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Section: Water Engineering

Anthropogenic Activity Impact on the Small River Catchment Water Quality

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Abstract

One of the main river water quality and environmental problems in Lithuania is pollution with biogenic and organic substances. Urban wastewater and diffuse source pollution from agricultural areas are the main sources of river water pollution with biogenic substances. Hydrochemical indicators of tendencies of change for the period of 1992–2010 were analyzed as well as the change of point pollution for the period of 2000–2010. The study included a field study, assessing the impact of point pollution in Šilutė town on the river Šyša water quality. The FYRIS model estimated the change in the impact of general nitrogen on the river Šyša diffuse and point water pollution for the period of 1997–2006. Statistical correlations between the observed concentrations in the water quality and those modelled were made.

Keywords: water quality; surface water; modelling; biogenic substances.

1. Introduction

Global research and analysis of the occurrence and level of water quality problems has shown that the critical region in the world is Central and Eastern European countries. Lithuania also falls within this category; therefore, the following relevant goals of surface water quality assessment arise: water object quality state assessment, surface water quality prediction, regulation, rational distribution, management, introducing measures aimed at reducing water pollution, etc. The relative importance of the different nutrient sources varies greatly between different catchments depending on anthropogenic pressures and discharge [1–3]. Therefore, qualitative and quantitative determinations of nutrients (i.e. concentration and loadings) are required in order to characterize and predict system responses. Rivers are particularly vulnerable due to their proximity to population centres and sensitivity to land use changes [4]. Regional differences in weather and the hydrological regime in catchments together with local variations in nutrient emissions from various point and diffuse sources have a great impact on the accuracy of estimating the riverine loadings [5]. The aim to reduce the N loading to groundwater and marine are as has led to a number of national and international initiatives. In Europe, the European Union has introduced two major directives to mitigate the effects of N emissions to the environment. Firstly, the Nitrates Directive (1991/696/EC) was introduced in 1991, aiming at reducing nitrate water pollution in the Nitrate Vulnerable Zones (NVZs) of Europe. Secondly, the Water Framework Directive (2000/60/EC) was introduced in 2000 with the aim to preserve groundwater resources and all surface waters in a state with only minor anthropogenic interference. As a result, N transport has declined in many streams and rivers in Europe, although an upward trend has been traced in some rivers, primarily in Eastern Europe, due to the recent intensification of agriculture [6]. Recently, various methods have been used in order to calculate pollution loadings and balance in river catchments. River catchment water quality management models can be grouped into two groups, according to the description of impact and result relationship in the model: semi-empirical conceptual models and physical (process-oriented) dynamic models [7]. The number of globally applied conceptual and physical models is very high. Shoemaker, Dai & Koenig [8] describe 33 catchment-type models applied in the USA.EUROHARP project report [9] describes 8 models applied in Europe. A number of models are also described in scientific articles [10–13]. The dynamic FYRIS model of the balance of nitrogen and phosphorus pollution was designed by Kvarnas [14] for the river Fyris in Sweden. Later this model was improved many times until in 2008 a FyrisNP 3.1 version was approved, which is suitable for the application in order to calculate the pollution source identification in medium and large river catchments. The aim of this paper is to analyse and evaluate the river Šyša water quality that is determined by point and diffuse pollution, and to carry

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out the analysis of the change of nitrogen and phosphorus balance elements in the river Šyša catchment applying the Fyris model.

2. Research object and data

The paper analyses the river Šyša catchment. It belongs to the Western Lithuanian hydrological area. The average annual catchment hydro module is approximately 12 l/s km^2, the average yield in Šyša mouth is approximately 4.7 m^3/s. The watercourse length of the river is 56.9 km and the total catchment area covers 391.5 km^2. The river concerned is attributed to the Nemunas river catchment and the sub-catchment of Nemunas minor tributaries (including Nemunas). Economic activity in the river Šyša catchment varied in the period of 2000–2010; some production companies went bankrupt and new ones appeared instead. According to the data of the Environmental Protection Agency, in 2000–2010 there were 25 point pollution sources present, their gully being the river Šyša.

2.1. Methods of Physical and Geographical Characteristics Evaluation

In order to evaluate physical and geographical characteristics, the influence of deposits and agricultural areas on the distribution of catchment within the catchment of the river Šyša was assessed. For this purpose, the ground infiltration and agricultural area permeability coefficients were used as well as the vectoral data base of the cosmic view map of the Republic of Lithuania of the scale of 1:50 000 [15] and the Lithuanian relief cadastre data [16].

