Aplinkos tyrimai, inžinerija ir vadyba, 2010. Nr. 3(53), P. 5-12 *ISSN 1392-1649*
Environmental Research, Engineering and Management, 2010. No.3(53), P. 5-12

Pollution of the River Venta within the Territory of Kuršėnai Town

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(received in June, 2010, accepted in September, 2010)

The impact of Kuršėnai town on the pollution of the river Venta and the effect of biogenic substances on the mass of phytoplankton are dealt with in the paper. Samples were taken and registration of the indicatory aquatic plants was carried out in three places of the river, i.e. upstream Kuršėnai, in the centre of the town and downstream Kuršėnai. Concentrations of biogenic substances (compounds of total soluble phosphorus and non-organic nitrogen) and organic substances were measured. Their effect on phytocenosis was estimated by measuring the concentration of chlorophyll *a* and by identifying indicator plants in the river.

The research has shown that large amounts of phosphorus enter the river in this territory. The average concentration of total soluble phosphorus upstream Kuršėnai (0.069 mg l^{-1}) does not exceed the maximum permissible concentration (MPC), whereas downstream Kuršėnai it is twice higher (0.135 mg l^{-1}) and thus exceeds the permissible limits.

The increased concentration of chlorophyll (10.49 µg l^{-1} downstream in comparison to 9.11 µg l^{-1} upstream Kuršėnai), plenty of water plants, their varietal diversity and indicatory features downstream Kuršėnai indicate more intensive water eutrophication in comparison with the state of the Venta river upstream Kuršėnai. Chlorophyll *a* concentration in the places of measurement correlates with the concentration of the total soluble phosphorus.

Nitrate concentrations are higher downstream Kuršėnai than upstream (3.44 mg l^{-1} in comparison with 2.27 mg l^{-1}) and exceed the MPC (2.3 mg l^{-1}). Concentrations of nitrites and organic compounds are not subject to seasons and in most cases exceed permissible limits within the entire examined section of the river (app. 15 km).

The excess amount of nitric compounds has been measured in the examined section of the river: the ratio of total soluble nitrogen and phosphorus is 45:1 upstream Kuršėnai and 27:1 downstream Kuršėnai, while optimum conditions to breed and develop the biota are when the ratio is 16:1. Relatively higher concentrations of phosphorus after the river passes the town are the reason of the increased eutrophication.

Key words: *Kuršėnai catchment of the river Venta, river pollution, biogenic substances, algae, chlorophyll a, yield.*

1. Introduction

Development of industry and agriculture, growth of the people's needs result in more and more pollutants being poured into natural waters. Among all surface waters rivers are the most polluted, since partly treated or untreated sewage enters them. Rivers are mainly contaminated with organic and biogenic substances, especially with nitric compounds, and large quantities of these substances do harm to river biocenosis.

All the rivers of Lithuania carry their waters to the Baltic Sea. One of the most relevant problems of the Baltic Sea is eutrophication which is stimulated by biogenic substances, i.e. by nitric and phosphorus compounds coming in large quantities by rivers (Aplinkos ministerija 2008). The impact of biogenic substances on the mass of phytoplankton is often estimated by measuring the concentrations of chlorophyll *a* (Kelli and Whitton 1998; Figueroa-Nieves et al. 2003; Räike 2003; Neal et al. 2006), although the development of the algae besides biogenic substances is effected by a number of other factors, including the nature of water flow as well as water turbidity.

The Venta is one of the most water-abundant rivers of the Baltic Sea basin in Lithuania. Although according to the state monitoring program the general ecological state of this river is rated as "good", the anthropogenic pollution from cities and villages located close to the river and its tributaries impedes the slow processes of self-cleaning (Stålnake et al. 2003; Kutra and Berankienė 2006).

The aim of this research is to evaluate both the impact of Kuršėnai town on the pollution of the river Venta and the effect of biogenic substances on the mass of phytoplankton.

