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Indices of bacteriological and chemical quality of waters in the Upper Silesian Industrial Region (Southern Poland) affected by atmospheric pollution and industrial wastes*

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Abstract — In bacteriological investigations carried out in 1976—1979 in the Upper Silesian Industrial Region various pollution of surface waters in the Rivers Brynica and Mała Panew basins was demonstrated. It was ascertained that in the River Brynica, which was polluted by atmospheric ducts, the water was relatively pure, while in the River Mała Panew basin it was strongly polluted by the inflow of wastes from plants in the Upper Silesian Industrial Region.

Key words: rivers, dam reservoirs, lakes, ponds, Upper Silesia, bacteria, water quality.

1. Introduction

A bacteriological investigation of waters in the Brynica (Starzecka 1985) and Mała Panew river basins in the vicinity of Tarnowskie Góry in the Upper Silesian Industrial Region was carried out in the period May 1976 — May 1979.

The aim of the work was to describe the bacteriological characteristics and determine the quality of the waters in the River Mała Panew basin polluted by industrial wastes and to make a comparison with those of the River Brynica basin polluted by atmospheric dusts.

* The investigation was carried out within Project No MR.II.15.

2. Study area

The studies were carried out at eight stations in the River Brynica basin (1, 2, 3a, 3d, 4, 5, 6, 7) and at five in the River Mała Panew basin (8, 9, 10, 11, 12). The location of the stations and their description are given in fig. 1 and Table I.

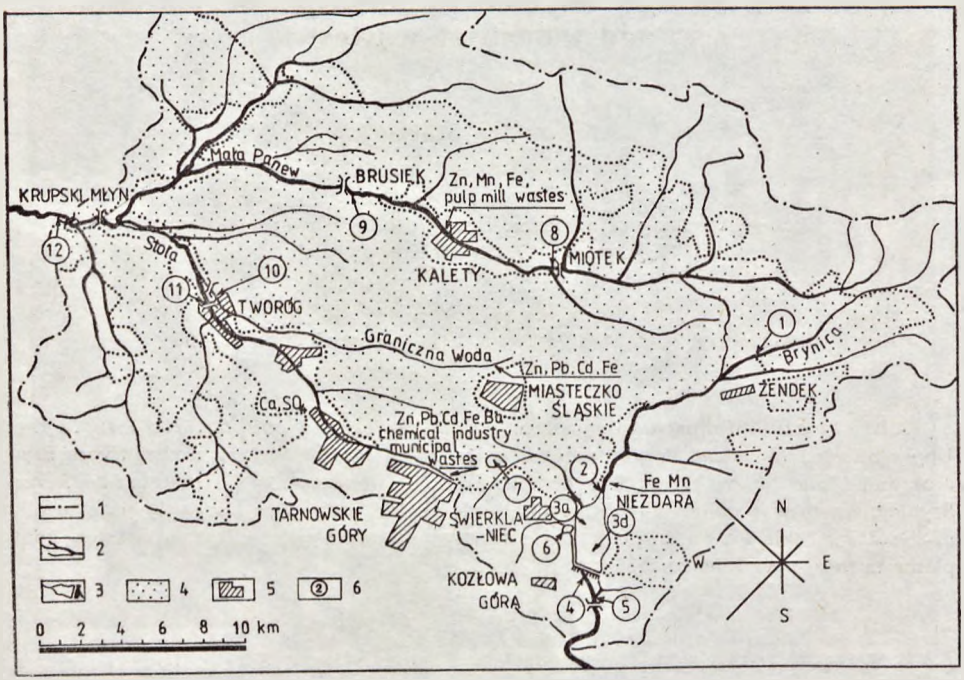


Fig. 1. Distribution of stations in the upper sectors of the catchment basins of the Rivers Mała Panew and Brynica, main pollution, wind rose. 1 — borders of the catchment basin; 2 — rivers; 3 — dam reservoir, lake; 4 — forest; 5 — built up areas; 6 — station numbers

The River Brynica forms part of the River Czarna Przemsza catchment basin, belonging to the River Vistula basin, and is situated on the Silesian Upland. The upper sector of the River Brynica with the dam reservoir at Kozłowa Góra, the small artificial Lake Chechło-Nakło, and the Świerklaniec park pond lie in a region where the prevailing wind is from the West. Hence, during most of the year the waters are polluted by dusts from the plants of Upper Silesian Industrial Region, e.g. the Zinc and Lead Plant at Miasteczko Śląskie, the chemical works „Czarna Huta" at Tarnowskie Góry, Non-Ferrous Metal Works at Strzebnica, the Paper Factory at Boruszowice, and the Paper Factory at Kalety.

