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WATER QUALITY STATUS OF THE BALTIC SEA COASTAL ZONE - BODY OF SEA BETWEEN DARŁOWO AND ŁEBA PORTS

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Abstract

In the years 1997 - 1999 the coastal water in the Baltic Sea between Darłowo and Łeba Village was analysed. Values of dissolved oxygen, BOD_5, COD, total and inorganic phosphorus and total and inorganic nitrogen were determined on seven stations. The investigations have shown the highest state of pollution in Ustka and Łeba region.

Key words: coastal sea water, pollution indicators, nutrients, eutrophication.

INTRODUCTION

The Baltic Sea is one of the most polluted water basins in the world (Łomniewski et al. 1975). It has a small area and it is relatively shallow. The shallow and narrow Danish straits which connect the Baltic Sea with the North Sea obstruct the exchange of water with the Atlantic Ocean. The characteristic two layers of water caused by the differences in salinity, and thereby in density, obstruct the exchange of water. The main causes of the pollution of the Baltic Sea are the highly industrialized and densely populated countries which introduce most refuse from the land by rivers and sewage systems. This is the reason why coastal waters are most polluted.

The Baltic Sea is a common fishery which is shared by many countries, a common water route, and that is why all efforts to protect its environment must be combined and many problems can be solved only internationally. Helsinki Convention of 1974 explicitly underlines the necessity to conduct extensive investigation of the Baltic Sea by all countries of its basin (Kalfus 1978, Korzeniewski 1978). In the years 1969-1980 study within international monitoring programme to specify the state of purity of the Baltic water was carried out by Department of Chemistry, University of Education in Słupsk in territorial waters between Jarosławiec and Rozewie and their results were presented at the 13th Oceanographic Conference in Helsinki in 1982 (Korzeniewski et al. 1982).

THE OBJECTIVE

The objective of the present work is:

- to study the quantitive and qualitive content (analysis) of coastal sea water at the selected measuring stations
- to specify the state of purity of the coastal waters between Darłowo Port and Łeba Port
- to show the influence of the town and port of Ustka and the summer season of Rowy Village on the level of sea pollution.

CHARACTERISTICS OF THE STUDIED AREA - MEASURING STATIONS

The study comprises territorial waters between Darłowo and Łeba Ports. The location of measuring stations is shown in Fig. 1, and the purpose of their arrangement was to specify the direction of pollution sewage translocation and to specify the influence of the waters flowing from the land on the trophic state of the sea.

