated with calcium chloride.

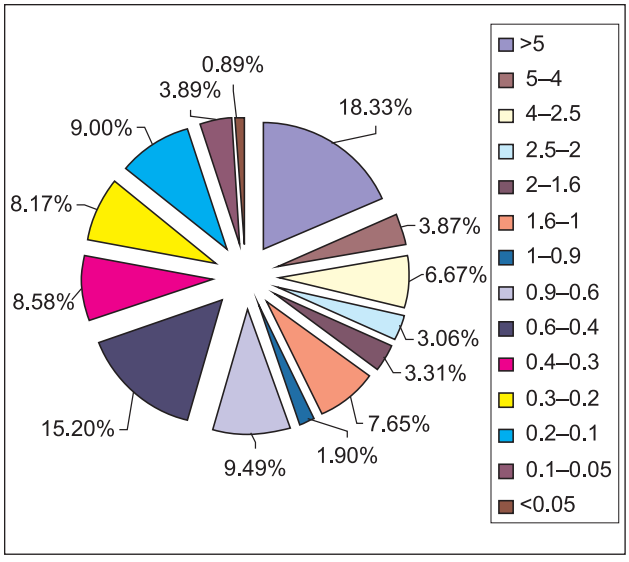

Fig. 2. Paving percentage fraction for road No. 3106

2 pav. Kelio Nr. 3106 dangos frakcinė sudėtis (%)

Data of meteorological parameters

The level of dustiness of gravelled roads depends on meteorological conditions.

The longer the duration of a high air temperature and low humidity, the higher the dustiness. Another factor affecting dustiness is wind velocity which predetermines the spread of dust. The higher the wind velocity, the bigger the area of dust spread.

Findings of research into particulate concentrations

Particulate matter concentrations in the air were measured at a vehicle driving velocity of 50 km/h.

As Fig. 3 shows, on the road section treated with emulsion, on 20 July 2007 the concentrations of particulate matter were by 97% lower as compared with an untreated road section where control measurements were recorded.

On 3 August 2007, on the road section treated with emulsion, the concentrations of particulate matter was by 95% lower as compared to an untreated road section where control measurements were taken (Fig. 4).

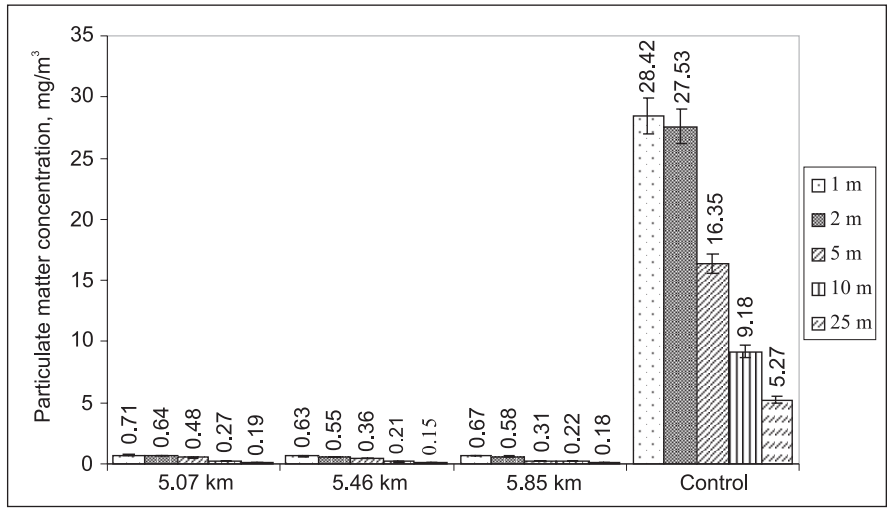

Fig. 3. Particulate concentrations in the section 5.07–5.85 km of the road No. 4310 Bagaslaviškis–Neveronys–Mikalajūnai on 20 July 2007

3 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2007 07 20)

Table 1. **Meteorological conditions during the measurement of particulate concentrations**

1 lentelė. **Meteorologinės sąlygos kietųjų dalelių matavimo metu**

Data	Temperature, °C	Humidity, %	Wind direction	Wind speed, m/s
Panevėžys county				
17 07 2007	29.8	43.5	Eastern	0.57
03 08 2007	22.6	62.3	South-eastern	1.35
14 09 2007	14.2	63.6	South-western	0.85
28 05 2008	23.2	63.1	North-western	0.68
24 07 2008	26.4	55.8	North-western	0.33
16 09 2008	18.9	66.3	North-western	0.72
Vilnius county				
20 07 2007	20.7	59.6	Western	1.34
03 08 2007	22.7	63.4	South-eastern	1.78
14 09 2007	14.4	61.9	South-western	1.44
30 05 2008	22.3	60.5	South-western	0.76
11 07 2008	23.4	63.7	South-western	1.39
08 09 2008	21.3	69.3	Eastern	0.79

