Temporal changes in water quality and quantity of the Rákos stream in view of sustainable agriculture

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Summary: Available water resources are increasingly limited, operation of different monitoring systems is indispensable regarding to get water quality and quantity data to further analyses. Another highlighted aspect is the use of water for different purposes. To determine the usability of the surface or groundwater, we need to collect information about physical, chemical and biological water quality parameters. Long-term monitoring systems can help us in many different water management questions: sustainable water management, water resource allocation, reuse potential. Frame of this recent study, environmental status of the Rákos Stream- focusing on water quality and quantity - have been analysed by in situ measurements. The monitored parameters were the following: water temperature, water flow, chlorophyll-a (Chl-a), phosphate (PO43-), ammonium (NH4+), nitrite (NO2-), nitrate (NO3-), pH value, conductivity, dissolved oxygen (DO).

Introduction

Water is one of the most highlighted natural resources in this fast-changing world. Within the available water resources, surface water is a sensitive and vulnerable resource in the sense of pollution of different origins. Monitoring water quality is an important tool for following the ongoing physical, biological, and chemical processes in the aquatic ecosystem (Zseni and Bulla 2002, Borics 2015). Analyzing the water quality allows for detecting the changing pattern in the different parameters. For this purpose, the European Union has created Directive 2000/60 / EC, also known as the Water Framework Directive (European Community 2000). The directive, which entered into force on 22 December 2000, aims to protect and rehabilitate our surface and groundwater (Cox et al. 1984). It is not only about the purity of water but also about the protection of riparian and near-water habitats, the availability of sufficient water and the pollution of river basins (Felföldy 1981, Barkács et al. 2012). As in many sectors – agriculture, industry, household – water plays a major role, both in terms of quantity and quality (Dévai et al. 1992). In applied hydrology, water resource management serves as basic knowledge to understand and model the different processes (Láng et al. 1993).

Water quality is a complex concept because it refers to the physical, chemical, biological, bacteriological and hydrological parameters (Dévai and Dévai 1979, Padisák 2005). Long-term water quality monitoring programs are essential to identify the possible pollution sources in a catchment. Today, the growing population, the misuse or poor quality of pesticides and fertilizers, various factors of climate change are influencing the quantity and quality of available water supplies to a high degree (Dukay 2000). Available water resources are narrow because of the effect of global warming, for example, changes of the frequency of extreme weather events. Collecting information about the environmental status of surface or subsurface waters is highlighted for water management. (Chapman 1996; Bartram and Ballance 1996) Available dataset of surface water resources regarding water quality or quantity is highly demanded by all parties involved (Bright et al. 1994).

The site of our measurements is Rákos stream, which is located close to Budapest, the capital city of Hungary. Searching among the available studies regarding the water quality of the stream, there was no previously carried out sampling campaign. This phenomenon – missing dataset for a small catchment – is not unique but it would be an important point to obtain data because these wetlands have a high relevance at a local scale. Our previous study focused on the temporal changes in land use and land cover patterns within Rákos catchment (Saeidi et al. 2019). During further sampling campaigns, the water depth, velocity, chlorophyll-a, pH, nitrite-ion, nitrate-ion, phosphate-ion and ammonium-ion contents, the total conductivity, and the dissolved oxygen (DO) concentration were measured. The main purpose of the study was to collect and analyze data about different biological and chemical water quality parameters influencing the environmental status of the stream. To achieve this main objective, we took the following steps:

- to examine and evaluate the water of the Rákos stream from the point of view of sustainable agricultural focusing on irrigation potential
- to build a long-term monitoring program with the specified sampling method on Rákos stream
- to establish the location of sampling points on the stream
- to set up an appropriate schedule for sampling considering the environmental and hydro-meteorological factors
- to create a dataset from the collected data to make analyses on different water quality parameters

Materials and methods

The study area is the Rákos stream that rises from Margita Hill which is located in the area of Gödöllő Hills and flows into the Danube from the left bank in District XIII of Budapest. The stream and its surroundings serve as an important recreational area and offer a unique wetland habitat for different species close to a highly populated zone. The first section of the Rákos Stream flows through the area of Gödöllő Hills, from the border of Szada, across Gödöllő where it meets the Fiók-Rákos Stream in a confluence, Isaszeg and Pécel, then along the second half of its length it flows through the capital Budapest to reach the Danube, while being fed by several smaller streams along the way. It was named after the crayfish that once lived there in large numbers.

In the frame of our previous study, land use and land cover changes have been analyzed. Results showed that the land use is very different in the lower and upper sections of the stream. This study provided a comprehensive picture of the different influencing factors on land use and land cover changes. The catchment area can be divided into an urban and an agglomeration section. In the agglomeration area, forested and agricultural areas prevail, while in the urban section, artificial land cover (built-up areas) is dominant. Forested and close-to-nature areas are in minority. Based on these data, it can be claimed that the use of the catchment areas of the Rákos stream can have a high impact on the state of water quality. For the whole section, about 75.3% are agricultural and dominated by populated areas, while the remaining 24.7% of the area is untouched nature and wetlands (Saeidi et al. 2019).

For the present study, sampling and measurements started in July 2020 and finished in August 2021. Seven sampling points have been identified along the stream. When locating the sampling points, we had to take into account their accessibility in all seasons. The distance between the first and the last measuring point is approximately 34.5 km. During this less than one-and-a-half-year, 28 sampling campaigns were carried out and 12 chemical and biological water quality parameters were measured at each of the points (Table 1).

