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The impact of lime on water quality when draining clay soils

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One of the tasks of environmental protection is to achieve a good ecological status of water bodies and reduce agricultural non-point pollution. Since drainage outflow may be identified as the leading source of water quality, reduction of nutrient transport through drains is of great importance. Field studies of the impact of lime admixture in trench backfill on the content of phosphorus and nitrogen in drainage outflow and the Šilupė stream water were conducted in the Kalnujai site (Raseiniai distr.) located in South-western Lithuania. Heavy-textured clay loam soils were drained by a composite subsurface drainage system with drain spacings of 16 and 24 m. To improve water permeability, drainage trenches were backfilled with soil mixed with 0.6% CaO. Results of seven-year studies (1999–2005) on water quality are reported in the paper.

Water samples were analysed for total phosphorus (TP), phosphate phosphorus (PO_4–P), nitrate nitrogen (NO_3–N) and ammonia nitrogen (NH_4–N). Significant differences in the PO_4–P concentrations in the control drainage outflow and treatments with lime added to trench backfill were estimated. In the water of the control drainage, these concentrations were found to be 2.8 times higher. Lime admixture reduces the annual load of TP and PO_4–P two and three times respectively as compared with the conventional drainage system. A slightly decreasing trend of TP ($r = 0.49$) and PO_4–P ($r = 0.54$) concentrations was determined in the stream where drainage water is discharged.

As regards nitrogen concentrations, the differences in drainage treatments were insignificant. The improved drainage trench backfill permeability did not increase NO_3–N leaching to drainage water; however, NO_3–N concentrations in the Šilupė stream were higher compared with rivers of natural background level pollution. The increase in agricultural activities enhanced NO_3–N concentrations in drainage water and thereby the NO_3–N input to the stream.

Key words: drainage, trench backfill, liming, water quality, phosphorus, nitrogen

INTRODUCTION

The Water Framework Directive (WFD) will require a good ecological status of all sizes of rivers and other water bodies across the European Union (EU) by 2015. Biogenic substances (nitrogen and phosphorus) will certainly appear as the prior pollutants in many river basins (Directive..., 2000; Heiskanen et al., 2004). In Lithuania as a new Member State, nutrient pollution from agriculture has been given much attention in the recent years. Many reports have identified agricultural non-point source pollution as the leading source of water quality in rivers and the Baltic Sea. The Curonian Lagoon is one of the most polluted and eutrophicated water bodies in Lithuania (The Ministry..., 2002). Šileika et al. (2005) found that in the basins without industry, 46% of phosphorus come mainly from settlements and agriculture, whereas 66% of nitrogen emissions are from agricultural land.

The territory of Lithuania lies in the zone of excessive humidity; therefore, 88% of farmlands are artificially drained. Subsurface drainage affects hydrology, soil erosion, and water quality (Fraser, Fleming, 2001; Baker et al., 2004). The impact of drainage on water quality is evaluated contradictorily. It stimulates the natural process of organic matter mineralization and accelerates the transport of nitrate nitrogen from the soil to surface waters (Soenksen, 1996; Busman and Sands, 2002). However, subsurface drainage is an effective method of reducing non-point source pollution in the areas where sediment and phosphorus are the major concerns (Tanji, Kielen, 2002). Tile drainage can reduce phosphorus losses from fields by about 45–50% (Zucker, Brown, 1998). Skaggs et al. (1994) reported that increasing the intensity of subsurface drainage generally reduced losses of phosphorus and organic nitrogen while increasing losses of nitrates and soluble salts. Also, increasing the drain spacings or decreasing the drain depth reduced nitrate nitrogen drainage losses and net mineralization and at the same time increased denitrification and runoff losses (El-Sadek et al., 2002; Skaggs, Chescheir, 2003).

Various technologies that promote reactions either within the soil or the end-of-pipe are currently being developed to reduce concentrations of biogenic substances in tile effluent. These technologies include controlled drainage (sub-irrigation), constructed wetlands and bioreactors in tile outlets. However, these means require a higher level of management and are expensive

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to operate (Blowes et al., 1994; Tan et al., 1999; Fraser, Fleming, 2001; Oertel, 2003). Some studies were conducted on the effect of amendments to the soil reducing surface water pollution. Schärer (2003) and Smith et al. (2005) determined that Fe and Al oxides tended to adsorb phosphorus very rapidly. Pulverized limestone is not very effective because the activity of Ca^{2+} is controlled by the dissolution of $CaCO_3$, which is rather slow. On the other hand, Ca oxides and gypsum contain free Ca^{2+} which can react with phosphate to form insoluble compounds (Rhoton, Bigham, 2005). Although Cox et al. (2005) reported that gypsum modified the soil chemistry and structure substantially, its impact on P concentrations in runoff was insignificant.

