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CHANGES OF QUALITY IN AGRICULTURAL DRAINAGE WATER BETWEEN NATURE'S SEASONS

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Abstract. Agricultural drainage and related water management systems are implemented to improve farming. Get higher yields of agricultural production. Remove excess water. When removing excess water in cultivated areas, it is important to reduce the leaching of polluting substances flowing out with drainage water throughout the year and in different seasons. Also ensure the safe and sustainable use of plant protection products and fertilizers. One of the possible solutions is to transform the old free drainage systems into controlled drainage systems. In such systems, it is possible to regulate the groundwater level in different seasons and according to the needs of the plants. In this way, to reduce the leaching of materials with drainage water. This article presents an analysis of controlled and free drainage water pollution in separate seasons. Researches were carried out in Pasvalys district, where both types of drainage systems operate next to each other.

Keywords: controlled drainage, free drainage, agricultural drainage, water pollution.

Introduction

Drainage of arable lands was started in ancient times. Lithuania is in a zone of excess moisture, for this reason effective development of agriculture is possible only after draining excessively wet areas by installing drainage systems (Ruminaitė, 2010; Stankevičienė & Stankevičius, 2014). The first drainage systems in Lithuania were of simple constructions, so the majority of about 84% of all drained agricultural areas in Lithuania were drained by free drainage. This is a traditional drainage system, the downside of which is that it works by constantly removing moisture and excess water from the soil (Bernikas & Rudzianskaitė, 2022). As water flows from agricultural fields, it also carries various chemical and biogenic substances (Manik et al., 2019; Rudzianskaitė, 2011). Such water is quickly removed from the soil with this system after intensive watering (Brazaitė & Šaulys, 2020). If there is an opportunity to retain it, the plants would be able to absorb substances such as nitrogen and phosphorus. In this way, they would not appear in open water bodies and would not deteriorate their quality (Halbach et al., 2021). Free drainage causes the soil water level to drop. Although from the point of view of saving water reserves, once a certain dewatering threshold is reached, it would be beneficial to pause it. With the help of controlled drainage systems, it is possible to regulate the soil water level in different seasons of the year. Contain drainage runoff and protect soil water reserves (Zubelzu et al., 2022). In this way, reducing the leaching of chemical and biogenic substances and their entry into open water bodies (Salo et al., 2021; Gramlich et al., 2018). With the help of controlled drainage, the annual leaching of nitrogen compounds can be reduced from 20 to 90%, and total phosphorus – from 10 to 30%.

Intense changes in climate, especially in different seasons, also have a huge impact on the yield of agricultural production (Øygarden et al., 2014; Tuohya et al., 2018). Considering the fact that the climate cannot be controlled, it is important to understand how it is possible to improve the quality of the soil in different seasons by using fertilizers. How much and what kind of fertilizers to use in the soil (Cai et al., 2022; Tang & Riley, 2021). How and when these fertilizers can be leached from the soil. What could be the consequences if they get into open bodies of water. One of the possible solutions to reduce the impact of climate change and the pollution of open water bodies is to transform free drainage structures into controlled drainage systems. A lot of research is currently being done on this topic. In recent years, scientific research has shown that drainage water management provides an opportunity to control the use of agrochemicals (fertilizers, nutrients and pesticides). Their loss in cropland due to surface runoff and

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subsurface drainage discharges (Fouss et al., 2007; Saadat et al., 2018; Bučienė et al., 2019).

The aim of the study is to analyze and compare the quality of water flowing from free and controlled drainage systems in different seasons.

Object of research

The research was carried out in Northern Lithuania, Pasvalys district, located in a cultivated agricultural field (Figure 1)

The district of Pasvalys is distinguished by the fact that, in terms of agricultural areas, larger than average farms prevail here. The average farm size in this region is about 125 ha and the most common crop grown here is wheat. About 96% of wheat is grown in the Pasvalys district as a percentage of all farms, about 38% of barley, and about 64% of rapeseed (Vaitekūnienė, 2021). The average Lithuanian soil productivity score is about 40. Pasvalys district is the second most fertile district in Lithuania. This district has a soil productivity score of 50.17. Such a high score led to the selection of the study area. In the research field, this score is even higher and ranges between 57 and 62 points. This means that this average score is even higher than the Lithuanian average. The field of arable land chosen for research is located in one of the most fertile cadastral areas in Lithuania, its area is 39.41 ha. All this large area is divided into several smaller fields. In this way, it is easier to do agricultural work in the whole area. In three of such fields, each of which has an area of about 3 ha, drainage systems have been installed in order to maintain a suitable soil type, to grow larger yields of agricultural production and at the same time to reduce the entry of biogenic substances together with underground and surface runoff from cultivated fields into open water bodies (Figure 1). Two fields have a modern controlled drainage system with drainage wells. One field has an older type of free drainage system

