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Bakteriologiczna charakterystyka wody Nidy i jej dopływów*

Bacteriological characteristics of water in the River Nida and its tributaries

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Abstract — The bacteriological characteristics of the River Nida and its tributaries was carried out on the basis of a change taking place in the total number of heterotrophic bacteria and some physiological groups — proteolytic, ammonifying, producing hydrogen sulphide, Ist phase nitrifying, and denitrifying bacteria.

Taking into consideration the mean numbers of bacteria for the whole investigation period (1973 to 1975) and the seasonal variations, 3 zones were distinguished in the River Nida: the first — the zone of clean waters, the second — the zone of heavily polluted waters, the third — the self-purification zone.

In the course of the last few decades a permanent deterioration of the surface water quality has been noticed, a result of miscellaneous human activities. It is known at present that investigations the objective of which is estimation of water quality and the degree of water pollution should be based upon ecological parameters, with reference both to biotic and abiotic factors. Under such circumstances only, the causes and the extent of the threatening danger can be found and precautions can be sought for. One of the most instructive factors giving a picture of changes resulting from pollution is the microflora.

Numerous papers have been published concerning the bacteriological characteristics of the water of various rivers, their pollution and self-purification processes. In the Soviet Union Kudrjavcev (1974), Mosevič (1961), Rjabov (1961), Rodina (1964), Rodina Kuzneckaja (1968), were concerned with these problems. In Czecho-

* Praca wykonana w ramach problemu węzłowego 10.2.

slovakia Mucha and Daubner (1966) traced the self-purification processes in the water of the Danube. In India Raj (1964) investigated the pollution degree of the main River Yamuna and confirmed the known phenomenon that bacteria increase in number in water in places of inflow of waste waters rich in organic substances.

In Poland bacteriological investigations on the occurrence of various physiological groups of bacteria in flowing waters were carried out by: Luchterowa (1961, 1962a, 1962b), Luchterowa, Grela (1969), Luchterowa, Michalska (1966), Starzecka (1977). Apart from the total number of heterotrophic bacteria, the authors also took into consideration the occurrence of proteolytic bacteria, titre of bacteria decomposing protein substances, celulosis, and carbohydrates. They were also concerned with denitrification bacteria and nitrate reducing bacteria. Paluch et al. (1956) showed that the water of the River Vistula, even at the springs, is slightly polluted with organic substances, this permitting a more intensive development of bacteria. A considerable deterioration in the bacteriological state of the River Vistula was found, however, as far as below the mouth of the River Bładnica which carries the waste waters from the industrial felt works and the tannery located in the town Skoczów. The occurrence of denitrification, sulphuric, cellulolytic bacteria and bacteria decomposing phenol was described by Cabejszek et al. (1967) and Paluch (1965). Investigations concerning quantitative relations of various morphological groups of bacteria in the waters of five rivers in the vicinity of the town Białystok were carried out by Czeczuga (1960) quoted after Mucha, Daubner (1966). That author found, among others, that the relation of rod bacteria to cocolytic forms is 1 : 53, and testifies to the state of water purity.

As it follows from the published data many authors determine the purity — or the pollution state — of the water according to the changes in the number of bacterioplankton, saprophytic bacteria, and physiological groups of bacteria. The number of bacteria in the rivers varies within a large range and surely depends, among many other factors, to a certain extent also on the content of nutrient salts, and especially of organic compounds in the water and bottom sediments (Keller 1960).

In the years 1973 to 1975 physical, chemical, and biological investigations of the water of the River Nida and its tributaries were carried out in the Laboratory of Water Biology of the Polish Academy of Sciences in Cracow. The choice of the River Nida for these investigations was suggested by its course including sectors differentiated as to the degree of water purity and by the planned building of a dam reservoir in the vicinity of the town Chęciny. Thus, it will be possible to refer the state of purity of the river water registered at present to the changes which will take place in the water after the building of the reservoir is completed.

The object of the present paper was to carry out an ecological characteristics of the water of the catchment area of the River Nida on the basis of changes in the total number of heterotrophic bacteria and of some physiological groups responsible for the basic metabolic processes.

Investigation territory and methods

At an altitude of 190 to 300 m, between the Cracow-and-Silesian Upland and the Kielce Upland there is a lowering of the territory called the syncline of the Nida region, including also the Upland of the town Miechów. This whole territory is drained by the River Nida which takes its beginning from the merger of the Rivers Biała Nida and Czarna Nida (fig. 1).

The River Czarna Nida (its total catchment area 1123 km^2, mean gradient 4‰), develops from the River Belnianka whose springs are in the Świętokrzyskie Mts at an altitude of 490 m (its catchment area is 490 km^2, mean gradient 6.9‰) and of the River Lubrzanka (catchment area 254 km^2, mean gradient 3.5‰) flowing out at an altitude of 360 m and breaking through the mountain range Łysogórze.

In its lower sector the River Czarna Nida takes in a fairly large right-bank tributary: the River Bobrza. The springs of that river are in the Świętokrzyskie Mts at an altitude of 420 m. Its catchment area is 375 km^2 and mean gradient 4.0‰. The lower course of that river is heavily polluted with municipal sewage and industrial waste waters from the town Kielce. Falling into the River Czarna Nida it pollutes heavily its further course and the waters of the River Nida as well.

The River Biała Nida takes its origin from a small pond Moskorzewski and from its springs at an altitude of 270 m. Its catchment area is 1033 km^2, and mean gradient 1.1‰. The main left-bank tributary of the River Biała Nida is the River Łososina („Wierna Rzeka") of a catchment area 312 km^2 taking its origin at an altitude of 130 m. At the foot of the southern mountain range in the Region of the town Chęciny, at the locality of the town Brzegi the waters of the Rivers Biała Nida and Czarna Nida flowing from the East and the West join and further on are known as the River Nida.

Flowing further on from the North to the South the River Nida forms numerous semicircles and windings among the plane territories of the syncline in the Nida region. Before reaching the town Pińczów it takes in a right-bank tributary: the River Mierzawa (catchment area 562 km^2 and mean gradient 1.4‰) whose springs are near the village Brydzyń at an altitude of 280 m. Before the town Nowy Korczyn, near its point of

Ryc. 1. Zlewnia rzeki Nidy. 1—12 stanowiska poboru prób

Fig. 1. Catchment area of the River Nida. 1—12 sampling stations

disgorging into the Vistula it takes in a small left-bank tributary: the River Maskalis. The length of the River Nida, from the springs of the River Czarna Nida is 179 km, its catchment area being 3862 km², and the mean gradient 1.8‰.

The subsoil of the River Czarna Nida is formed mainly of dolomites, limestones, and sandstones (also quartzite ones) of the Devonian and Jurassic Age. These formations are covered with morainic sands, glacial sands, and less frequently with aluvial ones; in larger valleys with peat soils (P a s t e r n a k 1973).

In the catchment area of the River Bobrza similar dolomites and limestones occur in its upper course as well as Triasic red and gray sandstones arranged in a mosaic form with loams and Cambrian gray rocks. The soil cover consists of various kinds of sands.

The subsoil of the River Biała Nida is formed of marls and chalky limestones which are covered with organic river clays on the outcrops of the limy rocks and with muddy peat soils in the valleys. In the upper and lower course of its tributary the River Łososina, sandstones and limestones occur under the sands and muddy peat soils, respectively.

