EVALUATION OF ENVIRONMENTAL CONDITION: WATER AND SEDIMENT EXAMINATION OF OXBOW LAKES

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Abstract
As a result of the river regulation a number of oxbow lakes have arisen in the floodplain of the Lower-Tisza. The floodplain lakes represent natural values and major recreation areas of the lowland region. Due to the human activity the oxbow lakes' condition declined. It can be shown by the water quality, the channel discharge by deposit, the high eutrophication of the lakes and the heavy metal elevation of the sediment. Discovering these processes, analysing the condition and recultivation of the oxbow lakes came into prominence only in the past few years. Our research aims to conclude the current environmental pollution of the oxbow lakes from statistical analyses of the heavy metal content of the sediment and from the water quality data. The oxbow lakes have been classified by chemistry instead of chemical. Results of the research show differences between the floodplain oxbows and the lakes outside the dam in terms of the quality of the sediment and the nutrient content of the water.

Keywords: oxbow, floodplain, sediment, heavy metal content, Lower-Tisza

1. Introduction

The Hungarian rivers' floodplains are unique natural values especially in the South-Plain. Smaller and bigger oxbow lakes near the rivers are of ecological importance: lots of the oxbow lakes function like a gene-bank.

The analyses of the condition of rivers and floodplains started in the 1980's, but these areas attracted high attention of researchers only after the cyanide contamination in 2000.

Many researches focused on the bottom sediment of the rivers, but we can find studies about the floodplain sedimentation and the oxbow lakes' surface water. Water of the oxbow lakes of Upper-Tisza was analysed by Babka and Szabó (2007). Ecological monitoring was followed by Györffy Gy. (2005). The surface water of Körtvélyes oxbow lake was studied by Fügedi and H.Mészáros (1982), the lake of Alpár was analysed by Hegedüs and Kajáry I. (1985). At the Upper-Tisza region, near the Boroszlókert Holt-Tisza, floodplain sediment was analysed by Szabó and Posta (2008) and Szabó et al. (2008). The results of the research were

evaluated with statistical methods by Szabó et al. (2009). After the pollution of the Upper-Tisza in 2000 floodplain soil contamination was determined by Alapi and Győri (2003). The issue called "Hungarian oxbows" (in Hungarian) (Pálfai, 2001) classifies the different types of oxbows. The backwaters are evaluated by the volume of the sedimentation, but it does not provide any data about the quality of the sediment.

Our aim was to estimate the nutrient content of the surface waters of the Lower-Tisza's oxbow lakes and to determine the total and the mobilizable heavy-metal contamination of the oxbows' sediment. By doing a complex environmental analysis we targeted to examine differences between the two types of oxbow lakes. The environmental condition of the oxbow lakes and the location of the backwaters were considered in order to analyse the diversity.

2. Methods and sample area

The sample area is the Lower-Tisza floodplain, especially the Csongrádi, Mártélyi, Körtvélyesi, Atkai, Sasér, Nagyfai Holt-Tisza. Some of the oxbows' surface water were classified in accordance with the water quality. Values of the sediment pollution of Csongrád, Mártély, Körtvélyes and Nagyfa oxbow lakes were collected from the previous documentation of the rehabilitation (Farsang, 2003, 2004, 2006, 2007). Sediments of Atkai Holt-Tisza and Sasér were collected in 2006 (Fig. 1).

To classify the oxbow lakes by water quality we applied the data from the laboratory of the Inspectorate of the Environmental Protection. The chemical oxygen demand (COD) and the nutrient content were examined between 1988 and 2005 in the surface water of the Csongrádi, Nagyfai, Mártélyi and Körtvélyesi Holt-Tisza. The water quality parameters of samples were determined according to the valid Hungarian standard (MSZ 12749:1993).

In 2006 fourteen sediment samples were collected from the Atkai Holt-Tisza and four samples were taken from Sasér. The samples derive from the upper 10 cm of the sediment. The average samples were collected from 6 spots of $1m^2$ areas.

