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Assessment of Water Quality in the Ukrainian Part of the Danube Delta Based on Biotesting and Bioindication of Bottom Sediments

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Abstract: The study presents the results of several years of monitoring (2007 to 2013) in the Ukrainian Delta region using biotesting and bioindication methods. The sampling stations were: Kilia arm (1 station), Ochakivskyi arm (2 stations), Bystryi arm (2 stations), and Vostochnyi arm (2 stations). Animal test-organism *Daphnia magna* Strauss together with plant test-organisms *Allium cepa* L. and *Lactuca sativa* L. were used in the biotesting. Bioindication was performed using taxonomic diversity of the macrozoobenthos organisms. The following biotic indices were calculated: Trent Biotic Index, Belgian Biotic Index, Biological Monitoring Working Party Index, and Goodnight-Whitley Index. The findings of biotesting showed a slow decrease in the toxic impact level from 2007 to 2012. However, the biotic indices mostly revealed a Poor ecological status for all sampling stations through all years of monitoring.

Keywords: Biomonitoring, ecotoxicology, delta region, bioindication

Introduction

Deltas and estuaries are unique natural objects playing a huge role in human life. At the same time, they are vulnerable formations, under large anthropogenic pressures and impacts. They are the end regions of the river systems, thus becoming the traps for various types of pollution that may accumulate in the bottom sediments. The aim of the present research was the estimation of the bottom sediment pollution in four branches of the Ukrainian part of the Danube Delta, carried out by bioindication and biotesting methods.

Material and Methods

The sampling was carried out once a year in June from 2007 to 2013 at seven stations in the Ukrainian part of the Danube Delta (Fig. 1). Each sample consisted of three bits, collected with a bottom-grab.

The sampling was carried out in the littoral mainly oozy area at depths up to 2.0 m, with the upper five-centimetres layer being taken for testing. The samples for biotesting were transported and stored in refrigerating chambers at a temperature no higher than +4°C. The macrozoobenthos samples were washed, fixed with 4% formalin and delivered to the laboratory for further analysis.

The biotesting of toxicity of water extracts of the bottom sediments (prepared with a 1:4 dilution) was carried out with the use of test organisms *Daphnia magna* Strauss, onion, *Allium cepa* L., and salad rootlets, *Lactuca sativa* L. (Fiskesjo 1997, Ho 2000, Arsan *et al*. 2006). The exposition time was 96 hours (4 days) for the tested animal species, and 168 hours (7 days) and 240 hours (10 days) accordingly, for the plant species.

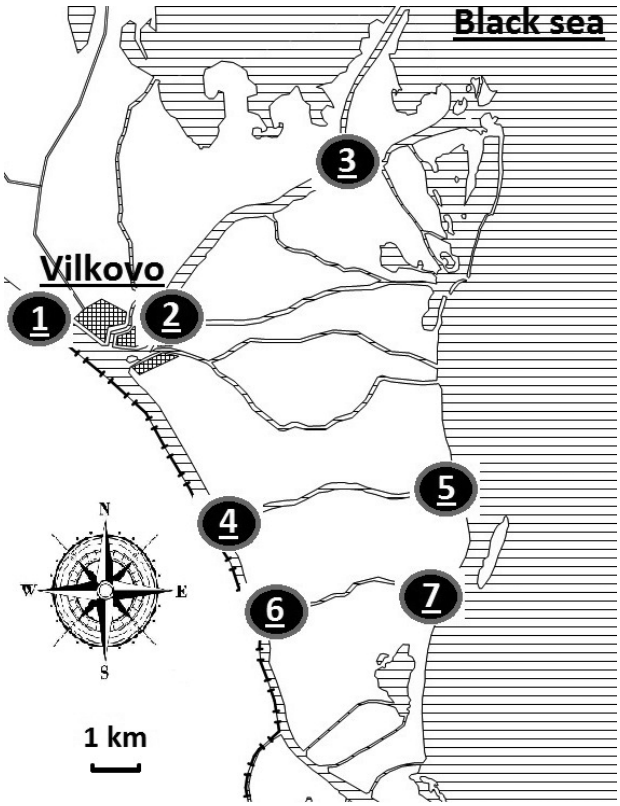

Fig. 1. Map of the sampling sites. Kilia arm (1), Ochakivskyi arm (2, 3), Bystryi arm (4, 5) and Vostochnyi arm (6, 7)