A great part of the subsoil of the catchment area of the River Nida is formed of marls and limestones. These rocks are covered with sandy soils and down from the mouth of the River Mierzawa on the right-bank side of the catchment area with a firm complex of soils formed of loesses. The left-bank part of the catchment area of the River Nida is built, apart from chalky limestones also of Tertiary gypsum superposed with soils which by their character recall fertile sulphate soils (Pasternak 1973).

Investigations were carried out during two years from June 1973 till June 1975. Water samples for bacteriological analysis were collected at 12 sampling stations (fig. 1), at 17 dates in the amount of 150 ml. Sampling was performed with the aid of a batometer with Bowden's flexible connector (Starzecka 1975) at a distance of ± 25 cm from the bottom. The samples, after a proper storing at a temperature of ± 4°C, were brought to the laboratory and inoculated in a sterile way always on the second day following the sampling.

The following was determined in the samples:

1. the total number of heterotrophic bacteria by means of the plate method on an agar substratum prepared on desiccated meat broth (produced by the Warsaw Laboratory of Sera and Vaccines), pH 7.4 ± 0.1, after 7 days long incubation at 22°C;

2. the number of proteolytic bacteria by means of the plate method on a 15 per cent gelatine substratum prepared on desiccated meat broth (produced by the Warsaw Laboratory of Sera and Vaccines), pH 7.0, after 48 hours long incubation at 20°C;

3. the titre of ammonifying bacteria on a nutrient solution with peptone water (1000 ml distilled water, 5 g peptone Difco were boiled for 5 minutes, when hot 1 g K_2HPO_4, 1 g KH_2PO_4, 0.5 g $MgSO_4 \cdot 7 H_2O$, traces of NaCl were added), pH 7.2, after 7 days incubation at 22°C, ammonia was determined with Nesler's reagent;

4. the titre of bacteria producing hydrogen sulphide, on nutrient solution with peptone water using stripes saturated with lead tetraacetate, after 7 days incubation at 22°C.

5. the titre of denitrifying bacteria, on a nutrient solution with glucose (1000 ml distilled water, 1 g KNO_3, 0.5 g K_2HPO_4, 0.5 g NaCl, 10 g glucose), pH 7.2, after 7 days incubation at 22°C; the occurrence of nitrites was detected by use of sulphanilic acid and alpha- naphtylamine;

6. the titre of the Ist phase nitrifying bacteria, on Winogradzki's nutrient solution (2 g $(NH_4)SO_4$, 1 g K_2HPO_4, 0.5 g $MgSO_4 \cdot 7 H_2O$, 2 g

NaCl, 0.4 g $FeSO_4 \cdot 7 H_2O$, 1000 ml distilled water, chalk in the sediment), pH 8.5, presence of nitrous acid salts detected by use of a solution of iodine, zink, starch (R o d i n a 1968), after 30 days incubation in temperature of 22°C.

All the inoculations were carried out in parallel repetitions the results being given in terms of the arythmetical mean.

The value of the titre was calculated into number using McCradye's statistical tables (C o l l i n s 1970, R o d i n a 1968).

Results

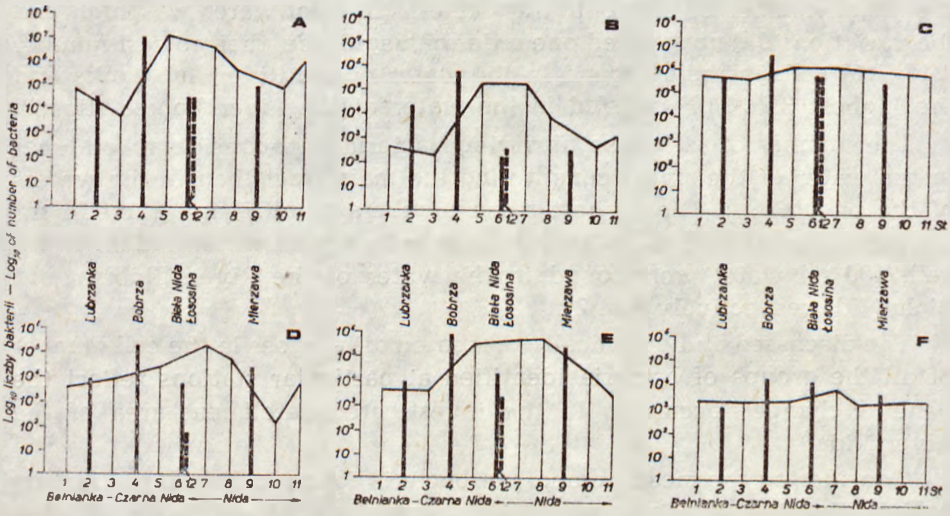
Bacteriological characteristics of the water in the River Nida and its tributaries.

Changes in the total number of heterotrophic bacteria and in the number of particular physiological groups (proteolytic bacteria, ammonifying bacteria, bacteria producing H_2S, Ist phase nitrifying bacteria, and denitrifying ones) in the water of the River Nida and its tributaries are shown in fig. 2.

For better illustration of the changes taking place in the number of bacteria in the investigated catchment area of the River Nida the main tract of the rivers was determined. These were the River Belnianka (st. 1), the upper course of the River Czarna Nida (st. 3), the lower course of the River Czarna Nida (st. 5), the upper and middle course of the River Nida (st. 7, 8), and the lower course of the River Nida (st. 10, 11). Changes in the number of the investigated groups of bacteria in the water at the above mentioned stations were presented with a continuous line. The other stations: 2, 4, 6, 9, and 12 as tributaries of the appointed tract of rivers were shown in the diagrams in columns, their location in the catchment area of the River Nida being preserved (fig. 1). The River Belnianka was included into the main tract of the rivers in view of the fact that the River Czarna Nida originates from its bed.

During the investigation period in the years 1973—1975 the highest total mean number of heterotrophic bacteria equaling 9.1×10^6 cells/ml water was found in the water of the River Bobrza.

In comparison with the number of heterotrophs in the water of the River Czarna Nida at the locality Morawica (above the waste water discharge point) this number was over 2000 times higher. A lower number relation was found in the waters of the Rivers Belnianka, Lubrzanka, Biała Nida, Łososina, and Mierzawa in which the content of heterotrophic bacteria was in relation to the number in the waters of the River Bobrza 100 to 500 times lower. In the River Czarna Nida, at the village Tokarnia (st. 5) the number of heterotrophic bacteria remained on the same level as in the River Bobrza, whereas at the town Brzegi (st. 7) it was only 2 times lower and equaled 5.0×10^6 cells/ml water. A further twenty-five times greater decrease in the number of heterotrophs to 3.6×10^5 cells/ml water was recorded at the town Motkowice (st. 8), whereas evident differences appeared only in the lower course of the River Nida at the locality of the town Chroberz (st. 10). The mean number of heterotrophs was there 5.1×10^4 cells/ml water and was over 170 times lower than the number of bacteria in the water of the River Bobrza. In that region the decrease in the number of bacteria results not only from the self-purification processes but also from dilution in consequence of an inflow of clean waters of the River Mierzawa in which the mean number of heterotrophs was 3.9×10^3 cells/ml water. Along the sector between



