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Determination of optimal sampling frequency for water quality attributes at River Tisza, Szolnok (Hungary)

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Introduction

The assessment and monitoring of ecological quality of freshwater is of central importance today (RUOPPOLA et al. 2003). Hungary has had a long tradition of objective water qualification (FELFÖLDY 1974), and an ecological approach of the water qualification was developed by Dévai and his co-workers in the early 1990s (DÉVAI et al. 1992a, 1992b, 1992c). The complex qualification procedure was tested during the study of Boroszló-kerti-Holt-Tisza in 1997 (DÉVAI et al. 1999).

Our paper is related to the implementation of EU Water Framework Directive (WFD) in Hungary. We analysed the influence of sampling frequency to the result of classification of water bodies and determined the minimum sampling intensity to produce ecologically relevant classification of the chemical status of the water bodies (Directive 2000).

During this study we analysed the data set of the Water and Sewage Works Franchising Joint Stock Company of Szolnok in Hungary. This water supply intake provides the drinking water of Szolnok city and their neighbouring villages (more than 120 000 people) based on the River Tisza. The Company controls the chemical water quality once every two hours. Our paper is based on the analysis of this data set.

Key words: water framework directive, chemical status, sampling frequency

Materials and methods

The water supply intake is at the 336.63 river km on the River Tisza (Fig. 1). No incoming watercourses to the Tisza significantly influence the water quality between Kisköre and Szolnok city (100 river km).

The present bed and basin-network of tributaries of River Tisza were formed about ten thousand years ago, making it older than the Danube-basin (FELFÖLDY et al. 1996). The total length of River Tisza is 964 km; the Hungarian section is 600 km between 758–158 river km. The Hungarian section of

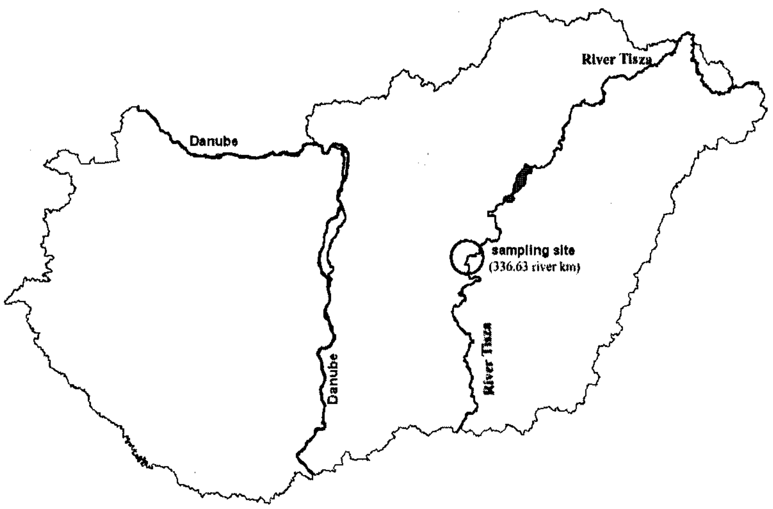

Fig. 1. The water supply intake at Szolnok city along the River Tisza in Hungary.

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the River Tisza can be divided into three zones on the basis of regime: Upper-, Middle- and Lower-Tisza. Smaller or middle-sized floods are possible every 2–3 years, a significant flood by 5–6 years, and an extraordinary one by 10–12 years on the home catchment area of the River Tisza. The variability within a year is extremely illustrative of the River Tisza; the discharge and the fluctuation varies between wide ranges. For example, in Middle-Tisza the fluctuation was 1318 cm, the recorded minimum discharge was 60 m^3/s, while the maximum discharge was 3320 m^3/s at city Szolnok.

The Laboratory of the Water and Sewage Works Franchising Joint Stock Company of Szolnok controls the chemical water quality every two hours; our analysis is based on the sample taken at 6 o'clock every day. We chose two characteristic years: 1987 was a typical year regarding the water regime, while 1998 was an extreme year with large floods. We examined the specific electrical conductivity, turbidity, chemical oxygen demand with potassium permanganate (COD) and inorganic nitrogen (the total of the ammonium, nitrate, and nitrite ions). Analysis was carried out according to the following National Standards: MSZ 448-32:1977, MSZ ISO 7027:1992, MSZ 448-20:1990, MSZ ISO 7150-1:1992, MSZ 448-12:1982.

