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"Gheorghe Asachi" Technical University of Iasi, Romania

HYDRAULIC CONDUCTIVITY OF DRAINAGE DITCH BACKFILL WITH A LIME ADDITIVE IN CLAY SOILS

Mindaugas Klimašauskas[1], Valentinas Šaulys[2], Raimundas Baublys[1*], Oksana Survilė[2]

[1]*Faculty of Water and Land Management, Vytautas Magnus University Agriculture Academy, Universiteto str. 10, LT- 53361 Akademija, Kaunas district, Lithuania*
[2]*Faculty of Environmental Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania*

Abstract

The efficiency of drainage installed in clay soils using ditch backfill of soil mixed with lime is presented in this paper. The drainage ditch backfill was mixed with lime where 0.6% of soil matter consists of active CaO. The paper proposes a methodology that determines an optimal amount of lime. The experimental site was set in Kalnujai, Raseiniai district, Lithuania. The measurement of filtration in drainage trench, the arable layer and the soil between drains was performed using a double ring infiltrometer. The mean values of the hydraulic conductivity of the arable layer, the soil between drains, the pilot backfill and drainage ditches backfill with a lime additive were respectively 1.66 ± 0.24, 0.65 ± 0.09, 0.94 ± 0.13 m/d and 2.47 ± 0.12 m/d under reliability of 95%. Dispersion analysis on pilot drainage backfill and drainage ditch backfill with lime additive under ditch backfill containing 0.6 % of CaO in soil matter showed that they significantly differ at a reliability of 95%. Thus, the effect of lime on the conductivity of the backfill of the drainage ditch for the following 30-year period of drainage operation in clay soils has remained critical.

Key words: backfill liming, drainage backfill, hydraulic conductivity

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1. Introduction

Around 68% of the territory of Lithuania is covered with loam soils, the vast majority of which is found in the plain of Central Lithuania. Although heavy loam is a soil of high-yielding crops, however, it has low hydraulic conductivity (Cann et al., 2018; Forsburg, 2003; Malota and Senzanje, 2016; Stătescu et al., 2017; Tuli et al., 2005). Infiltration into these soils is too slow, and therefore water usually stays on the surface of the soil. This leads to the poor drainage of loam soils and difficulties in cultivating them if soaked. Agricultural activity, and mechanized tillage in particular, is very limited in the case if drainage is not provided (Ritzema, 2006). It should be noted that hydraulic conductivity is subject to climatic conditions of the season, mostly because of swelling and subsequent drying (Fashi et al., 2019; Levy et al., 2005; Tuller and Or, 2003). Due to particle swelling in clay soils, precipitation cannot penetrate into deeper layers of the soil and finally into drains. This water forms surface runoff. To improve infiltration of arable land and to reduce surface runoff, installation or renovation of drainage systems is very important (Taylor et al., 2016). As 87% of agricultural land area in Lithuania is tile-drained, agricultural drainage has a large impact on the soil-water balance. Depending on local soil and climate conditions, the average annual specific subsurface drainage discharge in different parts of the country ranges from 4.0 to 6.0 L s/km^2 (Povilaitis et al, 2015).

The efficiency of underground drainage in loam soils depends on the hydraulic conductivity of the backfill of the drainage ditch. Conductivity must

* Author to whom all correspondence should be addressed: e-mail: raimundas.baublys@vdu.lt; Phone: +370 61189859; Fax: +370 37 752 392

be much higher than the surrounding naturally formed backfill. Under extreme weather, the rainwater of the soils with heavy mechanical composition (due to clay soil swelling) cannot penetrate into drains and leaks as surface runoff or accumulates on the surface. The action of drainage in clay soils during these periods is highly subject to the conductivity of the ditch backfill (Islam et al., 2019; Šaulys and Bastienė, 2006; Salo et al., 2017). As for the critical moments of operating drainage in clay soils, surface water runs into drains through a more conductive upper arable layer and ditch backfill.

