ANALYSIS OF THE MAIN INDICATORS OF POLLUTION IN THE DOTNUVELE AND SMILGA STREAMS

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Abstract
Due to intensive agricultural activities being developed in Middle Lithuania, the water quality of rivers in this region significantly decreases. Rivers, flowing through the town territory, should provide aesthetic delight to the residents, however, because of pollution, especially at the end of summer, they are usually covered in duckweed and algae layer. The paper presents the change of the main water pollution indicators (BOD_7, N_{total}, NH_4-N, NO_3-N, P_{total}, PO_4-P and O_2) in Dotnuvele and Smilga streams during 2013 – 2015. The aim of research is to determine the change of the main surface water pollution factors in Dotnuvele and Smilga streams, depending on the meteorological conditions. Data analysis showed that dissolved oxygen, nitrate and total nitrogen concentrations are affected by air temperature: the lower the air temperature, the more of these elements were found in the water of the streams, (r = -0.61), (r = -0.83) and (r = -0.64) respectively. An increasing precipitation was also increasing the amount of O_2 and NO_3-N in streams‘ water, (r = 0.44), (r = 0.49) respectively. Meteorological conditions did not have a significant impact on concentrations of other chemical elements, however, correlation analysis showed that concentrations of BOD_7 in streams' water were increasing as precipitation level was falling (r = 0.41), and PO_4-P – when air temperature was increasing (r = 0.46). It was determined that in every spring the streams‘ water quality according to the concentrations of N_{total} and N-NO_3 was in a bad or average ecological condition. This was caused by the farming fields from which these streams are collecting drainage water during the spring melt.
Key words: ecologial status, concentration, surface water.

Introduction

In 2013, European Commission prepared a report to the Council and the European Parliment, where, according to the 2008 – 2011 yr. data from all EU27 states river observation stations, it can be claimed that 16.3% and 6.3% of rivers respectively were in eutrophic and hypertrophic condition, while 35.4% and 20.6% of rivers were in oligotrophic and ultra-oligotrophic condition. The biggest percentage of stations in rivers with ultra-oligotropic condition were in Spain, Bulgaria, and Slovenia, while the biggest percentage of stations in rivers with hipertrophic condition were in Belgium and the Netherlands, also in the Check Republic and Finland. A high eutrophication level was also observed in Lithuania and Luxembourgh (Report..., 2013).

In order to accomplish the goals set in the water framework directive (2000/60EB), both surface and ground water monitoring is being undertaken in Lithuania. Even though there is a lot of effort put into reducing the water pollution, according to the national monitoring data, the ecological condition of Lithuanian water bodies is not good. From 822 researched water bodies in river category, 75 of them were in a very good (9%), 327 – good (40%), 291 – average (35%), 85 – bad (11%) and 42 – very bad (5%) ecological condition (Mereškevičienė, 2015).

Nevezis basin lies in the Middle Lithuania lowland, where there are the most fertile soils. Due to intensive agricultural activities, the water quality in rivers of this region significantly deteriorates. Nowadays water bodies‘ ecological condition in Kedainiai town is not good: in summer, water surface very often becomes covered in algae and duckweed layer, slowing down the self-cleaning process and deteriorating the aesthetic view of the town.

There are 4 inflows of Nevezis in Kedainiai town, the biggest of these are Smilga and Dotnuvele. These streams are waterless, therefore, due to low debit, the streams‘ condition is bad during the dry season. Point pollution sources in basins of Dotnuvele and Smilga streams are municipal wastewater treatment plants, storm water treatment plants, and JSC ‚Kedainiai Canning Factory‘. Not all residential houses are connected to the central sewer system, and part of the surface water from the town territory flows into the river. Wastewater accesses Dotnuvele and Smilga from various villages that are in their basins.

During 2009 – 2012 an environmental cleaning and restoration of these streams took place. Streams‘ water and shores were cleaned from pollutants. After this type of project, it is important to ensure a 5-year annual maintenance of cleaned water bodies and carry out streams‘ water monitoring. The aim of the research is to determine the change of the main surface water pollution factors in Dotnuvele and Smilga streams, depending on the meteorological conditions.