Table I. Brief environmental description of the investigated stations
Q_{10} - mean 10-year water discharge ($m^3 s^{-1}$)

Station	No	Situation	Width of the riverbed (m) area (km^2)	Depth (m)	Current	Remarks
River Brynica	1	at Zendek	0.5 - 1.5	0.2 - 0.5	medium	Q_{10} = 0.62 m^3 sec^{-1}
	2	at Niezdara	3.0 - 4.0	0.2 - 0.7	slow	
Dam reservoir at Kozłowa Góra	3a	at Kozłowa Góra	mean 4.62	0.5 - 1.8		
	3d	upper section lower section	maximum up to 6.21	1.8 - 3.0		
River Brynica	4	near the dam	1.0 - 1.2	0.2	medium	
	5	below the dam - 1.5 km	2.0 - 3.0	0.3 - 0.7	slow	Q_{10} = 0.44 m^3 sec^{-1}
Świerklaniec park pond	6	at Świerklaniec inshore	0.06	1.2 - 1.5		
Lake Chechło-Nakło	7	at Chechło inshore	0.66	0.3 - 0.6		
River Mała Panew	8	at Miotek	5.0 - 8.0	0.3 - 0.7	medium	17 km from springs Q_{10} = 1.05 m^3 sec^{-1}
	9	at Brusiek	3.0 - 5.0	0.3 - 0.7	medium	7 km below paper mill at Kalety
River Graniczna Woda	10	at Tworóg	2.0 - 2.5	0.15 - 0.35	slow	15 km from springs
River Stoła	11	at Tworóg	4.0 - 6.0	0.5 - 0.8	slow	16 km from springs Q_{10} = 1.56 m^3 sec^{-1}
River Mała Panew	12	at Krupski Młyn	6.0 - 8.0	1.0 - 1.5	medium	3.5 km below mouth of the River Stoła Q_{10} = 4.93 m^3 sec^{-1}

The River Brynica and other water bodies, with the exception of the run-off from the surrounding region and atmospheric dusts, are not polluted by other wastes.