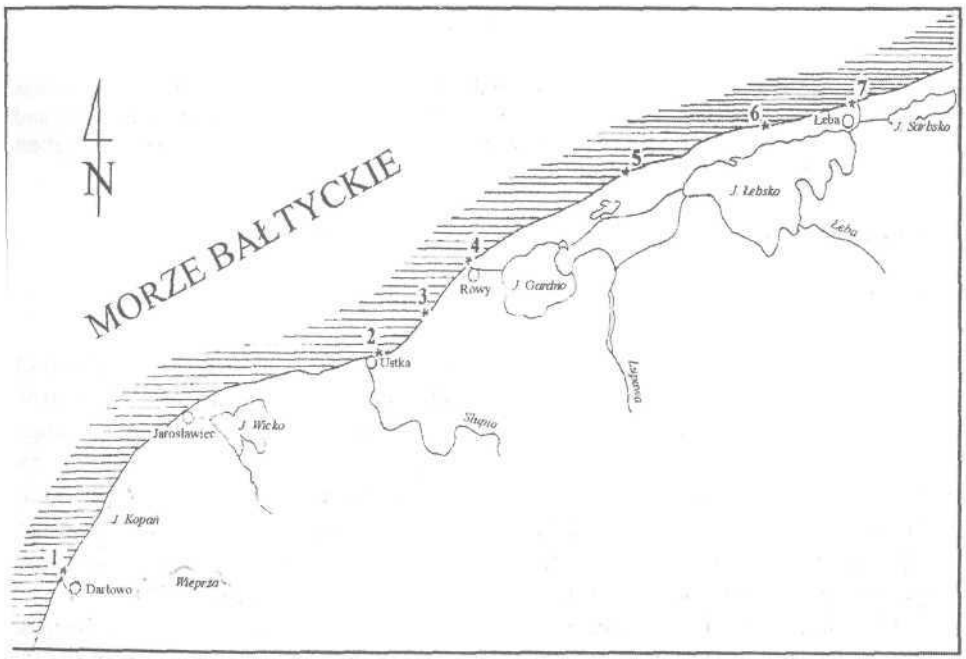

Fig. 3. The location of measuring stations

tation 1 was located opposite Darłowo, Station 2 was located near Ustka, a small ummer resort. Ustka is the biggest coastal town situated in the studied area, 19 km orth of Słupsk. It is a small port on the Central Coast, situated at the estuary of the łupia River. It is not only a town which has considerably expanded during the past ears and whose population has multiplied, but a popular and frequented tourist area,

health resort, port, shipyard and fishing industry. Dynamic development of Ustka, its function of the health – and recreation – resort as well as the merchant port with fishing industry facilities causes considerable pollution of the estuary zone of the Słupia River. A purification plant BIOXYBLOK type started operating in Ustka in the years 1990-1993. The plant has considerably lowered the amount of sewage introduced to the Słupia River, but the lack of the third stage of purification causes remaining of the very high level amount of biogenic compounds in the estuary part of the river (Przybyła et al. 1994) Station 3 was located near a small settlement called Orzechowo, and Station 4 was located at the estuary of the Łupawa River which connects Gardno Lake with the Baltic Sea near the summer resort of Rowy Village which has recently become popular tourist place as well. Sewage flowing from that area go directly into the sea because there is no purification plant there. Stations 5, 6 and 7 are placed in the territorial waters of the Słowiński National Park which was established in 1967 to protect natural environment. In 1979 UNESCO included the Słowiński National Park in the word nature reserve network (Kondracki 1994). Słowińskie Coast presents specific natural geosystem in which the land environment and the influence of the sea interfere with each other.

The coast line has been levelled straightened out mainly by the activity of waves building up coastal ridges which where later transformed by wind into dunes, which cut shallow lakes, e.g. Jamno, Wicko, Gardno, Łebsko, Dołgie of the Sea. There is big influence of the processes taking place in the atmosphere on the local climate of the coastal area.

MATERIAL AND METHODS

Samples of the sea water were taken from the 7 stations, from the distance of about 100 m from the seashore and from the depth of about 1 m. The aim of the distribution of the stations discussed in Chapter 3 was to study waters flowing from the land which influence the quality of the sea water. The results of the physical and chemical analysis of the water were concerned with the chosen parameters influencing the trophic state of the sea. They included the following indications: dissoluted oxygen, BOD_5, total phosphorus and total nitrogen, ammonia nitrogen and nitrate.

The analysis of the change of indications which influence the state of the Baltic between Darłowo and Łeba was carried out on the basis of the results of investigation beginning in November 1997 until the end of November 1999. The indications were made according to the method given by Hermanowicz et al. (1976) and according to Standard Methods (1992).

Samples of water used to indicate dissoluted oxygen and BOD_5 were taken to the bottles with the capacity of 100 cm^3.

Samples of water for indication of dissoluted oxygen were preserved on spot by adding the solution of sulphate (VI) manganese (II) and alkaline solution of potassium iodide.

The soluted oxygen was indicated by the Winkler method. The disengaged iodine was indicated titration by sodum tiosulfate (VI) in the presence of starch. The

indication BOD_5 is the result of a subtraction of the content of the oxygen solution at the beginning and after five days of incubation in 20°C. The dichromate method was used to indicate COD.

Total phosphorus T-P was counted as phosphate in mineralized sample. Phosphates $P\text{-}PO_4$ was determined by colorimetric method with molibdate ammonium. Total nitrogen T-N was determined by oxidating nitrogen compounds contained in water to nitrates, using persulfate potassium in alkaline environment. Nitrates $N\text{-}NO_3$ was analysed after their reduction with granular cadmium to nitrites $N\text{-}NO_2$, which were determined using sulfuric acid and 1-naphtylamina. Ammonium $N\text{-}NH_4$ was determined by colorimetric the Nessler method.

