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TRANSFORMATION OF THE WATER QUALITY IN THE SŁUPIA RIVER (POLAND)

SLUPIJAS UPES (POLIJA) ŪDENS KVALITĀTES IZMAIŅAS

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Abstract. *The objective of this paper was to present the water quality changes of the one of Polish rivers - Słupia River, located in the Pomeranian Region. The Słupia River receives pollutants derived from non-point and point sources of pollution. This is due to the agricultural and forested character of the river's basin and the location of the towns of Słupsk and Ustka on the river. The elaboration covers the period from 1988 to 2007 and is based on hydrological data, completed as a part of surface water monitoring programme run by the Inspectorate for Environment Protection and the Institute of Meteorology and Water Management. The changes of physicochemical properties of Słupia River i.e. phosphorus and nitrogen concentrations, BOD_5, and amounts of heavy metals were studied. Presented data, showed that the Słupia River has responded to a major nutrient loading reduction. The current concentration of nitrogen and phosphorus form in river allows qualifying the water to first quality class.*

Keywords: *flowing water quality, river, biogens, heavy metals.*

Introduction

The water quality in rivers and streams is strongly associated with the anthropopression intensity and is an important indicator of the human activity. No matter whether it concerns agriculture, animal breeding, industry or human subsistence, this activity always affects water quality. The improving of water parameters, observed in the recent years in European states is a consequence of many environmental, economic and political factors. In Poland, the reduction of nutrient inputs has been thus caused primary by the crisis in the agriculture i.e. by the large decrease in mineral fertilizer use (by nearly 2/3) and by the decrease in livestock levels. Moreover, after 1989 the significant increase of investment in nature conservation was noted, especially in wastewater and sewage management causing reduction in point source discharges.

The aim of this study was to present long-term changes in the quality of the water in the Słupia River against the background of the changes in the wastewater and sewage management and in the intensity of fertilization in this region of Poland.

Materials and methods

The Słupia River (Fig. 1) is one of the largest Polish coastal rivers. The total length of the river is 138.6 km. The surface area of the river's basin is 1623.0 km^2, of which almost half the land is covered by arable fields (47.8%), 43.4% by forests and 6.6% by meadows and pastures. The surface waters cover about 2% of the river's basin [1]. The river's source is found near Sierakowska Huta, in the north-west part of the Kaszubski Lake District. The river flows to the north-west to the Baltic Sea, and in the Ustka town introduces water directly to the sea. It is supplied with water by a number of several rivers and streams, of which the longest one – the Skotawa – is 44.6 km long.

The average flow of the Słupia amounts about 14.5 m^3/d [2], and it is characterised by low range of flow variability [3], differences between winter and summer half-years not exceed 25% [2].