Table 1 Summary of in situ measurements

1. táblázat. Vizsgált paraméterek

Measured and calculated parameters	Used instruments for measurements
Water temperature	ADWA AD14
Water depth	Water level depth meter
Velocity	FloWatch Flow Meter
pH	ADWA AD14
Conductivity	HANNA DiST 3
DO	ADWA AD630
NO_2^-	PF-12 Plus Photometer
NO_3^-	PF-12 Plus Photometer
NH_4^+	PF-12 Plus Photometer
PO_4^{3-}	PF-12 Plus Photometer
Chlorophyll-a	Algae Torch
Water flow	Calculated from measured parameters

Characterization of sample points and their surroundings was an important part of the study because the detected environmental circumstance can influence the environmental status of the stream. The first measuring point is in District XIV of Budapest, is located in a very frequented area, on the urban section of the stream. On both sides of the watercourse, after a few meters of green grassy bank section, there are urban, multi-story residential buildings (Figure 1). The second measuring point is located in District XVII of Budapest, also on the urban section. On either bank of the watercourse, after a wooded, grassy strip of about 150 meters, there are suburban residential houses, including some industrial facilities on the left bank and a railway on the right bank. The third measuring point is located in District XVII of Budapest. On the right side of the watercourse, in a 150-meter coastal strip, there is a railway along a woody, bushy area, while on the left side of the watercourse is an agricultural area of approximately 7 hectares, and there is a sewage treatment plant in the immediate vicinity. The fourth measuring point is located in Pécel. The railway is on the right bank of the watercourse, beyond a barren area of 50 meters. On the other side of the railway there are fishponds and agricultural land. Farm buildings and holiday zone houses also occur in the area. On the left side of the watercourse, there are woods for several kilometers' length, followed by fields. There is no residential, or industrial facility at this site. The fifth measuring point is located in Isaszeg. On the right side of the watercourse, there is a motorway and then a railway line. To the left of the watercourse there are residential houses. The sixth measurement point is located in an enclosed area. Unfortunately, we were not permitted to enter the area, so we had to delete the sixth measurement point from the list. The seventh point is located in the downtown part of Gödöllő. There is a wooded area on both banks of the watercourse. The eighth point is located on the edge of Gödöllő, close to the rise of the Rákos stream. There are residential and industrial facilities on both sides of the watercourse.

