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THE SEASONAL CHANGE OF WATER QUALITY PARAMETERS AND ECOLOGICAL CONDITION OF SOME SURFACE WATER BODIES IN THE NEMUNAS RIVER BASIN

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Highlights:
- change of main water quality parameters in different seasons in Nemunas River basin;
- water ecological conditions of some surface water bodies in the Nemunas River basin;
- main diffuse sources of pollution are agricultural activities and agglomeration.

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Abstract. The surface water quality analysis is very important in order to identify potential sources of contamination. The pollution of surface water can occur because of unauthorized discharge of a variety of materials or pollutants, and cultivated fields from which migratory pollutants are carried into the water bodies by melting snow. The current paper presents the results of quality indicators' analysis (oxygen saturation (dissolved oxygen) (mg O_2/l); an active water reaction, pH; suspended solids (mg/l); biochemical oxygen demand BOD_7 (mg O_2/l); phosphate (mgP/l); nitrite (mgN/l); nitrate (mgN/l); ammonium (mgN/l); total phosphorus (mgP/l); total nitrogen (mgN/l); colour (mg/l Pt)) of some surface water bodies (the Dubysa, Reizgupis, Vilkupis, Kriokle Rivers and Prabaudos pond) in the Nemunas River basin. The research demonstrated that the majority of non-compliances and exceedances with values and the maximum allowable concentrations stated in the hygiene norms can be found in the Reizgupis River. According to the analyzed surface water quality indicators, the ecological conditions of the surface water bodies were determined.

Keywords: surface water, water quality, rivers, pond, ecological condition.

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1. Introduction

The surface water quality is one of the most important environmental problems in Lithuania, whereas the impact of constantly increasing human economic activities on the environment and the tightening international environmental protection requirements have led to the improvement of nature and human interaction mechanism management (Sakalauskienė et al., 2002). In order to maintain the ecosystem, water quality is a very important part (Zou et al., 2023).

The factors determining the quality of river water can be divided into the direct and indirect. The direct factors (rock, soil, biota, human agricultural activities) supply soluble compounds into or take them from the water. The indirect factors allow substances interactions with water; these factors are climate, terrain, water regime, vegetation, hydrological and hydrodynamic conditions, etc. (Bagdžiūnaitė-Litvinaitienė, 2004). Surface water quality may contribute disproportionately to greenhouse gas emissions and future climate change (Kumar et al., 2023; Chandio et al., 2020; Badiou et al., 2019).

The ecological condition of rivers is characterized by the following indicators: nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), total nitrogen (N_b), phosphate phosphorus (PO_4-P), total phosphorus (P_b), biochemical oxygen demand within 7 days (BOD_7), and the quantity of dissolved oxygen in water (O_2).

The surface water flowing through the urbanized areas is additionally exposed to not only precipitation, but also the city's wastewater. Such water affects a variety of fish species (Wolfe, 2012; Ferreira et al., 2012). Hydrological parameters are dynamic and are constantly changing due to the change of various parameters (Horowitz, 2013; Baurès et al., 2013; Saghravani et al., 2011; Bagdžiūnaitė-Litvinaitienė et al., 2011).

On termination of liming works, the soil acidification is accelerating, while the mobility of total elements (Ag, B, Co, Cr, Cu, Ga, Ni, Pb ir V) is increasing. Therefore, the risk of these elements' concentration in plants increases and

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can result in these elements' entering the food chain and contamination of water (Marcinkonis et al., 2012).

The surface water temperature has been increasing for the last few years. According to the scientific research, the annual surface water temperature in the USA has increased by 0.009–0.077 °C (Kaushal et al., 2010; Null et al., 2013; Sloat et al., 2013), in Europe – 1.2 °C (Floury et al., 2012). The surface water temperature increases with the increasing ambient temperature (Yamakado, 2012).

During the spring floods, it has been found out that the quantity of dissolved oxygen (oxygen saturation) in the surface water decreases by 25.8% (2.15 mg/l), while BOD concentration decreased (Yamakado, 2012; Simon et al., 2011).

Scientific studies have shown that the approximate annual surface water load with suspended solids increases 5.5 times, the amount of total nitrogen increases 5.7 times, and total phosphorus – 8.9 times (Kroon et al., 2012).

Chinese scientists have found out that the level of total phosphorus in the surface water ranges from 571.67 to 1113.55 mg/kg (An & Li, 2009).

The scientific research conducted in the state of Quebec, Canada, has shown that the amount of total nitrogen has significantly decreased in 8 rivers, ammonium nitrogen – in 5 rivers, nitrates and nitrites – in 4 rivers, total nitrogen – in 3 rivers, and the amount of suspended solids has decreased in 2 rivers. Water turbidity has increase in 4 rivers. The phosphate reduction is explained by the decrease of phosphorus in the cultivated fields (Patoine et al., 2012).

In order to estimate the Baltic Sea pollution levels, it is necessary to estimate the pollution level in the surface waters flowing into the Baltic Sea.

The Nemunas River is the largest and most important river in Lithuania. It is the 14th longest river (937.4 km) and the 15th largest river basin (97863.5 km^2) in Europe. In the Baltic Sea basin, the Nemunas is the 4th largest river basin and the 3rd longest river. The river is rising in Belarus and draining into the Curonian Lagoon and then into the Baltic Sea at Klaipeda (Kilkus & Stonevičius, 2011).

The rivers in Raseiniai District are attributed to the basins of the Dubysa and the Jura, the small tributaries of the Nemunas. Raseiniai District belongs to Kaunas Regional Environmental Protection Department (REPD).

The Dubysa River (length – 130.9 km, the river basin – 1972 km^2) is the inverse river, i.e. its flow is inconsistent with the surface of the main slope. The Dubysa flows into the Nemunas.

The Dubysa River basin is narrow (the widest point is 50 km wide, the length of the basin is about 90 km). The basins' surface is dominated by moderate soils (70% of the basins' area). 11% of the basin is covered with sand, 9% – with loam. There are few forests left in the basin (forests cover only 13% of the basin), the most of them are in the upper reaches of the Dubysa. There are large marshes between hills and in troughs. These are Great Tyruliai (38 km^2), Pravirsulio Swamp (32 km^2), Tytuvenai Tyrelis swamp, Siluvos Tyrelis swamp. There are 40 lakes larger than 0.5 ha in the basin, but their total area is only 5.5 km^2, i.e. the area is dominated by small lakes, and lakes make only 0.27% of the area. The larger surface area is occupied by ponds.

The State intensive and performance monitoring is conducted in the Dubysa River. The basin's average annual runoff is 7 L/s per 1 km^2, in the upper reaches of the Dubysa – 6.8 L/s per 1 km^2. The average flow in the Dubysa estuary is 14.2 m^3/s.

The water bodies at risk are those water bodies that are exposed to the negative effects of human activities by 2015 even after the application of the main instruments to achieve good condition. The good condition is the condition when the ecological and chemical condition of the water body is evaluated good or very good according to the legal regulations. In order to identify the water bodies at risk and the causes of the unsatisfactory condition, the significant loads of human activities and their impact on the surface waters have been also identified.

The surface water bodies at risk have been identified according to the following loads of human activities:

- Diffuse pollution (caused by agricultural activities);
- Concentrated pollution (pollution from municipal and industrial wastewater facilities);
- Straightening of river beds (the water bodies flowing in non-urbanized areas);
- Hydropower stations.

The following rivers in Raseiniai District municipality have been included into the list of surface water bodies at risk: the Dubysa River, the Mituva River, the Alsa River, etc.

The surface water bodies' pollution and quality parameters. The quality of the surface water depends on the amounts and properties of pollutants falling into the water. The main pollutant is the wastewater from households and industrial enterprises. Raseiniai urban sewage is treated in the biological treatment plant. The wastewater treatment facilities have been renovated and can treat sewage in adherence to the European Union requirements. Therefore, the concentration of discharged pollutants does not exceed the permitted levels.

Huge quantities of biochemical substances in the river water are caused not only by urban-domestic and industrial wastewater discharges, but pollution also comes with rain (surface) run-off, melting snow and soil leaching water, which is not under investigation.

The main quality parameters of surface water bodies are: oxygen saturation (dissolved oxygen), pH, suspended solids, biochemical oxygen demand (BOD_7), phosphates, nitrates, nitrites, ammonium, total phosphorus, total nitrogen, and colour.

The aim of the current research paper is to determine the change of the main water quality parameters in different seasons of the year and evaluate water ecological conditions of some surface water bodies in the Nemunas River basin in Raseiniai District, South Lithuania.

2. Methods

Selection of the research sites. Industry is underdeveloped in the Dubysa River basin, the sub-basin of the Nemunas (Figure 1). A large part of pollutants comes into the surface water bodies from diffuse sources of pollution. The main diffuse sources of pollution are agricultural activities and agglomeration, the homes of which are not connected to the sewer systems.