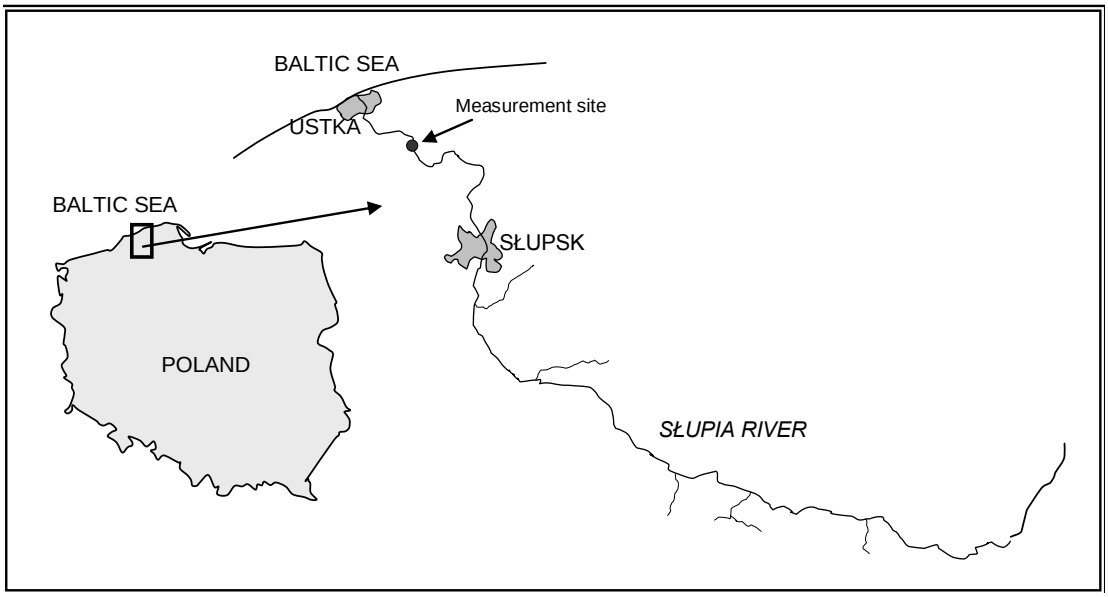

Fig.1. **Location of the Słupia River**

The Słupia River receives pollutants derived from non-point and point sources of pollution. This is due to the agricultural and forested character of the river's basin and the location of the towns of Słupsk and Ustka on the river. The primary sources of pollution are [4-6]:

- the mechanical and biological wastewater treatment plant in Słupsk (22700 m^3/d);
- the mechanical and biological wastewater treatment plant in Ustka (6250 m^3/d);
- the mechanical and biological wastewater treatment plant in Sulęczyno (134 m^3/d);
- the streams and rivers flowing into the Słupia, which carries waters affected by agriculture and waste from the fish farm and some amounts of municipal waste;
- villages lying in the river's basin, which do not have proper wastewater and sewage management;
- runoffs from fields and fish-farms.

In the study, the data for selected parameters (nitrogen and phosphorus forms, heavy metals, BOD_5) for last 20 years were utilised. Measurements of above parameters concentration were performed as a part of the water monitoring programme by the Institute of Meteorology and Water Management and Provincial Inspectorate of Environment Protection in Słupsk. The monitoring assays were performed at one station - Charnowo (Fig. 1), located about 11 km from the river outlet and covered about 98.5% of the river's basin surface area. The range of measurements and analytical procedures were established according to the then binding executive regulations of the Water Law. The measurement programmes were performed every year, with the frequency of 4 - 26 measurements per year.

Results and Discussion

1. *Changes in the anthropopression intensity in the Słupia River catchment*

According to Bogdanowicz (2004) [3] the catchment area of the Słupia River is classified as the area with "middle anthropopression level". In this classification into account were taken: (i) the intensity of agriculture production (arable land and fertilizer consumption); (ii) point source of pollution (scale and localization of the biggest wastewater treatment plants) and (iii) pollution level of river's water.

Agriculture is markedly abundant in the Słupia River catchment, and therefore the changes in the agriculture production level influences on the amount of non-point pollution transported to river.

During the last 20 years, especially at the turn of the 80s and 90s, substantial transformations in all Polish agriculture took place. After 1989 market economy was introduced so prices of mineral fertilizers were liberated, state subsidies were lifted and costs of raw materials for production of fertilizers increased due to the transfer to dollar prices. This meant that mineral fertilizers as products available on the market became expensive, and their consumption readily declined. Collected data [7] indicate, that in the Słupia River catchment area the mineral fertilizer consumption dropped after 1989 from 245 kg per ha of net NPK to 45,5 kg per ha of net NPK in 1991. Currently, the consumption of fertilizers is about two times higher but still over two times lower than before 1990. Moreover the gradual liquidation of state farms diminished the total area of farmland. Quite a large percentage of fields which had been cultivated by state farms were left fallow, and that meant that the share of uncultivated farmland increased. Also, the type of land use was gradually changing. Some of the arable land was forested (about 0.5 thous. ha/year).

Animal rearing in Słupia River region is concentrated on cattle for meat and milk and on pig breeding [2]. And also in this agriculture field, intensive changes after 1989 were observed. Liquidation of a lot of breeding centres – above all industrial farms of cattle breeding – caused significant decrease of animals.

The Słupia River catchment has not a rural character, and the point source of pollutant is above all associated with a communal wastewater. The region is characterised by small density of population – 58 persons/km^2 [8]. And there are only three communities with more than 10 thous. inhabitants. The Słupsk City is the regional centre with approximately 100 thous. inhabitants. In Słupsk, wastewaters from 100% of inhabitants are cleaned on wastewater treatment plant, which yearly take 8.29 hm^3 communal wastewater. The percent of purification was 98%. The pollution load from wastewater treatment plant, introduced into Słupia River amounts 40 t/year of BZT_5; 90 t/year of N_{total}; and 6 t/year of P_{total} [4]. With relation to 90s the total pollution load decreased about over 75% in the case of phosphorus and about 70% of nitrogen.

