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INFLUENCE OF THE TOWN OF NAKŁO ON WATER QUALITY IN THE NOTEĆ RIVER

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WPŁYW AGLOMERACJI NAKŁO NA ZANIECZYSZCZENIA RZEKI NOTEĆ

Ze względu na coraz bardziej rosnącą rolę zanieczyszczeń wód powierzchniowych na środowisko – zwłaczcza na terenach zaludnionych – w niniejszej pracy podjęto problem wpływu miasta Nakła na czystość rzeki Noteć.

Badania wykazały, że na terenie gminy Nakło wody rzeki Noteć charakteryzują się pod względem chemicznym II i III klasą czystości. Bardzo duże ilości zanieczyszczeń wprowadza miasto Nakło. Mimo pewnej poprawy w stosunku do lat 1993–1995, ładunek zanieczyszczeń dopływający z miasta jest jeszcze zbyt wielki i wynosi 3149 t zawiesin, 266 t azotu i 69 t fosforu w ciągu roku.

Summary

Due to more and more increasing role of pollution surface waters in environment – particularly in populous regions – in this paper the problem of the influence of the town of Nakło city on purity of the Noteć river has been presented.

Hydrochemical investigation of the Noteć river in the region of the community Nakło indicated II and III water quality classification. The town of Nakło discharges very much pollution into this river. In spite of recent certain improvement in comparison to 1993–1995 years the annual amount of pollution flowing from the town into the river is still too large and it is 3149 Mg of suspended matter, 266 Mg of nitrogen and 69 Mg of phosphorus.

INTRODUCTION

Water management has been seen as an important issue in our country for a long time. As compared to other countries, Poland has very little water resources and therefore water is getting a more and more precious [8]. An

assumed amount of water per one inhabitant per day is 4.5 m^3 in Poland, 6.9 m^3 in Germany, the mean European is 11.0 m^3 and the mean global is 3.0 m^3 [4]. The increasing usage of water results from a dynamic development of modern civilisation both in terms of industry and urbanism, an intensified agricultural production and constant elevation of the man's living standard. An increased usage of water produces an increased amount of sewage that is discharged into the surface waters; mainly the municipal sewage. Thus the natural shortage of water in Poland becomes intensified by its heavy pollution, which also causes economic problems. Mis-exploited small treatment plants in villages, or lack of them, make the facilities be a problem for the local water environments and cause their degradation. Those situations compel for economical of water and doing the best to keep them pure.

The discharde of sewage into river waters by perforation makes their purity state deteriorate constantly. Every year the amount of water classified as Class I and II diminishes. The river Łupawa provides an example of how fast the degradation of Pomeranian (Pomorze) rivers takes place [10, 12]. Some amount of the pollution discharged into rivers accumulates on the river bottoms, while the significant rest is transported to various water bodies thus affecting their quality by changing biochemical processes in those systems. The objective of the present paper was the following:

– defining the pollution extent of the river Noteć along the section flowing across the community of the town Nakło;

– examining the effect the municipality of Nakło may have on the purity state of the river;

– performing a transformation analisis of selected indicators of water contamination along the investigated section of the river;

– bringing about any actions that may enable the improvement of the river's quality and its sanitary state.

MATERIAL AND METHODS

The Noteć river is an upper tributary of the Warta river and starts in the Kujawskie Lake District, having as its source a water flow that starts near a village of Szczecin, next to Przedecze at 114 m a.s.l. and joins the river Warta at 20.3 m a.s.l.

In its upper part, the Noteć river runs through many lakes, including lake Gopło and then it reaches the town of Nakło. The middle part of the Noteć river flows from Nakło to the valley of the Gwda river. From its left and its right it is joined by many yet small rivers along all that section. Having incorporated the Gwda river, the Noteć begins its lower part near the town of Ujście [1, 7]. In the towns and communities located on the Noteć river there

have been recorded 15 sources of pollutions some of which discharge their sewage directly into the Noteć river.