THE RESULTS OF THE STUDY

The average values for the particular stations established according to the obtained results of the study period are presented in Fig. 2-4. The seasonal changes of average pollution indicators are illustrated in Tab. 1, 2 and 3 and Fig. 2-4. Territorial waters in the study area are well oxygenated. The highest average value of dissoluted oxygen was recorded at station 6 which equalled 8.96 mg and at stations 5-8.66 mg $O_2\,dm^{-3}$. At stations 2 and 7 (located in Ustka and Łeba) the minimal average value of dissolved oxygen was recorded 7-7,46 mg $O_2\,dm^{-3}$, considerable part of oxygen was used for biodegradation of pollution brought into the sea with the waters of the Słupia and the Łeba.

It has been confirmed by the oxygen concentration in the port canal in Ustka indicated by Trojanowski et al. (1997) – 8.1 mg $O_2\,dm^{-3}$. The amount of biogenic substances bigger than at other stations intensifies the growth of living organisms in this water area, which is connected with the considerable use of oxygen. On the other hand, at stations 5 and 6 located within the Słowiński National Park the growth of dissoluted oxygen has been recorded. According to the general accordance, the biggest values of dissoluted oxygen were recorded in autumn (8.3-10.1), and the smallest in summer during vegetation and biodegradation (5.5-7.4 mg $O_2\,dm^{-3}$).

The average level of BOD_5 reflecting the content of organic pollution (Zieliński et al. 1987, Dojlido 1980) ranges from 2.0 to 3.5 mg dm^{-3}. The lowest average value of BOD_5 in the studied period was recorded at station 6 in spring and it equalled 1.9 mg $O_2\,dm^{-3}$; the highest was recorded at station 7 in summer and it equalled 4.0 mg $O_2\,dm^{-3}$. The increase of the average value of BOD_5 at station 7 is probably caused by the biggest amount of the load of microorganism and nutrients brought by the Łeba River into the sea during the year. The highest values of BOD_5 at stations 2 and 7 were observed in summer and early autumn. At stations 5 and 6 the level of BOD_5 was moreless the same during the year (1.9-2.6 mg dm^{-3}).

The biggest values of BOD_5 are recorded in summer and the smallest in winter. The big values of BOD_5 in summer are caused by the increased vegetation of water organisms, which is connected with a very big use of oxygen. The increase in organic matter was caused by frequent rains, superficial fluction and communal sewage brought into the sea by the rivers, especially big during the increased touristic activity in summer.

