3.6. Eutrophication processes in the Danube River Bank Region nearby Novi Sad

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3.6.1. Introduction

Environmental monitoring and water quality assessment programs of the Danube River are being systematically undertaken for three decades. (Djukic *et al.* 1996, 1998). Measurement of chemical and physical aspects of the environment indisputably has its role, but it is the ecosystem health that is to be the primary concern, and the emphasis on biological measurements in the program reflect this awareness. (Loeb and Spacie, 1994). Quantitative estimation of the status and trends in the indicators of ecological conditions requires using standardised procedures for monitoring in the region and using comparable methods across ecological resources. Quantitative estimates of resource condition are critical in determining the relative risk to our ecological resources and they are also critical for the decision-makers in order to implement effective regulatory and management decisions. Therefore, complex surveillance of the Danube River bank region in period 1998/1999, including hydrological, physico-chemical and biological monitoring was undertaken in the section around Novi Sad. The objective of this study was to asses direct and indirect impact of untreated municipal discharges on water quality, species composition and functional organisation of the bank region ecosystems and to estimate eutrophication rate in the investigated section of the Danube River.

3.6.2. Material and methods

In period 1998-1999 samples (water - ASTM, 1995; plankton - plankton net N°22; and bank region bottom samples - Peterson dredge with catchment area 400 cm^2) have been taken seasonally on 12 sampling sites: Begec 1 (Danube), Begec 2 (Danube), Begecka Jama (the Danube River wetland), Kamenjar (Danube - 1262 km), Sremska Kamenica (Danube - 1259 km), Ribnjak (Danube - 1257 km), Danubius (Danube 1257 km), Petrovaradin (Danube - 1255 km), railway bridge - municpipal wasterwater discharge (Danube 1254 km), the confluence of the Canal System Danube - Tisza - Danube into the Danube River (1253,5 km), public beach (Danube 1253 km) and Sremski Karlovci (Danube 1245 km). Saprobic Index (Pantle and Buck, 1955) has been calculated according to indicator values and number of recorded taxon. Ichthyological investigation have been undertaken in two sections: upstream (1262-1269 km) and downstream (1250) Novi Sad. The samples have been collected using nets (various mesh size) and electric fishing. Chemical analysis have been done by standard methods (APHA, 1995).

3.6.3. RESULTS AND DISCUSSION

3.6.3.1. Chemical analysis

The samples for basic physico-chemical analysis were taken in 1999, seasonally , at 5 sampling sites (Begecka Jama wetlands, Kamenjar, Sremska Kamenica, mouth of the canal DTD ionto te Danube River and Sremski Karlovci) . The results are shown in Table 1.

In the River Danube section near Novi Sad, COD-MnO_4 ranged from 4.2 - 13.2 mg L^{-1} and O_2 content and saturation varied with the season, while the lowest values were recorded in winter period, due to lack of photosynthetic activity of algae. An exception to this was observed at Begeèka jama locality, where O_2 content decreased during summer period probably because of the high water temperature. BOD_5, as an indicator for organic matter pollution showed moderate values for the most of the localities. Maximum load was observed in summer period at sampling site Begecka jama wetland. Higher values for both COD and BOD_5 were also recorded downstream of Novi Sad municipal wastewater discharge input. Most of the total organic load were biodegradable organic compounds.

Table 1. Basic physico-chemical parameters -seasonal mean values 1999. Winter (I), spring (II), summer (III) and autumn (IV)