Materials and Methods

Dotnuvele and Smilga streams, flowing through Kedainiai town, are the right inflows of Nevezis river (Figure 1).

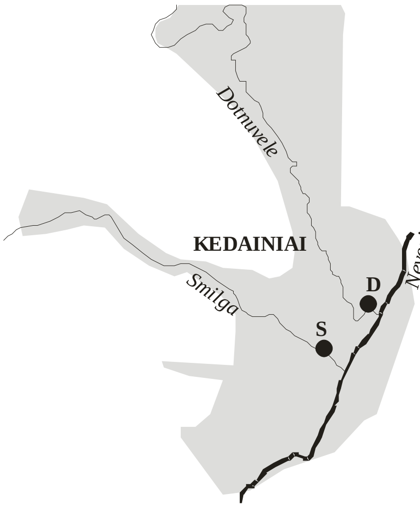

Figure. 1. The scheme of research object.
D – Dotnuvele stream‘s water sampling location,
S – Smilga stream‘s water sampling location.

Even though Smilga stream is almost twice shorter (32 km) than Dotnuvele (60.9 km), its basin is almost the same (208.8 km^2) compared to Dotnuvele‘s (192.7 km^2).

The cleaning of 1.95 km length of Dotnuvele stream (measured from the estuary of the stream) as well as restoration of 10 m width of coastal strip was completed in 2012. In 2013, 1.98 km length of Smilga stream and 2 ha of coastal land was cleaned, and 5157 m^3 of sludge removed.

Water samples were taken from the source of Dotnuvele (D) and Smilga (S) streams four times a year – in March, May, August, and November. Chemical analysis, was done by ASU Chemical Analytical Laboratory of Water Resources Engineering Institute.

In the samples total nitrogen (N_{total}) was determined by applying the spectrometric method, by mineralizing with potassium persulphate (LAND 59:2003), P_{total} was determined by spectrometric method after mineralization with potassium persulphate (LAND 59:2003), ammonium nitrogen (NH_4-N) – by spectrometric method, with Nessler‘s reagent (LAND 38:2000), nitrate nitrogen (NO_3-N) – by spectrometric with phenol sulfonic acid (LAND 65:2005), phosphorus residue (PO_4-P) – by spectrometric with ammonium molibdate and ascorbic acid. (LAND 59:2003)

BOD_7 was determined by estimating the difference in oxygen level after seven days of incubation (LAND 47-2:2007). Dissolved O_2 amount in water was determined using the electrochemical probe method (LST EN ISO 5814-2012).

According to this methodology, the ecological state of rivers is divided into 5 classes from a very good state, when N_{total} <2, P_{total} <0.1 to a poor state, when N_{total} >12, P_{total} >0.47 mg l^{-1} (Paviršinių..., 2011).

Statistical analysis of the data was performed using the computer program Excel and STATISTICA.

Results and Discussion

Average concentrations of researched chemical elements in the streams were changing unevenly: some of them were determined to be higher in Dotnuvele, others – in Smilga (Table 1).

Statistical data analysis showed that there is no significant difference between all researched chemical elements in both streams‘ water, because the calculated Student‘s t-test was lower than the 95% confidence level. The probability of confidence was also higher than the 0.05 level.

Oxygen amount in water is its pollution indicator. Therefore, the more oxygen is in water, the cleaner it is.

It was determined that water in both streams, according to the amount of dissolved oxygen, corresponded to a good and very good ecological condition (Figure 2). Data showed a tendency that there

Table 1

Average concentrations of researched chemical elements in streams‘ water

Indicator	Concentration, mg l^{-1}		$t_{fact.}$	$t_{theror.95\%}$	p
	In Dotnuvele	In Smilga			
BOD_7	2.54	2.94	-0.74	2.23	0.48
O_2	6.40	6.76	-0.14	2.18	0.89
NH_4-N	0.05	0.03	1.52	2.18	0.15
NO_3-N	3.60	4.38	-0.50	2.14	0.62
N_{total}	0.09	0.03	1.90	2.36	0.099
P_{total}	0.06	0.009	1.89	2.36	0.100
PO_4-P	9.64	11.14	-1.74	2.14	0.104

Note: $t_{fact.}$ – calculated Student‘s t-test, $t_{theor.95\%}$ – 95% Student‘s t-test probability; the difference between streams‘ water concentrations is significant when $t_{theor.95\%} < t_{fact.}$, p – confidence probability; when p<0.05 the relationship is significant.

