

Drainage Trench Conductivity and Biogenic Materials Retention

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Abstract. In the work, the effectiveness of hydrosystem functioning, when the filtration characteristics of the drainage trench backfill are improved by admixing lime materials, is analysed after a 28-year period of use. The tests of effectiveness of hydrosystem functioning were carried out in the test object of Raseiniai district, Kalnujai. The drainage was installed in the drying systems and the filtration characteristics of trench backfills were improved by admixing the lime material. Analysing the maximum comparative debits of drainage in the control drying systems in the period of spring and autumn 2016 (0.006 and 0.190 ml/s m, respectively) as well as comparative debits in the period of spring and autumn (0.015 and 0.311 ml/s m, respectively) in the drainage, which filtration characteristics of trench backfills were improved by admixing chalky materials (0.6% ground mass), the results were better by 60.0 and 38.9%, respectively. Assessing the drainage system effectiveness indexes of 2012, 2013 and 2016 with the reliability of 95%, it can be stated that the effectiveness of drainage functioning, when the lime materials were used for the improvement of the filtration characteristics of drainage, did not change essentially after a 28-year period of use.

Keywords: drainage, drainage trench conductivity, drainage renovation.

Conference topic: Water engineering.

Introduction

In Lithuania, wet lands make about 3,5 million ha, originally. Until 1990, 3,02 million ha of these lands were dried and drainage was used for 2,58 million ha of them (Šaulys 2011). Compared with other Baltic and Scandinavian states, Lithuania had the biggest amount of drainage: Latvia had about 1500 thousand ha, Estonia – 700 thousand ha, Sweden – 1200 thousand ha, Denmark – 1400 thousand ha, Finland – 1000 thousand ha (Povilaitis 2015). Melioration structures are designed and built in order to regulate the soil water, heat and weather regimen, create better conditions for agriculture, conserve and increase the fertility of soil and develop a rationally managed domain of land. Drainage removes the excess of humidity from soil and increases the amount of oxygen in it. It accelerates the mineralization process and formed biogenic and other soluble materials are removed from soil more quickly together with vertically filtrated precipitation water. Even if the effect of other factors is not assessed, the rise of drainage creates conditions for the elution of most biogenes (mostly NO₃-N) from soil by itself (Skaggs *et al.* 1994; Blann *et al.* 2009). In order to reduce the pollution of surface and underground waters with biogenic materials, it is suggested applying certain means for drying systems, for example, drainage trench backfills with the admixture of additional materials. In this way, biogenic materials would be retained in the dried area before getting to the water drain (trunk) network (Šaulys *et al.* 2011). Drainage trench backfills with the admixture of lime materials are installed in dried areas in order to reduce the pollution of waters. After admixing lime materials (calcium and magnesium oxide) in the drainage trench backfill, phosphor concentrations are reduced by 50–60% and the elution of total phosphor with drainage water is reduced by 2.5 times. The underlying place of installation of drainage trench backfills with the admixture of lime materials in dried areas is considered soils of Middle Lithuania with heavier mechanical composition. This mean is applied in the approaches to the bank protection zone of the water drainage network (ploughland) along trunk trenches, streams, lakes etc. by installing catching drains for the cleaning of surface runoff. The admixture of lime materials in the drainage trench backfill is also applied in the total drained area if the area is used for the irrigation with liquid organic fertilizers from stock-raising complexes (Bastienė *et al.* 2008). After testing samples of clay grounds mixed with slate ash containing 15–25% of calcium and magnesium oxides by applying complex X-ray and termographic methods, it was determined that the admixture of slate ash changed the physical characteristics of grounds essentially and for long periods. It is also demonstrated in the results of laboratory tests (Šaulys 2001). The necessity of use of the lime material for the improvement of the drainage trench backfill was more accentuated when drying hollows. The tests of intensity of hollow drying with the admixture of the lime material in the drainage trench backfill carried out in the experimental objects demonstrated that the ground water levels between drains in the hollows, where that means had been applied, had been

by 20–30% lower than in the control variants (Gurklys 1988). It enabled starting agricultural works by 4–6 days earlier. However, the tests performed by Šaulys and Bastienė (Šaulys, Bastienė 2006) showed a decrease in the effectiveness of use of lime materials for the improvement of the drainage trench backfill in clay soils, improvement of filtration characteristics and phosphate detention in the course of time.

