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HYDRO-CHEMICAL CHARACTERISTIC OF THE CZARNIAWKA RIVER

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CHARAKTERYSTYKA HYDRO-CHEMICZNA RZEKI CZARNIAWKI

W niniejszej publikacji przedstawiono wyniki badań jakości wody rzeki Czarniawki przeprowadzone w okresie grudzień 2003 – maj 2004. Scharakteryzowano jakość wody pod względem ogólnych wskaźników fizyczno-chemicznych. Wysokie stężenia azotu amonowego, ortofosforanów i ChZT w górnym biegu rzeki spowodowane są prawdopodobnie zrzutami nieoczyszczonych ścieków bytowo-gospodarczych. Spadek stężenia azotu amonowego przy jednoczesnym spadku zawartości azotu azotanowego wynika prawdopodobnie z dopływu wód niezawierających tych składników. Wysokie zasolenie oraz bardzo wysokie stężenie zawiesiny poniżej KWK „Makoszowy" spowodowane jest odprowadzaniem do rzeki silnie zasolonych wód dołowych oraz wód pochodzących z płuczki węgla. W zakresie omawianych wskaźników (poza odczynem i azotem azotanowym) rzeka Czarniawka prowadzi wody pozaklasowe. Porównując jakość wody na przestrzeni ostatnich kilkunastu lat, w górnym biegu rzeki obserwuje się nieznaczną poprawę stanu czystości, natomiast jakość wody w odcinku przyujściowym systematycznie się pogarsza. Czarniawka, choć jest niewielkim ciekiem, jest istotnym źródłem zanieczyszczenia Kłodnicy. Zmiana tego stanu wymaga zdecydowanych działań zmierzających do uporządkowania gospodarki wodno-ściekowej i ograniczenia ilości odprowadzanych ścieków przede wszystkim z terenu KWK „Makoszowy".

Summary

This study presents the results of investigations, carried out on the Czarniawka River from December 2003 to June 2004. The results indicate the changes of physicochemical parameters of water quality. High concentration of ammonium nitrogen, COD and orthophosphates are probably caused by discharge of municipal waste-water. A drop of ammonium nitrogen, nitrite nitrogen, nitrate nitrogen concentration along the river course is probably caused by inflow of water without these components. High salinity and very high concentration of suspended solids below the "Makoszowy" coal-mine is caused by discharge of coal-mine water and carbon dust from coal washer. All of the discussed parameters of water quality (except for pH-index and nitrate nitrogen) are beyond official classification. In comparison to previous analyses a slight improvement of water quality can be observed, especially in the top length. In the estuary water quality deteriorates. Although the Czarniawka River is small, it is one of the most important Kłodnica River contamination sources. Improvement of the existing situation will be possible only if firm waste-water management action will be taken, especially in the "Makoszowy" coal-mine area.

INTRODUCTION

The central part of Upper Silesia is described as the most transformed region of Poland [2–4, 10]. It is due to high industry concentration, especially mining industry, and high population [10]. Superficial and deep-seated mining exploitation, urbanization and other industrial activities had resulted in irreversible changes in geographic environment [1].

The last few years in Poland have resulted in many considerable changes: seclusion of many coal-mines and heavy industry factories, some of which changed manufacturing profile and introduction of technical solutions which reduce contamination of natural environment. This changes influence the present river pollution.

Upper Silesia Rivers may be divided into two groups: rivers with agricultural basin area (the Drama, the Potok Toszecki) and rivers with industrial basin area (the Kłodnica, the Potok Bielszowicki, the Bytomka). Agricultural basin area rivers are known for high concentrations of mineral substance, ammonium nitrogen, orthophosphates and COD [6, 7]. Water in industrial area rivers are characterized by high salinity and changes in suspended solids concentration and quality [8].

The Czarniawka is a small river, but it is a collector of waste-water from the towns of Ruda Śląska and Zabrze. This study purpose information supplements of water quality and indication the principal contamination sources. This article may be a reference to eventual activities to improve of the Czarniawka and the Kłodnica water quality.

BASIN CHARACTERISTIC

The Czarniawka River is the right-bank tributary of the Kłodnica River. The length of the Czarniawka River is 10.5 km and the basin area is 15.5 km^2 [9]. The river-head is located in Ruda Śląska. Next the Czarniawka River flows through the valley between Kończyce and Pawłów in Zabrze, Świerczewski park and industrial area of the "Makoszowy" coal-mine. The Czarniawka River estuary is located in Gliwice-Sośnica.