Nitrogen loss from the soil is greatly affected by the soil type (Tanji, Kielen, 2002; Es, 2001). Sandy soils with a high permeability are characterized as more vulnerable to leaching nitrogen into drainage effluent while on heavy, poorly drained soils nitrogen may be lost through denitrification (O'Leary et al., 2002). Water movement through clay soils much depends on the permeability of trench backfill. Therefore, adding of the amendments to the trench backfill increasing water infiltration is practiced frequently (Ritzema, 1994). In that case, the backfilled trench above drain tiles can be considered as a pathway for preferential transport of biogenic substances (Dekker et al., 2001; Cho et al., 2005). Field studies on lime admixture to trench backfill regarding both water regime and quality were carried out by researchers of the Water Management Institute of the Lithuanian University of Agriculture. This improvement significantly lowered the groundwater table and increased the surface water infiltration rate in clay soils (Šaulys, 1999; Šaulys, Bastienė, 2006).

The reported investigations were conducted on the biogenic substance concentrations and leaching into subsurface drainage and surface water in order to evaluate the impact of lime admixture on trench backfill in clay soils.

MATERIALS AND METHODS

Experimental site. The monitoring of lime impact on drainage water quality was performed in the experimental site Kalnujai located in the Jūra river basin of South-western Lithuania (Raseiniai district), which drains into the Curonian Lagoon and the Baltic Sea through the Nemunas river (Fig. 1). An experimental site with a total area of 14.59 ha was established over 15 years ago (in 1989) by a composite subsurface drainage system, with drain spacings of 16 and 24 m. Drainage water from the main collectors is discharged into the Šilupė stream. This stream (length 4.4 km, basin area 4.0 km^2) is a fourth-range tributary of the Nemunas. According to the Lithuanian river classification, it is attributed to small rivers which constitute 75.5% of the total length of rivers (Gailiušis et al., 2001). The river basin area is attributed to the agricultural non-point source pollution zone. Monitoring of water quality in the site has been ongoing since 1999. The results of seven-year studies are reported here.

Orthi- Haplic Luvisols (*LVh-or*) and *Hapli- Epihypogleyic Luvisols* (*LVg-p-w-ha*) prevail in the site. Slightly acidic (pH 6.1–6.8) sandy loam and clay loam soils are dominant. In the beginning of the investigations, the average bulk density determined in the soil profile to the depth of 1.0 m was 1.65 ± 0.02 g cm^{-3}, particle density 2.67 ± 0.01 g cm^{-3}, porosity 38.05 ± 0.43%, phosphorus content varied from very low to medium (27–144 mg kg^{-1}), potassium content