2. Research Methods

The object of the research is the river Venta which flows across Kuršėnai town. Samples were taken and registration of the plants was carried out in three places of the river, i.e. upstream Kuršėnai, in the centre of the town and downstream Kuršėnai, near the village of Šilėnai (Fig. 1).

The length of the river channel between the sides of the sampling locations is app. 15 km. There is a dam below the central place of sample taking. The depth of the channel upstream Kuršėnai and in the town centre is app. 2 m, and downstream Kuršėnai it amounts to 1.2 m. Several tributaries enter the river in the examined part of the river: the stream Šūdakojis flows into the river upstream Kuršėnai; downstream the town centre there is the Urdupis, sewage from the town water treatment plant enters whereof, and the stream Kumulša. The major part of this tributary is dammed and together with the stream Ringė makes artificial pond Pakulmušiai. The distance between the pond and the river Venta down the flow is app. three kilometres.

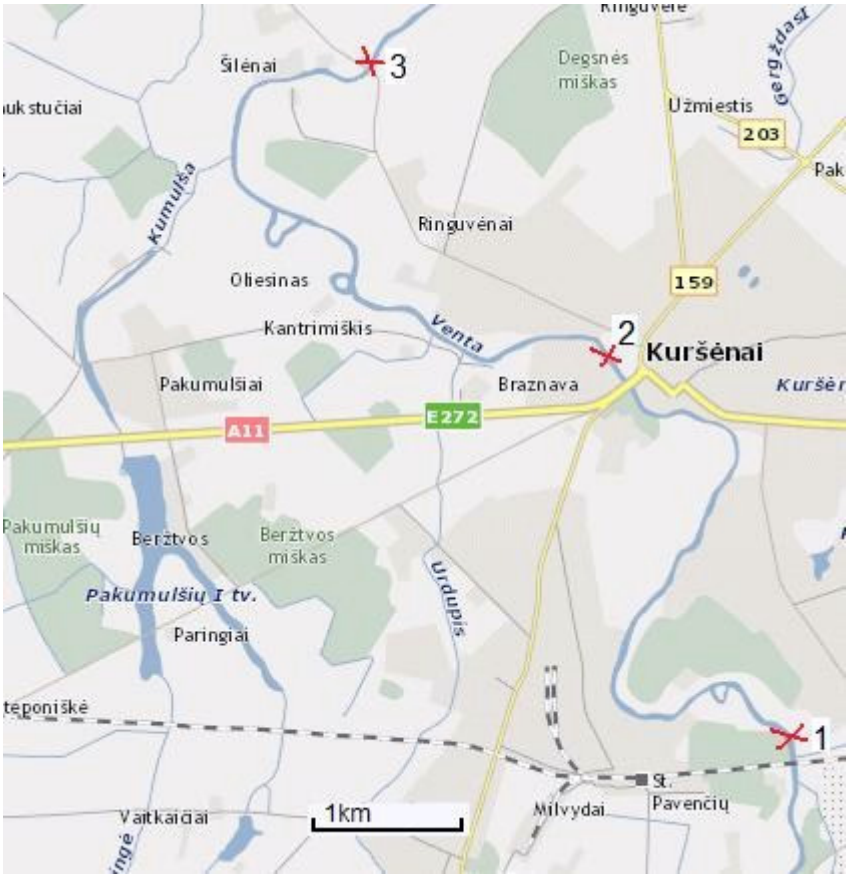


Fig. 1. Kuršėnai map and places of sampling: 1 – upstream Kuršėnai, 2 – town centre, 3 – downstream Kuršėnai

The area of the Venta catchment within the territory of Kuršėnai town is approximately 933 km^2; average annual discharge is 6.25 m^3 s^{-1} (Gailiušis et al. 2001).

Experimental research was carried out from July 2007 until October 2008, every month, except January and February. Concentrations of biogenic substances, total soluble phosphorus, nitrates, nitrites and

ammonium, as well as organic substances and chlorophyll *a* were measured. Water pH, electric conductivity and temperature were measured as well.