The major part of the basin is an industrial area. A little fragment only flows through the Świerczewski park and below the "Makoszowy" coal-mine it flows through anthropogenic forest. In the beginning the Czarniawka is a collector of municipal waste-water from Ruda Śląska. Next the river collects away waste-water from Zabrze quarters which are located in the Czarniawka basin, and industrial waste-water from "Zabrze-Bielszowice" coal-mine, coke and chemical works and the "Makoszowy" coal-mine [10].

The Czarniawka River has no natural tributaries. In the main the river is reinforced by precipitation and flows of municipal and industrial waste-water.

METHODS OF INVESTIGATION

SITES OF SAMPLES COLLECTION

Five sites were chosen for determination of changes in water quality in the Czarniawka River profile. These stations are situated as follows:

Station 1 – Ruda Śląska/Zabrze (1.0 km of the river course),

Station 2 – Zabrze, ul. Pszczyńska (3.6 km),

Station 3 – Zabrze, ul. 3. Maja (5.1 km),
Station 4 – Zabrze, under "Makoszowy" coal-mine (7.7 km),
Station 5 – Gliwice-Sośnica, "Sośnica" coal-mine area (10.0 km).

METHODS OF INDICATION

In collected water, suspended materials and bottom sediments there were determined: temperature, dissolved oxygen (measurer type CI-401, "Elmetron", Poland with temperature and oxygen electrodes), pH-index (pH-meter type CI-316, "Elmetron", Poland), conductivity (conductometer type CC-317, "Elmetron", Poland), alkalinity (PN-90/C-04540/03), ammonium nitrogen (PN-ISO 5664:2002), nitrite nitrogen (PN73/C-04576/06), nitrate nitrogen (ISO 7890-1:1986), orthophosphates (PN-89/C-04537/02), COD (PN-74/C-04578/03).

Organic carbon was determined at carbon analyzer TOC-5000A "Shimadzu", Japan. Suspended solids were determined by gravimetric method with cellulose nitrate membrane filters – pore 0.4 μm.

Bottom sediments, suspended solids and heavy metals in water will be discussed in other studies.

RESULTS OF INVESTIGATION

Results of investigation are discussed below.

pH-index

Oscillations of pH-index between 7.80 and 8.26 pH were noticed. Generally the lowest at Station 1 and the highest at Station 5.

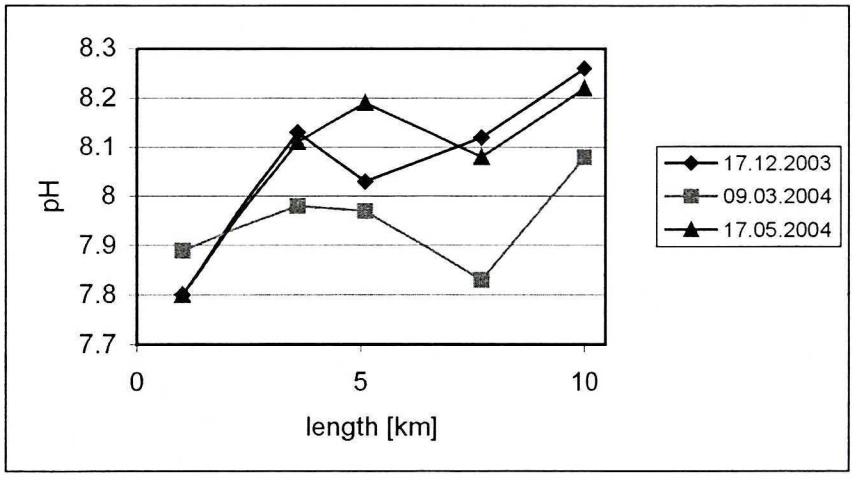

Fig. 1. Changes of pH-index in water of the Czarniawka River – hydrographic profile

Dissolved oxygen

Slight fluctuations of dissolved oxygen concentration were observed. The lowest concentrations at Station 1 were recorded – 4.46–8.15 mg O_2/dm^3, the highest at Station 4 – 7.27–10.20 mg O_2/dm^3 was observed. At Station 5 a slight drop to 5.61–8.49 mg O_2/dm^3 was noticed.