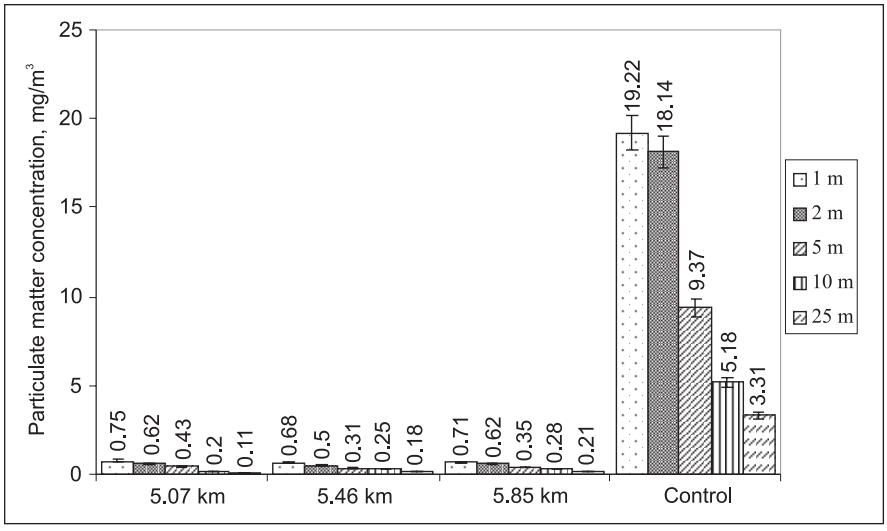

Fig. 4. Particulate concentrations in the section 5.07–5.85 km of the road (No. 4310) Bagaslaviškis–Neveronys–Mikalajūnai on 3 August 2007

4 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2007 08 03)

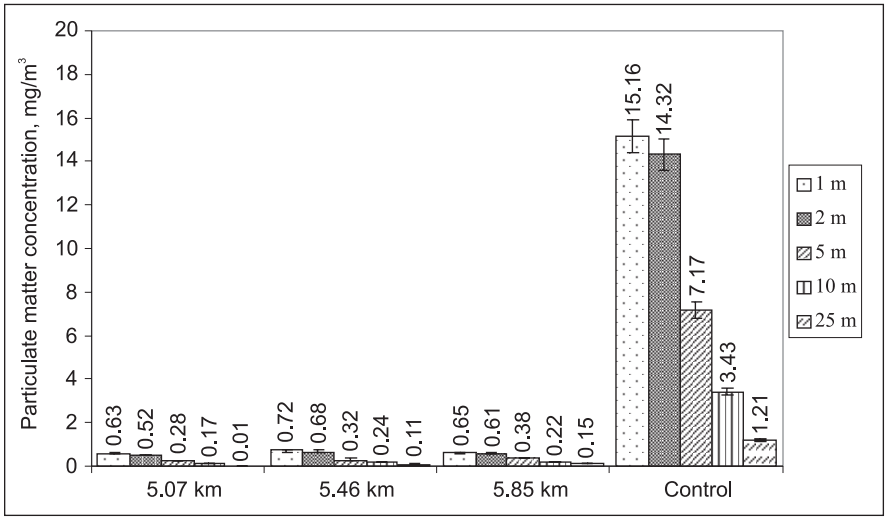

Fig. 5. Particulate concentrations in the section 5.07–5.85 km of the road No. 4310 Bagaslaviškis–Neveronys–Mikalajūnai on 14 September 2007

5 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2007 09 14)

A comparison of the findings obtained during the first and second expeditions did not show any significant changes in particulate matter concentrations in the treated section 5.07–5.85 km of the road No. 4310 one month after the first expedition, even though the control concentrations noticeably differed.

On 14 September, on the road section treated with emulsion, the concentrations of particulate matter were by 95% lower as compared to the untreated road section where control measurements were made.

Thus, after a repeated treatment of the road paving with bituminous emulsion, particulate matter concentrations in the air were around 95–97% lower as compared to those recorded in an untreated road section.

The road in question was repeatedly treated with bituminous emulsion in 2008. To measure the dustiness of the gravelled roads, three expeditions as in 2007 were organised.

On the road section treated with emulsion, the concentrations of particulate matter were by around 97% lower as compared to the untreated road section where control measurements were made. The highest particulate matter concentrations were recorded at a distance of 1 m from the road, and with the distance from the road the concentrations were gradually decreasing (Fig. 6).

