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Pollution of the water of Lithuanian rivers with nitrogen and phosphorus compounds in different periods of anthropogenic activities

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The paper analyses the concentration of biogenic substances and their changes in different periods (flows) in the water of 10 rivers located in different hydrologic regions of Lithuania. The goal of the paper is to reveal the relation between the water yield of the rivers and changes in biogenic substance concentrations during a long period (1974–2003) by analysing changes in river flow and the chemical composition of the water and taking account of physical-geographical conditions of and anthropogenic changes in river basins of Lithuania.

Analysis of the dependence of biogenic substances on the water yield of the rivers during two stages of economic activity of different intensity showed that the strongest relation between mineral nitrogen, nitrates and water yield was recorded only in some rivers (the Akmena, the Merkys and the Neris). The correlation coefficient showing the dependence of nitrate concentrations on the water yield did not exceed 0.46, while the concentrations of mineral nitrogen went down with a decrease in water yield. The correlation of the dependence of phosphate concentrations on the water yield was even weaker.

Analysis of both mineral nitrogen and phosphate flows revealed that the greatest amount of mineral nitrogen was transferred in the autumn–winter season. In the rivers of Southeast Lithuania, the amount transferred in this season made on the average 51.7% of the annual flows, in the rivers of Central Lithuania it made 51,9%, and in the rivers of Western Lithuania 65.4%. The smallest part fell to the summer season 13.7%; 13,1% and 7.2%, respectively. In spring the flows comprised 34.6%; 35.0% and 27.4% of the annual value.

Key words: anthropogenic activity, water yield in rivers, debits, biogenic substances

INTRODUCTION

The intensifying human economic activity has an increasing impact on nature. While developing the national economy it is important to adopt preventive measures that forward the improvement of the quality of all surface and underground waters, as they to a large extent contribute not only to the conditions of biota existence in river basins but also to the cleanness of the Curonian Lagoon and the Baltic Sea. One of the key goals of environment protection is reduction of water pollution with biogenic substances, caused by fertilisers used in agriculture and large cattle-ranches, industrial enterprises and urban wastewater. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy demands to ensure protection and sustainable use of water in the framework of a river basin. Thus, it is important to compile information on the actual state of water in every river basin.

Recently, analysis of river water quality has been given much attention in Lithuania. A number of publications analysing the reasons for the state of rivers have been available on this subject. B. Tilickis states that the anthropogenic activity has a lower impact on the surface water quality than do the physical–chemical properties of a river basin soil and atmospheric humidity regime (Tilickis, 1996). R. Tumas obtained similar results and stated that the chemical regime of rivers hydrogenically undergoes different formation in different regions (Tumas, 1997, 2001, 2002). A considerab-

Table 1. **Characteristics of the river basins being analysed**

Rivers	Merkys	Šventoji	Žeimena	Neris	Lėvuo	Šešupė	Venta	Akmena	Jūra	Šešuvis
Hydrological regions of Lithuania	Souteast				Central		Western			
River length, km	203.0	246.0	79.6	509.0	140.1	297.0	343.3	62.5	171.8	101.7
River length within the territory of Lithuania, km	197.3	246.0	79.6	228.0	140.1	157.5	159.1	62.5	171.8	101.7
Basin area, km^2	4415.7	6888.8	2793.0	24942.3	1628.8	6104.8	11800.0	580.2	3984.4	1915.7
Basin area within the territory of Lithuania, km^2	3780.7	6800.7	2793.0	13849.6	1628.8	4899.0	5140.0	580.2	3984.4	1915.7
Location of water sampling	Lower than Puvočiai	Lower than Ukmergė	Lower than Pabradė	Lower than Vilnius	Lower than Kupiškis	Lower than Marijampolė	Near Leckava	Near Tūbausiai	Lower than Tauragė	Near Skirgailiai
Basin area up to water sampling location, km^2	4300.0	5440.0	2580.0	15200.0	307.0	3210.0	4060.0	196.0	1690.0	1880.0
Hydrological and hydrochemical observation station, distance from the river mouth, km	13.6	35.8	19.0	141.1	107.0	205.0	200.0	41.0	34.5	0.4
Perennial precipitation amount, mm	740	740	730	700	670	700	700	900	850	800
Sand content, %	67	30	76	–	20	10	11	1	8	13
Forests, %	46	12	37	35	12	17	22	30	20	17
Swamps, %	10	9	10	10	5	11	9	1	6	4
Lakes, %	0.9	3.8	7	2.2	0.3	2	1	0	0.2	0.1