2. *Changes in the water quality*

Changes in annual mean concentrations of biogenic substances in the Słupia River, during the last 19 years studied are illustrated in Figures 2 – 4. The long-term development in ammonia nitrogen concentrations (Fig2.) changed markedly in the period 1988-2007. Until 1990, the concentrations varied the 3rd water quality class (according to 5-class Polish categorisation) (Tab.1.) and in the 1st class after 1993.

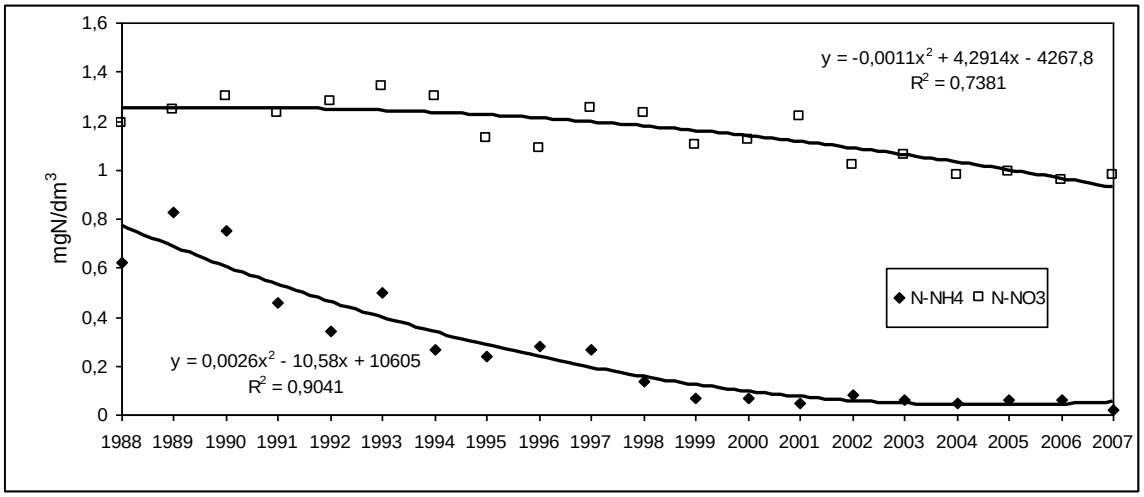

Fig.2. **Changes of ammonia and nitrate nitrogen concentration (mgN/dm^3) in Słupia River in years 1988-2007**

In the case of nitrate nitrogen, the changes were less dynamic, and just after 1998 the decrease of $N\text{-}NO_3$ was observed. Moreover, the level of $N\text{-}NO_3$ classified the water between 2nd and 1st quality class and after 2002 in 1st quality class.

Table 1.

Limit values for water quality of chosen physicochemical parameters

Parameter	Unit	I class	II class	III class	IV class	V class
BOD_5	mgO_2/dm^3	2	3	6	12	>12
COD_{Cr}	mgO_2/dm^3	10	20	30	60	>60
Ammonia nitrogen	mgN/dm^3	0.39	0.77	1.55	4.0	>4.0
Nitrate nitrogen	$mgNdm^3$	1.13	3.38	5.64	11.29	>11.29
Total nitrogen	mgN/dm^3	2.5	5	10	20	>20
Phosphates	mgP/dm^3	0.06	0.13	0.23	0.33	>0.33
Total phosphorus	mgP/dm^3	0.2	0.4	0.7	1.0	>1.0
Phenols	mg/dm^3	0.001	0.005	0.01	0.05	>0.05
Chromium	$mgCr/dm^3$	0.05	0.05	0.05	0.1	>0.1
Cadmium	$mgCd/dm^3$	0.0005	0.001	0.001	0.005	>0.005
Mercury	$mgHg/dm^3$	0.0005	0.001	0.001	0.005	>0.005
Lead	$mgPb/dm^3$	0.01	0.01	0.02	0.05	>0.05
Zinc	$mgZn/dm^3$	0.3	0.5	1.0	2.0	>2.0

The concentration of total nitrogen in the Słupia River (Fig.3.) decreased two times during the last 19 years from 4.34 mgN/dm^3 to 2.02 mgN/dm^3. The most intensive drop was observed in 90s.

