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CHANGES IN THE BIOTOPE QUALITY UNFAVOURABLE TO ICHTHYOFAUNA OF THE SZCZECIN LAGOON DURING THE FLOOD CREST OUTFLOW IN SUMMER 1997

Gorzysław Poleszczuk

Szczecin University, Department of Natural Sciences
Felczaka St. 3A, 71-412 Szczecin, POLAND
polesz@univ.szczecin.pl

Abstract

The article presents the results of analyses of 21 water quality indices measured at 15 stations in the area of the Odra River estuary during the summer flood crest outflow in 1997. It was found out that a number of the analysed indices, evaluated according to the legal criteria implemented in Poland for the assessment of the quality of inland water, reached excessive values pointing to unfavourable quality changes in the environment of the Odra River estuary which lasted for several days. These changes posed threat to health and living of ichthyofauna in the estuary.

Key words fish habitat, water quality, Odra River estuary, Szczecin Lagoon

INTRODUCTION

There was a number of environmental studies of water in the lower Odra, in the outlet of the river Świna into the Pomeranian Bay as well as in the coastal zone of the Pomeranian Bay during the outflow, and following this outflow, of the great flood crest in summer 1997. The results of water quality measurements in the lower Odra and in basins located south to the Szczecin Lagoon have been already presented by Protasowicki et al. (1999), Helios-Rybicka and Strzebońska (1997), Wolska et al. (1999), Müller and Wessels (1999), Bierawska et al. (1999), Damke et al. (1999) and Lehmann et al. (1999). The results of measurements of the nutrient loads entering then the Pomeranian Bay via the Świna Strait were described by Pastuszak et al. (1998, 1999), Siegel et al. (1998), Müller-Navarra et al. 1999, Witt and Trost (1999) and Grelowski et al. (2000), while the results of measurements of water chemistry changes in the Pomeranian Bay subsequently to the flood crest outflow were presented by Trzosińska and Andrulewicz (1998), Łysiak-Pastuszak et al. (1998), Łysiak–Pastuszak 2000, Łysiak –Pastuszak and Drgas 2000 and Morholtz et al.

(1998). However, the literature shows a noticeable lack of publications on water chemistry examination during the flood crest outflow from the Szczecin Lagoon as such.

The quality of water filling up the Szczecin Lagoon and taking residence there for several weeks* was an important problem from the point of view of the hydrobionts living in this environment, since the quality of their habitat had changed then dramatically and the negative effects of these changes can be observed even today.

The presented article was aimed to fill in the gap in the studies on the chemical composition of water in the Szczecin Lagoon during the outflow of the flood crest in 1997 and give the ground for discussion with biologists on the effects of the flood water on the health of hydrobionts and particularly the ichthyofauna of the Lagoon.

MATERIAL AND METHODS

Water samples for the analyses of water quality indicators were collected using a Patalas sampler from the surface water layer (0.5 m under the water surface) and from the near bottom layer (0.5 m above the bottom) between 16.07.-01.09.1997 synchronically to the movement of the flood crest. The sampling was done at 15 sampling stations (Fig.1), annotated A to P (the precise location of sampling stations is presented in Tab.1). However, because of considerable turbulence of the flow in the upper part of the estuary, the differentiation between the surface and near bottom layer was impossible.

Altogether 42 water samples were collected in sequence, as shown in lower part of Fig. 2, repeatedly at selected stations. The measurements started in the Western Odra in Szczecin (station A) and ended up in the river Świna outlet into the Pomeranian Bay (station P).

The water quality indicators measured in the field were: water temperature, pH, Eh, total alkalinity and dissolved oxygen. Chemical oxygen demand, by manganate method (COD-Mn), biochemical oxygen demand, after 5 days – BOD_5, nutrient concentrations (NO_3^-, NO_2^-, NH_4^+ and PO_4^{3-}) as well as mineralisation indices (concentrations of Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-}) and concentrations of Fe_{tot} and Mn_{tot} were determined in preserved samples in land laboratory, using analytical procedures described earlier in the papers by Poleszczuk and Sitek (1995) and Poleszczuk (1997, 1998).

* The capacity of reservoir of the Szczecin Lagoon according to Majewski (1964) is 2,8 km^3, while through Szczecin Lagoon flow 28 km^3 in year of river and seawaters (seawaters from estuary flowing into Pomeranian Bay) - average retention time of waters on Szczecin Lagoon would be 5,2 of week. According to Poleszczuk (1996) the flow of river and seawaters through Roztoka Odrzańska is 25 km^3 in year, what would suggest, that average retention time of waters would be somewhat larger. The value of coefficients of waters confusion $\left(\frac{\text{Amount of kilograms of seawaters}}{\text{1kg of riverwaters}}\right)$ grow from 0 to 1 (Poleszczuk 1998) as flow waters in hole estuary, and so average time retention of waters - particularly for reservoirs in northern part of Odra estuary – can be shorter even about half. Simultaneously for volumetric intensity of Odra waters flow larger from 800 $m^3 \cdot s^{-1}$ (ca. 25 $km^3 \cdot year^{-1}$), when stops inflow of seawaters, the retention times of water will be shorter, accord from intensity of river waters flow.