Ryc. 2. Średnia liczebność bakterii w wodzie rzeki Nidy i jej dopływów na poszczególnych stanowiskach (1—12) w latach 1973—1975. Liczbę bakterii podano w 1 ml wody. Wskaźnik bakterii nitryfikacyjnych podano w 100 ml wody. A — ogólna liczba bakterii heterotroficznych; B — liczba bakterii proteolitycznych; C — liczba bakterii amonifikacyjnych; D — liczba bakterii wydzielających H_2S; E — liczba bakterii denitryfikacyjnych; F — wskaźnik bakterii nitryfikacyjnych. St. — stanowiska

Fig. 2. Mean number of bacteria in the water of the River Nida and its tributaries at particular stations (1—12) in the years 1973—1975. The number of bacteria was given in 1 ml water. The index of nitrifying bacteria was given in 100 ml water. A — total number of heterotrophic bacteria; B — number of proteolytic bacteria; C — number of ammonifying bacteria; D — number of bacteria producing H_2S; E — number of denitrifying bacteria; F — index of nitrifying bacteria. St. — stations

the towns Chroberz and Nowy Korczyn (st. 11) a sevenfold increase in the number of heterotrophs to 3.9×10^5 cells/ml water was noted (fig. 2) in consequence of an inflow of fresh portions of waste waters.

Very similar quantitative changes were found in the group of proteolytic, hydrogen sulphide producing, and denitrifying bacteria. Below the mouth of the River Bobrza, in the lower course of the River Czarna Nida (st. 5) the number of those bacteria increased from 1 to 3 orders of magnitude, while a marked decrease was found as far as in the middle and lower sector of the River Nida at the towns Motkowice (st. 8) and Chroberz (st. 10). At the town Nowy Korczyn, similarly as in the case of the total number of heterotrophic bacteria, an increase in the number of proteolytic bacteria and hydrogen sulphide producing bacteria (fig. 2) was observed.

On the other hand, ammonifying bacteria were characterized by the smallest variations in the cell number both in the water of the main tract of the rivers and of their tributaries. At each of the investigated stations the mean number of ammonifying bacteria in 1 ml water was high and the variations did not exceed one order of magnitude, their lowest number 3.4×10^5 cells/ml being found in the water of the River Lubrzanka and the highest 3.2×10^6 cells/ml in the water of the River Bobrza (fig. 2).

The number of Ist phase nitrifying bacteria was considerably higher in the water of the rivers constituting the main tract than in the waters of the tributaries. The highest mean numbers of nitrifying bacteria for the whole investigation period 1.3×10^4 cells/100 ml water and 9.1×10^3 cells/100 ml water were found in the water of the Rivers Bobrza and Biała Nida respectively (fig. 2).

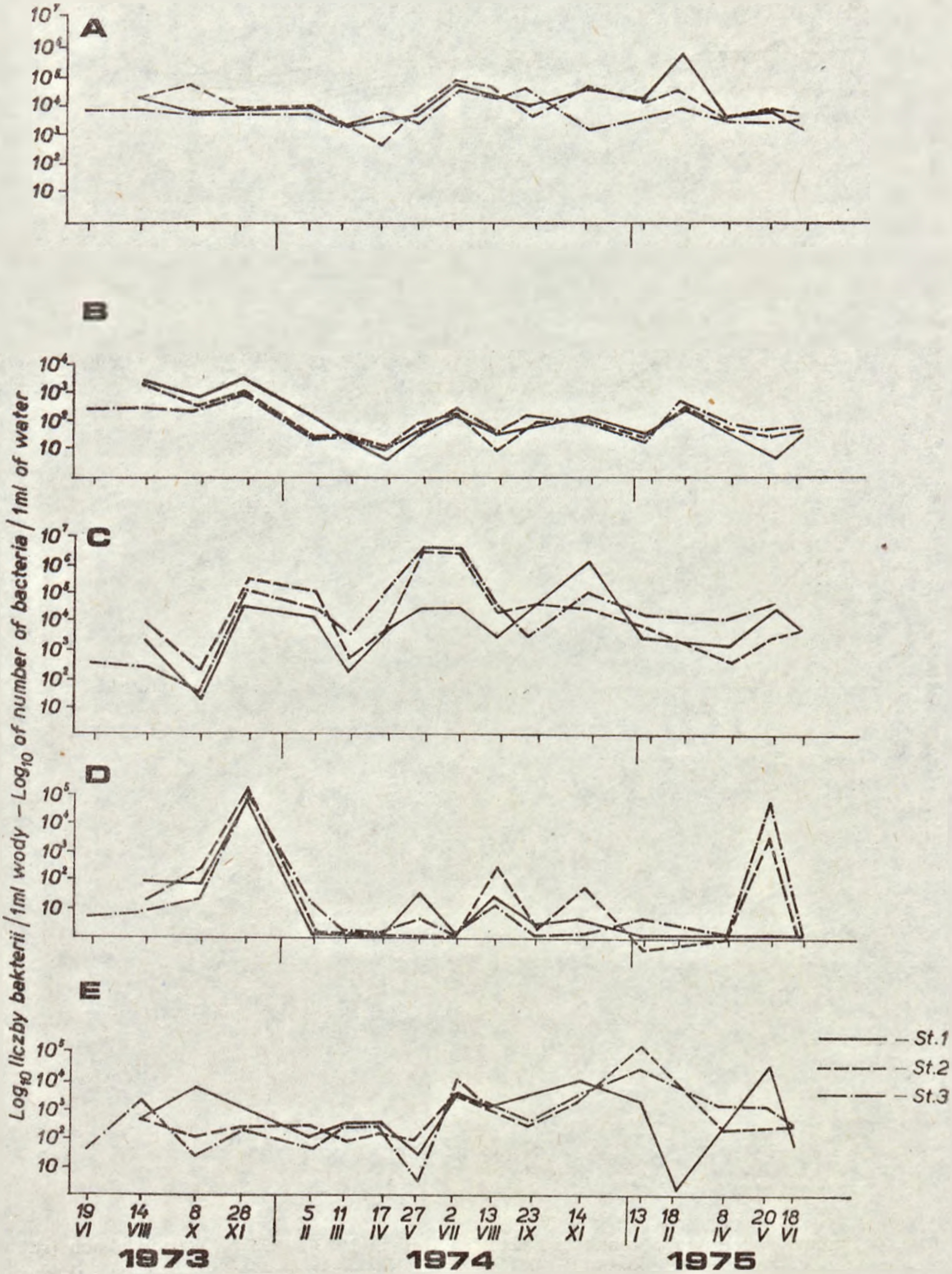
The discussed and graphically presented differences in the cell number of all the groups of bacteria identified at particular stations reflect the general changes occurring in the investigated catchment area of the River Nida.

Considering the mean numbers of bacteria for the whole investigation period (fig. 2) and basing upon the seasonal variations in the number of the bacterial microflora (figs 3, 4, 5) three sectors can be distinguished in the main tract of the rivers:

The first — the River Belnianka and the upper part of the River Czarna Nida (st. 1, 3, figs 2, 3) is characterized by a relatively clean water.

The second sector is the zone of highest pollution, below the mouth of the River Bobrza. It includes the lower course of the Czarna Nida (st. 5) and the upper sector of the proper River Nida (st. 7, figs 2, 4).