	Sampling sites				
Parameter:	1 (Begecka jama)	2 (Kamenjar)	3 (Sremska Kamenica)	4 (mouth of the canal DTD)	5 (Sremski Karlovci)
1.COD-MnO_4 (mg O_2 L^{-1})	I – 11.6 II – 11.1 III – 9.6 IV – 13.2	I – 5.5 II – 7.5 III – 5.9 IV – 6.2	I – 4.9 II – 6.8 III – 6.2 IV – 5.7	I – 4.2 II – 6.8 III – 9.1 IV – 11.2	I – 5.8 II – 6.9 III – 6.8 IV – 9.0
2. BOD_5 (mg O_2 L^{-1})	I – 7.02 II – 8.20 III – 11.48 IV – 8.57	I – 3.65 II – 5.10 III – 5.47 IV – 4.20	I – 4.90 II – 4.98 III – 5.76 IV – 3.45	I – 4.26 II – 6.55 III – 8.66 IV – 4.52	I – 5.34 II – 6.44 III – 5.28 IV – 7.55
3. NH_4^+-N (mg L^{-1})	I – 0.33 II – 0.07 III – 0.51 IV – 0.38	I – 0.34 II – 0.21 III – 0.08 IV – 0.75	I – 0.38 II – 0.19 III – 0.26 IV – 0.39	I – 1.20 II – 1.10 III – 2.00 IV – 1.62	I – 0.41 II – 0.35 III – 0.64 IV – 0.29
4. NO_3^--N (mg L^{-1})	I – 2.87 II – 0.03 III – 0.35 IV – 2.62	I – 11.60 II – 3.52 III – 4.58 IV – 8.55	I – 12.40 II – 3.00 III – 4.08 IV – 8.34	I – 9.46 II – 2.05 III – 1.51 IV – 6.84	I – 11.20 II – 2.55 III – 3.54 IV – 8.52
5. NO_2^--N (mg L^{-1})	I – 0.05 II – 0.03 III – 0.007 IV – 1.09	I – 0.10 II – 0.07 III – 0.05 IV – 0.11	I – 0.13 II – 0.06 III – 0.06 IV – 0.12	I – 0.06 II – 0.11 III – 0.10 IV – 0.13	I – 0.08 II – 0.08 III – 0.08 IV – 0.12
6. PO_4^{3-}-P (mg L^{-1})	I – 0.06 II – 0.08 III – 0.02 IV – 0.03	I – 0.08 II - Ø III – 0.06 IV – 0.08	I – 0.11 II – 0.02 III – 0.07 IV – 0.09	I – 0.27 II – 0.22 III – 0.54 IV – 0.17	I – 0.08 II – 0.04 III – 0.01 IV – 0.10
7. EC (dS m^{-1})	I - 670 II - 420 III - 380 IV - 1060	I – 410 II – 330 III – 320 IV – 410	I – 460 II – 330 III – 330 IV – 440	I – 690 II – 490 III – 520 IV – 600	I – 410 II – 360 III – 320 IV – 460
8. pH	I – 7.5 II – 8.3 III – 8.4 IV – 8.5	I – 8.1 II – 8.3 III – 8.3 IV – 8.3	I – 8.2 II – 8.1 III – 8.1 IV – 8.2	I – 8.0 II – 8.2 III – 8.0 IV – 8.1	I – 8.3 II – 7.8 III – 8.2 IV – 8.2

In the spring and summer period biochemical processes are more intensive so the nutrient content is low, remaining within maximal allowed concentrations for class I-II water. The content of ionic forms of nitrogen (NO_2^-, NO_3^-, NH_4^+) and phosphorus (PO_4^{3-}) have not exceeded limits recorded in previous years. (Anon, 1995,1996,1997). In autumn, and especially in winter period, primary production is much lower and the nutrient level increases. Maximum concentrations of nutrients and soluble salts is recorded at the mouth of the canal DTD into the River Danube just downstream Novi Sad. caused by the untreated and partly treated wastewater discharge of mineral fertilizer factory and food processing facilities located on the bank of the canal.

According to the results of physico-chemical analysis, a certain trend of nutrient and organic enrichment along the Danube River bank region around Novi Sad is observed. Moreover, the section of the river downstream municipal wastewater discharge could be regarded as europhic.

3.6.3.2. Macrophytes

Table 2. Aquatic macrophytes as water quality indicators of the Danube River near Novi Sad

