CHANGES IN THE CONCENTRATION OF DISSOLVED OXYGEN IN WATER FLOW IN THE SOUTHWESTERN PART OF THE SLOVAK REPUBLIC

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Abstract: *All chemical and biological processes and living conditions for organisms in watercourses are significantly affected by oxygen conditions. The aim of this paper is to evaluate changes of the concentrations of dissolved oxygen in water flow of Čaradice brook, which is located in the southwestern part of the Slovak Republic, during the period 2005-2010. The watercourse springs in the mountains of Pohronský Inovec in the southern foot of Drienka hill and it is the right tributary of the Hron River. Samples of the water from watercourse were carried out on a regular basis, in the second decade of the month. The places of taking samples were localized in a longitudinal profile of the watercourse to include all sources causing the changes of dissolved oxygen concentration. Samples of water were collected from six sampling sites.Water samples were taken from the middle of the main stream. The results show that the average concentration of dissolved oxygen for the whole monitored period was 7.24mg.dm^{-3}.Depending on the time of taking samples the highest average oxygen concentration was recorded in winter and early spring time, with the highest values in the month of February. From March there was a gradual decrease up to the minimum value in July. This decline was probably associated with an intensive degradation of organic substances by micro-organisms and also with higher water temperature. The sampling site had lower impact on the concentration of dissolved oxygen than the time of collection of water. Its minimum average concentration was found in the south point of Kozárovce. This decrease is related to the oxygen consumption on biodegradation of organic pollutants which got to the water flow with non-cleaned sewage effluent, as the village has not built a wastewater treatment plant. The highest concentration was recorded under the eco-system of permanent grassland, in the north point of Čaradice. Calculated values of 10-th percentile of the dissolved oxygen in all sampling locations was lower, as is specified in the requirements on the quality of the surface water in the Regulation of the Government of the Slovak Republic No. 269/2010 Coll. Based on the above mentioned it can be concluded that in the water stream in terms of oxygen ratios are favorable conditions for the organisms that are less demanding on the dissolved oxygen.*

Key words: *watercourse, dissolved oxygen, Čaradice brook*

INTRODUCTION

The concentration of oxygen is an important indicator of the quality of surface waters (Tölgyessy, Lesný, 2001, Langhammer, 2002, Ambrožová, 2004) to which it gets from the atmosphere by diffusion and photosynthetic assimilation of aquatic plants, algae blooms and cyanobacteria (Pitter, 2009). The solubility of oxygen in water depends mainly on water temperature. With increasing water temperature, its solubility goes down (Heteša, Kočková, 1997, Gabris et al., 1998, Šulvová et al., 2009). At the temperature of 0^{o}C is dissolved 14.65 mg O_2.dm^{-3}, at 15 ^{o}C 10.03 mg O_2. dm^{-3} and at 30 ^{o}C 7.44 mg O_2. dm^{-3} (Heteša, Kočková, 1997). In addition, the solubility of oxygen is affected by temperature and atmospheric pressure, and by the contents of salts in the water. If the content of salts increases, its concentration in the water decreases. However, in natural waters with saline concentrations up to 1000 mg. dm^{-3}, the difference is minimal (Gabris et al., 1998).

Oxygen in the water is used up by an aerobic biological decomposition of organic substances, dissimilation of green organisms, nitrification processes, and the oxidation of iron, manganese and sulfides. The presence or absence of oxygen decides whether there will run aerobic or anaerobic processes in water out of which the latter ones are undesirable in natural waters. Oxygen is essential for self-cleaning of water surface. When the water oxygen is used up from the environment, it becomes anoxic and micro-organisms will start to use oxygen for biochemical oxidation first by reduction of some inorganic substances (nitrates) and then the exhaustion of these resources by reduction of sulfates to sensory defective and toxic hydrogen sulfide and by reduction of organic matter to methane (Pitter, 2009). Oxygen is also necessary to keep fish alive (Pitter, 1999, Tölgyessy, Melichová, 2000).