The third sector includes the middle and lower course of the River Nida in the region of the town Motkowice (st. 8) and in the region of the towns Chroberz and Nowy Korczyn (st. 10, 11, figs 2, 5). This is the zone of self-purification.



Ryc. 3. Zmiany sezonowe liczebności bakterii w latach 1973—1975 na stanowiskach (st.) 1, 2, 3 (odcinek I). A — ogólna liczba bakterii heterotroficznych; B — liczba bakterii proteolitycznych; C — liczba bakterii amonifikacyjnych; D — liczba bakterii wydzielających H_2S; E — liczba bakterii denitryfikacyjnych

Fig. 3. Seasonal variations in the number of bacteria in the years 1973—1975 at stations (st.) 1, 2, 3 (sector I). A — total number of heterotrophic bacteria; B — number of proteolytic bacteria; C — number of ammonifying bacteria; D — number of bacteria producing H_2S; E — number of denitrifying bacteria

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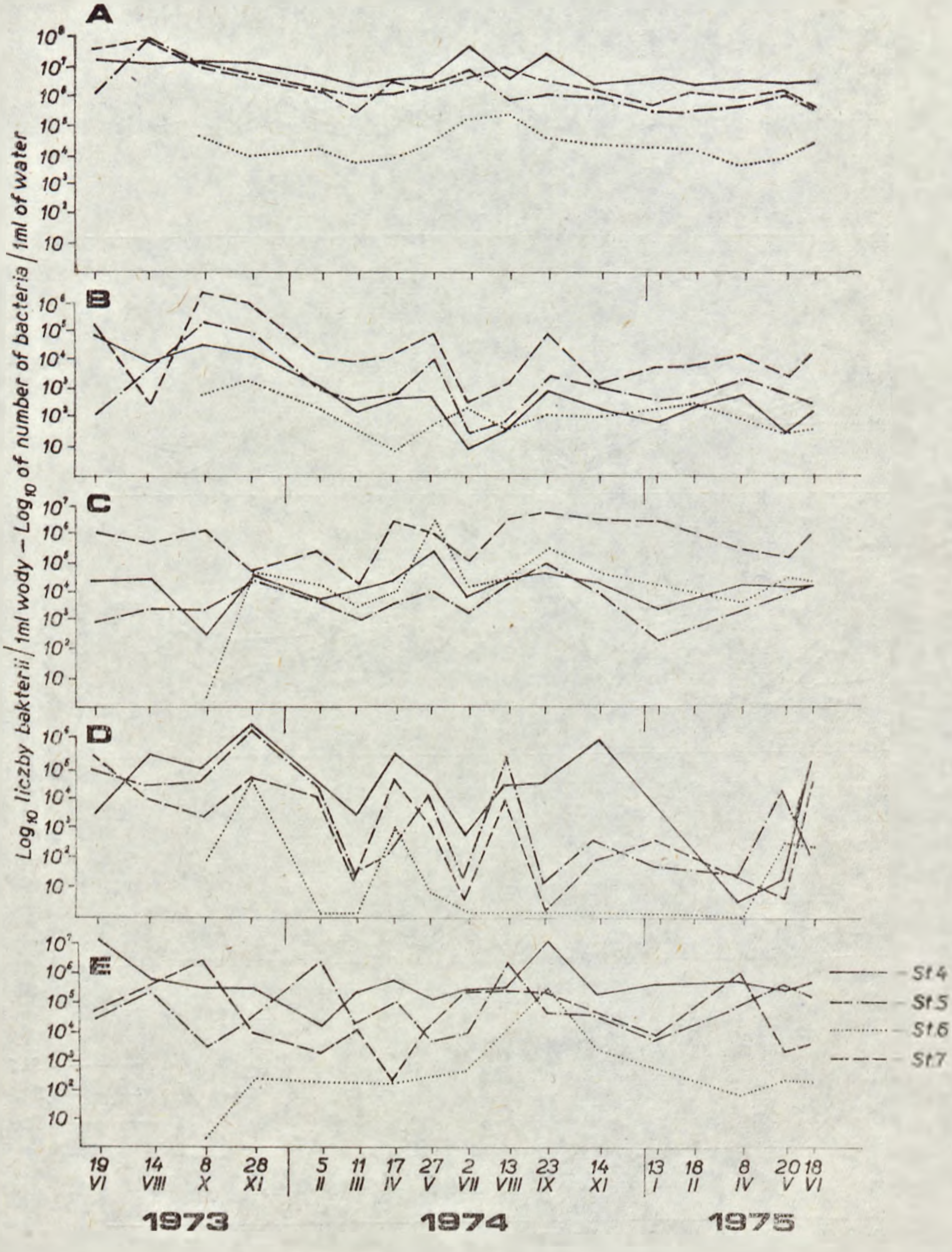
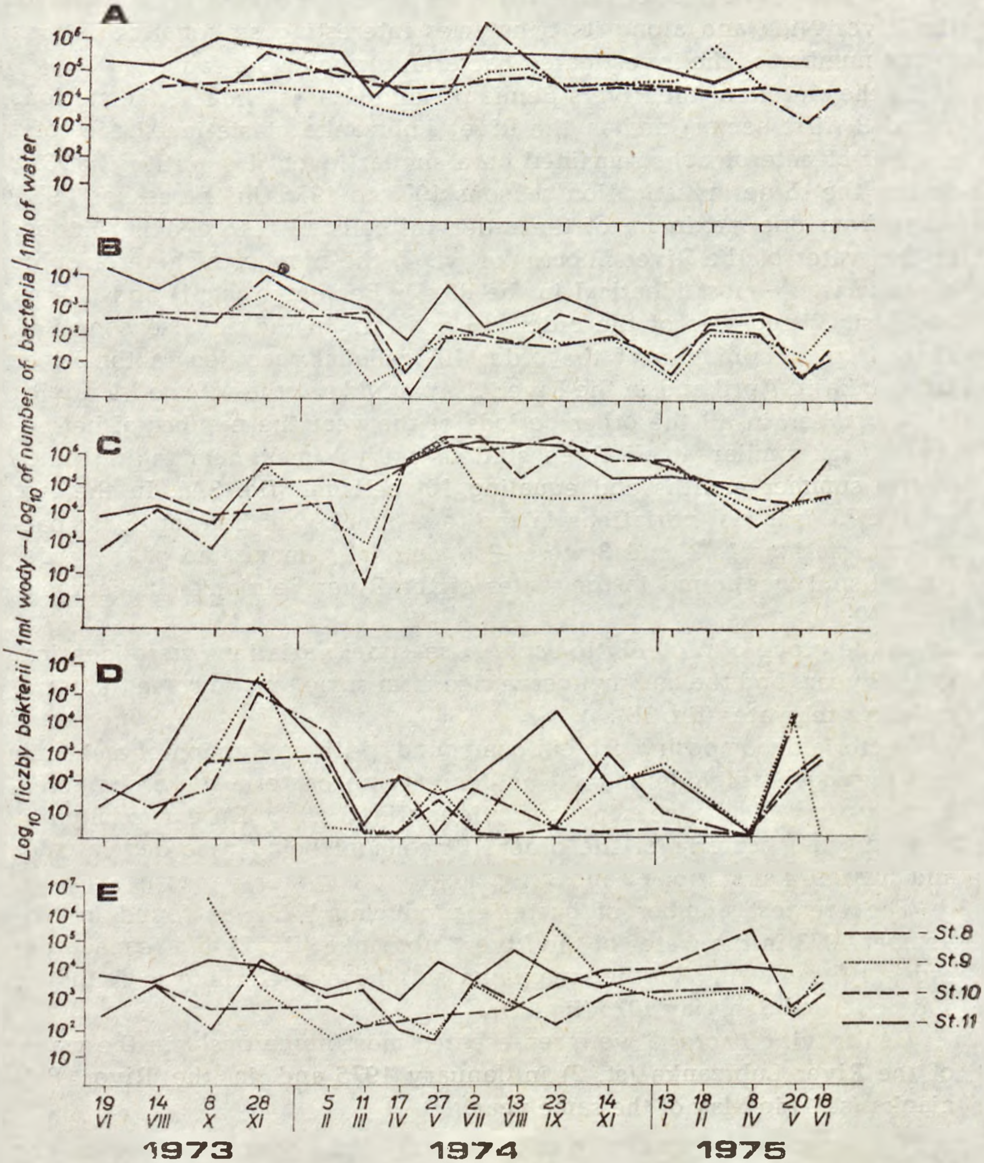