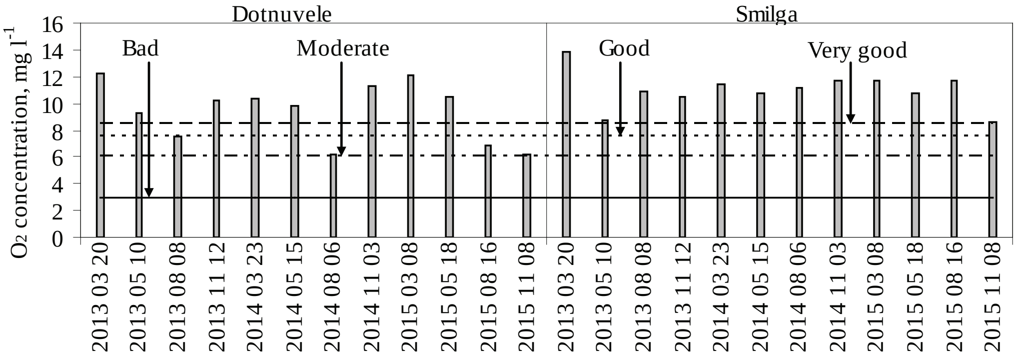

Figure 2. The change in dissolved oxygen concentrations in streams‘ water.

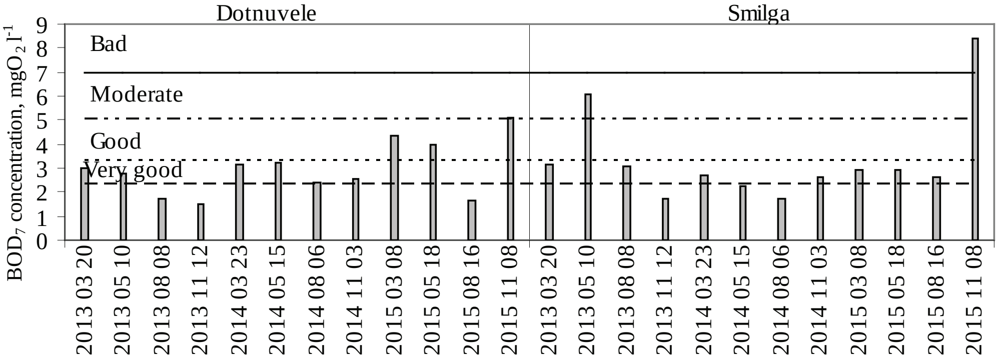

Figure 3. The change in BOD_7 concentrations in streams‘ water.

was less oxygen dissolved in Dotnuvele (6.22 – 12.3 mg l^{-1}) than in Smilga (8.7 – 13.9 mg l^{-1}), however, as literature states, open flow aeration directly depends on rivers‘ flow speed (Tilickis, 2005). The measured dry period lowest debits of Smilga (0.028 m^3 s^{-1}) are twice as big as those of Dotnuvele (0.015 m^3 s^{-1}) (Vaikasas & Poškus, 2004). The lowest oxygen concentrations in Dotnuvele were observed in August 2013, 2014, and November 2015, as there was the longest dry up period and water speed was the lowest. As there is a dam on Dotnuvele stream, its water speed has reduced even more, and this had an impact on the reduction of oxygen amount in water as well.

Organic matters reach rivers with industrial and household waste water, also large amounts of these materials accummulate in eutrophic river waters during vegetation degradation processes. A bigger organic matter amount essentially shows the pollution of that water body (Tilickis, 2005; Jouanneau *et al*., 2014; Simon *et al*., 2011; Gustavsson & Engwall, 2012; Chen *et al*., 2012). An increase in organic pollution was observed in Smilga stream in May 2013, when BOD_7 concentration had increased to 6.08 mg l^{-1}, and it corresponded to a bad ecological sream water condition (Figure 3).