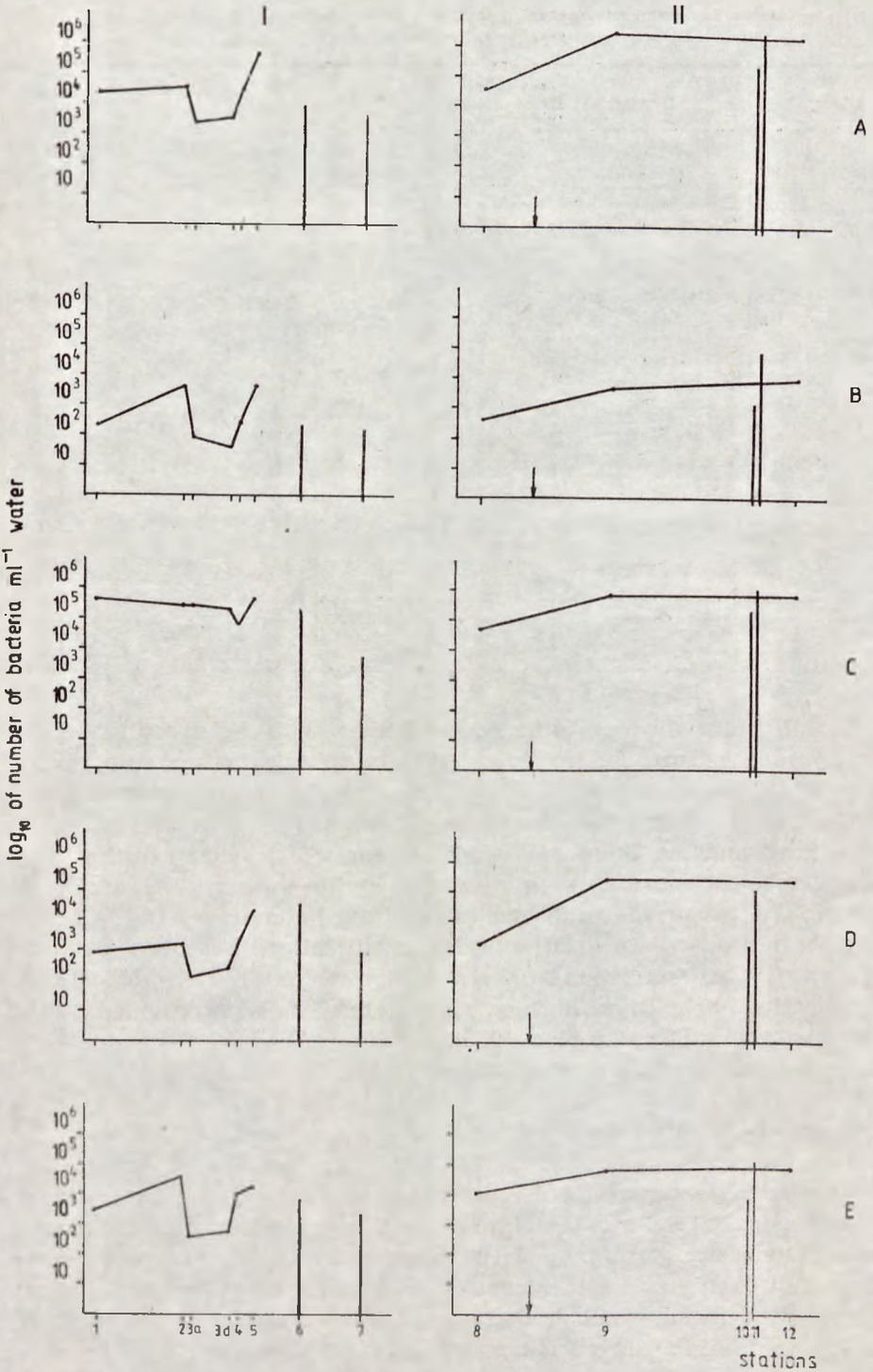
On the other hand, the River Mała Panew with its left tributaries the River Stoła and the Graniczna Woda stream, which belong to the River Odra catchment area, is strongly polluted by the wastes which are drained from the industrial establishments mentioned above.

An exact description of the investigated stations has been given by Zięba (1985a) and Bombówna (1986), while a bacteriological characterization of the River Brynica basin waters has been provided by the present author (Starzecka 1985).

3. Material and methods

Samples of water were collected 15 times, the following factors being determined: the total number of heterotrophic bacteria and the number of proteolytic bacteria using the plate method and the titre of bacteria taking part in nitrogen and sulphur transformation (ammonigying, denitrifying, protein decomposing with hydrogen sulphide releasing bacteria).

The value of the titre was converted to numbers, using the McCrady



statistical tables (Collins, Lyne 1970, Rodina 1968). The media used in the study were described earlier by Starzecka (1979). The quality of water at the examined stations was determined using the 4-class scale (purity classes I—IV) and the ten indices (5 biological and 5 chemical). The final quality of the water was defined using the numerical taxonomic value of pollution — NTVP. This value is the average of the sum of values assigned to the indices from 1.0 to 4.0, according to the classes of water purity (I—IV) (Starzecka et al. 1979, Starzecka 1984).

The data on BOD_5 and chemical indices used in classification are given by Bombówna (unpublished).

4. Results

4.1. Bacteriological characteristics of water in the Brynica and Mała Panew basins

The number of bacteria in the water of the examined stations is shown in figure 2.

The total number of heterotrophic bacteria, of the order 10^4 cells per 1 ml^{-1} of water, was similar in the two basins at the forest stations numbers 1 and 8. A larger number of heterotrophs was found in a backwater of the reservoir at Kozłowa Góra (station 2) and below the outflow of the Brynica from the reservoir (stations 4 and 5). In the Mała Panew the number of heterotrophs increased by two orders of magnitude at stations 9 and 12 (below the inflow of wastes from the Paper Factory at Kalety) and below the mouth of the strongly polluted River Stoła (station 11) with the Graniczna Woda stream (station 10).

Similar changes were marked in the proteolytic and decomposing protein substances with release of hydrogen sulphide and in the group of denitrifying bacteria.