There are 43 sources of pollutions within the Noteć river basin. Of which, 23 discharge their sewage directly into the river Noteć; the remaning ones do it indirectly discharging their contaminated matter into canals, lakes and streams that eventually flow into the Noteć. Those which are notorious for polluting according to the Regional Environment Protection Institute (Wojewódzki Inspektorat Ochrony Środowiska) in Bydgoszcz [6], are first of all the Kujawskie Fat Factory in Kruszwica, Chemical Plant in Inowrocław, Sodium Plant in Janikowo, Paper Mill in Świecie.

A 17.4 km long stretch of the Noteć was included in the physical and chemical examinations (Fig. 1). Sampling stations were distributed along that section to take water samples. Those stations were placed above and below those facilities whose sewage significantly affect the river water quality, and also at the mouths of the river tributaries. The placement of the stations was the following:

– station 1 – next to a town of Tur above the town of Nakło;
– station 2 – in the town of Chobelin-Młyn (behind the mill);
– station 3 – in the outskirts of the town Nakło, past the mouth of the Bydgoski Canal;
– stations 4 and 5 – in front of and behind the mouth of Struga Śleska, which receives the sewage from the Nakło sugar mill. Also the Meat Factory discharge thier sewage into the same stream;
– stations 6 and 7 – before and behind the sewage treatment plant. Between those two points there come the sewage discharged there by the Council Board of Water System and Sewage;
– station 8 – before the village of Bielawy, past Nakło;
– stations 9 and 10 – in the towns of Rozważyn and Polichno.

The water was sampled once in a month over the years 1995–1997. The samples were determined according to the methodology by Hermanowicz at all [2] and *Standard Methods* [9]. The following parameters were determined in the samples: BOD_5, oxygenation, ChDO, oxygen contents, nitrogen and phosphorus compounds and suspended matter.

The obtained data were then compared to the results of the measurements carried out by the Regional Inspectorate of Environment Protection in 1993–1995 when the Noteć river monitoring was held. In order to determine the load discharge, a method involving the relation between the second load and flow intensity was adopted. This interpretation must be based on a mathematical AREX program provided by the IMGW (Meteoroly and Water Management Institute) [3]. The flow rate was calculated by means of a hydraulic spin.