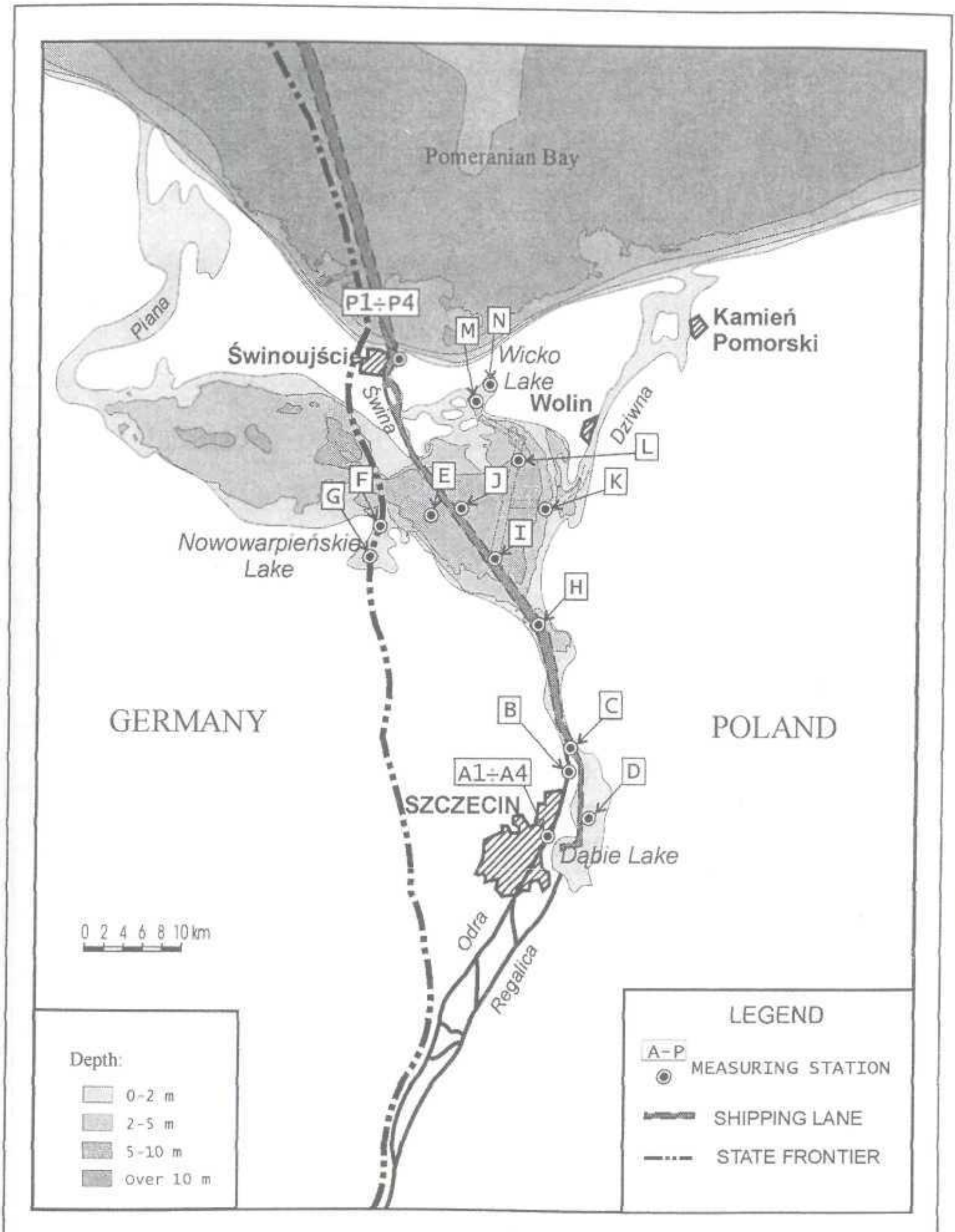

Fig. 1. Estuary of the river Odra; location of measurement stations

Table 1

Investigations of water quality in Odra River estuary during summer flood 1997 – location of measurement stations

No.	Station Code	Station location	Depth (m)	Short characteristic of the station location
1	A	Western Odra River 54°26'N and 14°35'E	6,0	near the Szczecin Port Authority
2	B	Western Odra River 54°29'45"N and 14°42'E	11,0	Szczecin – Skolwin site near fishing port
3	C	Western Odra River mouth to Domiąża Channel 54°32'N and 14°38'15"E	6,0	near buoy „B19z"
4	D	Dąbie Lake 54°28'38"N and 14°39'30"E	3,0	on NNE from Dębinka Island
5	E	Great Lagoon 54°45'N and 14°21'30"E	6,0	near buoy „WW-E"
6	F	Nowowarpieńskie Lake 54°44'25"N and 14°16'25"E	2,0	border buoy „7" and „B4ˢc" on water way from Nowe Warpno city to Altwarp city
7	G	Nowowarpieńskie Lake 54°42'30"N and 14°16'E	1,5	border buoy „4" on NE from Rietha Werder Island
8	H	Roztoka Odrzańska 54°39'N and 14°32'30"E	4,0	near track buoy „16"
9	I	Great Lagoon 54°43'N and 14°28'45"E	5,4	near Gate Way no.3
10	J	Great Lagoon 54°45'45"N and 14°24'20"E	5,8	near Gate Way no.2
11	K	Great Lagoon 54°46'40"N and 14°32'30"E	4,0	near water way buoy „12c"
12	L	Great Lagoon 54°49'N and 14°29'30"E	5,3	between buoys „KW-E" and „MJcb"
13	M	Wicko Wielkie Lake 54°53'N 14°26'15"E	2,6	in center on Wicko Wielkie Lake
14	N	Wicko Małe Lake 54°54'N and 14°26'15"E	1,6	near buoy „16"
15	P	Świna Channel mouth to Pameranian Bay 54°29'45"N and 14°42'E	11,0	near buoy „B3z"

Notation: c, cb – buoy colours: red and red-white buoy respectively
z – buoy colours: green

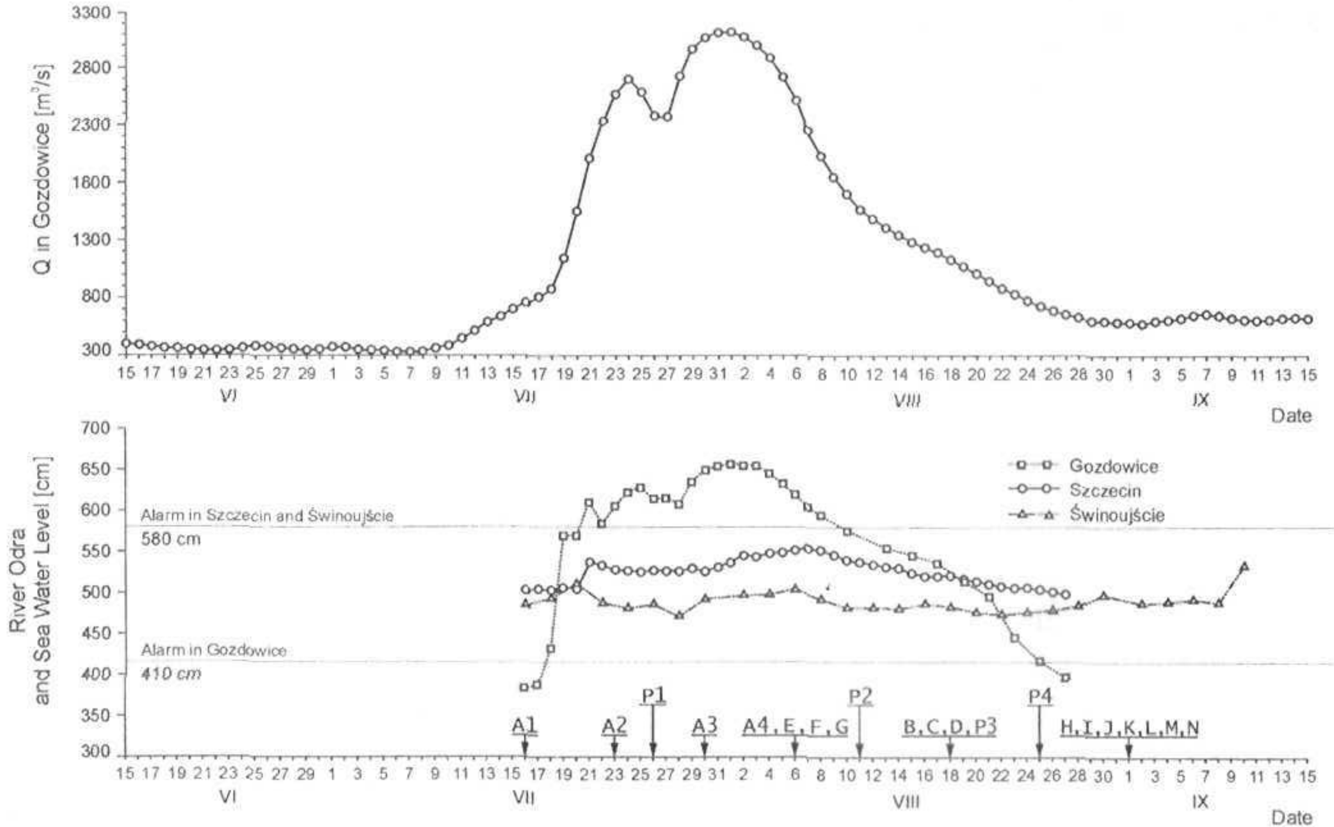

Fig. 2. Changes in flow intensity of the river Odra during the flood crest outflow in 1997; measurements by water-gauges in Gozdowice and Szczecin and sea level measurements by mareograh in Świnoujście (*data source: Institute of Meteorology and Water Management*)

Since in the Polish legislation there is lack of water quality criteria for estuarine water, water quality in the samples from the Odra River estuary was evaluated according to the quality criteria for surface freshwater, implemented in the Rozporządzenie (1991), and based on the global standards e.g. Alabaster et al. (1980), Svobodova et al. (1993). It was anticipated that water in the Szczecin Lagoon would show considerable excess of fresh water during the outflow of the flood crest hence the fresh water quality criteria have been rightly applied.