le part of pollutants get into water bodies from diffuse sources. Having carried out a detailed research of pollution in the Nevėžis basin, A. S. Šileika states that since 1992 nitrate concentration in the Nevėžis has increased four times, while pollution with phosphorus has signally decreased and does not exceed the permitted level. He stated that, in spite of the decrease in the production scale, the unexpected economic and social changes had a negative impact on river pollution with nitrate nitrogen (Šileika, 2005; Sileika et al., 2002, 2005). According to the above researches, most of nitrogen and phosphorus get into the Nemunas from the Nevėžis.

The impact of point sources on river water quality was analysed in river basins of the Nevėžis, the Šešupė, the Venta, the Mūša–Lielupė (Bagdziunaite-Litvinaitiene, Lukianas, 2005; Dumbrauskas, Larsson, 1997; Vincevičienė, Asadauskaitė, 1998, 2000; Vincevičienė, Jelisejevienė, 1999; Šileika et al., 2000; Januškevičius, Vincevičienė, 2001).

Foreign scientists analyse water quality changes in a complex way and take into account the anthropogenic and natural conditions. It has been found that the decrease in the amounts of mineral nitrogen that get into the river water could not cause major changes. The situation is different in case of phosphates: the decrease in their amount results in an immediate decrease of their concentration in water (Grimvall, Stalnacke, Tonderski, 2000). Scientists of Nordic countries pay a lot of attention to the euthrophication of the Baltic Sea. P. Stalnacke, A. Grimvall, K. Sundbland analysed the inflow of biogenic substances to the Baltic Sea in 1970–1993 (Stalnacke et al., 1999). Authors state that the major part of pollutants get into the Baltic Sea in an indirect way, i.e. not through rivers but with precipitation and from industrial areas and towns located in littoral areas.

Analysis of scientific works enables us to state that the cases analysed on hydrochemical changes in the river water and their dependence on possible impacting factors were mostly short-term and covered only individual factors. Changes in the level of biogenic substances showed a complex interaction of natural and anthropogenic processes in the river basins. The more intensive economic activities in a river basin, the more complicated is the estimation of the components that influence the changes and their properties become clear only after a long period. The volume of water in rivers has an insignificant impact on the state of water.

The aim of our research was to reveal the relation between the water volume of rivers and changes in biogenic substance concentrations, taking into account the physical-geographical conditions of and anthropogenic changes in river basins of Lithuania by analysing changes in river water yield and chemical composition during a long period (1974–2003).

MATERIALS AND METHODS

The concentration of biogenic substances and their changes were analysed in the water of 10 rivers located in different hydrologic regions of Lithuania. Characteristics of rivers selected for the study are given in Table 1.

Assessment of changes in anthropogenic activity. Changes in human economic activity were assessed taking into account the total industrial production growth and agricultural production intensity, i.e. the number of animals and fowl.

Assessment of changes in water yield. The annual water yield of rivers was assessed taking into account the average annual debit, annual flow volume and modular factor and drawing integral curves of deviation of modular factors of the annual flow from the average value. Statistical parameters of the study period and flow distribution by seasons were calculated.

The correlation coefficient was calculated by defining the dependence of the levels of biogenic substances on water debits throughout the period of research; besides, relations between the concentrations and modular factors in the periods of different water yield were determined. The analysis was carried out with the help of the statistical package for social sciences. The statistical programme was used to carry out dispersion analysis applying the linear regression model.

Methods for calculation of biogenic substance flows. In the analytical studies we used data on the concentrations of ammonia nitrogen (NH_4^+), nitrites (NO_2^-), nitrates (NO_3^-) and phosphates (PO_4^{3-}) received from the former Joint Research Centre and Environment Protection Agency of the Ministry of Environment. Biogenic substance flows were calculated when the level of biogens recorded during one monitoring per month was available, while the volume of river flow was calculated taking into account the monthly average debit.