The location and number of the research sites. The sampling sites in the water bodies in Raseiniai, Ariogala, and Vidukle, located in the northern and southern parts of Raseiniai District municipality, for the evaluation of the diffuse and concentrated pollution have been selected to assess the extent of urban pollution and impacts on the surface water bodies.

The sampling sites (Figures 2 and 3):

1. The Vilkupis River upstream of Raseiniai [V1];
2. The Vilkupis River downstream of Raseiniai [V2];
3. The Reizgupis River upstream of Raseiniai [V3];
4. The Reizgupis River downstream of Raseiniai [V4];
5. The Dubysa River outside Ariogala near the highway A1 [V5];
6. The Kriokle River upstream of Vidukle [V6];
7. The Kriokle River downstream of Vidukle [V7];
8. Prabaudos pond [V8].

Figure 1. Research location

There are two streams – the Raseika and the Vilkupe – and 4 ponds in Raseiniai. The Vilkupe belongs to the Jura River sub-basin and drains into the Slyna, the Saltuona, which flows into the Sesuvis River, then into the Jura River, which flows into the Nemunas. In order to estimate the impact of Raseiniai city on the pollution levels in the surface waters, the samples were taken in the Vilkupe River upstream [V1] and downstream [V2] of Raseiniai. The Raseika belongs to the Jura River sub-basin and flows into the Reizgupis, the Slyna, the Saltuona, which flows into the Sesuvis, then into the Jura, and ultimately into the Nemunas River.

The Reizgupis River belongs to the Jura River basin and flows into the Slyna River, the Saltuona that flows into the Sesuvis River, the Jura and ultimately into the Nemunas River. In order to estimate the impact of Raseiniai city on the pollution levels in the surface waters, the samples were taken in the Reizgupis River [V3] upstream of Raseiniai and also downstream of Raseiniai in the Reizgupis River [V4], where water from the wastewater treatment facilities is drained. This was done to assess the impact of the wastewater treatment facilities.

Prabaudos pond [V8] belongs to the Jura River basin. The Prabaudos River, which flows through the pond, flows into the Saltuona, then into the Sesuvis, the Jura, and ultimately into the Nemunas. A bathing-place is open to public in Prabaudos pond during the summer season.

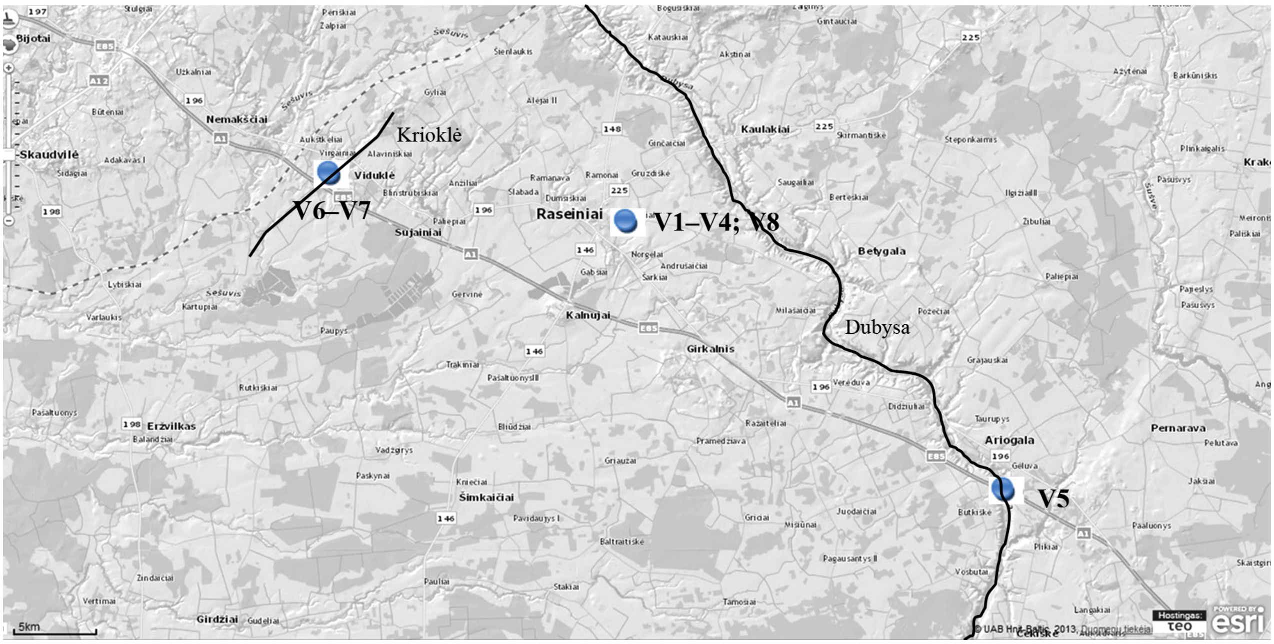

Figure 2. The location of the surface water sampling sites scheme in Raseiniai District municipality

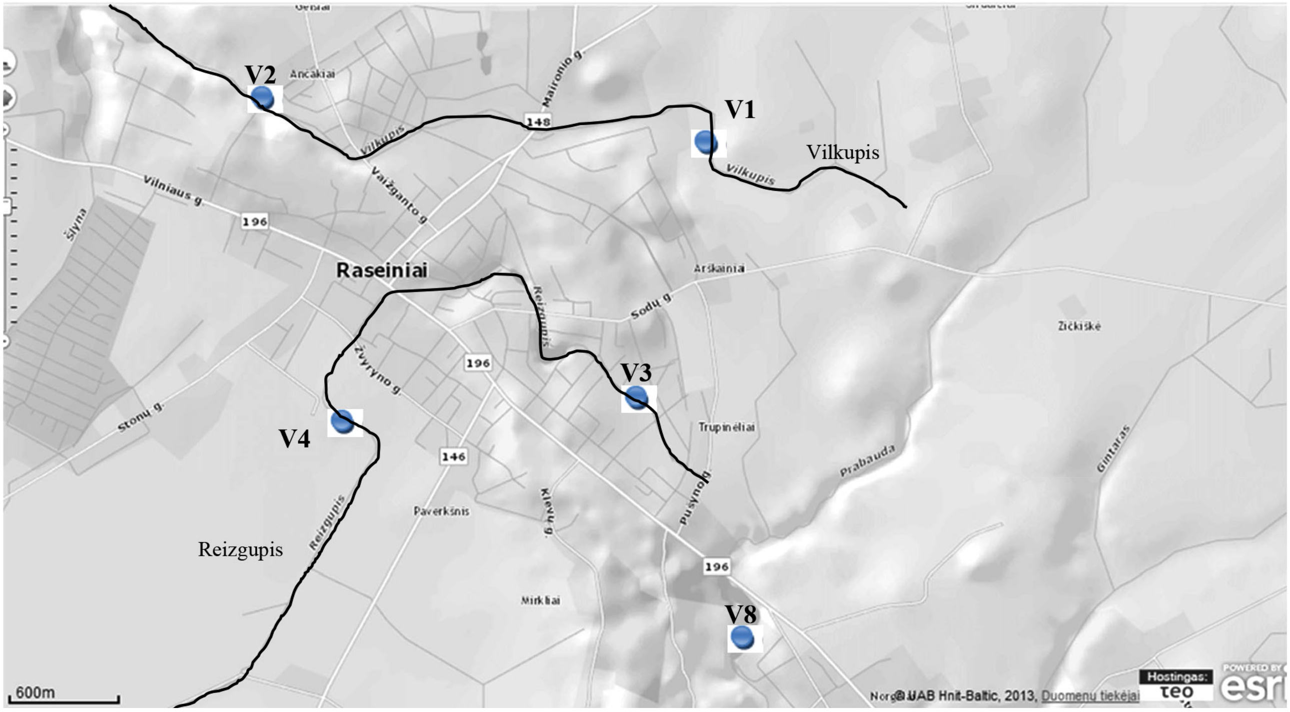

Figure 3. The location of the surface water sampling sites scheme in Raseiniai

The Dubysa River is a right tributary of the Nemunas. The surface water samples were taken at the A1 highway (Vilnius-Kaunas-Klaipeda) that connects the three largest cities in Lithuania.

The River Kriokle belongs to the Jura River sub-basin and flows into the Bebirvos River, the Saltuona, the Sesuvis, then into the Jura, and ultimately into the Nemunas. In order to assess the impact of Vidukle town on the pollution levels of the surface waters, the samples were taken in the Kriokle River upstream of [V6] and downstream of [V7] Vidukle.

The most important task of the research was to conduct the analysis of the surface water conditions in the selected sampling sites in **the Dubysa, the Reizgupis, the Vilkupis, the Kriokle** Rivers and **Prabaudos** pond.