The data on the flood crest flow intensity, registered in Gozdowice, were supplied by the Institute of Meteorology and Water Management, similarly to the data from the river Odra water-gauges in Gozdowice and Szczecin and the mareograph in Świnoujście (Fig. 2).

RESULTS

The results of measurements presented in time sequence are shown in table 2. The values of water quality indices corresponding to the I and II water quality classes, that is characteristic for the environment favourable to ichthyofauna (class I – habitat favourable for salmonide inhabitation, class II – habitat favourable for other fish), are specially marked. Also the results denoting class III are marked, i.e. indicating water of quality inadequate as fish habitat and out-of-class water (degraded). Separate marking was applied for the results indicating the out-of-class water quality as regards the mineralisation. These results should not be taken into account when assessing the quality of estuarine environment which is by definition characterised by higher degree of mineralisation, however this does not disqualify it as the habitat for the fresh water ichthyofauna.

The fact calling for attention during the measurements was the uniformity of chemical composition of the surface and near bottom water at the majority of sampling stations. It was solely at the stations in the northern part of the Great Lagoon that a marked difference in oxygen saturation between the surface and near bottom water was observed accompanied by negligible differences (<10%) in other water quality indices, and during the final stage of the flood crest outflow there appeared differences also in the surface and near bottom salinity. Contrary to that, the chemical composition of surface and near bottom water in the river Świna outlet into the Pomeranian Bay differed considerably throughout the entire period of the study.

Simultaneously the chemical composition of water differed characteristically depending on the location of sampling station and the sampling date. The results listed in tables 3 and 4 were selected to indicate the characteristic features of water chemistry in various parts of the river Odra estuary, specifically: Western Odra, Dąbie Lake, Roztoka Odrzańska, Great Lagoon, the lakes: Nowowarpieńskie, Wicko Wielkie and Wicko Małe, as well as the outlet of the river Świna into the Pomeranian Bay, and compared with the results, cited from literature, on chemical composition of water in these basins in summer (July-August) in the years proceeding the flood (Nowowarpieńskie Lake) or some years past the flood. The data from literature are considered the reference values in the water quality assessment of the flood water.

Table 2

Water quality indices in the Odra River estuary following the summer flood in 1997

No	Water quality indices		A1[1)] 16.07	A2[1)] 23.07	A3[1)] 30.07	A4[1)] 06.08	B[1)] 18.08	C[1)] 18.08	D[1)] 18.08	E[1)] 06.08	F[1)] 06.08	G[1)] 06.08	H[2)] 01.09	H[3)] 01.09	I[2)] 01.09	I[3)] 01.09	J[2)] 01.09	J[3)] 01.09
			Sample number and date															
1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	I. General indices																	
I.1	Temperature	(°C)	24,0	25,0	25,5	26,0	25,5	24,5	26,5	22,0	22,8	23,5	25,5	25,5	25,5	25,0	24,8	24,2
I.2	pH	(unit pH)	7,17	7,05	7,08	7,26	7,33	7,33	7,61	8,33	8,62	8,86	7,52	7,56	7,66	7,33	7,77	7,94
I.3	Eh	(mV)	395	350	285	315	296	295	290	289	286	225	325	322	325	319	353	334
I.4	COD-Mn	($mgO_2\ dm^{-3}$)	10,0	12,6	14,3	13,7	19,8	16,6	20,0	8,6	9,2	9,2	12,6	14,2	12,7	16,0	13,9	15,0
I.5	BOD_5	($mgO_2\ dm^{-3}$)	6,7	2,7	1,8	2,1	2,6	3,1	2,9	2,5	13,3	16,8	6,6	6,8	6,6	6,8	6,6	7,8
I.6	$O_{2\ (diss)}$ conc.	($mgO_2\ dm^{-3}$)	4,2	2,6	1,6	3,0	4,9	4,5	4,9	8,4	14,1	10,2	8,4	7,2	8,0	7,2	7,2	7,6
	II. Nutrients																	
II.1	NO_3^-	($mgN\ dm^{-3}$)	<0,01	<0,01	<0,01	0,01	0,68	0,53	0,55	0,16	0,22	0,03	0,12	0,16	0,10	0,12	0,07	0,10
II.2	NO_2^-	($mgN\ dm^{-3}$)	0,212	0,218	0,250	0,183	0,041	0,033	0,028	0,015	0,005	0,007	0,075	0,095	0,120	0,140	0,080	0,090
II.3	NH_4^+	($mgN\ dm^{-3}$)	2,30	2,60	2,80	2,50	0,77	0,87	1,00	0,06	0,05	0,04	0,08	0,12	0,10	0,14	0,11	0,14
II.4	$PO_4^{3-}{}_{(dissol)}$	($mgPO_4\ dm^{-3}$)	1,45	1,50	1,40	1,35	0,47	0,36	0,19	0,11	0,15	0,12	0,01	0,03	0,03	0,04	0,01	0,02
	III. Mineralization indices																	
III.1	Ca_{tot}	($mg\ dm^{-3}$)	65	70	68	71	80	75	75	67	72	80	80	87	88	80	100	80
III.2	Mg_{tot}	($mg\ dm^{-3}$)	7	7	7	8	<5	<5	<5	15	31	47	14	7	17	13	14	14
III.3	Cl^-	($mg\ dm^{-3}$)	111	109	105	96	126	114	114	135	325	535	76	76	89	96	142	156
III.4	SO_4^{2-}	($mg\ dm^{-3}$)	131	135	128	116	229	189	189	135	195	124	150	146	128	143	159	131
III.5	Total alkalinity	(mmol HCl dm^{-3})	2,14	2,05	2,00	2,10	3,40	3,40	3,40	2,60	2,40	2,10	3,30	3,00	3,20	3,00	3,30	3,10
III.6	Fe_{tot}	($mg\ dm^{-3}$)	2,80	2,90	3,20	3,00	0,13	0,16	0,16	0,46	0,90	0,70	0,14	0,20	0,10	0,12	0,12	0,18
III.7	Mn_{tot}	($mg\ dm^{-3}$)	0,07	0,09	0,08	0,07	0,30	0,27	0,27	0,12	0,62	0,56	0,38	0,50	0,32	0,45	0,25	0,38

1) - surface and near bottom waters (chlorinity differences ≤ 5%)

2) and 3) - surface and near bottom waters respectively (chlorinity differences ≥ 5%)

- water quality classified to I or II quality classes
- water quality classified to III quality class
- out – of – class water according to mineralization indices
- out – of – class water according to other indices

Table 2 (cont.)