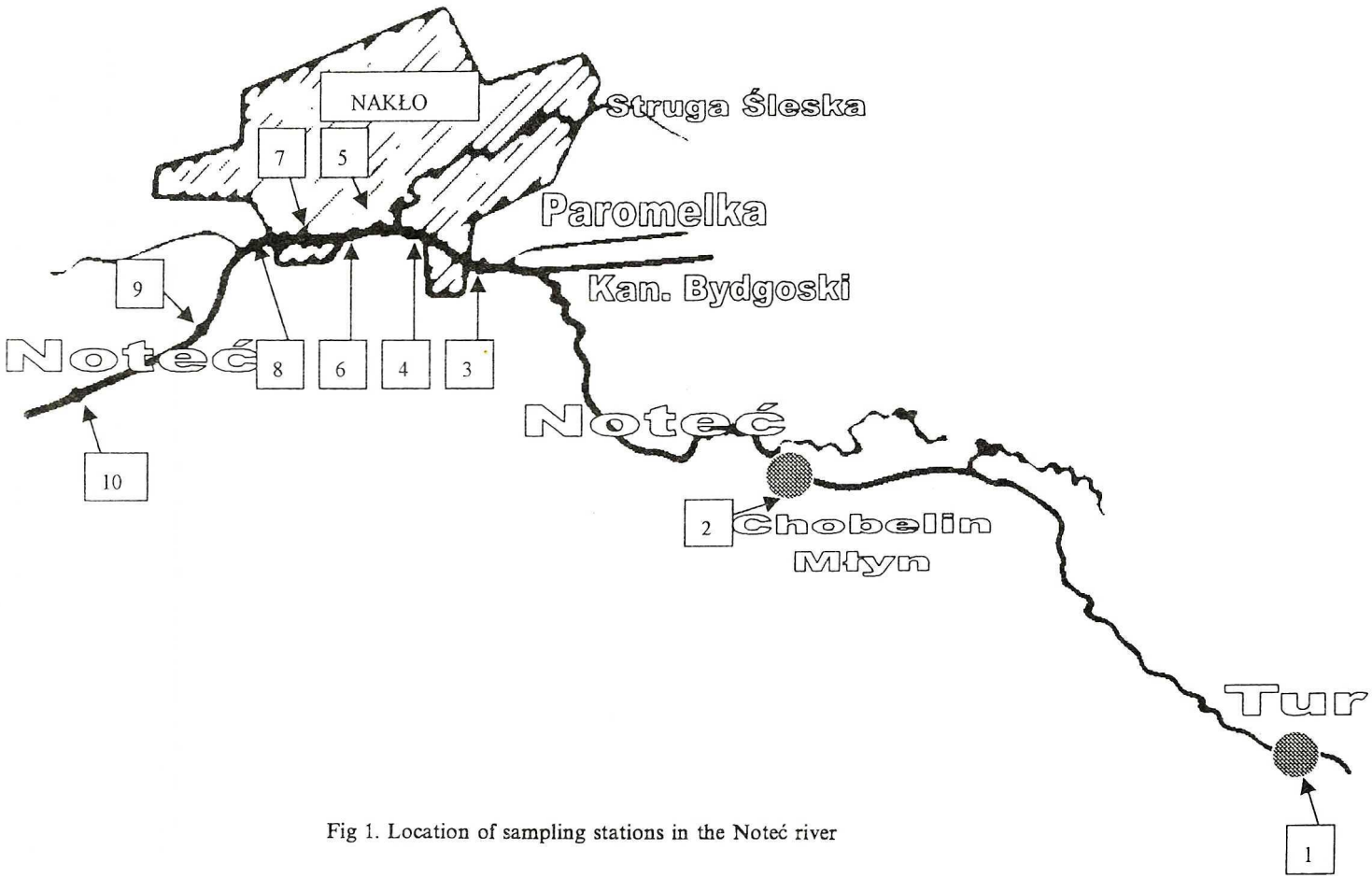

Fig 1. Location of sampling stations in the Noteć river

RESULTS

In 1995 – 1997, the Noteć river water was characterised by reactions with very small changes to pH values 7.3 – 8.2.

The highest mean contents of dissolved oxygen (6.8 mg $O_2 \cdot dm^{-3}$) was recorded at station 2, the lowest (5.6 mg $O_2 \cdot dm^{-3}$) at station 10 (Fig. 2). Over those 3 years, along the investigated section the dissolved oxygen contents dropped from 7.2 mg $O_2 \cdot dm^{-3}$ in 1995 [6] to 5.7 mg $O_2 \cdot dm^{-3}$ in 1997. The annual mean dissolved oxygen contents at all the sampling stations was not too high, but it came within the range fixed for the I and II class standards of water purity classification. The mean data resulting from changes of the amount of dissolved oxygen depending on the sampling date (Fig. 3) demonstrate that the highest value occurred in winter and spring (above 6.0 mg $O_2 \cdot dm^{-3}$). As compared to the data provided by the WIOŚ in 1993 – 1995, these results show that during the investigation period the oxygen conditions in the Noteć river improved within the borders of the town and below it, particulary along lower river sections where oxygenation rose from around 2 mg $O_2 \cdot dm^{-3}$ to 5.5 mg $O_2 \cdot dm^{-3}$ and thus approached the II class of water purity classification.