The quantities of biogenic substances and chlorophyll *a* in the examined water were measured according to the normative documents of the Ministry of Environment by applying a spectrometric method using a GENYSIS 10 spectrophotometer. Water pH and electric conductivity were measured with WTW InoLab pH 720 and WTW InoLab Cond 720 meters. Phosphorus was measured in the acidic medium by producing antimony-phosphomolybdate complex which is reduced to blue-coloured molybdenum complex by ascorbic acid (LR Aplinkos ministerija 2006). Ions of nitrate were determined by producing a yellow-coloured compound in the alkaline medium in reaction with sulphosalycilic acid (LR Aplinkos ministerija 2005). Nitrites were detected by producing a crimson azo dye, when sulphanilic acid diazotised in acidic medium reacts with 1-naphthylamine (Aplinkos ministerija 1994). Ammonium ions were detected by producing a blue-coloured compound in reaction with salicylate and hypochlorite ions and by applying catalyst sodium nitroprusside (LR Aplinkos ministerija 2001). The concentration of organic substances was measured by the method of chemical oxygen demand (COD_{Cr}) (LR Aplinkos ministerija, 2006 a). The amount of chlorophyll *a* in phytoplankton was measured spectrometrically (LR Aplinkos ministerija 2004) by filtrating algae and other suspended substances of the water sample through a membrane filter and by extracting pigments with 90% acetone.

3. Research Results and Discussion

The level of chlorophyll *a* was measured in October and November, 2007 and from April until October, 2008. Samples were taken in two places, upstream and downstream Kuršėnai. The average concentration of chlorophyll *a* upstream Kuršėnai was 9.11 μg l^{-1}, downstream Kuršėnai it was 10.49 μg l^{-1}, thus the growth of the chlorophyll *a* concentration after the river crossed the town was app. 15%. The largest amounts of chlorophyll were found in September, 2008, when the water temperature was 17°C, i.e. the highest water temperature that year (Fig. 2).

According to linear regression analysis the concentrations of chlorophyll *a* downstream Kuršėnai correlate with the water temperature (p=0.02) (Fig 3 b). Upstream Kuršėnai, due to the more complex nature of the river flow before the dam (Neal et al. 2006), there is no association between the concentrations of chlorophyll *a* and the water temperature (p=0.18) (Fig. 3 a).

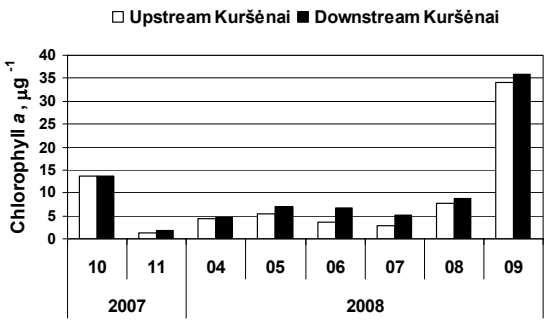
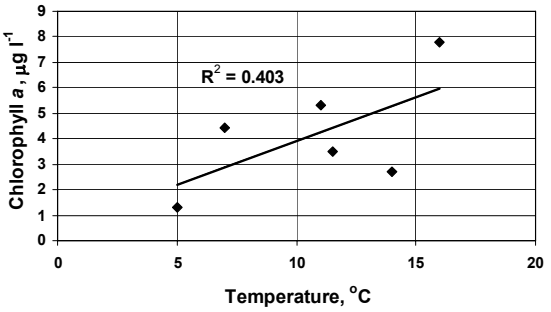


Fig.2. Changes in chlorophyll a concentration in Kuršėnai basin of the river Venta

Concentration levels of the total soluble phosphorus were measured in three places, i.e. additional samples were taken in the centre of the town (Fig. 4). The average concentration of phosphorus upstream Kuršėnai was 0.069 mg l^{-1}, and downstream Kuršėnai it was 0.135 mg l^{-1}, thus an increase in the phosphorous concentration was about 50%. The concentration level corresponds to the results of monitoring of the Venta downstream Mažeikiai carried out by the National Environmental Protection Agency in 2007 – 2008.