Water quality indices in the Odra River estuary following the summer flood in 1997

No.	Water quality indices		Sample number and date															
			K[2] 01.09	K[3] 01.09	L[2] 01.09	L[3] 01.09	M[1] 01.09	N[1] 01.09	P1[2] 26.07	P1[3] 26.07	P2[2] 11.08	P2[3] 11.08	P3[2] 18.08	P3[3] 18.08	P4[2] 25.08	P4[3] 25.08		
1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	I. General indices																	
I.1.	Temperature	(°C)	24,5	24,1	25,6	25,0	23,0	22,0	20,6	18,0	22,4	19,4	23,0	18,6	22,2	18,6		
I.2.	pH	(unit pH)	8,04	8,09	8,19	8,37	8,34	8,82	8,19	7,90	7,92	7,44	7,94	7,30	7,61	7,34		
I.3.	Eh	(mV)	328	316	321	315	286	284	312	307	287	290	297	300	372	380		
I.4.	COD-Mn	($mgO_2 \cdot dm^{-3}$)	12,6	13,0	13,9	15,2	11,8	14,7	6,4	4,7	8,9	5,4	8,4	5,0	7,6	4,0		
I.5.	BOD_5	($mgO_2 \cdot dm^{-3}$)	13,8	9,0	10,2	8,9	5,0	7,6	4,1	1,8	3,2	1,7	3,1	2,8	2,3	1,1		
I.6.	$O_{2\,(diss)}$ conc.	($mgO_2 \cdot dm^{-3}$)	9,2	8,8	9,0	7,8	14,3	12,1	10,0	5,2	8,4	4,7	7,6	0,0	7,4	0,4		
	II. Biogenic substances																	
II.1.	NO_3^-	($mgN \cdot dm^{-3}$)	0,09	0,09	0,09	0,09	0,44	0,70	0,20	0,06	0,15	0,06	0,07	0,02	0,09	0,06		
II.2.	NO_2^-	($mgN \cdot dm^{-3}$)	0,100	0,110	0,100	0,105	0,009	0,007	0,010	0,010	0,010	0,011	0,008	0,004	0,007	0,011		
II.3.	NH_4^+	($mgN \cdot dm^{-3}$)	0,08	0,09	0,05	0,06	0,23	0,17	0,01	0,01	0,02	0,04	0,04	0,41	0,04	0,18		
II.4.	$PO_4^{3-}{}_{(dissol)}$	($mgPO_4 \cdot dm^{-3}$)	0,04	0,05	0,11	0,12	0,28	0,63	0,27	0,20	0,22	0,13	0,37	0,62	0,27	0,34		
	III. Mineralization indices																	
III.1.	Ca_{tot}	($mg \cdot dm^{-3}$)	80	70	76	80	68	62	88	104	85	107	77	101	74	85		
III.2.	Mg_{tot}	($mg \cdot dm^{-3}$)	24	28	12	7	12	12	128	225	95	199	78	199	118	216		
III.3.	Cl^-	($mg \cdot dm^{-3}$)	142	142	71	71	66	120	1460	3490	1410	3660	1410	3660	2160	3920		
III.4.	SO_4^{2-}	($mg \cdot dm^{-3}$)	140	146	150	152	101	135	527	645	412	645	271	452	355	586		
III.5.	Total alkalinity	($mmol\ HCl \cdot dm^{-3}$)	3,10	3,00	3,50	3,40	2,30	3,60	1,70	1,90	2,60	3,00	2,80	2,20	2,40	2,00		
III.6.	Fe_{tot}	($mg \cdot dm^{-3}$)	0,08	0,10	0,04	0,06	0,09	0,07	0,02	0,01	0,18	0,16	0,07	0,17	0,01	0,04		
III.7.	Mn_{tot}	($mg \cdot dm^{-3}$)	0,45	0,55	0,59	0,65	0,80	0,48	0,80	2,90	1,80	0,41	1,30	0,17	0,40	0,17		

In the case of the Western Odra and Lake Dąbie (Tab.3, column 5), the trends in variations of particular water quality indices were also determined and the extreme values, indicating the degree of ichthyofauna endangerment (maximal or minimal) are shown. Water quality indices measured at station A were probably very similar to the results of such indices in Regalica the river flowing into the lake Dąbie. The results obtained at stations A and B and C and D rendered possible the determination of changes in water quality in the southern part of the estuary from 16.07. to 11.08. 1997, i.e. during the outflow of the maximal flood crest. The results listed in Tab.3. column 5, compared with the results from the Roztoka Odrzańska (Tab. 3, column 6) give the description of quality changes in water flowing downwards the estuary till 01.09.1997. At that time, water in Roztoka Odrzańska showed lower content of nitrate, dissolved orthophosphate, chloride and sulphate but higher content of nitrite than in the reference period.

Water in the Great Lagoon showed a relatively marked variability during the period of study (06.08.-01.09.1997). Total alkalinity, surface water saturation with oxygen, the concentration of reducing organic substances as well as the concentrations of NH_4^+, NO_2^- and Mn_{tot} increased during this period. In comparison to reference values - pH, BOD_5, oxygen concentration and the concentrations of NO_3^-, PO_4^{3-}, Cl^- and Mg^{2+} were lower and the concentrations of NH_4^+, NO_2^- SO_4^{2-}, Fe_{tot} and Mn_{tot} were higher.

The results of measurements in the lakes Nowowarpieńskie, Wicko Wielkie and Wicko Małe as well as in the river Świna Strait together with the near mouth section of the Pomeranian Bay are presented in table 4. The comparison of the measurement results with the reference data indicates that water in the Lake Nowowarpieńskie (particularly station G) and to a lesser extent in the lake Wicko Małe, which are the bay lakes to the Szczecin Lagoon, showed chemical composition similar to the reference period. The influence of flood water was observed in the Lake Nowowoarpieńskie at station F, located close to the strait connecting the Lake with the Great Lagoon.

Significant changes in water chemistry, as compared to reference data, were observed in the Lake Wicko Wielkie. Particularly so as regards water saturation with oxygen and concentrations of NO_3^-, NH_4^+, PO_4^{3-}, Cl, Mg^{2+} and Mn_{tot}. Water saturation with oxygen, nitrate concentration and the content of Mn_{tot} showed higher values than in the reference period and the remaining indices attained much lower levels.

In the strait of the river Świna, considerable differentiation between the chemistry of surface and near bottom water was observed during the entire period of the study. Water in both layers differed as regards all the examined indices. The near bottom water showed close resemblance to chemical composition of the near bottom water in the Pomeranian Bay in the vicinity of the river Świna mouth. Noticeable differences were found in the concentration of oxygen, which declined to 0 mg O_2 dm^{-3} near the bottom in the mouth of the river Świna, and in the concentration of NH_4^+, which was several times higher than in the reference period. The examined waters showed also elevated concentrations of Mn_{tot}.