The BOD_5 mostly reflects the organic compounds content in water. According to Fig. 2, the lowest content of BOD_5 was recorder at station 2 (6.8 mg$O_2 \cdot dm^{-3}$) and the highest at station 10 (11.9 mg$O_2 \cdot dm^{-3}$). As it seems,

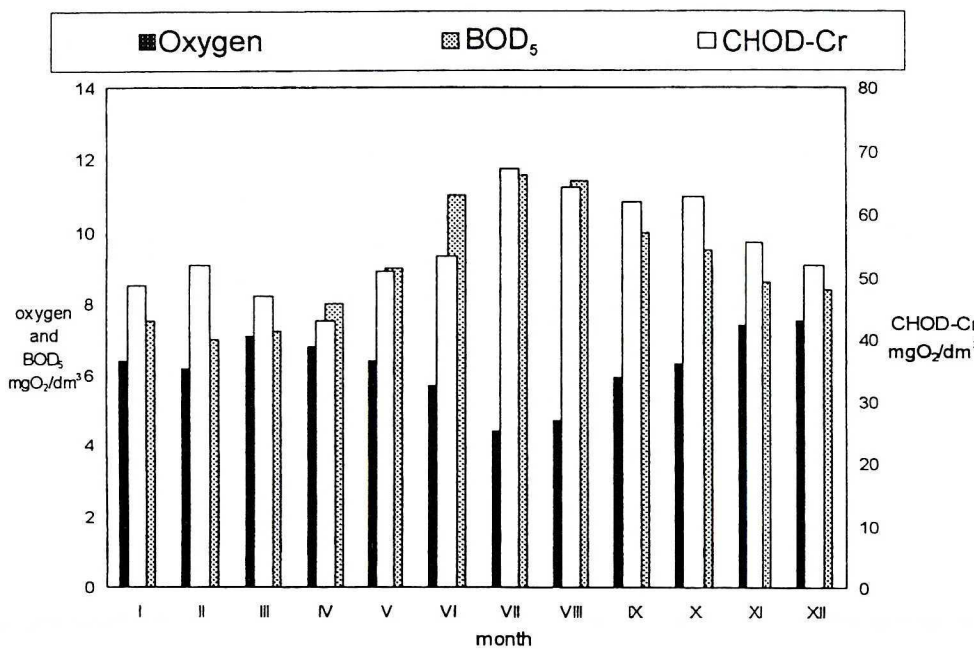

Fig 2. Mean values of oxygen, BOD_5 and ChOD in the Noteć river (within the Nakło community) in the period 1995 – 1997

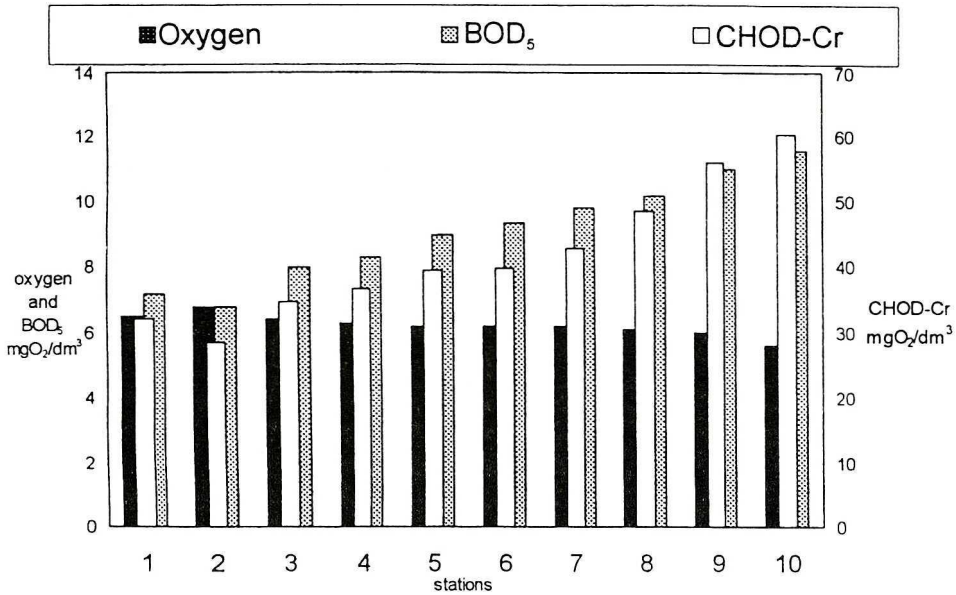

Fig 3. Sesonal changes in oxygen, BOD_5 and ChOD in the Noteć river (within the Nakło community) in the period 1995–1997