The monitored parameters. The following parameters were being monitored in the sampling sites in the Dubysa, the Vilkupis, the Kriokle, the Reizgupis Rivers and Prabaudos pond:

1. Temperature (°C);
2. Dissolved oxygen O_2 (mg/l O_2);
3. Active water reaction, pH;
4. Suspended solids (mg/l);
5. BOD_7 (mg/l O_2);
6. Phosphates (mg/l PO_4);
7. Nitrites (mgl/l NO_2);
8. Nitrates (mg/l NO_3);
9. Ammonium ions (mg/l NH_4);
10. P_{total} (mg/l P);
11. N_{total} (mg/l N);
12. Colour (visually);

The sampling. Water was sampled downstream, away from the river bank. Given the width of the riverbed, the distance from the river bank ranged from 50 cm (the Reizgupis [V3]) to 2 m (the Dubysa [V5]). To evaluate the quality parameters, the sampling volume was 5 l.

The periodicity of sampling. The water samples from the surface water bodies (rivers and the pond) were taken for testing during all four seasons: winter, spring, summer, and autumn. In Prabaudos pond the sample of water was not taken during the winter season.

The assessment of the quality parameters. The quality parameters of the surface water bodies were assessed according to LST EN ISO+AC 5667-1; LST EN ISO 5667-3; ISO 5667-6; LST EN 25814; LST ISO 10523; LST EN 872; LST EN 1899-1; LST EN 1899-2; LST EN ISO 6878; LST EN ISO 13395; LST EN ISO 6878; LST EN ISO 11905-1; LST EN ISO 7887; LAND 39-2000; LAND 38-2000 standards.

The quality of water bodies is assessed on its compliance with the MPLs established by the Minister of Environment on 18 May 2010 Order No D1-416 "On Approval of the Regulations on Wastewater Treatment" and 18 February 2011 Minister's Order No D1-144 "On the Surface Water, in which freshwater fish can live and breed, Protection Approval" .

If during the assessment of the salmonid or cyprinid water bodies' water quality according to the quality index it is found that the body of water meets the requirements, then the water samples can be taken or the measurements of certain parameters can be carried out less frequently than indicated. If the taken and analyzed samples show that at least one parameter of the water quality does not meet the requirements and the determined discrepancy(-ies) is(are) not accidental, then the environmental monitoring programme can be adjusted to the target parameter(s).

The ecological condition of rivers is assessed on the basis of physical-chemical quality elements – the general data indicators (nutrients, organic matter, oxygen saturation): nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), total nitrogen (N_t), phosphate phosphorus (PO_4-P), total phosphorus (P_t), biochemical oxygen demand within 7 days (BOS_7) and dissolved oxygen content in water (O_2). According to the average annual value of every indicator, the water body is assigned to one of the five classes of ecological conditions: very good, good, average, poor, very poor (Table 1).

The ecological potential of the water bodies is assessed according to the physical-chemical quality element – the general data (nutrients) indicators: total nitrogen (N_t) and total phosphorus (P_t). According to the average annual value of each indicator from the surface water samples, the water body is assigned to one of the five classes of ecological potential (Table 2). The methodology for determination of the surface water bodies' condition is adopted after the Lithuanian Minister of the Environment 12 April 2007 Order No D1-210 (the amendment of 4 March 2010 the Lithuanian Minister of the Environment Order No D1-178; Zin. 2010, No 29-1363).

Table 1. The rivers' ecological condition classes according to the physical-chemical quality elements indicators

No.	Indicators	The rivers' ecological condition classes according to the physical-chemical quality elements indicators				
		Very good	Good	Average	Poor	Very poor
1	NO_3-N, mg/l	<1.30	1.30–2.30	2.31–4.50	4.51–10.00	>10.00
2	NH_4-N, mg/l	<0.10	0.10–0.20	0.21–0.60	0.61–1.50	>1.50
3	N_t, mg/l	<2.00	2.00–3.00	3.01–6.00	6.01–12.00	>12.00
4	PO_4-P, mg/l	<0.050	0.050–0.090	0.091–0.180	0.181–0.400	>0.400
5	P_t, mg/l	<0.100	0.100–0.140	0.141–0.230	0.231–0.470	>0.470
6	BDS_7, mg/l	<2.30	2.30–3.30	3.31–5.00	5.01–7.00	>7.00
7	O_2, mg/l	>8.50	8.50–7.50	7.49–6.00	5.99–3.00	<3.00

Table 2. The water bodies' ecological condition classes according to the physical-chemical quality elements indicators

No.	Indicators	The water bodies' ecological condition classes according to the physical-chemical quality elements indicators				
		Maximum	Good	Average	Poor	Very poor
1	N_t, mg/l	<2.00	2.00–3.00	3.01–6.00	6.01–12.00	>12.00
2	P_t, mg/l	<0.100	0.100–0.140	0.141–0.230	0.231–0.470	>0.470

3. Results

During the sampling of the surface water bodies in winter season, three water bodies were covered with ice: V1 (the Vilkupis River upstream of Raseiniai) 20 cm, V3 (the Reizgupis River upstream of Raseiniai) 15 cm, V6 (the Kriokle River upstream of Vidukle) 30 cm. The data is presented in Figures 4–15. Water from Prabaudos pond [V8] was not sampled only during the winter season. Also, since the spring season, potassium was studied in three samples: in the Vilkupis River [V1] and [V2], and Prabaudos pond [V8].

Results of the surface water temperature measurements

The temperature of the surface water is determined by ambient temperature. Water warms up and cools down slowly. Such temperature fluctuations lead to different amounts of dissolved oxygen in the water.

Water temperature was measured during the sampling of the surface water. The data is presented in Figure 4.

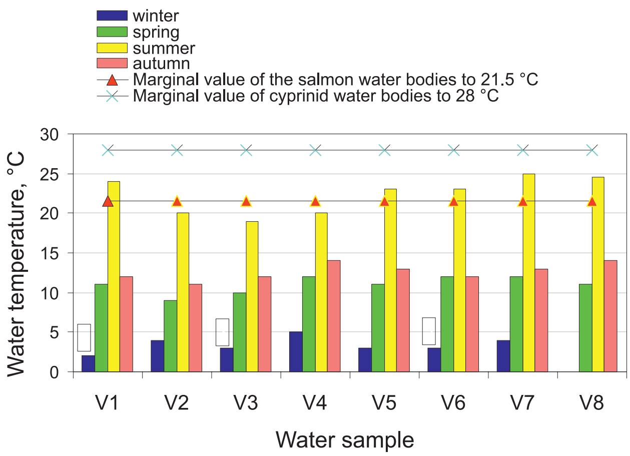

Figure 4. Temperature of the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 4, the highest water temperature was during the summer season. During this season, only in three sampling sites (the Vilkupis downstream of Raseiniai [V2], the Reizgupis upstream of Raseiniai [V3] and the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]), met the threshold temperature values for the salmonid temperature limit (up to 21.5 °C) and cyprinid (up to 28 °C) water bodies. All samples met the threshold temperature values for the cyprinid (up to 28 °C) water bodies.

The average annual water body's temperature values in the samples were: V1 – 12.25 °C; V2 – 11.00 °C; V3 – 11.0 °C; V4 – 12.75 °C; V5 – 12.50 °C; V6 – 12.50 °C; V7 – 13.50 °C; V8 – 16.50 °C. The average annual water body's temperature values in the samples met the threshold values for both the salmonid and cyprinid water bodies. The lowest average annual temperature value was measured in the Vilkupis downstream of Raseiniai [V2] and in the Reizgupis upstream of Raseiniai [V3], while the highest value was measured in

Prabaudos pond [V8]. The difference between these values is 1.5 times.

Results of the oxygen saturation measurements in the surface water bodies

Oxygen is probably one of the most important dissolved gases in natural waters. The main sources of oxygen in natural waters is the atmosphere and aquatic vegetation, photosynthesis that takes place in green organisms. The concentration of oxygen in natural waters should be measured assessing the living conditions of hydrobionts, organic matter production and decomposition processes, the intensity of the water body's self-cleaning, the efficiency of biological treatment facilities, water corrosion properties, etc. The amount of oxygen in the water is the indicator of water pollution (the less of oxygen in the water, the more organic solids in the water that consume oxygen to oxidize). The formation of organic solids in the surface water is caused by many factors. The most important factors are: the production and transformation processes of organic solids taking place in the water body, the contamination of the water body with organic solids from the surface and subsurface water run-off and atmospheric precipitation, the contamination of the water body with organic solids discharged with household and industrial wastewater. Organic solids in dissolved, colloidal and suspended forms can be traced in the surface waters. The dissolved oxygen levels in the surface water can be characterized by a significant seasonal dynamics and physical-geographic seasonality. For the survival of fish, the dissolved oxygen concentration shall not be less than 5 mg/l. Thus, hot water endangers fish. As the temperature rises, the gas solubility decreases, and at 0 °C the dissolved oxygen amount is 14.7 mg/l, while at 35 °C the amount is only 7.0 mg/l. The average oxygen concentration in natural unpolluted waters is about 10 mg/l. The amount of dissolved oxygen is quantifiable by the amount of oxygen (mg/l), which is equivalent to the consumed amount of the oxidant during the analysis. Natural water, the amount of dissolved oxygen in which does not exceed 3.0 mg/l, is good for domestic use and drinking.