The picture of changes was slightly different in the group of ammonifying bacteria. At the stations in the Brynica (1, 2, 4, 5) and in the Kozłowa Góra reservoir (3a, 3d) the number of these bacteria was on the same level. On the other hand, in the Mała Panew in the sectors receiving industrial wastes (stations 9, 12) there was a considerable increase in the number of ammonificators in comparison with the station situated at Miotek and polluted by atmospheric dusts (station 8). In the Świerklaniec

Fig. 2. Mean number of bacteria in the water of the particular stations (1—12) in the period 1976—1979 in the catchment basins: I — River Brynica, II — River Mała Panew. A — total number of heterotrophic bacteria; B — proteolytic bacteria; C — ammonifying bacteria; D — bacteria producing H_2S; E — denitrifying bacteria; ↓ — inflow of pollution from the Paper Factory at Kalety

park pond, with the exception of proteolytes, the number of the remaining determined groups of bacteria was similar to that observed at stations 4 and 5. A smaller number of bacteria was found in the water of the artificial Lake Chechło-Nakło (station 7), in the River Brynica basin and in the Graniczna Woda stream (station 10) in the Mała Panew basin.

4.2. Comparison of water quality in the Brynica and Mała Panew basins

The water quality at particular stations, judging by the average obtained from results for the whole investigation period, is shown on the fig. 3.

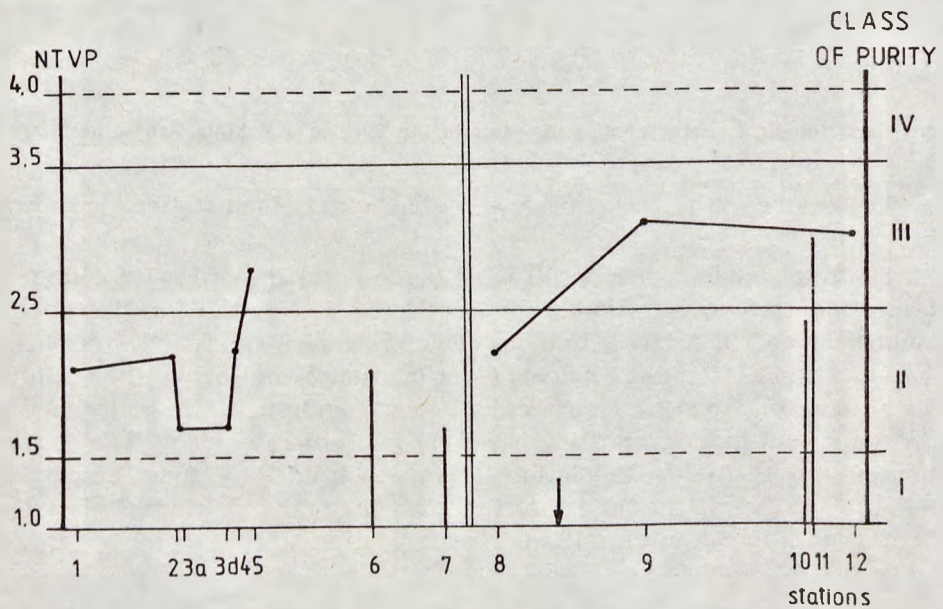


Fig. 3. Classification of water purity at stations 1—12. NTVP — Numerical Taxonomic Value of Pollution for the whole investigation period 1976—1979

In the River Mała Panew, apart from the forest sector (station 8, NTVP = 2.15), which was characterized by relatively pure water (class II), similarly as the River Brynica around the stations 1, 2, 4, and other water bodies (stations 3a, 3d, 6, 7), all stations were strongly polluted, with the exception of the Graniczna Woda stream (station 10, NTVP = = 2.35). The Mała Panew at Brusiek (station 9, NTVP = 3.04) as well as at Krupski Młyn (station 12, NTVP = 2.99) and the Stoła near Tworóg (station 11, NTVP = 2.99) conformed to purity class III, though the pollution was stronger than in the River Brynica, around station 5 (NTVP = = 2.73).

4.3. Seasonal changes in the purity of the Rivers Mała Panew, Stoła, and Graniczna Woda stream

The water of the Mała Panew at station 8 was relatively pure (class II). At station 9, however, below the inflow of wastes from the Paper Factory, and at station 12 below the mouth of the Stoła with the Graniczna Woda, the Mała Panew for the whole investigated period was strongly polluted (class III) (fig. 4).