The total and the moblizable heavy-metal content of the sediment samples was determined in the Laboratory of the Department of Physical Geography and Geoinformatics, University of Szeged. The samples were digested with aqua regia to measure total metal content and used method of Lakanen-Erviö to determine mobilizable metal content. The heavy-metal measurement was performed by Perkin Elmer 3110 AAS in accordance with Hungarian standard MSZ 21470-50:2006.

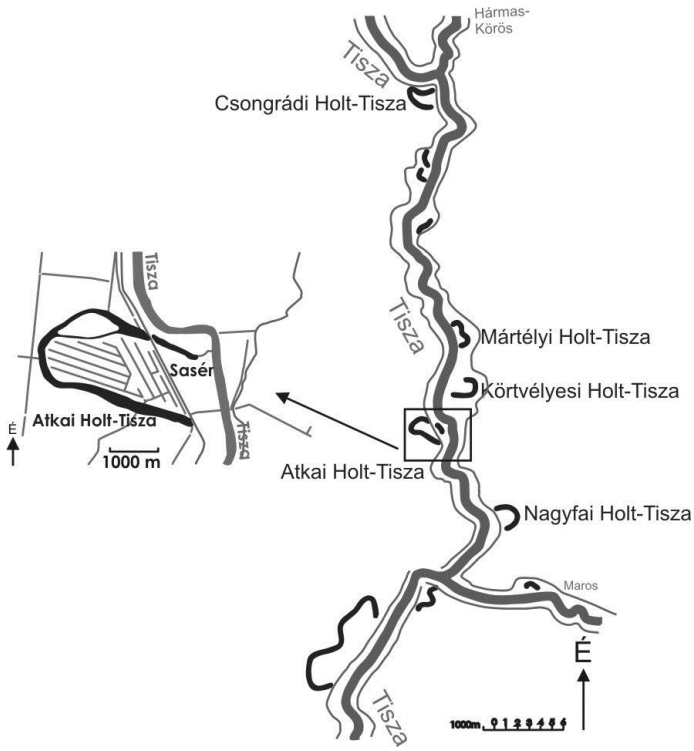

Fig. 1. Studied oxbow lakes of the Lower-Tisza

Contamination index was calculated with the following equation to establish the total contamination of the backwaters:

Ic = (Ex / Emax) * 100,
where Ic: index of contamination
Ex: maximum concentration of the total element in the specific oxbow
Emax: maximum concentration of the total element in all the measured oxbows

The contamination index is the ratio of the maximum total element concentration of all spots of the specific backwater and the maximum total element concentration of all spots of all backwaters.

The data processing was executed with Microsoft Excel 2003 and SPSS for Windows 16.0. The P-value was evaluated with two-tailed t-test at 95% confidence interval.

3. Results: Investigation of the Lower-Tisza oxbow lakes

3.1. Analyses of nutrient content in the surface water

Surface waters have shown the best quality in terms of nitrite content (excellent and tolerable classes) while most of the oxbow lakes were in tolerable or polluted categories by nitrate and ammonium content.

The Nagyfai Holt-Tisza had an especially bed water quality, it was classified as heavily polluted in several years (1992, 1993, 2003-2005). The Körtvélyes and Mártélyi Holt-Tisza were classified to the II. and III. categories, the Csongrádi Holt-Tisza varied between the II. and IV. categories. (I – excellent, II – good, III – tolerable, IV – polluted water quality).

Four oxbow lakes were compared (two was outside the dyke, two was at the floodplain) based on average ammonium, nitrate, nitrite content and chemical oxygen demand (Table 1). Two types of oxbow lakes were compared according to the average and standard deviation as well as the t-test ($p=0.05$). When we analysed the ammonium, nitrite and chemical oxygen demand the means of the random variable values were not equal ($p<0.05$) so we can conclude that there is significant difference between two type of lakes. Analysing the nitrate content of the water samples from the floodplain and outside the dyke ($p>0.05$) we determine there is not significant difference.