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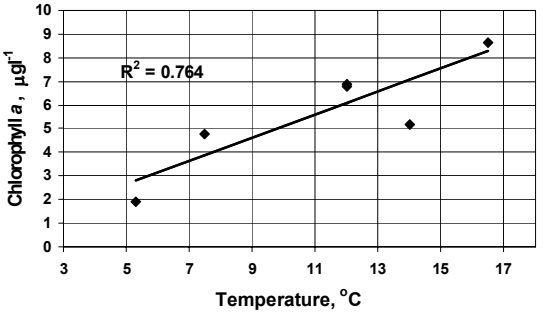


b)

Fig. 3. Dependence of the chlorophyll a concentration on the water temperature: a) upstream Kuršėnai, b) downstream Kuršėnai

The average annual concentration of total soluble phosphorus according those measurements was 0.071 mg l^{-1} (Aplinkos apsaugos agentūra 2010).

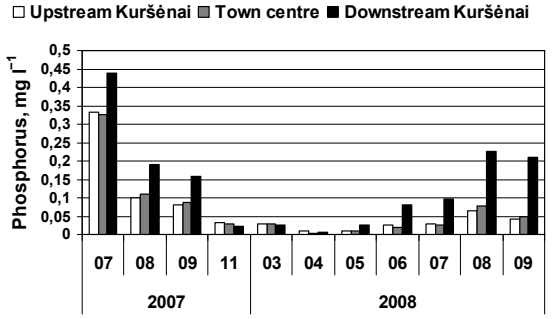
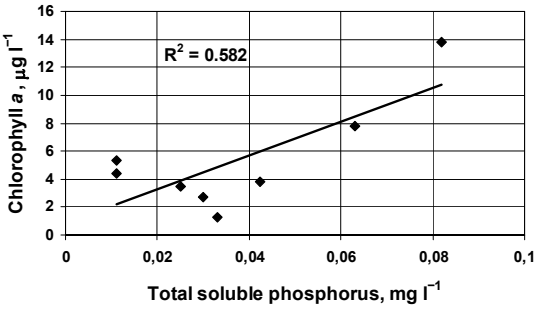


Fig.4. Changes in the total soluble phosphorus concentration in Kuršėnai basin of the river Venta

In July 2007, the concentration of the total soluble phosphorus was the highest (Fig. 4). At that time the maximum permissible concentration (MPC) (0.1 mg l^{-1}) was exceeded 3-4 times. The year 2007 was rainy, especially in July: precipitation in the region (158 mm) exceeded twice the many years' monthly rate (Šiauliai Weather Forecast Station), and biogenic substances were intensely leached from the soil. The river was heavily flooded; that month the Venta discharge (9.98 m^3 s^{-1}) exceeded the many years' Venta discharge in Kuršėnai basin six times (Lithuanian Hydrometeorological Service). The concentrations of phosphorus measured in the town centre and upstream Kuršėnai were very close. This indicates that by the level of phosphorus the state of the river Venta remains stable up to the dam in the town centre.

The concentration level of the total soluble phosphorus decreased greatly in November 2007, and it did not exceed the MPC upstream Kuršėnai and in the town centre throughout the entire remaining period of examination. The reason for such decrease might have been the long lasting summer flood which leached biogenic substances from the soil.

Downstream Kuršėnai there was plenty of total soluble phosphorus during all the summer months and September of the examination period. The measured concentrations were close to or exceeded twice the MPC (Fig. 4). Since phosphorus is the main nutrition source for freshwater plants and algae, this part of the river, downstream Kuršėnai, is heavily grown over with bank and aquatic plants. Among them there are plants indicating possible pollution and water eutrophication (Janauer and Dokulil 2006). These are common duckweed (*Lemna minor* L.) and greater duckweed (*Spirodela polyrhisa* L.), also populations of halfway immersed arrowhead (*Sagittaria sagittifolia* L.) and bur-reed (*Sparganium erectum* L.). The Urdupis stream wherein sewage from the town water treatment plant is poured to and the Kulmuša stream near which there are a number of farms might be the sources of the increased phosphorus level.