MATERIAL AND METHODS

Čaradice brook springs in the mountains of Pohronský Inovec in the southern foot of the hill Drienka (751.1 m) at an altitude of about 600 above sea level. The brook flows through the territories of Zlaté Moravce and Levice districts. It a right tributary of the river Hron, its length is 11.1 km. Near the village of Kozárovce a uniform reservoir called "Dam" was built, which is located between the villages Čaradice and Kozárovce. It is used for irrigation and sports fishing. From the right, from the area of Sejovský hill (295. 2 m above the sea level) flows the largest tributary of Čaradice brook - the Svätý brook, from the left side it has only short tributaries. The flow direction is predominantly north-south, on the lower reaches north-east. Čaradice creek flows into the river Hron near the village Kozárovce, in the area called Slovak gates, at an altitude of about 174 above sea level in relation to hydrographic conditions. Čaradice stream flows in the uplands - lowland area which is characterized by the type of rain-snow runoff with the highest flow rate in March and lowest in the month of September. According to the geological characteristics of the soil it has been shaped over the several stages of volcanic activity with rotation periods of destruction and denudation of volcanic complexes. Andesine, rhyolite and basalt neovolcanites are interspersed there (Konečný, 1998).

The territory belongs to the warm area and slightly dry subarea. The average temperature in 2005 was 9.1 ° C, in 2006-9.7 °C - 8.9 °C in 2007, in 2008 - 9.4 °C, in 2009 - 9.8 °C, 2010 - 10.03 °C. The average rainfall in 2005 represented 711.4 mm, in 2006 – 842.7 mm, in 2007-569.8 mm, , in 2008 – 679.7 mm, 2009 – 684.4 mm and 687.7 mm in 2010 (source: Kozárovce precipitation measuring stations).

In the upper segment of the river basin watercourse forest ecosystems and permanent grassland are situated. The greater part of the stream flows through the agroecosystem of agricultural crops on the arable land.

In terms of agro-productions the territory ranks to the corn – sugar beet region. Plant production is focused mainly on cereals growing (wheat, winter rye, and spring barley, maize for grain and for silage), perennial forage crops (Lucerne) and oilseeds (rapeseed, sunflower). Livestock production is oriented on the cattle breeding. Farmed land near the watercourse belongs to the cadastre of the agricultural cooperative of Volkovce.

During the monitored period industrial fertilizers were applied such as urea (N = 46%), the DAM 390 (N = 30%), NPK 15: 15: 15 at a dose of 200 $kg.ha^{-1}$ (N = 12%, P_2O_5 = 19%, K_2O = 19%), LAV - 350 kg. ha^{-1} (N = 27%), DASA - 250 kg ha^{-1} (N = 26%, S = 13%). Nitrogenous fertilizers were applied in the average batch 138 $kg.ha^{-1}.year^{-1}$, phosphate 39 kg. $ha^{-1}.year^{-1}$ and potassium at a dose of 6.01 kg. $ha^{-1}.year^{-1}$. In the fall of 2008 2 t. $ha^{-1}$of ground limestone were injected. Out of organic fertilizers manure was applied under the roots at a dose of 40 t .ha^{-1}. year^{-1} (source: Volkovce Agricultural Cooperative).

Samples of the water from Čaradice brook were carried out on a regular basis, in the second decade of the month in the years 2005 - 2010. The places of taking samples were localized in a longitudinal profile of the watercourse to include all sources causing the changes of dissolved oxygen concentration.Samples of water were collected from six sampling sites.Water samples were taken from the middle of the main stream.

- **1st sampling site** - the forest ecosystem Pohronský Inovec, 48 ˚ 22 '56" north latitude and 18 ˚ 29' 73" east longitude.
- **2nd sampling site** – in the north point of Čaradice, 48 ˚ 21 '91" north latitude and 18 ˚ 30' 53" east longitude.
- **3rd sampling site** – in the south point of Čaradice, 48 ˚ 21 '35" north latitude and 18 ˚ 30' 55" east longitude.
- **4th sampling site** - before the water tank, 48 ˚ 19 '82" north latitude and 18 ˚ 30' 50" east longitude.
- **5th sampling site** – behind the water reservoir in the north point of Kozárovce, 48 ˚ 19 '74" north latitude and 18 ˚ 30' 50" east longitude.
- **6th sampling site** – in the south point of Kozárovce, 48 ˚ 18 '77" north latitude and 18 ˚ 32' 25" east longitude.

