Hydroecological and water qualification monitoring of frontier watercourses, with field analyses and computer modelling methods

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Summary

The authors analyzed the relationship between the significant hydroecological and water-quality factors, and investigated the hydrological and morphological characters and conditions of the Berettyó River in the examined cross-sections, according to the recommendations of the Water Framework Directive of the EU. Determined, the different environmental qualification methods estimate the environmental quality status similarly.

Introduction

The climate change and water resources conservation require the rehabilitation, and natural, effective management of surface waters and wetlands (Ligetvári et al., 2006; Várallyay, 2007). Except chemical pollution, the bed regulations affect unfavourably on environmental condition of rivers. Improvement and reconstruction of hydrologic conditions have projecting importance in the revitalisation of regulated surface streams.

For access of good environmental qualification the common analyses of measured, and computer generated environmental data is necessary (Pregun and Tamás, 2005; Pregun et al., 2008).

The Berettyó River is a part of Körös-Berettyó drainage network of the Tisza river system. This watershed can be considered as the most influenced Hungarian country by river bed regulations. (Dóka, 1997; Somogyi, 2000).

Nowadays the discharge fluctuation of Berettyó is extreme, highly influenced by pointwise and diffuses pollution resources of inland and external catchment area. (Tamás and Bíró, 2001).

Maine objectives:

1. Developing and uploading a hydraulic model, which able to load and execute real time events, and able to simulate estimates, in order to generate hydraulic (water physical and geometric) data for environmental analysis.
2. Examine interactions between hydrologic physical, chemical and biological factors.
3. Search the relationship between the fluxation parameters and animal aquatic biocenosises.

Material and methods

The researches are in progress on the River Berettyó, on the Bihar Plain, the North Plain Region of Hungary. The river is part of Duna-Tisza River System. Altitude: lowland, catchment area: small, geology: calcareous (WFD). The river is a regulated inter-basin transfer and receiver of a drainage canal network.

There were selected upstream type reaches with gritty – sandy river bottom (Kismarja, Pocsaj, and Bakonszeg), a regulated middle stream type reach with sandy – muddy river bottom (Berettyóújfalu), and a downstream type reach with muddy river bottom (Szeghalom)*(Table 1, Figure 1.).*

Table 1:

Topographical data of sampling spaces

Sampling Space	Cross-section (XS)	River Station (km)	Cross-section coordinates (EOV)			
			Left overbank		Right overbank	
			X	Y	X	Y
Kismarja	**145.**	**72,540**	**861139.77**	**215818.69**	**861158.65**	**215902.43**
Pocsaj	**136.**	**68,234**	**858023.73**	**218544.66**	**858096.65**	**218765.03**
Berettyóújfalu	**86.**	**43,352**	**838702.39**	**209997.46**	**838642.16**	**210140.29**
Bakonszeg	**68.**	**34,206**	**830823.50**	**206277.20**	**830680.70**	**206321.70**
Szeghalom	**14.**	**6,532**	**812095.63**	**187608.84**	**812010.76**	**187754.77**

Figure 1: **The searching places of the River Berettyó with representative cross-sections**