The tests performed in Finland showed that lime used for the improvement of drainage trench conductivity increased pH of the trench backfill ground even up to 11, thus, this drainage trench backfill retains phosphorus moving together with water (Šaulys, Bastienė 2006; Hartge, Ellies 1976). The carried out studies demonstrate that the optimum norm of lime mixed with the dug trench clay ground is necessary (Šaulys, Bastienė 2003). In order to get a good structure of clay soil, the amount of lime should make about 5% of the weight of wet soil. Usually, 10–20 kg of slack lime are necessary per one linear meter of a drainage trench for drains laid with a drain machine.

This work was performed in 2010–2016 in order to continue previous studies. Outdoor tests, which goal was to investigate the effect of the admixture of lime materials in the drainage trench backfill on the chemical composition of drainage water were carried out in Kalnujiai study object, Raseiniai district.

Investigation hypothesis:

1. If a lime admixture is added to clay loam soils after 20–25-year drainage functioning, an increase in trench conductivity is obtained. If yes, how high is it?
2. If a lime admixture is added to clay loam soils after 20–25-year drainage functioning, a decrease of phosphates in the drainage runoff water is obtained. If yes, how high is it?

The purpose of this work is to continue investigations in order to determine an increase in drainage trench conductivity in the drainage with the lime admixture installed in 1989 in Kalnujiai study object as well as phosphate dynamics in the drainage runoff water.

What increase in trench conductivity is obtained if a lime admixture is added to clay loam soils after 20–25-year drainage functioning?

What decrease in the drainage runoff water is obtained if a lime admixture is added to clay loam soils after 20–25-year drainage functioning and how reliable is it?

Investigation methods

The tests of effectiveness of drainage functioning, when the filtration characteristics of the drainage trench backfill were improved by admixing lime materials, were continued in Raseiniai district, Kalnujiai study object, in 2012–2016 (Figure 1). Kalnujiai study object was installed in Raseiniai district in 1988, i.e., the drainage trench backfills, which filtration characteristics were improved by admixing lime materials, are over 25-year-old.

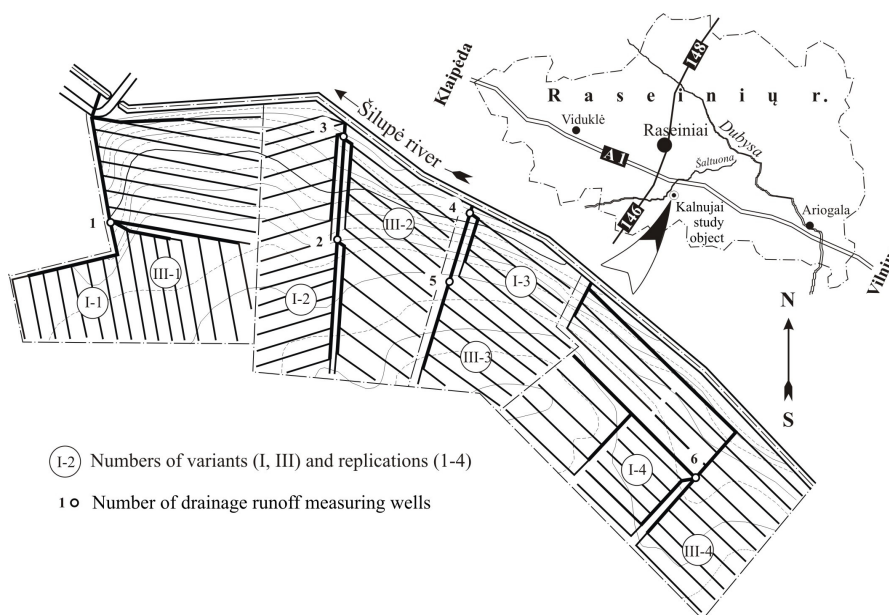


Fig. 1. Geographical location and test scheme of Kalnujiai study object

The soils of Kalnujiai study object are classified as genetic podzols. Turfy podzols, which are dominant in the object, make 45.3% of all Lithuanian soils. The soils of Kalnujiai study object near the Šilupė stream are classified as turfy weak podzol clay loam soils (*LVh-or typical simple luvisols*). Further from the Šaltuona stream, turfy carbonate podzols (*LVk-ha simple carbonate luvisols*) and turfy gley podzols (*LVg-p-w-ha simple shallowly gley luvisols*) with clear signs of soaking are found (Šaulys, Bastienė 2003). There are a lot of these soils in the intermediate region of Lithuanian Middle Lowlands and West and East Highlands (Hartge, Ellies 1976).