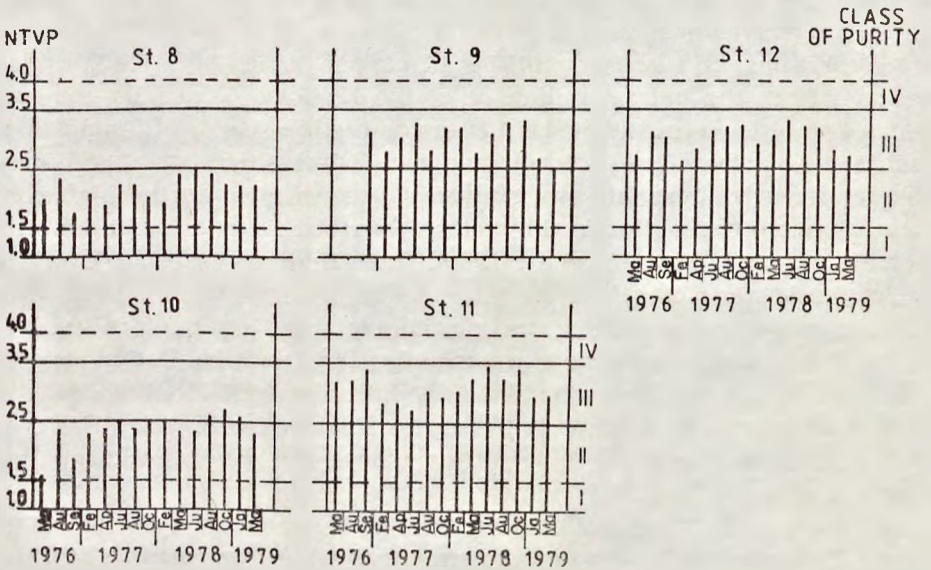


Fig. 4. Changes of water purity of the River Mała Panew (stations 8, 9, 12), the River Stoła (station 11), and the Graniczna Woda stream (station 10) in the period 1976—1979. NTVP — Numerical Taxonomic Value of Pollution

The quality of the water in the Graniczna Woda (station 10) for the investigation period varied on the border line between relatively pure (class II) and strongly polluted waters (class III), but with a tendency to increased pollution in the period 1976—79 (fig. 5). Much greater pollution was observed in the River Stoła (station 11). Biological and chemical indices classified this river as strongly polluted (class III) in the whole investigation period (fig. 4).

5. Discussion

The results obtained in the present investigation showed that the degree of purity of the waters from the basins of the Rivers Brynica and

Mała Panew is differentiated, this being caused by different types of pollution.

The River Brynica basin, polluted by surface run-off and dust emitted to the atmosphere by the industrial plants of the Upper Silesian Industrial Region, was characterized by waters rich in carbonates and periodically in calcium and magnesium sulphates. Among the mineral forms of nitrogen in the water the nitrate form dominated while the amount of nutrients rose in periods of higher water level, this being caused by run-off from the surrounding area (Bombówna 1985). The concentration of microelements periodically showed great variation but was lower than in the Mała Panew. However, as was shown by Reczyńska-Dutka (1985), the river transports large quantities of copper, zinc, and lead, which accumulate in the bottom sediments of the Kozłowa Góra reservoir and hence do not have any significant effect on the biocenosis of flood water. Both the Kozłowa Góra reservoir and the Świerklaniec park pond were characterized by constant availability of nutrients, while the high concentration of electrolytes in the water demonstrated considerable pollution of the pond (Bombówna 1985). These findings were also confirmed by the bacteriological investigations. The artificial Lake Chechło-Nakło, the purest in the whole basin, was characterized by low fertility. It is situated in a region of sandy wastelands, far from habitation, partly wooded, and has no great sources of pollution, except for those coming from atmospheric dusts from the plant at Miasteczko Śląskie. The concentration of lead and mercury in the water of the pond was lower than at the stations in the Mała Panew and its tributaries (Reczyńska-Dutka 1985). Hence, in the River Brynica basin relatively pure waters (class II) predominate. As was shown, only in the low part of the River Brynica (station 5) was pollution of the water strong (class III), this being revealed by a larger content of nutrients and organic matter (Bombówna 1985) and by a rich — and the greatest in the whole basin — development of bacterial microflora taking part in various biochemical processes. Moreover, the smaller water flow at station 5 as compared with stations situated in the higher sectors, prolonged the time of action of biotic and abiotic factors forming an unfavourable picture of the environment in this sector of the river (Starzecka 1985), the biocenosis of the river (except for station 5) was characteristic for relatively pure waters. It was reflected not only by the small number of bacteria (Starzecka 1985) but also by varied algal communities, among which species typical for pure water dominated (Bucka 1985), and microfauna in which alpha-mezosaprobic species predominated and macrofauna with predomination of beta- and alpha-mezosaprobic species (Grabacka 1985, Zięba 1985b).