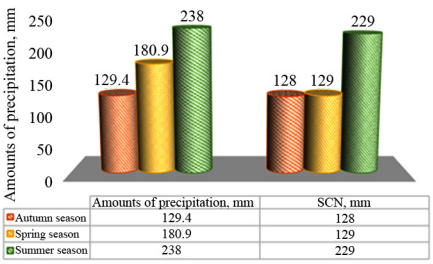
Water samples for research were taken from the drainage systems in the period of 2020–2021. In the most relevant seasons for soil moisture regime and productivity: autumn, spring and summer. In this period, the inflow of water from the atmosphere is the largest, and its consumption is also intensive. Water samples

Figure 1. Research location in relation to the territory of Lithuania

were taken both from the controlled and from the free drainage system by determining the flow rate and concentrations of nitrogen compounds such as nitrites, nitrates, ammonium nitrogen.

Results and discussion

Weather conditions, precipitation and temperature are among the most important factors that determine the intensity of drainage. These parameters are especially important for the runoff characteristics of the controlled drainage system. It depends on the amount of precipitation when, how, and for how long a controlled drainage system needs to be flooded or allowed to function as a free drainage system. Changes in precipitation and temperature have been determined based on the data of the Pakruojis Meteorological Station. In order to see the trend of precipitation change in the context of the whole of Lithuania over a multi-year period, the cumulative precipitation amounts of each studied season were compared to the Lithuanian standard climate norm (SCN) of thirty years (Figure 2).

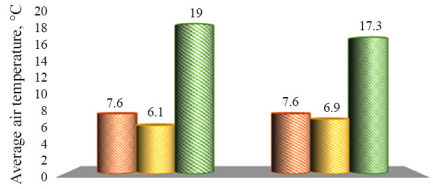


	Amounts of precipitation, mm	SCN, mm
Autumn season	129.4	128
Spring season	180.9	129
Summer season	238	229

Figure 2. Seasonal variation of precipitation

After analyzing the data graph, it can be seen that the cumulative precipitation amounts of the spring season of the studied period differ from the standard climate norm (precipitation rate). During the study period, the spring season saw 29% more than the standard climate norm (precipitation rate). Unequal distribution of precipitation in spring seasons affects the vegetation period of plants differently. The lower amount of precipitation is compensated by snowmelt water collected in controlled drainage systems. The larger, excess amount of precipitation accumulated up to the set accumulation level is removed through the drainage system. In the summer and autumn seasons, no significant changes were observed in total precipitation. In the summer season of the research period, 4% and 1% more precipitation fell in autumn than the long-term precipitation norm.

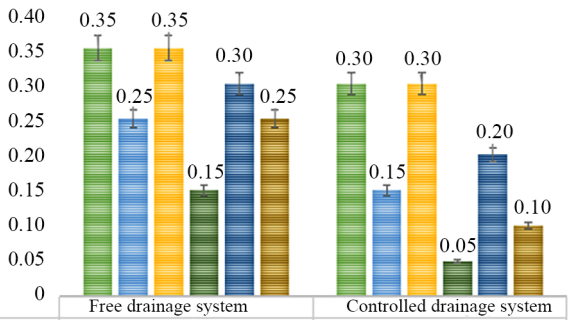
Temperature changes also affect the vegetation season of plants. After analyzing the data, it was noticed that the average temperature of the summer season was 1.7 °C higher compared to the standard climate norm. The spring season was slightly cooler (0.8 °C) than the standard climate norm. This may have delayed the start of vegetation. The autumn season did not differ in temperature mean deviation (Figure 3).



	Air temperature, °C	SCN, °C
Autumn season	7.6	7.6
Spring season	6.1	6.9
Summer season	19	17.3

Figure 3. Seasonal temperature variation

After the analysis of the water samples taken, it was found that in the majority of the samples, the maximum amounts and the highest concentration of suspended solids were recorded in the water of the free drainage system. This is because the excess drainage water is immediately led to the drainage system, along with it, particles of washed organic and mineral substances enter the collectors. The highest concentration of suspended solids was found in the autumn season, when it reached 0.35 mg/l. Meanwhile, in the water samples of the controlled drainage system, the highest concentration of suspended solids in the autumn and spring seasons reached only 0.3 mg/l, the lowest – 0.05 mg/l (Figure 4).



