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HETEROTROPHIC BACTERIA INHIBITING WATER OF THE RIVER BRDA ON THE BYDGOSZCZ TOWN SECTION

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Abstract

Research was carried out on the occurrence and physiological properties of heterotrophic bacteria inhabiting water of the River Brda in the Bydgoszcz town section. The highest number of microorganisms was found in water of the studied river in June and August at sites located in the centre of the town, and the lowest in November and March at the site located at the inflow of the river into the town. There were three times more psychrophilic organisms (CFU 20°C) than mesophilic (CFU 37°C) among bacteria. Gram-negative rods constituted about 97% of all the bacteria, of which fast-developing strains constituted from 51 to 61%. The most commonly occurring bacteria in the water of the River Brda were ammonifying bacteria (83.4%), those that reduce nitrates to nitrites (55.5%), those that produce hydrogen sulphide from organic compounds (54.1%), those that hydrolyse protein (45.1%) and fat (44.3%).The least numerous were pectinolytic (0.8%), urealytic (5.8%) and cellulolytic strains (13.6%). The majority of bacteria were capable of carrying out from two to six different physiological processes (83.5% altogether), about 12% of strains carried out only one process, and only 0.1-4.0% of bacteria carried out more than six processes.

Key words: heterotrophic bacteria, planktonic bacteria, mesophilic bacteria, psychrophilic bacteria, physiological properties

INTRODUCTION

Water bodies are a natural environment for various groups of organisms, including microorganisms, to inhabit and development. The water itself affects the organisms existing in it through its physical and chemical properties. This is why each organism living in water has specific vital requirements.

Bacteria occur in all types of surface waters and live in every zone of water bodies, from the surface layer to the bottom deposits. They inhabit clean and heavily polluted waters, fresh inland waters and the salt water of seas, stagnant water and watercourses. Microorganisms inhabiting the above water bodies belong to various groups, genera and species. They frequently come from different environments. The different condi tions prevailing in water mean that the bacteria inhabiting it differ from those occurring in soil, air or in the digestive tract of organisms. Apart from autotrophic forms, one can find heterotrophic and parasitic forms in water bodies, including those that are pathogenic for humans and animals (Paluch 1973).

Typically aquatic heterotrophic microflora includes numerous motile organisms, monotrichately or lophotrichately flagellated, numerous spirochetes (*Spirochaeta*), *Spirillum* and *Vibrio* as well as the majority of Gram-negative rods of the *Pseudomonas*, *Achromobacter* and *Flavobacterium* genera (Paluch 1973, Kunicki-Goldfinger 1998).

Microorganisms in water bodies carry out specific biochemical processes, forming groups with specific physiological properties. In this way they influence the environment they inhabit and the other microorganisms. Heterotrophic bacteria constitute one of the largest groups of microorganisms that take part in the processes of matter and energy circulation in the water ecosystems. The organic substances they decompose are utilised in the processes of building the structural and replacement components of cells and also constitute a source of energy that is indispensable for carrying out vital processes (Rheinheimer 1987). In water bodies they contribute to the biodegradation and transformation of organic matter, both of autochtonic and allochtonic origin, constituting an important link in the microbial loop, and thus take an active part in the self-purification process of waters (Świątecki 2003).

The aim of this paper was to determine the number of bacteria occurring in the water of the River Brda, and to define their morphology as well as some physiological properties.

MATERIALS AND METHODS

Study area

The research covered a 20 km section of the River Brda lying within the town limits of Bydgoszcz. The River Brda is one of the left-bank tributary of the River Vistula, which belongs to the catachment area of the Baltic Sea. The River Brda flows out from Lake Smołowskie, part of the Bytowskie Lake District. It is 238 km in length and the surface area of the river basin is about 4634 km^2. The River Brda flows into Bydgoszcz from the north and is a natural watercourse about 20-30 metres in width until the point where it joins the Bydgoski Canal. It is the source of drinking water for Bydgoszcz ("Czyżkówko" water intake) and simultaneously is the main site for the discharge of sewage (Adamowska and Płaza 1995).

Sampling

Water samples were taken for analysis on June, August, November 2000 and March 2001 from four sites. Site I was located in the Smukała district (where the river flows into the town). Sites II and III were located in the town centre near the road bridges Królowa Jadwiga (near the Grudziądzkie roundabout) and Kardynał Stefan Wyszyński (near the Fordońskie roundabout), while site IV was outside the town,