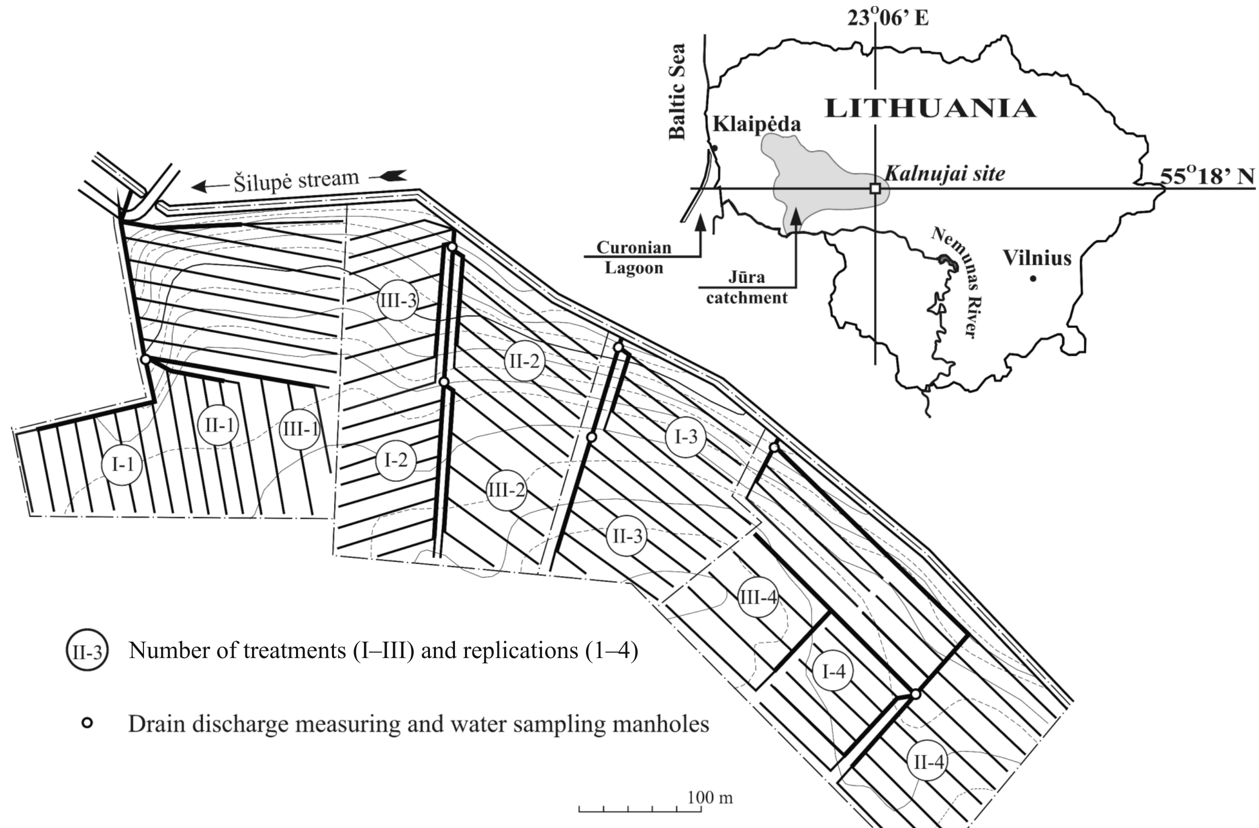

Fig. 1. Geographical location and experimental layout of the Kalnujai site

fluctuated from 84 to 124 mg kg^{-1}. Perennial grasses for hay were grown within the period of four years (1999–2002). In the autumn of 2002, the plot was tilled and since 2003 has been used for crop cultivation.

Data of the Raseiniai Meteorological Station were used to characterize the meteorological conditions of each year. The territory experienced 71% of annual precipitation during the warm season (April–October). The air temperature of the study period slightly exceeded the seasonal norm. As compared with the seasonal norm of precipitation, the years 1999, 2000, 2002 and 2004 are considered as moderate, 2001 is attributed to humid, 2003 to semi-dry and 2005 to dry years. The plant growing season was dry in 2000 and 2005, humid in 2001 and moderate in the other years (1999, 2002, 2003 and 2004) (Table 1). However, drainage runoff in the humid year 2001 was less than in the dry year 2000. A very small drainage runoff occurred in 2003 when the dormant period of the drainage lasted even for six months.

Drainage treatments. Three different treatments were installed with four replications of each: I – drainage trench backfill mixed with lime (0.6% CaO), drain spacing L = 16 m; II – the same, L = 24 m; III (control) – drainage trench backfilled with shredded clay loam soil, L = 16 m. Shale ash from Estonia, containing 21.5% of CaO, was used as the liming material. The amount of shale ash (24 kg m^{-1}) was calculated according to the optimal amount of lime that needs to be mixed with clay soil in order to reach its best hydraulic conductivity (Šaulys, 1999).

Data collection and analysis. To evaluate the effect of the three drainage treatments on water quality, water samples were taken from the outlets of drainage systems in manholes where drain discharges were measured. The periodicity of sampling was once a month within the study period (1999–2005). Water samples from the Šilupė stream were taken simultaneously. Chemical analyses were performed at the Chemical Analysis Laboratory of the Water Management Institute of the Lithuanian University of Agriculture. The water samples were analysed for total phosphorus (TP), phosphate phosphorus (PO_4–P), nitrate nitrogen (NO_3–N) and ammonia nitrogen (NH_4–N). Their concentrations were determined by the spectrometric method with a FIA Star 5012 analyser according to the water quality investigation standards (LAND 58:2003; LST EN ISO 13395:2000; LAND 38:2000). The runoff of phosphorus and nitrogen was calculated on the basis of the linear interpolation method recommended by the Helsinki Commission (Guidelines..., 1994). The reliability of the results was determined by processing them with the help of mathematical-statistical methods and using MS Excel 2000 Data Analysis Tool Pack. The trends of changes in concentrations of biogenic substances were evaluated applying the t test. The differences of drainage treatments were tested at the significance level $p = 0.05$ and $p = 0.01$.