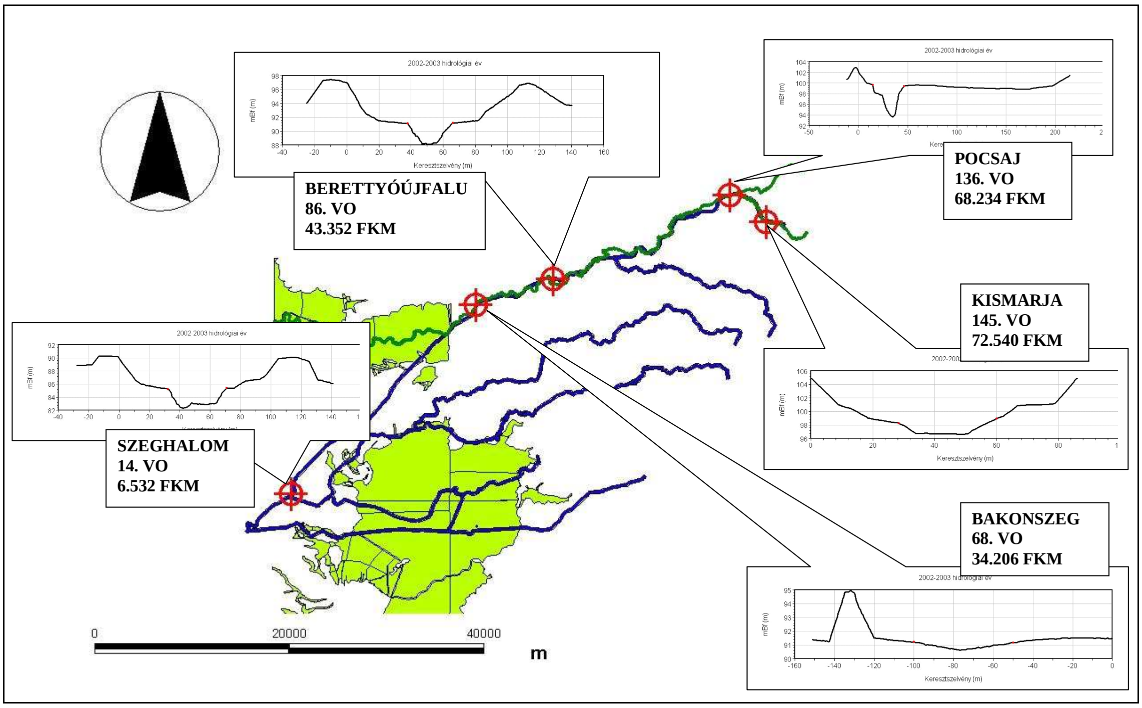
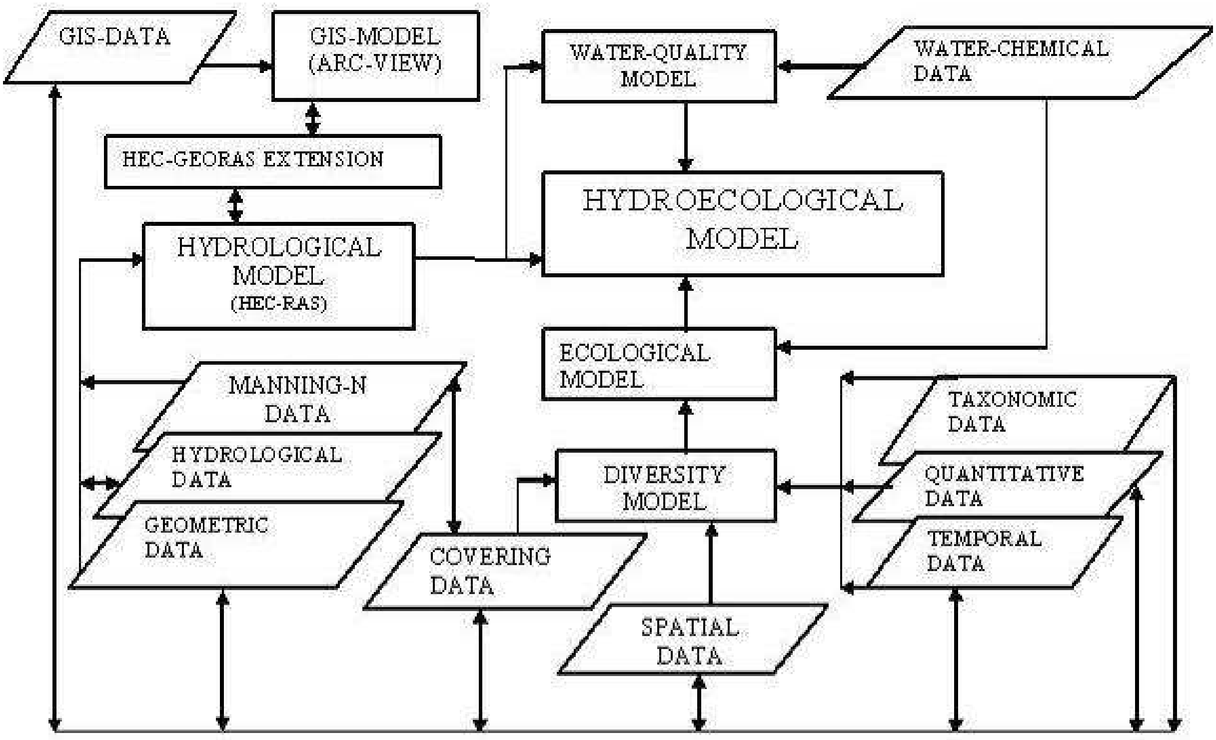


Figure 2: **The hydroecological model**



Foundation of the hydrologic model

The hydraulic time series were generated by the application of HEC-RAS (*Table 2-3, Figure 2*). The HEC-RAS is an interactive, integrated software system that works in a multi-module environment. The software is a one-dimensional hydraulic analysis programme, which can produce pseudo-3-dimensional model of streams by arranging of digitalized cross-sections (Warner et al. 2002). The boundary conditions of the search terms were determined by the records of water gauges of the section defence office of Szeghalom, Berettyóújfalu and Pocsaj settlements.