As Fig. 7 shows, on the road section treated with emulsion, the concentration of particulate matter was by 95% lower as compared to the untreated road section where control measurements were made.

On the road section treated with emulsion, the concentration of particulate matter was by around 95% lower as compared to the untreated road section where control measurements were recorded. Thus, after repeated treatment of the road paving with emulsion, particulate matter concentrations in the air were by around 95–97% smaller as compared to those recorded in an untreated road section. Such efficiency was recorded regardless of the measurement time and meteorological conditions during the measurement. A good efficiency of this material in reducing dustiness is evident.

A comparison of results obtained in two years shows the same results in 2007 and 2008. After a repeated treatment of the road paving with bituminous emulsion, the reduction

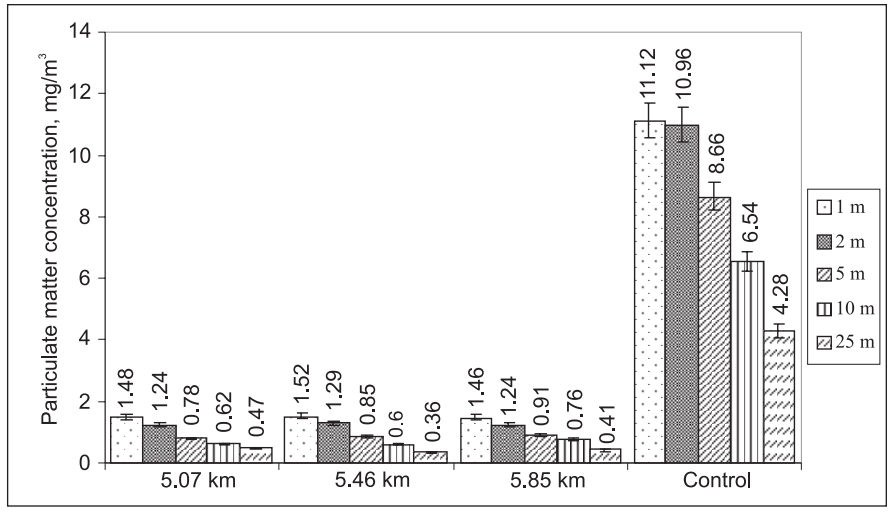

Fig. 6. Particulate concentrations in the section 5.07–5.85 km of the road No. 4310 Bagaslaviškis–Neveronys–Mikalajūnai on 30 May 2008

6 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2008 05 30)

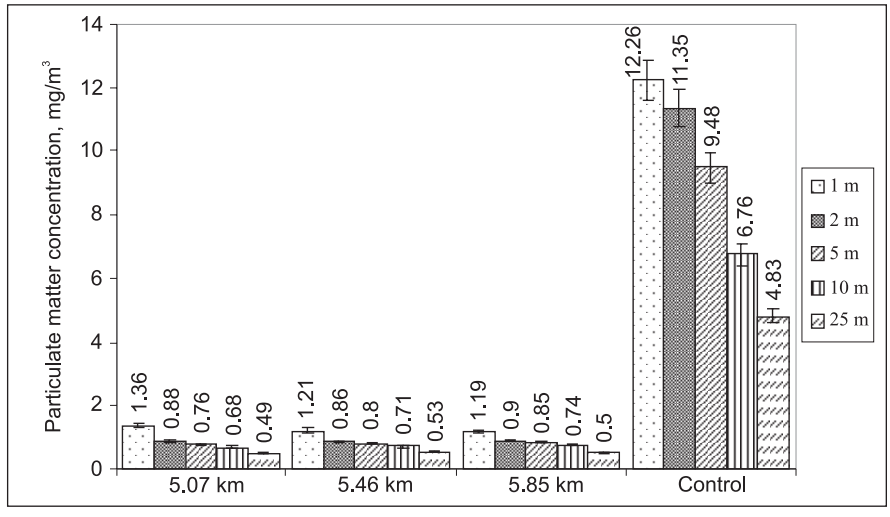

Fig. 7. Particulate concentrations in the section 5.07–5.85 km of the road No. 4310 Bagaslaviškis–Neveronys–Mikalajūnai on 11 July 2008

7 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2008 07 11)

