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THE INFLUENCE OF LĘBORK TOWN ON THE POLLUTANTS LOAD DISCHARGED INTO THE BALTIC SEA BY THE ŁEBA RIVER

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Abstract

The present paper contains the results of water quality tests carried out in the central part of the Łeba River in the years 1999-2001. Those tests consisted in defining physical and chemical content of water quality rating in the hydrographic profile of the river near the town of Lębork. From the obtained results it comes out that the concentration of nitrogen and phosphorus compounds and BOD_5 values was growing in the course of the Łeba River flow through the town of Lębork. This town brings into the Łeba River on average 2.92 million m^3 of sewage during a year, out of which it falls to one inhabitant during a year: BOD_5 – 3.2 kgO_2, 0.36 kg of phosphorus, 4.10 kg of nitrogen. The Łeba River constitutes, moreover, a significant source of pollution of the Baltic Sea waters because every year it brings into it 1785 tons of nitrogen and 154 tons of phosphorus.

Key words: oxygen demand, phosphorus, nitrogen, agglomeration, river.

INTRODUCTION

In Poland there are three regions that have the least devastated natural environment. These are the north-eastern part of Poland, the Bieszczady Mountains (south-eastern of Poland) and Central Pomerania (north part of Poland). It results from a low degree of industrialization and low density of population (57 inhabitants per square kilometer). The most polluted ecosystems in Central Pomerania are shallow rivers and lakes through which those rivers flow and bring a big load of wastes. In connection with it, those lakes are characterized by a fast rate of shallowing and overgrowing, and show a high tendency to degradation under the influence of anthropogenic factors.

The most important rivers dewatering the area of Central Pomerania are the Brda River, the Wieprza River, the Słupia River, the Łupawa River and the Łeba River. Those rivers are not long but relatively rich in water due to a high amount of atmospheric rainfall in that region. The swelling of rivers takes place through point

and region sources.

Out of few publications dealing with chemical character of water in the rivers of Central Pomerania, there should be quoted the works by (Dziabas-Krysa 1995, Friedrich, Wilamski 1985, Korzeniewski *et al.* 1961, Pastuszak 1985, Teleżyński 1985,Trojanowski 1990 and Wilmowski 1970). On the other hand, the Łeba River, undoubtedly an important water-course in Pomerania, has not seen any more thorough studies in this respect.

An essential role in river pollution is played by town communal and living sewage, industrial sewage and areas pollution from the fields beeing under cultivation. Accumulated pollutants flow along with river water in to the Baltic Sea, which thus becomes a receiver of those wastes.

The aim of the present study is to:
- define the state of water pollution of the Łeba River;
- show influence of a town agglomeration on the state of river pollution;
- estimate the load of pollutants brought by the Łeba River into the Baltic Sea.

STUDY AREA, MATERIAL AND METHODS

The Lębork land is situated within the Słowiński and Kaszubski Seashore, comprising the middle part of the southern littoral strip of the Baltic. From the geological point of view, the River Łeba basin is part of the Baltic syncline. The River Łeba has got a well-developed hydrographic network, characterized by a great variety of hydrographic elements. The area of the river basin comes to 1801.2 km^2, the river length – 117 km (Zubrycka 1991). In comparison with the remaining rivers of Pomerania, the river features a significant average drop amounting to 2.3‰ in the upper part.

An important hydrographic element that influences the outlet of waters in the Łeba River basin is Lake Łebsko. The main left-bank tributaries of the Łeba River are the Okalica River flowing into the Łeba at the locality of Lębork on 55.4 km of the river course, (the Okalica River basin is a woodland and agricultural basin) and the Pogorzelica flowing into the Łeba River on 45.2 km of the river course (Fig. 1). The right-bank tributary is the Struga Kisewska River that flows into the Łeba also at Lębork, at 52.7 km. There is a drainage ditch flowing into the same river that drains off fish-culture wastes from the ponds of Fish-Culture Centre and the Chełst River that passes through the coastal Lake Sarbsko and flows into the Łeba on 0.9 km of the river course.

Łeba River system joins three ecosystems: river, lake and sea. Those ecosystems being characteristic and distinct and having specific properties, influence one another. In the Łeba basin there are 37 point sources of pollution. In the middle part of the Łeba River the main source of pollution are communal sewage, living and domestic sewage and industrial sewage drained out from Lębork. A rapid development of Lębork took place after 1845 and was connected with an intensive extension of the town.