2.2. Field Study Methods

Having analysed the point pollution data collected by the Environmental Protection Agency during the period of 2000-2010 in the Šyša catchment, it was noticed that the majority of point pollution dischargers are located in Šilutė town. In order to evaluate what impact the wastewater released at the point pollution sources in Šilutė town has on the Šyša river water quality and to learn more about the actual concentration of polluting substances in the river water before and past the dischargers, a field study has been carried out. The largest pollution sources located in Šilutė town were selected for the study. These were Ltd. "Šilutės vandenys", urban wastewater treatment company, AB "Biofuture" drainage well system and Ltd. "Šilutės vandenys" Macikai urban wastewater treatment company. The measurement was carried out in January, 2011. During the research, 12 water samples were taken in the river.

2.3. The Application of the FYRIS Model in Evaluating Point and Diffuse Pollution

In order to evaluate the impact of the sources of pollution with general nitrogen on the river Šyša catchment, the conceptual FYRIS model was chosen. This model allows for sufficiently precise evaluation of river water quality, identification of the impact of point and diffuse pollution on the river water quality as well as the evaluation of the amounts of a polluting substance from point and diffuse pollution objects. This model works by using average monthly data (water quality, temperature, yield) and average annual data (point and diffuse pollution). The process in the model is divided into several stages. Firstly, the catchment concerned is divided into sub-catchments with water quality observation stations in them. Then point and diffuse pollution sources are identified in the sub-catchments concerned. The last stage consists of the calibration of the model and data submission.

3. Research Results

3.1. Influence of Physical and Geographical Characteristics on Catchment

The evaluation of the deposit distribution in the river Šyša catchment showed that sand makes 43% of all catchment area, glacial loam makes 53%, sandy loam and clay make 2% each. Sandy ground and that of glacial loam prevail in almost the entire territory where Šyša flows (including below it). The establishment of agricultural area distribution in the catchment revealed that from the territorial aspect, arable land dominates, taking up 77.9% of all catchment area. It prevails throughout the entire catchment area. Other agricultural areas are not equally distributed in the catchment: forest areas are located in the northern part of the catchment and take up 16.7% of all catchment area, while urbanized territory covers 5.39%. Having combined the maps of prevailing deposits and agricultural areas (Fig. 1), it shows that the type of soil basically determines the land use; namely, arable land areas prevail in the fertile territories of glacial loam as well as in the sandy areas characterised by good infiltration features. Sandy soils and glacial loam prevail throughout the entire Šyša catchment.

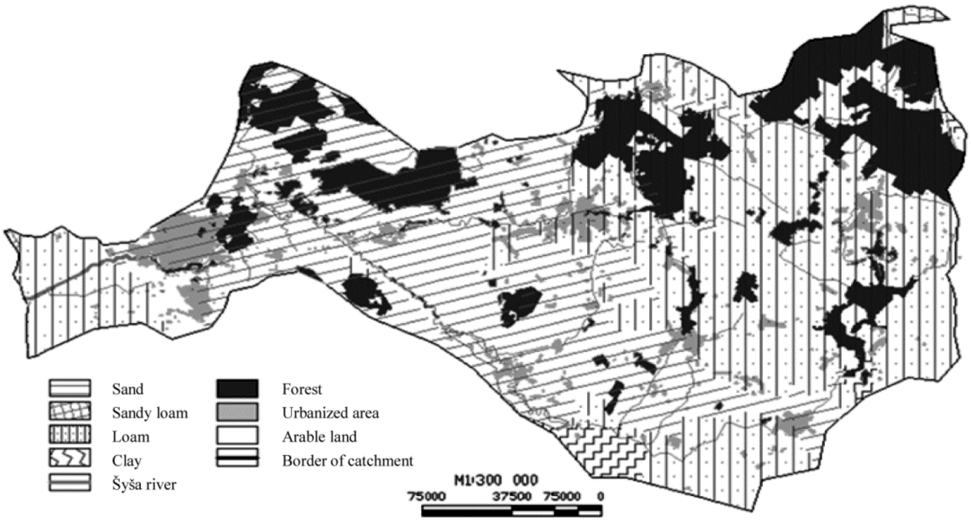

Fig 1. Deposit and agriculturalarea distribution in the territory of the Šyša catchment [9]

The evaluation of the dependence of infiltration on various permeability features of the ground revealed that the greater the ground permeability, the greater amount of precipitation could soak in it (the filtration speed was higher). The calculations carried out showed that out of the maximum precipitation amount during one downpour (during the period of 1979–2010, the highest level of precipitation was registered on the 26th of July, 2007) as much as 94.66% of precipitation is soaked in and only 5.34% remain forming surface catchment.

Therefore, the most part of precipitation goes down to the groundwater, melting various chemical substances, and later it reaches surface waters too.