Ryc. 4. Zmiany sezonowe liczebności bakterii w latach 1973—1975 na stanowiskach (st.) 4, 5, 7 i 6 (odcinek II). A — ogólna liczba bakterii heterotroficznych; B — liczba bakterii proteolitycznych; C — liczba bakterii amonifikacyjnych; D — liczba bakterii wydzielających H_2S; E — liczba bakterii denitryfikacyjnych

Fig. 4. Seasonal variations in the number of bacteria in the years 1973—1975 at stations (st.) 4, 5, 7, and 6 (sector II). A — total number of heterotrophic bacteria; B — number of proteolytic bacteria; C — number of ammonifying bacteria; D — number of bacteria producing H_2S; E — number of denitrifying bacteria



Ryc. 5. Zmiany sezonowe liczebności bakterii w latach 1973—1975 na stanowiskach (st.) 8, 10, 11 i 9 (odcinek III). A — ogólna liczba bakterii heterotroficznych; B — liczba bakterii proteolitycznych; C — liczba bakterii amonifikacyjnych; D — liczba bakterii wydzielających H_2S; E — liczba bakterii denitryfikacyjnych

Fig. 5. Seasonal variations in the number of bacteria in the years 1973—1975 at stations (st.) 8, 10, 11, and 9 (sector III). A — total number of heterotrophic bacteria; B — number of proteolytic bacteria; C — number of ammonifying bacteria; D — number of bacteria producing H_2S; E — number of denitrifying bacteria

Comparing the stations located along the three separate sectors of the River Nida and along its tributaries interesting seasonal variations in the number of the investigated bacterial groups were found.

In the waters of the Rivers Belnianka and Czarna Nida at the stations 1 and 3 (first sector) and in the River Lubrzanka at station 2 the total number of heterotrophs remained on a similar level of quantity (fig. 3A) during the three investigation seasons 1973 to 1975. In the season 1973, apart from one maximum of the order 10^4 cells/ml recorded in October in the water of the River Lubrzanka (st. 2) the number of heterotrophic bacteria was almost identical in the Rivers Belnianka (st. 1) and Czarna Nida (st. 3) and was of the order 10^3 cells/ml. In the next season 1974, apart from a minimum of the order 10^2 cells/ml recorded in the River Lubrzanka in April and in the River Czarna Nida at the village Morawica in November, in all the other periods of the year the number of heterotrophs was similar at all three stations with a maximum taking place in the summer months and equaling 10^4 cells/ml (fig. 3A). In the last year 1975 seasonal variations in the total number of heterotrophic bacteria at stations 1, 2, and 3 were also similar. A maximum of the order 10^5 cells/ml was found in the water of the River Belnianka in February (fig. 3A).

In the group of proteolytic bacteria seasonal variations were identical in all 3 years and the cell number varied from some tens to some thousand cells in 1 ml water (fig. 3B).

Bacteria decomposing protein compounds with production of ammonia and hydrogen sulphide as well as denitrifying bacteria were characterized by very similar seasonal variations (fig. 3 C, D, E); a maximum of ammonifying bacteria of the order 10^6 cells/ml being recorded in May and July 1974 at stations 2 and 3 (fig. 3C).

The greatest number of bacteria producing H_2S was found in November 1973 in the water of the River Lubrzanka (fig. 2) and reached the order 10^5 cells/ml. Another maximum of these bacteria was found at stations 2 and 3 in May 1975 (fig. 3D).

Denitrifying bacteria were represented most numerously in the water of the River Lubrzanka (st. 2) in January 1975 and in the River Belnianka (st. 1) in May of the same year.

Two marked minima of denitrifying bacteria were recorded in the waters of the River Czarna Nida at the village Morawica (st. 3) and in the River Belnianka (st. 1) in May 1974 and in February 1975 respectively. In the other periods the number of these bacteria was similar at stations 1, 2, and 3 with the exception of October 1973 when in the water of the River Belnianka the number of denitrifiers was higher by about 1 to 2 orders of magnitude in comparison with the water of the Rivers Lubrzanka (st. 2) and Czarna Nida (st. 3) (fig. 3E).

In the second sector, in the zone of heaviest pollution at stations 4, 5, and 7 the number of the total group of heterotrophic bacteria remained on a more or less equal level of the order 10^6 to 10^7 cells/ml and during the whole investigation period no important seasonal differences were found. It is characteristic that in spite of taking in clean waters of the River Biała Nida (st. 6) in which the total number of heterotrophic bacteria was as a rule by 2 orders of magnitude lower, no evident decrease in the number of those bacteria was found at station 7 in the River Nida at the locality of the town Brzegi (figs 2, 4A).

In the other identified groups of bacteria seasonal variations at the stations 4, 5, and 7 were similar. The greatest differences in number were found with regard to H_2S producing bacteria in November 1974 when their number in the water of the River Bobrza was about 3 to 4 orders of magnitude higher than that in the Rivers Czarna Nida (st. 5) and the Nida (st. 7); whereas, in comparison with the River Biała Nida this difference reached up to 6 orders of magnitude.