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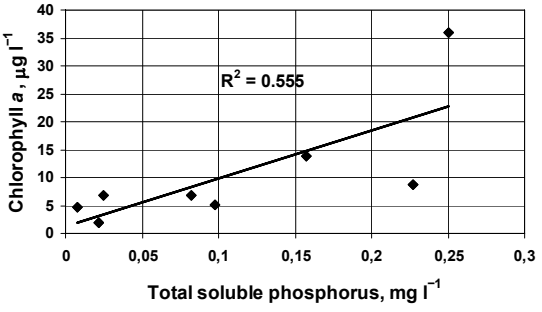

b)

Fig. 5. Dependence of chlorophyll a concentration on the concentration of total soluble phosphorus a) upstream Kuršėnai b) downstream Kuršėnai

The data regression analysis has revealed weak relationship between chlorophyll *a* and the total soluble phosphorus concentration upstream (p=0.028) and downstream (p=0.034) Kuršėnai (Fig. 5 a, b). The reason for such weak association may be on the one hand chlorophyll *a* evolutive impact of the increased temperature, on the other hand, the impact of the volatile nature of the stream.

No relation between the concentration of total soluble phosphorus and discharge of the river Venta in Kuršėnai basin was found. The data of Kutra and Berankienė research (2007) have also shown that there is no such relation in the rivers of normal water abundance.

Ammonium concentration levels were measured in two places of the Venta, i.e. upstream and downstream Kuršėnai (Fig. 6). Measurements were made in November and December, 2007 and from March until September in 2008. Average concentrations of ammonium in the examined section of the river were 0.123 mg l^{-1} and 0.094 mg l^{-1} upstream and downstream the town, respectively. The data do not correspond to the results of monitoring of the Venta downstream Mažeikiai carried out by the National Environmental Protection Agency. The average annual concentrations of ammonium according to those measurements are coniderably less: 0.048 mg l^{-1} and 0.067 mg l^{-1} in 2007 and 2008, respectively (Aplinkos apsaugos agentūra 2010).

During the whole period of examination, the ammonium concentration level in the river upstream Kuršėnai changed within small limits, i.e. from 0.06 to 0.17 mg l^{-1}, except for solitary instances in

November 2007 (1.18 mg l^{-1}) and July 2008 (4.36 mg l^{-1}), when ammonium concentration exceeded the MPC (0.39 mg l^{-1}) (Fig. 6). In Kuršėnai catchment of the river Venta there are neither intensive farmlands nor large stock farms, therefore sudden changes in the concentration might be caused only by accidental pollution coming from the upper reaches of the Venta.

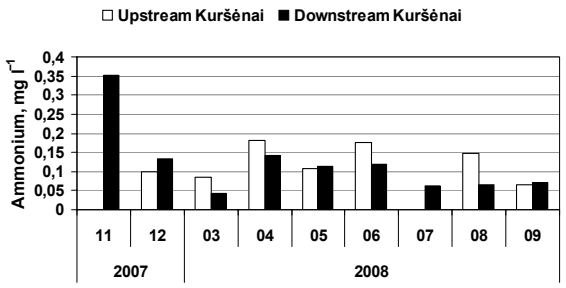

Fig. 6. Changes in ammonium concentration in Kuršėnai catchment of the river Venta

Ammonium concentration downstream Kuršėnai did not exceed the MPC throughout the whole period of measurement and was the largest in November 2007. The regression analysis of the results has shown no significant relationship between the chlorophyll *a* and ammonium concentration in the whole examined section of the river. The regression analysis of the results has also shown that the ammonium concentration downstream Kuršėnai is inversely proportional to the water temperature (p=0.015) (Fig. 7).

Upon the temperature rise the limestone solubility increases and, consequently, the hydrogen index increases. The pH was 7.93 in November 2007 when the water temperature was 5°C and it was 8.36 in September 2008 when T = 17°C. In the alkaline medium the balance of ammonium ions and ammonia moves to the part of volatile ammonia. Another reason for decrease in the ammonium amount may be acceleration of the nitriphication process at a higher temperature.