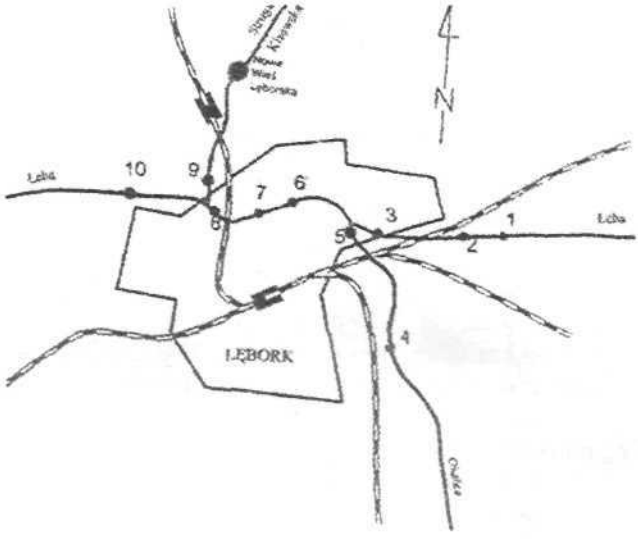

Fig. 1. The plan of Lębork town and location of sampling stations

Then, there came into being a number of industrial plants that have existed until now. Developed production technology of many plants contributes to the existence of sewage products. A significant share of them (about 70%) is disposed to the town sewage treatment plant in Lębork, the remaining wastes are dumped directly into the Łeba River flowing through that town.

The present work contains the results of water quality tests carried out in the central course of the Łeba River in the years 1999-2001. Those tests consisted in defining physical and chemical content of water quality rating in the hydrographic profile of the river. Water samples were taken at ten posts situated along the Łeba River course through the town of Lębork as well as two tributaries having their mouth on the territory of the town and, to a large extent, influencing the quality of the water. Those posts were located in such a way that it gave a possibility of assessing the state of river purity with indication of the main sources of pollution:

St. no. 1 – on 57,8 km of the river course; it characterizes the waters of the central part of the Łeba River, beyond the town of Lębork;

St. no. 2 – on 56.3 km of the river course; it characterizes the waters of the River Łeba flowing into Lębork at the level of King Chrobry's Park;

St. no. 3 – on 55.5 km of the river course, beyond the complex of pools;

St. no. 4 – on 3.3 km of the River Okalica course; it characterizes the waters of the lower part of the River Okalica above the town of Lębork and Form Frites Poland S Company;

St. no. 5 – on 0.1 km of the River Okalica course; it characterizes the waters of the estuary part of the River Okalica flowing into the Łeba River in

the town of Lębork;

St. no. 6 – on 53.7 km of the river course; it characterizes the estuary part of the River Młynówka flowing into the Łeba, beyond the mill of the Crops Processing Plant;

St. no. 7 – on 53.0 km of the river course beyond the estuary canal of the town sewage system in B. Głowacki Street;

St. no. 8 – on 52.1 km of the river course beyond the not sewered "The Paris Commune" Housing Estate;

St. no. 9 – on 1.2 km of the River Struga Kisewska course; it characterizes estuary waters of that river flowing into the Łeba, above the town sewage plant;

St. no. 10 – on 43.6 km of the river course; it characterizes the waters of the lower part of the River Łeba, beyond Lębork.

For testing purposes the water was taken with Ruttner's sampler once a season in the years 1999-2001. The analysis of water samples was carried out according to the methodology of Standard Methods (Standard methods 1992). The content of oxygen in the water under analysis was determined with the use of Winkler's method and the water reaction – with the use of pH-meter. Phosphate phosphorus was determined by means of colorimetry with ammonium molybdate and ascorbic acid. The concentration of nitrite nitrogen was determined by means of colorimetric method with sulfanilic acid and naphthylamine, nitrate nitrogen – with the use of colorimetric method with phenyldisulfonic acid and ammonia nitrogen – by means of colorimetric method of direct nesslerization. In order to determine total nitrogen and total phosphorus the sample was mineralized with potassium persulfate. Organic nitrogen and phosphorus were determined from the difference between total and inorganic forms. Calcium and magnesium were determined with the use of complexometric titration with sodium versenate.