RESULTS AND DISCUSSION

Fluctuation of biogenic substance concentrations in the Kalnujai site

The highest average concentrations of TP and PO_4–P were determined in the drainage outflow of the control treatment (Table 2). They reached 53.7 ± 4.1 and 38.1 ± 3.2 μg l^{-1} respectively. To sum up the whole study period, the mean value of PO_4–P was 1.8 times higher than the average concentrations in the Šilupė stream water (21.5 ± 2.3 μg l^{-1}) and 2.8 times higher than the average concentrations in the outflow of drainage treatments with lime additives (13.6 ± 1.2 μg l^{-1}). Extreme annual values of PO_4–P (48.8 ± 8.9 μg l^{-1}) were quantified in the dry year 2003 when the annual drainage runoff was the lowest (33 mm). Partly

Table 1. **Precipitation and drainage runoff in the Kalnujai site, 1999–2005**

Index	Year						
	1999	2000	2001	2002	2003	2004	2005
Annual precipitation, mm	635	640	765	680	592	706	486
Percentage of seasonal norm	93	94	112	100	87	104	71
Precipitation of warm period*, mm	397	341	510	422	418	463	294
Percentage of seasonal norm	89	77	115	95	94	104	66
Annual drainage runoff, mm	125	165	159	148	33	129	93
Drainage runoff of warm period, mm	10	5	50	5	9	27	30

* Warm period in Lithuania spans from April to October.

Table 2. **Statistical estimation of phosphorus concentrations (μg l^{-1}) in drainage water and in the Šilupė stream, 1999–2005**

Sampling site	n	Min	Max	Mean	Median	SE	SD	C_V %	CI 95%
				TP					
I (CaO, L = 16 m)	157	2	86	26.4	20	1.4	17.0	64.4	2.7
II (CaO, L = 24 m)	155	6	94	27.7	22	1.5	18.3	66.0	2.9
III (control)	168	10	136	53.7	48	2.1	27.0	50.3	4.1
Stream	74	14	96	41.5	34.5	2.3	19.9	48.0	4.5
				PO_4–P					
I (CaO, L = 16 m)	158	1	33	13.4	12	0.6	7.6	56.8	1.2
II (CaO, L = 24 m)	152	1	52	13.8	13	0.7	8.7	63.3	1.4
III (control)	168	9	93	38.1	31	1.6	21.4	56.1	3.2
Stream	74	2	49	21.5	20	1.2	9.9	46.1	2.3

Note: n – number of data, SE – standard error of mean, SD – standard deviation, CV – variation coefficient, CI – confidence interval of the mean at p = 0.05.

they were caused by changes in land use when grassland was tilled. The research carried out by Benham et al. (2007) reinforces this argument with facts documenting the effectiveness of no-till practices in reducing losses of biogenic substances.

In the outflow of drainage treatments I and II, where trench backfill was mixed with lime (0.6% CaO for the soil mass), TP concentrations were by 50% and PO_4–P concentrations by 64.4% lower than in the control drainage water. The dispersion analysis of the data showed those differences to be statistically significant at p = 0.05. Thus, drainage with lime admixture in trench backfill may reduce phosphorus concentrations considerably.

TP concentrations in the Šilupė steam varied from 14 to 96 μg l^{-1} during the period 1999–2005 (the mean value 41.5 ± 4.5 μg l^{-1}). The PO_4–P concentration ranged between 2 and 49 μg l^{-1} (the mean value 21.5± 2.3 μg l^{-1}). Natural concentrations of TP and PO_4–P in European rivers are approximately 5 to 50 μg l^{-1} and 0 to 10 μg l^{-1} respectively. They vary depending upon factors such as geology and soil type of catchments. Water containing TP concentrations above 500 μg l^{-1} is considered of bad quality (Nixon, 2004). According to the rates approved in Lithuania, the maximum admissible concentrations (MAC) in river water are 100 μg l^{-1} of TP and 65.3 μg l^{-1} of PO_4–P (Dėl nuotekų..., 2006). Consequently, the water of the Šilupė stream can be considered uncontaminated with phosphorus because its concentrations do not exceed the Lithuanian surface water quality standards. However, in the EU, surface water quality is considered to be good when TP concentrations do not exceed 25 μg l^{-1} (The Harmonised..., 1996). Therefore, it will be observed that the risk of eutrophication in the Šilupė stream still exists.