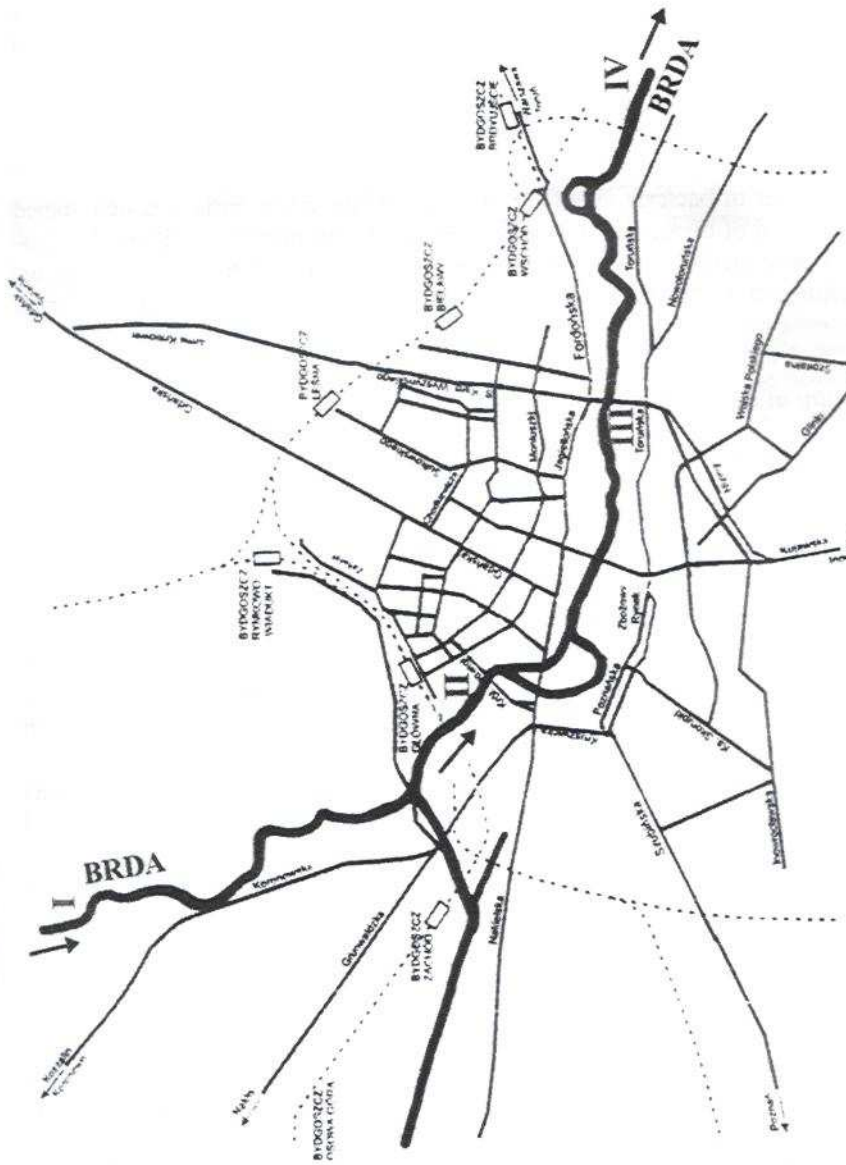

Fig. 1. Location of the sampling sites

before the flood plain in Łęgnowo (Fig. 1.) Water was collected from the middle of the river at a depth of about 20 cm into sterile glass bottles with a capacity of 1 litre, and 100 ml of it was immediately preserved in a solution of formaldehyde (final concentration 0.7%). The collected samples of water were transported to the laboratory in a container with ice inside, where the temperature was about +7°C. The time from the moment the samples were taken to the beginning of the analyses did not usually exceed 3 hours.

Determination of the total number of planktonic bacteria

The total number of bacteria (TNB) in the water of the River Brda was determined using the method of direct counting of bacterial cells on membrane filters (Nucleopore with a pore diameter of 0.22 μm). The bacteria were stained with acridine orange according to Zimmerman and Meyer-Reil (1974) and were counted under an epifluorescence microscope “Jenalumar” (Carl Zeiss Jenna).

Enumeration of heterotrophic bacteria

Number of heterotrophic bacteria (CFU) was determined by the spread plates method using iron-peptone agar medium after Ferrer et al. (1963). The collected samples of water were diluted with sterile physiological liquid (0.85 % NaCl) and 0.1 ml was poured into the surface of solid medium. The psychrophilic bacteria were incubated at a temperature of 20°C and the colonies that grew were counted after 3 and 6 days. Mesophilic bacteria were incubated at a temperature of 37°C and the colonies that grew were counted after 24 h and after 6 days. While colonies of heterotrophic bacteria were counted, colonies of pigmented bacteria were also counted. The results were calculated per 1 ml of water. All inoculations were conducted in three parallel repeats.
After the bacterial colonies were counted, 100 bacterial cultures each were transplanted at random each time and placed on semi-liquid iron-peptone medium, and after the purity of the culture was checked they were stored in the refrigerator (+4°C) for further tests, and transplanting every 2 months onto fresh iron-peptone medium.

Indication of physiological properties

The isolated bacteria used for the research were incubated on slants of iron-peptone medium for 3 days at a temperature of 20°C and then seeded on test medium after Donderski and Głażewska (1974), Donderski and Strzelczyk (1992). The results were read after 6 days of incubation at a temperature of 20°C. The following were taken into account in this research: the ability of the bacteria to carry out the process of ammonification, reduction of nitrates to nitrites, production of hydrogen sulphide from organic compounds, decomposition of protein, cellulose, urea, pectin, starch and fat.

RESULTS AND DISCUSSION

The enrichment of water with organic substances is reflected in the development of heterotrophic bacteria and their proportion in individual physiological groups. Research by Donderski and Strzelczyk (1992) and Świątecki (1997) on the number of bacteria in lake water showed a fluctuation in the density of microorganisms depending on the trophy of the water body. Therefore calculating the number of bacteria provides a basic piece of information in microbiological studies of water. In clean environments this number depends on the autochtonic matter, made up of exometabolites of phyto- and zooplankton excretions as well as allochtonic matter, which gets into water in spring surface run-off and atmospheric precipitation. Research on the River Brda confirmed that the maximum number of bacteria occurs in places where allochtonic matter flows into the river, thus polluting the water in the river. These are domestic and industrial waste discharge points and places where surface run-off from the drainage basin flows in.