Light clay loam and loam soils are dominant in the object. The mean amount of physical clay particles (<0,01 mm) in the drainage depth soil profile was 43.0% and the optimum amount of lime to be mixed with trench ground was determined in the calculations; the density of ground was 1.58 g/cm³ in Kalnujiai object (Figure 1), the drainage was installed and the filtration characteristics of its trench backfills were improved by admixing the lime material. In the first variant of testing (I), the drainage trench backfill was mixed with lime so that active CaO made 0.6% of dry ground mass; in the control variant (III), the drainage trench was filled with local soil mixed by digging trenches with a multi-scoop excavator. The distances between drains are 16 m in the variants. The variants were repeated four times and their areas and lengths of laid drains are provided in Table 1.

Table 1. Test variants in Kalnujiai object (Raseiniai district)

Number of variant	Drainage trench backfill	Number of runoff measurement well	Area of replication, ha	Length of drain, m
I	Mixed with lime (CaO – 0.6% of ground mass)	1	1.28	544
		2	1.24	612
		4	1.20	676
		6	1.05	552
III (control)	Local mixed soil	1	1.05	572
		3	1.47	788
		5	1.29	648
		6	1.46	708

When installing the object in 1988, the chosen lime material was widely-used limed slate ash of Estonia which activity according to the total amount of CaO and MgO was 21.5%. The optimum amount of lime *A* mixed with one linear meter of trench ground is calculated according to the formula (1):

$$A = 500\rho h \frac{0.13 + 0.011N}{n}, \quad (1)$$

where ρ – density of ground g/cm³; h – depth of a dug drainage trench m; N – amount of physical clay particles (<0,01 mm) in the ground %; n – activity of lime according to the total amount of CaO and MgO %.

Formula (1) is applied if the amount of physical clay particles in the ground is 20 to 80% and the width of a drainage trench is 0.5 m.

After the calculation according to formula (1), we determined it would be necessary to admix 24.3 kg slate ash in 1 m of a dug trench. The rounded amount of 24.0 kg according to the amount of active CaO and MgO made 0.6% of ground mass. Slate ash was sprinkled on the dug ground of a drainage trench by using a lime material sprinkling tanker with an additional cyclone reducing the slate ash sprinkling speed and it was mixed with a screw bulldozer. The drainage trenches of the control variant were also filled with the screw bulldozer.

The drainage runoff measured in drainage runoff wells by applying the volumetric method was the main indicator of effectiveness of functioning of all the variants. The drainage runoff was measured every day in the period of spring and autumn floods and every 2–3 days in other periods.

The meteorological conditions were assessed on the basis of the data provided by Raseiniai Meteorological Station.

Investigation results and discussion

During the period of investigations (2011–2012), the testing area was ploughed in autumn and barley, peas and rapes were sown there in spring. The meteorological conditions of the period were quite different. The air temperature was insignificantly higher than the mean of many years. The annual amount of precipitation was more different (from 101.9% in 2011 to 108.4% over the norm in 2012). The amount of precipitation in the vegeta-

tion period fluctuated more – from 113.5% in 2011 to 107.6% over the norm in 2012. The differences between the monthly amount of precipitation were even bigger: from 46% of the monthly norm of precipitation in November to 223% of the monthly norm of precipitation in July 2011. According to the precipitation data of 1940–2012 provided by Raseiniai Meteorological Station, 2011 (694 mm) is classified as an averagely wet year with a 35% likelihood of precipitation. 2012 (738 mm) is classified as a wet year with a 20% likelihood of precipitation (Figure 2). Analyzing the precipitation of the warm period in April–October, it is obvious that 2011 (505 mm) and 2012 (479 mm) would be wet and averagely wet with 23 and 33% likelihoods of precipitation, respectively.