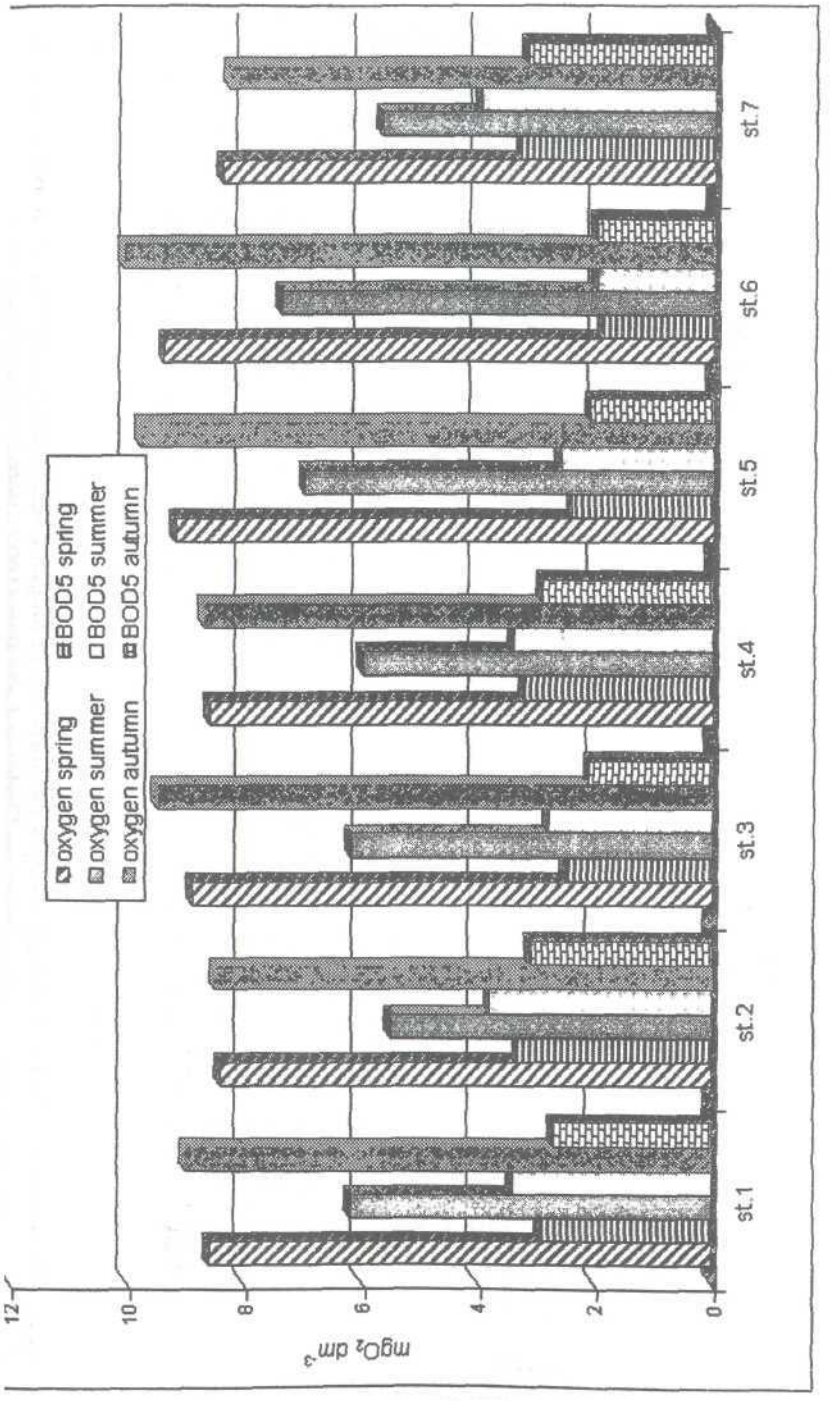

Fig.2. The seasonal changes of dissolved oxygen and BOD_5 in coastal Baltic Sea water beetwen Darłowo-Łeba Port (1997-1999)