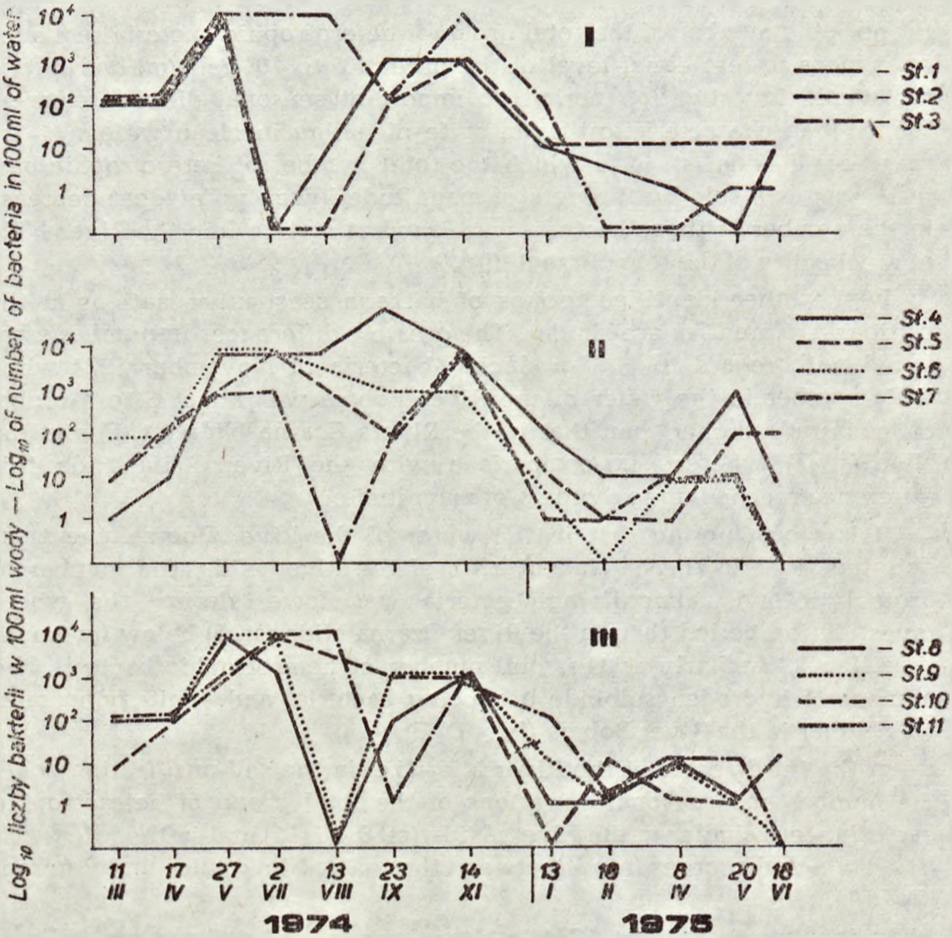
It is worth noting that in the water of the River Bobrza, the most polluted river in the catchment area of the River Nida, the number of proteolytic and ammonifying bacteria was lower during the whole investigation period than in the River Czarna Nida (st. 5) below its mouth (fig. 4B, C). Similarly as the total number of heterotrophic bacteria, the number of hydrogen sulphide producing bacteria, and denitrifying ones was higher in the River Bobrza (fig. 4D, E).

In the third sector of the River Nida, i.e. in the self-purification zone, the number and seasonal variations of the total group of heterotrophic bacteria were similar in the Rivers Nida (st. 8, 10, 11) and in the Mierzawa (st. 9) which disgorges into it between the towns Motkowice and Pińczów (fig. 5A).

In the summer season 1974 two maxima of the total number of heterotrophic bacteria were found in the water of the River Nida at station 11 and in February 1975 in the water of the River Mierzawa (st. 9). In comparison with station 8 at the town Motkowice and station 10 at the locality of the town Chroberz these maxima were 1 to 2 orders of magnitude greater (fig. 5A).

In the other groups of bacteria seasonal variations were similar (fig. 4B, C, D, E). In the same sector greater differences in the shift in time of maxima and minima were noted in the group of bacteria decomposing protein compounds with production of hydrogen sulphide and in denitrifiers.

It is worth noting that the number of bacteria in the water of the River Mierzawa is during some seasons of the year on the same level as that observed in the water of the River Nida in the region of the town Motkowice (st. 8) or even exceeds it; this was clearly seen in the groups of bacteria producing hydrogen sulphide (28th November 1973, 27th May



Ryc. 6. Wskaźnik bakterii nitryfikacyjnych I fazy w latach 1974—1975 na stanowiskach (st.) 1—11 i dopływach trzech odcinków. I — odcinek pierwszy; II — odcinek drugi; III — odcinek trzeci

Fig. 6. Index of Ist phase nitrifying bacteria in the years 1974—1975 at stations (st.) 1—11 and in the tributaries of three sectors. I — first sector; II — second sector; III — third sector

1974, 13th January 1975) and in the denitrifying bacteria (8th October 1973, 13th September 1974).

Upon analysing the findings for particular dates it can be said that the lowest number of bacteria was found in the waters of the region situated closest to the spring zone (st. 1, 2, 3). There, too, the seasonal variations were the most consistent, both in the whole group of heterotrophic bacteria and in particular physiological groups (fig. 3).

In the second sector, below the mouth of the River Bobrza, the greatest consistency in seasonal variations was reached in the total number of

Tabela I. Zmiany liczebności bakterii w rzece Łososinie (stanowisko 12)

Table I. Changes in the number of bacteria in the Łososina River (station 12)

Data poboru prób Date of sampling	Liczba komórek w 1 ml wody - Number of cells in 1 ml of water				
	Ogólna grupa bakterii heterotroficznych General group of heterotrophic bacteria	Bakterie proteolityczne Proteolytic bacteria	Bakterie amonifikacyjne Ammonifying bacteria	Bakterie wydzielające H_2S H_2S producing bacteria	Bakterie denitryfikacyjne Denitrifying bacteria
19.VI. 1973	$2.4 \cdot 10^3$	$3.0 \cdot 10^2$	$9.5 \cdot 10$	$4.5 \cdot 10^2$	$4.5 \cdot 10$
14.VIII. 1973	$2.7 \cdot 10^4$	$1.2 \cdot 10^3$	$0.5 \cdot 10^3$	$1.5 \cdot 10^2$	$2.5 \cdot 10^3$
2.VII. 1974	$1.0 \cdot 10^5$	$4.3 \cdot 10^2$	$2.5 \cdot 10^6$	$0.7 \cdot 10$	$0.5 \cdot 10^2$
23.IX. 1974	$1.6 \cdot 10^4$	$1.9 \cdot 10^2$	$1.5 \cdot 10^4$	-	$6.5 \cdot 10^2$
14.XI. 1974	$9.6 \cdot 10^3$	$2.5 \cdot 10$	$4.0 \cdot 10^3$	$0.4 \cdot 10$	$4.5 \cdot 10^3$

heterotrophic bacteria and in the group of proteolytic and ammonifying bacteria. Whereas, bacteria producing hydrogen sulhpide and to a greater extent the denitrifying bacteria were characterized by greater variations and a greater shift in time of particular number maxima and minima at particular stations (fig. 4).

In the third sector, covering the self-purification zone, the agreement in seasonal variations was better, more significant variations in the number of bacteria and in the shifts in time of maxima and minima being found also in the group of bacteria responsible for the decomposition of protein substances with production of H_2S and for denitrification processes (fig. 5).

Seasonal variations in nitrifying bacteria of the Ist phase were similar in the sector of clean waters (fig. 6 I) as well as in the heavily polluted ones (fig. 6 II) and in the self-purification zone (fig. 6 III). Overlooking exceptional situations when no nitrifying bacteria of the Ist phase were found in the investigated samples, it may be generally said that the maximum values (about 10.000 and more) of the index of these bacteria were noted in the spring. summer and autumn months (from May till November 1974), whereas a marked decrease and smaller variations in the index were found in all three sectors in the winter and early spring months in 1975.