	Free drainage system	Controlled drainage system
Autumn maximum conc.	0.35	0.30
Autumn minimum conc.	0.25	0.15
Spring maximum conc.	0.35	0.30
Spring minimum conc.	0.15	0.05
Summer maximum conc.	0.30	0.20
Summer minimum conc.	0.25	0.10

Figure 4. Distribution of suspended solids concentrations in mg/l in separate seasons

The lower concentrations of suspended solids in this system may be due to the retention of water percolated from the soil in the well of the controlled drainage system. In this way, part of the suspended solids settles in the well and does not enter to open water bodies. As a result, silting and swamping of the bottom of rivers, streams, and ditches is reduced, and it is easier and simpler to clean and later remove sediments formed and accumulated due to suspended solids from drainage wells than from open water bodies.

Analyzing the samples taken and the tests carried out, it was found that the average concentrations of all nitrogen compounds in the water of the free drainage system during the autumn season are higher compared to the water of the controlled drainage system. This shows that the leaching of these biogenic substances in such drainage systems is more intense and on average 11% more of them are leached. Water flows faster through pipes and does not clean itself. In the spring season, due to the low amount of precipitation during the sampling period (34 mm), the average flow rate from the free drainage system was extremely low. Water did not flow from the controlled drainage system into the natural environment. It was accumulated. Thus, in the spring season, the average concentration of nitrogen compounds in water samples from the free drainage system was 35% lower than in the controlled drainage system. This is because in the absence of discharge of excess water into the natural environment, the samples were taken from the wells of the controlled drainage system. In these wells, the water filtered through the soil is retained together with the biogenic substances contained in it. Such water does not enter the surface water bodies, and when the soil moisture decreases, it is returned to the soil together with the nitrogen compounds in it, where it is successfully absorbed by the plants.

The highest concentration of nitrate nitrogen was determined i, n the spring season, which reached 12.5 mg/l. As observed by Šatavičiūtė (2017) in her research, this may be related to the transformation of nitrogen in soils, which occurs more intensively in the direction of increasing nitrate nitrogen (NO3-N). Also by fertilizing the fields and with the fact that nitrates are the form of nitrogen compounds that are difficult for the soil to absorb and are taken up more slowly by plants (Pinton et al., 2016). Nitrates are one of the most soluble forms of nitrogen in water (Pocienė & Pocius, 2011), so most of the nitrogen compounds are washed out in this form. The concentration determined in the spring samples does not exceed the permissible norm of the limit concentration of water pollutants that can enter the natural environment (23 mg/l).

An exceptional case was in the month of August 2021, a few days before the sampling, a large amount of precipitation fell. The principle of operation of a free drainage system is to immediately remove excess water from the soil. In the controlled drainage system, the filtered water was stored for some time until the retention wells were filled, and only when the overflow limit was reached, it was released over a period of several days. It is likely that this is precisely the reason why twice the average concentration of nitrogen compounds (2.4 mg/l) was found in excess water compared to free drainage (0.9 mg/l). Nitrogen compounds were continuously washed out through the pipeline of the free drainage system, so their lower concentrations were determined at the time of sampling. In other sampling cases, there was no excess water from controlled drainage systems during the summer season, so it was all stored in wells and not released into the natural environment. The average concentration of nitrogen compounds was 3.9 mg/l, and 1.55 mg/l in water from free drainage systems, which is not retained and flows into surface water bodies.

Limit values of phosphorus concentrations of phosphates in the tested water are not controlled and specified. Phosphorus is the second most important element in agriculture, but in the soil it is in a form that is difficult for plants to access and is not very mobile. In autumn, when the air temperature drops below 13 °C, phosphorus absorption drops and is very weak. However, no significant spike in concentrations was found during the autumn season. In the controlled and free drainage systems, the average phosphorus concentration of phosphates in the autumn season differed by about 10%. It was higher in controlled drainage water samples. Usually, the lowest concentration of this substance is during the vegetation period, when it is intensively used and absorbed by plants, intensive photosynthesis takes place. The greatest in the cold season, during the mineralization of organic matter. As plant residues in the soil mineralize and primary phosphorus-bearing minerals are lost, it turns into a partially soluble form. In controlled systems, the amount of these substances in the summer season was very low, up to 5.2 mg/l. In the uncontrolled drainage water sample, there was one spike in concentration, which was also recorded in August at 11.9 mg/l, which is associated with a higher amount of precipitation during that period. During the other investigated spring and summer seasons, the amount of phosphates in the drainage water remained stable and did not differ significantly in either the free or controlled drainage systems. Although the migration of phosphates is not high, the excess of phosphates formed during many years of constant fertilizing of the soil is washed away (Adomaitis et al., 2010).