Oxygen saturation depends on temperature, oxygen partial pressure and salinity. The analytical value of oxygen saturation can be caused by eutrophication (i.e. rapid reproduction of algae and microorganisms resulting in the lack of oxygen to water animals). According to the chemical water quality parameters, this is the analyte that is most often incongruous with quality requirements. Most of oxygen is consumed during the biochemical oxidation of organic solids. The amount of oxygen can increase due to the abundance of humic substances.

The results of oxygen saturation measurements are presented in Figure 5.

As it can be seen in Figure 5, the threshold value for the *cyprinid* water bodies (more than 7 mg/l O_2) during all 4 seasons was met in samples taken from the Kriokle River upstream of Vidukle [V6] and Prabaudos pond [V8], and was not met in the samples taken from Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]. In the V4 sampling site, the closest to the threshold value for the cyprinid water bodies was measured in spring (1.2 times lower than the threshold value).

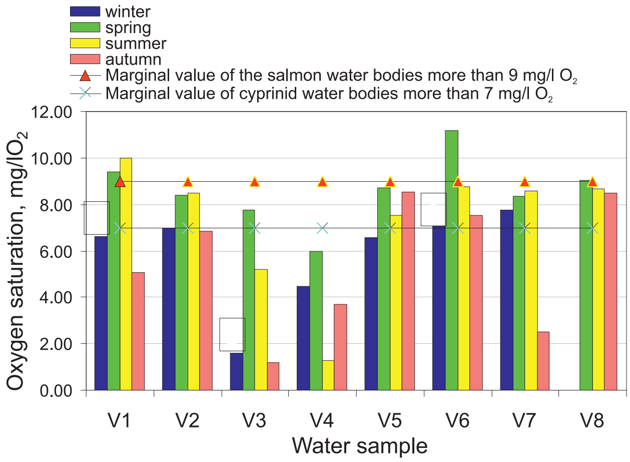

Figure 5. Oxygen saturation in the surface water body (the marked samples were taken under the ice)

The threshold values for the *salmonid* water bodies (more than 9 mg/l O_2) during 4 seasons of the year were not met by all the samples (Figure 5). The closest to this value were samples taken in the Vilkupis River upstream of Raseiniai [V1]: the value measured in winter was 1.4 times and in autumn 1.8 times lower than the threshold value. The threshold value for the salmonid water bodies in the Kriokles River upstream of Vidukle [V6] and in Prabaudos pond [V8] was in line during 1 season.

The threshold values for the *cyprinid* water bodies (more than 7 mg/l O_2) during all 4 seasons were met in samples taken from the Kriokle River upstream of Vidukle [V6] and Prabaudos pond [V8] (samples were taken during 3 seasons). The threshold value for the cyprinid water bodies were not met by samples taken during 1 season from the Dubysa River outside Ariogala [V5] and the Kriokle River downstream of Vidukle [V7]. The threshold value for the cyprinid water bodies has been never met in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

The average annual oxygen saturation values in the samples were as follows: V1 – 7.76 mg/l O_2 (met the threshold values only for the cyprinid water bodies); V2 – 7.68 mg/l O_2 (met the threshold values only for the cyprinid water bodies); V3 – 3.94 mg/l O_2 (did not meet the threshold values); V4 – 3.85 mg/l O_2 (did not meet the threshold values); V5 – 7.84 mg/l O_2 (met the threshold values only for the cyprinid water bodies); V6 – 8.64 mg/l O_2 (met the the threshold values only for the cyprinid water bodies); V7 – 6.80 mg/l O_2 (did not meet the threshold values); V8 – 8.74 mg/l O_2 (met the threshold values only for the cyprinid water bodies). The greatest discrepancy with the threshold values was measured in the sample taken in the Reizgupis River downstream of Raseiniai wastewater treatment facilities [V4]: the average annual value was 2.3 times lower than the threshold value for the salmonid and 1.8 times lower than the value for the cyprinid water bodies.

According to the assessment of the research results according to the oxygen saturation, the studied rivers can be assigned to the following classes of the rivers' ecological conditions (Table 1): **very good** – the Kriokle River upstream of Vidukle [V6], **good** – the Vilkupis River upstream of Raseiniai [V1], the Vilkupis River downstream of Raseiniai [V2], the Dubysa River outside Ariogala [V5], **average** – the Kriokle River downstream of Vidukle [V7], **poor** – the Reizgupis River upstream of Raseiniai [V3], the Reizgupis River downstream of Raseiniai wastewater treatment facilities [V4].

Results of the pH measurements in the surface water bodies

There is a wide variety of both inorganic and organic chemical substances in the surface water that alter its properties. The pH parameter is extremely important in the assessment of the water quality.

Various biological and biochemical processes in the water, the development of aquatic plants, migration forms of chemical elements, the water activity in respect of many substances and other phenomena depend on water pH. Natural water pH is usually determined by the amount of free carbon dioxide and bicarbonate concentration ratio. The levels of pH in such water ranges from 4.5 to 8.3. Also, the levels of pH can be determined by the increased concentrations of humic substances, carbonates and hydroxides generated by photosynthesis. In contaminated surface waters, pH levels can be the result of strong acids and alkalis. Due to the intensive processes of photosynthesis in the water (during the summer-autumn seasons), pH levels increase.

The results of the active water reaction (pH) measurements are presented in Figure 6.

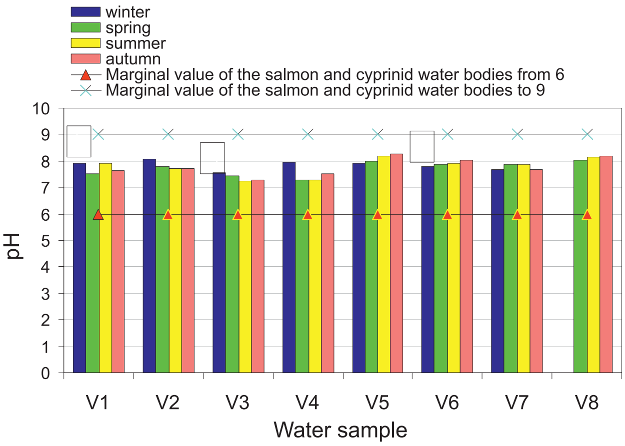

Figure 6. The active water reaction (pH) in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 6, in all of the analyzed samples pH values met the threshold value for both the salmonid and cyprinid water bodies (from 6 to 9). The decreasing active water reaction was measured in the Vilkupis River downstream of Raseiniai [V2], and the increasing reaction was measured in the Dubysa outside Ariogala [V5], in the Kriokle upstream of Vidukle [V6] and in Prabaudos pond.

The average annual active water reaction (pH) values in the samples were: V1 – 7.74; V2 – 7.83; V3 – 7.39; V4 – 7.51; V5 – 8.09; V6 – 7.90; V7 – 7.78; V8 – 8.12. Thus, the lowest pH value was measured in the Reizgupis upstream of Raseiniai [V3] (7.39), and the highest – in Prabaudos pond [V8] (8.12). The difference between the two values is 1.1.

Results of suspended solids measurements in the surface water bodies

The turbidity of water is the result of suspended solids in the water. Turbidity is the expression of the emitting and light-absorbing properties of the water sample.

The results of the suspended solids measurements are presented in Figure 7.

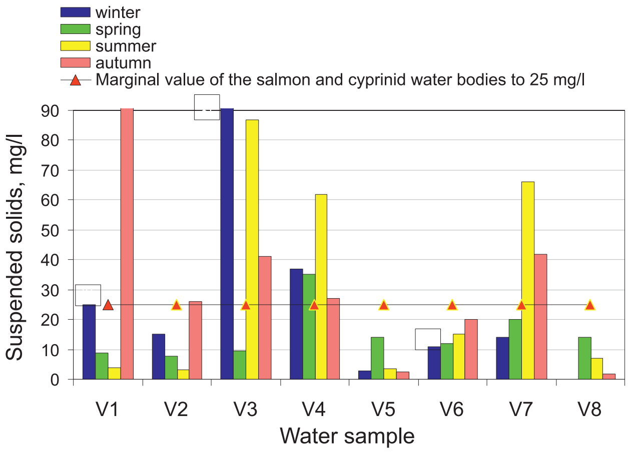

Figure 7. The suspended solids in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 7, the threshold value of suspended solids for both the salmonid and cyprinid water bodies (up to 25 mg/l) during all four seasons of the year were met only in the Dubysa outside Ariogala [V5], in the Kriokle upstream of Vidukle [V6], and in Prabaudos pond [V8]. The threshold value was exceeded in the Reizgupis downstream of Raseiniai waste water treatment facilities [V4] (on the average, the results were 1.6 times higher than the threshold value). In other locations, the threshold value of suspended solids for the salmonid and cyprinid water bodies (up to 25 mg/l) has been exceeded during 1 (V1, V2), 2 (V7), and 3 (V3) seasons.