the BOD_5 content was growing with the course of the river. Mean content of BOD_5 met the standards set by III class of water purity classification. The BOD_5 unitary values of water oscillated from 7.2 to 19.6 mg $O_2 \cdot dm^{-3}$ most at station 8. Maximal BOD_5 values were recorded in summer. When comparing the characteristic 1993 concentrations [6], one could notice a very distinct drop in mean BOD_5 concentraions. This points to the fact that in the years 1995–1997 the Noteć river received less pollution with organic matter.

Figure 2 presents the ChDO changes along the investigated section of the Noteć. Mean ChDO value oscillated between 28.5 (st. 2) and 60.4 mg $O_2 \cdot dm^{-3}$ (st. 10) during the investigation period. The Figure 3 also shavs that organic compounds content increased along the course of the river, thus reaching the highest value at station 10. As compared to 1993 [6], a significant drop in ChDO was recorded at all sampling stations. For example, in 1993 at station 2 the mean value was 42.0 mg $O_2 \cdot dm^{-3}$ and at station 10–67.2 mg $O_2 \cdot dm^{-3}$. The greatest ChDO values were recorded in summer (Fig. 2).

The mean value of suspended matter grew along the river current from 25 to 65 mg $\cdot dm^{-3}$ (Fig. 4). Between station 2 and station 4 the river had water class II in terms of suspended matter concentration (30 mg $\cdot dm^{-3}$). At the further three stations the mean suspended matter concentration value met the standards of class III of the water classification, while above those points the suspended matter concentration exceeded 50 mg $\cdot dm^{-3}$ thus causing the water standard fall out of class, as it reached the value 65 mg N $\cdot dm^{-3}$ at station 10.

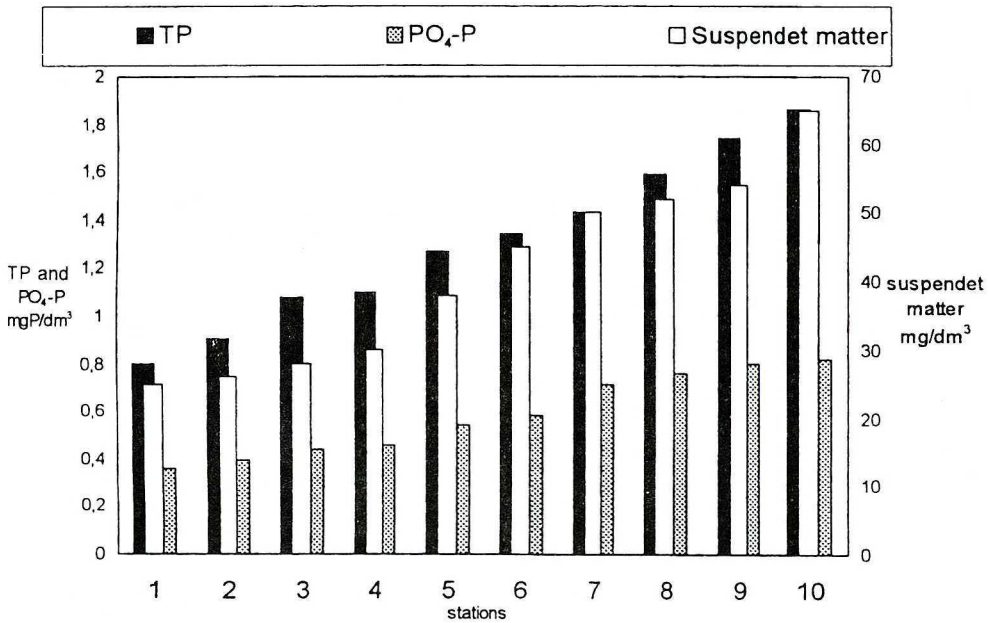

Fig 4. Mean values of suspended matter, phosphates (PO_4-P) and total phosphorus (TP) in the Noteć river (within the Nakło community) in the period 1995–1997

The highest mean values of suspended matter were recorded in spring and in autumn (about 70 mg $\cdot$ dm^{-3}). The most obvious cause for greater suspended matter content in river water in spring and autumn is the occurrence of surface rain water which carries great amount of both organic and inorganic matter.