Data concerning the total number of bacteria (TNB) occurring in the water of the River Brda on the section under investigation and the number of heterotrophic bacteria (CFU) are presented in Table 1. The greatest total number of bacteria was found in August and June (9.3 and 8.1×10^6 cells/ml, respectively), and the lowest in November and March (4.6 and 4.9×10^6 cells/ml, respectively). Research conducted by Donderski and Kalwasińska (2003) also shows that the maximum number of planktonic bacteria in Lake Chełmżyńskie was found in summer, and the minimum in autumn.

Generally the total number of bacteria in the river increased in the direction of flow. The lowest number of bacteria was found at site I (4.3×10^6 cells/ml), while at site III in the town centre their number was twice as high at 8.8×10^6 cells/ml. The greatest number of microorganisms, i.e. from 8.1 to 8.8×10^6 cells/ml, was found on the section of the river flowing through intensely built-up and industrially developed areas.

A significant factor affecting the number of microorganisms in the environment is temperature. Research by Świątecki (1997) on three groups of lakes showed that seasonal changes in temperature are correlated with the dynamics of bacteria development and thus with their number.

During the research carried out on the River Brda, the greatest number of heterotrophic bacteria was found in August – on average 1426.9×10^3 cells/ml, at an average water temperature of 13-19°C, while the lowest was during winter season – on average 66.4×10^3 cells/ml, when the water temperature was 2-5°C.

During the whole of the research period, psychrophilic bacteria were three times more abundant than mesophilic (Table 2). The percentage share of psychrophilic bacteria varied from 56.8 to 99.3% of the total number of heterotrophs. The percentage of psychrophilic bacteria decreased in the direction of flow of the river from 92.6% at site I to 65.8% at site IV. The opposite phenomenon was observed for mesophilic bacteria. These organisms constituted from 0.7 to 43.2% of the total number of heterotrophs in the water of the River Brda.

Among the isolated heterotrophic bacteria of the River Brda, 40% of strains displayed an ability to produce pigments (Table 3). The greatest number of chromo-

Table 1

Total number of planktonic bacteria (TNB) and abudance of heterotrophic bacteria (CFU) in water of the River Brda on the Bydgoszcz town section

	Date of sampling								Average at sites	
	June 2000		August 2000		November 2000		March 2001			
	TNB	CFU	TNB	CFU	TNB	CFU	TNB	CFU	TNB	CFU
I	6.3 [2.9-13.7]	6.5 [3.0-14.0]	5.4 [2.4-12.4]	4.3 [1.7-10.9]	2.1 [0.6-7.6]	7.8 [3.9-15.7]	3.5 [1.3-9.7]	14.0 [8.3-23.7]	4.3	8.2
II	6.7 [3.2-14.2]	118.3 [98.5-142.1]	7.7 [3.8-15.6]	30.0 [20.9-43.1]	3.8 [1.4-10.2]	17.1 [10.6-27.6]	4.9 [2.1-11.7]	30.7 [21.4-44.0]	5.8	49.0
III	9.9 [5.3-18.5]	530.3 [486.2-578.4]	13.6 [8.0-23.2]	5170.0 [5028-5316]	6.2 [2.8-13.6]	37.7 [27.3-52.1]	5.4 [2.4-12.4]	164.4 [140.7-192.1]	8.8	1475.6
IV	9.7 [4.9-18.5]	1473.4 [1398.5-1552.1]	10.5 [5.7-19.3]	503.4 [460.4-550.4]	6.2 [2.8-13.6]	203.0 [176.4-233.6]	6.0 [2.7-13.3]	200.8 [174.4-231.2]	8.1	595.2
Average	8.1	532.1	9.3	1426.9	4.6	66.4	4.9	102.5		

TNB – bacteria x 10^6 cells/ml; CFU – bacteria x 10^3 cells/ml; I-IV sites of taken samples (see materials and methods), [ ] – range

Table 2

Occurrence of mesophilic (CFU 37°C) and psychrophilic bacteria (CFU 20°C) in water on the research section of the River Brda

Sites	Date of sampling								Average at sites	
	June 2000		August 2000		November 2000		March 2001			
	CFU 37°C	CFU 20°C	CFU 37°C	CFU 20°C	CFU 37°C	CFU 20°C	CFU 37°C	CFU 20°C	CFU 37°C	CFU 20°C
I	1.0* [15.4]	5.5* [84.6]	1.2* [27.9]	3.1* [72.1]	0.1* [1.3]	7.7* [98.7]	0.1* [0.7]	13.9* [99.3]	0.6* [7.4]	7.6* [92.6]
II	36.0* [30.4]	82.3* [69.6]	2.7* [9.0]	27.3* [91.0]	0.8* [4.7]	16.3* [95.3]	6.9* [22.5]	23.8* [77.5]	11.6* [23.7]	37.4* [76.3]
III	120.3* [22.7]	410.0* [77.3]	1 320.0* [25.5]	3 850.0* [74.5]	3.7* [9.8]	34.0* [90.2]	8.1* [4.9]	156.3* [95.1]	363.0* [24.6]	1 112.6* [75.4]
IV	636.7* [43.2]	836.7* [56.8]	106.7* [21.2]	396.7* [78.8]	50.7* [25.0]	152.3* [75.0]	20.8* [19.4]	180.0* [89.6]	203.7* [34.2]	391.4* [65.8]
Average	198.5* [27.9]	333.6* [72.1]	357.7* [20.9]	1 069.3* [79.1]	13.8* [10.2]	52.6* [89.8]	9.0* [9.6]	93.5* [90.4]		