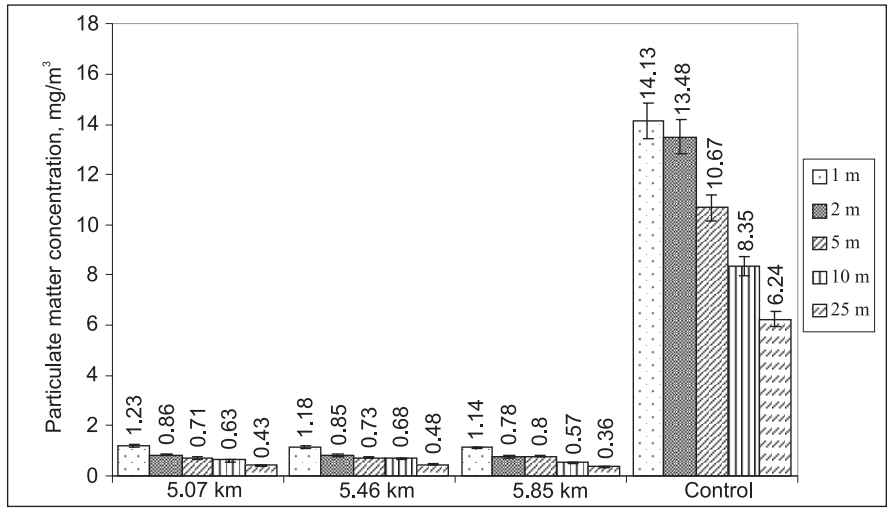

Fig. 8. Particulate concentrations in the section 5.07–5.85 km of the road No. 4310 Bagaslaviškis–Neveronys–Mikalajūnai on 8 September 2008

8 pav. Kietųjų dalelių koncentracijos ore kelio Bagaslaviškis–Neveronys–Mikalajūnai (Nr. 4310) 5,07–5,85 km aplinkoje (2008 09 08)

of dustiness was 95–97%. This material is water-proof, not leached out by rain, and therefore its efficiency in reducing dustiness does not decrease.

Measurements of particulate matter concentrations in the air in the environment of the road section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai treated with calcium chloride were recorded two years in turn.

As demonstrated in Fig. 9, the road section treated with $CaCl_2$ showed around 25% lower concentrations of particulate matter as compared with the untreated road section where control measurements were recorded. The particulate

matter concentrations within a road section in question at an equal distance from the road differed by the size of error. The highest particulate matter concentrations were recorded at a distance of 1 m from the roadway.

As Fig. 10 shows, the road section treated with $CaCl_2$ showed an around 17% lower concentration of particulate matter as compared with the untreated road section where control measurements were recorded.

On 14 September 2007, the particulate matter concentration in the road section treated with $CaCl_2$ was hardly by several tenths of unity lower than in the untreated road section (Fig. 11).

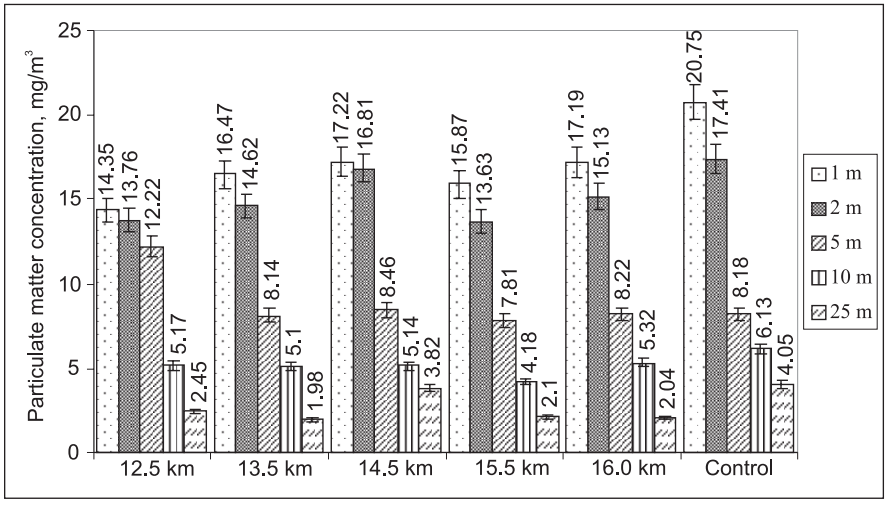

Fig. 9. Particulate concentrations in the section 12.5–16.3 km of the road (No. 3106) Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 17 July 2007

9 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2007 07 17)