Experimental tests were carried out to assess the dependence of biogenic substances on the water yield of the rivers. In the summer of 2002 (July, August) and the spring (March, April) and summer (May, June, July, August) of 2003 the frequency of sampling in

Table 2. **Hydrological data on the rivers analysed**

Rivers		Merkys	Šventoji	Žeimena	Neris	Lėvuo	Šešupė	Venta	Akmena	Jūra	Šešuvis
Annual debit norm, m^3/s		35.3	40.8	21.2	111.0	1.76	8.91	30.6	2.56	21.0	15.4
Statistical parameters	Average debit during observation period, m^3/s	32.3	40.6	21.9	97.0	1.7	8.9	29.7	4.1	22.3	16.0
	Variation coefficient	0.41	0.89	0.48	0.51	1.73	1.12	1.26	1.88	1.53	1.48
	Error of variation coefficient	0.003	0.011	0.004	0.004	0.037	0.16	0.02	0.04	0.029	0.02
	Asymmetry coefficient	3.37	2.48	2.31	2.66	3.98	3.44	2.99	4.44	3.95	3.50
	Error of asymmetry coefficient	0.034	0.07	0.03	0.04	0.18	0.09	0.11	0.22	0.15	0.14
Limit values of debits during observation period	The highest debit, m^3/s	219.0	350.0	107.0	627	42.3	106.0	375.5	99.9	394.0	269.0
	The lowest debit, m^3/s	12.0	4.30	7.38	29.70	0.00	0.33	1.74	0.00	1.56	0.89
Average annual water yield module during observation year, $l/(s \cdot km^2)$		7.5	7.43	8.51	6.39	5.7	5.14	7.33	14.09	13.2	8.52
Average water yield height during observation period, mm		237	236	268	201	175	87	231	660	416	269

Table 3. **Amplitudes of mineral nitrogen flows (kg/km^2) in the years of different water yield**

Rivers	Year		
	High water yield	Medium water yield	Low water yield
Merkys	208–263	223–229	155–277
Šventoji	195–573	241–338	130–381
Žeimena	157–218	110–124	94–189
Neris	246–367	242–270	137–300
Lėvuo	575–670	65–675	61–124
Šešupė	522–763	193–462	109–458
Venta	529–695	500–739	168–451
Jūra	342–1264	528–703	385–789
Akmena	1626 (38% of probability)*	789–1530	425–938
Šešuvis	596–979	297–763	308–421

*Note. In the period 1993–2003, there were no years of high water yield.