CFU 37°C – mesophilic bacteria; CFU 20°C – psychrophilic bacteria; I-IV (see table 1), * – bacteria x 10^3 cells/ml, [ ] – bacteria in %

Table 3

Occurrence of some morphological forms and chromogenic bacteria in water of the River Brda (bacteria in %)

Date of sampling	Morphological forms			Chromogenic bacteria
	rods	cocci	bacilli	
June 2000	97.0 [94.0-100.0]	2.5 [0-6.0]	0.5 [0-2.0]	42.5 [40.0-44.0]
August 2000	99.5 [98.0-100.0]	0.0 [0.0]	0.5 [0-2.0]	43.0 [36.0-48.0]
November 2000	96.0 [90.0-100.0]	2.0 [0-8.0]	2.0 [0-4.0]	37.0 [36.0-40.0]
March 2001	96.5 [93.5-100.0]	2.5 [0-6.0]	1.0 [0-2.0]	36.5 [26.0-44.0]
Average	97.25	1.75	1.0	39.8

[ ] – range

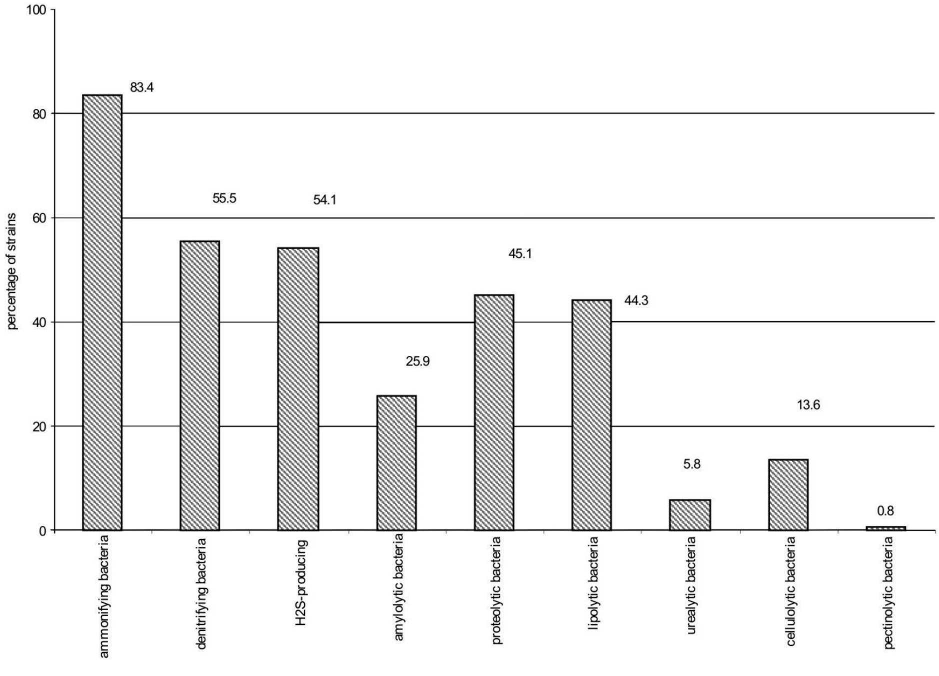

Fig. 2. Occurrence of physiological groups among bacteria isolated from water of the River Brda (percentages derived from the pooled data of all sites and swasons)

genic bacteria was found in the spring-summer period (on average 42.5% and 43%), and the lowest in autumn and winter (on average 37% and 36.5%). According to Kunicki-Goldfinger (1998) the ability to produce pigment in bacteria in the water is a response to the exposure of microorganisms to sunlight. A particular concentration of pigmented microorganisms occurs in the surface water (Donderski and Strzelczyk 1992). According to Rheinheimer (1987) the number of pigmented bacteria in water with poor transparency in polluted waterbodies is decidedly lower.

Among morphological forms in the water of the River Brda, Gram-negative rods were decidedly dominant, constituting 97.25% of the studied strains (Table 3). A similar domination of rods in the water of different lakes was found by many authors (Potter 1964, Donderski 1971, Borsodi et al. 1998, Donderski and Kalwasińska 2003). According to Donderski and Strzelczyk (1992) this morphological type can account for up to 96% of all the heterotrophic bacteria in the water of Lake Jeziorak. The percentage share of cocci and bacilli in the water of the River Brda was similar at 1.75% and 1.0%, respectively. Matusiak et al. (1965), Niewolak (1971), Chróst (1977) have observed that the growth and development of gram positive bacteria is impeded by active biological substances secreted by numerous algae and cyanobacteria, particularly during blooming.

It follows from the research carried out on the physiological properties of bacteria that microorganisms capable of carrying out the process of ammonification occurred in the greatest numbers in the water of the River Brda. They constituted on average 83.4% of the tested strains (Fig. 2.). The number of ammonifiers increased with the direction of flow. At site I, before the town limits, there were $3.8x10^3$ cells/ml water, and at site III $4446.2x10^3$ cells/ml water (Table 4).

The dominance of ammonifying bacteria in the investigated section of the River Brda confirms the results of research in other water bodies (Donderski 1971, Donderski and Strzelczyk 1992; Świątecki 1997; Danielak 1998). According to Rheinheimer (1987) ammonification in an aquatic environment is a particularly important process conditioning the circulation of ammonia nitrogen ($N\text{-}NH_3$) in water ecosystems, and amino acids, now common in waters, are used by bacteria as a source of nitrogen or nitrogen and carbon together.