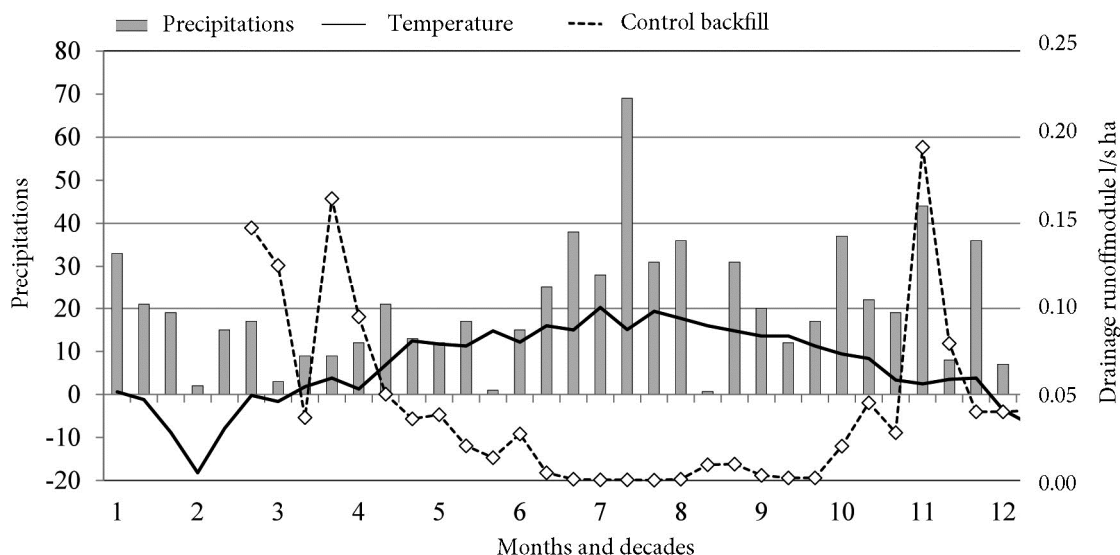


Fig. 2. Precipitation and drainage runoff module in Kalnujai study object in 2012

The main climatic factors (precipitation, air temperature) affecting the drainage runoff are constantly interrelated, especially in the warm period. If the amount of precipitation is higher and the air temperature is lower, the drainage runoff is lower; as the air temperature rises, the runoff decreases, often without a decrease in precipitation, because a higher amount of soil humidity evaporates in this period. Thus, the humidity conditions of a certain location are assessed as relative hydrothermic coefficient HTK_s , according to the main meteorological factors. In Kalnujai study object, the meanings of hydrothermic coefficient HTK_s in the vegetation period during the testing period of 2011–2012 were 1.84 and 1.85, respectively. The authors suggest assessing the humidity conditions of the location as a wet period if the meanings of hydrothermic coefficient HTK_s are ≥ 1.2 .

Analyzing the drainage runoff and meteorological conditions in Kalnujai object in 2012 (Figure 2), it is obvious the biggest drainage runoff modules were measured on the 25th of February when the air temperature became positive. The drainage runoff modules were 0.32 l/s·ha in the systems with the drainage trench backfill with the admixture of lime (0.6% of ground mass), the distances between the drains were 16 m (variant I). The drainage runoff modules were 0.15 l/s·ha in the systems with the control drainage trench backfill, the distances between the drains were 16 m (variant III). The second spring increase in the drainage runoff modules was measured on the 24th of March. The drainage runoff modules were 0.17 l/s·ha in the systems with the drainage trench backfill with lime and 0.16 l/s·ha in the control systems. It is explained with a low amount of precipitation in that period and the water of melting snow in spring ran off mostly after the 25th of February. As the temperature rises after the 24th of March, the drainage runoff decreases evenly and becomes minimal in June–July although there was a double norm of precipitation (2.2) in the 2nd decade of July.