	sampling stations				ecological indices			
	Begecka Jama	Sremska Kamenica	Petrovaradin	Sremski Karlovci	R	N	H	D
Submersed macrophytes								
Ceratophyllum demersum L.	*	*	*	*	4	5	3	5
Myriophyllum spiccatum L.	*				4	2	4	5
Potamogeton pectinatus L.	*				4	4	3	4
Potamogeton lucens L.	*			*	4	4	4	5
Potamogeton acutifolius Link	*				4	3	3	5
Vallisneria spiralis L.				*	2	2	3	5
Elodea canadiensis Rich.				*	4	4	3	4
Floating macrophytes								
Nymphaea alba L.	*				3	3	4	5
Potamogeton fluitans Roth.			*		3	3	3	3
Trapa natans L (agg.)	*				3	3	4	5
Hydrocharis morsus-ranae L.	*				3	4	3	5
Polygonum amphibium L.	*				3	4	3	5
Salvinia natans L.	*	*		*	2	3		
Lemna minor L.	*	*	*	*	3	3		
Spirodela polyrrhiza (L.) Scheild.	*	*	*	*	3	3	3	4
Emergent macrophytes								
Veronica anagallis-aquatica L.			*		3	4	4	5
Phragmites communis Trin.	*			*	3	3	3	4

ecological indices - based environmental evaluation (R,H,N and D percent values)	R3 50% H3 > 50% N3 >50% D5 > 70%	R3 >70% H3 100% N3 70% D5 50%	R3 80% H3 >70% N3 60% D5 50%	R3,R4 40% H3>80% N3 50% D4,D5 50%

R - pH indicator; N- nitrogen and N-compounds content indicator H - indicator of organomineral compounds content; D index of transparency

According to indicator values - ecological indices (Landolt, 1977) of the most abundant macrophytes, the difference between the Danube River water quality upstream and downstream of Novi Sad has been observed. (Table 2) Sampling site Begecka Jama wetland is characterised by the presence of *Nymphaea alba*, *Myriophyllum spiccatum* and *Phragmites communis* - indicators of mesotrophic environment.

However, the appearance of a few *Potamogeton* species as well as *Hydrocharis morsus-ranae* indicate occasional nutrient enrichment (mainly runoff from the surrounding agricultural soil). In the "inner city" river section (sampling sites Sremska Kamenica and Petrovaradin) the presence of small-sized floating macrophytes (*Lemna minor, Spirodela polyrrhiza* and *Salvinia natans*) indicate mezzo - eutrophic environment. (Donk *et al.* 1993). Yet,, downstream Novi Sad (sampling site Sremski Karlovci) the high abundance of the duckweed, as well as occurrence of *Elodea canadiensis* imply the significant increase of nutrient input and eutrophic environment. (Lewis, 1995). The values of ecological index R suggest neutral to slightly alkaline pH of the Danube River, while high values index D point out impaired transparency along the section.

3.6.3.3. Phytoplankton

Qualitative analysis of phytoplankton reveals the presence of 100 taxon, with the absolute dominance of *Bacillariophyta* (62 taxon). Besides, 10 taxon of *Euglenophyta* and *Chlorophyta*, 6 taxon of *Cyanobacteria* and 1 from *Pyrrophyta*, *Xanthophyta* and *Crysophyta* were recorded. *Asterionella formosa (Bacillariophyta)* with saprobic index value 1.4, indicator of oligo towards β-mezzosaprobic waters, appears as subdominant species at all sampling sites, except Begecka jama wetland. However, *Nitzschia acicularis*, the typical indicator of α-mezzosaprobic waters has been recorded also at all sampling site, except Begecka jama wetlands. Species richness and saprobic Index at 11 sampling sites along the Danube River section Begec - Sremski Karlovci are shown in Fig. 1. The highest

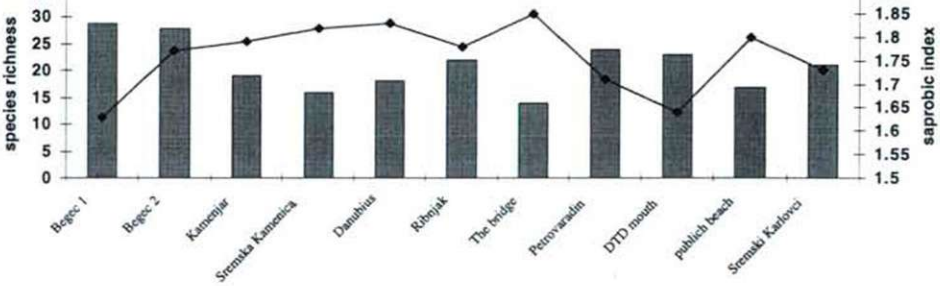

Fig. 1. Phytoplankton species richness and saprobic indices in the Danube River section near Novi Sad