A far poorer water quality was found in the River Mała Panew basin, which was polluted not only by the domestic, farmyard, and municipal

sewage, but above all by wastes from the industrial works densely located in the Upper Silesian Industrial Region (fig. 1).

The upper, wooded sector of the Mała Panew (station 8), similarly as the Brynica basin, subject to atmospheric pollution and run-off was characterized by relatively pure water (class II). The remaining stations on the Mała Panew (stations 9, 12) and on the Stoła close to the village of Tworóg (station 11) were strongly polluted (class III). The much higher value of NTVP for these sectors of the Mała Panew and Stoła than those of the lower sector of the Brynica (station 5) confirmed the distinctly stronger pollution of the waters receiving industrial wastes.

Throughout the investigation period pollution of the Mała Panew was maintained at the village of Brusiek (station 9), 7 km below the discharge of wastes from the Paper Factory at Kalety, and at Krupski Młyn (station 12) below the mouth of the Stoła to the Graniczna Woda. Thus the paper factory and the River Stoła are two main sources of pollution on the studied sector of the Mała Panew.

The strongest pollution was found at Brusiek, below the discharge of wastes from paper factory. It was manifested by a rich development of bacterial microflora with differentiated biochemical abilities, this certainly being due to the frequently observed highest content of organic matter in the whole basin. Also were noted a low content of dissolved oxygen — or its total disappearance — a high content of ammonia (over 2 mg dm^{-3}), and high values of BOD_5 — reaching about 60 O_2 mg dm^{-3} — manifesting intensive destructive processes taking place on this sector of the river (B o m b ó w n a 1986).

At Krupski Młyn (station 12) 17 km below Brusiek, despite the self-purification processes, the Mała Panew was constantly classified as purity class III, this also being caused by the huge load of wastes carried in by the Stoła (station 11) with its tributary, the Graniczna Woda (station 10). Although the average value of NTVP for the whole investigation period allows classification of the Graniczna Woda around station 10 in purity class II, nevertheless pollution of the river increased from year to year, reaching in 1978/79 values of purity class III, i.e. strongly polluted water. At this time the Graniczna Woda was characterized by a calcium sulphate water type (maximum content of sulphate 260 mg dm^{-3}), a very high concentration of ammonia, and the highest content of free CO_2 in the whole basin (B o m b ó w n a 1986). On the other hand, the water from the Stoła which had a sodium-chloride, chloride- or sulphate-calcium character throughout the investigation period, contained a high concentration of anions and kations, demonstrated by conductivity of electrolytes over 1900 μS. The form of ammonia nitrogen was several hundred times higher than nitrate together with considerable decrease in oxygen in the water, indicating the existence of strong destructive processes (B o m b ó w n a 1986). The pollution of the waters of the Mała

Panew and its tributaries was greatly increased by the heavy metals flowing in with the wastes from the industrial plants of the Upper Silesian Industrial Region. The concentration of Cu, Zn, Cd, Co, Ni and Fe in these wastes many times exceeded that contained in the dusts falling on the region of the River Brynica basin. It was far higher than in the regions not affected by industrial pollution (Reczyńska-Dutka 1985, unpublished).

In the biocenoses of the polluted sectors of the Mała Panew and its tributaries the domination of bacteria and reduction of other living organisms was observed. This results from the very high sensivity of many organisms to the harmful effect of heavy metals, upsetling the biochemical processes (Frieden 1974, Bowen 1966, Riordan, Vallee 1974, Friberg et al. 1974, Arvic, Zimdahl 1974, Price et al. 1972). On the other hand it also results from the ability of bacteria to prevent too great an accumulation of metals in their cells (Silver et al. 1976), or to immobilize them by metal bioaccumulation inside or outside the cells (Tornabene, Edwards 1972, Jones et al. 1976, Chmielowski, Kłapcińska 1984). These properties not only allow the bacteria to survive but also to grow and to develop in environments polluted by metals.