We analysed the time series of the two studied years with decreasing sampling frequency throughout the year: 365 samples (each day), 53 (every week), 27 (every second weak), 14 (every 28 days), 12 (every month). In addition we studied extremely spare sampling frequencies: 5, 4, 3, 2 samples per year. We compared the behaviour of the extremes of the time series (minimum and maximum) and the yearly averages based on the samples. The characteristics of the time series with decreasing sampling frequency were compared to the time series based on daily measurements. We have also explored the influence of decreasing sampling intensity to the characteristics by cluster analysis. Euclidean distance and average link (UPGMA) fusion algorithm was used (LEGENDRE & LEGENDRE 1998).

Results and discussion

Time series with decreasing sampling frequencies were statistically analysed for the two studied years (Table 1).

Changes in characteristics by decreasing sampling frequency are demonstrated for COD in 1987 for each statistic (Fig. 2). Figures for all the studied components and both years were very consistent.

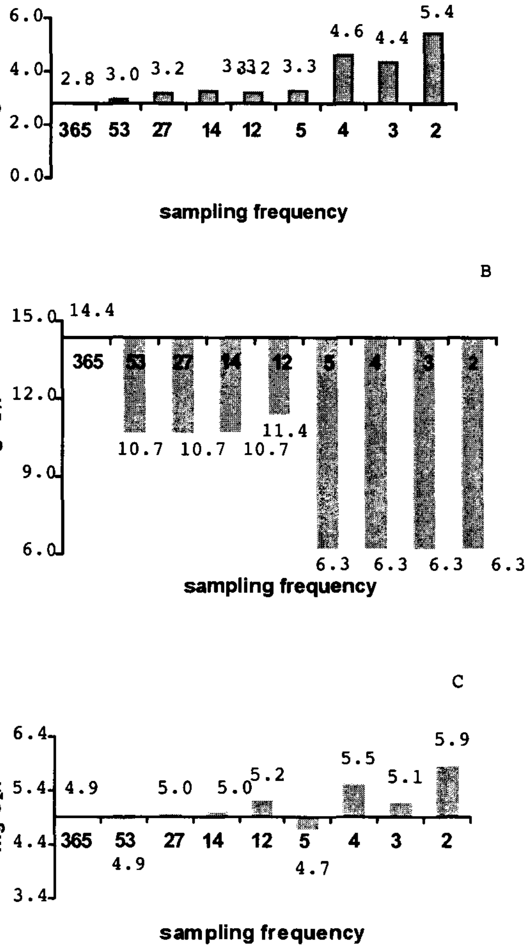

Fig. 2. Changes of characteristics by decreasing sampling frequency for COD in 1987. The characteristics were compared to the time series based on daily measurements. Minimum (A), maximum (B), average (C).

Both the three-dimensional scatter plots and the tree diagrams of the cluster analysis revealed that the time series based on the daily sampling is different from the others based on the extremes and averages for COD in 1987. Two definite, separate groups of the other time series arose (Fig. 3). The first group included the time series with 53, 27, 14, and 12 samples in a year; the other group included the times series with 5, 4, 3, and 2 samples per year. The scatter plots and cluster analysis showed the

Table 1. Statistics of the analysed time series with decreasing sampling frequencies for the two studied years.