According to Lindström and Ulén (2003) for improving infiltration, quicklime (CaO), also known as burnt lime, can be added to drain backfill. Field experiments have demonstrated that the incorporation of the lime allows the water to pass through the backfill faster (Lindström and Ulén, 2003). A significant impact on drainage efficiency was determined (Šaulys and Bastienė, 2006) when the trench backfill was mixed with lime (0.40% of soil mass). It was found that such backfill can flush drainage water 55 times faster than the reference backfill. A number of authors suggest improving loam conductivity by inserting/mixing limestone materials in drainage ditches (Halme et al., 2003; Mubeen, 2005; Palko and Weppling, 1994; Puusttinen, 2001). Other literature (Velykis et al., 2003) suggests that straw significantly increased water permeability in clay soil, while in sandy loam soil, straw increased water permeability by 1.2 times compared with the reference backfill. Apart from such lime-filter ditches, under the influence of liming (using different types of lime to the entire topsoil) water infiltration can be improved over the whole field area, thereby reducing the risk of surface water ponding (Ulén et al., 2018).

A number of researchers point out that lime additives contribute significantly to modification of physical properties of clay soils (Halme et al., 2003; Mubeen, 2005; Puusttinen, 2001; Rajasekaran and Narasimha, 2002). They stated that due to the added certain amount of lime, soil density could be reduced by 25%, porosity could be increased by 30%, the hydraulic conductivity could be raised 100-300 times and the accumulation volume (0.25-10 mm) could be enhanced 3 times, which, in fact, removed swelling. Therefore, the soil mixed with lime is less susceptible to compression, since calcium and magnesium carbonates form hydro silicates and cause soil resistance to compression. Inserted into the ground calcium oxide (CaO) in interaction with the water in soil forms calcium hydroxides ($Ca(OH)_2$), part of which react with carbon dioxide (CO_2) and form calcium carbonates ($CaCO_3$). The other part of calcium hydroxide interacts with silicon dioxide (SiO_2) present in soil and forms stable calcium hydro silicates ($CaOSiO_2$), the strength of which increases with time. Moreover, lime modifies the properties of clay particles and they fall in flakes thus facilitating the motion of all essential ingredients for plant development, i.e. increases the amount of active phosphorus, potassium, nitrogen, sulphur, calcium and magnesium and decreases the amount of active aluminium (Woo and Kumar, 2019). Hence, lime helps with improving the mode of water and changes water quality.

According to Finnish scientists (Puusttinen, 2001), lime used for improving the conductivity of the drainage ditch increases the pH of the soil of ditch backfill up to 11, and therefore such a backfill of the drainage ditch retains water-bound phosphorus. If lime filters (catchwater drains) were installed into the shores of the main water drain ditches located in the lower part of the fields sloping downward, surface water would enter to the ditch through filters and well-bonded phosphates present in the water would reduce entering the ditches. Significantly different concentrations of phosphorus phosphate (PO_4-P) from discharged water were established (Šaulys and Bastienė, 2007) in the pilot drainage systems and drains, the ditch backfill of which was with added lime.

Although the concentrations of phosphates-phosphorus found in pilot drainage water were 2.7 times higher, however, no substantial differences between the concentrations of ammonia and nitrate nitrogen in water considering different versions of installing drainage were found. Various literature sources affirm that clayey soil treated with lime amendments could significantly prevent the migration of phosphorus (P) (Murphy and Stevens, 2010; Rhoton and Bigham, 2005).

According to Andersson et al. (2016), a very effective tool for reducing phosphorus concentrations in drainage water is mixing lime into the drainage trench backfill, which lowered the phosphorus leaching to 49% versus 51% without the addition of lime. The addition of lime to the sandy soil also reduced phosphorus leaching compared to using only natural soil. When clayey soil as drainage trench backfill was mixed with 0.6% CaO, the total phosphorus (TP) and PO_4-P concentrations decreased by 50% and 64.4%, respectively, relative to the reference backfill (Bastienė et al., 2012). However, subsurface drainage is an effective method of reducing non-point source pollution in the areas where sediment and phosphorus are the major concerns (Hongkai and Zhiming, 2017; King et al., 2014).