Table 1. Measured nutrient content in the surface water of oxbow lakes between 1988 and 2005 (average and standard deviation values, mg/l)

Parameter	Oxbow outside the dyke		Floodplain oxbow		P-value
	Csongrád	Nagyfa	Mártély	Körtvélyes	
NH4+ (mg/l)	0.30 ± 0.35 (n=109)	0.85 ± 1.58 (n= 102)	0.16 ± 0.16 (n=111)	0.20 ± 0.31 (n=106)	3.50E-06
NO2- (mg/l)	0.08 ± 0.11 (n=102)	0.09 ± 0.17 (n=97)	0.03 ± 0.04 (n=105)	0.04 ± 0.07 (n=96)	2.15E-05
NO3- (mg/l)	0.87 ± 1.29 (n=105)	0.92 ± 1.07 (n=99)	1.00 ± 1.45 (n=109)	1.41 ± 2.33 (n=98)	0.056
COD (mg/l)	13.11 ± 2.63 (n=102)	38.27 ± 24.35 (n=97)	7.65 ± 2.82 (n=105)	10.67 ± 3.85 (n=96)	1.61E-21

3.2. Comparative analyses of the toxic content in the lakes' sediments

In the course of the analyses of the oxbow lakes' sediment our aim was to estimate the condition of this region and to discover the regional differences. Pending the comparison we allowed for the oxbows' location because the sample area contains some floodplain lakes as well as some oxbows outside the dyke. The sediment

quality data of the Csongrádi, Mártélyi, Körtvélyesi and Nagyfai Holt-Tisza were systematized and compared with our newly measured results.

The heavy metal contents of the sediment samples were evaluated with the relevant decree's (no. 6/2009. (IV.14.) KvVM-EüM-FVM) limit values of soils (Table 2). Considering the average values of the measured Ni, Cd, Zn and Cu concentrations we have realized that several samples exceed the critical contamination level of soils.

Table 2. Limit value of soil of decree no. 6/2009. (IV.14.) KvVM-EüM-FVM (mg/kg)

Limit value	**Parameter**				
	Pb	**Cd**	**Zn**	**Cu**	**Ni**
Critical contamination level of soil	100	1	200	75	40

The heavy metal content of the floodplain lakes' sediments was higher for all measured elements than that of the oxbows outside the dyke (Table 3). As a result the floodplain's sediment values exceed the critical contamination level more often than the sediments of the oxbows outside the dyke (bold values in the Table 3).

Table 3. Measured total heavy metal content in the sediment of oxbow lakes (average and standard deviation values) (mg/kg)

Parameter	**Oxbow outside the dyke**			**Floodplain oxbow**			**P-value**
	Csongrád (n=7)	**Atka (n=14)**	**Nagyfa (n=5)**	**Mártély (n=6)**	**Körtvélyes (n=4)**	**Sasér (n=4)**	
Pb	50.36±17.48	25.01±14.18	41.38±10.10	77.14±8.21	86.55±8.24	65.93±12.61	2.04E-10
Cd	0.81±0.29	**1.35±0.24**	0.60±0.00	**1.93±0.21**	**1.40±0.27**	**1.60±0.11**	2.93E-06
Zn	161.59±60.68	107.55±45.73	136.60±25.31	**274.50±17.81**	**242.50±12.66**	197.53±7.92	7.63E-10
Cu	37.66±19.54	22.34±7.81	37.60±5.02	**76.67±9.81**	66.08±5.72	**80.50±13.00**	7.58E-13
Ni	33.13±7.00	35.05±8.90	**43.02±4.24**	**54.00±1.55**	**47.58±4.40**	**59.67±3.09**	1.27E-09

The p-values for all measured elements show significant differences between the two type of oxbow lakes ($p<0,05$).