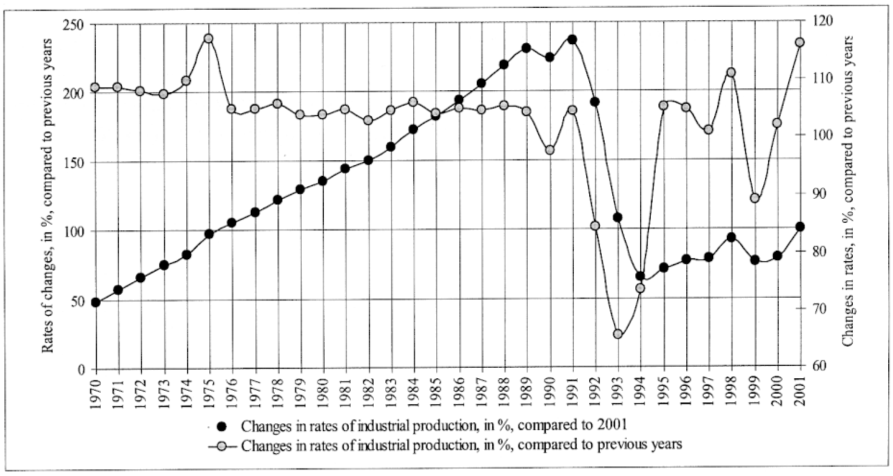

Fig. 1. Rate of changes of industrial production

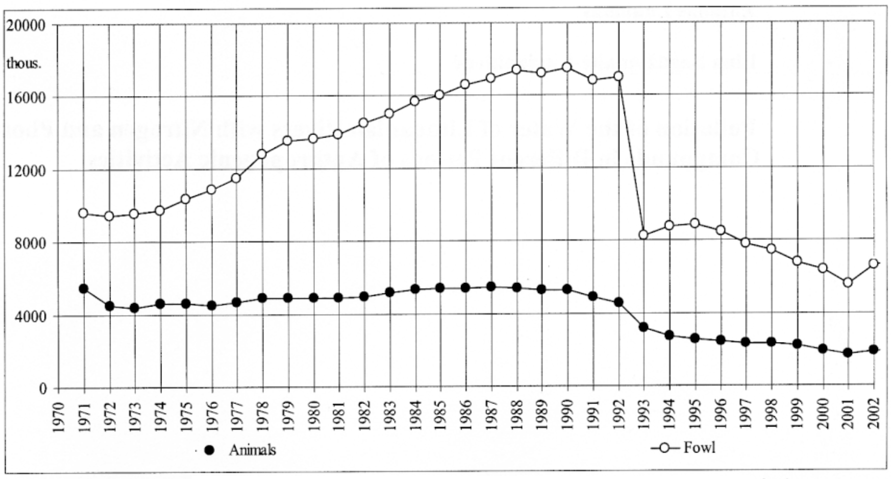

Fig. 2. Changes in the number of animals and fowl during observation period

four rivers located in Southeast Lithuania was increased to three times per month.

Finding possibilities to reduce the frequency of sampling. To find the possibilities to reduce the frequency of sampling, methods of mathematical statistics were used. The statistical parameters of biogen concentrations (variation coefficients when the data of 12, 8, 6 and 4 monitorings per year are available) were calculated.

Based on these data and analysing the change in biogen concentrations when the number of measurements was no more than 12 per year, the appropriate months were selected considering the volume of flow: January, March, April, May, July, October, November, and December when the number of measurements was 8; April, May, July, October, December, and January when data of six measurements were analysed; April, July, October, and December when data of four measurements per year were analysed.

RESULTS

Changes in anthropogenic activity in 1974–2003

The recent three decades were unstable with regard to Lithuanian industry, agriculture, and urbanisation. Substantial changes in the national economy occurred after restoration of the independence of Lithuania and after transfer from the planned economy to the market one. Analysing changes in the anthropogenic activities and the intensity of river water pollution which also depends on economic activities of man, two stages were singled out: 1974–1990 and 1991–2003. Until 1990, industrial production was rapidly growing, and in 1991 it started decreasing. After 1994, industrial production started slightly growing (Fig. 1).

Changes in the agricultural intensity during the period in question have been defined by changes in the number of animals and fowl in all categories of farms. Until 1990, the number of animals was more or less even, while later it decreased. The change in the number of fowl is also considerable (Fig. 2).

Patterns of changes in water volume

Water yield is the key characteristic showing the total water volume of the river basin in question. Hydrological data on the rivers for the study period are given in Table 2.

Accumulated integral curves were drawn to reveal the phases of water yield of the rivers in question. In most rivers, a low water yield was seen in 1974–1979, except the Šventoji, the Merkys, and the Žeimena where the phase of a low water yield continued till 1997, 1986 and 1989, respectively. The phase of a high yield of most rivers started in 1980 and lasted till 2003.

Changes in biogenic substance concentrations and the influencing factors

During the first stage (1974–1990), the highest amplitude of changes in nitrate concentrations was recorded in the Akmena (0.030 to 4.858 mg/l), the Venta (0.044 to 3.964 mg/l) and the Šešuvis (0.040 to 2.845 mg/l). In other rivers this amplitude was slightly lower (0.00 to 2.86 mg/l). In the second stage, the amplitude of concentration changes in some rivers (the Neris, the Šventoji, the Jūra, the Akmena) became lower, however, in most rivers it increased.

Analysis of the trend of the maximum permissible level (the MPL) increase showed that in 1974–2003 the number of cases when the MPL was exceeded in the rivers of Southeast Lithuania was the lowest: it changed from 1 to 6, in the rivers of Western Lithuania it changed from 8 to 31, while the highest number of cases when the MPL was exceeded was seen in the rivers of Central Lithuania: it changed from 32 to 42. A considerable number of cases when the MPL was exceeded (limit value 2.26 mg/l) was seen in the Lėvuo River since 1991 (Fig. 3).

In 1974–1990, the number of samples that exceeded the permitted levels of nitrates in rivers of Southeast Lithuania was only 0–3% (of the total number of samples), while in 1991–2003 it increased to 4%. In rivers of Middle Lithuania, in the first stage nitrates exceeded the maximum permitted level by 0–1%, while in the second stage by 21–25%. In the rivers of Western Lithuania, the number of samples that exceeded the MPL was 14%, while after 1991 it was 4–28% (Fig. 4).