The structurally displaced backfill soil over a tile drain shapes a good pathway for generating rapid phosphorus transport in the soil. This process could be close to the flow through macropores, especially in the first few years after drain installation. The incorporation of burnt lime (CaO) with the backfill material in drains is known as backfilling method developed in Finland (the FOSTOP method). The results of this method is that backfill material becomes stable and poriferous. The lime requirement has been determined in trials to be 3-8% of soil wet weight. The method has been tested in a number of experiments and has been found to reduce the phosphorus concentrations in running water by more than 80% in most cases. In the cases of impervious clay soils the lime filter drain can also improves the process of drainage and thus decreases erosion. (Šaulys and Bastienė, 2007).

Improvements in the infiltration capacity of the trench fill improve the water and air regime, which in turn improves conditions for the development of microorganisms, which are directly involved in the mineralization of slurry organic matter. Lime application increases the number of ammonifying and nitrifying microorganisms, which increases the soil nutrient reserves and ensures good conditions for plant growth (Bambara and Ndakidemi, 2010; Dinizi et al., 2019; Jokubauskaite et al., 2015; Moreira and Fageria, 2010; Narendrula-Kotha and Nkongolo, 2017). In our research, the NO_3-N concentrations in drainage water decreased by 52% with the application of lime compared to the reference backfill. Bastienė et al. (2012) also found that average concentrations of NO_3-N in drainage water were 15% higher for the reference backfill compared to the treatment with lime in a silty clay loam soil.

However, the longevity of lime still remains unclear. For the period of 1995–1999, in Finland, drainage with a lime additive was installed in almost 1000 ha as a measure aimed at fighting for adverse environmental effects caused by drainage to acid sulphate-induced soils (Aström et al., 2007; Barlund et al., 2005). The average life span of lime drainage turned out to exceed 10 years and the effect of treatment did not disappear. In Sweden, this method was studied only on a single test site, and long-term effects were not monitored.

The results obtained from Lithuanian experimental research sites show (Šaulys and Bastienė, 2007) that drainage with a lime additive is a long-term measure for improving the conductivity of clay soils. Drainage with a lime additive has a positive effect on the quality of drainage water. This measure can significantly reduce the concentrations of potassium, chloride, sulphate and phosphate in drained water. This paper presents research carried out to determine the efficiency of drainage performance in the soils of a heavy mechanical composition and to assess the durability of the hydraulic conductivity of drainage ditches the backfill of which was mixed with a lime additive.

2. Materials and method

For the period 2012-2017, study on the effectiveness of operating drainage was in progress on Kalnujai research site in Raseiniai district and included improvements in the filtration properties of the backfill of drainage ditches by adding lime materials (Fig. 1). The research object on Kalnujai site was established in 1988, which means that the backfill of drainage ditches the filtration properties of which were improved by adding lime materials has exceeded a period of 25 years.

The soils on Kalnujai research site are classified as those of a podzolic genotype. Sod-podzolic soils prevailing on the site make 45.3% of all soils in Lithuania. The soils on Kalnujai research site located near the Silupė stream are attributed to sod-podzolic weak podzolled loam soils J_1^v (*LVh–or Orthi-Haplic Luvisols)*). In the distance from the Saltuona stream, sod-carbonated podzolic VK^j (*LVk–ha Hapli-Calc(ar)ic Luvisols*) and sod-podzolic gleyic JP_1^v (*LVg–p–w–ha Hapli-Epihypogleyic Luvisols*) soils with clear signs of soaking have been found. These types of soils are numerous in the transitional region of Lithuania between Middle Lowland and Western and Eastern heights. Light loam and clay soils are predominating on the site. A layer below 40 cm consists of 60-34% of clay particles. For determining an optimal amount of lime needed to be mixed with the ditch soil, the average amount of physical clay particles (<0.01 mm) in the profile of the soil considering drainage depth was accepted to be equal to 43.0% while soil density made 1.58 g/cm^3.