Table 3

Water quality indices of the southern part of the Odra River estuary and Great Lagoon in summer flood 1997 compared with water quality data in these areas in summer before 1997

No	Water quality indices		Quality standards[1]		Southern part of the Odra River estuary			Great Lagoon	
			I class*	II class	Flood waters[2]	Flood waters[3]	Reference data[4]	Flood waters[5]	Reference data[6]
1	2		3	4	5	6	7	8	9
1	Temperature	[°C]	≤ 22	≤ 26	24,0→26,0 25,0→26,0	25,5	≤ 23,2	22,0→25,6	≤19,0 (July) ≤19,5 (August)
2	pH	[pH units]	6,5 – 8,5	6,5 - 9,0	7,17→7,05→7,36 7,45	7,56	7,80 - 8,40	7,33 - 8,40	8,70 – 9,00
3	Total alkalinity	[mmolHCl·dm^{-3}]	n d	n d	2,14→2,00→2,10 3,40	3,00	2,60 - 2,80	2,60→3,50	3,00
4	BOD_5	[mgO_2·dm^{-3}]	≤ 4	≤ 8	6,7→8,8→2,1 2,8	6,8	2,6	2,5→8,4 - 13,8	... 2,4
5	COD-Mn	[mgO_2·dm^{-3}]	≤ 10	≤ 20	10,0→14,8→13,7 18,0	14,2	-	8,6→11,5-13,0 (surface) 8,6→14,0 -15,2 (near bottom)	10
6	$O_{2(diss.)}$ concentration	[mgO_2·dm^{-3}]	> 6	> 5	4,2→1,6→3,0 4,8	7,2	8,7	8,4→8,8 - 9,0 (surface) 8,4→7,2 - 7,8 (near bottom)	10,0
7	O_2 saturation	[%]	n d	n d	51→19→36 58	88	89	96→av 100 (surface) 96→av 91 (near bottom)	108
8	Eh	[mV]	n d	n d	325→285→315 293	325	200	290 - 325	250 (July) 180 (August)
9	pE	[pE units]	n d	n d	5,49→4,82→5,32 4,95	5,44	3,80	4,91 - 5,50	4,4 (July) 2,9 (August)
10	rH	[rH units]	n d	n d	25,32→23,73→25,37 24,80	26,00	24,10	24,50 - 27,80	27 (July) 23 (August)
11	$NH_{4\ total}$	[mgN-NH_4·dm^{-3}]	≤ 1,00	≤ 3,00	2,30→2,80→2,50 0,90	0,08	0,05	0,06→0,14 - 0,66	0,04
12	NO_3	[mgN-NO_3·dm^{-3}]	≤ 5,00	≤ 7,00	<0,01→0,01 0,55	0,12	1,56	0,16→0,07 - 0,10	0,60
13	NO_2	[mgN-NO_2·dm^{-3}]	≤ 0,020	≤ 0,030	0,212→0,250→0,183 0,036	0,075	0,001	0,015→0,075 - 0,140	0,005
14	$PO_4^{3-}{}_{soluble}$	[$mgPO_4$·dm^{-3}]	≤ 0,20	≤ 0,60	1,50 0,35	0,01	0,51	0,11→0,01 - 0,04	0,80

1	2		3	4	5	6	7	8	9
15	Total hardness	[$mgCaCO_3 \cdot dm^{-3}$]	≤ 350	≤ 550	199 <208	258	233	233 - 296	292 (July) 346 (August)
16	Ca^{2+}_{total}	[$mg \cdot dm^{-3}$]	n.d.	n.d.	68 75	80	68	70 - 90	80
17	Mg^{2+}_{total}	[$mg \cdot dm^{-3}$]	n.d.	n.d.	7 < 5	14	15	14 - 17	22 (July) 35 (August)
18	Cl^- surface waters	[$mg \cdot dm^{-3}$]	≤ 250	≤ 300	111 →96 120	76	120	71 - 142	300 (July) 500 (August)
	Cl^- near bottom waters	[$mg \cdot dm^{-3}$]					120		600- 700
19	SO_4^{2-}	[$mg \cdot dm^{-3}$]	≤ 150	≤ 200	130 →115 210	150	90	135 - 159	100 (July) 120 (August)
20	Fe_{total}	[$mg \cdot dm^{-3}$]	≤ 1,00	≤ 1,50	2.80 →3.20 →3.00 0.14	0.14	0.24	0.46 →0.08 - 0.14	≤ 0.15
21	Mn_{total}	[$mg \cdot dm^{-3}$]	≤ 0,10	≤ 0,30	0,08 0,28	0.38	0.23	0.12 →0.40 - 0,60	≤ 0,15

[1] classification standards for inland waters (Rozporządzenie 1991)
[2] data for the southern part of the Odra River estuary (stations A-D) in summer 1997 (16.07. – 18.08.1997). In table – over: date for a measurement from A1 to A4 with extremal values of the indices (between: 16.07. - 06.08.1997); below – averages for stations B, C and D (on 11.08.1997)
[3] data for Roztoka Odrzańska (station H, date: 01.09.1997)
[4] average values of water quality indices for Roztoka Odrzańska in July -August 1991-1994 (Poleszczuk 1997)
[5] data for Great Lagoon (stations E, I, J, K and L) in summer 1997 (date of the investigations for station E – 06.08.1997, for *other stations* – 01.09.1997). *Arrow points* the change in direction of water quality indices in the period from 06.08.1997 to 01.09.1997
[6] average values of water quality indices for Great Lagoon in July -August 1991-1994 (Poleszczuk 1997)

Others notations:
n.d. – not specified in Rozporządzenie (1991)
av. - average

Table 4.

Water quality indices of the Nowowarpieńskie, Wicko Wielkie and Wicko Małe Lakes and Świna Channel mouth to Pomeranian Bay in summer flood 1997 compared with water quality data in these areas in summer before 1997

No.	Water quality indices	Nowowarpieńskie Lake		Wicko Wielkie Lake		Wicko Małe Lake		Flood water in Świna Channel mouth		Bottom water in Pomeranian Bay near Świna mouth (<10m) References data [8]
		Flood water[1]	Reference data[2]	Flood water[3]	Reference data[4]	Flood water[5]	Reference data[6]	Surface water[7]	Bottom water (<10m)[7]	
1	2	3	4	5	6	7	8	9	10	11
1	Temperature [°C]	22,8 23,5	20,0	23,0	20,0	22,0	21,2	20,5 - 22,2	18,0 - 18,6	19,0 - 22,0
2	pH [pH units]	8,62 8,86	8,20	8,34	8,90	8,82	9,10	7,61 - 8,20	7,34 - 7,90	8,00 - 8,20
3	Total alkalinity [mmolHCl dm^{-3}]	2,40 2,10	2,85	2,30	2,90	3,60	2,95	1,70 - 2,80	1,70 - 3,00	2,20
4	BOD_5 [mgO_2 dm^{-3}]	13,3 16,8	6,0	5,0	5,5	7,6	7,8	2,3 - 4,4	1,1 - 2,8	1,4 - 3,1
5	COD-Mn [mgO_2 dm^{-3}]	9,2	10,7	11,8	10,4	14,7	12,3	3,2 - 2,8	1,7 - 4,7	5,0 - 5,6
6	$O_{2(diss.)}$ concentration [mgO_2 dm^{-3}]	10,2 14,1	9,8	14,3	11,2	12,1	12,9	7,4 - 10,0	0,0 - 5,2	8,5 - 9,0
7	O_2 saturation [%]	119 164	108	166	128	138	140	82 - 111	0 - 57	100 - 105
8	Eh [mV]	286 225	430	286	200	284	160	290 - 310	290 - 310	370 - 375
9	pE [pE units]	4,87 3,84	7,40	4,87	3,20	4,86	2,70	4,98 – 5,33	5,03-5,36	6,39-6,41
10	rH [rH units]	27,46 24,92	32,20	26,42	24,03	27,36	23,70	25,18–27,06	24,74-26,52	29,78-29,22
11	$NH_4^+{}_{total}$ [mgN-NH_4 dm^{-3}]	0,05 0,04	0,05	0,23	0,60	0,17	0,22	0,01 - 0,04	0,01 - 0,41	< 0,01 – 0,03
12	NO_3^- [mgN-NO_3 dm^{-3}]	0,22 0,03	0,03	0,44	0,04	0,70	0,02	0,01 - 0,20	0,06	< 0,01 - 0,10
13	NO_2^- [mgN-NO_2 dm^{-3}]	0,005 0,007	0,002	0,009	0,003	0,007	0,002	0,007- 0,010	< 0,001-0,011	0,001 - 0,005
14	$PO_4^{3-}{}_{soluble}$ [mgPO_4 dm^{-3}]	0,15 0,12	0,20	0,28	1,25	0,63	0,40	0,22 - 0,37	0,13 - 0,62	0,01 - 0,05
15	Total hardness [mg$CaCO_3$ dm^{-3}]	309 396	315	220	426	205	426	510-753	813-1198	1233-1531
16	$Ca^{2+}{}_{total}$ [mg dm^{-3}]	72 80	66	68	77	62	87	74 - 88	85 - 104	60 - 114