In the collected samplings of water the concentrations of dissolved oxygen were determinated by galvanic oxygen probe StirrOx (G) using the apparatus inoLab Multi Level 3. In order to assess the quality of surface water for dissolved oxygen the value of the 10-th percentile (P10) was calculated from the measured values and then compared with the matching set of limit values referred to the regulation of the Government of the Slovak Republic No. 269/2010 Coll.

The SAS statistical system was used for statistical evaluation. There were calculated basic statistical characteristics of particular sets of values (table 1). Analysis of variance was carried out on the basis of three qualitative factors (year, month, and site collection) (tab.2).

RESULT AND DISSCUSION

The average concentration of dissolved oxygen in the watercourse of Čaradice brook in the years 2005-2010 varied from 5.48 (in 2010) to 9.30 mg.dm^{-3} (2009) and for the whole period it was 7.24 mg . dm^{-3} (Fig. 1). Analogous average concentration (7.26 mg.dm^{-3}) was recorded by Babošová (2005) in the water flow of Kadaň. Higher average concentration was found by Sozanský (2004) in the Čerešňový creek (9.13 mg.dm-3) and by Kontrišová et al. (2010) in a water tank in an agglomeration of Modra (12.29 mg.dm-3).

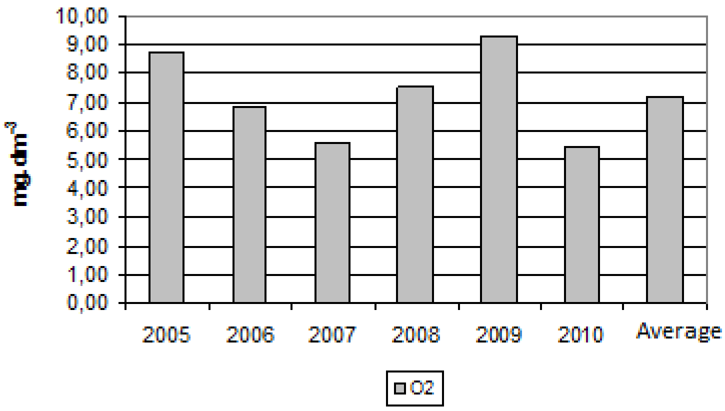

Fig. 1. Average concentration of dissolved oxygen in the years 2005-2010

Depending on the time of sampling (Fig. 2), the highest average concentrations were recorded in the winter and early spring time, with the highest mean concentration for the whole monitored period in the month of February (9.79 mg. dm-3). In February 2009 there occurred also its maximum concentration (17.38mg dm^{-3}.). Similarly, Noskovič et al.(2003) have found the highest average concentrations of dissolved oxygen in the water flow during winter months. Oxygen average concentration for the entire period from the month of March was gradually decreasing up to its minimum value in the month of July (4.90 mg. dm^{-3}).

From the literary data (Pitter, 1999, Tölgyessy, Melichová, 2000) it is known that the process of decomposition of organic substances by micro-organisms leads to consumption of oxygen, and thus to its reduction of the concentration in surface water. Guo et al. (2009) states that besides the consumption of oxygen in biological processes, its content is also significantly affected by water temperature. With increasing temperature, the solubility of oxygen decreases (Pitter, 2009).This is documented by Fig. 3, showing the negative relationship between two indicators. This was confirmed by the negative correlation between dissolved oxygen and water temperature (r =-0.55).

