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Bacteriogical Monitoring of Lake Water in Wigry National Park in the Summer

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Abstract

This paper presents the results of examination of the number of indicatory bacteria of pollution degree (TVC 20"C, TVC 37°C) and sanitary state (TC, FC, FS) in the water of Lake Wigry and 41 other lakes on the area of Wigry National Park (WNP) carried out in the summer of 1995. Generally, lower numbers of the above-mentioned indicatory bacteria were found in the watershed of the Kamionka and Samlanka Rivers, higher numbers were observed in the water of direct watershed of Lake Wigry, the Wiatrotuza River and canals connecting some lakes with Lake Wigry. The numbers TVC 20°C, TVC 37°C, FC show most often purity or only insignificant pollution of the examined lake waters. The samples of polluted water were most often found in the direct watershed of Lake Wigry. Only single water samples of Lake Wigry, lakes in the watershed of the Wiatroluza and Samlanka rivers contained above-average numbers of TC and FC from the point of view of their utilization for recreation. FS dominated in most water samples of the examinated lakes.

Keywords: national park, lakes, pollution, recreation, bacteriological monitoring

Introduction

Intensification of agriculture, forestry, fisheries and the development of tourism in the northeastern regions of Poland in endangering the purity of lake waters in this area. Many lakes are a source not only of recreation, but of drinking water. This requires taking early action leading to the protection of surface and underground waters. In the case of lakes situated in Wigry National Park it is suggested that "The agricultural, forestry and fishery economies should be subjected to the requirements of water protection. All the concentrations of tourist places should be reconsidered as far as their dispersion is concerned, and a total elimination of polluted inflows from inhabited settlements, recreational centres, waste removal outside the park, and prevention of lake degradation should be enacted" [15]. At the moment, the present state of water protection in the area of Wigry National Park is far from the above--mentioned wishes of "protectors," but a spreading building program near the lakes (especially Lake Wigry) is becoming a common phenomenon. Sanitary-bacteriological aspects connected with recreation and utilization of these lake waters has not been mentioned in the suggested undertaking. In literature on lakes in Wigry National Park there are no data concerning bacteriological purity. The sanitary-bacteriological evaluation of lake waters in the protected area showed [7, 12] the presence of enteric bacteria in numbers often higher than in unprotected areas as a result of numerous populations of wild animals. In Wigry National Park this concerns beavers and cormorants living in numerous colonies. This paper presents the results of examination of the number of indicatory bacteria of pollution (TVC 20°C, TVC 37°C) and sanitary states (TC, FC, FS) in pelagic waters in 41 out of 45 smaller and larger lakes in Wigry carried out in the summer of 1995.

Materials and Methods

Lakes in Wigry National Park

Created in 1989, Wigry National Park is a protected area of postglacial landscape. It is situated in the Lithuanian Lake District within the two climatic regions of Poland (Suwalski and West-Augustowski) in the middle of the basin of the Czarna Haricza River (the basin of the Niemen River). According to Bajkiewicz-Grabowska [3] mean yearly air temperature is 6.2°C, the period of plant