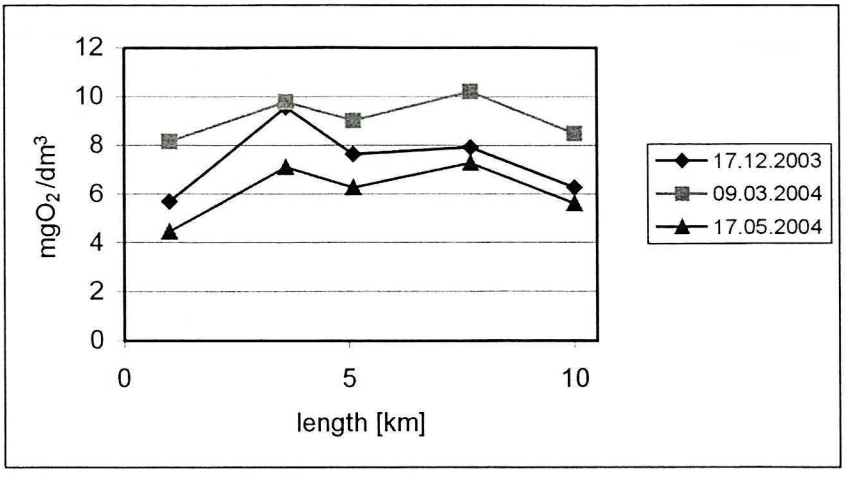

Fig. 2. Changes in the content of dissolved oxygen in water of the Czarniawka River – hydrographic profile

Ammonium nitrogen

The maximal concentration of ammonium nitrogen in March was observed at Station 1 – 14.48 mg N-NH_4/dm^3. Generally the concentration dropped along the river course. The lowest concentrations of ammonium nitrogen were noticed at Station 5 – 3.64–5.82 mg N-NH_4/dm^3.

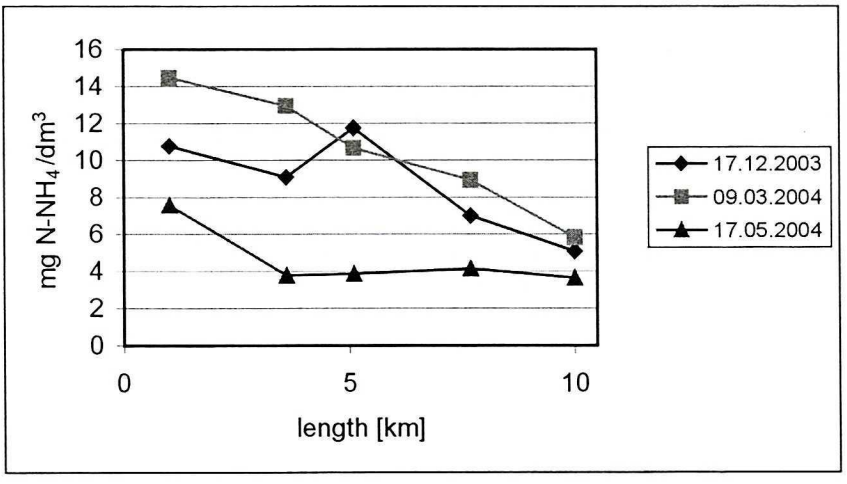

Fig. 3. Changes in the content of ammonium nitrogen in water of the Czarniawka River – hydrographic profile

Nitrite nitrogen

The highest concentrations of nitrite nitrogen were observed at Station 1 – 0.363 to 0.574 mg $N\text{-}NO_2/dm^3$. The minimal concentration was observed at Station 2 – 0.206 mg $N\text{-}NO_2/dm^3$. The concentration dropped along the river course, except for March, where a slight rise at Station 2 was recorded. At Station 4 the concentrations ranged between 0.218–0.292 mg $N\text{-}NO_2/dm^3$. Then a rise up to 0.268–0.341 mg $N\text{-}NO_2/dm^3$ at the Station 5 was noticed.