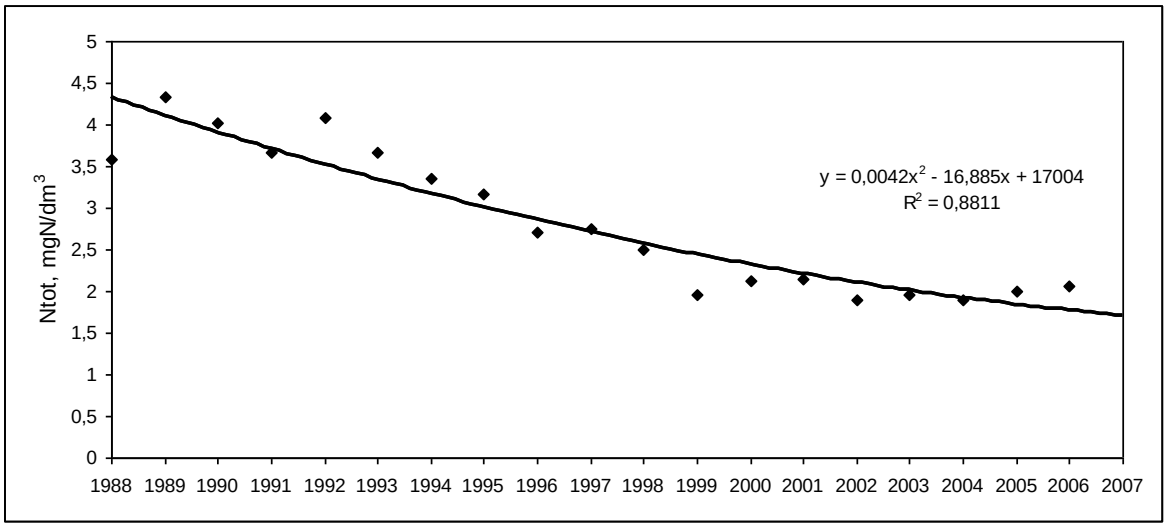

Fig.3. **Changes of total nitrogen concentration (mgN/dm^3) in Słupia River in years 1988-2007**

Until 1990 the concentrations of mineral and total phosphorus were increasing (Fig.4). The level of P-mineral increased up to 0.3 mgP/dm^3 (4th quality class), and P-tot up to 0.58 mgP/dm^3 (3rd quality class). The analyses completed in the following years (1991-2007) showed that the quality of the river water improved considerably in terms of the content of inorganic and total phosphorus. The mean annually concentration of $P\text{-}PO_4$ in 2006 dropped to the level of 0.06 mg/dm^3 (1st quality class). Total phosphorus concentration decreased to 0.12 mgP/dm^3 from 2002 (1st quality class).

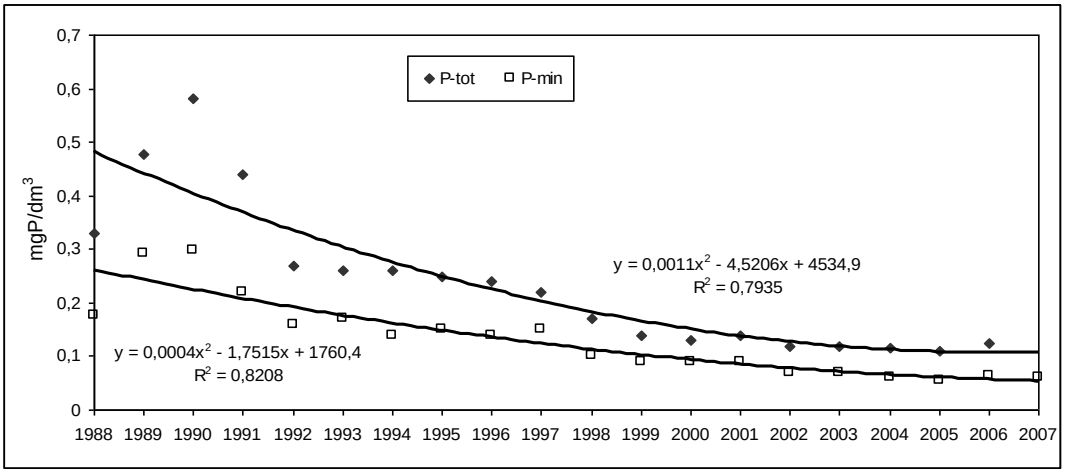

Fig.4. **Changes of mineral and total phosphorus concentration (mgN/dm^3) in Słupia River in years 1988-2007**

The amount of organic substances is indicated by BOD_5. As can be seen in Fig. 5 BOD_5, in the long-term development, fluctuated in its mean annual values between 5.3 mgO_2/dm^3 in 1988 and 2.4 mgO_2/dm^3 in 2007. Until 1998 the BOD_5 value varied within the 3rd purity class and in the 2nd class after 1998.