In November 2015, organic pollution in both Dotnuvele and Smilga was the highest compared to the whole research period and was 5.13 and 8.37 mg O_2 l^{-1} respectively, and corresponded to a very bad ecological water condition. This was affected by precipitation that had fallen after a long and dry period, which washed town‘s streets from pollutants and increased organic pollution in the streams. According to Mallin *et al*. (2009), higher BOD concentrations can be found in rain water from urbanised territories, because town territories with impermeable coating increase surface wastewater and have an impact on hydrology and geomorphology of the streams (Paul & Meyer, 2008). During other seasons, Dotnuvele and Smilga streams‘ water was in a very good and good ecological condition.

In surface water bodies, even not affected by anthropogenic pollution, nitrogen and its compounds can be found all the time. According to literature, the most of total nitrogen can be found in rivers in Middle Lithuania, however, this is affected not only by human activity, but also by natural factors (Tumas, 2003; Šileika, 2012).

Ammonium nitrogen in both streams was observed to be very low; therefore, their water quality

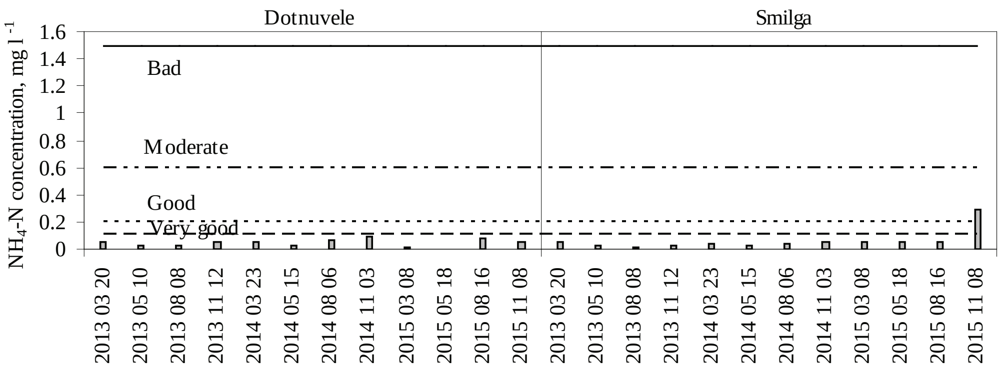

Figure 4. The change in NH_4-N concentrations in streams‘ water.

corresponded to a very good ecological condition, except November 2015, when NH_4-N concentration in Smilga stream was determined to be 0.287 mg l^{-1} and according to this element water quality was average (Figure 4).

This was probably affected by a large amount of precipitation (8.5 mm) that fell after a long dry period, as rain water dischargers from the town streets are installed on Smilga stream.

The analysis has shown that nitrate concentration in summer is lower: in August 2013, 2014, and 2015 it was 0.369, 0.651 and 0.814 mg l^{-1} respectively in Dotnuvele, and 1.08, 0.846 and 0.85 mg l^{-1} respectively in Smilga (Figure 5). This can occur due to water vegetation intensive assimilation.

In autumn, intensive rain washes a lot of organic and inorganic pollutants from the soil, which flow into streams and rivers. Besides, vegetation and algae start to decompose; therefore, nitrate concentration in water increases: it was determined to be 2.87, 0.973 and 1.17 mg l^{-1} in Dotnuvele, and 9.57, 2.09 ir 0.922 mg l^{-1} in Smilga. At the end of the cold period nitrate concentration in ecosystems was the highest and corrersponded to a bad ecological streams‘ condition:

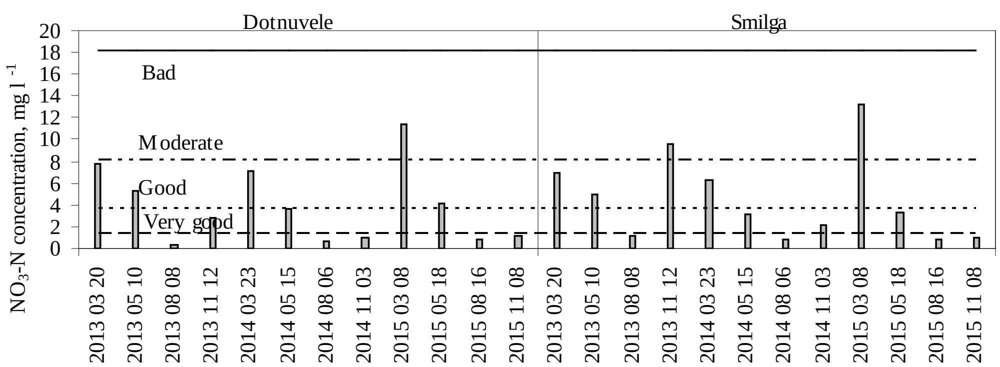

Figure 5. The change in NO_3-N concentrations in streams‘ water.

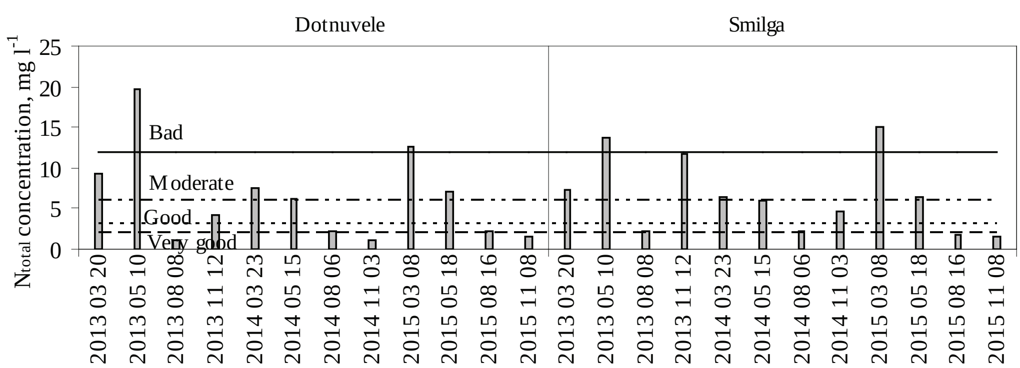

Figure 6. The change in N_{total} concentrations in streams‘ water.

in Dotnuvele it was 7.78, 7.15 and 11.4 mg l^{-1}, while in Smilga it was 7.01, 6.35 and 13.2 mg l^{-1}.

Due to human activity, nitrate nitrogen inflow into water bodies increases a lot; however, it depends on the season of the year (Gustavsson & Engwall, 2012; Stankevičienė, 2012; Kutra & Berankienė, 2006). There can be times when nitrate concentrations can depend not only on river‘s runoff, but also on other factors, such as plant vegetation, winter conditions, soil freezing depth, and snow cover (Tilickis, 2005).

In order to determine eutrophication tendencies of rivers, it is very important to analyse the fluctuation in total nitrogen in their water. Figure 6 shows that higher concentrations of this element as well as nitrate nitrogen were observed during the cold season or at the start of vegetation – at this time water condition in both streams was in a bad or very bad ecological condition. Dotnuvele and Smilga streams‘ water receives biogenic matters from agricultural lands, as higher concentrations of these elements were observed most often in spring, when, during the snow melt, water with dissloved nutrients reaches these streams by drainage.

PO_4-P concentrations in Dotnuvele and Smilga streams were observed to be very low and fluctuated between 0.006 and 0.061 mg l^{-1} in Dotnuvele and between 0.0049 and 0.038 mg l^{-1} in Smilga (Figure 7).

Only in August 2014 and 2015, phosphates and total phosphorus concentrations in Dotnuvele stream increased significantly (up to 0.235 and 0.237 as well as 0.32 and 0.298 mg l^{-1} respectively) and the water quality was in a bad ecological condition (Figures 7, 8). This was possibly affected by secondary pollution from algae accummulated in the stream.