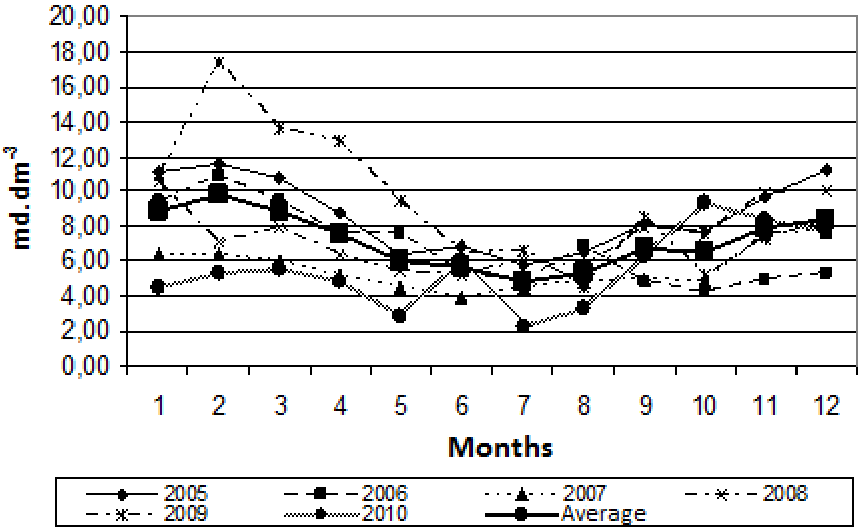

Fig. 2 Average concentrations of dissolved oxygen (mg.dm^{-3}) depending on sampling Time

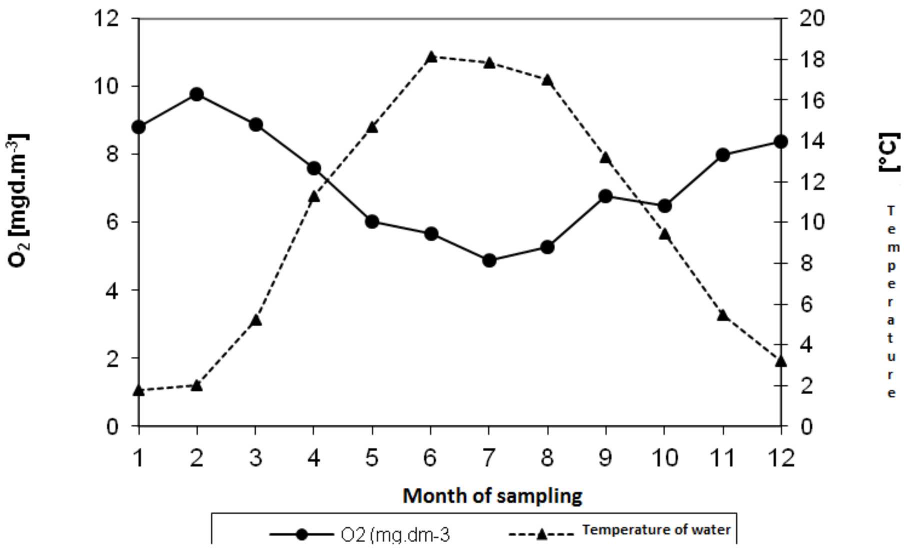

Fig. 3 The concentration relationship between dissolved oxygen (mg.dm^{-3}) and temperature of water (°C)

The lowest average concentration for the whole period (7.07 mg.dm^{-3}), depending on the sampling points have been reported in the sampling site no. 6 (in the south point of Kozárovce). The community has not built a wastewater treatment plant, so it can be assumed that the decrease is associated with the consumption on the biodegradation of organic matter in the water flow, which gets there with uncleaned sewage effluent. This agrees with the view of Tölgyessy, Melichová (2000), who point out that an important feature of surface water pollution by organic substances is the decrease of the dissolved oxygen under the source of pollution, because it is consumed on the decomposition of these substances.

The highest mean concentration for the whole monitored period (7.87 mg. dm-3) was found in sampling point No 2 (under the eco-system of permanent grassland, near the village of Čaradice). In the sampling site No 5, located behind the water tank, in the north point of Kozárovce, there has been a slight decrease in its concentration, which is probably related to its consumption in decomposition processes in water during its detention in the tank. From a statistical point of view sampling site did not have such a significant impact on the change in dissolved oxygen concentration as the year and month of collection (tab.2).