We calculated the total-pollution for the Cd, Ni, Pb and Cu for all examined oxbow lakes to compare the sediment quality of the oxbows. We used Cd, Ni, Pb and Cu contents for this calculation because these elements were measured in all six backwaters. The "contamination index" explains for each metal what proportion occurs in the specific oxbow in comparison with the measured highest concentration. With this index we can show the relative contamination ratio of the

examined backwaters (Tamás et al. 2011). The Mártélyi Holt-Tisza is the most polluted of the Lower-Tisza region's oxbow lakes followed by the Sasér then the Körtvélyes. Oxbow lakes located outside the dyke (Csongrádi, Atkai, Nagyfai Holt-Tisza) show a relatively low heavy-metal concentration (Fig. 2).

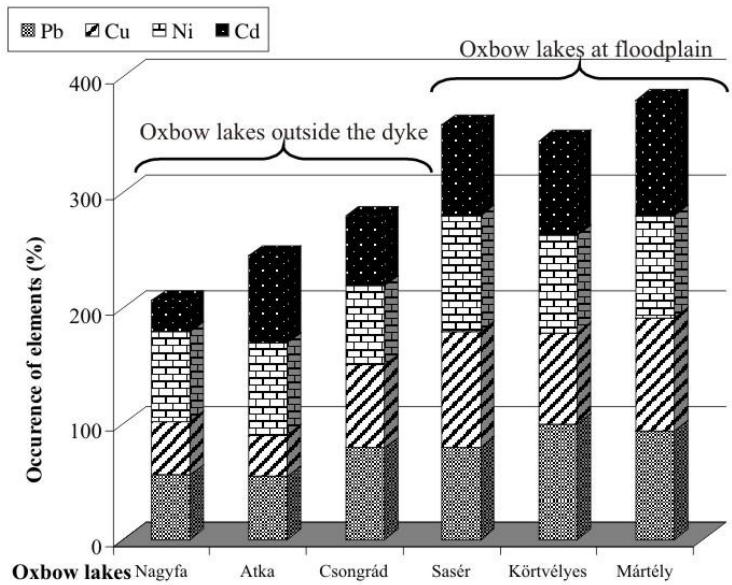

Fig. 2. Contamination index of the oxbow lakes of Lower-Tisza

3.3. Mobilization of metals in the Atkai and Sasér Holt-Tisza's sediments

The minimum, maximum, average and standard deviation of total and mobilizable metal content have been calculated in sediment samples of Atkai and Sasér Holt-Tisza (Table 4). The ratio of the metal mobilization and the total metal content was studied. The lead and the copper proved to be the most mobile metals. Based on the average of all sampling points in Atkai and Sasér Holt-Tisza the mobilizable heavy metal ratio is in case of lead 70%, in case of copper 47%, cadmium 32%, zinc 12%, nickel 9% of the total nickel-content.

We analysed the Atkai and Sasér Holt-Tisza together. We calculated all of the eighteen sample's average and standard deviation of total and mobile metal content represented at Figure 3. Studying the results zink and nickel were proved to be least mobile elements. Analysing the lead content we can conclude that the ratio of the total lead to the mobilizable lead is very high (average 70%). Except for the result of one sample point, all the analysed sample points have the ratio of mobilizable lead content exceeding 50%. In case of one sample point this ratio is higher than 90%.

Table 4. Measured total and mobile heavy metal contents in the sediment of Atkai and Sasér Holt-Tisza (minimum, maximum, average and standard deviation values) (mg/kg)