number of recorded species (>25) and the lowest saprobic index values (1.63) were recorded at sampling site upstream Begec. Sampling site The Bridge (municipal wastewater discharge point) is characterised by decrease in species richness (<15) and high recorded saprobic index value (1.85). Therefore, according to phytoplankton analysis, an impairment of the Danube River water quality downstream Novi Sad is obvious. Yet, the highest saprobic index value (1.98) and the biggest species richness (37) were recorded at Bagecka jama wetland, which was expected, since this wetland represent a specific ecosystem, with rather poor connection with the main flow of the Danube River.

3.6.3.4. Zooplankton

As sample was taken only in winter 1998/1999 , only four groups - *Protozoa, Rotatoria, Cladocera* and *Copepoda* with total number of 11 species were recorded. (Table 3). Such low biodiversity within the zooplankton is typical for cold period of the year.

Table 3. Relative abundance of zooplankton in the Danube River section Kamenjar-Sremski Karlovci (winter 1998)

	Sampling stations								
	Kamenjar	Sremska Kamenica	Ribnjak	The bridge	public beach	Petro-varadin	Danu-be	DTD mouth	Sremski Karlovci
PROTOZOA									
Epistylis plicatilis		1	1						
Paramecium aurelia	1	1	1	1	1	1	1	1	1
Votricella microstoma	1	1	1	3	1	1	1	1	1
ROTATORIA									
Asplanchna priodonta	1								1
Brachionus angularis	1	1			1		1	1	1
B. calyciflorus	1	1	1	1	1	1	1	1	1
Keratella quadrata	1		1				1	1	1
Polyarthra dolichoptera	1			1					1
Rotaria rotatoria	1	1	1	1	1	1	1	1	1
CLADOCERA									
Bosmina longirostris			1			1			
COPEPODA									
Acanthocyclops vernalis								1	

3.6.3.5. Macrozoobenthos

Qualitative analysis of the bank region benthos in the Danube River section Begec - Sremski Karlovci - revealed the presence of 3 groups: *Oligochaeta, Gastropoda* and , *Diptera (Chironomidae)*. The dominant gro In winter 1998/1999. 16 taxon - 8 genera and 2 families - *Naididae* and *Tubificidae* : *Aulophorus furcatus, Amphichaeta rostrifera, Dero digitata, N. barbata, Nais bretscheri, N christinae, N. communis, N. elinguis, N. stolci, Ophydonais serpentina, L. claparedeanus, Limnodrilus hoffmeisteri, L. udekemianus, Potamothrix hammoniensis, P. isochaetus* and *Tubifex tubifex* were recorded.

Total number of Oligochaeta in the Danube River bank region along the section Begec - Sremski Karlovci (Fig. 2) ranged from 1666 at sampling site Ribnjak to 15453 ind/m^2 at sampling site Sremski Karlovci, in mixing zone downstream Novi Sad municipal wastewater discharge point. The number of Oligochaetes in samples from Begecka jama wetlands, was, as expected, much higher than in the Danube River, and reached 26058 ind/m^2.

According to these results, which are in agreement with the previous research (Djukic *et al.* 1997), the Danube River bank region nearby Novi Sad can be regarded as eutrophic, while particularly enhanced eutrophication process have been observed in the section Kamenjar - Sremski Karlovci. Nevertheless, the situation in future could easily worsen. During the recent events in Yugoslavia, three bridges across the Danube River in Novi Sad section have been destroyed and ruins remained in the river ever since. Besides, the pontoon across the Danube River, just downstream sampling site Ribnjak, has been built as the only connection between left and right bank. Consequently, the Danube River flow drastically slowed down. As a result, the total number of Oligochaetes in the section Sremska Kamenica - Ribnjak increased from 1666 to almost 30000 ind/m^2, the number typical for almost stagnant waters. (Djukic *et al.* 1998).