3.2. Water Quality Evaluation in the River Šyša in 1992–2010

One of the problems of river water quality is its pollution with biogenic and organic substances. The amount of biogenic substances in river water is shown by general nitrogen and general phosphorus concentrations. The majority of general nitrogen composition consists of nitrates, the other component being ammonium nitrogen that is toxic to aqua fauna. The main biogenic sources of river water pollution are diffuse agricultural pollution and urban wastewater. The concentration variation of these substances depends on biochemical processes in the water. Higher biogenic concentrations may result in eutrofication in slow rivers, which causes ecological conditions in water bodies. In order to reach good ecological condition, it is necessary to reduce the river water pollution with these materials. Following the EU requirements, the river water quality is determined according to physical, chemical and biological parameter characteristics.

The data presented in Table 1 shows that the ecological condition in the river Šyša is improving; however, not according to all chemical indicators. The average concentration of nitrate nitrogen and general nitrogen fall within good ecological class. However, BOD_7, NH_4–N, PO_4–P and P_b are still attributed to the average ecological class, despite improvement noticed. The chemical composition of a river is a reflection of the natural conditions in the entire catchment as well as human economic activity. Water chemical composition is determined by several interrelated factors. Therefore, statistical analysis was carried out in order to evaluate the relation between various concentrations determining the river Šyša water quality.

Correlation coefficients between water quality indicators and their reliability were calculated (Table 2). Correlation coefficient values vary from the absence of correlation (statistically unreliable values) to the correlation of average strength. Water quality concentrations mainly depend on the amount of dissolved oxygen and water temperature, since the correlation between the two is of average strength.

The amount of oxygen dissolved in the water is one of the most important indicators when analysing the river water quality. The most oxygen reaches the water from the atmosphere. As well as during photosynthesis taking place in the water, when organisms containing chlorophyll omit oxygen when in the light. The correlation between water temperature and dissolved oxygen concentration is of average strength (r = 0.63), which is the strongest correlation of all water quality concentrations.

Ammonium nitrogen (NH_4–N) in most cases comes from untreated household or animal husbandry wastewater and the main nitrate nitrogen source is diffuse pollution. Ammonium nitrogen concentrations during the period concerned did not follow a stable variation pattern. Until the year 2000 the concentrations of this compound exceeded the maximum allowable concentration (MAC) (0.78 mg/l) by 45% but later they decreased significantly down to 8% and the minimum concentration would only reach 0.3 mg/l. The pollution with nitrate nitrogen (NO_3–N) of the water of the river Šyša is low. The maximum nitrate nitrogen value was determined in March, 1998 (3.8 mg/l).The river is not highly polluted with nitrogen substances.

Table 1. Ecological class evaluation in the river Šyša according to physical and chemical quality element indicator classes

Date	BOD_7	NH_4–N	NO_3–N	PO_4–P	N_b	P_b
Good ecological condition indicator classes	2.3–3.3	0.1–0.2	1.3–2.3	0.05–0.09	2.0–3.0	0.1–0.14
1992–1996	very poor	poor	good	average	average	poor
	7.71	1.13	1.42	0.15	5.43	0.26
1997–2001	poor	poor	good	average	average	average
	5.57	0.65	1.73	0.10	3.11	0.20
2002–2007	average	average	very good	average	good	bad
	4.34	0.28	1.29	0.17	2.20	0.27
2008–2010	average	average	very good	average	good	average
	4.21	0.30	1.24	0.12	2.07	0.21
1992–2010	bad	average	good	average	good	bad
	5.45	0.58	1.43	0.14	2.75	0.24

Table 2. Correlations between water quality concentrations

	Dissolved oxygen	Temperature	BOD_7	NH_4–N	NO_3–N	NO_2–N	PO_4–P
Dissolved oxygen	–	–0.63	–0.40	–0.34	0.41	–0.43	–0.24
Temperature	–0.63	–	0.26	–	–0.55	0.43	0.14
BOD_7	–0.40	0.26	–	0.54	–0.14	0.22	0.16
NH_4–N	–0.34	–	0.54	–	–	0.33	0.25
NO_3–N	0.41	–0.55	–0.14	–	–	–	–
NO_2–N	–0.43	0.43	0.22	0.33	–	–	0.18
PO_4–P	–0.24	0.14	0.16	0.25	–	0.18	–

Note: Hyphens indicate statistically unreliable values (p> 0,05).

Seasonal changes are characteristic of all forms of nitrogen compounds; therefore, ammonium and nitrate nitrogen concentrations in the water of the river Šyša decrease significantly during the warm period, as vegetation processes take place, while they can be almost completely used up when intensive photosynthesis is taking place. Prior to the year 1998, significant excess of the MAC of ammonium nitrogen is observed during spring, summer and autumn months (Fig. 2). The increase of nitrate nitrogen concentrations takes place in winter and spring; however, the concentrations rarely exceed the allowable limits.