Table 2:

Examined hydraulic parameters

Geometric Parameters	**Energetic Parameters**	**Parameters of Conveyance**
- Water Surface Elevation (m) - Maximum Main Channel Depth (m) - Flow Area (m^2) - Wetted Perimeter (m) - Top Width (m) - Hydraulic Radius (m) - Hydraulic Depth (m)	- Shear Total (N/m^2) - Total Energy (m) - Power Total (J/m2 s) - Slope of Energy Gradeline ($^0/_{00}$) - Friction Loss (m) - Total Energy Loss (m)	- Total Flow (m^3/sec) - Average Velocity (m/sec) - Froude-Number (F_r) - Reynolds-Number (Re)

Table 3:

Measured water-quality parameters

Halobity and other physical-chemical parameters	**Trophity**	**Saprobity**	**Toxicity**
- Conductivity, - Temperature, - pH, - Dissolved oxygen content, - Turbidity, - Ammonia	- Green algae, - Cyan bacteria, - Bacillariophyceae = Diatoms, - Pyrrophyta - Chlorophyll-a content	- Total organic carbon (TOC)	- Toxicity (green alga test)

Aims of the statistical analyses have been the next:

-How can to minimize the number of hydrological and water quality factors without considerable information lost?

-How can be represented the hydrologic and environmental status which is determined by primary coefficients, by the calculated, uncorrelated factors?

-What relationships exist among the prime, and the calculated factors?

-The hydrological and water quality factors how are clustered by the theoretical factors?

-The factors how can be aggregated and rearranged?

-The individual calculated factors how can be identified as the attribute of the Berettyó River?

The comprehensive evaluation of the environmental status was calculated by the Spencer’s environmental indicator method (Spencer et al., 1998) *(Table 4).*

Water quality classification was done according to the Hungarian standard (MSZ 12 749).

The list of environmental indicators was supplemented with hydraulic factors that have significant effect on the formation and changes of the river ecosystem. The measured and calculated results of MMCP (Hungarian Makrozoobenthos Score System, macroinvertebrata water quality test method) were included in the list (Németh, 1998, Pregun and Tamás, 2004, 2005).

Table 4.

Calculation of the environmental qualitative index

Score of the environmental factor/indicator	
Soil	**Stability of the coast**
Water	**Shearing stress**
	Stream
	Average velocity
	Conductivity
	Absolute Oxygen Content
	5-day Biochemical Oxygen Demand
	H-concentration
Water quality index	**Water-quality indicators (MMCP)**
	Biodiversity
Vegetation	**Cover**
	Heterogeneity of habitats

Results and discussion

The results of the multivariate analysis of the hydraulic data:

The flow regime of the Berettyó River is fluctuating and extreme. The difference between the lowest and highest rate of streamflow can be 20 – 25 fold. Flood hydrograph can be represented with the extremities of flood waves, which are usually short in time.

The difference between the 2002-2003 and 2004-2005 hydrologic year is most apparent in the second half of the year *(Figure 3- 4).*

Figure 3: **The calculated discharge record of Berettyó (Pocsaj, 2002-2003 hydrological year (11. 01 – 10. 31.)**

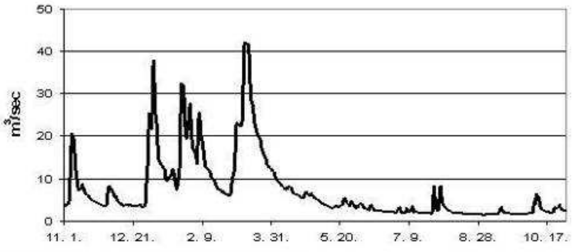
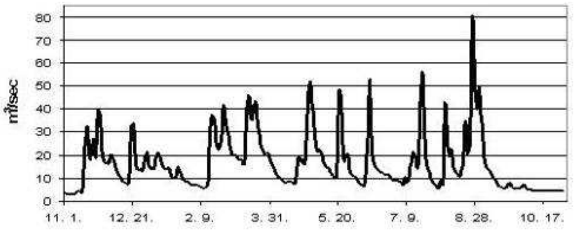