The average annual values of suspended solids in the samples were as follows: V1 – 44.65 mg/l (the threshold value for the cyprinid and salmonid water bodies was exceeded 1.8 times); V2 – 13.00 mg/l (met the threshold value); V3 – 83.88 mg/l (was 3.4 times higher); V4 – 40.25 mg/l (was 1.6 times higher); V5 – 5.65 mg/l (met the threshold value); V6 – 14.50 mg/l (met the threshold value); V7 – 35.50 mg/l (was 1.4 times higher); V8 – 7.57 mg/l (met the threshold value).

Result of the biochemical oxygen demand measurements in the surface water bodies

The amount of organic solids in the water can be indirectly inferred from the biochemical oxygen demand (BOD).

The indicator of the amount of organic solids in the river water is the biochemical oxygen demand within seven days (BOD_7). This indicates the amount of dissolved oxygen needed for the biochemical oxidation of organic solids in the water. Rivers are contaminated with organic solids through industrial and household wastewater. Also, the amount of these solids are formed in the eutrophic river water during the vegetation decomposition process. The contamination of the river water with organic solids worsens the chemical, biological and microbiological quality of water and negatively affects the biological diversity of the water environment.

The result of the biochemical oxygen demand (BOD_7) measurements are presented in Figure 8.

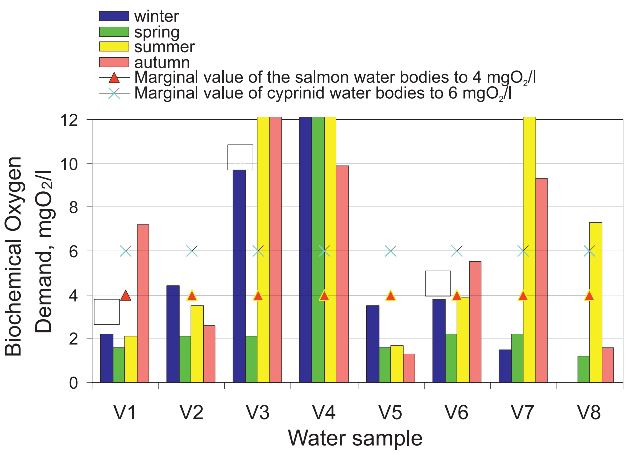

Figure 8. The biochemical oxygen demand (BOD_7) in the surface water body (the marked samples were taken under the ice)

As can be seen in Figure 8, the threshold value for the *salmonid* (up to 4 mgO_2/l) and *cyprinid* (up to 6 mgO_2/l) water bodies during all the seasons was not exceeded only in the Dubysa outside Ariogala [V5], was exceeded in the samples taken from the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (for the salmonids the threshold was exceeded 4.4 times, and for the cyprinids – 2.9 times). The threshold value for the salmonid and cyprinid water bodies was exceeded during three seasons (except for the spring season) in the Reizgupis upstream of Raseiniai [V3] (3.6 and 2.4 times respectively), during two seasons (the summer and autumn seasons) in the Kriokle downstream of Vidukle [V7] (3 and 2 times respectively), during one season in the Vilkupis upstream of Raseiniai [V1] (in autumn, 1.8 and 1.2 times respectively), in Prabaudos pond [V8] (in winter, 1.8 and 1.2 times respectively). The threshold value for the salmonid water bodies (up to 4 mgO_2/l) was exceeded during one season in the Vilkupis downstream of Raseiniai [V2] (in winter, 1.1 times) and in the Kriokle upstream of Vidukle [V6] (in autumn, 1.4 times). In other sampling locations, the threshold value was not exceeded.

The average annual biochemical oxygen demand (BOD_7) values in the samples were as follows: V1 – 3.28 mgO_2/l (met the threshold values for both the salmonid and cyprinid water bodies); V2 – 3.15 mgO_2/l (met the threshold values); V3 –11.20 mgO_2/l (was 2.8 times higher for the salmonid and 1.9 times higher for the cyprinid waters); V4 – 17.48 mgO_2/l (was 4.4 times higher for the salmonid and 2.9 times higher for the cyprinid waters); V5 – 2.03 mgO_2/l (met the threshold values); V6 – 3.85 mgO_2/l (met the threshold values); V7 – 7.00 mgO_2/l (was 1.8 times higher for the salmonid and 1.2 times higher for the cyprinid waters); V8 – 3.37 mgO_2/l (met the threshold values).

According to the assessment of the research results according to the BOD_7, the studied rivers can be assigned to the following classes of ecological conditions of rivers (Table 1): **very good** – the Dubysa outside Ariogala [V5], **good** – the Vilkupis upstream of Raseiniai [V1], the Vilkupis downstream of Raseiniai [V2], **average** – the Kriokle upstream of Vidukle [V6], **poor** – the Kriokle downstream of Vidukle [V7], **very poor** – the Reizgupis upstream of Raseiniai [V3], the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

Results of the phosphate measurements in the surface water bodies

Nitrates and phosphates are essential plant nutrient (biogenic) materials, but the fluctuations of their amounts in the river water are different. Phosphate levels during the vegetation period increase. These trends suggest that the excess of phosphate is associated with the pollution of rivers with household wastewater. This is characterized by a "dilution" effect – with the increasing runoff of wastewater the concentration of phosphates decreases. In the rivers where the concentrated contamination does not occur, such high fluctuations of phosphorus levels is uncommon.

The phosphate concentration in the natural surface water bodies is usually hundredths milligrams or even thousandths parts of a milligram, but the concentration in the contaminated waters may reach several mg/liter.

Since plants are overfed with phosphates, the abundance of phosphates in the natural water bodies can have devastating effects on aquatic ecology. In the past, one of the main sources of phosphate were detergents. Because of their impact on the ecology of waters, metaphosphates are now used very sparingly as a detergent fillers. In some cases, plants, fish and other living organisms in lakes die because of contamination with phosphate (phosphoric acid salts). Lakes are contaminated through tributaries. The sources of contaminants are poly-phosphates in synthetic detergents and sewage and wastewater from farms and agricultural fields. Although there are many other nutrients in lakes, phosphates promote the growth of algae. When a huge mass of algae dies and starts to decompose because of oxidation reactions, the fish starts to choke because it lacks dissolved oxygen in water. The water has an unpleasant odour, turns green and becomes slimy, and loads of fish and aquatic plants are rotting on the shore.

The results of phosphate measurements are presented in Figure 9.

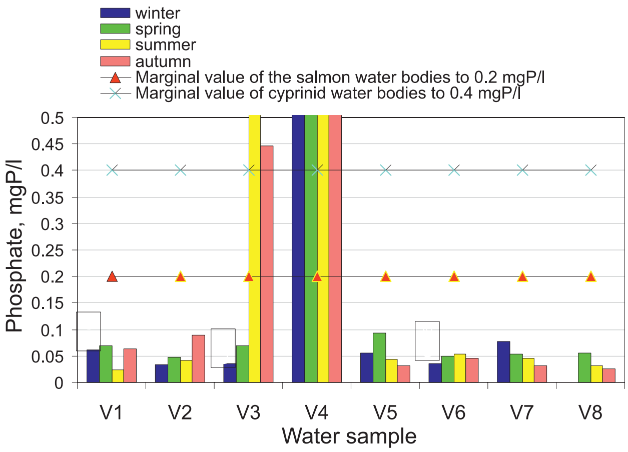

Figure 9. Phosphate in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 9, the threshold value of phosphate for the cyprinid (up to 0.4 mgP/l) water bodies during all four seasons was exceeded only in one analyzed sample taken in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (in winter, the value was 5.2 times higher; in spring, 6.4 times; in summer, 3.2 times; in autumn, 3.2 times higher), during two seasons (in summer and autumn) the threshold value was exceeded in the Reizgupis upstream of Raseiniai [V3] (was 2.2 and 1.1 times higher, respectively). In the above mentioned samples, the threshold value for the salmonid (up to 0.2 mgP/l) water bodies was also exceeded.

In other samples, the threshold values for both the salmonid and cyprinid water bodies were not exceeded.