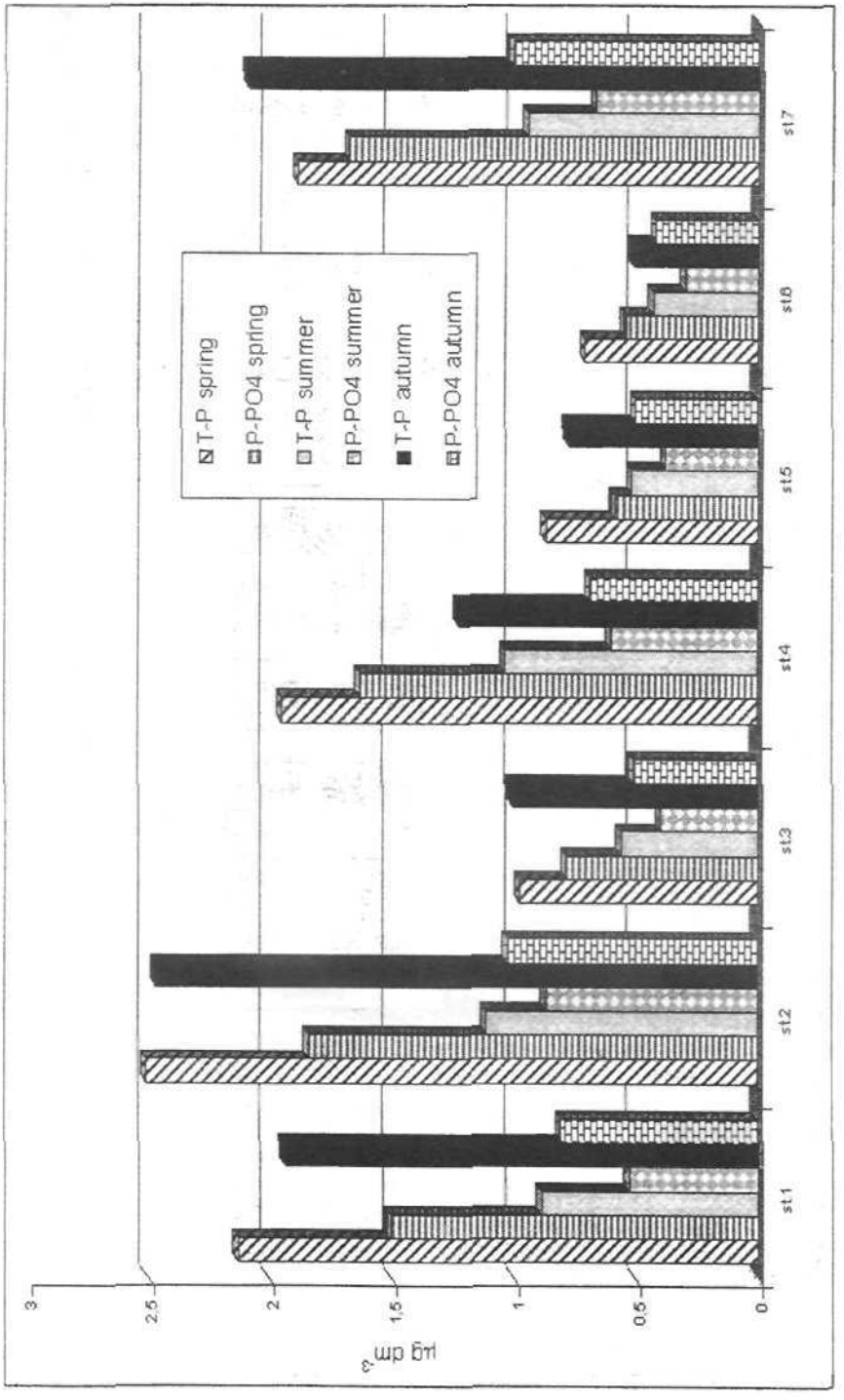

Fig.3. The seasonal changes of average values concentrations of biogenic substances indices in coastal Baltic Sea water beetwen Darłowo-Leba Port (1997-1999)