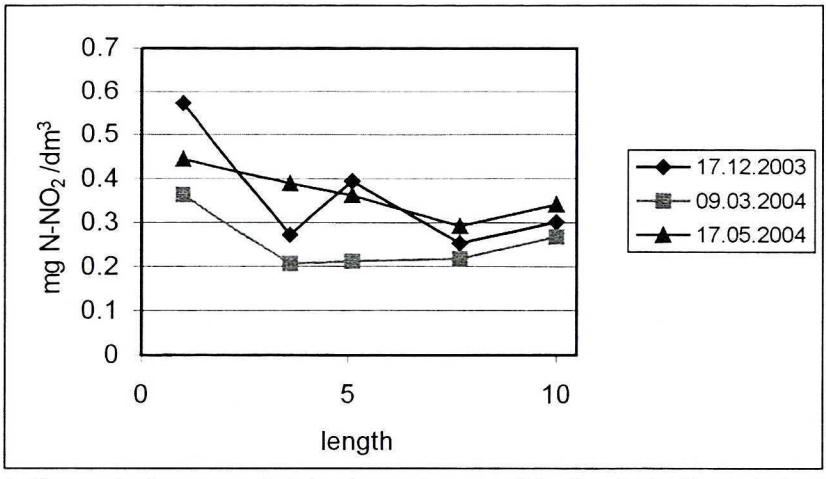

Fig. 4. Changes in the content of nitrite nitrogen in water of the Czarniawka River – hydrographic profile

Nitrate nitrogen

Like in the case of ammonium nitrogen and nitrite nitrogen the highest concentration of nitrate nitrogen was noticed at Station 1 – 4.77 to 9.81 mg $N\text{-}NO_3/dm^3$. Along the river course a drop of nitrate nitrogen concentration was observed – in the estuary (Station 5) very low concentrations were noticed – 0.28 to 0.47 mg $N\text{-}NO_3/dm^3$.

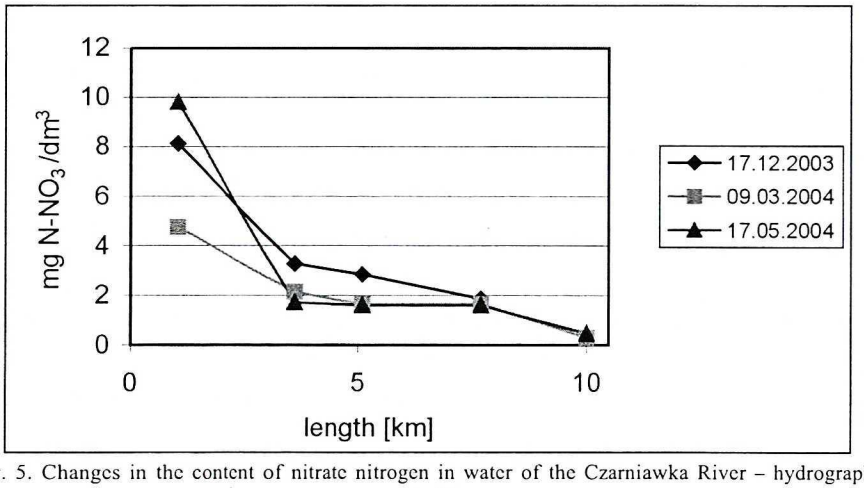

Fig. 5. Changes in the content of nitrate nitrogen in water of the Czarniawka River – hydrographic profile

Orthophosphates

The diagram of orthophosphates concentration is about the same as in the case of the nitrogen forms which are taken above – the highest concentrations at Station 1 – 3.324 to 3.803 mg $P\text{-}PO_4/dm^3$, and the lowest at Station 5 – 0.555 to 1.004 mg $P\text{-}PO_4/dm^3$ were observed.

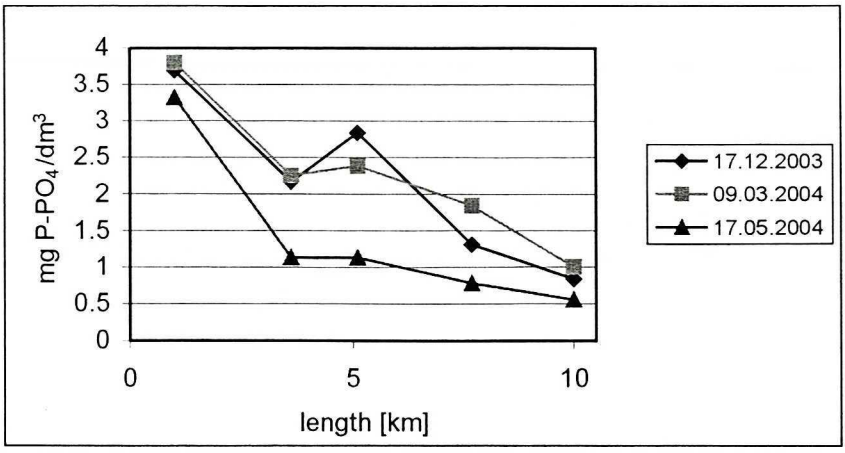

Fig. 6. Changes in the content of orthophosphates in water of the Czarniawka River – hydrographic profile

Organic carbon

A slight drop of organic carbon concentration is observed along the river course – 18.05 to 20.24 mg C_{org}/dm^3 at Station 1 and 11.09 to 13.41 mg C_{org}/dm^3 at Station 5. In December and March a little rise up to 24.17–26.54 mg C_{org}/dm^3 at Station 2 was observed.