1	2		3	4	5	6	7	8	9	10	11
17	Mg^{2+}_{total}	[mg·dm^{-3}]	31 47	36	12	56	12	50	78 - 128	144 - 225	260 - 299
18	Cl	[mg·dm^{-3}]	325 535	540	66	330	120	490	1410 - 2160	3490 - 3920	3850 - 4500
19	SO_4^{2-}	[mg·dm^{-3}]	195 124	145	101	82	135	190	281 - 527	452 - 625	537 - 595
20	Fe_{total}	[mg·dm^{-3}]	0,90 0,70	0,22	0,09	0,08	0,01	0,55	0,01 - 0,18	0,01 - 0,17	
21	Mn_{total}	[mg·dm^{-3}]	0,62 0,56	0,15	0,80	0,54	0,48	0,78	0,80 - 1,80	0,17 - 2,90	

[1] data for Nowowarpieńskie Lake (stations F and G) in summer 1997 (date of the investigations – 06.08.1997). In Tab.4. - left data for station F, right date for station G. Arrow points the change in water quality indices from higher to lower value

[2] *personal investigations in* Nowowarpieńskie Lake, unpublished data from summer 2000

[3] data for Wicko Wielkie Lake (station M) from summer 1997 (date: 01.09.1997)

[4] personal investigations in Wicko Wielkie Lake, unpublished data from summer 1996

[5] data for Wicko Małe Lake (station N) from summer 1997 (date: 01.09.1997)

[6] personal investigations in Wicko Małe Lake, unpublished data from summer 1996

[7] data for Świna Channel mouth to Pomeranian Bay (station P) from summer 1997 (date: 26.07., 11.08., 18.08. and 25.08.1997)

[8] data from Poleszczuk et al. *(2001)*.

DISCUSSION

In summer 1997, two flood crests formed in the upper flow of the river Odra and combined in its lower part (Fig.2). This finally resulted in the prolonged outflow of high water, lasting in the Odra estuary from 20 July (the rise of water level in the water-gauge Szczecin) until the second half of August (the decline of water level in the water-gauges Szczecin and Świnoujście). The maximal water flow was noted on the turn of July and August. The data presented in Fig.2 indicate that the flow of flood water through the estuary was detected in the river Świna mouth on 30 July and ended on 25.08.1997. The flood crest was flattened out already in the upper part of the estuary and water levels in Szczecin and Świnoujście never exceeded the alarm level.

The water masses, only slightly mineralised, but transporting large loads of pollutants, when flowing through the upper and middle parts of the Odra estuary exerted a vehement, and subsequently lasting for several weeks, change in chemical composition of water in these parts of the estuary as compared to the composition typical for these waters under the ordinary climatic conditions (Poleszczuk 1997, 1998).

Salinity, expressed usually in terms of chlorinity, is the indicator characterising the changes in water quality of the river Odra estuary as regards the proportions in which the fresh and marine water are mixed in this estuary (Poleszczuk 1998).

Flood water entering the estuary showed a relatively low mineralisation, e.g. the following values were determined at station A on 23.07.1997: Cl^- - 109 mg dm^{-3}, Mg^{2+} - 7 mg dm^{-3}, Ca^{2+} - 70 mg dm^{-3} and SO_4^{2-} - 135 mg dm^{-3}, and resulted in dilution of estuarine water in the entire area of the Szczecin Lagoon (look up the data on mineralisation at all the examined stations in the central part of the Lagoon) with the exception of the lake Nowowarpieńskie (station G), the lake Wicko Małe (station N) and to a lesser degree the lake Wicko Wielkie (station M), through which the great amount of surface water had to pass anyhow. The freshening of water reached down to the near bottom water (down to about 10 m depth).

The effect of freshening the water in the Odra river estuary starts, as it was shown earlier, when the flow in the river reaches intensity of about 800 m^3 s^{-1} (Poleszczuk 1996). Hence from 16-17 July 1997 until 25-26 August 1997 the central part of the Szczecin Lagoon, down to the depth of about 10 m, was filled with water of specific chemical composition which flew down in the river-bed of the Odra.

During that time, solely in the near bottom water layer of the river Świna mouth into the Pomeranian Bay (from the bottom to 10 m depth), the more saline water was inflowing from the Pomeranian Bay. With the flood intensity declining, the riverine water outflew in the surface layer and near the bottom, mainly in the waterway, more saline water from the Pomeranian Bay was transported into the Szczecin Lagoon. Poleszczuk (1996) is of the opinion that the intrusions of saline water occur when the riverine flow is between 400-800 m^3 s^{-1}. At the beginning of September (01.09.1997), through the river-bed of Świna, water of chemical composition typical for the Pomeranian Bay close to the Świna mouth was transported (Poleszczuk et al. 2001), while in the surface layer - water of increased salinity was flowing, transformed by mixed the riverine and marine waters. The mixing of fresh water with the saline water occurs in the Szczecin Lagoon relatively fast due to specific movements of water caused by the changes in barothropic pressure, wind circulation and convection currents (Majewski 1980, Robakiewicz 1993, Poleszczuk 1997, 1998, Poleszczuk and Piesik 2000).

The flood water flowing into the estuary indicated higher than usual temperature, by 3-5°C, a relatively low pH (7.1-7.6) and oxygen content (1.5-5.0 mg O_2 dm^{-3}), and transported relatively large load of dissolved organic matter of reducing character (ChZT-Mn = 10-15 mg O_2 dm^{-3}) and limited ability to oxidise organic matter (BZT_5=2-7 mg O_2 dm^{-3}) (Poleszczuk 1997).

Simultaneously these waters preserved high redox status (Eh=290-350 mV), which resulted from the presence of various (different than oxygen) substances combining in redox pairs (Garrels and Christ 1962). In the starting stage of the outflow, the flood waters contained negligible amounts of nitrate (V) (<0.01 mg N dm^{-3}), relatively high concentrations of nitrite (III) (0.200-0.250 mg dm^{-3}) and ammonium derivatives (2.30-2.80 mg N dm^{-3}) and low concentrations of reactive dissolved phosphate (ca. 0.15 mg PO_4 dm^{-3}).