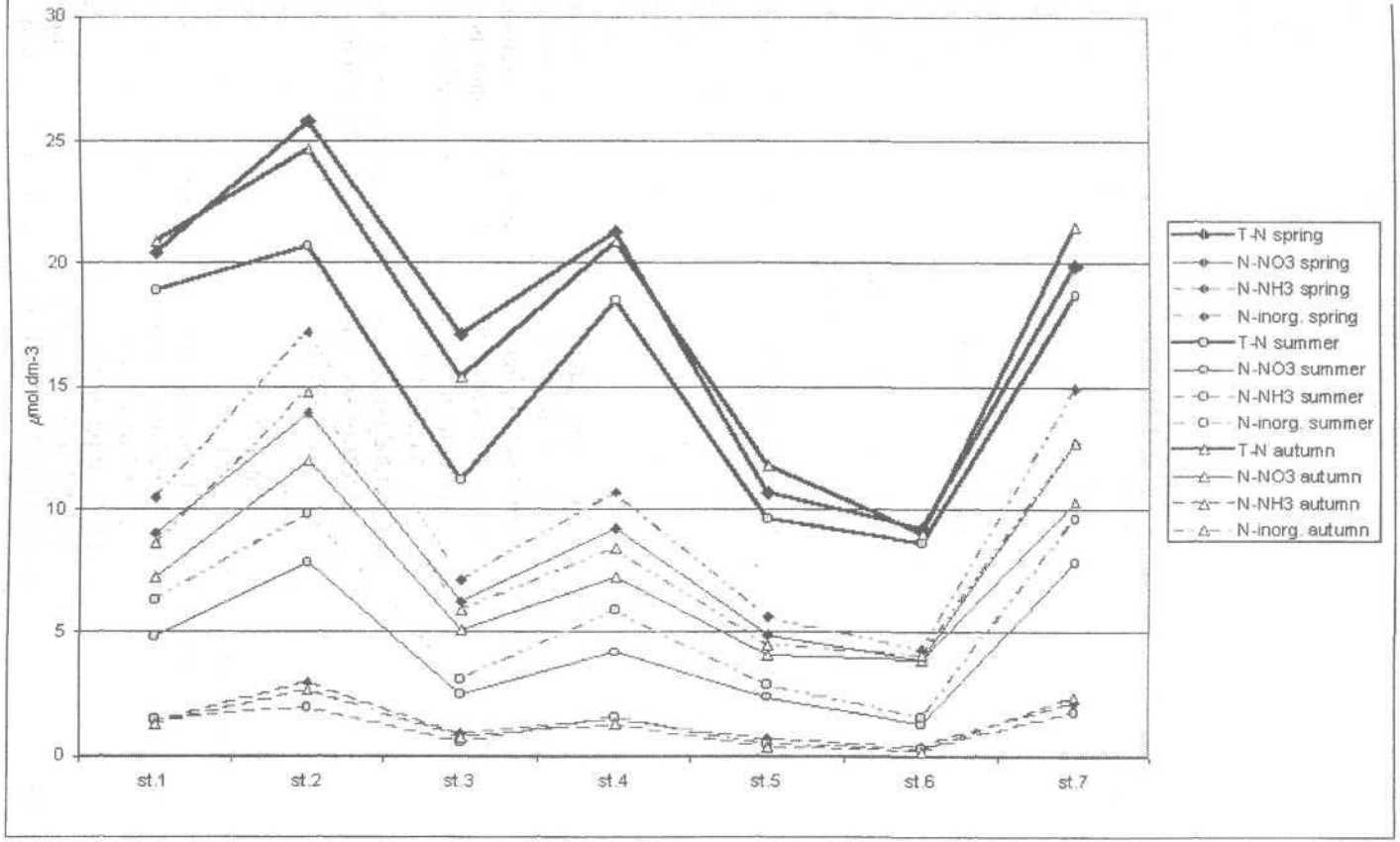

Fig.4. The seasonal changes of average values of some indicators of pollution in coastal Baltic Sea water beetwen Darłowo-Łeba Port (1997-1999)

Table 1

The average values of some indicators of pollution in coastal Baltic Sea water between Darłowo-Łeba Port (1997-1999)

Indicators	Stations No.						
	1	2	3	4	5	6	7
Oxygen mg O_2 dm^{-3}	7,90	7,47	8,20	7,76	8,66	8,96	7,46
BOD_5 mgO_2 dm^{-3}	3,0	3,4	2,5	3,2	2,4	2,0	3,5
T-P µmol dm^{-3}	1.65	2,03	0,85	1,41	0.72	0,55	1,64
$P\text{-}PO_4$ µmol dm^{-3}	0.95	1,24	0,57	0,97	0,49	0,42	1,12
T-N µmol dm^{-3}	20,1	23,7	14,6	20,2	10,7	8,9	20,0
$N_{inorg.}$ (summ $N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$) µmol dm^{-3}	8,5	13,9	5,4	8,3	4,3	3,3	12,4
$N_{inorg.}/P_{inorg.}$	8,95	11,2	9,5	8,5	8,8	7,8	11,1

The amount of nutrients is an important indicator of eutrophication of surface waters. Phosphorus as nutritive element for microorganisms, in condition of their optimal growth is assimilated by them. Such a phenomenon takes place in summer and a decline of phosphorus in water is observed at the same time. In winter, however an increase concentration of phosphorus in surface waters is observed as the result of mineralization of organic matter (Mazur 1995).