The bioindication of pollution regarding the macrozoobenthos organisms was implemented by using the widely known 4 indices tested earlier in the large rivers of the world (Alba-telchedor 1988, Wright 1993), including the Danube River (*e.g.* Danube Survey 3, held in 2013): Trent Biotic Index (TBI), Belgian Biotic Index (BBI), Biological Monitoring Working Party Index (BMWP), and Goodnight-Whitley index. Program Asterics 3.1.11 was used to calculate the BBI and BMWP indices; TBI and Goodnight-Whitley were calculated according to Goodnight, Whitley (1961) and Woodiwiss (1964). The assessment of results was performed on a five-classes scale, which meets the recommendations of the EU Water Framework Directive EU (2000/60/EC) (Table 1).

Results

The results of biotesting are presented in Table 2. The toxic impact of the water extracts from bottom sediments was used to describe the water quality.

The toxicity of bottom sediments, according to the results of tests with the use of *L. sativa,* was characterised mainly by a low level: the quality status *Good* and *High* prevailed. The average level of toxicity *Moderate* was recorded only at one station (station 4) in 2011. As a whole, a decrease in toxicity of bottom sediments was found during the period of observation (2007-2013).

The toxicity of bottom sediments, according to the results of tests with the use of *A. cepa,* appeared to be a little higher than in the tests with salad rootlets; the majority of values indicated ecological status *Moderate* and *Good*. The *Poor* ecological status was registered at two stations (3 and 6) in 2007, while *High* at three stations (2, 6 and 7) in 2011 and at three stations (stations 1, 2 and 7) in 2013. It was also possible to ascertain a decrease in toxicity of the bottom sediments during the period of observation.

Natural differences in the toxicity level per sampling station both in the tests with onion and in the tests with salad rootlets were not found. The level of pollution by the substances of a toxic nature on a year-by-year basis was within the limits of one or two classes of the quality status.

The toxicity of bottom sediments according to the results of tests with the use of *D. magna* appeared to be higher than in the tests with the plant test organisms. High toxicity levels, corresponding to *Bad* ecological status, were registered in 2007 and 2011 for all stations, as well as *Bad* and *Poor* ecological status in 2012 for the majority of stations (2, 3, 4, 5). Probably, the tested plants and the animal had a different sensitivity to toxic substances.

The toxicity level at all stations during the research had a wide range of values: within four classes of toxicity for station 4, and within all five classes of toxicity for all other stations. We can assume a discrete entry of toxic substances in 2007 and 2011 and their short-term toxic effect on the tested animal.

During the implementation of the bioindication analysis, 98 species of bottom invertebrates were recorded. The macrozoobenthos was characterised by a mosaic structure of distribution. From 1 to 18 species were recorded at the sampling stations. The results of the bioindication of the bottom sediments are shown in Table 3. The calculations of biotic indices were used to describe the water quality.

According to the results for the TBI, BBI, BMWP indices, the water quality status was *Poor* and *Bad* at the majority of stations. Any differences of the ecological status per sampling station were not

Table 1. Classification of the ranges of toxicity and values of biotic indices according to the EU Water Framework Directive 2000/600/EC

Ecological status	High	Good	Moderate	Poor	Bad
Mortality of animals, %	<10	10–20	21–33	34–50	>50
Plant growth stimulation or inhibition, %	<10	10–25	26–50	51–75	>75
TBI	9-10	7-8	5-6	3-4	0-2
BBI	9-10	7−8	5−6	3-4	0-2
BMWP	>51	31-50	21-30	11-20	0-10
Goodnight-Whitley	0-45	46-70	71-80	81-90	91-100