The number of cases when the MPL of phosphates, the same as that of nitrates, was highest in the rivers of Central Lithuania, and it changed from 96 to 154; in the rivers of Southeast Lithuania the number of cases when the MPL of phosphates was exceeded changed from 30 to 128, and the lowest number was noticed in the rivers of Western Lithuania, where the number of cases when the the MPL was exceeded changed from 21 to 82. The number of cases when the MPL of phosphates were exceeded was higher in the first period (1974–1990). In the rivers of Central Lithuania, the number of samples exceeding the maximum permitted level amounted to 69–72% of the total number of samples. In the water of the other rivers in the first stage, the maximum permitted concentration was often exceeded, too: in the rivers of Southeast Lithuania this indicator was 35–65%, while in the rivers of Western Lithuania it reached 14–66%. In the second stage, the number of cases of exceeding the maximum permitted level reduced but was still high. The highest number was recorded in the rivers of Central Lithuania: in the Šešupė it amounted to 70% and was also rather frequent in the other rivers, in the Neris amounting to 47% and in the Lėvuo to 32%. The MPL was exceeded rarer in the Žeimena, the Šventoji, the Jūra (3, 6, and 8%, respectively).

Analysis of the dependence of the concentrations of nitrites, mineral nitrogen, and phosphates on water yield during two stages of a different intensity of economic activity revealed that

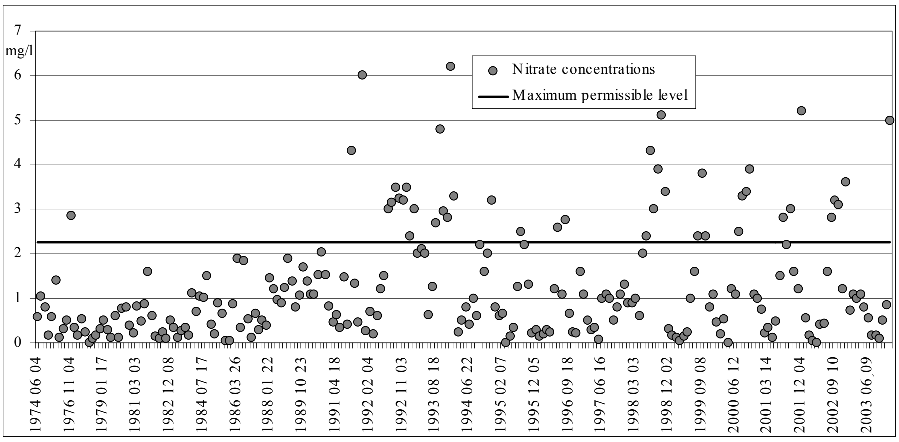

Fig. 3. Changes in nitrate concentrations in the Lėvuo River

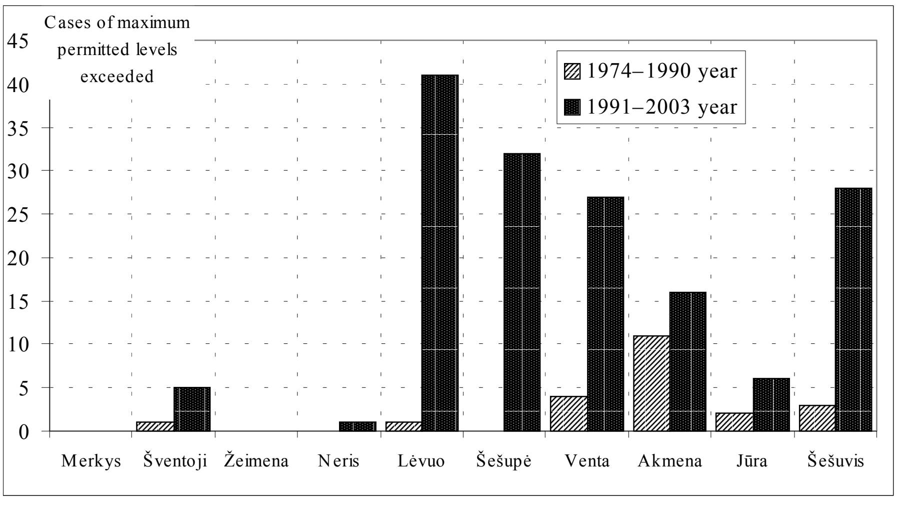

Fig. 4. Number of times the nitrate concentration exceeded the maximum permitted level