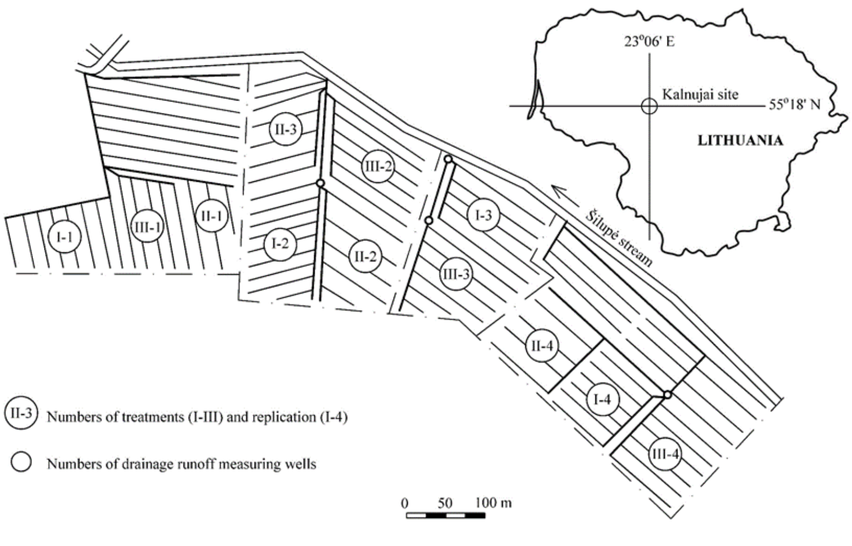

Fig. 1. Geographical location and test scheme for Kalnujai site

The research site of the experimental object installed in 1989 was drained using a systemic underground drainage network. Drainage pipes (length – 33 cm, diameter of dehumidifiers – Ø50 mm, diameter of collectors – Ø75 mm) were set up at a depth of 1.1 m, and the width of the drainage ditch made 0.5 m. Three drainage options were provided and included four iterations:

I – the backfill of the drainage ditch was mixed with lime so that active CaO should make 0.6% of the dry matter of the soil, the distance between dehumidifiers, E = 16 m;

II – the backfill of the drainage ditch was mixed with lime so that active CaO should make 0.6% of the dry matter of the soil, the distance between dehumidifiers was increased by 1.5 times and reached E = 24 m;

III - (verification) the drainage ditch was filled with the local mixed soil, distance between dehumidifiers, E = 16 m.

In 1988, the lime material selected for construction of the object consisted of the widely used Estonian shale ash with the total amount of CaO and MgO activity of 21.5%. The optimum amount of lime required to be mixed with one linear metre of the ditch soil is calculated according to the equation (Šaulys, 1999) (Eq. 1):

$$A = \rho bh\left(0.13 + 0.011N\right)n^{-1} \qquad (1)$$

where: A – optimal amount of lime per one linear meter of the excavated ditch, kg; ρ – soil density, kg/m^3; b – width of the excavated drainage ditch, m; h – depth of the excavated drainage ditch, m; N – content of physical clay particles in the soil (<0.01 mm), %; n – lime activity according to the total amount of CaO and MgO, %.

The Eq. (1) is applied when the content of the physical clay particles varies from 20 to 80 % according to Kachinsky's soil texture classification previously applied in Lithuania. With reference to laboratory tests on the soil and used lime, equation (Eq. 1) was used for calculations (ρ = 1580 kg/m^3, b = 0.5 m, h = 1.1 m, N = 43.0 %, n = 21.5 %), which showed that 1 linear meter of the excavated ditch would need a 24.3 kg additive of shale ash. Thus, the approximated quantity of 24.0 kg was obtained, which, based on the active content of CaO and MgO in Estonian shale ash made 0.6% of soil matter. Shale ash was poured onto the excavated soil of the drainage ditch employing a limestone dispersion tank with an additionally equipped cyclone reducing the rate of ash dispersion while the excavated ditch soil was blended with a screw bulldozer. The drainage ditches of the pilot version were buried with a screw bulldozer.