Figure 5 presents the changes in ammonia nitrogen content. It dropped from 1.33 (st. 2) to 2.79 mg N $\cdot$ dm^{-3} (st. 10). In the period under investigation, ammonia nitrogen concentration was greater than 1.0 mg N $\cdot$ dm^{-3} at all sampling stations, but lower than 3.0 mg N $\cdot$ dm^{-3} thus it did not exceed the standard limit for class II. However, at the remaining sampling stations the concentration met the standards for class II of water purity classification. The greatest unit value of this indicator was recorded at station 10 (2.79 mg N $\cdot$ dm^{-3}). That component concentration was increasing along with the Noteć river receiving water from the pollution sources along the river run. Ammonia nitrogen concentration depends very much on the process of fertilizers leaching in the area of the river basin and also the process of organic matter compounds mineralization, which is at its highest in summer.

During the investigation period, the nitrate nitrogen oscillated between 0.85 (st. 1) and 2.85 mg N $\cdot$ dm^{-3} (st. 10) (Fig. 5), which met the standards for classes I and II of the water purity classification. Starting from station 5, that is within the town of Nakło and below, nitrate concentration exceeded 1.5 mg N $\cdot$ dm^{-3} and the Noteć river met the standards of class II of water purity classification. The mean percentage share of ammonia nitrogen in total nitrogen is usually

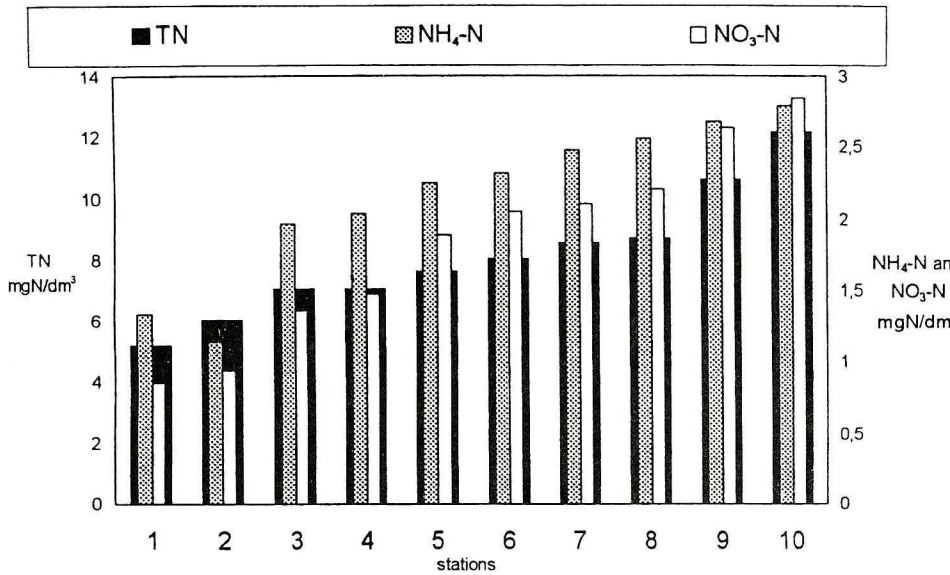

Fig. 5. Mean values of total nitrogen (TN), ammonia nitrogen (NH_4-N) and nitrates (NO_3-N) in the Noteć river (within the Nakło community) in the period 1995–1997

about 1.5%, whereas that of nitrate nitrogen about 10%. The organic nitrogen share was much greater and made about 73% of total nitrogen.