The nitrate nitrogen (NO_2–N) concentrations during the period concerned exceeded the norm by 46%. The average nitrogen concentrations in the form of nitrates exceed the MAC (0.03 mg/l) in all years of the study. Extremely high levels of pollution in the water of the river Šyša were reached in the period of 1995–2000 (0.042–0.21 mg/l), and the value of nitrite concentration in May, 1998, was 0.21 mg/l, which is 7 times higher than the MAC. Having compared the data of the years 1992–2010, a significant trend of the decreasing concentration of pollution with nitrite nitrogen can be noticed. Although the concentration of nitrite nitrogen is decreasing significantly, the river is not attributed to a good ecological class due to human activity. Nitrite nitrogen concentrations of a good ecological class are exceeded by 46%. In cases of the majority of rivers investigated, the nitrite nitrogen values increase during the cold period; however, in the river Šyša the increase from 0.056 to 0.074 mg/l is observed during the summer period. Particular change in NO_2–N is noticed almost every year when in summer the concentrations of nitrite nitrogen exceed the MAC three times. The greatest increase in the concentrations of NO_2–N is noticed in the years 1995–1999. The average for nitrite nitrogen is 0.04 mg/l. During the cold period, the concentrations decrease significantly down to only 0.001 mg/l. While analysing the concentrations of nitrite nitrogen in the river concerned, quite a significant decrease in concentrations can be noticed in recent years.

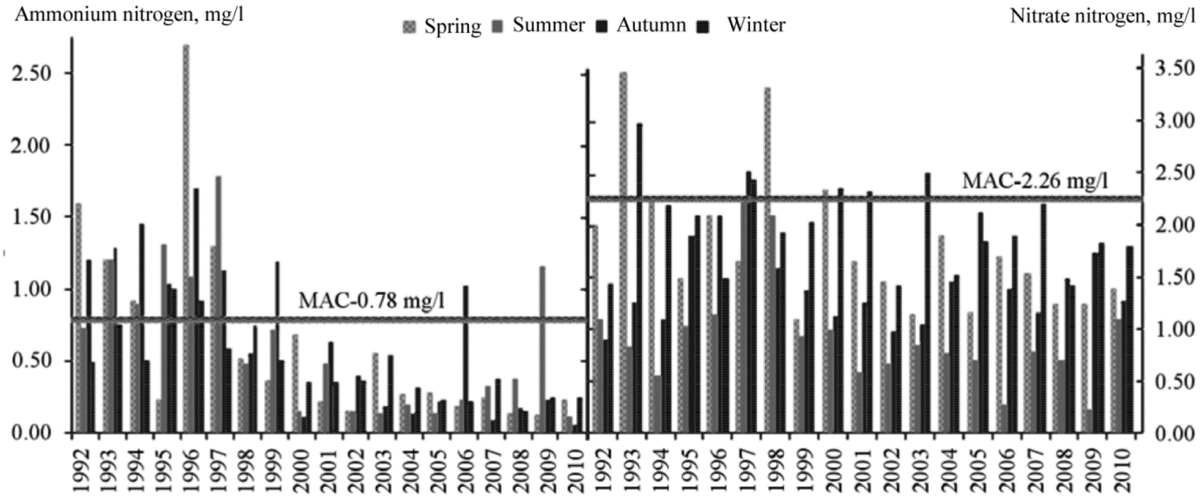

Fig 2. Seasonal change dynamics of ammonium nitrogen and nitrate nitrogen in the water of the river Šyša during the period of 1992–2010

Phosphorus is one of the main biogenic substances determining the productivity of a water body. It is not highly soluble and only small amounts of it reach water bodies. Phosphorus concentrations during summer and spring are significantly lower than those during the cold period. This can be explained by active sedimentation and vegetation. However, in the catchment concerned, a significant increase of phosphorus concentration is noticed in summer and autumn, i. e. from 0.085 to 0.314 mg/l. The phosphorus concentration values in the river Šyša vary between 0.002 and 3.79 mg/l. The average annual phosphorus concentration constantly exceeds the MAC (by up to 48%), and sometimes even more significantly. Phosphorus concentrations are particularly high during the warm period of the year. The largest amount determined (3.79 mg/l) in November, 2005, exceeded the MAC (0.065 mg/l) 57 times. Although phosphorus is the main biogenic nutrient for plants, its change in the river water varies. The amount of phosphorus increases during the period of vegetation. Particularly high phosphorus concentrations in Šyša water were observed in 2005–2009. Due to excessive phosphorus concentrations, the river in question does not have good ecological state ($\leq$ 0.065 mg/l), where point pollution is absent and that great change in the amount of phosphorus compounds is not characteristic.