Parameter		Atkai (n=14)		Sasér (n=4)	
		Total	**Mobile**	**Total**	**Mobile**
Pb	Min.	7.05	3.71	47.95	46.32
	Max.	52.11	40.86	76.72	57.08
	Average	25.46	17.35	65.93	53.01
	Stand. dev.	13.42	10.19	12.61	4.66
Cd	Min.	0.92	0.18	1.45	0.78
	Max.	1.66	0.58	1.72	1.07
	Average	1.35	0.35	1.60	0.89
	Stand. dev.	0.24	0.12	0.11	0.13
Zn	Min.	2.89	1.50	188.20	38.48
	Max.	201.00	21.05	206.10	51.29
	Average	107.55	9.72	197.53	47.92
	Stand. dev.	45.73	5.21	7.92	6.30
Cu	Min.	6.01	2.53	62.30	20.05
	Max.	33.66	17.99	93.14	34.98
	Average	22.34	10.62	80.50	27.88
	Stand. dev.	7.81	4.17	13.00	6.77
Ni	Min.	15.00	0.88	55.67	4.71
	Max.	50.02	5.44	63.21	6.49
	Average	35.05	2.95	59.67	5.65
	Stand. dev.	8.90	1.40	3.09	0.78

4. Conclusions

The aim was to give complex environmental evaluation of the oxbow lakes at Lower-Tisza and determine the differences between the two types of lakes.

Generally the concentration of dissolved nutrients was higher in the oxbows outside the dyke than in the floodplain lakes (except the nitrate). This result is in accordance with Szabó and Babka (2007). They suppose that deviation is caused by Tisza dynamism: when the Tisza overflows the water of the floodplain lakes, the water of such lakes is refreshed by the flood; however, water of the oxbows outside the dyke has condensed due to the evaporation.

Analysing the nutrient content of water of the Lower-Tisza's oxbow lakes were classified II-IV. categories. But the evaluation of the water quality data does not show exact results about the environmental status of the lakes. Therefore it is very important to analyse the sediments of the oxbows to recognize the longer term processes and the contamination impacts.

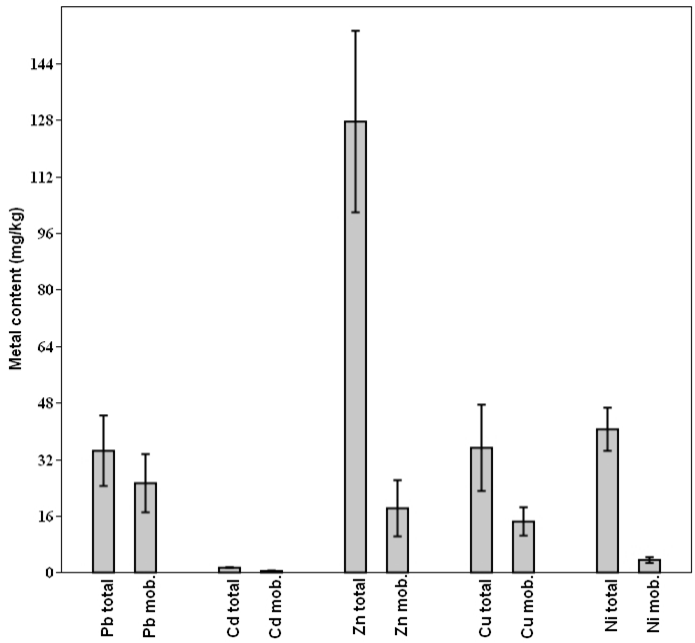

Fig. 3. Average and standard deviation of total and mobilizable metal content in the samples from Atkai and Sasér Holt-Tisza together (n=18)

Studying the sediment of lakes we can prove that the metal content of the sediment from floodplain oxbow is more polluted than the sediment of the lake outside the dyke. Analysing the total and the mobile metal content in sediment of Atkai Holt-Tisza we can conclude that the floodplain' sediment metal content is more mobilizable than the metal content of the sediment from outside the dyke.

The critical contamination level for soils was not suitable to evaluate the quality of the sediments. Therefore it is deemed to be necessary to work out a classification system – similarly to the surface water body classification – referring to the sediments which consider the high mobilizable metal ratio of the sediment.

It is essential to define the environmental impacts and risks of the sediments during the classification of oxbows. The risk calculation is important, because the sediment (containing high percentage of mobile metals) is deposited at an agricultural area during the oxbow's recultivation. Then to give complex environmental evaluation of the oxbow lakes it is necessary to take into consideration the mobilizable metal content of the sediment.

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