As follows from our research, less numerous among heterotrophs were bacteria capable of carrying out the process of denitrification (on average 55.5 % of strains) and production of hydrogen sulphide from organic compounds (on average 54.1 % of strains) (Fig. 2.).

The greatest number of denitrifying bacteria was found in August at site III ($3929.2x10^3$ cells/ml) and the lowest in November at site I ($2.0x10^3$ cells/ml) (Table 4). In Donderski and Kalwasińska (2003) research the highest percentage of denitrifying bacteria was observed in summer period too.

The maximum number ($3825.8x10^3$ cells/ml) of microorganisms that produce hydrogen sulphide in the water of the River Brda was found in August at site III (Table 4).

A less numerous group of heterotrophic bacteria in the investigated section of the River Brda consisted of organisms that hydrolyse high-molecular compounds. The trophic level of a given water body is determined by the proportion of bacteria carrying out certain hydrolytic processes. 44.3% of the isolated strains in the River

Occurrence of some physiological groups of bacteria

Date of sampling	Sites	Number of bacteria			
		A	B	C	D
June 2000	I	5.5 [2.4-12.6]	3.6 [1.3-9.9]	3.6 [1.3-9.9]	2.1 [0.6-7.6]
	II	71.0 [56.1-89.9]	54.4 [41.5-71.3]	42.6 [31.4-57.8]	63.9 [49.8-82.0]
	III	328.8 [294.5-637.1]	307.6 [274.5-344.7]	190.9 [165.2-220.6]	254.5 [224.6-288.4]
	IV	1296.6 [1226.6-1370.6]	1149.0 [1083.2-1218.8]	1119.8 [1054.9-1188.7]	736.7 [684.4-793]
August 2000	I	3.8 [1.4-10.2]	2.1 [0.6-7.6]	2.7 [0.9-8.5]	0.4 [0.1-4.7]
	II	28.2 [19.4-41.0]	17.4 [10.8-28.0]	22.21 [14.6-33.8]	3.0 [1.0-9.0]
	III	4446.2 [4314.9-4581.5]	3929.2 [3805.9-4056.5]	3825.8 [3704.1-3951.5]	517.0 [473.5-564.5]
	IV	463.1 [422.0-508.2]	372.0 [335.4-412.6]	352.4 [316.8-392.0]	110.7 [91.6-133.8]
November 2000	I	5.9 [2.7-13.1]	2.0 [0.5-7.5]	1.6 [0.4-6.8]	2.0 [0.6-7.4]
	II	14.0 [8.3-23.7]	6.8 [3.2-14.4]	5.1 [2.2-12.0]	2.1 [0.6-7.6]
	III	33.2 [23.5-46.9]	21.9 [14.3-33.5]	25.6 [17.6-37.9]	9.8 [5.2-18.4]
	IV	174.6 [150.1-203.1]	97.4 [79.6-119.2]	97.4 [79.6-119.2]	60.9 [47.2-78.6]
March 2001	I	11.5 [6.4-20.6]	5.3 [2.3-12.3]	5.0 [2.1-11.9]	3.4 [1.2-9.6]
	II	29.5 [20.5-42.5]	15.4 [9.3-25.5]	19.0 [12.1-29.9]	6.8 [3.2-14.4]
	III	128.2 [107.5-152.9]	108.5 [89.6-131.4]	78.9 [63.0-98.8]	23.0 [15.2-34.8]
	IV	184.7 [159.5-213.9]	136.5 [115.1-161.9]	140.6 [118.8-166.4]	48.2 [36.2-64.2]

A – ammonifying bacteria; B – denitrifying bacteria; C – H_2S producing bacteria; D – amylolytic bacteria, I – pectinolytic bacteria; I-IV (see table 1), [ ] – range

Table 4

in water on the research section of the River Brda

x10^3 cells/ml				
E	F	G	H	I
4.4 [1.8-11.0]	3.8 [1.4-10.2]	0.8 [0.1-5.5]	0.9 [0.2-5.6]	0.0 [0.0-0.0]
47.3 [35.4-63.2]	56.8 [43.6-74.0]	14.2 [8.4-24.0]	33.1 23.4-46.8]	7.1 [3.4-14.8]
222.7 [194.8-254.6]	328.8 [294.5-367.1]	63.6 [49.5-81.7]	31.8 [22.4-45.2]	10.6 [5.8-19.4]
559.9 [514.5-609.3]	1031.4 [969.1-1097.7]	88.4 [71.5-109.3]	58.9 [45.4-76.4]	0.0 [0.0-0.0]
2.8 [0.9-8.7]	1.7 [0.4-7.0]	0.2 [0.01-4.4]	1.4 [0.3-6.5]	0.0 [0.0-0.0]
9.6 [5.1-18.1]	13.2 [7.7-22.7]	1.2 [0.3-6.1]	5.4 [2.4-12.4]	0.0 [0.0-0.0]
2378.2 [2282.7-2477.7]	2171.4 [2080.2-2266.6]	0.0 [0.0-0.0]	310.2 [276.9-347.5]	103.4 [85.0-125.8]
211.4 [184.3-242.5]	382.6 [345.4-423.8]	0.0 [0.0-0.0]	50.3 [38.0-66.6]	10.1 [5.4-18.8]
3.9 [1.5-10.3]	1.6 [0.4-6.8]	0.5 [0.1-4.9]	1.7 [0.4-7.0]	0.0 [0.0-0.0]
7.5 [4.0-15.8]	5.1 [2.2-12.0]	0.0 [0.0-0.0]	1.7 [0.4-7.0]	0.0 [0.0-0.0]
12.1 [6.9-21.3]	16.6 [10.2-27.0]	5.3 [2.3-12.3]	5.3 [2.3-12.3]	0.0 [0.0-0.0]
89.3 [72.3-110.3]	56.8 [43.6-74.0]	12.2 [6.9-21.5]	12.2 [6.9-21.5]	0.0 [0.0-0.0]
7.3 [3.5-15.1]	6.2 [2.8-13.6]	0.6 [0.1-5.1]	3.6 [1.3-9.9]	0.0 [0.0-0.0]
12.9 [7.5-22.3]	12.3 [7.0-21.6]	0.0 [0.0-0.0]	3.7 [1.4-10.0]	0.0 [0.0-0.0]
65.8 [51.5-84.1]	49.3 [37.1-65.5]	9.9 [5.3-18.5]	9.9 [5.3-18.5]	0.0 [0.0-0.0]
92.4 [75.1-113.7]	64.3 [50.1-82.5]	12.0 [6.8-21.2]	8.0 [4.0-16.0]	0.0 [0.0-0.0