3.3. Water Point Pollution in the River Šyša Catchment

River water quality is mostly determined by human economic activity. In order to distort the balance of natural factors to the least extent possible, the European Council has adopted various documents that oblige controlling human economic activity that influences river water quality.

Economic activity in the river Šyša varied during the period of 2000–2010; some companies went bankrupt, new ones appearing instead, others were forced to suspend their activity due to stricter environmental requirements. Nevertheless, the urbanized area, including small villages and the town of Šilutė itself, expanded in the catchment concerned. According to the data given by the Environment Protection Agency (Lithuanian River... 2000–2010), the change of organic and biogenic substances was analysed during the period of 2000–2010 (the beginning of the period for the data analysis was chosen due to unreliable data from earlier years). The number of companies influencing water quality and the surrounding environment changed. At the beginning of the period concerned, the number of dischargers was 6 and only one discharger dealt with untreated wastewater. The number did not exceed 11 until the year 2004. The biggest number of point pollution dischargers was present in 2010 (20 units) and as many as 12 of them did not contain wastewater treatment facilities (WTF).

The amounts of the measured parameters of point pollution in wastewater released varied greatly during the period of 2000–2010. At the beginning of the period concerned, the amounts of the measured parameters of wastewater released were not high. However, the actual BOD_7 loadings made 37%, and those of the materials in suspension made 42%, which is the biggest number of loadings during the period concerned. The amounts of loadings almost did not change till the year 2009; however, the accident that took place in Šilutė wastewater treatment facilities caused a significant increase in BOD_7 (72.45 t/year) and general phosphorus loadings (2.45 t/year). That year the amount of wastewater released by a Ltd. "Biofuture" was too high, which resulted in a breakdown in the wastewater treatment facilities and wastewater was released without mechanical treatment.

At the beginning of the period in question, the concentrations of general nitrogen and phosphorus made 22–14% and a decrease is noticed until the year 2010. In 2008 the concentrations were only 3–2%. The concentrations of general nitrogen and phosphorus in 2000–2010 were measured in two companies, namely, Ltd. "Šilutės vandenys" urban WTF and Ltd. "Junkada" (this company is not operating anymore) surface WTF. The river is polluted with general phosphorus and nitrogen mainly from Šilutė wastewater treatment facilities that release from 6.5 (in 2008) to 29 (in 2001) tN/year and from 0.7 (in 2007) to 5.2 (in 2001) tP/year. The highest concentrations were registered in the years 2000, 2001 and 2009 in LTD. "Šilutės vandenys". High phosphorus concentrations were observed in 2000 and 2009 too. Positive changes occurred following the reconstruction of the WTF, which increased wastewater treatment efficiency. However, in 2009 the concentrations increased up to 21–12%, which was the result of the accident in Šilutė WTF.

3.4. 3.4 The Impact of Šilutė Town Point Pollution on the River Šyša

During the recent years, the river Šyša suffered from ecological accidents and point pollution sources. The first extreme situation in 2007 was registered on the 4th of March when the death of fish was registered in the river Šyša when 22.500 m^3 of slurry got into the environment following an accident in Ltd. "Grabupėliai" when the slurry reservoir embankment was broken. On the 23rd of June, 2007, 18.8 m^3 of brewer's grain was spilled into the river Šyša through the rainwater collection system discharger from the reservoirs in brewer's grainstoring site belonging to Ltd. "Biofuture". On the 26th of June the death of fish was registered in the river Šyša.

On the 3rd of July, 2009, the technological wastewater treatment process was completely disturbed due to the entry of Ltd. "Biofuture" wastewater with high concentration of polluting materials into Šilutė urban wastewater treatment facility; as a result, only mechanically treated wastewater was released to the river Šyša until the beginning of August. On the 11th-16th of September, 2010, fish and other hydrobionts also died continuously due to a leaking facility in the Ltd. "Biofuture" that released industrial alcohol production liquid into the environment.

Therefore, having carried out field study in January, 2011, i.e. taking samples, the results showed that the water quality of the river Šyša is greatly influenced by phosphate phosphorus compounds, the concentrations of which exceeded the norm in the samples from the entire river section analysed. The least analysed territory was polluted with ammonium nitrogen compounds and the MAC excess was registered in one location only. Meteorological conditions also have a great impact on the water quality, since dissolved oxygen concentrations exceeded the MAC only in several locations throughout the territory analysed. The MAC excess for NH_4–N is noticed up to 3 times, closer to the lower reaches only. This is influenced by the location of the sample since the concentration increases in a meander due to weaker plant assimilation. Further in the river Šyša the NH4–N concentration decreases but remains the highest of all samples taken. This was influences by the largest Šilutė WTF "Šilutės vandenys". While analysing the impact of the dischargers on the water quality in the river Šyša, it was established that the majority of ammonium nitrogen came from "Šilutės vandenys". There 0.62 mg/l were registered. According to the ecological state class, the river section falls within the class of average state. While analysing the concentrations of nitrite nitrogen (NO_2–N) in the river section in question, the MAC (0.03 mg/l) excess is noticed. The concentration of nitrite nitrogen exceeded the 0.03 mg/l in almost the entire section. During the winter season, the concentration changed from 0.02 to 0.09 mg/l. Figure 3 shows significant increase in the concentration of NO_2–N; however, the increase decreases rapidly down the stream.