The distribution of the annual average concentrations in stream water within the period 1999–2005 shows a slightly decreasing trend of TP (r = 0.49) and PO_4–P (r = 0.54) (Fig. 2). These results correspond to the general character of downward trends found in Lithuanian rivers within agricultural areas (Povilaitis, 2004). These decreases are likely to be due to changes in agricultural activities during the economic transition period (Lukianas, Bagdžiūnaitė-Litvinaitienė, 2006). At the same time, an increasing trend of PO_4–P concentrations in the control drainage water was detected (r = 0.54). Irrespectively, the annual average concentrations of TP in the control treatment (missing the value of 2003) have a decreasing trend. The relatively higher (r = 0.82) correlation coefficient of linear regression shows that this correlation is statistically significant. There is no trend in the annual median concentrations of phosphorus in water of the drainage treatments I and II; TP and PO_4–P generally remained steady during 1999–2005. In summary, phosphorus concentrations in the Šilupė stream water near the Kalnujai site were 1.5 times higher than in the effluent of the experimental subsurface drainage installed with lime admixture to the trench backfill, indicating that this improvement may reduce surface water pollution with phosphorus compounds.

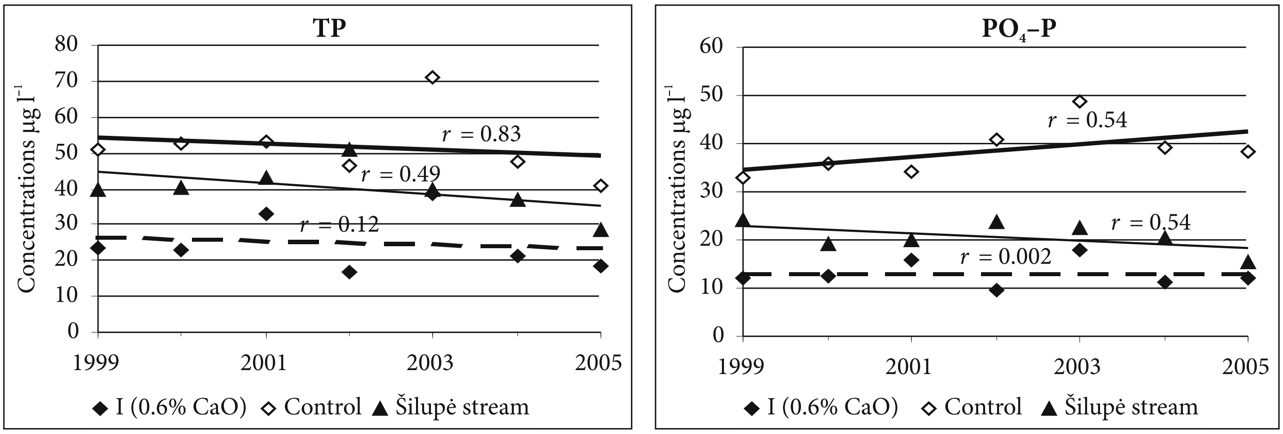

Fig. 2. Phosphorus concentrations and general trends in drainage water and in the Šilupė stream, 1999–2005

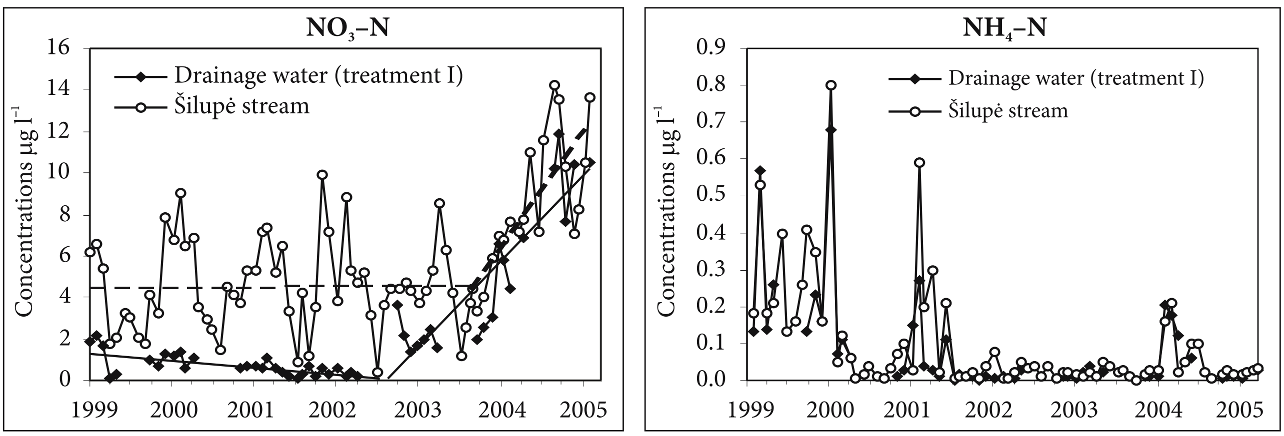

Fig. 3. Dynamics of nitrogen concentrations in the Kalnujai site (dash and line show linear trends of NO_3–N in stream water: r = 0.003 and r = 0.76, solid line – in drainage water: r = 0.66 and r = 0.88)