Drainage runoff was considered the main indicator of operating efficiency taking into account all versions and was measured in drainage runoff wells employing the volumetric method. During spring and autumn floods, drainage runoff was measured every 2-3 days and less frequently in the other periods. Runoff is presented in a comparative form from the linear meter of the drainage ditch.

Meteorological conditions were evaluated based on the data collected by Raseiniai meteorological station. Investigation into the soil filtration on Kalnujai site was carried out in 2017. The hydraulic conductivity of the vegetation layer of the soil was set at a depth of 0.1 m underground. The hydraulic conductivity of the soil between drains, the pilot backfill of drainage ditches and backfill with a lime additive containing 0.6 % of CaO in soil matter was established at a depth of 0.5 m underground. Filtration studies on Kalnujai site were carried out using a double ring infiltrometer.

The reliability of the obtained results was determined by processing findings according to mathematical statistics methods and employing the data analysis tool pack for MS Excel 2013. Differences between the results of drainage were investigated based at significance level $p < 0.05$.

3. Results and discussion

3.1. Variations in runoff

For the period 2012-2017, drainage runoff on Kalnujai research site was examined. Substantial variations in runoff in both pilot systems and those when the filtration properties of the backfill of drainage ditches were improved by adding lime materials can be observed. Higher values of drainage runoff were set in autumn 2016 and spring 2017 (Fig. 2). For the period from 29 October 2016 to 20 December 2016, the compared discharge of drainage increased up to 0.829 ml/s m in the 2nd version systems where the backfill of the drainage ditch was mixed with lime and distances between drainage drains made E = 24 m. As for the 1st version systems, the backfill of the drainage ditch was mixed with lime, the distance between drains was E = 16 m and drainage runoff in the pilot version systems was similar and reached 0.523 and 0.551 ml/s respectively. The highest values of autumn runoff were recorded on 20 December 2016 when runoff amounted to 0.828 ml/s m in the 2nd version systems and 0.523 and 0.551 ml/s m in the 1st and pilot version systems.

On 23 February 2017, the backfill of the drainage ditch mixed with lime reached 0.771 ml/s m in the 1st version systems, and 0.584 and 0.322 ml/s m – in the 2nd and pilot version systems. The highest value of spring runoff was observed on 8 March 2017 making 0.849 ml/s m in the 2nd version systems and 0.371 and 0.490 ml/s m – in the 1st and pilot version systems respectively.

Trends and cycles of variations in the runoff of the investigated period correlate directly with climatic conditions (precipitation and temperature) of that period in Lithuania. In autumn of 2016, the maximum drainage comparatives in the 2nd version systems, where the backfill of the drainage ditch was mixed with lime and distances between drains E = 24 m amounted to 0.687-0.829 ml/s m, which is only 88% of the calculated runoff module. The runoff of the investigation period in the pilot drainage systems reached only 58% of the calculated module. This is explained by the fact that, under the same amount of precipitation, a single drain of a scarce drainage network (E = 24 m) takes a relatively higher amount of water in order to create the same hydrological conditions for all drains (Bastienė et.al., 2012). The authors tested drainage runoff on the simulation site.

3.2. Infiltration

Table 1 presents hydraulic conductivity and statistical characteristics of the arable layer, the soil between drains, the pilot backfills of drainage ditches and the backfill of drainage ditches with a lime additive under the mixture of 0.6% of CaO in soil matter defined on Kalnujai site.