in the first stage a strong or medium relation between mineral nitrogen and phosphates and water yield was recorded in the Akmena (correlation coefficients were 0.57 ir 0.8, respectively) and between mineral nitrogen and water yield in the Merkys (correlation coefficient 0.45). The trend of a decrease in mineral nitrogen concentrations with an increase in water yield was noticed in the waters of other rivers (except the Neris and the Žeimena) but this relation was weak (the correlation coefficients changed from 0.09 to 0.31).

The correlation between the phosphate concentration and water yield was also weak, the correlation coefficients varying from 0.14 to 0.31.

In the second stage, a medium relation between mineral nitrogen and water yield was recorded only in the Merkys and the Žeimena; the correlation coefficients were 0.47 and 0.46, respectively; in the other rivers it varied from 0.09 to 0.47. The medium relation between phosphates and water yield was recorded in the Merkys (correlation coefficient 0.45). Thus, although in the second stage human economic activity was less intensive, an insignificant trend of increase in the concentration of mineral nitrogen and a decrease in phosphates with the increasing water yield was observed.

Dependences of biogenic substance concentrations on the water yield of rivers in low and high water yield phases were determined considering the differential integral curves of river flow in the stages of anthropogenic activities of different intensity (1974–1990 and 1991–2003).

As this analysis integrates many potential factors influencing changes in biogen concentrations, these factors are analysed as monofactorial parameters, otherwise the significance of the interaction among the parameters could not be established.

To find out the patterns of hydrological regime and biogenic substance concentrations, the debit in the years of different water yield was calculated by singling out the most characteristic debits in the years of high (probability up to 33%), medium (probability up to 66%), and low (probability higher than 66%) water yield.

In the rivers of Southeast Lithuania, the dependence of nitrogen compounds on water yield became vivid when the water yield was high. Of the rivers of Central Lithuania, only in the Šešupė the change in nitrate and mineral nitrogen concentrations when the water yield was high depended on the river debit. In the rivers of Western Lithuania, the correlation coefficients revealing a relation between nitrogen compounds and water yield were low (the maximum value R in the Venta in the year of high water yield reached only 0.53).

Phosphate concentrations are not related to changes in water yield.

Changes in biogen flows

Annual flows of mineral nitrogen are shown in Fig. 3. One can see that the amplitudes of flows are huge. The biggest flows were observed in the rivers of Western Lithuania where in the years of large water volume they exceeded 1000 kg/km^2. In the years of medium water yield the flows in these rivers varied from 297 to 1530 kg/km^2, while in the years of low water yield they varied within 168 to 938 kg/km^2. The lowest flows were seen in the rivers of Southeast Lithuania: in the years of high water yield they ranged from 157 to 573 kg/km^2, in the years of medium water yield they ranged from 110 to 338 kg/km^2, while in the years of medium water yield they ranged from 94 to 381 kg/km^2. In 1993–2003, the average annual flows of mineral nitrogen in the rivers of Southeast Lithuania on the average varied from 145 to 327 kg/km^2, in the rivers of Central Lithuania from 252 to 445, while in the rivers of Western Lithuania from 475 to 1044 kg/km^2. During this period, the absolutely highest flow was observed in the Akmena in 1998 (1626 kg/km^2), and the lowest one was observed in the Lėvuo in 2002; it was only 61 kg/km^2.

Analysing changes in both mineral nitrogen and phosphates, it was found that changes in their values in different seasons were similar to the distribution of river yield in the course of a year. Summer yield accounted for the lowest part of the year yield, while in spring and autumn the yield was respectively 43.3 ir 40.7% (Gailiušis et al., 2001).

Analysis of the flows of mineral nitrogen in different seasons showed that its highest amounts were observed in winter and autumn seasons. In the rivers of Southeast Lithuania, the amount transferred in this season was on the average 51.7% of the annual flows; in the rivers of Central Lithuania it reached 51.9%, while in the rivers of Western Lithuania 65,4%. The smallest part falls to the summer season. In summer flows in the river in the above-mentioned hydrological areas it reached 13.7%, 13.1% and 7.2%, respectively. In spring the flows were 34.6%, 35.0% and 27.4% of the annual value.