In Fig. 3, the dynamics of nitrogen concentrations in the Kalnujai site is represented. Two periods can be discerned in relation to land management while analysing the fluctuation of nitrogen concentrations in drainage water: the first – when the site area was used for grassland (1999–2002) and the second – since crop cultivation (2003–2005). During the first streak, the average NO_3–N concentrations in water of drainage treatments (I–III) were 0.77 ± 0.15, 0.64 ± 0.12 and 1.02 ± 0.13 mg l^{-1} respectively (confidence level was calculated at $p = 0.05$). A conspicuous moderate downward trend (r =0.66–0.74) in all treatments was determined in the time series. Since the differences in drainage treatments were insignificant, only data of treatment I are presented in Fig. 3. The situation changed after the grassland had been tilled in the autumn of 2002. The concentrations of NO_3–N began progressively increase every year. The mean values of nitrate nitrogen concentrations of the second streak versus those observed at the onset of investigations increased 7.2–12.4 times and reached 8.38 ± 1.65, 7.96 ± 1.73 and 7.40 ± 1.98 mg l^{-1} respectively in drainage treatments I–III. The trend of NO_3–N for 2003–2005 can be expressed by a strong linear regression ($r = 0.88$). It is evident that the increase of agricultural activities (crop cultivation) affected the increase of NO_3–N concentrations in drainage water. According to the guideline nitrate nitrogen concentrations (DLK 2.3 mg l^{-1}), the water of drainage treatments may be considered to be of a poor quality.

Despite seasonal changes, the average concentrations of NO_3–N in the Šilupė stream (5.43 ± 0.72 mg l^{-1}) generally remained steady during 1999–2003. NO_3–N concentrations in the stream water started rising from the autumn of 2003 (approximately a year later than in drainage water). The average NO_3–N concentrations of 9.83 ± 1.92 mg l^{-1} were determined in 2004–2005. In Lithuanian rivers with a natural background level pollution, the average concentrations of 0.29 mg l^{-1} NO_3–N and 0.13 mg l^{-1} NH_4–N were established (Povilaitis, 2006). The concentrations of NO_3–N below 0.3 mg l^{-1} are considered to be natural or background levels for most European rivers (Nixon, 2004). It is obvious that in comparison with rivers of the natural background level pollution, nitrate nitrogen levels in the Šilupė stream are about 20–30 times higher and exceed the guideline concentration for NO_3–N (2.3 mg l^{-1}) for the surface water. The concentrations of NO_3–N above 7.5 mg l^{-1} are indicative of a relatively poor quality, although twice higher concentrations (15.20 mg l^{-1}) were determined in 2005 in the Šilupė stream.

In the water of small rivers, ammonium nitrogen makes up about 5–10% of the total amount of nitrogen, therefore, the concentrations of this element are substantially lower. During investigations in the Kalnujai site, the average NH_4–N concentrations in the stream water were 0.12 ± 0.04 mg l^{-1} and continued to be higher than in the drainage water (0.09 ± 0.02 mg l^{-1}). The NH_4–N level both in the Šilupė stream and drainage water changed strongly from the beginning of the investigations until the mid- 2001. Later fluctuations of ammonium nitrogen concentrations were of a moderate character and did not exceed the MAC approved in Lithuania (1 mg l^{-1}).

Loads of biogenic substances with drainage water

The annual loads of biogenic substances with drainage runoff in the Kalnujai site are presented in Table 3. The greatest annual mean of TP losses (0.06 ± 0.017 kg ha^{-1}) was calculated in the control treatment. In treatments with lime additives, the mean leached amounts of TP (0.029–0.031 kg ha^{-1}) were 1.9–2.0 times less than in the control treatment, while PO_4–P amounts (0.015–0.016 kg ha^{-1}) were even 2.7–3.0 times lower (0.045 ± 0.011 kg ha^{-1}). Applying Student's test and using the statistical risk $f = 0.01$, the differences between the mean annual loads of PO_4–P from the control treatment III and treatments I and II were statistically significant. The same differences in terms of total phosphorus loads were statistically significant at $f = 0.05$. A comparison of phosphorus loads in the drainage treatments with drain spacings 16 m (I) and 24 m (II) revealed no significant difference. Hence, lime as an amendment of heavy textured soils positively affects the quality of drainage water and reduces the transport of phosphorus into open water bodies.