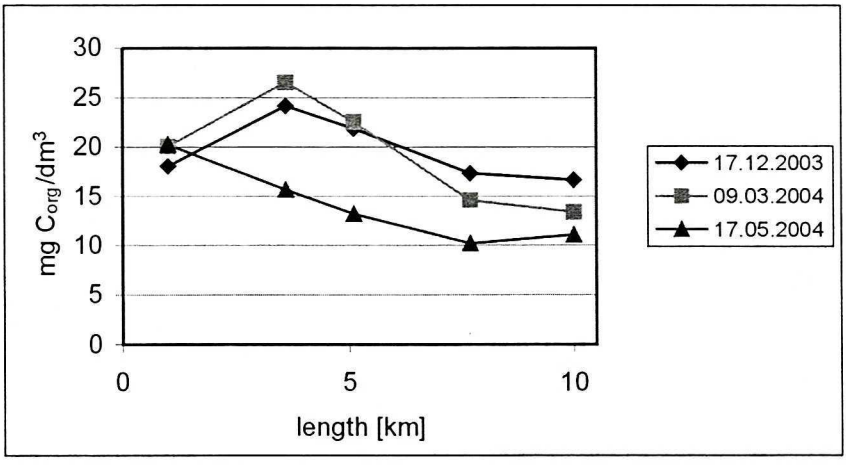

Fig. 7. Changes in the content of organic carbon in water of the Czarniawka River – hydrographic profile

COD

From Station 1 to Station 3 changes between 62.52 and 195.90 mg O_2/dm^3 were observed. At Station 4 an important rise up to 1479.6–16899 mg O_2/dm^3 was noticed. In the estuary 973.4 to 1955.7 mg O_2/dm^3 was noticed.

Table 1. Changes in the content of COD in water of the Czarniawka River

Localization	17.12.2003	09.03.2004	17.05.2004	22.06.2004
	mg O_2/dm^3	mg O_2/dm^3	mg O_2/dm^3	mg O_2/dm^3
Station 1	62.52	125.94	110.27	-
Station 2	87.53	140.75	68.44	-
Station 3	195.9	107.42	68.44	-
Station 4	1479.6	2089.1	7680.8	16899
Station 5	1338.8	1955.7	973.4	748.1

Conductivity

From Station 1 to Station 4 conductivity changed within a little range – at Station 1 the lowest conductivity 1642 μS/cm was noticed. The highest at Station 2 in May – 2460 μS/cm. At Station 5 a rise up to 13260–13490 μS/cm was observed.

Table 2. Quantity changes of conductivity in water of the Czarniawka River

Localization	17.12.2003	09.03.2004	17.05.2004
	μS/cm	μS/cm	μS/cm
Station 1	1642	2010	2020
Station 2	2230	2040	2460
Station 3	2170	1990	2370
Station 4	2390	2100	2100
Station 5	13380	13490	13260

Suspension

Considerable changes of suspended solids concentration were noticed. From Station 1 to Station 3 suspended solids concentration oscillated from 8.3 to 70.5 mg/dm^3. The highest and the lowest concentrations were observed at Station 3. Below the "Makoszowy" coal-mine a rise even to 32643 mg/dm^3 was observed. In the estuary a drop of suspended solids concentration was noticed.

Table 3. Changes in the content of suspended solids in water of the Czarniawka River

Localization	17.12.2003	09.03.2004	17.05.2004	22.06.2004
	mg/dm^3	mg/dm^3	mg/dm^3	mg/dm^3
Station 1	42.6	33.4	26.3	–
Station 2	29.4	32.1	20.2	–
Station 3	70.5	31.8	8.3	–
Station 4	1425	2007.5	5987	32643
Station 5	1277	1830.6	5461	2372

DISCUSSION

Although the Czarniawka River is a small river with a little basin area, it is ranked among the most contaminated Upper Silesia rivers. High concentration of nitrates and phosphates in the beginning of the river may be probably caused by the discharge of municipal waste-water.