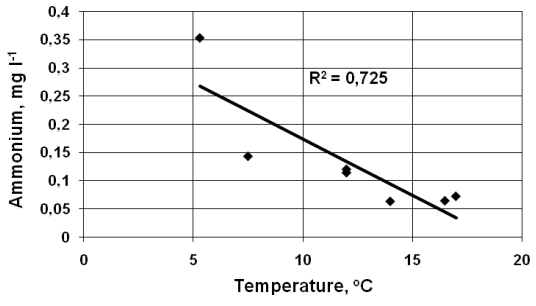

Fig. 7. Dependence of ammonium concentration in the Venta downstream Kuršėnai on the water temperature

Nitrites are the most unstable form of non-organic nitrogen of an intermediate oxidation degree. They usually enter natural waters together with sewage, thus higher levels of nitrites show anthropogenic water pollution. During the entire period of examination the quantities of nitrites in the Venta exceeded the MPC (0.025 mg l^{-1}), in some instances from two to ten times (Fig. 8). Average concentration of nitrites upstream and downstream Kuršėnai was 0.12 and 0.14 mg l^{-1}, respectively.

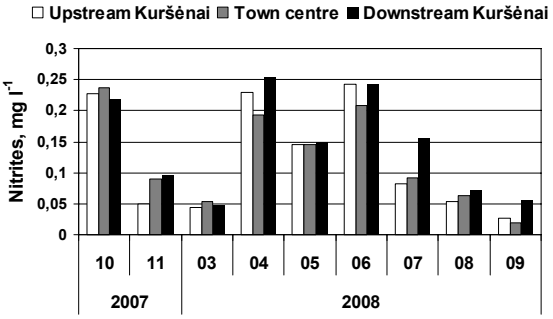

Fig. 8. Changes in nitrite concentration in Kuršėnai basin of the Venta

This quantity exceeds the data of monitoring the river downstream Mažeikiai. The mean annual concentrations of nitrites according to measurement of the National Environmental Agency were less in an order: 0.013 and 0.017 mg l^{-1} in 2007 and 2008, respectively (Aplinkos apsaugos agentūra 2010). Large quantities of nitrites indicate that the river is contaminated with sewage.

Nitrates are biogenic substances, standing in the second place after phosphorus by importance to the water biota. Besides naturally degrading organisms, the main causes of river pollution are agricultural and industrial activities.

Throughout the whole analyzed period nitrate concentrations in the Venta upstream and downstream Kuršėnai varied a little, average concentrations were 2.27 mg l^{-1} and 3.44 mg l^{-1}, therefore concentrations downstream Kuršėnai were higher by app. 50%. According to the results of monitoring of the Venta downstream Mažeikiai carried out by the National Environmental Protection Agency, annual concentrations of nitrates were 2.26 and 1.78 mg l^{-1} in 2007 and 2008, respectively; thereby the data are fairly coincident (Aplinkos apsaugos agentūra 2010).

During the cold period of the year nitrate concentrations upstream Kuršėnai were higher than or close to the MPC (2.3 mg l^{-1}) (Fig. 9). During the warm period, i.e. May to September inclusive, nitrate concentrations were smaller and almost steady.

Seasonal fluctuation of nitrates downstream Kuršėnai remains the same; however, concentrations exceed the MPC not only during the cold period of the year, but in the second half of the summer as well (Fig. 9). This indicates that excess of nitrates remains during the period of vegetation in the whole examined section of the river, especially downstream Kuršėnai, when concentration of the total soluble phosphorus decreases considerably during the vegetation (Fig. 4).

The result regression analysis has shown that there is no correlation between chlorophyll and nitrate concentration.