Figure 4: **The calculated discharge record of Berettyó (Pocsaj, 2004-2005 hydrological year (11. 01 – 10. 31.)**



Geometric data were in the prime principal in each case with significance. The dynamical hydraulic factors at No. 145 (U-trapeze shaped), No. 136 (V-shaped) and No. 68 (U-shaped) cross-sections (=XS) changed from first principal component to the second component in the high water periods.

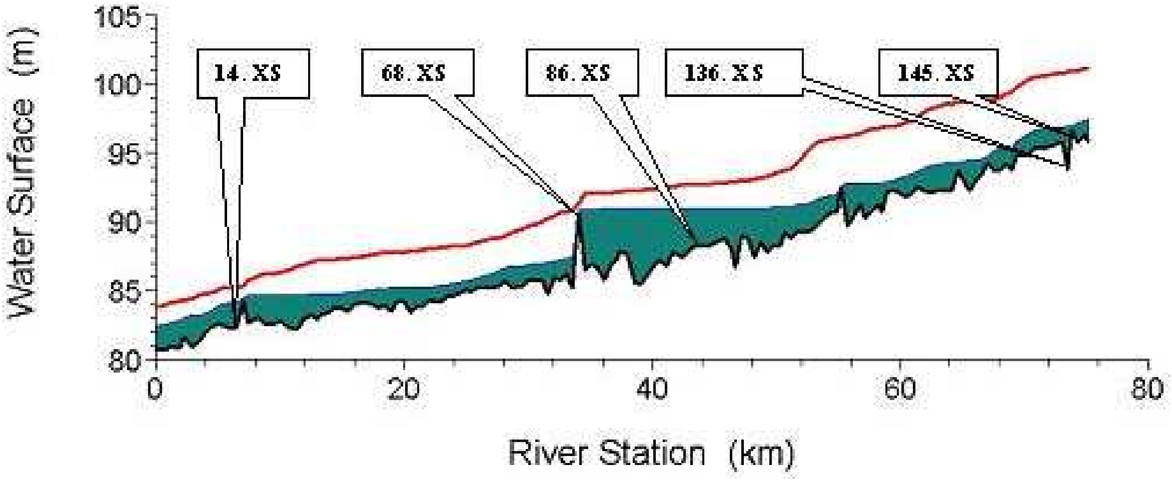
The dynamical hydraulic factors changed from first principal component to the second component in the low water periods in the trapeze-shaped cross-sections No. 14 and 86.

In this case the derivative geometrical data (hydraulic radius and depth, distribution), and the top width and the perimeter moves to the second component with a negative sign. This indicates the inverse proportion between the average depth and the energy losses in low runoff. In the case of high-water stage the average depth does not influence the energy status.

The stream was subcritical in the examined cross-sections, except for XS 68. The stream states were laminar or weekly turbulent in all the examined sections.

From the point of view of the average velocity extreme hydraulic circumstances were formed at XS 68. This section of River Berettyó behaves like a mountain stream and makes an ecological barrier not just for the rheoxen species – typical in still waters and slow watercourses – but also for the rheofil species that can be found in middle river sections. The average slope of water surface is 0.0002 m/m on the Hungarian reach of River Berettyó, but between XS 67 and 68 (this section is 530m long) the slope is 33 times higher in low water period and 9 times in high water period. The stream is permanently supercritical or critical; the average velocity is independent of the bed-geometric data. XS 68 has special hydraulic sessions because of the hydraulic radius and the depth is relatively small, so the top width and the wetted perimeter are large *(Figure 5).*

Figure 5: **The longitudinal profile of the Hungarian section of the Berettyó River**



Yearly changes of the water quality

According to the permanency of the water quality data we can conclude the followings:

- The water according to the pH was perfect (neutral) or good (slightly alkaline) in researched periods.
- The conductivity (salt-content) in hydraulic year 2002-2003. was perfect or good in 67%, middle in 24% and low in 9%. The middle and the low states were realized in low runoff cases. In the hydraulic year 2004-2005, there were not low water periods so the conductivity was perfect or good in 83% and middle in 17%.
- By the dissolved oxygen content in the first year the water was perfect or good in 18%, middle in 42%, low in 34% and bad in 6% during the low water states. In the second hydraulic year the water was good and perfect in 93% and middle in 7%.
- The water quality of the Berettyó River is most endangered by Total Organic Carbon (TOC) content. In the 2002-2003 hydrologic years the category was middle or low in 31%, and in 19% (50% in total). In the 2004-2005 year it was 37% and 22% and bad in 6% (65% in total). The increasing TOC attracts attention to the point or diffuse pollution sources in the upper sector which become more dangerous during the risings.
- The rate of the ammonification progresses was low. Medium quality period evolved in 10% at the summer of 2003. The concentration was lower in the second year.
- The quality of the water was mostly perfect or good and medium in 3% according to the trophity.
- The toxicity of the water was always better than class II. But the quality was worse in the lower runoff periods because of floated organic pollutants.

The results of collective analysis:

Summarizing the principal component analysis of examined water quality and hydraulic factors, it was established that the hydraulic parameters (runoff, energetic and geometric attributes) influence the water quality by effecting the physical and chemical parameters of the water. They affect the dilution process at high water situations and the temperature at low water cases. The obverse connection between the temperature and the pH shows the dependence of biological degradation processes on temperature. The increase of the degradation is connected to acidification. The trophity (chlorophyll-content) is connected to the conductivity in summer time (low water conditions) and to the Total Organic Carbon (TOC) in winter time (high water floods). This may refers to the pollution sources at the flood plain of the upper sector.

Assessment and results of the Hungarian Macrozoobenton Family Point-system (MMCP)

The taxons, taxon-scores and the water quality of the Berettyó River in the *Table 5* can be finding.

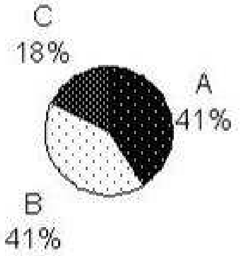
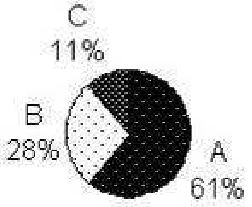
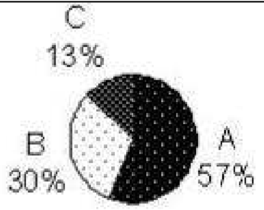
Table 5.

The examined Hungarian macrozoobenthos families and other taxons

	Kismarja	**Berettyóújfalu**	**Szeghalom**
QI	**Family Taxon**	**Family Taxon**	**Family Taxon**
6	Ephemeridae – Burrowing Mayflies Libellulidae – Skimmer Dragonflies	Leptoceridae – Longhorned Caddisflies Leptophlebiidae – Common Mayflies	Ephemeridae – Burrowing Mayflies Leptoceridae - Longhorned Caddishflies Leptophlebiidae – Mayflies
5	Haliplidae – Crawling Water Beetles Unionidae – Freshwater Molluscan Shells Hydropsychidae - Spotted Sedges Limnephilidae – Caddisflies Pisidiidae – Pea Mussels)	Caenidae – Small Squaregill Mayflies Dytiscidae – Water Beetles Haliplidae – Crawling Water Beetles Hydropsychidae - Spotted Sedges Pisidiidae – Pea Mussels	Dytiscidae – Water Beetles Haliplidae – Crawling Water Beetles Hydrophylidae – Water Lover Hydropsychidae – Spotted Sedges Limnephilidae – Caddis flies Pisidiidae – Pea Mussels
4	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Gerridae – Water Striders Nepidae – Water scorpions Coenagrionidae – Pond Damselflies Notonectidae – Backswimmers	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Nepidae – Water scorpions Gerridae – Water Striders Pleidae – Pigmy Backswimmers	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Gerridae – Water Striders Nepidae – Water scorpions Pleidae – Pigmy Backswimmers
3	Asellidae Platycnemididae – White-legged Damselflies. Corixidae – Water Boatmen	Bithyniidae – Mud Snails Corixidae – Water Boatmen Lymnaeidae – Swamp Snails Tipulidae - Crane Flies	Asellidae Bithyniidae – Mud Snails Corixidae – Water Boatmen Erpobdellidae - Leeches Hirudidae - Leeches Lymnaeidae – Swamp Snails Tipulidae - Crane flies
2	Culicidae - Mosquitoes	Culicidae - Mosquitoes Diptera – Flies	Culicidae - Mosquitoes Diptera – Flies
	Water quality class: 5 – Good quality (II/A)	**Water quality class:** 4 – Good quality (II/B)	**Water quality class:** 4,5 – Good quality (II/A)

Table 6.