The negative charge on clay particles retains ammonium ions (NH_4^+) and protects them from leaching. Nitrate ions (NO_3^-) are negatively charged and are not retained by clay particles, therefore, subsurface drainage increased the amount of nitrates that can potentially leach from soil to drainage water. The calculations showed that in the control drainage treatment the average NO_3–N load amounted to 6.049 ± 3.2 kg ha^{-1} year^{-1}. In treatment I where trench backfill was mixed with lime (0.6% CaO) and drain spacing L = 16 m, the load of nitrate nitrogen amounted to 5.946 ± 3.5 kg ha^{-1} year^{-1}. In treatment II (with lime additives and drain spacing L = 24 m), the average NO_3–N load was by 9% lower (5.397 ± 3.6 kg ha^{-1}). During the seven-year investigations, the nitrate nitrogen load was 1.7% and 10.8% lower

Table 3. **Annual load of biogenic substances (kg ha^{-1}) by drainage runoff in the Kalnujai site, 1999–2005**

Year	PO_4–P			TP			NO_3–N		
	I	II	III	I	II	III	I	II	III
1999	0.016	0.014	0.042	0.030	0.029	0.062	1.784	1.585	1.951
2000	0.018	0.018	0.058	0.042	0.040	0.085	2.058	1.449	1.856
2001	0.021	0.026	0.048	0.042	0.047	0.074	5.660	3.690	7.510
2002	0.021	0.017	0.062	0.037	0.033	0.078	0.696	0.491	0.791
2003	0.008	0.008	0.016	0.015	0.012	0.022	13.490	12.320	10.900
2004	0.011	0.018	0.050	0.023	0.034	0.062	8.804	11.590	9.513
2005	0.011	0.012	0.036	0.017	0.021	0.038	9.133	6.652	9.822
Total	0.104	0.114	0.313	0.205	0.216	0.420	41.624	37.777	42.343
Annual mean*	0.015 ±0.004	0.016 ±0.004	0.045 ±0.011	0.029 ±0.008	0.031 ±0.009	0.060 ±0.017	5.946 ±3.5	5.397 ±3.6	6.049 ±3.2

* ± confidence interval at p = 0.05.

from the drainage systems with lime admixture than that from the control drainage, but these differences could not be treated as statistically significant. Furthermore, it must be noted that nitrate loads in particular years differed much more (variation of data 72–91%) than phosphorus, the load variation of which was only 35–38%. In the same treatment, the ratio between marginal values of nitrate load varied from 13.8 to 25.1 during the study period. The largest nitrate nitrogen input to the stream water in 2003 was likely due to intensified agricultural activities (tillage of grassland and crop cultivation, application of mineral fertilizers). Other references also prove that the magnitude of nitrogen loss depend on soil management (Zucker, Brown, 1998; Povilaitis, 2006). However, the results obtained in the Kalnujai site showed that the drainage trench backfill permeability, improved with lime additives, did not increase nitrate leaching to drainage water.

CONCLUSIONS

In the outflow of drainage treatments where trench backfill was mixed with lime, the total phosphorus concentrations were by 50% and phosphate phosphorus concentrations by 64.4% lower than those in the control drainage water. Statistically significant differences among drainage treatments conffirmed that lime admixture in heavy-textured soils may reduce phosphorus concentrations in subsurface drainage water considerably. Moreover, the results obtained in the experimental site showed that adding 0.6% of CaO to the soil mass reduced the annual load of total phosphorus and phosphate phosphorus two and three times respectively as compared with the conventional drainage system.

Differences of nitrogen concentrations in drainage treatments were insignificant. During the seven-year period of investigations, the nitrate nitrogen load was by 1.7% and 10.8% lower from the drainage systems with lime admixture than from the control drainage, but these differences could not be treated as statistically significant. Therefore, it may be concluded that the improved drainage trench backfill permeability does not increase nitrate leaching to drainage water. The largest nitrate nitrogen input into the stream water was related to intensified agricultural activities.