The mean value of hydraulic conductivity of the stationary mode of the arable layer (at a depth of 0.1 m underground) was 1.66 ± 0.11 m/d. The confidence interval of hydraulic conductivity, under a reliability of 95%, was equal to 1.66 ± 0.24 m/d (from 1.42 to 1.90). The confidence interval of the hydraulic conductivity of the arable layer, under a reliability of 95%, was obtained on Kalnujai site in 2003 (Šaulys and Bastienė, 2008) and amounted to 0.95 ± 0.05 m/d, which means that the conductivity of the surface soil layer was by 74.7 % lower. In this case, variations in the conditions for the filtration of the arable layer depend heavily on soil tillage and the amount of organic matter. Therefore, as reclamation-free technologies have been recently applied on the site, such fluctuations in the conductivity of the arable layer are accepted as a natural result.

The hydraulic conductivity of the soil between drains was investigated at a depth of 0.5 m underground. Upon reaching the stationary filtration mode, the mean value of the hydraulic conductivity was 0.65 ± 0.04 m/d (Table 1). Under a reliability of 95%, the confidence interval of the hydraulic conductivity of the soil between drains is equal to 0.65 ± 0.09 or ranges from 0.56 to 0.74 m/d. Under a reliability of 95%, the obtained confidence interval of the hydraulic conductivity of the soil between drains on Kalnujai site was equal to 0.83 ± 0.09 m/d in 2003. As regards the mean value of the hydraulic conductivity, the conductivity of the soil between drains was by 27.7% lower (0.65 m/d) in 2017. However, at the level of a reliability of 95%, conditions for the filtration of the soil between drains remained unchanged, except difference in the measurement error.

There is no doubt that the hydraulic conductivity of the soil between drains at a depth of 0.5 m underground should be less variable in time, because the soil at this depth is not approached by tillage machinery, and not all plant roots may reach this depth.

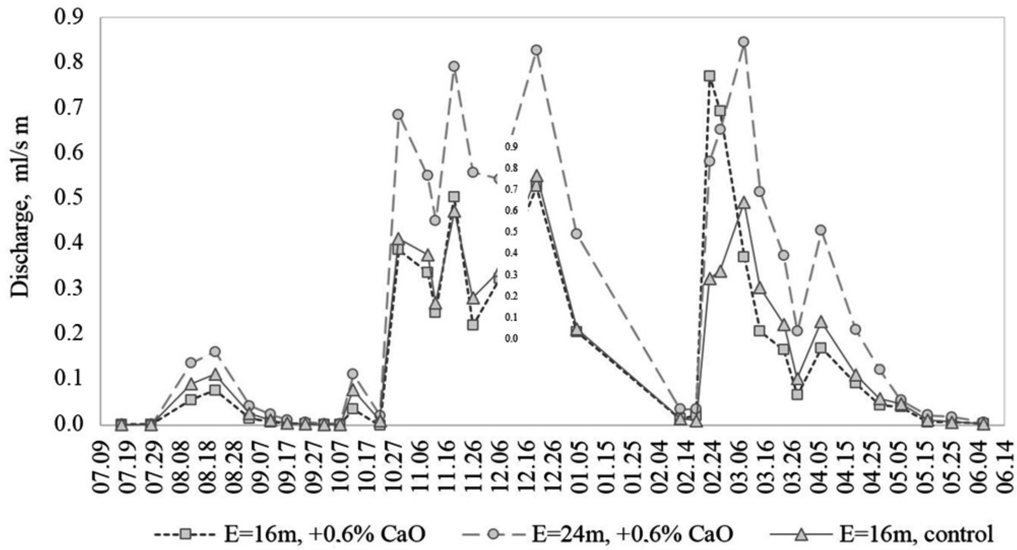

Fig. 2. A comparison of drainage discharge on Kalnujai site in 2016–2017

Table 1. Hydraulic conductivity and statistical moments obtained on Kalnujai site in 2017