The flood waters transported significant amounts of iron (the concentration of Fe_{tot}=2.80-3.20 mg dm^{-3}) and scarce amounts of manganese (the concentration of Mn_{tot} <0.10 mg dm^{-3}). Low total alkalinity (2.00-2.10 mmol HCl dm^{-3}) was also their characteristic feature.

The chemistry of flood water changed on its way from the upper most stations (B, C, and D) down the estuary into the sea (stations E and M). The concentration of dissolved oxygen increased, as well as the concentration of nitrate and dissolved phosphate. These changes confirmed the fact that the impetuous flow assured good oxidation of the flowing water with oxygen from the atmosphere, and also pointed out to the undergoing intensive processes of organic matter oxidation in these waters. The oxidation processes were accompanied by an increase in pH and total alkalinity on one hand and on the other - a decrease in total iron concentration and an increase in total manganese (up to 0.8 mg dm^{-3} in the Lake Wicko Wielkie).

When the flood crest reached the central part of the Great Lagoon (stations I, J, K, and L), water in the surface and near bottom (depth < 10 m) layers revealed relatively homogenous chemical composition regarding the mineralisation and other water quality indices (solely at stations J and K a slightly increased values of Cl^- were found.

The concentrations of examined mineralisation indices were as follows Cl^-: 71-88 mg Cl dm^{-3}; SO_4^{2-}: 128-150 mg SO_4 dm^{-3}; Ca^{2+}: 70-80 mg Ca dm^{-3}; Mg^{2+}; 7-24 mg Mg dm^{-3}; total alkalinity: 2.00-3.50 mmol HCl dm^{-3}.

A weak differentiation between surface and near bottom water composition was noticed at station J in the southern part of the Great Lagoon, probably due to an inflow of saline water on the sampling date (01.09.1997).

The total concentrations of iron and manganese were lower in the flood water (as compared to measurements at stations E and H), this can be taken as evidence for washing out the surficial sediments from the Lagoon into the sea, because the sediments are rich in both theses elements (Osadczuk et al. 1996).

It is well proved that in flood waters in the central part of the Great Lagoon more intensive processes of biochemical degradation of organic matter occurred than in the southern part of the estuary, as the concentration of BOD_5 varied between 0.5-0.8 mg O_2 dm^{-3} and they contained more dissolved organic matter of reducing character (COD-Mn: 12.5-16.0 mg O_2 dm^{-3}). The redox status of these waters was relatively stable (Eh=290-325 mV), oxygen concentration between 8.8-9.0 mg O_2 dm^{-3} in the surface layer and between 7.2-7.8 mg O_2 dm^{-3} in the near bottom layer, but the water near the bottom was more abundant in dissolved organic matter of reducing character. The concentrations of mineral nitrogen compounds were negligible (NO_3: 0.12-0.16 mg N dm^{-3}; NO_2: 0.075-0.140 mg N dm^{-3}) and dissolved reactive phosphate were at similarly low concentrations (0.01-0.04 mg PO_4 dm^{-3}), with the exception of stations E and L located at a greater distance from the main flow of the flood water along the water-way Szczecin-Świnoujście.

Waters in the lakes Nowowarpieńskie (station G) and Wicko Małe (station N), and also to a lesser extent water in the Lake Wicko Wielkie (station M) retained their typical estuarine chemical composition during the flood, however the vast masses of flood water had passed the latter basin much earlier. The characteristic features of water in the mentioned lakes were: lower temperature (22-23°C), high pH (8.33-8.88), relatively low values of Eh (225-280 mV) and elevated concentrations of oxygen (10.2-14.3 mg O_2 dm^{-3}). The elevated concentrations of oxygen indicated the ongoing phytoplankton bloom.

Water in the Lake Nowowarpieńskie showed relatively low level of COD-Mn (8.6-9.2 mg O_2 dm^{-3}) and increased level of BOD_5 (13.3-16.8 mg O_2 dm^{-3}). Simultaneously they revealed low concentrations of mineral nitrogen compounds ($NO_3^- \approx$ 0.03 mg N dm^{-3}, $NO_2^- \approx$ 0.007-0.017 mg N dm^{-3}, $NH_4^+ \approx$ 0.04 mg N dm^{-3}). Evidently, within the complex structure of the river Odra estuary these were the enclaves where the flood did not exert any effects.

In natural water basins, every sudden change in the chemistry of water poses an intensive stress to ichthyofauna. Fish from the salmonide family are particularly sensitive to the changes in the chemistry of inhabited water. Due to increased secretion of cortisol, that leads to the reduction of leucocyte number in blood, the fish are less immune to infections (Antychowicz 1996). Simultaneously, variable chemical substances can be harmful and toxic to fish and pose direct endangerment to ichthyofauna. According to the data listed in Tab. 2, flood water transported compounds of deadly threat to ichthyofauna of the Odra estuary. Two "death zones" were formed during the outflow of the surface water, where oxygen concentrations declined to critically low values: in the southern part of the estuary, especially in the Western Odra - oxygen concentration dropped there to 1.6-3.0 mg O_2 dm^{-3} between 23.07 and 06.08.1997, and less affected areas of the Eastern Odra, Regalnica and the Lake Dąbie (oxygen concentrations: 4.5-4.9 mg O_2 dm^{-3}). The other endangered zone was situated near the outlet of the river Świna into the Pomeranian Bay, where a complete exhaustion of oxygen (0 mg O_2 dm^{-3}) in the near bottom water was observed from 18.08. to 25.08. 1997. The formation of such strong oxygen deficit in the Świna strait and close to the Świna mouth along the shores of the Pomeranian Bay was also detected by Pastuszak and Sitek (1998). An inflow of saline water from the Pomeranian

Bay through the Świna strait and further into the Szczecin Lagoon, that started on 25.08.1997 (according to Pastuszak and Sitek (1998) – from 26-29.08.1997) did not improve the oxygen situation in the endangered areas because water in the Pomeranian Bay close to the Świna mouth was also poorly supplied in oxygen. The occurrence of oxygen deficits in the Pomeranian Bay close to the river Świna mouth was described already by Wiktor and Wiktor (1961), who observed regular decline in water saturation with oxygen to 80% and attributed this to mass mortality in the saline water in the Bay of fresh water hydrobionts transported from the Szczecin Lagoon and the ensuing enhanced demand for oxygen for the mineralisation of the dead biomass. The same phenomenon, though considerably magnified must have occurred during the inflow of flood water into the Pomeranian Bay in summer 1997. The salinity of water in the Pomeranian Bay reached then 6.6 (Pastuszak and Sitek 1998).