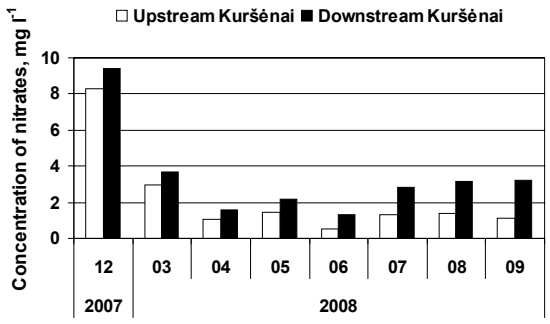

Fig. 9. Changes in nitrate concentration in Kuršėnai basin of the Venta

Measured concentration levels of total soluble nitrogen were 2.52 mg l^{-1} and 3.68 mg l^{-1} upstream and downstream Kuršėnai. The data according to the measurement of the national Environmental Protection Agency are coincident: 3.42 mg l^{-1} and 2.875 mg l^{-1} in 2007 and 2008 (Aplinkos apsaugos agentūra 2010).

Optimum conditions for the biota to breed and develop are when the ratio of nitrogen and phosphorus concentrations in water is 16:1 (Tumas 2003), whereas the average ratio of total soluble nitrogen and phosphorus has been 45:1 upstream Kuršėnai and 27:1 downstream Kuršėnai.

It should be noted that in the examined section of the river weak correlation between chlorophyll *a* and total soluble phosphorus and no correlation between chlorophyll *a* and total soluble nitrogen were obtained. Average load of total soluble nitrogen into the river Venta in Kuršėnai town was 66 tons per year and total soluble phosphorous – 4 tons per year, when annual water discharge - 1.8 m^3/s. The change in water quality was noticed by the increased concentration of the chlorophyll *a* by 15% and by appearance of plenty of water plants identifying water pollution and eutrophication in the river section downstream Kuršėnai. More responsive bioindicators, for example, diatoms, should be applied to have more reliable definition of the impact of biogenic substances on the ecological state of the water.

Hence, as in many Lithuanian rivers, there is an excess amount of nitrogen in the Venta, and reproduction of phytoplankton is limited due to the amount of phosphorus in the water, but not due to the amount of nitrogen.

COD(Cr) measurements have shown that concentrations of organic substances were very unsteady during the whole period of research and in most instances exceeded MPC (28 mg $O_2 l^{-1}$) (Fig. 10).

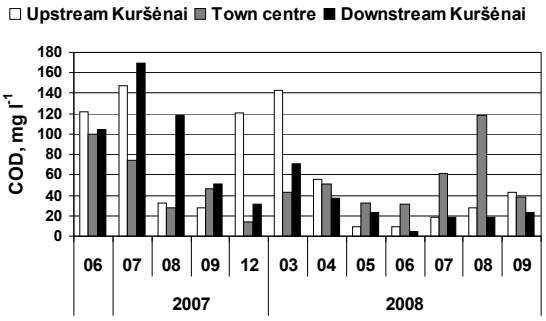

Fig. 10. Changes in chemical oxygen demand in Kušėnai basin of the Venta

Average concentrations in all the places of sampling were app. 60 mg O_2 l^{-1}. Such big pollution should be of anthropogenic nature, leached by plenty of precipitation from the town territory.

All the results indicate that ecological state of the river upstream and downstream Kuršėnai differs a lot. Data collected up to the town centre in most cases coincide or are similar; however, downstream Kuršėnai varietal composition and abundance of plants as well as quantities of dissolved substances are significantly larger.

River water pollution in Kuršėnai basin is thought to increase from the following sources:

- Proprietary houses, since there is no centralized sewage system in this part of the town.
- The stream Urdupis, to which insufficiently cleaned waste water may be poured from Kuršėnai biological water treatment plant.
- The stream Kumulša, which may carry contaminants from the artificial Pakulmušių pond.