The absolute values of phosphate flows were much lower than those of mineral nitrogen; moreover, the fluctuation amplitudes were much lower and no explicit differences were observed among the values of water yield in rivers located in different hydrological areas. Phosphate flows in the rivers of Southeast Lithuania fluctuated from 4 to 24 kg/km^2, in the rivers of Central Lithuania from 3 to 43, while in the rivers of Western Lithuania from 4 to 42 kg/km^2.

Possibilities to reduce the frequency of water samplings

Optimisation of the number of river water samplings is a relevant issue, as the accuracy of water quality assessment and financial costs depend on it. Possibilities to reduce the frequency of water sampling were analysed taking into account the changes of the variation coefficient of biogenic substance concentrations.

The coefficients of variations in mineral nitrogen concentrations underwent the least changes in the Lėvuo (0.81

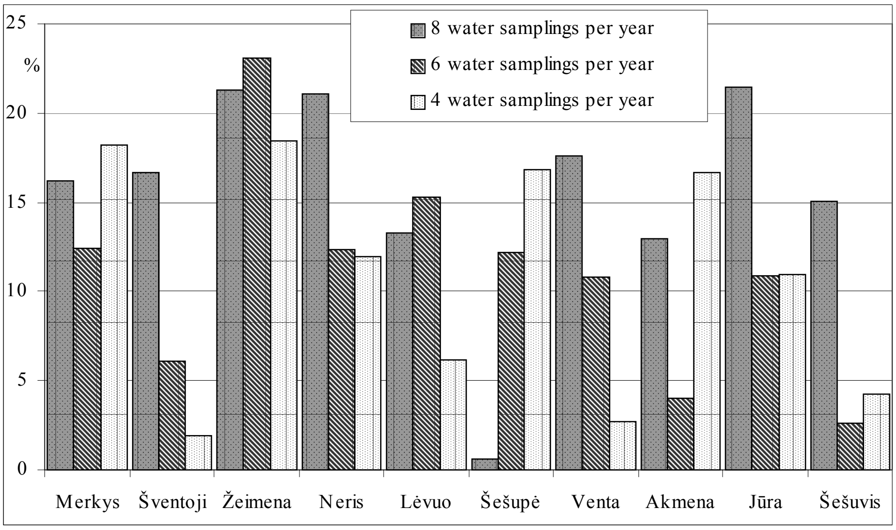

Fig. 5. Percentage of the ratio of the values of comparison of variation coefficients of mineral nitrogen concentrations and the reference variation coefficient

to 0.88), in the Venta (0.73 to 0.82), in the Akmena (0.45 to 0.54), while the highest changes in the variation coefficients were recorded in the Žeimena (0.47 to 0.61).

Analysis of changes in phosphate concentrations revealed the lowest fluctuation in variation coefficients in the Lėvuo (1.37 to 1.38); while the greatest fluctuations were recorded in the Šventoji – 0.50 to 0.86.

A comparison of the values of biogenic substances, when data of two or three monthly samplings were available, showed that the amplitude of changes in relative differences was very wide and reached up to 100%. Relative differences of mineral nitrogen were lower in spring, while those of phosphates were lower in summer.

A comparative analysis of the variation coefficients was carried out, i.e. the variation coefficients of every river were calculated with 12 water samples per year available; this value was taken as a reference for a comparison with other variation coefficients when the number of water samplings per year was lower.

A reduced number of water samplings results in the loss of part of information on the water quality. To answer the essential question in which river the number of measurements could be reduced, we used the criterion that the variation coefficients of biogen concentrations obtained using different calculations must be close to each other. The critical value was chosen to be 5%. Analysis results are given in Fig. 5.

Presuming that the critical value does not exceed 5%, the number of mineral nitrogen sampling could be reduced to 8 only in the Šešupė. Phosphate sampling could be reduced to 8 in the Merkys and the Žeimena, to 6 in the Akmena, to 4 in the Neris, Lėvuo and Šešupė.