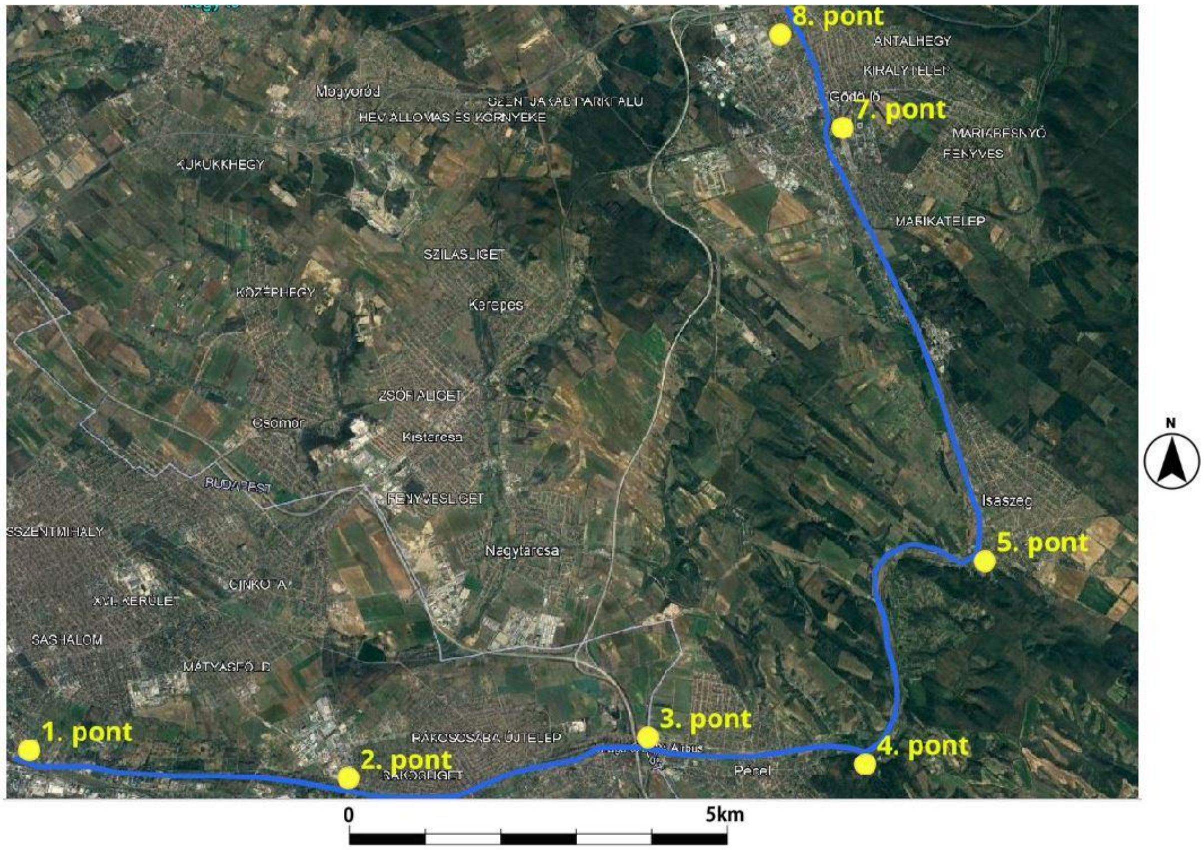

Figure 1 Location of sampling points

1. ábra. A mintavételi pontok elhelyezkedése

Results and Discussion

The change in water temperature was mostly characterized by natural seasonal changes. Measured values ranged from 20°C to 28°C in the summer period and between 5°C and 10°C in the winter season (Figure 2). An outlier value was found at the third measuring point next to the wastewater treatment plant. In general, the water temperature was higher significantly (2–4°C) than the other measurement points. At the eighth measuring point, which was located in the Gödöllő, water temperature was slightly higher than elsewhere. The possible reason for these higher values was the outflow from the wastewater treatment plant and the industrial activities.

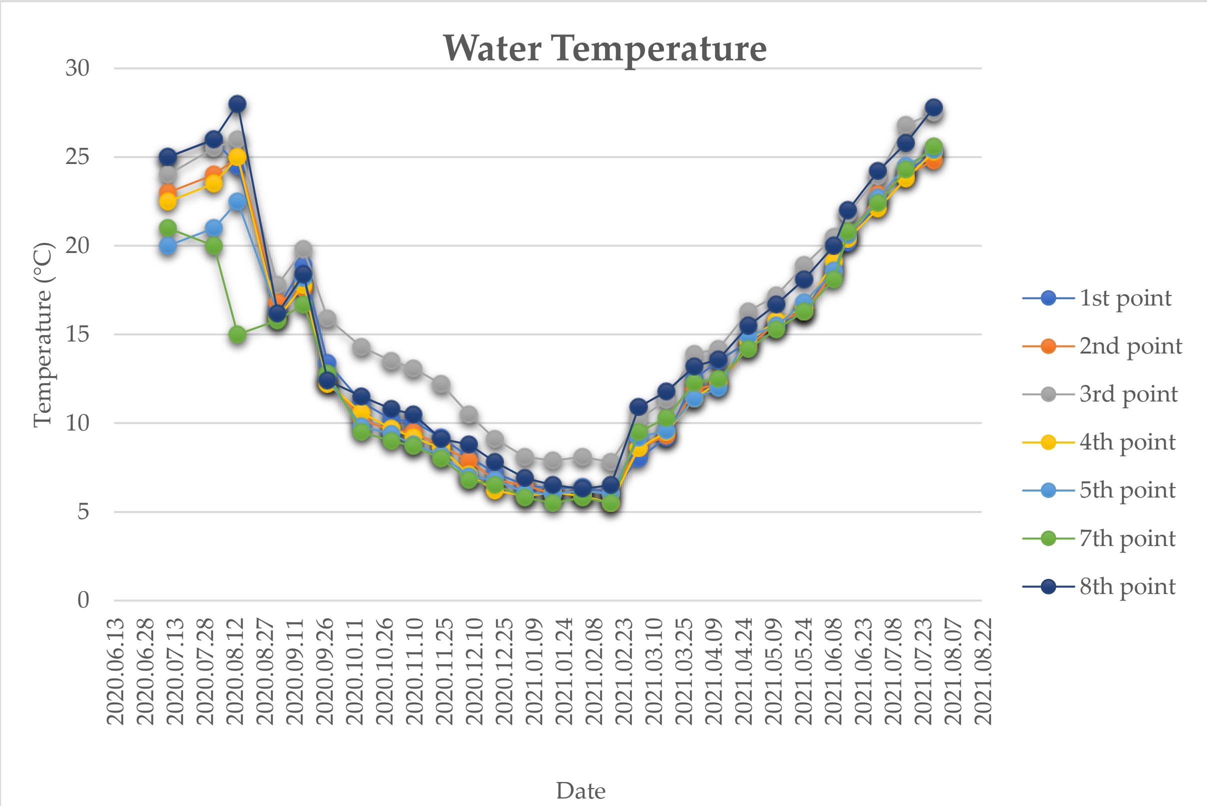

Figure 2 Water temperature data

2. ábra. Vízhőmérséklet

The amount of water flow during the one-year measurement cycle has changed naturally according to season and weather conditions. Measured values have ranged between 0.1 $m^3 s^{-1}$ and 1.4 $m^3 s^{-1}$.

The pH values did not show significant changes during the sampling campaign except for sampling point 3 (ranged 6,5–9). The pH values were changing rapidly at this point. The measured pH values ranged between 7 and 8,5. Based on the 10/2010 (VIII. 18) Decree of the Ministry of Rural Development on the water pollution limit values for surface water and the rules for their application, the limit value for pH can range between 6.5 and 9. Accordingly, the pH values were in the range.

Another measured water quality parameter was conductivity (Figure 3). The environmental limit for conductivity is 900 µS cm^{-1} based on 10/2010 (VIII. 18) Decree of the Ministry of Rural Development. These measured values were significantly higher than the limit. The same pattern emerged from the data, higher values were detected again at point 3 (sewage treatment plant) and at point 8 (car wash).