Very interesting is the relation of ammonium and nitrate nitrogen concentrations. In comparison to the Bytomka River [8], high dissolved oxygen concentration suggests nitrification process and a rise of nitrate nitrogen should be observed. But all of the nitrogen forms recorded drop along the river course. It may be explained by an inflow of water without those nitrogen forms which takes place near the Stations 4 and 5, because the large inflow from coal washer and coal-mine water is observed. A drop of orthophosphates could be explained in the same way, as well as the sorption on the bottom sediments and suspended solids.

Below the "Makoszowy" coal-mine a rise of dissolved oxygen concentration is observed. It is caused by mechanical oxidation which takes place in coal washer, what verifies a drop of dissolved oxygen at Station 5, which is discharged to the atmosphere.

From Station 1 to the "Makoszowy" coal-mine suspended solids qualities and concentration characterized rivers which are contaminated by the municipal waste-water. Oscillations of suspended solids concentration at Station 3 in authors opinion are caused by run off surface from the river basin area, especially in the winter. Under the "Makoszowy" coal-mine the change of suspension character is observed. Suspended solids concentration rise suddenly, which is caused by an inflow from the "Makoszowy" coal-mine coal washer. Carbon dust is observed only in the water. High variability of suspended solids concentration is caused by contamination thrust irregularity from the coal mine area as well as a probability of higher suspended solids concentration (when the investigation took place in the morning, at Station 4 suspended solids concentration higher than 32000 mg/dm^3 was noticed).

Situation of salinity looks alike. From Station 1 to Station 4 conductivity of about 2000 μS/cm is noticed. So at Station 5 conductivity is higher than 13000 μS/cm. Local investigation show relation between the river salinity and the "Makoszowy" coal-mine depositor, located near the Czarniawka River, where there are no coal dust sediments and suspension. About 200 m under Station 4, there is situated a drain from this depositor. The

indication showed that water conductivity in that reservoir is higher than 40000 μS/cm.

All of the discussed parameters of the Czarniawka River water quality (except for pH-index and nitrate nitrogen) are beyond official classification (Table 4).

Table 4. Classification of the Czarniawka River water quality (according to maximum concentrations of individual parameters)

Parameter	Water quality classification
pH	I
COD	under classification
$N\text{-}NO_3$	I–III
$N\text{-}NO_2$	under classification
$N\text{-}NH_4$	under cl assification
$P\text{-}PO_4$	under classification
Conductivity	under classification
Suspended solids	under classification

Table 5. Comparison of the Czarniawka River water quality parameters (minimum and maximum concentration of individual parameters)

Parameter	Unit	1992	1998	2003/2004
COD	mg O_2/dm^3	108.6–186.5	–	62.52–7680.8
dissolved oxygen	mg/dm^3	–	3.10–8.60	4.46–10.20
$N\text{-}NO_3$	mg/dm^3	6.84–11.20	1.04–3.15	0.28–9.81
$N\text{-}NO_2$	mg/dm^3	–	0.146–0.534	0.206–0.574
$N\text{-}NH_4$	mg/dm^3	2.16–7.67	0.78–3.87	3.64–14.48
$P\text{-}PO_4$	mg/dm^3	–	0.760–2.570	0.555–3.803
conductivity	μS/cm	4040–6370	3760–13520	1642–13490
suspended solids	mg/dm^3	21–129	10–1765	8.3–32643

CONCLUSION

The investigations demonstrated that the Czarniawka River, as well as other Upper Silesia rivers are very strongly contaminated. That river is a collector of municipal waste-water from Zaborze, Pawłów and Kończyce quarters. But contrary to other rivers which

receive contamination from many sources, the most important source of the Czarniawka River contamination is the "Makoszowy" coal-mine, which flows to the river a lot of coal dust and salty water. Making a comparative study of the presently discussed results with those obtained in 1992 and 1998 [5, 12] it may be observed a slight improvement in the quality of water the Czarniawka from its beginning to the "Makoszowy" coal-mine, especially such parameters as COD, suspended solids and salinity. In the case of nitrogen forms and orthophosphates concentration no changes were observed in the last few years. But under the "Makoszowy" coal-mine, such parameters as COD and suspended solids concentration have even grown.

The Czarniawka River is an important source of the Kłodnica River contamination. Improvement of this existing situation will be possible only if firm waste-water management action will be taken. The most important are:

1. To set in order water and waste-water, and reduce inflow of municipal waste-water especially in the top length of the Czarniawka River,
2. To reduce discharges of suspended solids (carbon dust) from "Makoszowy" coal mine,
3. To reduce discharges of high salinity water from "Makoszowy" coal-mine depositor.

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