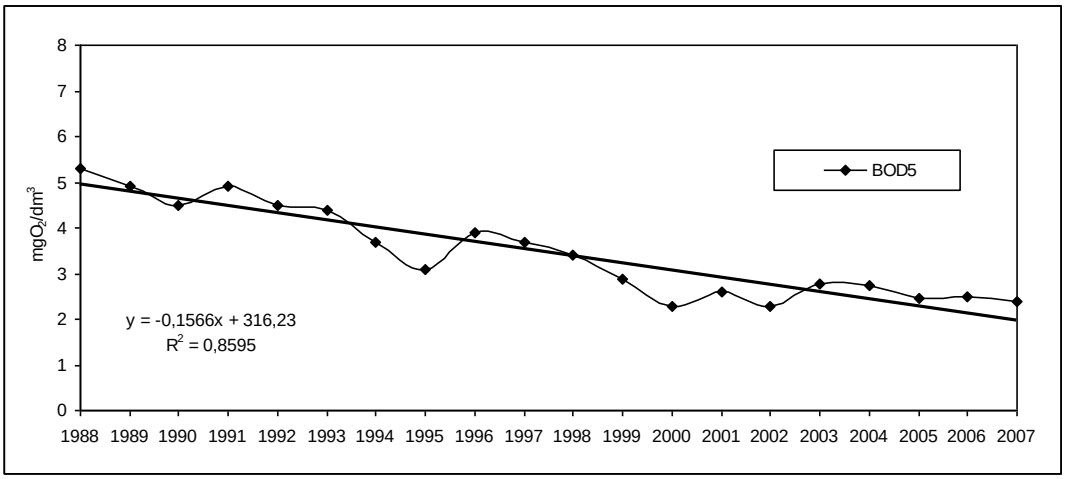

Fig.5. **Changes of BOD_5 (mgO_2/dm^3) in Słupia River in years 1988-2007**

Concentrations of heavy metals was presented as a sum of Hg, Pb, Zn, Cu, Cd and Cr concentration (Fig.6.). Zinc constituted about 65%, lead about 17%, and consecutively Cu – 9%, Cr – 6,5%, Hg – 1,5%, Cd – 1%. Measurements performed in years 1988 – 2007 indicate, that amounts of heavy metals fluctuated markedly. Three main stages can be distinguished during those 19 years: from 1989 to 1996, after 1996 to 2002, and from 2002 to 2007. In the first stage the concentration of heavy metals significant decreased from about 0.07 mg/dm^3 to below 0.01 mg/dm^3. After 1996 the increase of metal concentration to about 0.035 was observed, and after 2002 successive decrease to 0.018 mg/dm^3 in 2007.

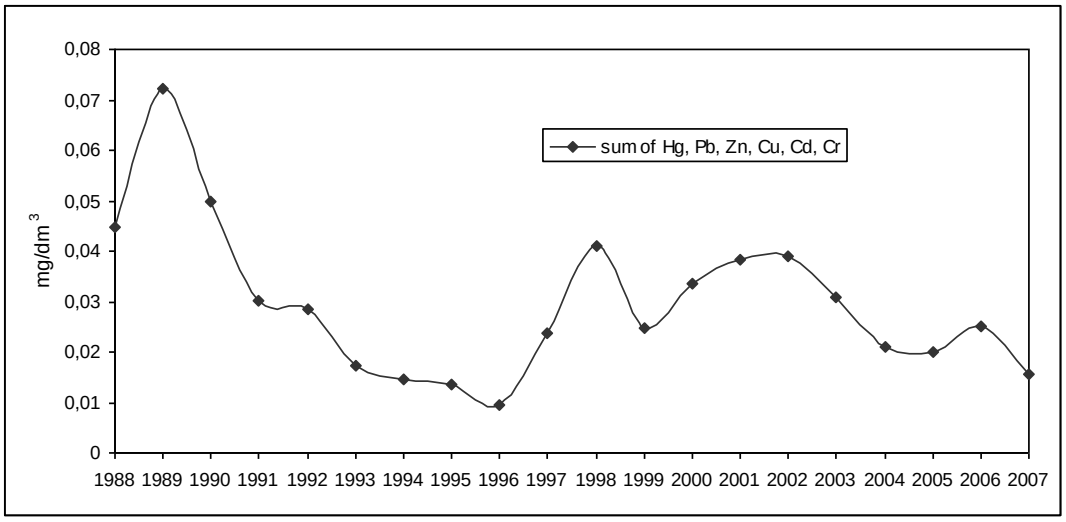

Fig.6. **Changes of heavy metals concentration (mg/dm^3) in Słupia River in years 1988-2007**