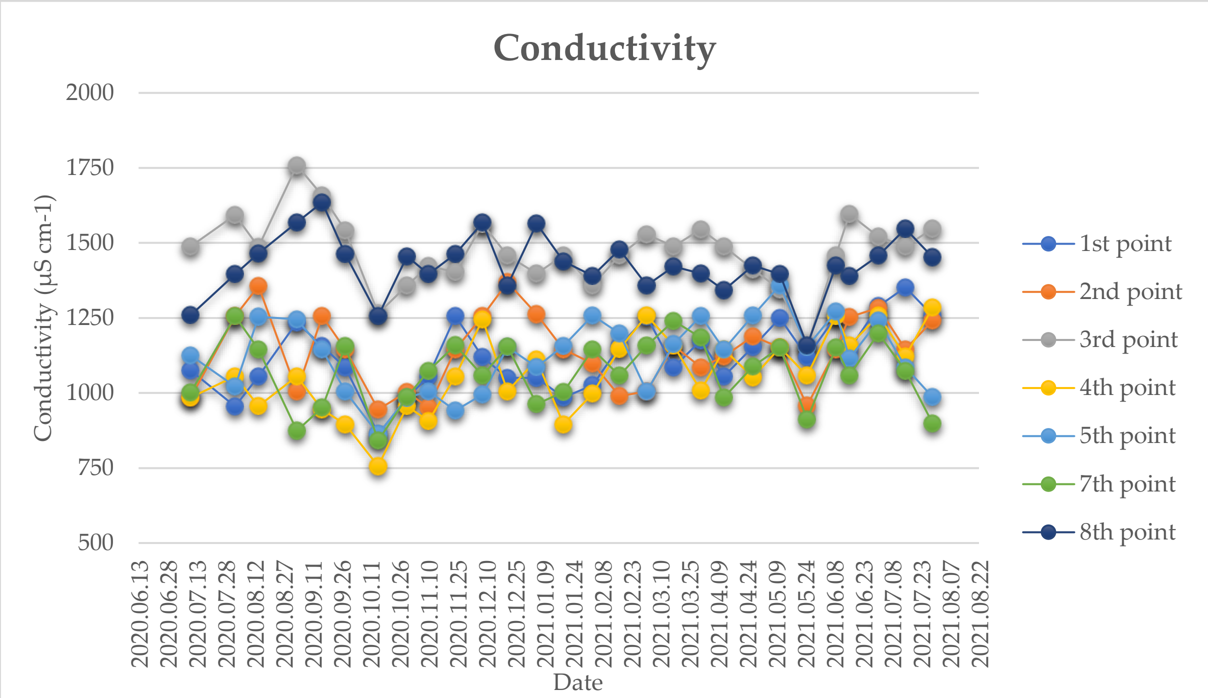

Figure 3 Measured conductivity values

3. ábra. Vezetőképesség

Dissolved oxygen saturation (Figure 4) is an important indicator of chemical and biological water quality. According to the 10/2010 (VIII. 18) Decree of the Ministry of Rural Development, the limit value for DO saturation ranges between 80–110%. The detected values were ranged in a lower category. The lower value was detected in the summer period for every sampling point due to the higher chlorophyll-a content. Significantly lower (25%) DO saturation was measured at sampling points 3 and 8.

Chlorophyll-a concentration was measured among the biological water quality parameters (Figure 5). Significantly higher concentration values were detected at sampling points 3 and 8. In general, the values ranged from 25 µg l^{-1} to 100 µg l^{-1}. In contrast, the chl-a concentration was between 150 µg l^{-1} and 250 µg l^{-1} at sampling points 3 and 8.