4. Conclusions

1. The results of the research show that Kuršėnai town and nearby villages have an impact on the state of the water in Kuršėnai catchment of the river Venta.
2. Main sources of river pollution comprise the part of the town where there is no centralized sewage system and two streams the Urdupis and Kumulša.
3. Concentration levels of total soluble phosphorus downstream Kuršėnai are higher by 50% than upstream the town (0.069 mg l^{-1} and 0.135 mg l^{-1} upstream and downstream Kuršėnai).
4. Concentration of total soluble nitrogen has increased in the examined section of the river by 45% (2.52 mg l^{-1} and 3.68 mg l^{-1} upstream and downstream the town).
5. Whereupon the river passes the town, the concentration of chlorophyll *a* increases by app. 15% (from 9.11 μg l^{-1} to 10.49 μg l^{-1} upstream and downstream the town, respectively).
6. Regression analysis has discovered weak relationship between chlorophyll *a* and the total

soluble phosphorus concentration upstream (p=0.028) and downstream (p=0.034) the town.

7. Nitrate concentrations downstream Kuršėnai are larger by 50% than upstream the town (2.27 mg l^{-1} upstream and 3.44 mg l^{-1} downstream the town) and there MPC is higher. Regression analysis has revealed that there is no association between chlorophill *a* and nitrate concentration.
8. Concentrations of nitrites and organic substances are unsteady and often exceed permissible limits. This may be pollution of anthropogenic nature.
9. Due to the excess of total soluble nitrogen there is no correlation between chlorophyll *a* and total soluble nitrogen concentrations.
10. For estimating the ecological state of the river it is important to apply bioindicators that are more responsive to chemical pollution.

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Ventos upės tarša Kuršėnų miesto ribose

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(gauta 2010 m. birželio mėn.; atiduota spaudai 2010 m. rugsėjo mėn.)

Darbe nagrinėjama Kuršėnų miesto įtaka Ventos upės taršai, taip pat biogeninių medžiagų poveikis fitoplanktono masei. Mėginiai buvo imami ir indikatorinių vandens augalų registracija buvo atliekama trijose upės vietose – aukščiau Kuršėnų, miesto centre ir žemiau Kuršėnų. Nustatytos biogeninių medžiagų (bendrojo tirpaus fosforo, neorganinio azoto junginių) ir organinių medžiagų koncentracijos. Jų poveikis fitocenozei įvertintas matuojant chlorofilo *a* koncentracijas ir identifikuojant indikatorinius augalus upėje.

Tyrimas parodė, kad šioje teritorijoje į upę patenka dideli fosforo kiekiai. Bendrojo tirpaus fosforo vidutinė koncentracija aukščiau Kuršėnų (0,069 mg l^{-1}) neviršija didžiausios leistinos koncentracijos, o žemiau Kuršėnų yra didesnė du kartus (0,135 mg l^{-1}) ir viršija leistinas ribas.

Padidėjusi chlorofilo koncentracija (nuo 9,11 aukščiau iki 10,49 μg l^{-1} žemiau miesto), vandens augalų gausa, jų rūšinė įvairovė ir indikatorinės savybės žemiau Kuršėnų rodo, kad yra intensyvesnė vandens eutrofikacija, palyginti su Ventos upės būkle aukščiau Kuršėnų. Chlorofilo koncentracija matavimų vietose koreliuoja su bendrojo tirpaus fosforo koncentracija.

Nitratų koncentracijos žemiau Kuršėnų yra didesnės nei aukščiau miesto (nuo 2,27 iki 3,44 mg l^{-1}) ir viršija DLK (3,44 mg l^{-1}). Nitritų ir organinių junginių koncentracijos nepriklauso nuo sezonų kaitos ir daugeliu atvejų didesnės už leistinas ribas visoje tyrinėtoje upės atkarpoje (apie 15 km).

Tyrinėtoje upės atkarpoje nustatytas azoto junginių perteklius: bendrojo tirpaus azoto ir fosforo koncentracijų santykis aukščiau Kuršėnų yra 45:1, žemiau Kuršėnų yra 27:1, kai biotai optimalios sąlygos daugintis ir vystytis susidaro esant santykiui 16:1. Santykinai didesnė fosforo koncentracija pratekėjus upei miestą yra padidėjusios eutrofikacijos priežastis.