The maximum average content of total phosphorus T-P was recorded at station 2 in spring was 2,51 µmol/dm-3, the content of phosphate ion being 1.84 µmol/dm-3, and the minimum average content T-P at station 6 in sumer was 0.43 µmol/dm-3, $P\text{-}PO_4$ being 0.30 µmol/dm-3. The average values T-P were exposed to the biggest fluctuations in spring: from 0.71 µmol/dm-3 at station 6 to 2.51 µmol/dm-3 at station 2, $P\text{-}PO_4$ ranging from 0.54 µmol/dm-3, to 1.84 µmol/dm-3, respectively, at the same stations. On the other hand, the values of concentration T-P in summer were exposed to the smallest fluctuations: from 0.43µmol/dm-3 at station 6 to 1.12 µmol/dm-3 at station 2 and from 0.30 µmol/dm-3 to 0.87 µmol/dm-3 respectively, at the same stations. The highest average concentration of phosphorus compound is at station 2 and near Ustka average is 2.03 µmol/dm-3 T-P and 1.24µmol/dm-3 $P\text{-}PO_4$, but the smallest is near Łebsko Lake in the Słowiński National Park area (average T-P 0.55 and $P\text{-}PO_4$ 0.42 µmol/dm-3 respectively.

Table 2

The seasonal changes of average pollution indicators in coastal Baltic Sea water beetwen Darłowo-Łeba Port (1997-1999)
A – spring, B – summ, C – autumn

No Stations	Season	Indicators							
		Oxygen mg O_2 dm^{-3}	BOD_5 T-P	µmol dm^{-3} P-PO_4	µmol dm^{-3} T-N	µmol dm^{-3} N-NO_3	µmol dm^{-3} N-NH_4	µmol dm^{-3} N_{inorg}	(summ N-NH_4, N-NO_3, N-NO_2) µmol dm^{-3}
1	A	8,6	2,9	2,13	1,51	20,4	9,0	1,4	10,5
	B	6,2	3,4	0,89	0,53	18,9	4,8	1,5	6,3
	C	9,0	2,7	1,94	0,81	20,9	7,2	1,3	8,6
2	A	8,4	3,3	2,51	1,84	25,8	13,9	3,0	17,2
	B	5,5	3,8	1,12	0,87	20,7	7,8	2,0	9,8
	C	8,5	3,1	2,47	1,03	24,7	12,0	2,7	14,8
3	A	8,9	2,5	0,98	0,79	17,1	6,2	0,9	7,1
	B	6,2	2,8	0,56	0,40	11,2	2,5	0,6	3,1
	C	9,5	2,1	1,01	0,51	15,4	5,1	0,8	5,9
4	A	8,6	3,2	1,95	1,63	21,3	9,2	1,5	10,7
	B	6,0	3,4	1,04	0,60	18,5	4,2	1,6	5,9
	C	8,7	2,9	1,23	0,69	20,9	7,2	1,3	8,4
5	A	9,2	2,4	0,87	0,59	10,7	4,9	0,7	5,6
	B	7,0	2,6	0,52	0,38	9,6	2,4	0,5	2,9
	C	9,8	2,1	0,78	0,50	11,8	4,1	0,4	4,5
6	A	9,4	1,9	0,71	0,54	9,2	3,9	0,4	4,3
	B	7,4	2,0	0,43	0,30	8,6	1,3	0,3	1,6
	C	10,1	2,0	0,51	0,42	9,0	3,9	0,2	4,1
7	A	8,4	3,3	1,89	1,68	19,9	12,7	2,2	14,9
	B	5,7	4,0	0,95	0,67	18,7	7,8	1,8	9,6
	C	8,3	3,2	2,09	1,01	21,5	10,3	2,4	12,7

During the studied period the maximum average total nitrogen was noted at station 2 in spring equalling 25.8 µmol/dm-3, inorganic nitrogen (the sum of NH_4^+, NO_3^- and NO_2^-) being17.2 µmol/dm-3, nitrate nitrogen being 13.9 µmol/dm-3 and ammonium – 3.0 µmol/dm-3. The smallest value of total nitrogen was recorded in summer at station 6-8.6 µmol/dm-3 and inorganic nitrogen was 1.6 µmol/dm-3, in this N-NO_3 being 1.3 and N-NH_3 - 0.3 µmol/dm-3. The average values T-N were exposed to the biggest fluctuations in the spring months (from 9.2 at station 6 to 25.8 µmol/dm-3 at station 2).