In view of the low number of the samplings (only 5 dates during the whole investigation period 1973 to 1975) seasonal variations concerning the number of particular groups of bacteria at station 12, located on the River Łososina (a left-bank tributary of the River Biała Nida), were not discussed in the present paper. On the basis of the obtained data (Table I) it may be only stated that the total number of heterotrophic bacteria varied there from 10^3 to 10^4 cells/ml water. Among the physiological groups of bacteria the greatest numbers were found in the case of ammonifying bacteria (from 10^2 to 10^6 cells/ml) while the lowest numbers in the case of bacteria decomposing protein compounds with production of hydrogen sulphide (from 0 to 10^2 cells/ml).

Discussion

Various relations between the density of the population of microorganisms, intensity of their development, and concentration of nutrient compounds in the natural environment are complex and depend evidently on one another. Determination, however, of growth kinetics is very useful and expresses the dynamical character of microorganisms. Hence, on the basis of the quantitative changes in some physiological groups of bacteria responsible for specific metabolic processes, the quality of the water of the River Nida and of its tributaries was characterized as the outcome of a complex influence of various factors co-modifying its environment.

Taking into consideration the mean numbers of bacteria for the whole investigation period and basing upon seasonal variations in the number of the bacterial microflora in the main tracts of the rivers (the Rivers Belnianka, Czarna Nida, Nida) three sectors were distinguished.

The first — the River Belnianka and the upper sector of the River Czarna Nida is characterized by relatively clean waters, with a great amount of dissolved oxygen (8.0 to 13.0 O_2 mg/dcm^3), low oxidability (2.4 to 7.4 O_2 mg/dcm^3), low BOD_5 (0.0 to 0.2 O_2 mg/dcm^3), and low content of chlorides (8.0 to 14.0 mg/dcm^3), potassium (2.2 to 3.2 mg/dcm^3), and sodium (0.0 to 0.9 mg/dcm^3) (Pasternak, Starzecka 1979). Though the total number of heterotrophic bacteria undergoes there fairly great variations during the year, yet in the majority of cases it equals some thousand cells in 1 ml water. Among the physiological groups of bacteria the most numerous ones are the ammonifying bacteria whose number in the spring-summer period reaches some million cells in 1 ml water. This abundant development of ammonifying bacteria is most probably stimulated by protein substances which are supplied by the algae decayed after blooming and by relicts of higher vegetation occurring frequently in the river bed.

The second sector — the lower course of the River Czarna Nida and the upper course of the River Nida is the zone of the heaviest pollution. Below the heavily polluted River Bobrza whose water is characterized by a low content of dissloved oxygen (0.0 to 10.9 O_2 mg/dcm^3) great oxidability (6.3 to 34.7 O_2 mg/dcm^3) considerable content of chlorides (15.0 to

59.0 mg/dcm^3) and of nutrient compounds (Pasternak, Starzecka 1979). The water quality in the lower sector of the River Czarna Nida undergoes marked deterioration. The content of oxygen dissolved in the water decreases several times. The total hardness increases, as does also the content of organic pollution indices and the content of calcium, potassium, and manganese ions (Pasternak, Starzecka 1979). According to Pasternak (1973) in the water of that sector of the River Czarna Nida the concentration of microelements such as Zn, Cr, Mn, Pb, whose toxicity is lessened by considerable buffering and hardness of the water of the River Czarna Nida, increases as well. The total number of heterotrophic bacteria increases there markedly in relation to the waters of the upper sector of the River Czarna Nida and usually varies from some to some tens million cells in 1 ml water. In the physiological groups of bacteria the number of cells is also higher than in the upper sector of the River Czarna Nida. Greatest variations occur in the group of proteolytic and denitrifying bacteria. In spite of the self-purification processes and intake of clean waters of the River Biała Nida along with the River Łososina, the upper sector of the proper River Nida is further on characterized by waters heavily polluted, with great amounts of bacteria whose development is promoted by an abundance of organic substances and macroelements. The concentration of microelements, except strontium and barium, decreases there, most probably in consequence of their low content in the water of the River Biała Nida disgorging into it (Pasternak 1973).

The third sector is the self-purification zone. In the middle course of the River Nida (town Motkowice) the water quality improves in consequence of self-purification. A marked improvement is observed in the oxygen conditions (5.3 to 14.2 O_2 mg/dcm^3); the oxidability decreases (2.6 to 15.7 O_2 mg/dcm^3). A decrease is also observed in the content of manganese (5.2 to 13.9 mg/dcm^3), potassium (2.0 to 6.6 mg/dcm^3), phosphates (0.1 to 1.3 mg/dcm^3), and chlorides (13.3 to 20.5 mg/dcm^3) Pasternak, Starzecka 1979).

The number of all the investigated groups of bacteria decreases on the average by 2 orders of magnitude, but, nevertheless it still remains on a level between some tens to some hundred thousand cells in 1 ml water. In spite of a rather small change in the chemical composition of the water of the River Nida some improvement of the quality of the water takes place in the further course of the River Nida below the mouth of the relatively clean River Mierzawa. According to Pasternak (1973) in that sector of the River Nida the concentration of some microelements, especially zink, copper, and lead decreases at a greater extent. Better oxygen conditions in that region of the river are conducive to more intensive self-purification processes which is reflected in a marked decrease in the total number of heterotrophic bacteria to some tens thousand cells in 1 ml water and in the number of the investigated groups of bacteria. As a result of an inflow of fresh portions of waste water, occurring between the towns Pińczów and Nowy Korczyn, an increase in oxidability and in the concentration of chlorides, sodium, sulphites, and calcium (Pasternak, Starzecka 1979) is noticeable in the zone close to the mouth of the River Nida. Another increase in the total number of heterotrophic, proteolytic, and hydrogen sulphide producing bacteria takes place. Among the microelements, the concentration of zink, chromium, cobalt, and cadmium increases in the zone close to the mouth (Pasternak 1973).

The bacteriological characteristics of the River Nida and its tributaries as well as the data concerning the chemical composition of the water seem to point, to a certain extent, to the formation of several open, in a sense balanced but differing from one another ecosystems with the course of the river. The bacteria living in those ecosystems, their development, and distribution confirm the variety of relations prevailing in the determined sectors of the River Nida and its tributaries. This variety results from amassement of processes to which inflow of fresh water, waste water discharge, the phenomena of water self-purification processes and the properties of the catchment area can be included.

The most balanced ecosystem is represented by the Rivers Belnianka, Lubrzanka, and the upper course of the River Czarna Nida. It is a territory lying closest to the spring zone. A fairly balanced chemical composition of the water and lack of influencial sources of pollution with organic compounds are conducive to the retainment of the total number of heterotrophic bacteria on an almost equal level during the whole investigation period, if we disregard the particular maxima and minima connected with natural seasonal variations.

An ecosystem largely disturbed is found in the lower sector of the River Czarna Nida and the upper course of the River Nida. The inflow of waste waters carried by the River Bobrza changed entirely the relations prevailing in the zone closest to the springs. The abundance of organic substances was conducive to the development of bacteria whose number underwent marked variations in all the investigated groups.