Statistical parameters of hydraulic conductivity	***Arable layer, h = 0.1 m.***	***Soil between drains, h = 0.5 m.***	***Pilot backfill, h = 0.5 m.***	***Backfill mixed with 0.6 % of CaO, h = 0.5 m.***
Infiltration rate, m/d	1.66	0.65	0.94	2.47
Standard deviation, m/d	0.39	0.12	0.25	0.22
Standard error, m/d	0.11	0.04	0.06	0.06
Error when p<0.05, m/d	± 0.24	± 0.09	± 0.13	± 0.12

The stationary filtration mode of the ditch backfills of pilot drainage, which is 0.5 m depth underground, made 0.94 ± 0.06 m/d (Table 1). Under a reliability of 95%, the confidence interval of the hydraulic conductivity of the ditch backfill of pilot drainage was 0.94 ± 0.13, (0.81 – 1.07) m/d. As for the site in Kalnujai (Šaulys and Bastienė, 2008), the confidence interval of the hydraulic conductivity of the ditch backfill of pilot drainage, under a reliability of 95%, equalled 2.20 ± 0.13 m/d. In 2017, the conductivity of the ditch backfill of pilot drainage was by 2.3 times lower. This is explained by the fact that a ditch excavated by a multi-bucket excavator, later is buried under a light soil, and over time becomes denser thus approaching the characteristics of the soil between drains. Nevertheless, with reference to the research data received in 2017, the hydraulic conductivity of the ditch backfill of pilot drainage is by 44.6% higher than that of the soil between drains (0.65 ± 0.04).

The hydraulic conductivity of drainage ditch backfill with a lime additive under the 0.6 % mixture of CaO in soil matter was also investigated on Kalnujai site at a depth of 0.5 m underground. The dynamics of the hydraulic conductivity of drainage ditch backfill with a lime additive as well as the ditches of the soil between drains and pilot versions are presented in Fig. 3.

The stationary filtration mode of drainage ditch backfill with a lime additive was achieved following 2/3 of time for testing filtration, i.e. 55 studies per minute. The mean value of the hydraulic conductivity reaches 2.47 ± 0.06 m/d (Table 1). Under a reliability of 95%, the mean value of the hydraulic conductivity of drainage ditch backfill with a lime additive varied from 2.35 to 2.59 m/d while, in 2003, the value of the hydraulic conductivity obtained to 3.29 ± 0.19 m/d when 0.6% of CaO contained in soil matter was included into ditch backfill.

In 2017, the conductivity of drainage ditch backfill with a lime additive was by 0.3 times lower than that observed in 2003. This is explained by the fact that the excavated ditch filled with a light soil becomes denser over time; however, if ditch backfill was added 0.6% of CaO present in soil matter, density was reduced. In 2017, conditions for the filtration of the ditch backfill of pilot drainage decreased by 2.3 times, and conditions for the filtration of drainage ditch backfill with a lime additive were reduced only by 0.33 times. The research has found (Šaulys and Bastienė, 2003; Šaulys and Bastienė, 2006) that adding lime to ditch backfill assists with the stabilization of the structure of clay soils, stable calcium hydrosilicates are formed, and soil swelling is reduced, which leads to remaining soil filtration properties more stable. This tool extensively improves the filtration properties of drainage ditches.

According to the data collected on Kalnujai site in 2017, under a reliability of 95%, the conductivity of drainage ditch backfills with a lime additive (0.6 % in soil matter) is by 2.6 times higher than that of the backfill of pilot drainage ditches and by 3.8 higher than that of the soil between drains.

The conductivity of drainage ditches is accepted as one of qualitative parameters for drainage performance mainly during the critical periods of drainage operation when in summer, and particularly in the rainy periods of autumn, their conductivity to water decreases due to clay soils. The drainage ditch backfill with a lime additive reduces the swelling of clay soils thus improving ditch conductivity precisely throughout critical drainage periods.