bacteria; E – proteolytic bacteria; F – lipolytic bacteria; G – ureolytic bacteria; H – cellulolytic

Brda displayed lipolytic capabilities (Fig. 2.). In lakes, bacteria display differing abilities to decompose lipids. According to Niewolak (1971) 18-25% of bacteria of the hyponeuston hydrolyse lipids. Donderski and Strzelczyk (1992) and Lalke-Porczyk (1999) also contend that lipolytic bacteria are one of the most numerous groups of bacteria occurring in the waters of Lake Jeziorak. In the opinion of Műnster and Albrecht (1994) lipids produced by both plants and animals are one of the most important groups of biopolymers occurring in fresh waters. Bacteria can actively cumulate and use fatty compounds, among others, as a source of energy (Arts et al. 1992).

Among the tested planktonic bacteria of the River Brda, 45.1% of strains displayed an ability to decompose protein (Fig. 2.). Research conducted by Strzelczyk et al. (1976) and Donderski and Strzelczyk (1992) shows that the number of proteolytic bacteria in water bodies increases with a rise in their trophy. According to Donderski and Strzelczyk (1992), in the oligo-mesotrophic lake Jasne there were 50% of them, while in the eutrophic lake Jeziorak about 66%. Saava (1985) and Suigita et al. (1987) claim that bacteria decomposing protein in water basins can account for 70% up to 100% of the total number.

It follows from the results contained in this paper that bacteria capable of decomposing starch constituted about 26%, while in the water of the eutrophic lake Jeziorak they constituted, according to Donderski (1971), as much as 80%, and in the oligo-mesotrophic lake Jasne only 3% of the total bacteria population (Donderski and Strzelczyk 1977). The research on starch decomposition leads to a conclusion that amylolytic bacteria account for a relatively numerous bacterial group (Suigita et al. 1987, Borsodi et al. 1998). Starch is natural ingredient of water plants, and active bacteria use is as a source of carbon and energy.

Cellulolytic abilities were found in about 14% of the studied strains (Fig. 2.). The determination of the properties of cellulolytic bacteria can present problems because the number of these bacteria can be limited by the selective properties of the iron--peptone medium after Ferrer et al. (1963) used for isolating bacteria and the overly

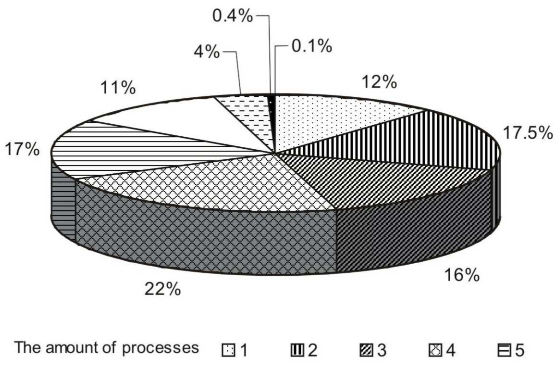

Fig. 3. The amount of processes which are carried out by bacteria from the River Brda (bacteria in %)

short (6 days) incubation period, insufficient to initiate the synthesis of cellulase after cultivation on the medium with cellulose (Donderski and Strzelczyk 1992).
The small proportion of bacteria decomposing urea, only about 6%, that was found during this research could be caused by the presence of ammonia released by ammonifying bacteria, a finding which is emphasised by Rheinheimer (1987). According to Paluch (1973) ureolytic bacteria is an important link in the process of putting vast amounts of nitrogen back into circulation.
The very small quantity of pectinolytic bacteria (about 1%) could testify to the fact that this compound is reluctantly decomposed by the planktonic bacteria in the River Brda. This could also be linked to the presence of larger amounts of more easily absorbed organic substances in the river. Donderski and Kalwasińska (2003) demonstrated that among bacteria isolated from the water of Lake Chełmżyńskie pectinolytic bacteria made up 19% of the studied strains. It follows from research conducted by Donderski and Strzelczyk (1992) on lakes Jasne and Jeziorak that pectin was more readily decomposed by bacteria in the oligo-mesotrophic lake Jasne than in the eutrophic lake Jeziorak, which confirms the above findings. They are also confirmed by research concerning the metabolic activity of bacteria occurring in lakes with varying trophy, from which it follows that organisms in lakes with a lower trophy are generally more active (Strzelczyk et al. 1976).
The majority of the bacteria isolated from the water of the River Brda were capable of carrying out from two to six different physiological processes, which involves 83.5% of the bacteria population (Fig. 3.). Highly specialised organisms, i.e. those carrying out only one physiological process, were not very numerous (12%) and neither were bacteria capable of carrying out more than six different physiological processes (0.1-4.0%).
The number of heterotrophic bacteria and the value of the water quality coefficient "Q" after Korsh (1959) (Fig. 4.) testify to the fact that the least polluted water in the River