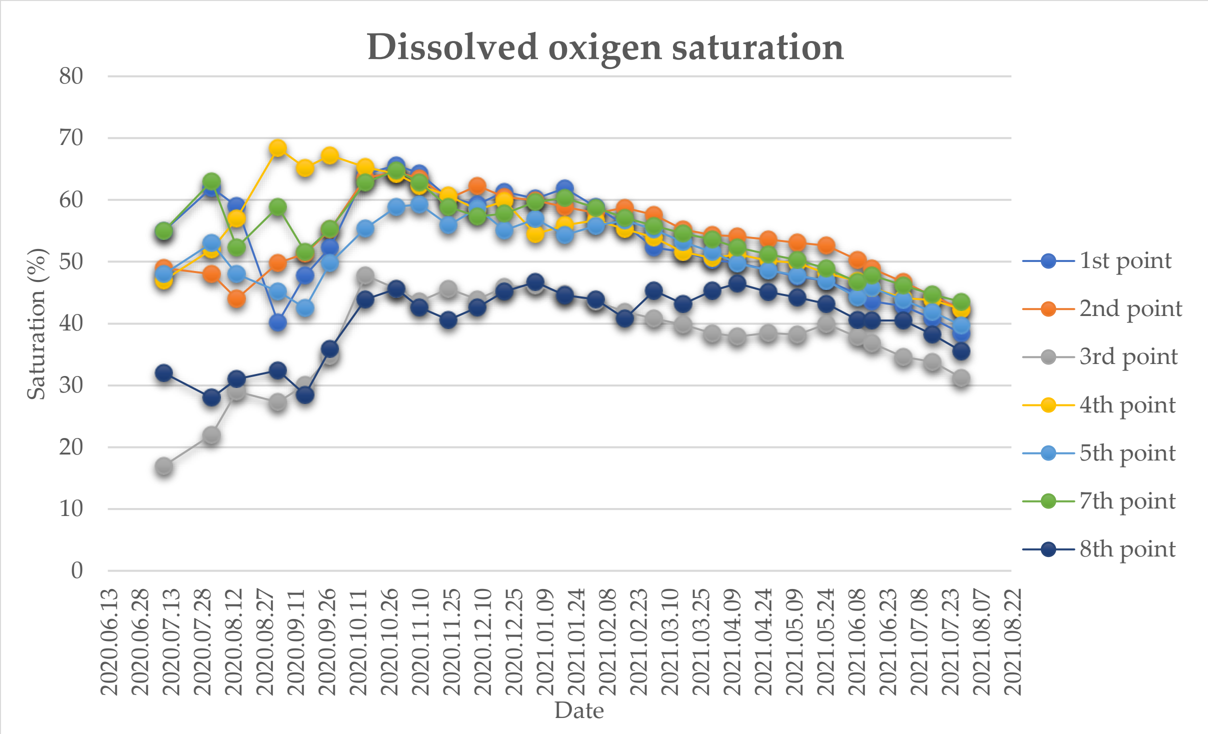

Figure 4 Dissolved oxygen saturation

4. ábra. Oldott oxigén telítettség

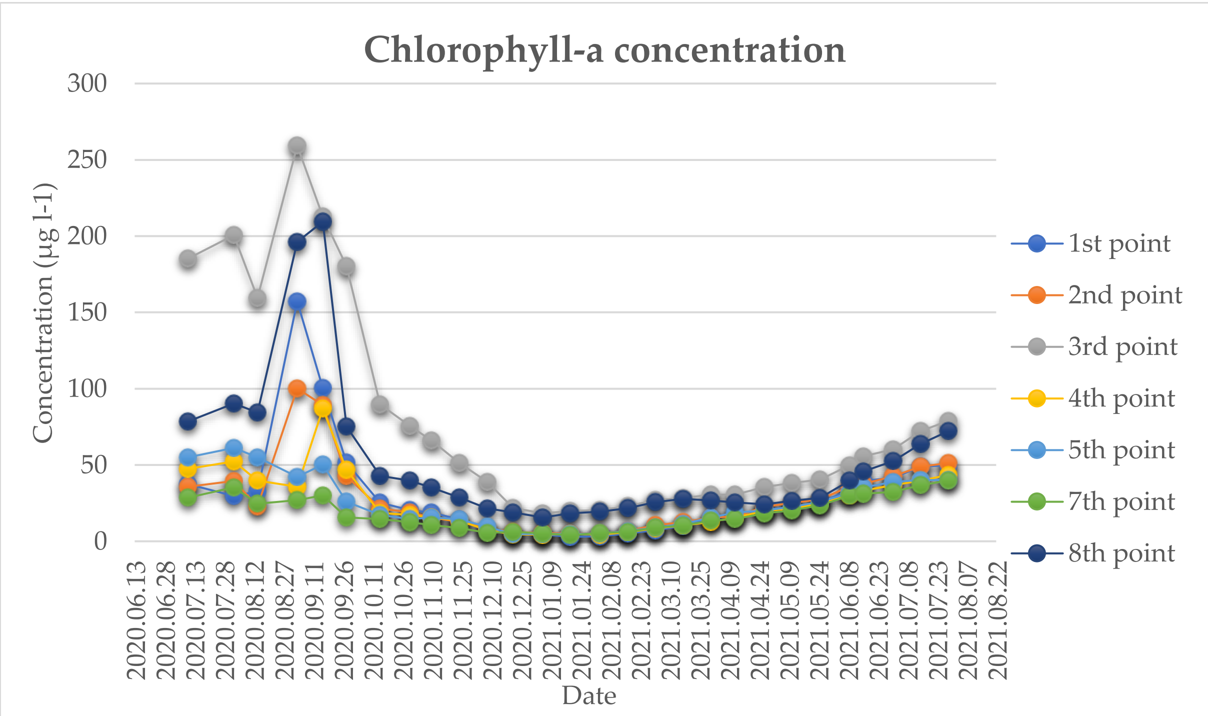

Figure 5 Chlorophyll-a content

5. ábra. Klorofill-a tartalom

The same pattern was observed in the results of nitrite-ion (Figure 6), nitrate-ion (Figure 7) and ammonium-ion (Figure 8) contents. In view of the 10/2010 (VIII. 18) Decree of the Ministry of Rural Development, the environmental values of parameters: 0,06 mg l^{-1} ($NO2^{-}$–N), 3 mg l^{-1} ($NO3^{-}$–N), 0,2 mg l^{-1} ($NH4^{-}$–N). The measured values in some cases were higher than the specific limit for all three parameters. Exceedances were most often seen at sample points 3 and 8. The highest detected concentration in $NO2^{-}$–N was 0,21 mg l^{-1}. In the case of $NO3^{-}$–N the value was 19,3 mg l^{-1}. As for the $NH4^{-}$–N concentration, the maximum value was 4 mg l^{-1}. The chemical water parameters changed along with water flow. During the rainy season, the concentration decreased because the precipitation in the water diluted the ion concentration. From this information, it can be concluded that agricultural, industrial and human activities near the Rákos stream can greatly influence the values measured in the water. Leakage of municipal and industrial effluents, unintentional or deliberate, and the effects of the use of agricultural fertilizers and pesticides must be taken into account too.