RESULTS AND DISCUSSION

The changes of mean values of pH of the River Łeba along its course did not show distinct differences (Fig. 2.), at the same time the average pH value remained on the level 7.5. Water reaction changed within the range (7.2 - 7.8) and was included within the 1st class purity. At the same time, there can be noticed an increased value of pH in the water after crossing the town borders. Probably, that is caused by the processes of metabolism included in those waters and giving them an alkaline character.

The average content of oxygen dissolved in the water under analysis was significant at all research stations, it was included in the range of the 1st class of purity (after Kudelska, Cydzik 1983) and amounted to 10.9 mg O_2 dm^{-3}. The highest mean value of dissolved oxygen was noted at the st. 6 and 7, which came to 11.7 mg O_2 dm^{-3} and 11.9 mg O_2 dm^{-3}, and a significantly lower at the st. 10 – 10.2 mg O_2 dm^{-3}. It results from the fact that at the posts 6 and 7 the waters of the river have a fast flow and come across numerous gorges, which causes their high oxygenation.

those originated in Lębork as well as coming with the Struga Kisewska River, using a big amount of oxygen in oxidation processes.

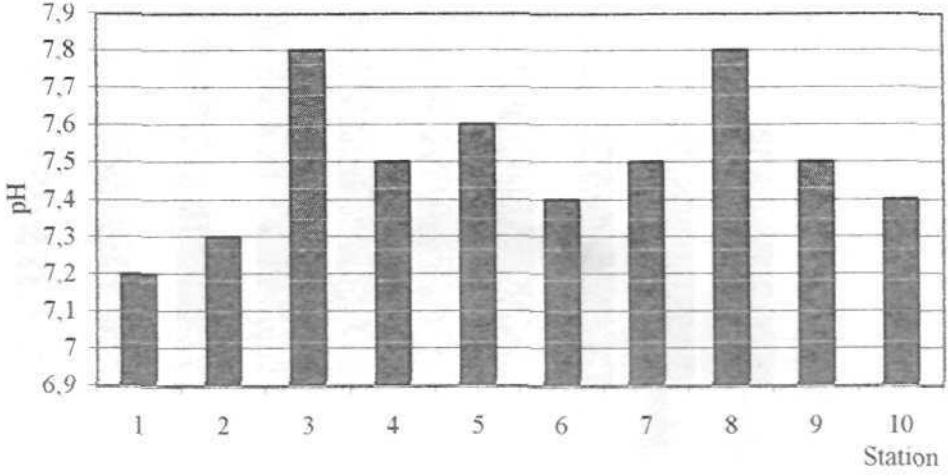

Fig. 2. Changes of waters reaction on the Łeba River course

Along the course of the Łeba River an average annual value of BOD_5 was 3.7 mg O_2 dm^{-3}. On the greater length of the river its value was within the 1st class of purity (that is up to 4 mg O_2 dm^{-3}). In its middle course the River Łeba flowing through the Lębork agglomeration collects effluent waters from the surrounding fields under cultivation, which enriches its waters with nutrients that cause eutrophication. As it can be seen from figures 3 and 4, due to the continuous inflow of wastes the level of that indicator in the water of the River Łeba steadily increases from 2.7 mg O_2 dm^{-3} at the st. 1 above the town of Lębork to 3.6 mg O_2 dm^{-3} at the st. 3 after receiving the waters from the fields under cultivation. The increase of BOD_5 indicator value has also been observed between the stations 4 and 5 situated on the Okalica River – from 3.6 to 4.2 mg O_2 dm^{-3}, which is caused by run-off of communal wastes from the residential districts of private housing. The waters of the Okalica River also collect sewage from a yeast factory in Maszewo, a distillery in Łebunia and the waters flowing from the fields. The waters of the Okalica River from the locality of Osowo and beyond it did not comply with the 3rd class of purity norms due to bacteriological contamination (Zubrycka 1991). After receiving by the Łeba the waters from the tributary of the Okalica River there can be observed an insignificant decrease of BOD_5 value to 3.8 mg O_2 dm^{-3} until the reception of another tributary of the Struga Kisewska. That river brings into the Łeba fish-culture wastes from fish-culture centers in Pogorszewo, thus enriching its waters with organic material. The results of the tests showed that the waters at that station 9 are characterized by a high value of BOD_5 amounting to 4.0 mg O_2 dm^{-3}.