Animal ecotypes of aquatic biocenosyses

	Sampling spaces								
	No. I. Kismarja			**II. Berettyóújfalu**			**III. Szeghalom**		
A. Benthic taxons of still and sluggish surface waters	Libellulidae Unionidae Hydropsychidae Limnephilidae Pisidiidae Calopterygidae Culicidae (7)			Caenidae Hydropsychidae Pisidiidae Calopterygidae Leptophlebiidae Lymnaeidae Tipulidae Pleidae Bithyniidae Culicidae DIPTERA* (11)			Pisidiidae Limnephilidae Hydropsychidae Leptophlebiidae Pleidae Calopterygidae Bithyniidae Erpobdellidae Hirudidae Lymnaeidae Tipulidae Culicidae DIPTERA* (13)		
B. Animal taxons of open waters biomes (nekton, plankton and metaphyton etc.)	Haliplidae Gerridae Nepidae Coenagrionidae Notonectidae Asellidae Corixidae (7)			Dytiscidae Haliplidae Nepidae Gerridae Corixidae (5)			Dytiscidae Haliplidae Hydrophylidae Gerridae Nepidae Asellidae Corixidae (7)		
C. Benthic taxons of rapid streams	Ephemeridae Baetidae Platycnemididae (3)			Leptoceridae Baetidae (2)			Ephemeridae Leptoceridae Baetidae (3)		
The dispersion of biotic communities in the sampling spaces									
Average velocity (2004-2005. hydrologic year, 11.01. – 10.31.)	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
	0.32	0.78	**0.39**	0.07	0.36	**0.22**	0.20	0.56	**0.33**
*DIPTERA – Ordo Resource: Varga, Z. (1999)									

By the means and duration curves of the average water velocity the No. I. and No. III. sampling spaces are medium speed, No. II. is slow river reach.

By the taxon composition percentage rate the sector of Kismarja has strong open water surface character, with benthic taxons (41-41%), and 18% rapid stream taxons. The two other sampling spaces on the lower reach have sluggish character with typical taxons *(Table 6-7).*

Table 7:

Classification of surface streams by the average velocity, with characteristic ecotypes.

Velocity limit values & waterspace types & regions	**Velocity ecotypes of animal taxons**
0.0 – 0.3 m/sec Still and slow stream waters, down reaches of rivers	Rheoxen (rheofób) taxons – only still waters
0.3 – 0.8 m/sec Bigger creeks, wold brooklets, middle reaches of rivers	Rheofil taxons – still and stream waters alike
>0.8 m/sec Mountain creeks, upper reaches of rivers	Rheobiont taxons – only streamwaters

Environmental indicator test (Spencer, 1998):

The water-quality of the stream fluctuates between poor and good status in summer time; the most hazardous factors are the high organic matter content (TOC and BOD_5), the low oxygen content and the salt content (electric conductivity). The macroinvertebrata bioindicators (MMCP) show better environmental conditions than physical–chemical properties, because the river connects to the network of semi-natural channels, which function as a system of ecologic corridors.

Table 5:

Water quality of the Berettyó (2003 april - august)

	SZEGHALOM	**BERETTYÓÚJFALU**	**KISMARJA**
H-concentration	Mildly alkaline	Mildly alkaline	Mildly alkaline
Halobity - LF (mS/cm)	β-mesohalobe	β-mesohalobe	β-mesohalobe
Saprobity - BOI_5 (mg/l)	α-mesosaprobe	α-mesosaprobe	α-mesosaprobe
Water Qualification (Hungarian Standard, 12749)	Tolerable water III.	Polluted water IV.	Tolerable water III.
Water Qualification - MMCP	Good quality IV.	Good quality IV.	Good quality II.
Simpson-index of bioindicators	Middle status 0.82 – III.	Middle status 0.82 – III.	Middle status 0.79 – III.
Spencer-index	Good status 3.91	Middle status 3.47	Good status 3.77

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