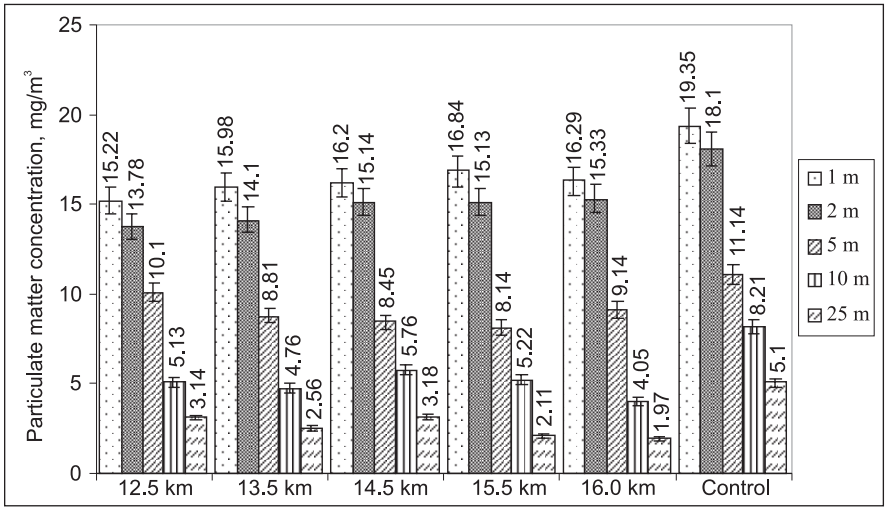

Fig. 10. Particulate concentrations in the section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 3 August 2007

10 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2007 08 03)

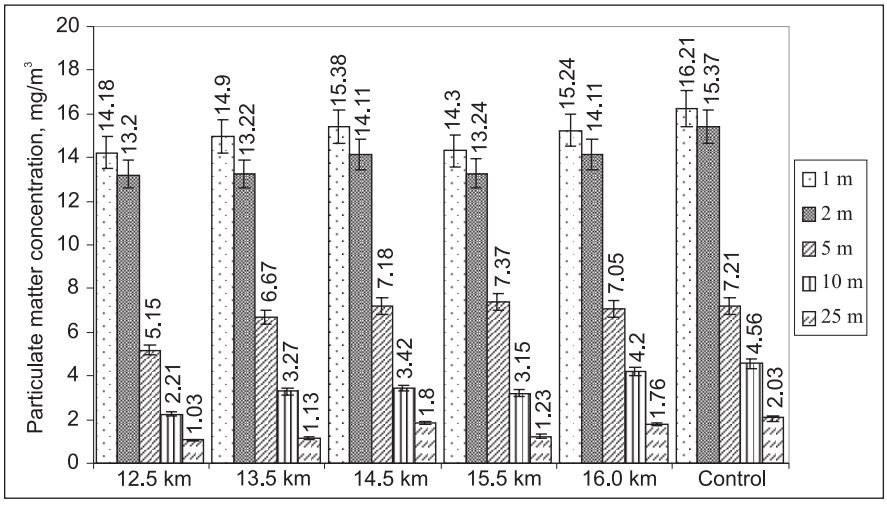

Fig. 11. Particulate concentrations in the section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 14 September 2007

11 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2007 09 14)

Three measurements of particulate matter concentrations in the road section of 12.5–16.3 km of the road Krinčinas–Žvirgždė–Šukionys–Meiliūnai at different times have shown that after a repeated treatment of the road paving with $CaCl_2$ particulate matter concentrations in the air were by around 6–25% lower (depending on the time elapsed from the road treatment) as compared to those recorded in an untreated road section. The low efficiency might have been predetermined by a poor quality of $CaCl_2$ spreading, an insufficient amount of $CaCl_2$ or by other reasons such as meteorological conditions.

The road No. 3106 was repeatedly treated with calcium chloride in 2008.

As Fig. 12 shows, on 28 May 2008 the road section treated with $CaCl_2$ had around 25% lower concentrations of particulate matter as compared with the control section.

On 24 July 2008, the road section treated with $CaCl_2$ had around 17% lower concentrations of particulate matter compared to the untreated road section (Fig. 13).

A comparison of the data obtained during the first and the second expeditions shows that despite very similar control concentrations of particulate matter, the concentrations recorded in the treated section during the second expedition were higher as compared with those of the first expedition. According to data obtained in 2007, the efficiency of calcium chloride decreased due to heavy precipitation in the summertime.

On 16 September 2008, the road section treated with $CaCl_2$ had around 10% lower concentrations of particulate matter as compared to an untreated road section.

Upon making three measurements of particulate matter concentrations in the road section of 12.5–16.3 km of the road Krinčinas–Žvirgždė–Šukionys–Meiliūnai at different times, it was evident that after a repeated treatment of the road paving with $CaCl_2$, particulate matter concentrations in the air were around 10–25% smaller as compared to those recorded in an untreated road section.