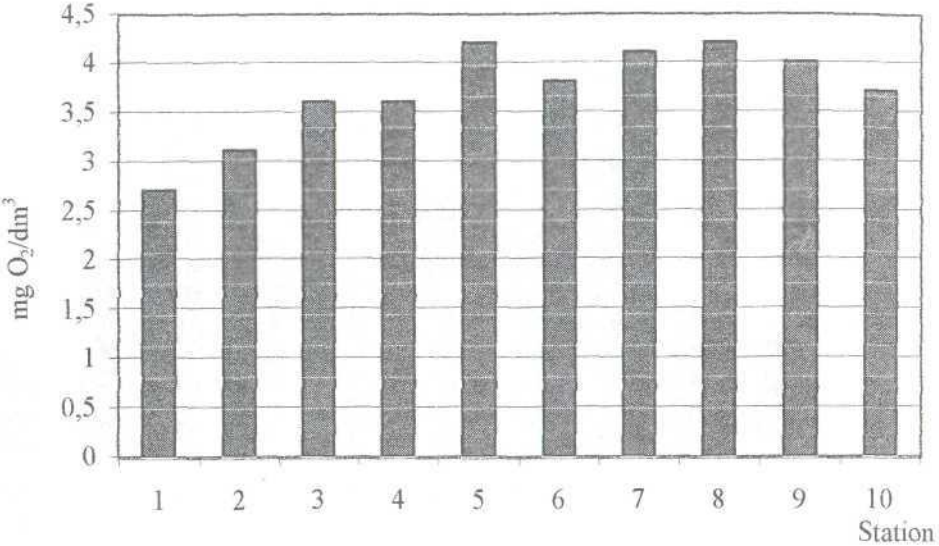

Fig. 3. The values of the BOD_5 in the Łeba River water in depending on the station.

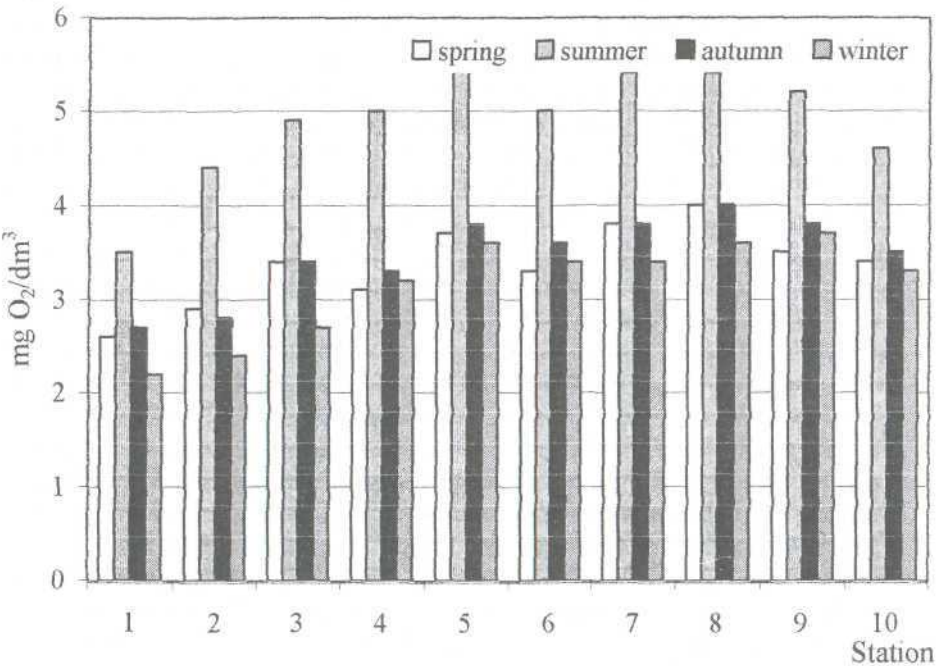

Fig. 4. Seasonal changes of the BOD_5 in depending on the Łeba River station

The average concentration of phosphate phosphorus ($P\text{-}PO_4$) in water on an examined segment of the Łeba River did not exceed admissible value for the 1st class of purity and ranged from 0.118 to 0.171 mgP dm^{-3} (Fig. 5.). The highest value of that component has been noted at the st. 8 (0.171 mg P dm^{-3}) reflecting the state of purity of the Łeba beyond the not sewered "The Paris Commune" Housing Estate.