The observed phenomena were fully confirmed in the investigations of phyto- and zoocenoses. For instance, phytoplankton was represented by species typical for polluted waters, sometimes only single specimens occurring (Bucka 1986). Zooplankton was poor with regard to number and species composition. However, at some stations the absence of rotifers and crustaceans was also observed (Żurek 1985). In the communities of microbenthos ciliates typical for the strongly polluted environments occurred, with domination of polysaprobic species (Grabacka unpublished), but the macrofauna was poor in number and species composition (Zięba 1986). As the result of biotest investigations, using *Chlorella pyrenoidosa* Chic., defining the trophic value and the pollution of the water, Bednarz (1985) also found that the waters of the River Brynica basin are relatively pure but in that of the River Mała Panew they are mostly strongly polluted.

6. Polish summary

Bakteriologiczne i chemiczne wskaźniki jakości wód Górnośląskiego Okręgu Przemysłowego (Polska Południowa) w warunkach zanieczyszczeń atmosferycznych i ścieków przemysłowych

W latach 1976—1979, na terenie Górnośląskiego Okręgu Przemysłowego (GOP), przeprowadzono badania bakteriologiczne wód w zlewniach rzeki Brynicy i Małej Pan-

wi, zanieczyszczonych pyłami atmosferycznymi (Brynica) i ściekami przemysłowymi (Mała Panew).

W próbach wody pobieranych na 13 stanowiskach (ryc. 1, tabela I) oznaczono zmiany liczebności kilku grup bakterii o zróżnicowanych zdolnościach biochemicznych (ryc. 2). Określono także stan czystości wód przy zastosowaniu 4-stopniowej klasyfikacji i 10 wskaźników: 5 biologicznych, 5 chemicznych (ryc. 3, 4).

Najmniejszy rozwój mikroflory bakteryjnej stwierdzono w wodzie zbiornika zaporowego Kozłowa Góra (st. 3a, 3d) i jeziora Chechło-Nakło (st. 7). Niewielką liczebnością bakterii charakteryzowały się odcinki śródleśne (st. 1, 8) zanieczyszczone, podobnie jak powyższe zbiorniki wodne, zmywami powierzchniowymi i pyłami emitowanymi do atmosfery przez zakłady przemysłowe GOP-u (ryc. 2).

Bardzo silny rozwój bakterii wystąpił w zlewni Małej Panwi na stanowiskach: 9, 11 i 12, zanieczyszczonych w głównej mierze ściekami odprowadzanymi z licznych zakładów przemysłowych Górnego Śląska (ryc. 2). W Granicznej Wodzie (st. 10) rozwój bakterii był nieco słabszy niż w pozostałych punktach przyjmujących ścieki, co jednak związane było z faktem mniejszego zanieczyszczenia tej rzeki na początku okresu badawczego, a czego nie uwidacznia średnia liczba bakterii, wyliczona dla okresu 1976—1979 (ryc. 2).

Na podstawie średniej wartości LWTZ (Liczbowa Wartość Taksonomiczna Zanieczyszczenia), wyliczonej dla całego okresu badawczego, wszystkie punkty w zlewni Brynicy (poza st. 5) oraz odcinek Małej Panwi (st. 8) i potok Graniczna Woda (st. 10) zaliczono do wód względnie czystych (II klasa czystości) (ryc. 3). Przy czym, jak wykazano na podstawie zmian czystości wody, zanieczyszczenie potoku Graniczna Woda wyraźnie wzrastało z biegiem lat, osiągając w końcowej fazie badań wartości charakterystyczne dla wód silnie zanieczyszczonych (III klasa czystości) (ryc. 4).

Mała Panew (st. 9, 12) i rzeka Stoła (st. 11) charakteryzowały się przez cały okres badań wodą silnie zanieczyszczoną (III klasa czystości) (ryc. 3, 4).

Otrzymane wyniki są zgodne z danymi, które uzyskali inni autorzy w badaniach chemicznych, algologicznych i faunistycznych, prowadzonych w tych samych punktach równolegle z badaniami bakteriologicznymi.

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