			Sampling frequency								
			365	**53**	**27**	**14**	**12**	**5**	**4**	**3**	**2**
1987	Turbidity (NTU)	Minimum	8	11	14	14	18	20	36	36	36
		Maximum	714	602	602	602	451	118	250	118	62
		Average	77	73	71	92	97	59	103	77	49
	Conductivity (µS/cm)	Minimum	207	212	212	280	306	290	399	290	399
		Maximum	802	770	685	685	690	685	685	685	685
		Average	418	422	395	416	443	472	486	455	542
	Inorganic nitrogen (mg N/l)	Minimum	0.9	2.1	2.4	2.4	4.1	4.4	5.1	5.0	5.3
		Maximum	18.2	14.0	14.0	14.0	12.1	9.6	9.6	9.6	9.6
		Average	7.0	6.9	7.0	6.8	7.0	6.7	6.9	7.1	7.4
	COD (mg O_2/l)	Minimum	2.8	3.0	3.2	3.3	3.2	3.3	4.6	4.4	5.4
		Maximum	14.4	10.7	10.7	10.7	11.4	6.3	6.3	6.3	6.3
		Average	4.9	4.9	5.0	5.0	5.2	4.7	5.5	5.1	5.9
1998	Turbidity (NTU)	Minimum	7	7	7	7	15	20	15	40	102
		Maximum	772	510	330	330	108	102	108	102	108
		Average	88	85	76	87	43	52	61	73	105
	Conductivity (µS/cm)	Minimum	135	208	225	242	230	344	345	350	345
		Maximum	540	508	470	429	475	419	398	419	350
		Average	352	356	356	344	355	379	361	380	348
	Inorganic nitrogen (mg N/l)	Minimum	1.5	1.7	1.8	2.6	2.7	2.6	5.0	3.9	5.0
		Maximum	11.0	10.4	7.1	6.6	8.0	6.6	6.6	6.6	6.6
		Average	5.1	5.3	5.1	5.0	5.3	4.6	5.5	5.1	5.8
	COD (mg O_2/l)	Minimum	2.1	2.1	2.1	2.1	2.9	2.1	2.9	3.7	4.1
		Maximum	17.6	10.5	10.5	10.5	6.9	4.1	6.9	4.1	6.9
		Average	4.9	4.8	4.7	4.8	4.0	3.5	4.2	3.9	5.5

same groups for all the studied variables and both years.

Note the strong pattern revealed by cluster analysis. The time series based on 2, 3, 4, and 5 samples per year are clearly separate from the other samples because the characteristics of these time series are different from those based on more frequent sampling. These numerical differences are shown for all variables (Table 1). The maximum shows the most pronounced differences (Fig. 2); however, the differences for the minimum and average values are also large for low sampling frequency. These differences are also clearly demonstrated by the three dimensional scatterplots based on the studied statistics (Fig. 3).

Our results demonstrate that the averages of daily sampling and 12 samples per year were not considerably different, suggesting that < 12 samples per year may produce spurious results regarding the chemical water quality of rivers. In Hungary today the official standard of the water qualifying by Environmental Inspectorates is 26 samples per year. According to our results this sampling frequency can achieve the correct assessment of the water quality. Four samples per year, which is the minimum requirement of the EU Member States, is a questionable frequency for correct classification of water bodies according to their good chemical status (Directive 2000).

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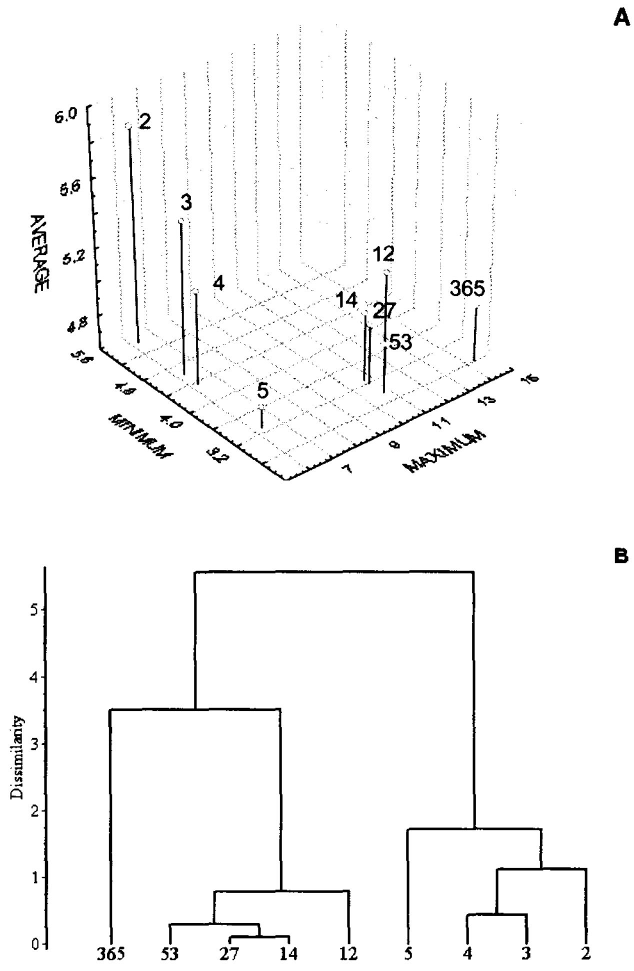

Fig.3. (A) Scatter plot of COD of time series with decreasing sampling frequency in 1987. (B) Tree diagram of the time series with decreasing sampling frequency by Euclidean distance and average linkage (UPGMA) algorithm. Note – figures show the number of yearly samples.