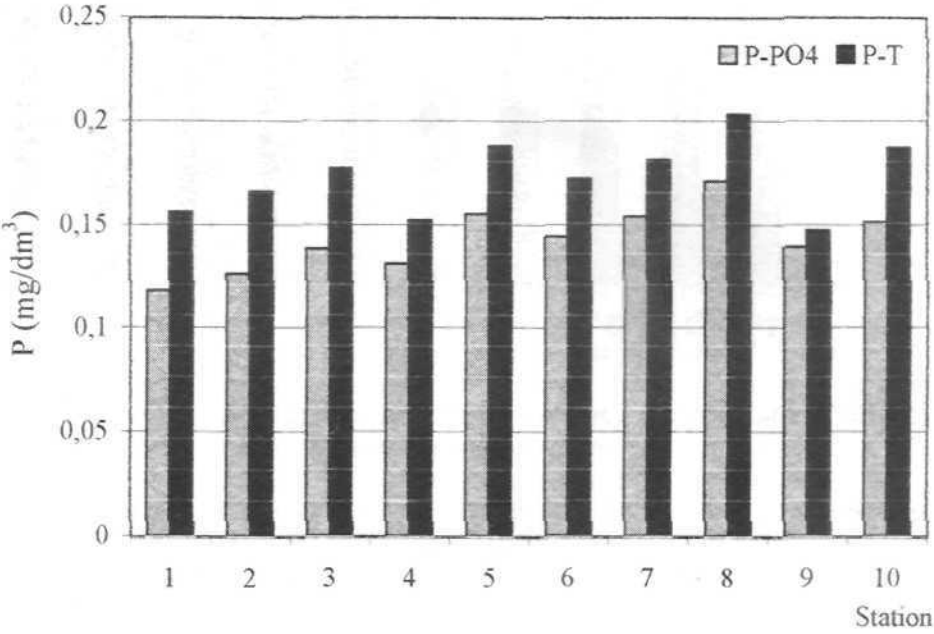

Fig. 5. The contents of the phosphorus compounds in the Łeba River water in depending on the station

The average content of total phosphorus (P-T) in the period under examination ranged 0.147-0.263 mg P dm^{-3}. The concentration of phosphorus compounds in the Łeba River was intermediate between the concentration of that component in the Słupia River (0.24 mg P dm^{-3} on average (Dziabas-Krysa 1995) and the Łupawa River (0.15 mg P dm^{-3}) (Korzeniewski 1992).

The level of ammonia nitrogen ($N\text{-}NH_4$) ranged from 0.089 mg $N\text{-}NH_4$ dm^{-3} at the posts 1 and 2 to 0.147 mg $N\text{-}NH_4$ dm^{-3} at the st. 8. The average concentration of that component in the period under analysis amounted to 0.106 mg $N\text{-}NH_4$ dm^{-3}.

The average annual content of ammonia nitrogen at all research stations was 0.106 mg $N\text{-}NH_4$ dm^{-3} and was much lower than the admissible value for water of the 1st class purity (that is, 1.0 mg $N\text{-}NH_4$ dm^{-3}). An increase of ammonia nitrogen along the river course is caused by pollution of the river with pollution rich in nitrogen compounds.

Also, the content of nitrates ($N\text{-}NO_3$) was included in the 1st class of purity (that is up to 1.5 mg $N\text{-}NO_3$ dm^{-3}) and averaged 1.294 mg $N\text{-}NO_3$ dm^{-3} (Fig. 6.).