Chloride concentrations in roadside soil

The 12.5–16.3 km section of the road Krinčinas–Žvirgždė–Šukionys–Meiliūnai without asphalt paving, four years in turn was treated with calcium chloride with the aim to reduce particulate matter concentrations in the air. On the basis of the investigations carried out for two years as well as analysis

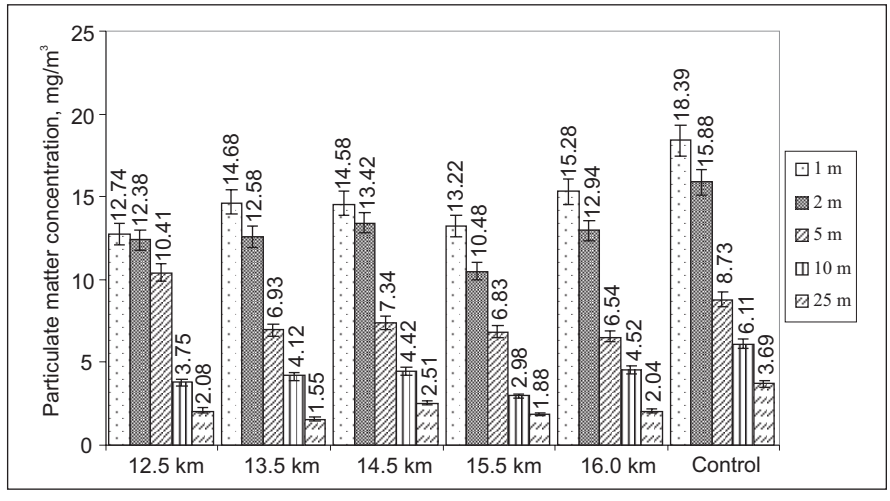

Fig. 12. Particulate concentrations in the section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 28 May 2008

12 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2008 05 28)

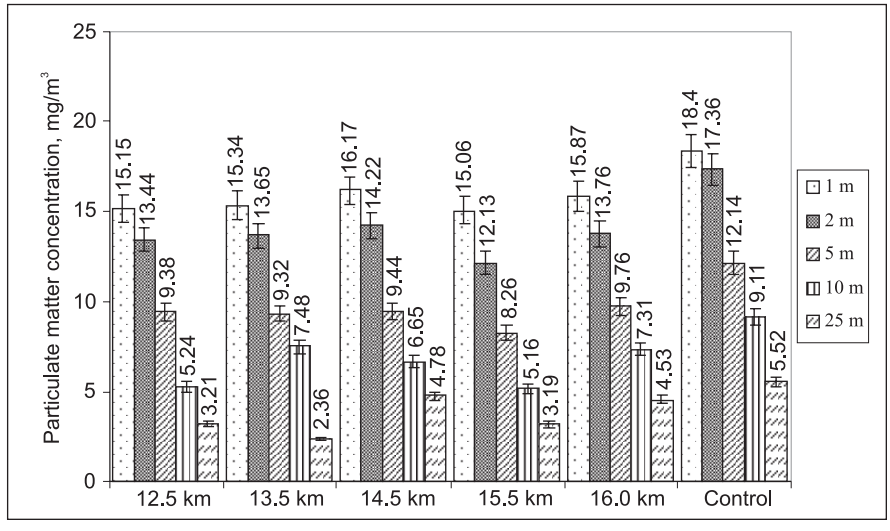

Fig. 13. Particulate concentrations in the section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 24 July 2008

13 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2008 07 24)

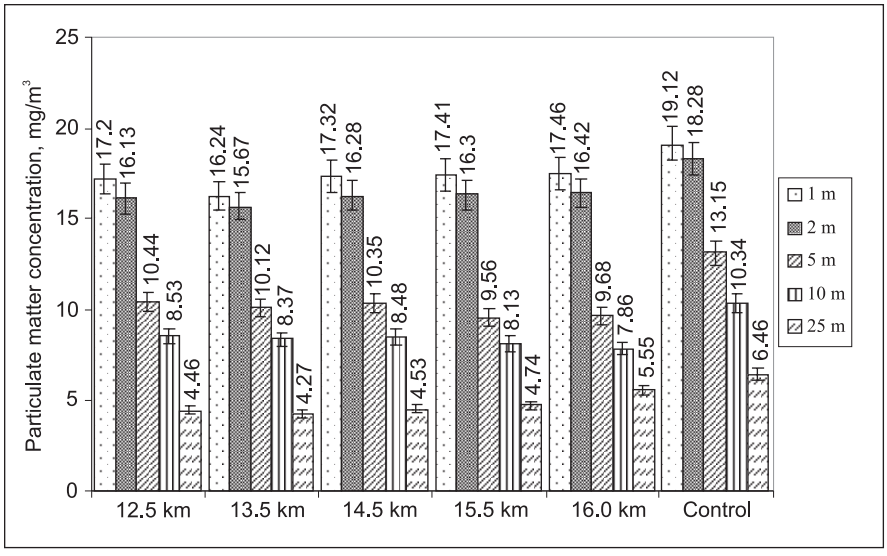

Fig. 14. Particulate concentrations in the section 12.5–16.3 km of the road No. 3106 Krinčinas–Žvirgždė–Šukionys–Meiliūnai on 16 September 2008