The drainage runoff renewed in August–September and the maximum of the autumn period was on the 10th of November after more abundant precipitation in October (1.3 of the monthly norm). The drainage runoff modules were 0.23 l/s·ha in the systems with the drainage trench backfill with lime (variant I) and 0.19 l/s·ha in the systems with the control drainage trench backfill (variant III); it is by 1.21 less than with the drainage trench backfill with lime.

According to the data of 2003 (Bastienė *et al.* 2008), an increase in the drainage runoff was measured at the beginning of the vegetation period. Then, the drainage runoff modules were 0.22 l/s·ha in the systems with the drainage trench backfill with lime and 0.14 l/s·ha in the control systems.

The dynamics of alternation of comparative drainage debits is analogous to the alternation of drainage runoff modules (Figure 3). The comparative drainage debits were 0.297 ml/s·m in the systems, where lime was admixed in the drainage trench backfill (0.6% of ground mass) (variant I), on the 24th of March. The comparative drainage debits were 0.250 ml/s·m with the control drainage trench backfill (variant III). The comparative drainage debits were 0.392 ml/s·m in the systems, where lime was admixed in the drainage trench backfill, on the 10th of November and the comparative drainage debits were 0.288 ml/s·m with the control drainage trench backfill – it it by 1.36 times less than with the admixture of lime.

The comparative drainage debits were obtained in Kalnujiai study object in 2003 (Bastienė *et al.* 2008; Šaulys 2001; Gurlklys 1988), at the beginning of the vegetation period (14th of April); they were 0,378 ml/s·m in the systems with the drainage trench backfill with lime and 0.304 ml/s·m in the systems with the control drainage trench backfill.

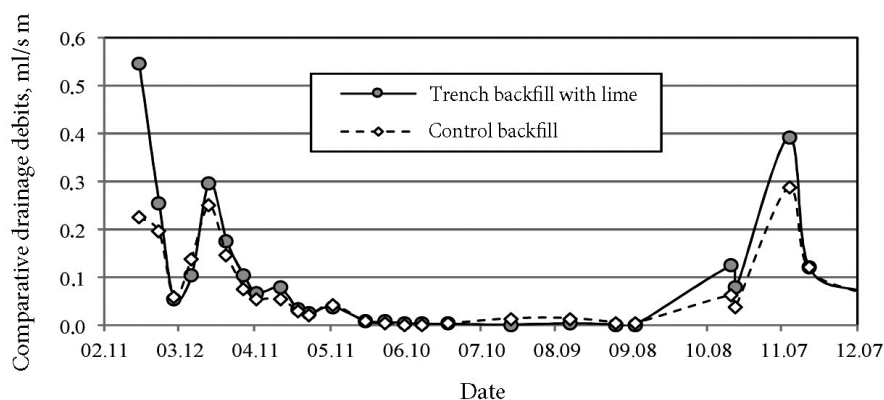


Fig. 3. Comparative drainage debits in Kalnujiai study object in 2012

As we have already mentioned, Kalnujiai study object was installed in Raseiniai district in 1988. Analyzing the maximum comparative drainage debits in the control drying systems in the spring and autumn periods of 2012 (0.250 and 0.288 ml/s m, respectively) as well as comparative debits in the spring and autumn periods (0.297 and 0.392 ml/s m, respectively) in the drainage, which filtration characteristics of trench backfills were improved by admixing lime materials (0.6% of ground mass), the results were better by 15.2–31.9%, respectively. Thus, it can be stated with the reliability of 95% today, after a 25-year period of use of drying systems, that the effectiveness of drainage functioning did not decrease.

Conclusions

In 2012, the maximum comparative drainage debits in the control drying systems in the spring and autumn periods were 0.250 and 0.288 ml/s m, respectively. The comparative drainage debits in the spring and autumn period in the drying systems, which filtration characteristics of trench backfills were improved by admixing lime materials (0.6% of ground mass), were 0.297 and 0.392 ml/s m, respectively, or they were higher by 15.2–31.9%.

Assessing the drainage system effectiveness indexes of 2003 and 2012 with the reliability of 95%, it can be stated that the effectiveness of drainage functioning, when the lime materials were used for the improvement of the filtration characteristics of drainage, did not change essentially after a 25-year period of use.

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