The average annual phosphate values in the samples are as follows: V1 – 0.05 mgP/l (met the threshold values for both the salmonid and cyprinid water bodies); V2 – 0.05 mgP/l (met the threshold values); V3 – 0.36 mgP/l (met the threshold values for the cyprinid water bodies, exceeded the threshold values for the salmonid water bodies 1.8 times); V4 – 1.80 mgP/l (exceeded the threshold values 9 for the salmonid and 4.5 times for the cyprinid water bodies); V5 – 0.06 mgP/l (met the threshold values); V6 – 0.05 mgP/l (met the threshold values); V7 – 0.05 mgP/l (met the threshold values); V8 – 0.04 mgP/l (met the threshold values).

According to the assessment of the research results according to the amount of phosphates, the studied rivers can be assigned to the following classes of ecological conditions of rivers (Table 1): **very good** – the Kriokle upstream of Vidukle [V6], **good** – the Vilkupis upstream of Raseiniai [V1], the Vilkupis downstream of Raseiniai [V2], the Dubysa outside Ariogala [V5], the Kriokle downstream of Vidukle [V7], **poor** – the Reizgupis upstream of Raseiniai [V3], **very poor** – the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

Results of the nitrite measurements in the surface water bodies

Since nitrite and ammonium nitrogen ions are associated with a low abundance of oxygenated organic compounds, their increase in the river water indicates the "fresh" pollution.

The concentration of nitrites in the natural water is very low due to their instability. They are not analytically spotted in clean water, or they are found in only a thousandth milligram parts. Slightly more of them can be found at the end of the vegetation period at the onset of the decomposition of organic matter. Nitrites are an intermediate link in the nitrification process. The increased concentration of nitrites indicates that water contamination is high, the self-purification process is disturbed, the nitrification process does not finish. Nitrites are an important natural water sanitation indicator.

The results of the nitrite measurements are presented in Figure 10.

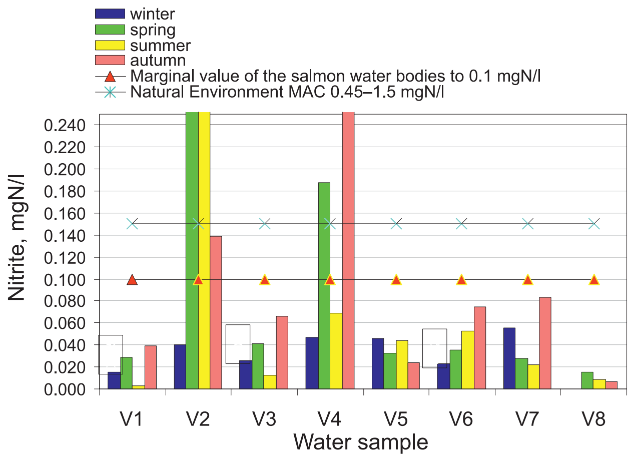

Figure 10. Nitrite in the surface water body. The MPLs in the environment 0.45–1.5 mgN/l (the marked samples were taken under the ice)

As it can be seen in Figure 10, the MPL of nitrite in the natural environment (1.5 mgN/l) was not exceeded in all the samples, and only in one sample (taken in autumn in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]) the lowest MPL in the natural environment (0.45 mgN/l) was 1.02 times higher.

The threshold value for the *cyprinid* water bodies (up to 0.15 mgN/l) was exceeded during two seasons in the Vilkupis upstream of Raseiniai [V2] (in spring and summer) (2.2 and 2.8 times, respectively) and in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (in spring and autumn) (1.3 and 3.1 times, respectively).

The threshold value for the salmonid water bodies (up to 0.1 mgN/l) was exceeded during three seasons in the Vilkupis upstream of Raseiniai [V2] (in spring – 3.24 times, in summer – 4.2 times, and in autumn – 1.4 times), during two seasons in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (in spring – 1.9 times, and in autumn – 4.6 times).

In other analyzed samples, the threshold values for both the salmonid and cyprinid water bodies were not exceeded.

The average annual nitrite values in the samples are as follows: V1 – 0.022 mgN/l (met the threshold values for both the salmonid and cyprinid water bodies); V2 – 0.231 mgN/l (the threshold values were exceeded 1.5 times for the cyprinid and 2.3 times for the salmonid water bodies); V3 – 0.036 mgN/l (met the threshold values); V4 – 0.191 mgN/l (the threshold values were exceeded 1.3 times for the cyprinid and 1.9 times for the salmonid water bodies); V5 – 0.037 mgN/l (met the threshold values); V6 – 0.047 mgN/l (met the threshold values); V7 – 0.047 mgN/l (met the threshold values); V8 – 0.010 mgN/l (met the threshold values). Thus, the lowest amount of nitrites was measured in the samples taken in Prabaudos pond [V8] (0.010 mgN/l), the highest – in the Vilkupis upstream of Raseiniai [V2] (0.231 mgN/l). The difference in the amounts of nitrites between the lowest and the highest levels was 23.1 times.

Results of the nitrate measurements in the surface water bodies

Nitrates are one of the major plant nutrient (biogenic) materials. Nitrates are the most steady of all the inorganic nitrogen compounds. During the vegetation period in the water, the concentration of nitrates is tithe of milligram or they are not found at all, while during the winter season the concentration can reach up to several milligrams in one liter of water.

The most worrying contaminant is *nitrate ion* NO_3. The main source of nitrate is water from farmlands. It was originally believed that the main source of nitrate is oxidized animal remains, plant unused ammonium nitrate (NH_4NO_3) and other nitrogenous fertilizers. However, subsequent studies have shown that the intensively cultivated soil, aerated and watered, even not fertilized, increases the organic matter oxidation of reduced nitrogen to nitrate. Algae is intensively developing due to the surplus of nitrates in the surface water bodies and the Baltic Sea. The dying and decomposing algae contaminates water. In clean water, nitrate ions do not cause such a phenomenon because phosphates, but not nitrate ions, is the main fertilizer for algae. In the absence of phosphate ions with increasing NO_3^- concentrations, the growth and reproduction of algae does not speed up. However, sometimes, it is nitrates, not phosphates, that become a temporary algae growth speed limiting material.

The results of the nitrate measurements are presented in Figure 11.

As it can be seen in Figure 11, in all of the analyzed samples the amount of nitrates did not reach the minimum permissible MPL in the natural environment value (23 mgN/l).

The average annual nitrate values in the samples were: V1 – 2.42 mgN/l; V2 – 3.83 mgN/l; V3 – 0.79 mgN/l; V4 – 1.14 mgN/l; V5 – 2.33 mgN/l; V6 – 2.241 mgN/l; V7 – 2.94 mgN/l; V8 – 1.79 mgN/l. Thus, the lowest nitrate level was measured in the samples taken in the Reizgupis north of Raseiniai [V3] (0.79 mgN/l), the highest – in the Vilkupis downstream of Raseiniai [V2] (3.83 mgN/l). The difference between the highest and the lowest levels of nitrate is 4.8 times.

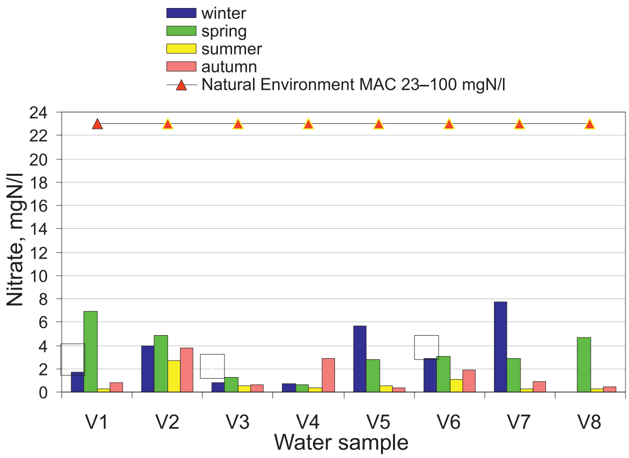

Figure 11. Nitrate in the surface water body (the marked samples were taken under the ice)

According to the assessment of the research results according to the amount of nitrates, the studied rivers can be assigned to the following classes of ecological conditions of rivers (Table 1): **very good** – the Reizgupis upstream of Raseiniai [V3], the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4], **good** – the Kriokle upstream of Vidukle [V6], **average** – the Vilkupis upstream of Raseiniai [V1], the Vilkupis downstream of Raseiniai [V2], the Dubysa outside Ariogala [V5], the Kriokle downstream of Vidukle [V7].

Results of the ammonium measurements in the surface water bodies

As mentioned above, since nitrite and ammonium nitrogen ions are associated with a low abundance of oxygenated organic compounds, the increase of their amounts in the river water shows "fresh" pollution.

The results of the ammonium measurements are presented in Figure 12.