14 pav. Kietųjų dalelių koncentracijos ore kelio Krinčinas–Žvirgždė–Šukionys–Meiliūnai (Nr. 3106) 12,5–16,3 km aplinkoje (2008 09 16)

of literature data, it can be stated that heavy rains in the summers of 2007 and 2008 could leach the calcium chloride used to reduce dustiness out of the gravelled road paving, which resulted in a decreased efficiency in dustiness reduction.

During measurements of particulate matter concentrations in the air, samples of technogenic soil for determining the content of chlorides were taken from the roadsides of the section 12.5–16.3 km of the road No. 3106. It was not expedient to determine the concentrations of chlorides on the sides of the road No. 4310 as the gravelled road was treated with bituminous emulsion.

In 2007, soil sampling for chloride content determination was for the first time done on 17 July, i. e. 2 months and 2 weeks after the road paving treatment with $CaCl_2$. The second soil sampling was made on 14 September, i. e. 4 months and 1 week after the road paving treatment.

As Fig. 15 shows, the concentration of chlorides in the road paving sample was 10–26% higher as compared with the concentrations recorded at a distance of 1 m from the road edge.

Chloride concentrations in the soil sampled for the second time (in September) were 1.6–2.3 times lower than those obtained for the first time (in July). Samples taken in September had Cl^- concentrations 3.0–3.5 times higher than the control one (5.0 mg/kg).

As shown in Fig. 16, in 2008 soil sampling for chloride determination was done on 28 May, one month after the road paving treatment with $CaCl_2$. The second soil sampling was made on 16 September, i. e. 4 months and 2 weeks after the road paving treatment. That the lowest chloride concentrations in soil samples were found on a gravelled road paving (like in 2007), while somewhat higher Cl^- concentrations were accumulated on the roadsides at a distance of 1 m from the road edge.

Chloride concentrations in the soil sampled for the second time (in September) were 1.3–2.5 times lower than in May. More than two months elapsed between the soil samplings. The concentrations of chlorides in the samples taken for the second time were lower because $CaCl_2$ had been leached out from the top layer of the gravelled road paving when the rainy precipitation filtered through the gravelled road paving. In samples taken in September, chloride concentrations were 8.8–10.5 times higher than in the control

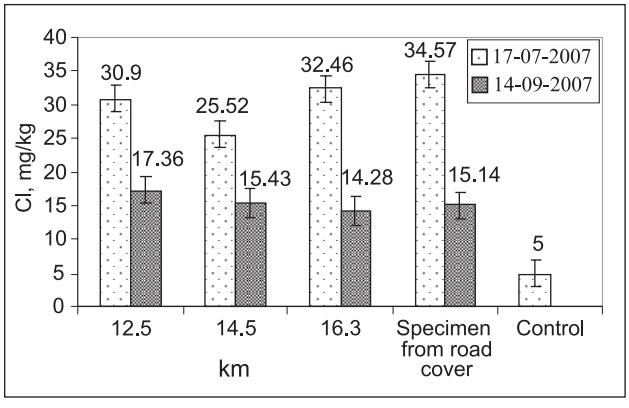

Fig. 15. Chloride concentration on the sides of road No. 3106 in 2007

15 pav. Chloridų koncentracija kelio Nr. 3106 pakelės dirvožemyje (2007)

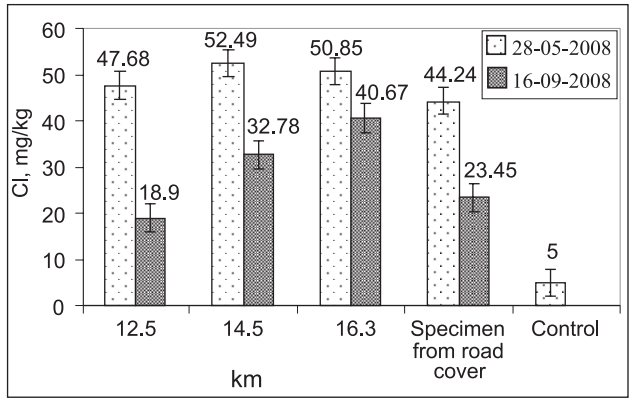

Fig. 16. Chloride concentration on the sides of road No. 3106 in 2008

16 pav. Chloridų koncentracija kelio Nr. 3106 pakelės dirvožemyje (2008)

sample (5.0 mg/kg). In soil samples from the second sampling, chloride concentrations were 3.8–8.1 times higher than in the control sample.