The long-term changes of different parameters concentration indicate a significant improvement of Słupia River quality. The concentration changes of respective parameters were different and associated with different reason. The drop, observed in the case o ammonia nitrogen (Fig.2) was caused by a decrease in the intensity of animal production after 1989, and by changes in farmland cultivation i.e. especially by reduction of ammonia fertilizer (water solution of NH_4OH), and better farm management control. The long-term changes of nitrate nitrogen concentration were different. After 1989 no substantial decrease occurred although the rapid and significant reduction of nitrate fertilizer dosage. Lack of the nitrate nitrogen reaction to the fertilizer reduction can be connected with a small participation (several %) of fertilizer – NO_3 in total amount of N-NO_3 transported with groundwater to the river. According to the *Polish map of spatial-varied of nitrate nitrogen concentration in groundwater,* the Słupia River catchment is characterized by N-NO_3 concentration about 15-20mg/dm^3 [9]. Most of nitrate nitrogen come from mineralization of organic matter (organic fertilizer, after-harvest scraps). The second potential source of NO_3 are a soil reserves released via erosion [10; 11].

Higher phosphorus concentrations in rivers usually are detected near the larger agglomeration. Therefore the main source of phosphorus are point pollution sources. The participation of point pollutions in Poland in phosphorus supply amounted about 60% [9]. The drop in P-concentration (mineral and total) (Fig. 4) after 1990 was caused by increasing investment in wastewater and sewage management and, as a consequention, construction or modernisation of a municipal wastewater treatment plant. Moreover, the lifestyle of the local population was changed i.e. the increase of phosphate-free washimg agents was observed.

The long-term changes of heavy metals concentration were very dynamic (Fig.6.). The decrease after 1989 was probably associated with the better wastewater situations and, with the decrease of fertilizer dosage, especially phosphates fertilizer (material used in the production of P-fertilizer includes some amount heavy metals) (12). The explanation for the heavy metals concentration increase after 1996 is dificult, but probably associated with the ability of heavy metals to bioaccumulation and sediment-accumulation [13].

Conclusions

Presented data, showed that the Słupia River has responded to a major nutrient loading reduction. The current concentration of nitrogen and phosphorus form in river allows qualifying the water to first quality class. Knowing, that the water ecosystems are strictly

connected with the catchment area and all changes in the land use change the water quality, very important becomes the correct land management to achieve a good ecological quality in water bodies in 2015.

Bibliography

1. Purity state of running waters of the Słupia catchment area based on measurements performed in 2003. Provincial Inspectorate of Environmental Protection, Office in Słupsk
2. Lipczyński W. Surface water, pp. 35-59. In: Lipczyński W. (ed.) Natural resources of the Słupia and Łupawa river basins, Gravipol, Słupsk, 2002.
3. Bogdanowicz R. Hydrological factors influencing transport of selected nitrogen and phosphorus compounds from the Odra River, the Vistula River and Polish coastal rivers to the Baltic Sea, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk, 2004.
4. Report on the state of the environment in the Province of Pomerania in 2005. Provincial Inspectorate of Environmental Protection in Gdańsk, Gdańsk, 2006.
5. Report on the state of the environment in the Province of Pomerania in 2002. Provincial Inspectorate of Environmental Protection in Gdańsk, Gdańsk, 2003.
6. Lipczyński W. Water management of the Słupia and Łupawa river basins, Gravipol, Słupsk, 2005.
7. Statistical yearbook 1989-1995, Słupskie Voivodship, Statistical Office in Słupsk, Koszalin, 1989., 1991., 1995. www.stat.gov.pl
8. Ilnicki P. The Polish agriculture and environment protection, WAR, Poznań 2005.
9. Worrall F., Burt T. P. Inter-annual controls on nitrate export from an agricultural catchment – how much land-use change is safe?, Journal of Hydrology, 243, 2001. pp. 228-241
10. Oenema O., Roest C. W. J. Nitrogen and phosphorus losses from agriculture into surface waters; the effects of policies and measures in the Netherlands, Wat. Sci. Tech., 37, 1998. pp. 19-30.
11. Gorlach E., Mazur T. Agriculture Chemistry, PWN, Warszawa, 2001.
12. Wrembel H.Z. Civilization effects of mercury in the Baltic Sea, Słupskie Prace Matematyczno-Przyrodnicze, 12a, 1999. pp. 67-99.