The value for dissolved oxygen is in requirements more than 5 mg. dm^{-3} on the quality of surface water in the regulation of the Government of the Slovak republic No. 269/2010 Coll. Calculated values of 10-th percentile of this indicator in all sampling locations was lower. Based on the above mentioned it can be concluded that in water stream in terms of oxygen ratios are favorable conditions for the organisms that are less demanding on the dissolved oxygen.

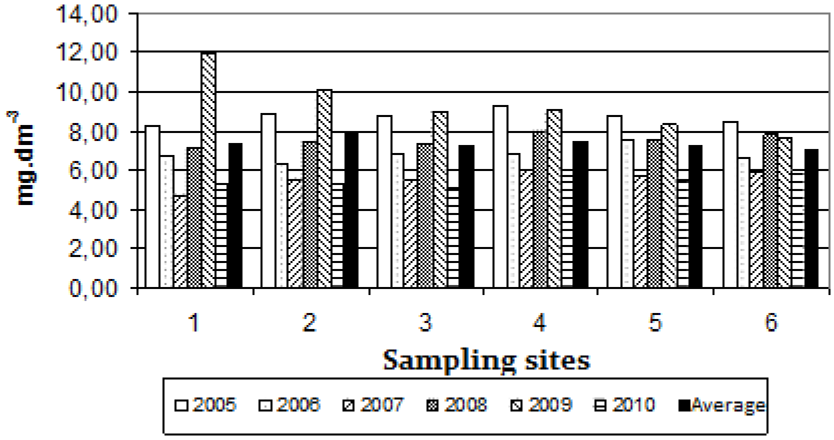

Fig. 4. Average concentrations of dissolved oxygen ($mg.dm^{-3}$) depending on sampling site.

Table 1

The basic statistic characteristics of dissolved oxygen

Indicator	**O_2**
Unit	**$mg.dm^{-3}$**
Arithmetic. average	7.245
Mean error	0.147
Median	6.6

Mode	5.8
The standard deviation	3.041
Variance	9.246
The coefficient of variation	41.97 %
Variation range	26.2
Minimum	2.1
Maximum	28.3

Table 2

ANOVA- Analysis of variance for dissolved oxygen

One-dimensional test of significance for O_2					
effect	**sum of squares**	**degree of freedom**	**Variance**	**Value of F**	**evidence**
Abs. member	22278.73	1	22278.73	4130.998	0.000000
year	910.04	5	910.04	33.415	0.000000
month	832.46	11	832.46	14.032	0.000000
place	8.13	5	8.13	0.301	0.911900
error	2178.8	404	5.39		

CONCLUSION

In the years 2005-2010 the concentration of dissolved oxygen in the water flow of Čaradice creek, which flows through the districts of Zlaté Moravce and Levice was evaluated. Its average concentration for the whole monitored period was 7.24 $mg.dm^{-3}$. Depending on the time of taking samples the highest average oxygen concentration was recorded in winter and early spring time, with the highest values in the month of February. From March there was a gradual decrease up to the minimum value in July. This decline was probably associated with an intensive degradation of organic substances by micro-organisms and also with higher water temperature. The sampling site had lower impact on the concentration of dissolved oxygen than the time of collection of water. Its minimum average concentration was found in the south point of Kozárovce. This decrease is related to the oxygen consumption on biodegradation of organic pollutants which got to the water flow with non-cleaned sewage effluent, as the village has not built a wastewater treatment plant. The highest concentration was recorded under the eco-system of permanent grassland, in the north point of Čaradice. Calculated values of 10-th percentile of the dissolved oxygen in all sampling locations was lower, as is specified in the requirements on the quality of the surface water in the Regulation of the Government of the Slovak Republic No. 269/2010 Coll. Based on the above mentioned it can be concluded that in the water stream in terms of oxygen ratios are favorable conditions for the organisms that are less demanding on the dissolved oxygen.

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