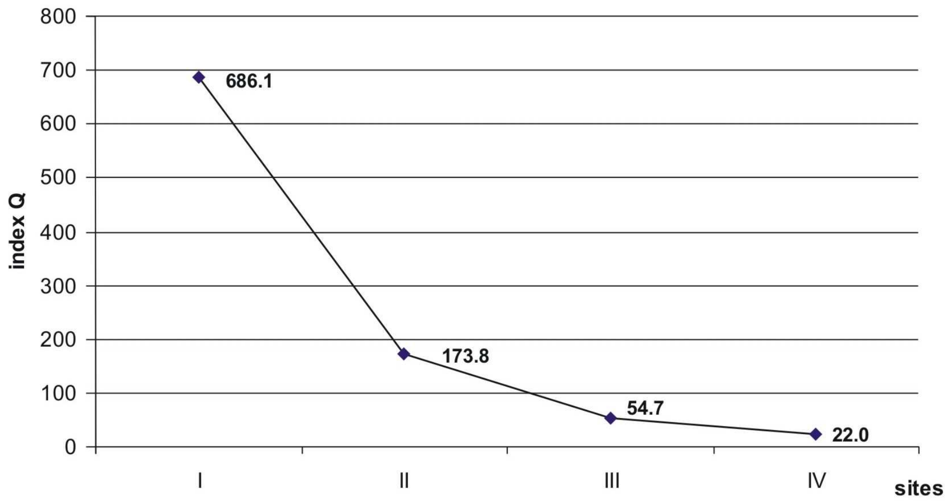

Fig. 4. Cleanliness index Q of the River Brda on the Bydgoszcz town section

Brda was before the point where it flows into the centre of Bydgoszcz (Q = 686.1). The extent of pollution increased as it flowed through the town, as confirmed by the falling values of "Q" to 22.0 at site IV and the growing numbers of bacteria in the studied physiological groups. The large proportion of ammonifiers and denitrifiers points to the fact that self-cleaning processes take place in the river. The proportion of individual physiological groups of bacteria at the studied sites also suggests that the type and composition of domestic waste discharged into the River Brda on the studied section was mostly similar for the whole study period and any variation in the number of bacteria was undoubtedly linked to the temperature of the water.

Bacteria isolated on artificial laboratory substrates are of course only a part of those that inhabit studied water bodies and the properties of these strains in laboratory conditions may be different from their real activity in the natural environment. The results obtained from the research do, however, provide the opportunity to investigate their potential abilities to carry out biochemical processes and also to predict the capability and intensity of the self-purification process. Thus studies of this type should be continued, and some parameters and microbiological processes should even be monitored.

CONCLUSIONS

1. The number of bacteria in the River Brda increases in the direction of flow. The lowest number of bacteria was found, where the river flows into the town. The greatest number of bacteria was found in the town centre. The increase in the number of heterotrophic bacteria and the decrease in the value of the water quality coefficient "Q" after Korsh with the direction of flow testify to the increasing pollution of the water within the town of Bydgoszcz.
2. The number of psychrophilic bacteria in the water of the River Brda was three times higher than that of mesophilic bacteria. The number of mesophilic bacteria grew with the increase in the degree of pollution of the water in the river. The greatest number of these bacteria was found in summer, the lowest in autumn and winter.
3. Gram-negative rods were dominant in the water of the River Brda and chromogenic bacteria constituted about 40 % of the population.
4. Among the physiological groups of ammonifying bacteria were dominant. Denitrifying bacteria were also a large group as were bacteria that produce hydrogen sulphide from organic compounds. The least numerous were pectinolytic bacteria, those decomposing urea and cellulose.

REFERENCES

Adamowska H., Płaza W., 1995. Hydrografia dorzecza Brdy. W: Charakterystyka i uwarunkowania gospodarki wodnej. Dorzecze Brdy. (Hydrography of the Brda river-basin. In: Characteristics and conditions of water management. The Brda river-basin). Wojewódzkie Biuro Planowania Przestrzennego w Bydgoszczy (Office of the spatial planning in Bydgoszcz Province), (in Polish).

Arts M. T., Evans M. S., Roberts D., 1992. Seasonal patterns of total and energy reserve lipids of dominant zooplanktonic crustaceans from hypereutrofic lake. *Oecologia*, 90, 560-572.

Borsodi A. K., Farkas I., Kurdi P., 1998. Numerical analysis of planktonic and reed biofilm bacterial communities of lake Fertő (Neusidlersee, Hungary, Austria). *Water Res*., 32 (6), 1831-1840.

Chróst R. J., 1977. O niektórych współzależnościach pomiędzy glonami i bakteriami w środowiskach wodnych. (Some co-relationships between alga and bacteria in water environment). *Wiad. Ekol*., 23, 343-358, (in Polish).

Danielak K., 1998. The distribution and ecology of Gram-negative organisms other then Enterobacteriaceae in lakes. *J. Appl. Bacteriol*., 23, 510-514.

Donderski W., 1971. Incidence of physiological types among bacteria isolated from water and mud of Lake Jeziorak. Zesz. Nauk. UMK Toruń, *Limnol. Papers*, 6, 15-37.