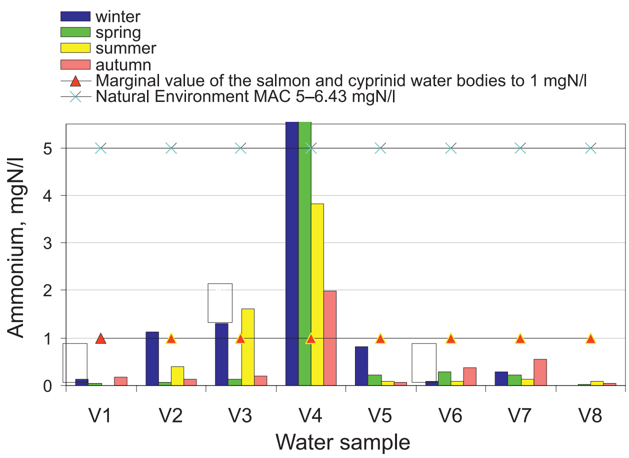

Figure 12. Ammonium in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 12, the MPL in the environment (5–6.43 mnN/l) was exceeded 8.5 times in the winter season and 4 times in the spring season in the samples taken in Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]. The threshold value for both the *salmonid* and *cyprinid* water bodies (up to 1 mgN/l) was exceeded during all four seasons in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (in winter – 54.8 times, in spring – 25.5 times, in summer – 3.8 times, in autumn – 2 times), during two seasons in the Reizgupis upstream of Raseiniai [V3] (in winter – 1.3 times, in summer – 1.6 times), during one season in the Vilkupis downstream of Raseiniai [V2] (in winter – 1.1 times).

In other samples, the threshold value for both the salmonid and cyprinid water bodies was not exceeded.

The average annual ammonium values in the samples were: V1 – 0.093 mgN/l; V2 – 0.433 mgN/l; V3 – 0.816 mgN/l; V4 – 21.5 mgN/l (the threshold values were exceeded 21.5 times for the cyprinid and for the salmonid water bodies, MPL – 3.3 times); V5 – 0.296 mgN/l; V6 – 0.212 mgN/l; V7 – 0.304 mgN/l; V8 – 0.054 mgN/l. Thus, the lowest concentration of ammonium was measured in samples taken in Prabaudos pond [V8] (0.054 mgN/l), while the highest – in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (21.5 mgN/l). However, in the samples taken in the Reizgupis during the summer and autumn seasons, a significant decrease in the amounts of ammonium can be observed.

According to the assessment of the research results according to the amount of ammonium, the studied rivers can be assigned to the following ecological conditions classes of rivers (Table 1): **very good** – the Vilkupis upstream of Raseiniai [V1], **average** – the Vilkupis downstream of Raseiniai [V2], the Dubysa outside Ariogala [V5], the Kriokle upstream of Vidukle [V6], the Kriokle downstream of Vidukle [V7], **poor** – the Reizgupis upstream of Raseiniai [V3], **very poor** – the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

Results of the phosphorus measurements in the surface water bodies

Phosphorus belongs to a group of biogenic nutrients. Nitrogen and phosphorus compounds fall into the rivers both from the cities and from agriculture, but mostly the sources of contamination with nitrogen are farm fields, and with phosphorus – the cities.

Phosphorus is one of the key biogenic nutrients determining the productivity of the water body. The surface water bodies are contaminated with phosphorus during the soils or rock leaching processes; also, phosphorus contaminates the surface waters as a product of aquatic organisms' life and decomposition. An important source of phosphorus is human agricultural activities: soil fertilization with phosphorus fertilizers, detergents containing phosphate (PO_4), softening of water.

The results of the total phosphorus measurements are presented in Figure 13.

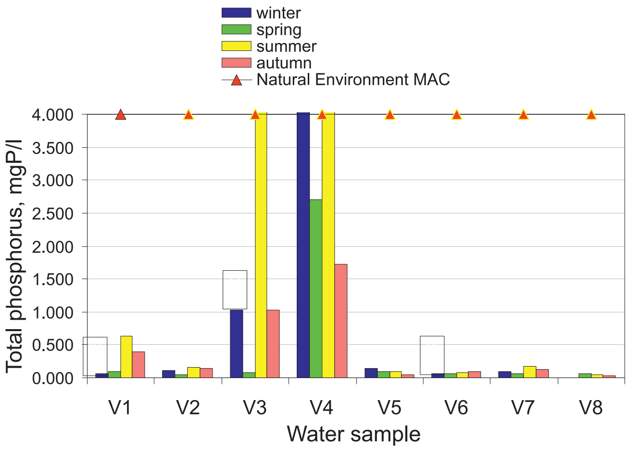

Figure 13. Total phosphorus in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 13, the MPL in the environment (4 mgP/l) was exceeded in three samples: in the Reizgupis upstream of Raseiniai [V3], in summer (was 4.2 times higher) and in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4], in winter (was 1.7 times higher), and in summer (was 3.2 times higher).

In other analyzed samples, the MPL in the environment was not exceeded.

The average annual total phosphorus values in the samples were: V1 – 0.30 mgP/l; V2 – 0.11 mgP/l; V3 – 4.74 mgP/l (the MPL was exceeded 1.2 times); V4 – 5.99 mgP/l (the MPL was exceeded 1.5 times); V5 – 0.10 mgP/l; V6 – 0.08 mgP/l; V7 – 0.11 mgP/l; V8 – 0.05 mgP/l. Thus, the lowest amount of total phosphorus was measured in the samples taken in Prabaudos pond [V8] (0.05 mgP/l), while the highest amount was measured in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (5.99 mgP/l). The difference between the highest and the lowest 2012 average annual amount of total phosphorus is 120 times.

According to the assessment of the research results according to the amount of total phosphorus, the studied rivers can be assigned to the following classes of ecological conditions of rivers (Table 1): **very good** – the Dubysa outside of Ariogala [V5], the Kriokle upstream of Vidukle [V6], **good** – the Vilkupis downstream of Raseiniai [V2], the Kriokle downstream of Vidukle [V7], **poor** – the Vilkupis upstream of Raseiniai [V1], **very poor** – the Reizgupis upstream of Raseiniai [V3], the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

According to the assessment of the research results according to the amount of total phosphorus, Prabaudos pond [V8] can be assigned to the **maximum** criterion of the ecological potential class (Table 2).

Results of the total nitrogen measurements in the surface water bodies

Nitrogen belongs to a group of biogenic nutrients. As mentioned above, nitrogen and phosphorus compounds fall into the river both from the cities and agriculture, however, mostly the sources of contamination with nitrogen are farm fields, and with phosphorus – the cities.

Nitrogen is found in both organic and inorganic compounds. The concentration of nitrogen is characterized by seasonal fluctuations. Mineral nitrogen makes up a major part of total nitrogen. Mineral nitrogen is easily absorbed by vegetation, therefore, the fluctuation of its amounts is closely related to the beginning and the end of the vegetation period.

The monitoring of nitrogen concentrations in surface waters is necessary to evaluate the sanitary condition of the surface waters.

The results of the total nitrogen measurements are presented in Figure 14.

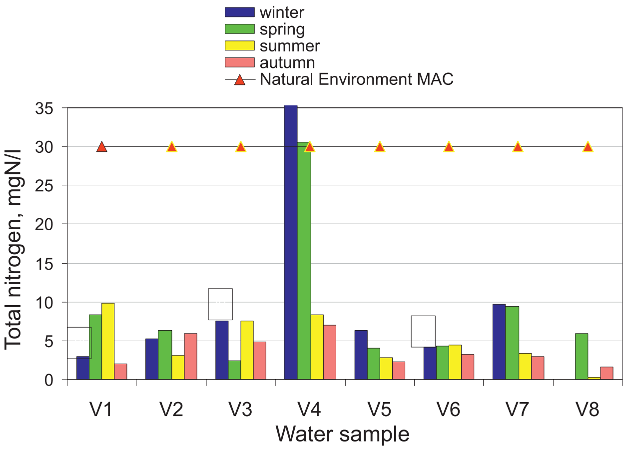

Figure 14. Total nitrogen in the surface water body (the marked samples were taken under the water)

As it can be seen in Figure 14, the MPL in the environment (30 mgN/l) was exceeded only in one sample taken in the Reizgupis south of Raseiniai downstream from the wastewater treatment facilities [V4] during the winter and spring seasons. The MPL in this sample was exceeded 2 times in winter and 1.02 times in spring.

In other samples, the MPL in the environment was not exceeded.

The average annual total nitrogen values in the samples were: V1 – 5.78 mgN/l; V2 – 5.15 mgN/l; V3 – 5.61 mgN/l; V4 – 26.06 mgN/l; V5 – 3.85 mgN/l; V6 – 4.03 mgN/l; V7 – 6.35 mgN/l; V8 – 2.60 mgN/l. Thus, the lowest amount of total nitrogen was in the samples taken in Prabaudos pond [V8] (2.60 mgN/l), while the highest – in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (26.06 mgN/l). The difference between the lowest and the highest amount of total nitrogen is 10 times.