References

Dévai, G., Juhász-Nagy, P. & Dévai, I., 1992a: A vízminőség fogalomrendszerének egy átfogó koncepciója. 1. rész: A tudománytörténeti háttér és az elvi alapok [A comprehensive concept of water quality. Part 1: Historical background and principles]. – Acta Biol. debrecina, Suppl. oecol. Hung. 4: 13–28.

Dévai, G., Juhász-Nagy, P. & Dévai, I., 1992b: A vízminőség fogalomrendszerének egy átfogó koncepciója. 2. rész: A hidrobiológia és a biológiai vízminőség fogalomkörének értelmezése [A comprehensive concept of water quality. Part 2: An interpretation of the conceptual sphere of hydrobiology and biological water-quality]. – Acta biol. debrecina, Suppl. oecol. Hung. 4: 29–47.

Dévai, G., Dévai, I., Felföldy, L. & Wittner, I., 1992c: A vízminőség fogalomrendszerének egy átfogó koncepciója. 3. rész: Az ökológiai vízminőség jellemzésének lehetőségei [A comprehensive concept of water quality. Part 3: The possibilities of the characterization of the ecological water-quality by water bodies]. – Acta biol. debrecina, Suppl. oecol. Hung. 4: 49–185.

Dévai, G., Végvári, P., Nagy, S. & Bancsi, I. (eds.), 1999: Az ökológiai vízminősítés elmélete és gyakorlata. 1. rész [évai, Gy., Végvári, P., Nagy, S. & Bancsi, I. (eds.): Theoretical and practical aspects of ecological water qualification. Part 1]. – Acta biol. debrecina, Suppl. oecol. Hung. **10**/1., 216 pp.

Directive 2000/60/EC of the European Parliament and of the Council 23 Oct. 2000 establishing a framework for Community action in the field of water policy. – Off. J. Eur. Communities **43**: 1–72.

Felföldy, L., 1974: A biológiai vízminősítés [Biological water qualification]. – Vízügyi Hidrobiológia 3. VIZDOK, Budapest, 242 pp.

Felföldy, L., Gönczy, J., Pintér, K., Széky, P., Tasná-

DI, R. & TÖLG, I., 1996: Halgazdálkodás. I. kötet: Elméleti alapok [Fish culture. Vol. I: Theoretical basis]. – MOHOSZ, Budapest, 203 pp.

LEGENDRE, P. & LEGENDRE, L., 1998: Numerical Ecology. – Elsevier Science, Amsterdam, The Netherlands, 853 pp.

MSZ 448–32:1977, 1977: Ivóvízvizsgálat. Fajlagos elektromos vezetőképesség meghatározása [Drinking water – Tests. Determination of the specific electrical conductivity]. – Magyar Szabványügyi Hivatal, Budapest, 4 pp.

MSZ 448–20:1990, 1990: Ivóvízvizsgálat. A permanganátos kémiai oxigénigény meghatározása [Drinking water analysis. Determination of the chemical oxygen demand with potassium permanganate]. – Magyar Szabványügyi Hivatal, Budapest, 3 pp.

MSZ 448–12:1982, 1982: Ivóvízvizsgálat. Nitrát- és nitrition meghatározása [Drinking water analysis. Determination of nitrate- and nitrite ions]. – Magyar Szabványügyi Hivatal, Budapest, 6 pp.

MSZ ISO 7150–1:1992, 1992: Az ammónium meghatározása vízben. Manuális spektrofotometriás módszer [Water quality. Determination of ammonium. Part 1: Manual spectrometric method]. – Magyar Szabványügyi Hivatal, Budapest, 8 pp.

MSZ ISO 7027:1992, 1992: A víz zavarosságának meghatározása [Water quality. Determination of turbidity]. – Magyar Szabványügyi Hivatal, Budapest, 7 pp.

RUOPPOLA, M., HEINONEN, P., PILKE, A., REKOLAINEN, S., TOIVONEN, H. & VUORISTO, H., 2003: How to assess and monitor ecological quality in freshwaters. – TemaNord, Copenhagen, 214 pp.

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