The changes to phosphate phosphorus concentration as recorded along the investigated section of the Noteć oscillated between 0.36 (st. 1) and 0.82 mg $\cdot$ dm^{-3} (st. 10) and have been presented in Figure 4. In terms of phosphates content the section including stations 1 to 4 met the II class water purity standards as it did not exceed 0.5 mgP $\cdot$ dm^{-3} concentration. The remaining water below that section came within the III purity class. Total phosphorus along that section oscillated between 0.80 (st. 1) and 1.87 mgP $\cdot$ dm^{-3} (st. 10). The mean percentage share of phosphate phosphorus in total phosphorus made about 44%. However, in spring and autumn the percentage share of mineral formations in total phosphorus was greater and amounted to 60–85%. At that time concentrations of phosphorus and nitrogen compounds were at their highest. The main source of nitrogen and phosphorus compounds that charge the surface water is domestic sewage. Pollution to the area makes a significant source of biogenes. In order to estimate the extent of the town's (Nakło) influence on the river's condition a load of indicators transported by the river was measured. The loads were estimated on the basis of the water flow running through station 3 (mean 3.88 m$^3 \cdot$ s^{-1}), which contained water inflowing into the town, and also station 8 where water was flowing out of the town. Basing on the above it was possible to state that in a year the town of Nakło introduced into the river Noteć 149 Mg of suspended matter, 38 Mg of nitrogen and 69 Mg of phosphorus (Tab. 1). Table 1 presents the calculations referring to the charge of those indicators provided per one inhabitant of Nakło.

Table 1. Loading of pollutions in form BOD_5, suspended matter, total nitrogen (TN) and total phosphorus introduced into Noteć river from Nakło city in a year

Pollutions indices	Unit	Loading of pollutions			
		st.3	st.8	all town	1 inhabitant
BOD_5	MgO_2/year	979	1290	311	14.2 kgO_2/year
Suspended matter	Mg/year	3426	6575	3149	144.0 kg/year
TN	tN/year	861	1099	238	11.0 kgN/year
TP	tP/year	133	202	69	3.14 kgP/year

DISCUSSION

The Noteć river is a tributary to the Warta river. A study done in 1995–1997 showed that along all the section of the Noteć that flows through the community of Nakło (between the towns of Tur and Polichno) its pollution was growing gradually. It was confirmed by BOD_5, ChDO, suspended matter, nitrogen and phosphorus compounds values which were becoming greater with time. Those components concentrations increase in the Noteć was caused by the inflow of pollution from subsequent site and surface sources that were located along the river. The main sources were in district town of Nakło. Quite distinct growth of concentrations of the components under investigation were recorded at stations 3 and 5. The concentration increase of the analysed components at station 3 resulted from great amount of pollution brought in by Bydgoski Canal and the Paramelka, past which the station was located. Apparently, station 5 was located behind the Struga Śleska mouth, which brings in all the sewage from the Nakło sugar mill.

As it happens, the Noteć river flows through the town of Nakło thus gathering all its sewage. Unlike the Łeba or Słupia, the Noteć makes a recipient of not only domestic and industrial sewage but agricultural run-off as well. However, the mean content of nitrate nitrogen (1.09 $mgN \cdot dm^{-3}$) and phosphates (0.58 $mgP \cdot dm^{-3}$) within the town does not confirm the presence of great amounts of elements of agricultural origin. On the contrary, the ratio between ammonia nitrogen (1.27 $mgN \cdot dm^{-3}$), BOD_5 (9.1 $mgO_2 \cdot dm^{-3}$) and ChDO (40.4 $mgO_2 \cdot dm^{-3}$) points to pollution as the river is heavily polluted along the section investigated. In comparison to the Łeba and Słupia rivers, Noteć is most polluted. The Łeba river within the town of Lębork has mean content of nitrates (0.42 $mgN \cdot dm^{-3}$), phosphates (0.07 $mgP \cdot dm^{-3}$), BOD_5 (3.7 $mgO_2 \cdot dm^{-3}$) while the Słupia within the city of Słupsk has a mean content of nitrates (0.51 $mgN \cdot dm^{-3}$), phosphates (0.10 $mgP \cdot dm^{-3}$), BOD_5 (4.5 $mgO_2 \cdot dm^{-3}$) [11].