In 2008, the concentrations of chlorides in the first samples were on average by 40% higher than those in the first samples taken in 2007 because only one month had elapsed from the road paving treatment with $CaCl_2$ in 2008 versus 2 months and 2 weeks in 2007. Therefore, a bigger amount of $CaCl_2$ had already been leached by precipitation out of the gravelled road top layer.

CONCLUSIONS

1. Upon taking measurements of particulate matter concentrations in the gravelled road section treated with bituminous emulsion for a couple of years in turn, the efficiency of this material in the summer and autumn seasons was determined. The measurements of particulate matter concentrations in the air both in summer and autumn show that they were by 95% lower as compared to those recorded in road sections not treated with the emulsion.

2. Bituminous emulsion binds road dust. This material is resistant to the effect of precipitation. The efficiency of bituminous emulsion drops only 2–4% after the summer season. Consequently, this emulsion is suitable for a long-time reduction of gravelled road dustiness.

3. The efficiency of calcium chloride in reducing dustiness reached 17–25% in the summer season. The residual efficiency of $CaCl_2$ was significantly decreased in the autumn season, reaching 8–12%.

4. The efficiency of calcium chloride is reduced by precipitation in the summer season. This dustiness-reducing material is soluble in water and thus is leached out from the top layer of the treated gravelled road paving.

5. To prolong the effect of calcium chloride and to increase its efficiency, the quantity intended for dustiness reduction may be inserted twice; half of the quantity may be inserted in the top layer of the gravelled road paving at the initial phase and the rest part either at the end of July, or at the beginning of July after heavier rain. If a dry period lasts long, the remaining part of the salt may be applied by watering the paving with the prepared solution.

6. The duration of $CaCl_2$ effect on dust binding depends on relative air humidity because calcium chloride shows good hygroscopic properties. The efficiency also depends on whether a sufficient quantity of $CaCl_2$ is spread, the duration of the dry period and a proper preparation of the gravelled road top layer.

7. After the summer season, the concentrations of chlorides on gravelled roadsides exceeded the control value (5 mg/kg established in conditionally clean territories) 2.5–8.1 times.

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KIETŲJŲ DALELIŲ IR CHLORIDŲ KONCENTRACIJŲ TYRIMAI ŽVYRKELIŲ APLINKOJE

Santrauka

Pagrindinė žvyrkelių problema yra jų dulkėjimas šiltuoju metų laiku. Didžiausią įtaką dulkių susidarymui turi transporto eismas, klimatas bei panaudoto žvyro kokybė. Dulkėtumo problema sprendžiama apdorojant žvyrkelių dangą įvairiomis medžiagomis. Lietuvoje populiariausios ir dažniausiai naudojamos bituminė emulsija bei kalcio chloridas. Straipsnyje pateikiami tyrimų rezultatai, gauti nagrinėjant žvyrkelių ruožus, apdorotus bei neapdorotus skirtingomis dulkėjimą mažinančiomis medžiagomis įvairiuose Lietuvos regionuose. Tyrimo duomenimis, efektyviausiai dulkėjimą mažina į žvyrkelių dangą įterpta bituminė emulsija – iki 95 %. Kalcio chloridą krituliai išplauna iš apdoroto viršutinio žvyrkelio dangos sluoksnio, todėl jo efektyvumas, sujungiant kietąsias daleles, siekia 17–25 %.

Раса Вайналавичюте, Агне Казлаускене, Пранас Балтренас, Аудроне Янкайте

ИССЛЕДОВАНИЕ КОНЦЕНТРАЦИЙ ТВЕРДЫХ ЧАСТИЦ И ХЛОРИДОВ ВОЗЛЕ ГРАВИЙНЫХ ДОРОГ

Резюме

Основной проблемой гравийных дорог является пыль в теплое время года. Образование пыли обусловлено следующими факторами: движением транспорта, климатическими параметрами, качеством гравия. Для решения проблемы пыли применяются различные методы обработки гравийных дорог и материалы. В Литве наиболее популярными и чаще всего применяемыми средствами для уменьшения пыльности являются битумная эмульсия и хлорид кальция. В статье представлены результаты исследований участков гравийных дорог в разных регионах Литвы, обработанных и необработанных различными снижающими пыльность препаратами. Из данных исследований видно, что наиболее эффективно (до 95 %) снижает пыльность битумная эмульсия, включенная в верхний слой гравийного покрытия. Хлорид кальция под воздействием осадков вымывается из обработанного верхнего слоя гравийного покрытия, и его эффективность по связыванию твердых частиц составляет лишь 17–25 %.