Beginning from the middle course of the River Nida a gradual normalization of the ecological relations was noticeable. In consequence of the self-purification processes and inflow of cleaner waters of the River Mierzawa a slow decrease in the bacteria took place proving that the abundance of nutrient compounds in the water was decreasing. Nevertheless, in that ecosystem fairly great variations in the number of bacteria, especially in the course near the mouth of the River Nida, still occurred because of fresh portions of waste waters flowing in between the towns Pińczów and Nowy Korczyn.

STRESZCZENIE

W latach 1973—1975 przeprowadzono badania bakteriologiczne wody Nidy i jej dopływów.

Próby do badań pobrano w 17 terminach na 12 stanowiskach. Oznaczono ogólną liczbę bakterii heterotroficznych, liczbę bakterii proteolitycznych oraz liczby kilku grup fizjologicznych, odpowiedzialnych za przeprowadzanie określonych procesów metabolicznych, jak: amonifikacja, rozkład substancji białkowych z wydzieleniem H_2S, nitryfikacja I fazy i denitryfikacja.

Opierając się na zmianach liczebności mikroflory bakteryjnej przedstawiono ogólny obraz zmian zachodzących w wodzie Nidy i jej dopływów.

Na podstawie średnich liczb bakterii za cały okres badań (1973—1975), jak również zmian sezonowych (w poszczególnych latach), w Nidzie wyróżniono trzy odcinki. Pierwszy, położony najbliżej strefy przyźródłowej, charakteryzują wody względnie czyste, z małą liczebnością bakterii rzędu 10^3 komórek/ml. Drugi odcinek, obejmujący dolny odcinek Czarnej Nidy i górny bieg Nidy (poniżej ujścia silnie zanieczyszczonej rzeki Bobrzy), to strefa największego zanieczyszczenia. Ogólna liczba bakterii heterotroficznych osiąga tutaj rząd 10^6—10^7 komórek/ml i tym samym potwierdza obecność w wodzie dużych ilości substancji organicznych, sprzyjających ich rozwojowi. I wreszcie trzeci odcinek, obejmujący środkowy, dolny i przyujściowy bieg Nidy, stanowi strefę samooczyszczania, w której obserwuje się wyraźny spadek liczebności bakterii, wskazujący na poprawę jakości wody.

Potwierdzające się w okresie dwóch lat stosunki panujące w poszczególnych odcinkach Nidy wskazują, że mamy tu do czynienia z trzema połączonymi ze sobą ekosystemami, różniącymi się między sobą troficznością.

REFERENCES

C a b e j s z e k I., B. G a w r y c h, J. Ł u c z a k, J. M a l e s z e w s k a, C. S i k o r o w s k a, J. S t a n i s ł a w s k a, 1967. Stan higieniczno-sanitarny rzeki Wisły w rejonie Płocka w 1966 r. Gaz, Woda, Techn. Sanit., 41, 58—62.

C o l l i n s C. H., P. M. L y n e, 1970. Microbiological methods. London, Butterworths.

K e l l e r G., 1960. Bacteriological aspects of pollution in the Juskei-Crocodile river system in the Transval, South Africa. Hydrobiol., 14, 205—256.

K u d r j a v c e v V. M., 1974. Produkcija fitoplanktona, destrukcija organičeskogo veščestva i čislennost bakterii v Volge i ee vodochraniliščach (ijul 1969). Trudy Inst. Biol. Vnutr. Vod, 28 (31), 19—27.

L u c h t e r o w a A., 1961. Z badań nad biocenozą bakteryjną rzeki Wisły. 5 Zjazd Hydrobiol. Pol. w Gdańsku. Streszcz. Ref., 77—78.

L u c h t e r o w a A., 1962a. Zespół bakteryjny potoku Wielka Puszcza — Bacterial association of the Wielka Puszcza stream. Acta Hydrobiol., 4, 21—28.

L u c h t e r o w a A., 1962b. Niektóre zespoły bakteryjne rzeki Wisły w rejonie Płocka. Roczn. PZH, 13, 245—253.

L u c h t e r o w a A., J. G r e l a, 1969. Zespoły bakteryjne Małej Wisły w rejonie Czechowic — Bacterial associations of the Mała Wisła river in the region of Czechowice. Acta Hydrobiol., 11, 273—283.

L u c h t e r o w a A., D. M i c h a l s k a, 1966. Bakteryjne zespoły w rzece Wiśle — Bacterial associations of the Vistula. Acta Microbiol. Pol., 15, 187—192.

Mosevič M. V., 1961. Vlijanie stočnych vod nekotorych vidov promyslennosti na mikrobiologičeskie procesy v vodoemach. Trudy Soveśč. Komisji Ak. Nauk SSSR, 10, 87—91.

Mucha V., Daubner, 1966. Hydromikrobiologie československého úseku Dunaja (w — in: Mucha V. (red.) — Limnológia československého úseku Dunaja. Bratislava, Slov. Ak. Vied), 182—217.

Paluch J., 1965. Microflora of the river polluted with cellulose and papee mill waste waters. Acta Microbiol. Pol., 24, 327—336.

Paluch J., S. Radecka, J. Filipowicz, 1956. Stan sanitarny górnego biegu Wisły i jej dopływów oraz terenu zalewu w Goczałkowicach — Der bakteriologische Zustand der Oberlaufes der Wisła und ihrer Nebenflüsse, sowie des zu überflutenden Gebietes bei Goczałkowice. Acta Microbiol. Pol., 5, 187—196.

Pasternak K., 1973. Występowanie i zmienność mikroelementów w wodzie w podłużnym przekroju rzeki Nidy — The occurrence and variability of microelements in the water in the longitudinal section of the river Nida. Acta Hydrobiol., 15, 357—378.

Pasternak K., A. Starzecka, 1979. Chemizm wody rzeki Nidy i niektóre relacje z bakteriologicznymi jej cechami — Chemism of the River Nida water and some relations between its bacteriological and chemical features. Acta Hydrobiol., 21, 361—395.

Raj H., 1964. The bacteriological studies on the Yamuna river (Delhi, India). Sb. Vys. Školy Chem. Techn. w Praze, Techn. Wody, 8, 1.

Rjabov F. P., 1961. Mikrobiologičeskaja charakteristika verchnej časti Kachovskogo vodochranilišča v svjazi s zagrazneniem ego stočnymi vodami. Trudy Soveśč. Ichtiol. Komisji Ak. Nauk SSSR, 10, 96—98.

Rodina A. G., 1964. Mikrobiologičeskie issledovanija reki Oki. Zagraznenie i samoočiščenie reki Oki. Trudy Zool. Inst., 32, 52—80.

Rodina A. G., 1968. Mikrobiologiczne metody badania wód. Warszawa, PWRiL.

Rodina A. G., H. K. Kuzneckaja, 1968. Zagraznenie i samoočiščenie reki Nevy. Čislennost bakterioplanktona v reke Neve i ee pritokach. Trudy Zool. Inst., 45, 117—166.

Starzecka A., 1975. Nowy typ batometru z cięgnem giętkim Bowdena. Wiad. Bot., 19, 243—246.

Starzecka A., 1977. Biocenoza potoku wysokogórskiego pozostającego pod wpływem turystyki. 2. Bakterie jako wskaźnik zanieczyszczenia wody Rybiego Potoku — Biocenosis of a high-mountain stream under the influence of tourism. 2. Bacteria as an index of pollution of the Rybi Potok stream. Acta Hydrobiol., 19, 257—270.

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