Heavy pollution makes the Noteć river contain less oxygen than the Łeba (9.9 $mgO_2 \cdot dm^{-3}$) or Słupia (10.4 $mgO_2 \cdot dm^{-3}$) rivers. Nonetheless, the No-

teć is purer than the Drama river examined by [5]. It contains about 21 $mgN-NO_3 \cdot dm^{-3}$, 1.3 $mgP-PO_4 \cdot dm^{-3}$, 34 $mgN-NH_4 \cdot dm^{-3}$, 49 $mgO_2 \cdot dm^{-3}$ (BOD_5) and 120 $mgO_2 \cdot dm^{-3}$ (ChOD).

Making a comparative study of the presently discussed results with those obtained earlier 1993–1995 by the WIOŚ, one is able to state that both the area conditions and the investigated pollution indicators have improved. That tendency may be interpreted as a result of an improved operation performed by the existing sewage treatment plants and opening new ones.

The analyses data enabled forming an estimation of the Noteć water quality along the investigated section of the river. The obtained data (Tab. 2) place the section of the Noteć river before the town of Nakło within II class of the water purity standards, while the section flowing through the town itself – as one meeting the III class standard of water purity classification. The section flowing below the town of Nakło may be regarded as one meeting the class III standard within that classification, but due to the load of suspended matter it does not come exactly within that classification.

Table 2. Water quality classification of Noteć river in region of Nakło community (1995–1997)

Indices	Class of purity		
	before town (st. 1–3)	in town (st. 4–8)	behind town (st. 9–10)
pH	I	I	I
Oxygen	I	I	II
BOD_5	II	III	III
ChOD	I	II	II
$N-NH_4$	II	II	II
$N-NO_3$	I	II	II
TN	II	III	III
$P-PO_4$	II	II	III
TP	II	III	III
Suspended matter	II	III	Out class

CONCLUSIONS

The analysis of transformation of selected pollution indicators along the Noteć run within the community of the town of Nakło carried out in 1995–1997 according to the Polish current regulations concerning the surface waters classification resulted in a statement that, when compared to data from previous years, the purity situation of the river flowing out of Nakło has slightly improved in terms of chemical content. The indicators in the water above Nakło (st. 1–3) point to the water's I and II class of purity standards. However, below Nakło (st. 8–10) there are more indicators that meet the class III of the purity standards. Besides the slight improvement of the river's

water, its general condition remains still beyond the necessary quality. Low quality of water and heavy europhication result from large amount of suspended matter, nitrogen and phosphorus compounds contained in it. It is the municipality of Nakło that is to a great extent responsible for that state of affairs concerning the Noteć water condition. The town discharges into the river a load of contaminants that can be converted into 14.2 $kgO_2 \cdot y^{-1}$ of BOD_5, 144 $kg \cdot y^{-1}$ of suspended matter, 11 $kgN \cdot y^{-1}$ of total nitrogen and 3.14 $kgP \cdot y^{-1}$ of total phosphorus per one inhabitant. Those data exceed the values that have been recorded for such towns as Słupsk or Lębork. The following pollution sources are present in the area of Nakło that contaminate the river Noteć:

– the Council Board of Watersystem and Sewage;
– Meat Factory;
– domestic sewage discharged directly into the river from households that are not connected to the municipal sewage system;
– the tributaries: Bydgoski Canal and Struga Śleska which receive the sewage runnig off from the Sugar Mill.

The bad condition the Noteć river may be improved only by a rapid renovation and upgrading of the existing little sewage treatment plants in the area. The constant pollution of the river will certainly be stopped by biological sewage treatment plant which is due to open soon in Nakło. Also planting trees along the banks of the river where the agricultural run-off is most likely to occur should be a practicable remedy.

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