The fact that the NO_2–N concentration increases in a short distance due to point pollution, shows that the water plants assimilate nitrites even in winter. The greatest increase was noticed by the LTD. "Šilutės vandenys" discharger and the location of sampling might have influenced the result. The sample was taken from a small bay where the river water is dead. A decrease in the amount of dissolved oxygen is noticed in the same location. The dissolved oxygen concentration in the samples taken upstream from the first discharger exceeds the MAC (9 mg O_2/l).

All samples taken in the river Šyša section exceeded the phosphate MAC (0.065 mg/l). Such increase is also observed in the analysed part of the river Šyša. The highest concentrations are registered upstream from the Šitulė town, by the biological wastewater treatment facility of Macikai social care institution. The MAC was exceeded up to 26 times, which was influenced by the melting snow since arable land and cemetery prevail there. 500 m from the point pollution discharger, the amount of phosphate phosphorus decreased by 2.5 times. In the sampling location, the river was surrounded by forest; therefore, the amount of diffuse pollution also decreased. The situation upstream from the AB "Biofuture" dischargers was similar; however, the increase was caused more by the melting snow. Even greater decrease in the PO_4–P concentration was noticed by the reaches of Šyša, down to 0.07 mg/l. According to the ecological state class, this river section is of very poor state.

3.5. Mathematic Modelling of the Pollution of the River Šyša Catchment with General Nitrogen

The FYRIS conceptual water quality model calculates the general nitrogen concentrations in a river. The river Šyša catchment, located in the western Lithuania, was chosen for the study, which belongs to the Nemunas minor tributaries (including the river Neris) sub-catchment. The catchment was divided into two sub-catchments, according to water quality observation stations (Upstream and downstream from the Šilutė town) (Table 3), which allowed for more detailed evaluation of point and diffuse pollution impact on the water quality in the river.