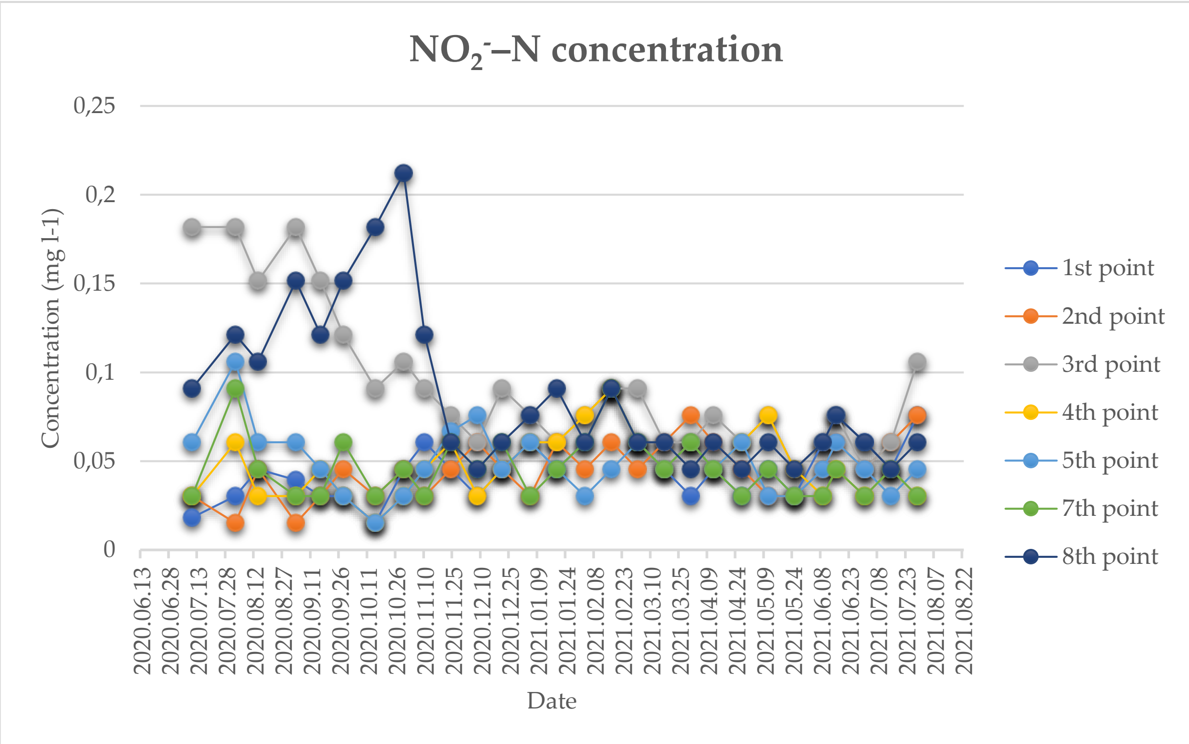

Figure 6 NO^{2-}–N concentration

6. ábra. NO^{2-}–N koncentráció

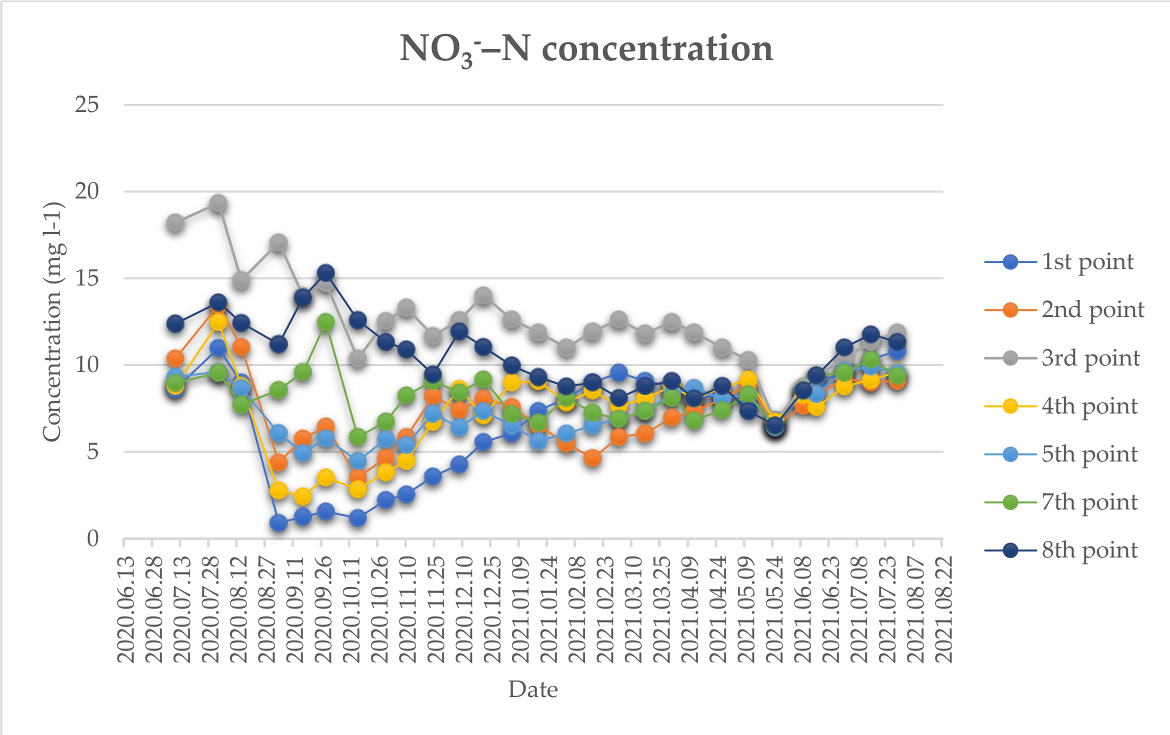

Figure 7 NO_3^-–N concentration

7. ábra. NO_3^-–N koncentráció

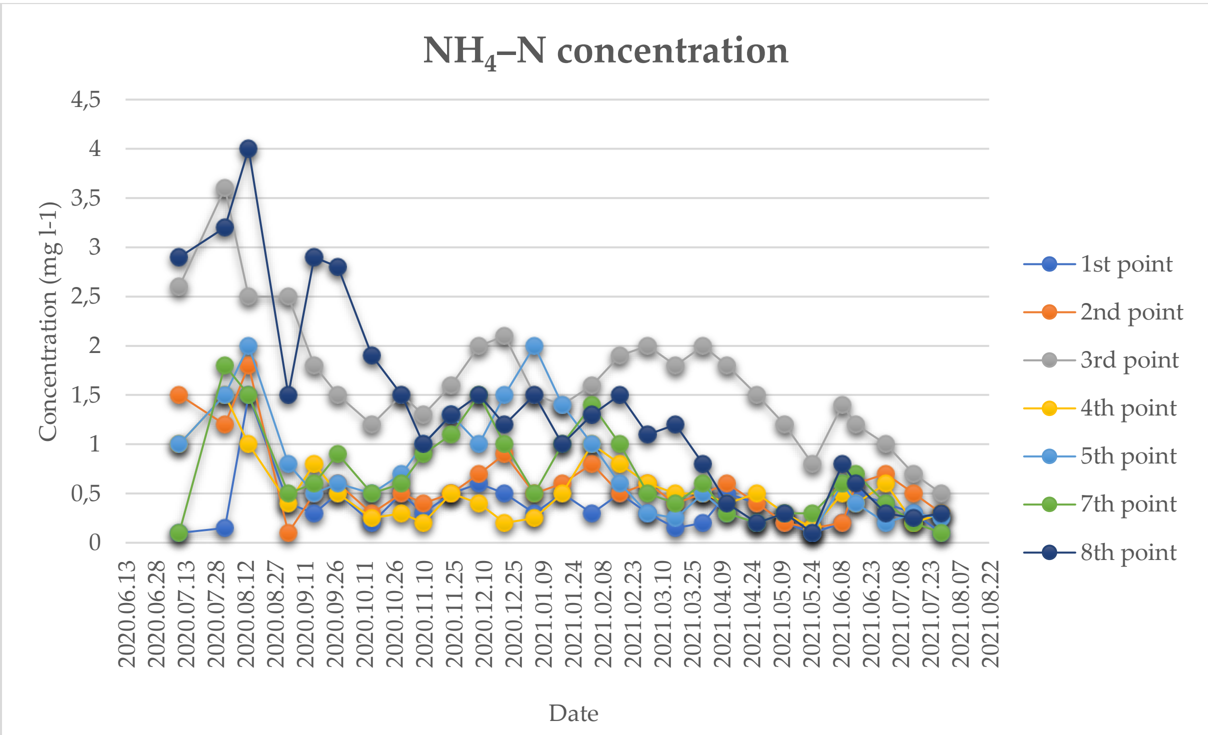

Figure 8 Ammonium concentration

8. ábra. Ammónium koncentráció

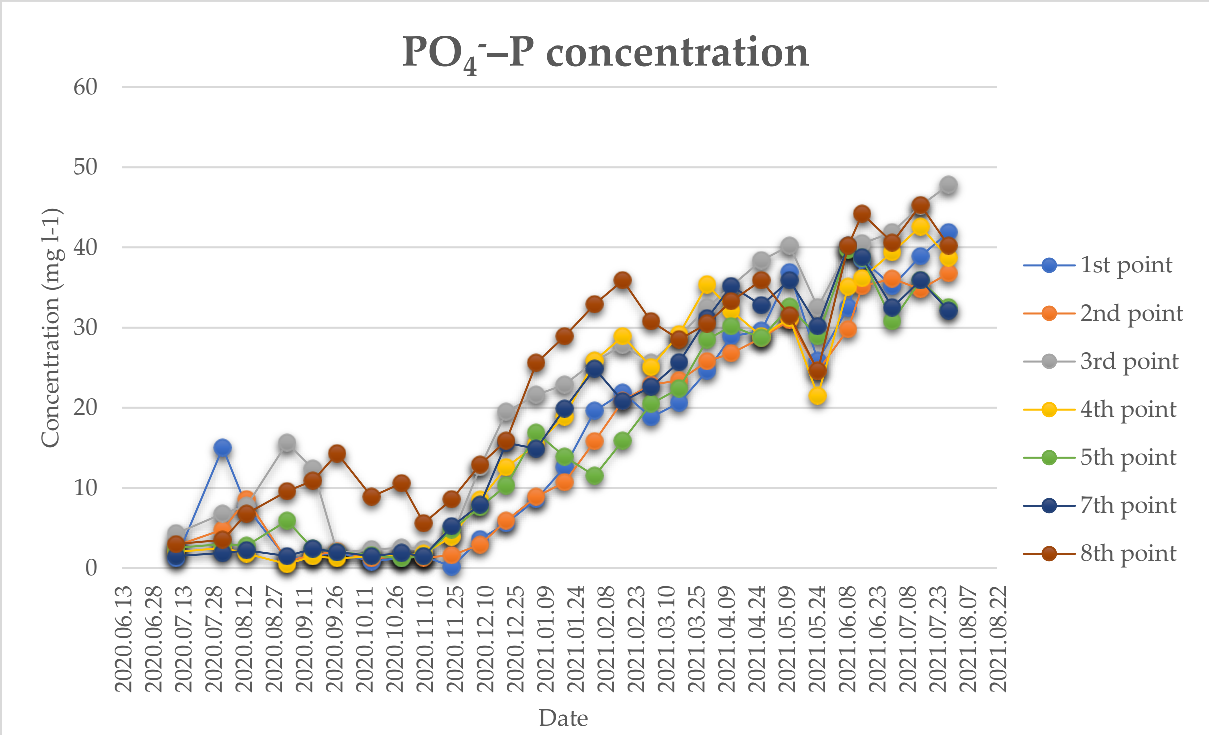

Figure 9 PO_4^-–P concentration

9. ábra. PO_4^-–P koncentráció

Different trends were detected for phosphate ion (Figure 9). The concentration limit of phosphate is 100 mg l^{-1} based on the 10/2010 (VIII. 18) Decree of the Ministry of Rural Development. The concentration values ranged between 0,1–47,9 mg l^{-1}. The measured values were lower than the limit, thus the water quality was adequate form this point. Summarizing the one-year dataset, the phosphate-ion concentration increased continuously for every sampling point. The measured value only dropped at one occasion, after a heavy rainfall event. Apart from this, the phosphate ion concentration showed a continuous upward trend. In search of the cause of this phenomenon, the source of the increasing phosphate ion concentration can be the use of additional N-P-K fertilizers and the phosphate content of detergents in infiltrating wastewater.

Conclusions

The results of the research were evaluated on the basis of the 10/2010 (VIII. 18) Decree of the Ministry of Rural Development. With the help of the one-year dataset, the environmental status of Rákos stream was sufficient based on the measured physical chemical and biological water quality parameters. There were some outstanding data during the sampling campaigns. As