Considering the ratio of total nitrogen and total phosphorus in the streams‘ water, it was determined that the most nitrogen in the streams was observed in the first, second, and fourth quarters of the year, while more phosphorus was observed in the third. This means that the third quarter provides good conditions for water vegetation to develop and thus streams become covered in duckweed.

The statistical data analysis has revealed a relationship of between concentrations of some chemical elements in streams‘ water and meteorological conditions (Table 2).

The data analysis has shown that dissolved oxygen, nitrate and total nitrogen concentrations are largely affected by air temperature: the lower the temperature, the higher is the concentration of

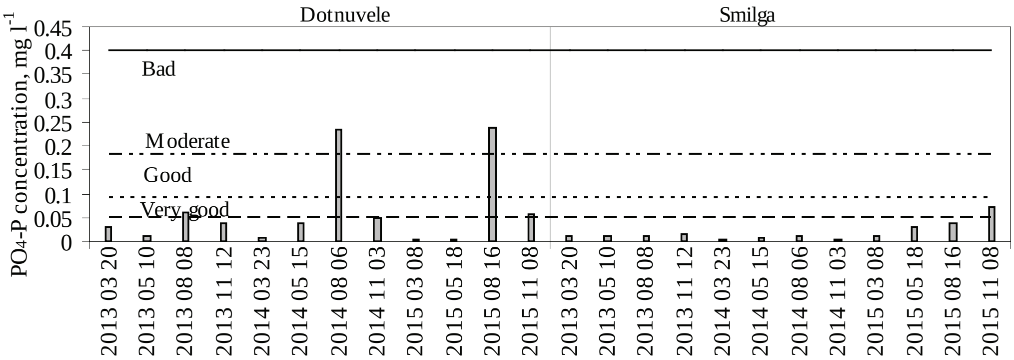

Figure 7. The change in PO_4 – P concentrations in streams‘ water.

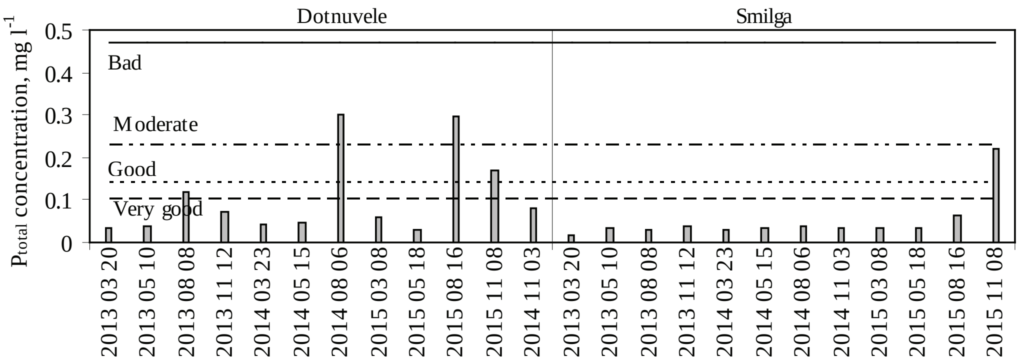

Figure 8. The change in P_{total} concentrations in streams‘ water.

Table 2

The influence of meteorological factors to the change in concentrations of chemical elements in streams‘ water

Indicator	Equation	n	r	Coefficient of partial correlation		$F_{fact.}$	p
				r_1	r_2		
BOD_7	$z=5.1-0.037x_1-0.013x_2$	24	0.44	-0.19	-0.39	2.52	0.10456
O_2	$z=9.6-0.162x_1-0.016x_2$	24	**0.65**	**-0.61**	**0.44**	**7.79**	**0.0294**
NH_4-N	$z=0.07+0.001x_1-0.0002x_2$	24	0.19	0.13	-0.15	0.38	0.68587
NO_3-N	$z=4.65-0.42x_1-0.024x_2$	24	**0.84**	**-0.83**	**0.49**	**24.65**	**0.0000**
N_{total}	$z=11.45-0.45x_1-0.009x_2$	24	**0.65**	**-0.64**	**-0.11**	**7.86**	**0.00282**
P_{total}	$z=0.09+0.005x_1-0.0004x_2$	24	0.43	0.41	-0.23	2.41	0.11388
PO_4-P	$z=0.03-0.004x_1-0.0002x_2$	24	0.49	0.49	-0.18	3.36	0.05409