Concentrations of NO_2^- between 0.100-0.250 mg $N\text{-}NO_2$ dm^{-3}, which occurred and persisted for several weeks (from 16.07.1997 in the southern parts of the estuary till 01.09.1997 in the central part of the Great Lagon) in water of the Lagoon, posed the danger of causing methemglobinemia in fish. Nitrite concentrations of this level, persisting for prolonged period, cause serious pathological disturbances in ichthyofauna. Simultaneously nitrite exerted direct toxic effects, irrelvant to obstructing the hemoglobin transport of oxygen in fish. Nitrate, at the described level of concentrations and occurring under low oxygen content in water and relatively low pH, are liable to cause mass mortality in fish. The toxic effect of nitrite was enhanced by synergetic action of ammonium compounds that appeared in elevated concentrations (up to 2.80 mg $N\text{-}NH_4$ dm^{-3}). Nitrite also impaired the fish vitality. The prevalence of fresh water in the Szczecin Lagoon and the reduction of chloride concentration to 70-80 mg Cl dm^{-3}, posed additional endangerment factor for fish health, because higher concentrations of chloride form a barrier in fish against the assimilation of nitrate (III). There is no doubt that nitrite concentrations that appeared in water of the Szczecin Lagoon during the summer flood in 1997 were decidedly harmful and even lethal to salmonide fish (Siwicki et al. 1994, Antychowicz 1996).

Another threatening factor to the health of ichthyofauna posed the high content of iron and manganese in the flood water (Prost 1994), though the endangerment with iron occurred solely in the Western Odra (Fe concentration 2.80-3.20 mg dm^{-3}) and high concentrations of manganese appeared mainly in the surface water of the river Świna mouth (the measurements $P^{2)}$ and $P^{3)}$) as well as in the central part of the Great Lagoon. These high concentrations of manganese were most probably related to peptidation, resuspension and washing off the bottom sediments from the estuary into the sea by the flowing flood water.

Relatively high concentrations of ammonium ions, especially in the Western Odra, if evaluated according to the Rozporządzenie (1991), did not threaten the health of ichthyofauna because of the low pH in surface water. Due to this, dissolved ammonia concentration could not attain the harmful level. However, the problem of ammonium harmful effects is not equivocal. The Water Framework Directive of the European Union (Directive 78/659/EEC) states the permissible ammonia concentrations for salmonide and cyprinide families at, respectively, 0.005 and 0.025 mg NH_3 dm^{-3}. Concentration of NH_3 in estuarine water, calculated according to the tables given by Emerson et al. (1975), reached ca. 0.056 mg $N-NH_3$ dm^{-3} for the measurement A3[1)], and ca. 0.0075 mg $N-NH_3$ dm^{-3} for the measurement J[3)]. Similar situation arises when analysing the permissible concentrations of ammonium (NH_4^+). The Water Framework Directive decides that ammonium concentration in fresh water, under warm weather conditions, low salinity and intensive mineralisation processes, should not exceed 1 mg NH_4^+ dm^{-3} (0.078 mg $N-NH_4^+$ dm^{-3}).

High concentrations of reactive dissolved phosphate in Western Odra and BOD_5 values exceeding standard level (stations: F, G, K and L) can be mentioned as the additional disadvantageous changes in the aqueous environment. High water temperature, up to 26.5°C, was also of disadvantage to ichthyofauna occurring in all parts of the estuary.

The examination of water chemistry in this study was fragmentary because of accidental situation (a limited number of measurement stations) and the analysis were limited to a reduced number of parameters, out of 53 physical, chemical and biological parameters obligatory in the national programme of fresh, surface water monitoring in Poland (Rozporządzenie 1991). However, the parameters were selected according to the recommendation of the Water Framework Directive (1990). Irrelevant to the completeness or incompleteness of these results of the study, their presentation and preliminary discussion on the health endangerment of ichthyofauna during the summer flood in 1997 seemed profitable and interesting to the specialists studying biocenoses of the river Odra estuary.

CONCLUSIONS

1. In 1997, the inflow of flood water, characterised by specific chemical composition differing from the typical water composition in the Odra river estuary and containing large amounts of potentially toxic substances, was undoubtedly the source of severe stress to fish inhabiting the estuary, increasing their vulnerability to harmful effects of these substances and to variable infections.
2. During the outflow of flood water through the estuary, two endangerment zones were discerned: in the southern part of the estuary (Western Odra, Regalica, Dąbie Lake), where oxygen concentrations in the near bottom layer dropped to 1.6 mg O_2 dm^{-3} between 23.07. and 06.08.1997 and the oxygen deficit zone – in the mouth of the river Świna and along the coastal band of the Pomeranian Bay, where oxygen was completely exhausted from the near bottom water and hydrogen sulphide appeared.
3. The high concentrations of nitrite (0.100-0.250 mg $N-NO_2$ dm^{-3}), persisting from 16.07. (Western Odra) till 01.09.1997 (central part of the Great Lagoon), which is directly toxic to ichthyofauna and impaired the oxygen assimilation and transport in fish (methemglobinemia) under the presence of large amounts of ammonium compounds (up to 2.80 mg $N-NH_4$ dm^{-3}) and decreased water salinity (60-70 mg Cl dm^{-3}), posed significant threat to the estuarine ichthyofauna wholesomeness and survival.
4. The high total concentrations of iron and manganese, exceeding the Polish fresh water standards, as well as strongly elevated water temperature, BOD_5 and con-

centrations of dissolved reactive phosphate appeared only locally, and besides the high manganese values – incidentally, confirmed the general unfavourable to ichthyofauna water quality conditions in the Odra estuary.

5. According to the Polish surface water quality criteria, the high concentrations of ammonium compounds, particularly in water of the Western Odra and higher than normal in other parts of the estuary could not be harmful to the ichthyofauna, while these concentrations, when evaluated according to the criteria of the Water Framework Directive of the European Union were classified as inadmissible. In fact these concentrations, because of synergetic effects, enhanced the toxic effect of nitrite and other harmful substances.

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NIEKORZYSTNE DLA ICHTIOFAUNY ZMIANY JAKOŚCI BIOTOPU TONI WODNEJ ZALEWU SZCZECIŃSKIEGO PODCZAS SPŁYWU WÓD POWODZIOWYCH LATEM 1997 ROKU

Streszczenie

Przedstawiono wyniki prowadzonych podczas spływu wód powodziowych latem 1997 roku badań wybranych 21 fizycznych i chemicznych wskaźników jakości wód (ogólnych: temperatura, pH, alkaliczność ogólna, potencjał redoks Eh oraz wskaźniki redoks pE i rH, COD-Mn, BOD5, stężenie tlenu rozpuszczonego, stopień natlenienia wód; wskaźniki trofii: stężenie NO_3^-, NO_2^-, NH_4^+ i $PO_4^{3-}{}_{rozp.}$; wskaźniki mineralizacji: total hardness, stężenie Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} oraz $Fe_{og.}$ i $Mn_{og.}$) w miejscu 15 stacji pomiarowych w estuarium Odry poczynając od Odry Zachodniej w Szczecinie i jeziora Dąbie do ujścia Świny do Zatoki Pomorskiej.

Wykazano, że wody powodziowe o specyficznym składzie (niskiej mineralizacji i znacznej zasobności w substancje o charakterze zanieczyszczeń) wypełniały akweny południowej części estuarium Odry i Wielki Zalew. Wartości szeregu badanych wskaźników jakości tych wód w miejscach stacji na Odrze Zachodniej i jeziorze Dąbie oraz w obszarze ujściowym Świny do Zatoki Pomorskiej oceniano na podstawie prawnie obowiązujących w Polsce norm oceny środowiska wodnego dla słabo zmineralizowanych wód śródlądowych, wskazywały na występowanie i utrzymywanie się w przeciągu wielu dni niekorzystnej jakości środowiska wodnego zagrażającej zdrowotności i przeżywalności ichtiofauny.