According to the assessment of the research results according to the amount of total nitrogen, the studied rivers can be assigned to the following classes of ecological conditions of rivers (Table 1): **average** – the Vilkupis upstream of Raseiniai [V1], the Vilkupis donstream of Raseiniai [V2], the Reizgupis upstream of Raseiniai [V3], the Dubysa outside Ariogala [V5], the Kriokle upstream of Vidukle [V6], **poor** – the Kriokle downstream of Vidukle [V7], **very poor** – the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

According to the assessment of the research results according to the amount of total nitrogen, Prabaudos pond [V8] can be assigned to the **good** criterion of the ecological potential class (Table 2).

Results of the colour measurements in the surface water bodies

Water colour and turbidity, i.e. suspended organic and mineral solids in the water, determine its transparency.

Clean natural water is usually colourless. Water gains its colour because of humic matter and ferric compounds in it. The colour-determining agents are present in natural water because of the weathering of rock, are washed out of soil or peat, come from underground waters, or are produced in the water because of biochemical or chemical processes. These agents colour the surface water yellowish-brown. The colour of water may be determined by the industrial wastewater.

The results of the water colour measurements are presented in Figure 15.

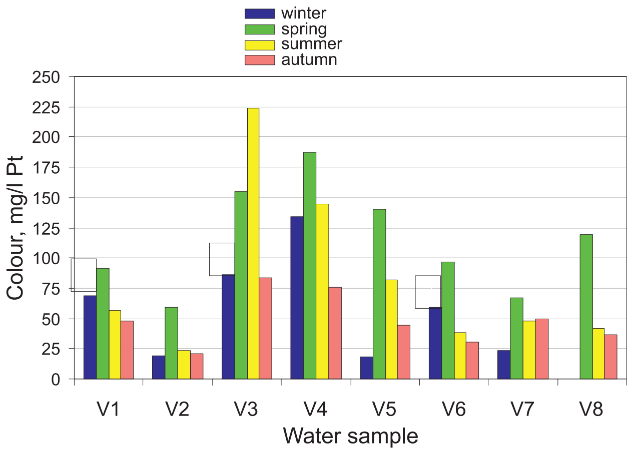

Figure 15. Colour in the surface water body (the marked samples were taken under the ice)

As it can be seen in Figure 15, the highest intensity of colour (224 mg/l Pt) was measured in the sample taken in summer in the Reizgupis upstream of Raseiniai [V3]. The lowest intensity of colour (18.1 mg/l Pt) was measured in the sample taken in winter in the Dubysa outside Ariogala [V5].

The highest intensity of colour was measured during the spring season in all the samples, except for the sample from the Reizgupis upstream of Raseiniai [V3]. In the latter location, the highest intensity of colour was measured during the summer period.

The average annual total colour values in the samples were: V1 – 66.3 mg/l Pt; V2 – 30.8 mg/l Pt; V3 – 137.3 mg/l Pt; V4 – 135.4 mg/l Pt; V5 – 71.0 mg/l Pt; V6 – 55.9 mg/l Pt; V7 – 46.9 mg/l Pt; V8 – 65.7 mg/l Pt. Thus, the lowest intensity of colour was measured in the samples taken in the Vilkupis downstream of Raseiniai [V2]

(30.8 mg/l Pt), the highest – in the Reizgupis upstream of Raseiniai [V3] (137.3 mg/l Pt). The difference between the lowest and the highest values of the intensity of colour is 4.5 times.

4. Conclusions

1. The threshold temperature and active water reaction (pH) values for the salmonid and cyprinid water bodies as well as nitrate and total nitrogen MPLs in the environment were not exceeded in neither of the analyzed samples.

2. The majority of non-compliances and exceedances with values and the maximum allowable concentrations were observed in the sample taken in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]: *oxygen saturation* was 2.3 times lower than the threshold value for the salmonid and 1.8 times lower than the value for the cyprinid water bodies; the amount of *suspended solids* was 1.6 times higher than the threshold value for both the salmonid and cyprinid water bodies; *biochemical oxygen demand* was exceeded 4.4 times for the salmonid and 2.9 times for the cyprinid water bodies; the amount of *phosphates* was 9 times higher than the threshold value for the salmonid and 4.5 times higher that the value for the cyprinid water bodies; the amount of *nitrites* exceeded the threshold value for the salmonid water bodies 1.9 times, and 1.3 times for the cyprinid water bodies; the MPL of *ammonium* amount in the environment was 3.3 times higher, it exceeded the threshold values for both the salmonid and cyprinid water bodies 21.5 times; the MPL of *total phosphorus* amount in the environment was exceeded 1.5 times.

3. The oxygen saturation threshold value for the cyprinid water bodies (more than 7 mg/l O_2) was not met in the samples taken in the Reizgupis upstream of Raseiniai [V3], the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] and in the Kriokle downstream of Vidukle [V7]. The threshold value for the salmonid water bodies (more than 9 mg/l O_2) was not met in all of the samples.

4. The amount of suspended solids did not meet the threshold value for both the salmonid and cyprinid water bodies (up to 25 mg/l) in the samples taken in the Vilkupis upstream of Raseiniai [V1] (was 1.8 times higher), in the Reizgupis upstream of Raseiniai [V3] (was 3.4 times higher), in Reizgupis downstream of Raseiniai [V4] (was 1.6 times higher), and in the Kriokle downstream of Vidukle [V7] (was 1.4 times higher).

5. The measured amount of biochemical oxygen demand was higher than the threshold value for the *salmonid* (up to 4 mgO_2/l) and the *cyprinid* (up to 6 mgO_2/l) water bodies in the samples taken in the Reizgupis upstream of Raseiniai [V3] (2.8 and 1.9 times higher, respectively), in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (4.45 and 2.9 times higher, respectively), and in the Kriokle downstream of Vidukle [V7] (1.75 and 1.2 times higher, respectively).

6. The amount of phosphates and total phosphorus did not meet the threshold values in the samples taken in the Reizgupis upstream of Raseiniai [V3] and in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4].

7. The measured amount of nitrite MPL in the environment (0.45 mgN/l) was exceeded in the sample taken in autumn in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (it was 1.02 times higher). The threshold values of nitrite for the *salmonid* (up to 0.1 mgN/l) and the cyprinid (up to 0.15 mgN/l) water bodies were exceeded in the samples taken in the Vilkupis downstream of Raseiniai [V2] (2.3 and 1.5 times, respectively) and in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (1.9 and 1.3 times, respectively).

8. The measured amount of ammonium MPL in the environment (6.43 mgN/l) was higher in the samples taken in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (8.5 times higher in winter and 4 times higher in spring). The threshold values of ammonium for the *salmonid* and *cyprinid* water bodies (up to 1 mgN/l) were higher only in the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4] (3.3 times higher).

9. According to the assessment of the obtained results according to the chemical quality elements' indicators (dissolved oxygen, BOD_7, phosphates, nitrates, ammonium, total phosphorus and total nitrogen), the studied rivers can be assigned to the following classes of ecological conditions of rivers: **good** – the Vilkupis upstream of [V1] and downstream of [V2] Raseiniai, the Dubysa outside Ariogala [V5], the Kriokle upstream of Vidukle [V6], **average** – the Kriokle downstream of Vidukle [V7], **poor** – the Reizgupis upstream of Raseiniai [V3], the Reizgupis downstream of Raseiniai wastewater treatment facilities [V4]. According to the assessment of the obtained results (total phosphorus and total nitrogen), Prabaudos pond [V8] can be assigned to the **maximum** and **good** criteria of ecological potential class.

10. According to the obtained indicators of chemical quality elements, it is obvious that the sections of rivers before the city (Raseiniai and Vidukle) are of a better quality. The deterioration of the quality of the surface water outside the city was determined by the cultivated fields, gardens, the unknown contaminants discharged by the residents.

11. The quality of water in the Vilkupis upstream of Raseiniai [V1], the Reizgupis upstream of Raseiniai [V3] and the Kriokle upstream of Vidukle [V6] is determined by the adjacent gardens and cultivated fields. The quality of water in the Vilkupis downstream of Raseiniai [V2] and the Kriokle downstream of Vidukle [V7] is determined by the various contaminants from the city, while the quality of water in the Reizgupis downstream of Raseiniai [V4] is determined not only by the various contaminants from the city, but also the water discharged from the wastewater treatment facilities. The quality of water in the Dubysa

River outside Ariogala near the highway A1 [V5] is not affected by the emissions from motor vehicles. The quality of water in Prabaudos pond [V8] is determined by the cleaned water from the inflowing Prabaudos River.

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