Note: z – concentration of chemical element; x_1 – air temperature ºC; x_2 – precipitation amount mm; n – sample data points, r – sample correlation coefficient, coefficients of partial correlation: r_1 – air temperature, r_2 – precipitation, $F_{fact.}$ – calculated Fisher criterion, $F_{theor.95\%}$ – theoretical 95% probability of Fisher criterion = 3.44; relationship is significant when $F_{theor.95\%} < F_{fact.}$, p – confidence probability; relationship is significant when p<0.05.

these elements in streams‘ water (r = -0.61), (r = -0.83) and (r = -0.64), respectively. An increase in precipitation also increased O_2 and NO_3-N amount in streams‘ water, (r = 0.44), (r = 0.49) respectively. Meteorological conditions did not have a significant impact on concentrations of other chemical elements, except BOD_7 and PO_4-P. Correlation analysis was used to determine what effect precipitation and air temperature had on BOD_7, NH_4-N, P_{total} and PO_4-P concentrations in streams' water individually. It showed that concentrations of BOD_7 in streams' water were increasing as precipitation level was falling (r = 0.41) ($t_{theor.95\%}$ = 2.07<2.10), and PO_4-P – when air temperature was increasing (r = 0.46) ($t_{theor.95\%}$ = 2.07<2.44).

Conclusions

1. There was enough dissolved oxygen in streams‘ water – this corresponded to a good and very good ecological water condition. More oxygen was found when the water temperature was low (r = -0.6) and after more precipitation (r = 0.44).
2. It was determined that the quality of Dotnuvele and Smilga streams‘ water is mostly diminished by total and nitrate nitrogen. At the end of the cold period the concentations of these elements in the streams were found to be the highest and were 19.6 and 15.1 mg l^{-1} as well as 7.78 and 13.2 mg l^{-1} respectively. This corresponded to a very bad and bad streams‘ ecological water condition. This was influenced by the fact that these streams collect water from farming fields, which are fertilised and during the spring melt water containing the mentioned elements reaches the streams through drainage. It was determined that an increase in NO_3-N and N_{total} concentrations in streams‘ water were affected by meteorological conditions (r = 0.84 and r = 0.65) respectively. As air temperature fell, the amount of both these elements was observed to be higher in the water of both of the streams (r = -0.83) and (r = -0.64) respectively: NO_3-N when there was higher precipitation (r = 0.49), while N_{total} – when precipitation was lower (r = -0.11).
3. Ammonium nitrogen concentrations in streams‘ water corresponded to a very good ecological water condition, except in Smilga on the 11th November 2015, when 0,287 mg l^{-1} was observed and according to this element water quality was average. This was influenced by accidental pollution. Meteorological conditions had no effect on the concentration of streams‘ water (r = 0.19).
4. BOD_7 concentrations in the streams were found to be low, except in Dotnuvele in May 2013 (5.13 mg O_2 mg l^{-1}) as well as in May 2013 and November 2015 in Smilga streams when the pollution with organic matters was determined to be 6.08 and 8.37 mg O_2 l^{-1}. Meteorological conditions had a minor effect on it (r = 0.44): however correlation analysis showed that as there is less precipitation, organic pollution increases (r = 0.41).
5. According to the concentrations of phosphates and total phosphorus, streams‘ water was clean, except three samples from Dotnuvele stream in August 2014 as well as in August and November 2015, and Smilga stream in November 2015, when the amounts of these elements corresponded to a bad ecological condition. It was determined that meteorological factors had weak impact on the increase of these chemical elements (r = 0.49 and r = 0.43) respectively. Correlation analysis showed that as air temperature increases, phosphates concentrations in streams' water increase statistically significantly (r = 0.46).

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