for the measured parameters, nitrite, nitrate, and ammonium concentrations were significantly higher than the specified limits. There was also an overshoot in conductivity. These parameters can have a negative impact on water quality and the use of water resources. Sampling points 3 and 8 showed significantly different values for all parameters. The possible reason for this phenomenon, the wastewater treatment plant does not operate efficiently enough close to sampling point 3. Increased levels of nitrite, nitrate, and ammonium ion concentrations, high water temperature values and hectically changing pH levels were found during the measuring period. There were some industrial activities close to sampling point 8. The water flow was changing naturally, higher water flow rate was observed after rainy periods when concentrations were reduced by dilution. One of the main purposes of the study was to evaluate the water quality and quantity of the Rákos stream regarding to environmental status assessment and impact of the agriculture (more precisely the irrigation potential). Analysing the measured values, the water of the Rákos stream is unsuitable for agricultural purposes due to the high conductivity, nitrite, nitrate and ammonium concentration (evaluated by 10/2010 (VIII. 18) Decree of the Ministry of Rural Development).

Further studies are needed to get a more accurate aspect of the available water resources for agricultural purposes. Sodium and magnesium concentration, SAR must be among the measured parameters. High conductivity, higher chlorophyll-a concentrations would cause problems with clogging and deposition in irrigation systems in the long run. Algae and sodium compounds would deposit in pipes, valves and nozzles, causing clogging. Repairing and fixing any problems would be time-consuming and labor-intensive, which would mean additional expenditure for the farms. High nitrogen content would have a negative effect on plants (Füleky, 1999). For example, the plant becomes more susceptible to diseases. Nitrogen over-application reduces the frost resistance of plants.

Acknowledgements

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A Rákos-patak vízminőségének és mennyiségének időben változásának elemzése a fenntartható mezőgazdaság szempontjából

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Kulcsszavak: vízminőség, kémiai vízminőség, patak, középtávú elemzés

Összefoglalás: A rendelkezésre álló vízkészletek egyre korlátozottabbak, a különböző monitoring rendszerek működtetése elengedhetetlen ahhoz, hogy a vízminőségi és mennyiségi adatok további elemzésre kerüljenek. Egy másik kiemelt szempont a víz különböző célokra történő felhasználása. A felszíni vagy felszín alatti víz használhatóságának meghatározásához információkat kell gyűjtenünk a víz fizikai, kémiai és biológiai minőségi paramétereiről. A hosszú távú monitoring rendszerek számos vízgazdálkodási kérdésben segíthetnek: fenntartható vízgazdálkodás, vízkészlet-allokáció, újrahasználati lehetőség. Jelen tanulmányunk keretében a Rákos-patak környezeti állapotát – a vízminőségre és mennyiségre fókuszálva – in situ mérésekkel elemeztük. A vizsgált paraméterek a következők voltak: vízhőmérséklet, vízhozam, klorofill-a, PO_4^{3-}, NH^{4+}, NO^{2-}, NO_3^-, pH, TDS, DO.