Donderski W., Strzelczyk E., 1977. Bacteriological studies of mesotrophic Lake Jasne. Zesz. Nauk. UMK Toruń, *Limnol. Papers*, 10, 15-27.

Donderski W., Kalwasińska A., 2003. Occurrence and physiological properties of bacterioplankton of Lake Chełmżyńskie (Poland). *Polish. J. Env. Stud*., 3, 287-295.

Donderski W., Strzelczyk E., 1992. The ecology and physiology of aerobic heterotrophic bacteria in lakes of different trophy. In: Some Ecological Processes of the Biological System in North Poland, R. Bohr, A. Nienartowicz, J. Wilkoń-Michalska (Ed.), N. Copernicus University Press.

Ferrer E. B., Stapert E. M., Sokolski W. T., 1963. A medium for improved recovery of bacteria from water. *Can. J. Microbiol*., 9, 420-422.

Korsh L. E., 1959. Prijamoj metod opredelenija bakterji pri sanitarnom izucenii vodojemov. Gigiena 9, 85, (in Russian).

Kunicki-Goldfinger W., 1998. Życie bakterii. (The life of bacteria). PWN, Warszawa, (in Polish).

Lalke-Porczyk E., 1999. Występowanie, rozwój i aktywność metaboliczna bakterii epifitycznych makrofitów. (Occurence, development and metabolic activity of epiphytic bacteria on macrophytes). Praca doktorska (Ph. Doctoral thesis), UMK Toruń (in Polish).

Matusiak K., Jaroszyńska T., Krzywicka A., 1965. Activity of antibacterial substance in (*Chlorella vulgaris*) and (*Chlorella pyrenoidosa*) at various stages of their development cycle and the influence of light on the process. *Bull. Acad. Pol. Sci. B*, 13, 667-670.

Münster U., Albrecht D., 1994. Dissolved organic matter: analysis of composition and function by a molecular-biochemical approach. In: Microbial Ecology of Lake Pluβsee, J. Overbeck, R. Chróst (Ed.), Springer-Verlag, New York.

Niewolak S., 1971. A microbiological study on heterotrophic hyponeuston of the Iława lakes in the summer season. *Acta Hydrobiol*., 3, 295-311.

Paluch J., 1973. Mikrobiologia wód (Water Microbiology). PWN, Warszawa, (in Polish).

Potter L., 1964. Planktonic and benthic bacteria of lakes and ponds. In: Principles and Aplication in Aquatic Microbiology, H. Heukelekian, N. S. Dondero (Ed.), New York-London-Sydney.

Rheinheimer G., 1987. Mikrobiologia wód. (Water Microbiology). PWRiL Warszawa (in Polish).

Saava A.,1985. First periodic assessment of state of marine environment of the Baltic Sea area. In: The background document for the first periodic assessment, Baltic Marine Environment, Protection Commisioni Rostock-Warneműnde.
Strzelczyk E., Donderski W., Stopiński M., 1976. Studies on physiological properties of heterotrophic bacteria isolated from water and mud of the three lakes. Zesz. Nauk. UMK Toruń, *Limnol. Papers*, 9, 27-39.
Suigita H., Oshima K., Fushino T., Deguahi Y., 1987. Substrate specificity of heterotrophic bacteria in the water and sediment of carp culture pond. *Agriculture*, 64, 39.
Świątecki A., 1997. Zastosowanie wskaźników bakteriologicznych w ocenie wód powierzchniowych. (Application of bacteriological indicators to the assessment of surficial water quality). WSP Olsztyn, (in Polish).
Świątecki A., 2003. Microbial Loop – Dialectic of Ideas and Perspective of Future Studies. Acta UNC Toruń, *Limnol. Papers*, 23, 3-9.
Zimmerman I., Meyer-Reil L. A., 1974. A new method for fluorescence staining of bacterial populations on membrane filters. Kieler Meeresforsch., 30, 24-27.

WYKORZYTYWANIE AMINOKWASÓW I CUKRÓW PRZEZ BAKTERIE WYIZOLOWANE Z PLAŻY MORSKIEJ

Streszczenie

Przeprowadzono badania nad występowaniem i właściwościami fizjologicznymi bakterii heterotroficznych bytujących w wodzie rzeki Brdy, na odcinku miasta Bydgoszczy. Najwięcej mikroorganizmów w wodzie badanej rzeki stwierdzono w czerwcu i sierpniu, na stanowiskach usytuowanych w centrum miasta, a najmniej w listopadzie i marcu na stanowisku zlokalizowanym na wpływie rzeki do miasta. Wśród bakterii 3-krotnie więcej było organizmów psychrofilnych (TVC 20°C) niż mezofilnych (TVC 37°C). Pałeczki gram-ujemne stanowiły ok. 97% ogółu bakterii, wśród których szczepy szybko rozwijające się stanowiły od 51 do 61%. Najliczniej w wodzie rzeki Brdy występowały bakterie amonifikacyjne (83.4%), redukujące azotany do azotynów (55.5%), wytwarzające siarkowodór z organicznych związków (54.1%), hydrolizujące białko (45.1%) i tłuszcz (44.3%). Najmniej liczne były szczepy pektynolityczne (0.8%), mocznikowe (5.8%), i celulolityczne (13.6%). Większość bakterii zdolna była do przeprowadzania od dwóch do sześciu różnych procesów fizjologicznych (83.5% łącznie), jeden tylko proces przeprowadzało około 12% szczepów, a więcej niż sześć procesów tylko 0.1-4.0 % bakterii.