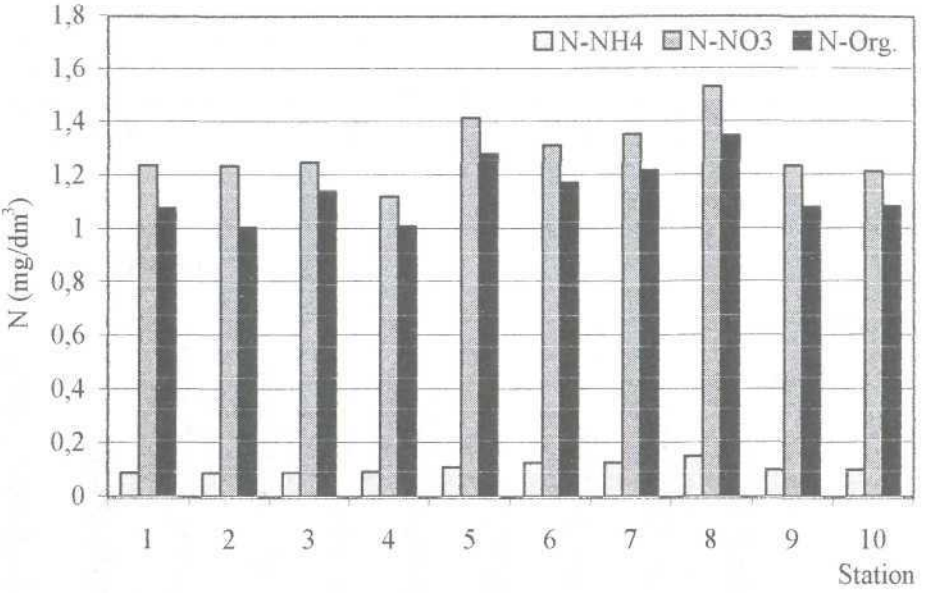

Fig. 6. The contents of different forms of nitrogen in the Łeba River water in depending on the station

One should note a relatively big content of that compound in comparison with other rivers of Western Pomerania (the Reda River – 0.94 mg $N\text{-}NO_3$ dm^{-3}, the Pasłęka River – 0.74 mg $N\text{-}NO_3$ dm^{-3}, the Słupia River – 1.10 mg $N\text{-}NO_3$ dm^{-3}, the Wieprza River – 1.10 mg $N\text{-}NO_3$ dm^{-3}), which bears evidence of a significant share of region run-offs in chemical swell of that river (Niemirycz, Bierawska 1998).

The increase of nitrates concentration is influenced, among others, by wastes and run-offs of ground waters from drainage areas (Fig. 6). They wash out from the fields under cultivation nitrate ions, which are components of the fertilizers in use.

The average content of nitrite nitrogen in the period under analysis did not exceed the admissible value for the 1st class of purity (that is, 0.02 mg $N\text{-}NO_2$ dm^{-3}) and ranged from 0.006 mg $N\text{-}NO_2$ dm^{-3} to 0.018 mg $N\text{-}NO_2$ dm^{-3}.

The content of mineral nitrogen, which consists of ammonia nitrogen, nitrate nitrogen and nitrite nitrogen, in the Łeba River ranged from 1.21 mg N dm^{-3} to 1.68 mg N dm^{-3} with the average value of 1.40 mg N dm^{-3}. Ammonia nitrogen constituted about 7.6% of inorganic nitrogen. Probably, due to intensive run-offs from the drainage areas and their concentration during the processes taking place in winter, the concentration of those components was the highest in spring (NH_4-N – 0.14; NO_3-N – 1.84 mg N dm^{-3}). A big consumption of mineral nitrogen in water during the vegetation period in the section under analysis caused an extensive decrease of ammonia nitrogen content (0.12 mg N dm^{-3}) and nitrate nitrogen content (1.33 mg N dm^{-3}).

Inorganic nitrogen constituted 57.6% of total nitrogen (N-T). The main component – organic nitrogen determined that the biggest concentration of total nitrogen (2.60 mg N dm^{-3}) was observed in summer, during the period of intensified vegeta-

tion. Similarly, as in the case of overall phosphorus, also overall nitrogen showed the lowest level (2.46 mg N dm^{-3}) on the turn of summer and autumn.

The content of all forms of total nitrogen did not exceed the accessible value for the 1st class of water purity (that is, 5 mg N dm^{-3}) and amounted to 2.4 mg N dm^{-3} on average, while for the water in the Słupia River it was on a comparable level of 2.6 mg N dm^{-3} (Dziabas-Krysa 1995); slightly higher values of overall nitrogen were observed in the Łupawa River, on average 2.9 mg N dm^{-3} (Korzeniewski 1992).

Statistical correlation analysis showed a very strong relationship between total nitrogen and total phosphorus content in the water of the river's under analysis ($r = 0.802$ with $n = 120$ and significance level 0.05).

The Łeba burdened with such a significant load undergoes partial self-cleaning but only to some small extent because it receives water pollution from the surrounding fields. It brings that load into Łebsko Lake through which it flows and then to the waters of the Baltic Sea. In table 1 there are presented load values of particular indicators brought into those water ecosystems in 1999 (Trojanowski 1999).

On the basis of the tests carried out in that period there has been estimated the amount of nitrogen and phosphorus brought into Lake Łebsko. It comes out from the data that generally over 2500 tons of nitrogen and over 200 tons of phosphorus get into the lake during one year, of which 67% of nitrogen and phosphorus is the share of the Łeba River only. From the lake the Łeba carries about 1800 tons of nitrogen and about 160 tons of phosphorus to the Baltic. Thus, in the lake there remain over 850 tons of nitrogen and 50 tons of phosphorus (Niemirycz, Bierawska 1998).