Investigations of water quality in the Šilupė stream (where the water of the experimental drainage system discharges) revealed that concentrations of total phosphorus and phosphate phosphorus did not exceed the maximum admissible concentrations approved in Lithuania. However, the mean value of total phosphorus (41.5 ± 4.5 μg l^{-1}) exceeds the surface water quality standards of the EU from the point of view of eutrophication (25 μg l^{-1}). Nitrate nitrogen levels in the Šilupė stream varied from 1.50 to 15.20 mg l^{-1} and were notably higher in comparison with the rivers of natural background level pollution (0.29 mg l^{-1}) or exceeded the maximum admissible concentrations for surface waters (2.3 mg l^{-1}).

A weakly significant downward trend of TP ($r = 0.49$) and PO_4–P ($r = 0.54$) was detected in the Šilupė stream water during the seven-year period (1999–2005). At the same time, the annual median phosphorus concentrations generally remained steady in the outflow of drainage treatments with lime admixture to trench backfill.

The tendency of variation of nitrate nitrogen concentrations depended on soil management in the experimental site. When the plot was used for grassland, changes of NO_3–N in the Šilupė stream (despite seasonal variation) generally remained steady and reached 5.43 ± 0.72 mg l^{-1} on the average. At the same time, a moderate downward trend ($r = 0.66$–0.74) of NO_3–N in all drainage treatments was detected. After the grassland was tilled, a significant increase ($r = 0.76$–0.88) in nitrate nitrogen concentrations in the stream water and drainage outflow was determined, indicating that the increase of agricultural activities (crop cultivation) reflected on the increase of nitrogen concentrations in the site.

Lime as an amendment of heavy textured soils exerts a positive effect on the quality of drainage water and reduces the transport of phosphorus into open water bodies. This drainage practice can be treated as an effective measure preventing non-point pollution of surface waters in agricultural areas.

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KALKIŲ POVEIKIS VANDENS KOKYBEI SAUSINANT MOLIO DIRVOŽEMIUS

Santrauka

Vienas svarbiausių gamtosaugos uždavinių yra sumažinti pasklidąją žemės ūkio taršą ir siekti, kad būtų gera vandens telkinių ekologinė būklė. Kadangi drenažo nuotėkį galima laikyti pagrindiniu vandens kokybę nulemiančiu veiksniu, svarbu sumažinti biogeninių medžiagų – fosforo ir azoto – išplovimą drenomis. Į tranšėjų užpilą įmaišytų kalkių poveikio fosforo ir azoto kiekiams drenažo ir upelio vandenyje tyrimai atlikti Pietvakarių Lietuvoje esančiame Kalnujų (Raseinių r.) lauko bandymų objekte. Sunkios struktūros priemolio dirvožemiai nusausinti sistemiu drenažu, atstumai tarp drenų – 16 ir 24 m. Kad pagerėtų dirvožemio vandens laidumas, drenažo tranšėjų gruntas sumaišytas su 0,6% CaO. Straipsnyje pateikti vandens kokybės tyrimų 1999–2005 m. rezultatai.

Nustatyti esminiai skirtumai tarp fosforo koncentracijų kontrolinio varianto drenažo vandenyje ir variantų, kuriuose į tranšėjų užpilą įterpta kalkių, – pastaruosiuose koncentracijos buvo 50–64,4% mažesnės. Drenažo variantuose su kalkėmis bendrojo ir fosfatų fosforo išplovimas drenomis buvo atitinkamai 2 ir 3 kartus mažesnis negu kontroliniame variante. Upelyje, į kurį suteka drenažo vanduo, bendrojo fosforo koncentracijos kito nuo 14 iki 96 $\mu g\ l^{-1}$ ir buvo ne didesnės už koncentracijas, leidžiamas vandens telkiniuose-imtuvuose. Be to, tiriamuoju laikotarpiu upelyje nustatytos bendrojo fosforo ($r = 0{,}49$) ir fosfatų fosforo ($r = 0{,}54$) koncentracijų mažėjimo tendencijos.

Azoto koncentracijų skirtumų drenažo variantuose nenustatyta. Pagerinus tranšėjų laidumą kalkėmis, drenomis išplautų nitratų nepadaugėjo, tačiau nitratų koncentracijos Šilupės upelio vandenyje, palyginti su gamtinio fono upėmis, buvo gerokai didesnės. Didesnes nitratų koncentracijas ir gausesnį jų išplovimą lėmė žemės naudojimo intensyvumas.

Raktažodžiai: drenažas, tranšėjų užpilas, kalkinimas, vandens kokybė, fosforas, azotas