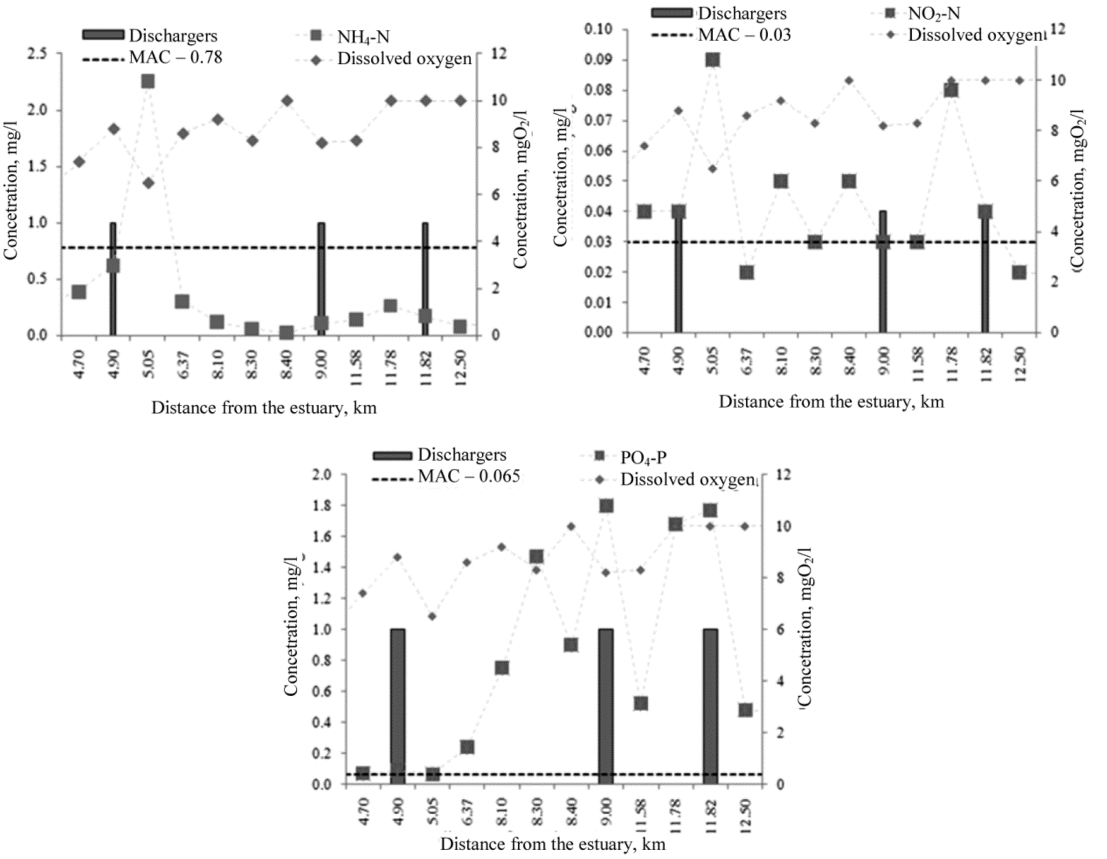

Fig 3. The change of ammonium nitrogen, nitrite nitrogen and phosphate phosphorus concentrations in the section of the river Šyša

Arable land areas cover most of the territory in both sub-catchments, i.e. 52.80–43.31%. Grazing land and forests prevail in the first sub-catchment (22.20%and 20.42%), and as much as 32.37% in the second one is covered by cities and built-up territories. Having prepared and organized the input data, the model of the river Šyša catchment was designed. The modelling covers the period of ten years (1997–2006). When applying the FYRIS model, first, calibration was carried out by changing empirical coefficients c_0 and *kvs*. The calibration results showed that the efficiency coefficient reached 0.60 and the correlation coefficient was 0.78, when c_0 was 0.99 and *kvs* was 9.47, which indicates strong correlation between the concentrations observed and those modelled.

Table 3. Characteristics of the sub-catchments analysed

River observation location	Sub-catchment area, km^2	Area distribution according to the use, km^2 and % of sub-catchment area				
		Arable land	Grazing land	Forests	Water bodies	Urban and built-up territories
Šyša, upstream from Šilutė	356.92	184.87	79.23	72.89	0.93	19.00
		52.80	22.20	20.42	0.26	5.32
Šyša, downstream of Šilutė	34.60	14.98	6.42	1.85	0.14	11.20
		43.31	18.56	5.35	0.41	32.37
Total of the Šyša catchment	391.52	199.85	85.65	74.75	1.07	30.20
		51.05	21.88	19.09	0.27	7.71

Statistical calculations that were carried out showed strong linear correlation between the general nitrogen concentrations observed and those modelled. A weaker correlation was observed in the river Šyša downstream of Šilutė, which could have been caused by the fact that higher concentrations were registered there due to a LTD. "Šilutės vandenys" discharger present nearby the measuring station. This prevented nitrogen concentrations from purifying during the accidents when the concentrations were high. When analysing pollution loadings formed in the sub-catchments, point pollution data gaps were inevitable. General nitrogen concentrations in the river Šyša catchment were measured in two companies only, although other companies are also likely to release it. This could influenced the model results, pollution evaluation inaccuracies may occur, and it may influence the precision of the model results.

While analysing the changes in the point pollution loadings of general nitrogen in the river Šyša catchment, it was established that the highest loadings were formed in the river Šyša upstream from Šilutė.

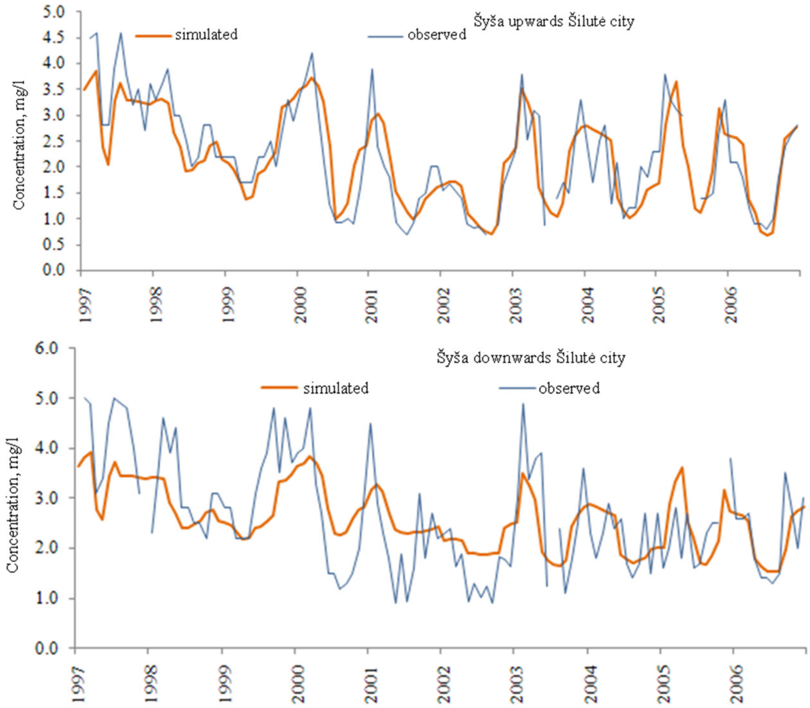

Fig. 4. General nitrogen concentrations observed and those modelled in the river Šyša monitoring stations