From the obtained results it comes out that the concentration of nitrogen and phosphorus compounds and BOD_5 values was growing in the course of the Łeba flow through the town of Lębork. A load of wastes flowing into the river significantly contributed to the increase of trophicity of that river. It was mainly caused by the wastes flowing into the river from the town. Undoubtedly, a considerable share in such big amounts of inorganic compounds of nitrogen and phosphorus in the Łeba have the waters flowing from the surrounding areas, used mainly in agriculture. However, thanks to great abilities of the river to self-clean the concentration of those indicators outside the town was gradually going down.

One of vital sources of wastes delivered to the Łeba River is the town of Lębork. In order to determine the level of Lębork's influence on the state of the Łeba purity, values of particular components existing above the st. 2 and beyond that town (st. 10) have been compared. On the basis of the carried out measurements it has been proved that after the Łeba's flow through the town of Lębork all its waste components increase their value. This town brings into the Łeba River on average 2.92 million m^3 of sewage during a year, out of which it falls to one inhabitant during a year: BOD_5 – 3.2 kg O_2; 0.36 kg of phosphorus; 4.10 kg of nitrogen (Table 2). Those values make it possible to compare the intensity of pollution with other towns. For example, 1 inhabitant of Słupsk brings during a year 2.7 kg of O_2 as BOD_5; 0.17 kg of phosphorus and 2.5 kg of nitrogen (Dziabas-Krysa 1995).

From those comparisons it comes out that the Lębork town negatively influences the state of river purity and it is the main source of pollution in its middle course. First of all, it introduces big amounts of nitrogen and phosphorus compounds.

The load of wastes carried by the Łeba after flowing through Lębork significantly increases. That growth is respectively: 47% of BOD_5, 11% N-T, 34% $P\text{-}PO_4$, 21% P-T.

CONCLUSIONS

- The area of Lębork town is the main source polluting the River Łeba in the middle part of Łeba River course. From the town there flow into the river sewage and surface run-offs containing big amounts of nitrogen and phosphorus compounds and organic matter (in the year: 123 t N, 14 t P and BOD_5 – 114 t oxygen demand). Although Lębork town belongs to smaller town agglomerations in the country (it has 35.900 inhabitants), nevertheless its influence threatens to shake the ecological balance of the river.
- From the comparison of chosen indicator loads in the two rivers (the Słupia and the Łeba) after flowing through the Słupsk and the Lębork agglomerations it comes out that Lębork pours much more waste loads than Słupsk converted per one inhabitant.
- An additional source of pollution with nitrate and phosphorus compounds is the waters flowing into the river from particular fields being under cultivation.
- Moreover the Łeba River constitutes, a significant source of pollution of the Baltic waters because every year it brings into it 1785 tons of nitrogen and 154 tons of phosphorus.

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WPŁYW AGLOMERACJI LĘBORK NA ŁADUNEK ZANIECZYSZCZEŃ WNOSZONYCH PRZEZ RZEKĘ ŁEBĘ DO MORZA BAŁTYCKIEGO

Streszczenie

Przedstawiona praca zawiera wyniki badań jakości wody rzeki Łeby w jej środkowej części wykonane w latach 1999-2001. Badania te polegały na określeniu zawartości fizyczno-chemicznych wskaźników jakości wody wzdłuż biegu rzeki w okolicach Lęborka. Z uzyskanych rezultatów wynika, że koncentracja związków azotowych i fosforowych oraz wartości BZT_5 rosły w miarę przepływu rzeki Łeby przez Lębork. Miasto to odprowadza do rzeki Łeby średnio 2.92 mln m^3 ścieków w ciągu roku, w tym na jednego mieszkańca na rok przypada BZT_5 - 3,2 kgO_2; 0,36 kg fosforu; 4,10 kg azotu. Rzeka Łeba stanowi ponadto istotne źródło zanieczyszczeń wód Bałtyku, ponieważ wprowadza do niego rocznie poprzez jezioro Łebsko 1785 t - azotu, 154 t - fosforu oraz ładunek łatwo rozkładalnych zanieczyszczeń organicznych, do których mineralizacji niezbędnych jest 1401 t O_2.