In 2017, no critical period of drainage operation was observed in the course of study on filtration. The module of drainage runoff within the period did not reach 0.1 l/s ha when the calculated module of drainage runoff on Kalnujai site was 0.6 l/s ha. The carried-out dispersion analysis on pilot drainage backfill and on drainage ditch backfill with a lime additive shows that the hydraulic conductivity of pilot drainage backfill was 0.94 ± 0.06 m/d and the hydraulic conductivity of drainage ditch backfill with lime additive was 2.47 ± 0.06 m/d with 95% confidence interval, have significant difference.

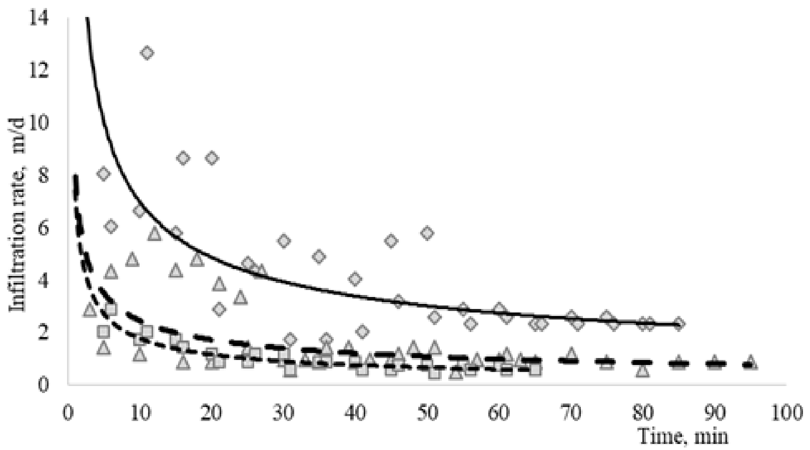

Fig. 3. The dynamics of drainage ditch backfill with a lime additive, the pilot version ditch and the hydraulic conductivity of the soil between drains on Kalnujai site in 2017

The experimental site in Kalnujai was established in 1988 to investigate the effect of lime on the conductivity of the drainage ditch under production conditions. By adding 0.6% of CaO in soil into the drainage ditch, the hydraulic conductivity received in 2003 (following 15 years after establishment) obtained to 3.29 ± 0.19 m/d and that in 2017 – 2.47 ± 0.12 m/d compared to the hydraulic conductivity of the backfill of the pilot drainage ditch have significant differences with 95% confidence interval.

It can be proposed that, following 30 years of drainage operation in clay soils, the effect of lime on the conductivity of the backfill of the drainage ditch remains essential.

4. Conclusions

1. Higher values of drainage runoff of the investigated period were obtained in autumn 2016 and spring 2017: when ditch backfill was mixed with lime, respectively 0.829 and 0.849 ml/s m, at the same time in pilot drainage system - 0.551 and 0.490 ml/s m. That is only 88–58 % of the calculated runoff model.

2. The trends towards variations in runoff correlate directly with climatic conditions (precipitation and temperature) of that period. Under a reliability of 95 %, the confidence interval of the hydraulic conductivity of drainage ditch backfill with a lime additive when 0.6% of CaO is added to soil matter equals 2.47 ± 0.12 m/d, which is 2.6 times more than that of the backfill of pilot drainage (0.94 ± 0.13 m/d) and 3.8 times more than that of the soil between drains (0.65 ± 0.09 m/d).

3. By adding 0.6% of CaO present in soil matter into the drainage ditch, the hydraulic conductivity was 3.29 ± 0.19 m/d in 2003 and 2.47 ± 0.12 m/d in 2017. The results compared to the hydraulic conductivity of the backfill of the pilot drainage ditch with 95% confidence interval had significant difference after 15-year interval.

4. It can be proposed that, following 30 years of drainage operation in clay soils, the effect of lime on the conductivity of the backfill of the drainage ditch, under a reliability of 95%, remains essential when 0.6% of CaO present in soil matter is added to the drainage ditch.

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