It is estimated that the largest loadings come from arable land areas. And the river Šyša downstream of Šilutė is mostly polluted from point pollution sources. When analysing the changes in the river Šyša loadings from all pollution sources present in the Šyša catchment, it was established that the biggest loading was in 1997 (577 t a year). Later the pollution loadings decreased and in 2002 the smallest loading of general nitrogen in the period concerned was registered (162 t a year). The average multiannual general nitrogen pollution loading calculated in the river Šyša catchment was 323 t a year. When analysing the entry of phosphorus from various pollution sources to the river Šyša catchment in more detail, it was established that the greatest part of phosphorus came from arable land areas (92.7 %), while the percentage for grazing lands was 5% and for forests it was 1.3%. Only 1.1 % reached the catchment from wastewater treatment facilities and built-up territories (Table 4).

Table 4. Nitrogen (in tons) entering from various sources during the period concerned

River observation location	Arable land	Grazing land	Forests	Urban and built-up territories	From discharger WTF	Total
Šyša, upstream from Šilutė	2618.49	140.28	37.75	9.84	0.00	2806.35
Šyša, downstream of Šilutė	21.22	1.14	0.10	0.58	19.64	42.67
Total of the Šyša catchment	2639.71	141.41	37.84	10.42	19.64	284.02

Arable land covers approximately 51.05% of the territory in the river Šyša catchment; therefore, the farming culture and land cultivation and use determines the environment and water pollution. The modelling results showed that the largest source of pollution in general nitrogen in the Šyša catchment are arable land areas and point pollution. During the period concerned, 2659.34 t of general nitrogen was washed out from them. With the help of the model, it was established that the largest amount of nitrogen enters the river Šyša catchment upstream from Šilutė from arable land areas, namely, 2618.5 t., since around 52 % of the sub-catchment area is covered by arable land territories where intensive farming takes place, while forests that could reduce the surface catchment cover only 20%. The largest amount of general nitrogen reaches the river Šyša in its sub-catchment downstream of Šilutė town from the arable land (212.2 t) and point pollution sources (196.4 t), which makes 96% of all general nitrogen in the sub-catchment. It can be presumed that the general nitrogen that enters the river Šyša in its sub-catchment downstream of Šilutė town comes from point pollution sources since here wastewater from Šilutė urban wastewater treatment facility is discharged.

Next to other results needed for water quality management, the FYRIS model allows calculating the general nitrogen retention in separate sub-catchments. The modelling results showed that during the period concerned, the largest amount of general nitrogen was contained before the section at the river Šyša, downstream of Šilutė town monitoring station (0.81). In this sub-catchment, water bodies cover a large territory since the width of the river here varies from 10 m to 20 m. In the river Šyša upstream from Šilutė town, the largest amounts of pollution in the entire catchment territory accumulate.

The modelling results clearly indicate the sources of water pollution in the river Šyša, they allow calculating point and diffuse pollution loadings and evaluate the efficiency of potential environment protection measures.

4. Conclusions

The analysis of the river Šyša water quality data for the years 1992–2010 showed that according to a number of ecological indicators, the river is of average or poor state. The biogenic substance concentrations (in per cent) in the river Šyša often exceed the MAC. The highest concentration excesses observed are the following: BOD_7–47%, NO_2–N–43%, PO_4–P–42% and general phosphorus as much as 76%.

The largest amount of polluters is released into the Šyša catchment from the urban wastewater treatment facility LTD. "Šilutės vandenys". Of general loadings in the catchment, as much as 96% are nitrogen and up to 76% are BOD_7, materials in suspension and general phosphorus. This is the main point pollution source in the river Šyša catchment; therefore, its operation efficiency and equipment maintenance have great influence on the water quality.

The loadings of household wastewater dischargers show a reduction trend; however, the amount of untreated wastewater released into the Šyša catchment grows every year. The largest amount of household wastewater was discharged in 2001 (BOD_7 was 136.79 t/year), as well as in 2009 following the accident (BOD_7 was 58 t/year).

In Šilutė town, a point pollution source affecting the river Šyša water quality was identified. The field study data showed it by indicating that it is the MAC norms of nitrite nitrogen and phosphate phosphorus that are exceeded to the largest extent (78–100%).

With the help of the FYRIS model, it was established that the Šyša catchment is mostly polluted from arable land areas (92.7%). In order to reduce pollution loadings, either arable land areas should be reduced, or the regulations of farming and land use should be stiffened.

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