Table 3

The chemical characteristic of coastal Baltic Sea water between Darłowo-Łeba Port (1997-1999)

x_{min} – minimal value, x_{max} – maximal value, $\bar{x}$ – mean value, s – standard deviation, dx – changeability coefficient.

Indicators	x_{min}	x_{max}	$\bar{x}$	s	dx (%)
Oxygen $mgO_2\ dm^{-3}$	5.5	10.8	8.4	2.3	27.4
BOD_5 $mgO_2\ dm^{-3}$	1.8	4.2	2.8	0.45	16.1
T-P $\mu mol\ dm^{-3}$	0.41	2.58	1.22	0.42	34.4
$P\text{-}PO_4$ $\mu mol\ dm^{-3}$	0.30	1.69	0.82	0.22	26.8
T-N $\mu mol\ dm^{-3}$	8.4	26.4	16.9	6.2	36.7
$N_{inorg.}$ (summ $N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$) $\mu mol\ dm^{-3}$	1.1	14.2	6.4	1.6	25.0
$N_{inorg.}/P_{inorg.}$	0.1	3.2	1.31	0.57	43.5

The highest average annual values of biogenic compounds were recorded at the rivers' mouths and near the summer resorts, i.e. at station 2 (Ustka) average 2.03 T-P and 23.73 T-N µmol/dm-3, at station 4 (Rowy) 1.41 T-P and 20.2 T-N µmol/dm-3 and at station 7 (Łeba) 1.64 T-P and 20.0 T-N µmol/dm-3.

CONCLUSIONS

Coastal waters between Darłowo and Łeba are well oxygenated. The biggest amount of oxygen was found in the waters near the Słowiński National Park (stations 5 and 6). The biggest demand for oxygen in the studied territorial waters took place in summer: from June till September. The Słupia River brings into the sea waters reduced in oxygen. On the other hand, the waters of the Łupawa River along with the sewage from Rowy Village bring bigger amounts of biogenic substances, mainly organic matter, than the Słupia River.

The important criterion of evaluating the state of the sea environment fertility are mutual proportions of biogenic elements controlling the process of primary production, i.e. the relation of inorganic nitrogen to phosphorus (N_{inorg} : P_{inorg}). In the coastal area of the central coast the relation was guide stable, ranging between 10 and

20, whereas in the waters of Zatoka Pomorska and Zatoka Gdańska it was exposed to big seasonal changes: during the spring growth of phytoplankton values which exceeded 100 many times were recorded, dropping in winter to 30. This evidence of big destabilization and big pollution in the area (Falkowska et al. 1999).

The waters near the Słowiński National Park show the lowest Concentration of nitrogen and phosphorus compounds. The proportion of N_{inorg}/P_{inorg} was 7,8-8,8.

During the study period between 1997 and 1999 in the observational territorial waters streams parallel to the seashore from the east to the west dominated. The distribution of BOD_5, COD and biogenic substances along the studied seashore indicate translocation of territorial waters from the east to the west. The water streams brought from the east waters rich in biogenic substances and moved them to the areas near Ustka and Łeba, where big amounts of phytoplankton and microorganisms caused their decline. The highest values of the proportion N_{inorg}/P_{inorg} which were 11.2 and 11.1 respectively were recorded there.

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STAN JAKOŚCIOWY WODY BAŁTYCKIEJ W STREFIE PRZYBRZEŻNEJ POMIĘDZY DARŁOWEM I ŁEBĄ

Streszczenie

W latach 1997-1999 zbadano przybrzeżne wody morskie na odcinku Darłowo-Łeba. Określono: zawartość tlenu rozpuszczonego i BZT_5 oraz zawartość nutrientów: fosforu ogólnego, fosforu fosforanowego, azotu ogólnego, azotu azotanowego (V), azotanowego (III) oraz amonowego na siedmiu stacjach pomiarowych. Badania wykazały najwyższy stopień zanieczyszczenia w okolicy Ustki i Łeby.