Table 2. Results of the biotesting of water extracts from the bottom sediments

Number of station	Test-object	2007	2008	2010	2011	2012	2013
1	*Lactuca sativa*	-	-	-	High	High	-
	Allium cepa	-	-	Moderate	Good	Moderate	High
	Daphnia magna	-	-	High	Bad	High	Good
2	*Lactuca sativa*	Good	-	-	Good	High	High
	Allium cepa	Moderate	Moderate	Good	High	Moderate	High
	Daphnia magna	Bad	Bad	High	Bad	Bad	Good
3	*Lactuca sativa*	Good	-	-	High	Good	High
	Allium cepa	Poor	Moderate	Moderate	Good	Moderate	Good
	Daphnia magna	Bad	Good	Bad	Bad	Bad	Good
4	*Lactuca sativa*	Good	-	-	Moderate	Good	Good
	Allium cepa	Moderate	Moderate	Good	Good	Good	Good
	Daphnia magna	Bad	Good	Bad	Bad	Poor	Good
5	*Lactuca sativa*	Good	-	-	High	High	High
	Allium cepa	Moderate	Good	Moderate	Good	Moderate	Good
	Daphnia magna	Bad	Moderate	High	Bad	Bad	Good
6	*Lactuca sativa*	Good	-	-	Good	Good	Good
	Allium cepa	Poor	Moderate	Moderate	High	Moderate	Good
	Daphnia magna	Bad	Good	Moderate	Bad	High	Poor
7	*Lactuca sativa*	-	-	-	Good	High	High
	Allium cepa	-	Moderate	Moderate	High	Good	High
	Daphnia magna	-	Good	Good	Bad	High	High

recorded. For each year, the ecological status ranged within one or two classes.

The water quality status also varied weakly during the entire period of observation (2007-2013): for stations 1-6 within three classes – *Moderate, Poor* and *Bad*; and for station 7 within four classes (since *Good* status was registered in 2008).

According to the results of the Goodnight-Whitley index, the quality status *High* and *Good* prevailed. At the same time, a wide range of values was reported during the period of research – within 4-5 classes of the ecological status.

Conclusions

The obtained results had to be compared with those of JDS 2 (Joint Danube Survey 2 2008) and JDS 3 (reports in preparation) and also with the national research (Liashenko 2012). Such matching proved low water quality as had been ascertained by the

Table 3. Results of the biondication of the bottom sediments

Number of station	Index	2007	2008	2009	2010	2011	2012
1	TBI	-	Moderate	Poor	Bad	Poor	Moderate
	BBI	-	Moderate	Moderate	Bad	Moderate	Poor
	BMWP	-	Moderate	Moderate	Bad	Poor	Poor
	Goodnight-Whitley	-	High	Poor	Poor	Good	Good
2	TBI	Poor	Moderate	Bad	Moderate	Poor	Bad
	BBI	Poor	Poor	Poor	Poor	Moderate	Bad
	BMWP	Poor	Poor	Poor	Poor	Poor	Bad
	Goodnight-Whitley	High	Moderate	Poor	Good	High	Good
3	TBI	Bad	Moderate	Bad	Bad	Bad	Moderate
	BBI	Poor	Moderate	Bad	Bad	Bad	Poor
	BMWP	Bad	Good	Bad	Bad	Bad	Poor
	Goodnight-Whitley	Bad	Poor	Poor	Moderate	Poor	Good
4	TBI	Moderate	Moderate	Bad	Bad	Moderate	Bad
	BBI	Moderate	Moderate	Bad	Bad	Moderate	Bad
	BMWP	Moderate	Moderate	Bad	Bad	Poor	Bad
	Goodnight-Whitley	Moderate	Good	Good	Bad	Good	High
5	TBI	Poor	Moderate	Bad	Poor	Bad	Moderate
	BBI	Poor	Moderate	Bad	Poor	Bad	Poor
	BMWP	Bad	Poor	Bad	Bad	Bad	Moderate
	Goodnight-Whitley	Poor	Poor	Bad	Poor	High	High
6	TBI	Poor	Moderate	Moderate	Poor	Moderate	Bad
	BBI	Moderate	Poor	Poor	Poor	Moderate	Bad
	BMWP	Poor	Poor	Poor	Poor	Moderate	Bad
	Goodnight-Whitley	Good	Good	High	Good	Good	Bad
7	TBI	Bad	Good	Bad	Bad	Bad	Moderate
	BBI	Bad	Moderate	Bad	Bad	Bad	Moderate
	BMWP	Bad	Good	Bad	Bad	Bad	Moderate
	Goodnight-Whitley	Bad	Poor	Good	Bad	Good	High

biotic indices. The long-term low biotic diversity throughout the Ukrainian part of the Danube Delta might be a result of the continuous anthropogenic pressure.

At the same time, the toxic impact of the water extracts had a tendency towards decrease, which was clearly expressed. This allows us to exclude the toxic pollution from the main causes of low water quality in the Ukrainian part of the Danube Delta.

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