CONCLUSIONS

1. Multiple regression analysis assessing the intensity of human economic activity and the water yield (debit changes in 1974–2003 and seasonal changes) revealed that in all the study rivers the relation between biogenic substance concentrations and debits on water sampling days and the intensity of anthropogenic activity was statistically reliable. In all the rivers studied, except the Šventoji, a trend of a decreasing nitrogen concentration with the increasing debits on the days of sampling was observed, although no close relation was found. Phosphate concentration did not depend on changes in the debit values.

2. Analysis of the dependence of biogenic substances on the water yield of rivers during two stages of economic activity of different intensity showed that the strongest relation between mineral nitrogen, nitrates and water yield was recorded in the Akmena, the Merkys and the Neris. The correlation coefficient showing the dependence of nitrate concentrations on water yield did not exceed 0.46, while the concentrations of mineral nitrogen went down with a decrease in water yield. The correlation between the phosphate concentrations and water yield was even weaker.

3. Analysis of both mineral nitrogen and phosphate flows revealed that the change in their values taking into account the seasons was similar to the river flow distribution per year. The highest amount of mineral nitrogen was transferred in the autumn–winter season. In the rivers of Southeast Lithuania, the amount transferred in this season was on the average 51.7% of the annual flows, in the rivers of Central Lithuania it reached 51.9%, and in the rivers of Western Lithuania 65.4%. The smallest part falls to the summer season. In summer, flows in the river in the above-mentioned hydrological areas were 13.7%, 13,1% and 7.2 %, respectively. In spring, the flows were 34.6%, 35.0% and 27.4% of the annual value, respectively.

4. Analysis of changes in the coefficients of concentrations of biogenic substances throughout the long period of the research, when the number of water samplings per year varied, revealed that when calculating mineral nitrogen only in the Šešupė water sampling could be carried out only in characteristic months 8 times per year; in the other rivers, the number of sampling could not be reduced. To assess changes in phosphates, 8 annual samplings would be sufficient in the Merkys and the Žeimena, 6 times in the Akmena, 4 times in the Šešupė, the Lėvuo and the Neris.

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LIETUVOS UPIŲ VANDENS TARŠA AZOTO IR FOSFORO JUNGINIAIS SKIRTINGAIS ANTROPOGENINĖS VEIKLOS LAIKOTARPIAIS

Santrauka

Tirta biogeninių medžiagų koncentracijų ir jų kiekių įvairiais laikotarpiais (srautų) kaita 10 upių, esančių skirtingose Lietuvos hidrologinėse srityse, vandenyje. Tyrimų tikslas – analizuojant upių nuotėkio ir vandens cheminės sudėties kaitą per ilgą laikotarpį (1974–2003 m.), atskleisti upių vandeningumo ir biogeninių medžiagų koncentracijų kitimo ryšį, įvertinant Lietuvos upių baseinų fizines-geografines sąlygas bei antropogeninės veiklos pokyčius.

Išnagrinėjus biogeninių medžiagų koncentracijų priklausomybę nuo upių vandeningumo per du skirtingo ūkinės veiklos intensyvumo laiko tarpsnius gauta, kad mineralinio azoto, nitratų ir vandeningumo stipriausias ryšys yra tik kai kuriose (Akmenos, Merkio ir Neries) upėse. Kitų upių nitratų koncentracijų kaitos priklausomybę nuo vandeningumo parodantis koreliacijos koeficientas ne didesnis kaip 0,46, o mineralinio azoto koncentracijos mažėja didėjant vandeningumui. Fosfatų koncentracijų priklausomybės nuo vandeningumo koreliacinis ryšys dar silpnesnis.

Analizuojant tiek mineralinio azoto, tiek fosfatų srautų kaitą, nustatyta, kad mineralinio azoto daugiausiai pernešama rudens–žiemos sezonu. Pietryčių Lietuvos upėse šiuo sezonu pernešama vidutiniškai 51,7% nuo metinio srautų dydžio, Vidurio Lietuvos upėse – 51,9%, o Vakarų Lietuvos upėse – 65,4%. Vasarą srautai upėse pagal minėtas hidrologines sritis sudaro atitinkamai 13,7, 13,1 ir 7,2%. Pavasarį srautai sudarė atitinkamai 34,6, 35,0 ir 27,4% metinio dydžio.

Raktažodžiai: antropogeninė veikla, upių vandeningumas, debitai, biogeninės medžiagos