The pH of water in drainage systems varies from 7.02 in the summer season to 8.08 in the autumn season. It is a neutral seedbed. Summing up the pH data, it was found that, regardless of the season, the pH of the water of the free system is higher than the pH of the water of the controlled drainage systems. The mean pH values were 7.6 and 7.4, respectively. Lower values pH 7.28 are recorded in both systems during the summer period, when intensive growth takes place at. Highest in autumn

season: 7.78 and 7.47. The total pH of the drainage water of the entire field is equal to 7.5 (Figure 5). Soils and the water in them with a pH of 7.5–8.0 are the most fertile.

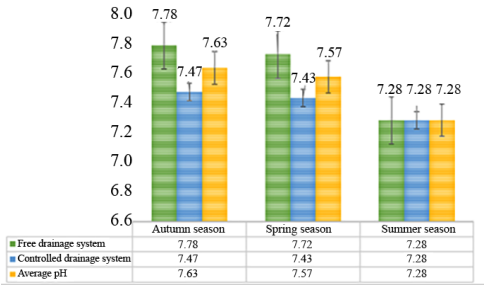


Figure 5. pH concentration in different seasons

Drained agricultural fields are more sensitive to both atmospheric and anthropogenic pollution. The water flowing out of the free drainage system will quickly get into the pipelines, and the water that flows out of them will not have the opportunity to clean itself sufficiently, thus accelerating the migration of pollutants and the pollution of surface waters, which negatively affects the natural environment. Controlled drainage is one means of reducing diffuse pollution from agricultural fields and improving the condition of surface water bodies. It is most effective to contain biogenic substances at the place of their spread or formation, preventing them from entering surface water bodies. This problem can be solved by installing or changing free drainage systems to controlled drainage, along with the installation of a drainage runoff control system and excess water retention wells. In this way, it is possible to control the entry of biogenic substances into the natural environment during individual seasons of the year or even months.

Conclusions

After the analysis of the data, it was found that the cumulative precipitation amounts of the spring season differ from the standard precipitation rate. Precipitation was 29 percent above normal. In the summer and autumn seasons, no significant changes were observed in total precipitation. In the summer season of the research period, 4% and 1% more precipitation fell in autumn than the long-term precipitation norm.

After analyzing the temperature data, it was found that the average temperature of the February season was 2 °C higher than the standard climate norm. The spring season was slightly cooler (0.8 °C). The autumn season did not differ in temperature mean deviation.

The concentration of suspended solids in the water of the controlled drainage system is 1.5 times lower than in the water of free drainage. This is because the water that has filtered out of the soil is retained in the regulation well, and thus some of the suspended matter settles in it.

The average concentration of nitrogen compounds in water samples taken in the spring season from the free drainage system was 35% lower than in the controlled drainage system. This is because, in the absence of excess water, the samples were taken from the wells of the controlled drainage system, where the concentrations in the accumulated water are naturally higher, such retained water is returned to the field where it is successfully absorbed by the plants when the soil moisture decreases.

In the autumn season, the leaching of nitrogen compounds from the free drainage system was 11% higher than from the controlled drainage. The concentration determined in the spring samples does not exceed the permissible norm of the limit concentration of water pollutants that can enter the natural environment (23 mg/l).

In autumn, when the air temperature drops below 13 °C, phosphorus absorption drops and is very weak. In the controlled and free drainage systems, the average phosphorus concentration in the autumn season differed by about 10%. In controlled systems, the amount of these substances in the summer season was very low, up to 5.2 mg/l. During the spring and summer seasons, the amount of phosphates in the drainage water remained stable and did not differ much in the drainage or controlled drainage systems.

The pH of water in drainage systems varies from 7.02 in the summer season to 8.08 in the autumn season. Lower values pH 7.28 are recorded during the summer period, when intensive growth takes place at. Highest in autumn season: 7.78 and 7.47. The total pH of the drainage water of the entire field is equal to 7.5.

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