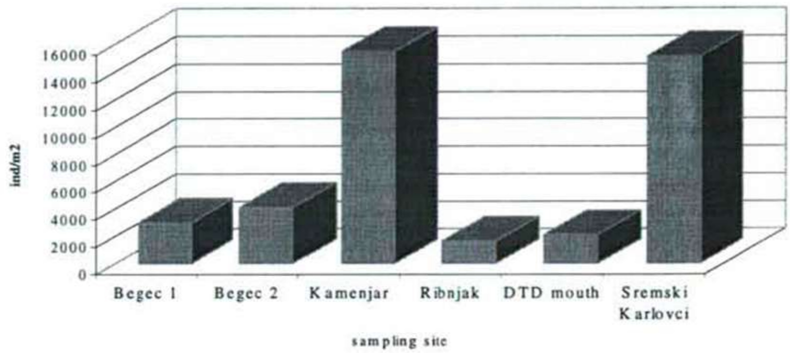

Fig. 2. Total number of Oligochaeta in the Danube River bank region (section Begec - Sremski Karlovci)

Moreover, qualitative analysis of the sample taken even before the pontoon construction, in spring 1999, in high-water level period, at sampling site Sremska Kamenica, suggested the total dominance of *Limnodrilus hoffmeisteri* (Miljanovic, unpublished) - the typical indicator of stagnant, highly eutrophic waters. (Lang, 1985). Yet, if the ruins remain, even worse situation can be expected in forthcoming period of low water levels and high temperatures in summer, while the impact of slowing flow might spread upstream

3.6.3.6. Fish communities

Qualitative analysis of the Danube River bank region using electric fishing showed the presence of 15 species from 5 families. The highest species richness was recorded within *Cyprinidae* family (10 species). Family *Percidae* was represented by 2, while the other 3 families were represented by a single species. Quantitative analysis reveals the dominance of *Blicca bjoerkna* (50%) and sub-dominance of *Alburnus alburnus* (17%). According to mass percentage, B. bjoerkna is also found as a dominant species (50%), while Leuciscus idus was sub-dominant (14% out of the total catch).

Fish community of Bagecka jama wetland is represented by 16 species from 6 families. Again, the highest species richness was recorded within *Cyprinidae* family (11 species), while all the other families were represented by a single species. According to quantitative analysis, *Carassius auratus* can be regarded as totally dominant species (71%), while *B. bjoerkna was sub-dominant* (15%). However, *Silurus glanis* made 54 mass % out of total catch, while *C. auratus* made 25% and *B. bjoerkna* only 11mass % of total catch.

Structure and composition, particularly regarding nutrition types, indicate complexity and stability of the fish community in investigated regions, which mainly applies to the Danube River and to a smaller extent to the wetlands. Consequently, a better interconnection of the Danube River and the wetlands must be provided.

3.6.4. CONCLUSION

The results of the integrated surveillance of the Danube River bank region in period 1998/1999, indicate that bank region of the Danube River section around Novi Sad must be evaluated as eutrophic environment. The highest rates of the eutrophication process were recorded at sampling sites Kamenjar (upstream) and at the sampling site Sremski Karlovci - downstream Novi Sad's municipal wastewater discharges, within the mixing zone. The problem of depleted velocity of the Danube River flow along the investigated section, caused by the remaining ruins of the three destroyed bridges and the recently built pontoon, could, in future, even worsen the situation by weakening self-purification capacity of the Danube River, which, eventually, leads to acceleration of already enhanced eutrophication process in the section around Novi Sad.

3.6.5. SUMMARY

Complex surveillance of the Danube River bank region in period 1998/1999, including hydrological, physico-chemical and biological monitoring was undertaken with an aim to estimate eutrophication level in the river section around Novi Sad. During the whole investigated period, The Danube River water levels were unexpectedly extremely high. Even in winter, in high water level periods, with low rate biochemical processes, the nutrients (N, P) concentrations were, at several sampling sites elevated up to III-IV class level. Nevertheless, biological monitoring (phyto and zooplankton dynamics, bottom fauna and ichtyofauna) indicate high primary and secondary production as a result of the organic load. Therefore, the bank region of the Danube River section around Novi Sad must be regarded as eutrophic, while the highest rates of the eutrophication process were recorded at sampling sites Kamenjar (upstream) and at the sampling site Sremski Karlovci - downstream Novi Sad municipal wastewater discharges, within the mixing zone.

3.6.6. REFERENCES

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