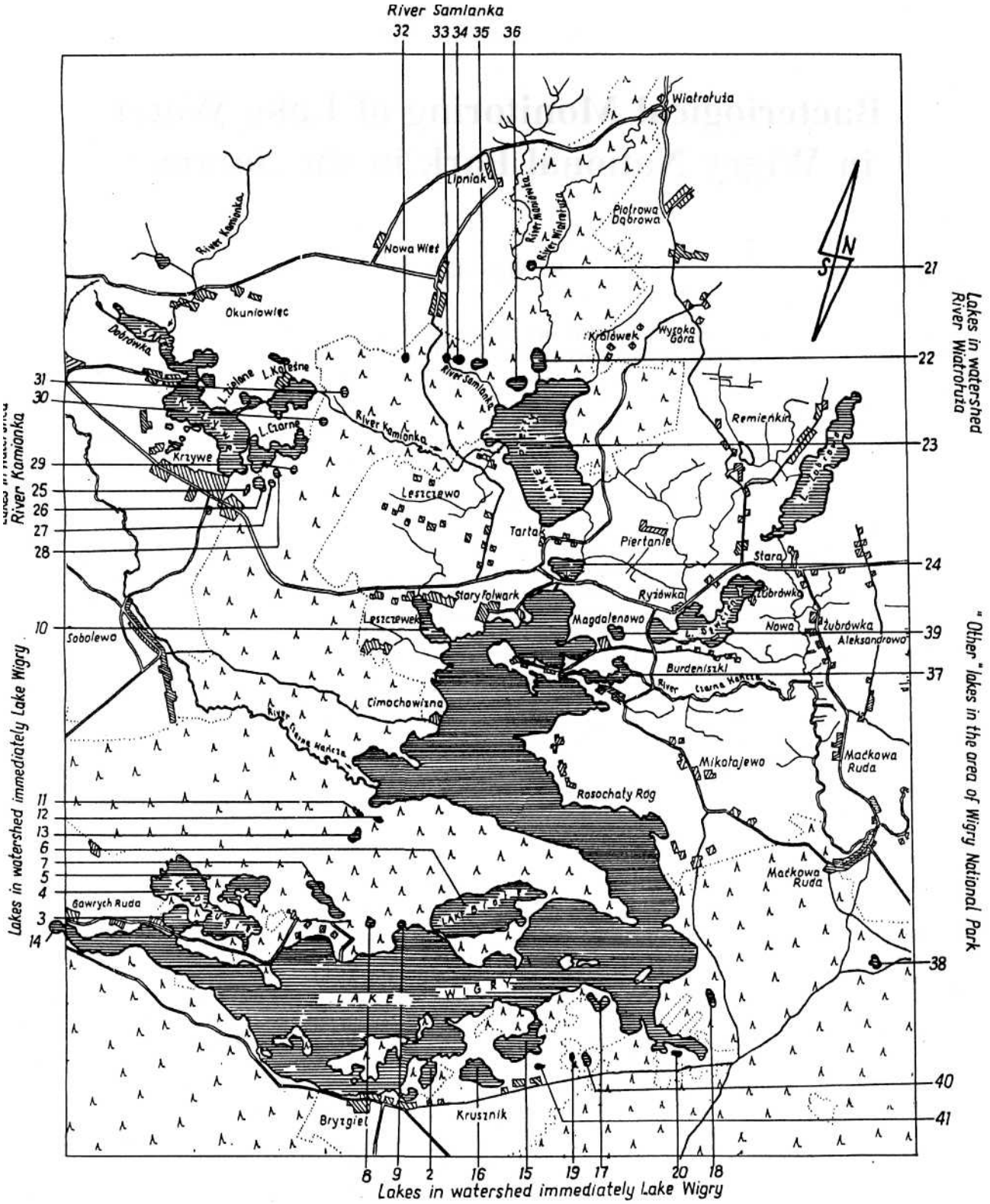

Fig. 1. Situational sketch of investigated lakes in the area of the Wigry National Park. Lakes: 1. Wigry, 2. Czarne near Bryzgiel, 3. Okrągłe, 4. Długie Wigierskie, 5. Muliczne, 6. Białe Wigierskie, 7. Suchar Wielki, 8. Suchar Rzepiskowy, 9. Rzepiskowe, 10. Leszczewek, 11. Suchar Zachodni, 12. Suchar Wschodni, 13. Suchar Dembowskich, 14. Czarne near Gawrych Ruda, 15. Krusznik, 16. Mulaczysko, 17. Klonek, 18. Ślepiec (Wygorzele), 19. Sucharek near Bryzgiel, 20. Ślepe Krzyżańskie, 21. Pietronajcie, 22. Królówek, 23. Pierty, 24. Omul6wek, 25. Suchar I, 26. Suchar II, 27. Suchar III, 28. Suchar IV, 29. Suchar V, 30. Suchar VI, 31. Suchar VII, 32. Wadolek, 33. Samle Male, 34. Samle Wielkie, 35. Gałęziste, 36. Białe Pierciańskie, 37. Postaw, 38. Konopniak, 39. Mozguć, 40. Widne, 41. Ślepe Zielone; A, B, C... M - sampling stations on canals.

vegetation lasts about 135 days, the frost-free period is from 135 to 146 days. Autumn frosts sometimes start in the beginning of August. Winter is long (about 120 days) and frosty. Snowcover lasts about 100 days. Mean time of ice-cover on lakes is about 60 days. Annual sum of precipitation averages 547 mm. The highest precipitation is in June, July and August, while the lowest is noted in January, February and March. Wigry comprises 14,956 ha but only 396 ha is protected. Lake Wigry (2170 ha) and 45 other lakes are a dominating element of the WNP. There are 11 small distrophic lakes called "suchar," surrounding woods which belong to the northern part of Augustowska Primeval Forest, numerous peatlands, a fragment of the Czarna Hancza River valley, and land utilized by agriculture. The total area of water is 2812 ha; woods comprise 9155 ha; agricultural areas, farm buildings and roads occupy 2989 ha [11]. The central part of the WNP is a direct watershed of Lake Wigry (9430 ha) and a watershed of the Wiatroluza River, where the Maniowka River has an outlet into Lake Wigry. A watershed of the Kamionka River from its outflow from Lake Kolesne to the outlet into Lake Pierty, the watershed of a part of the Czarna Hancza River, and a fragment of the Czarna Hancza River below the outflow from Lake Wigry (Fig. 1) are all included in Wigry National Park. 24 lakes are situated in the direct watershed of Lake Wigry. Some of them (Muliczne, Okra.gle Wigierskie, Dlugie Wigierskie, Biale Wigierskie, Krusznik, Klonek/Zakqty, Cieslinajki, Leszczewek, Widne, Slepe, Slepiec) were once the bays of Lake Wigry. Lake Pierty (232 ha) is situated to the north of Lake Wigry and is the second largest lake in the Park. There is a complex of small lakes - Krolowek, Biale Piercianskie, Galeziste, Samle Male and

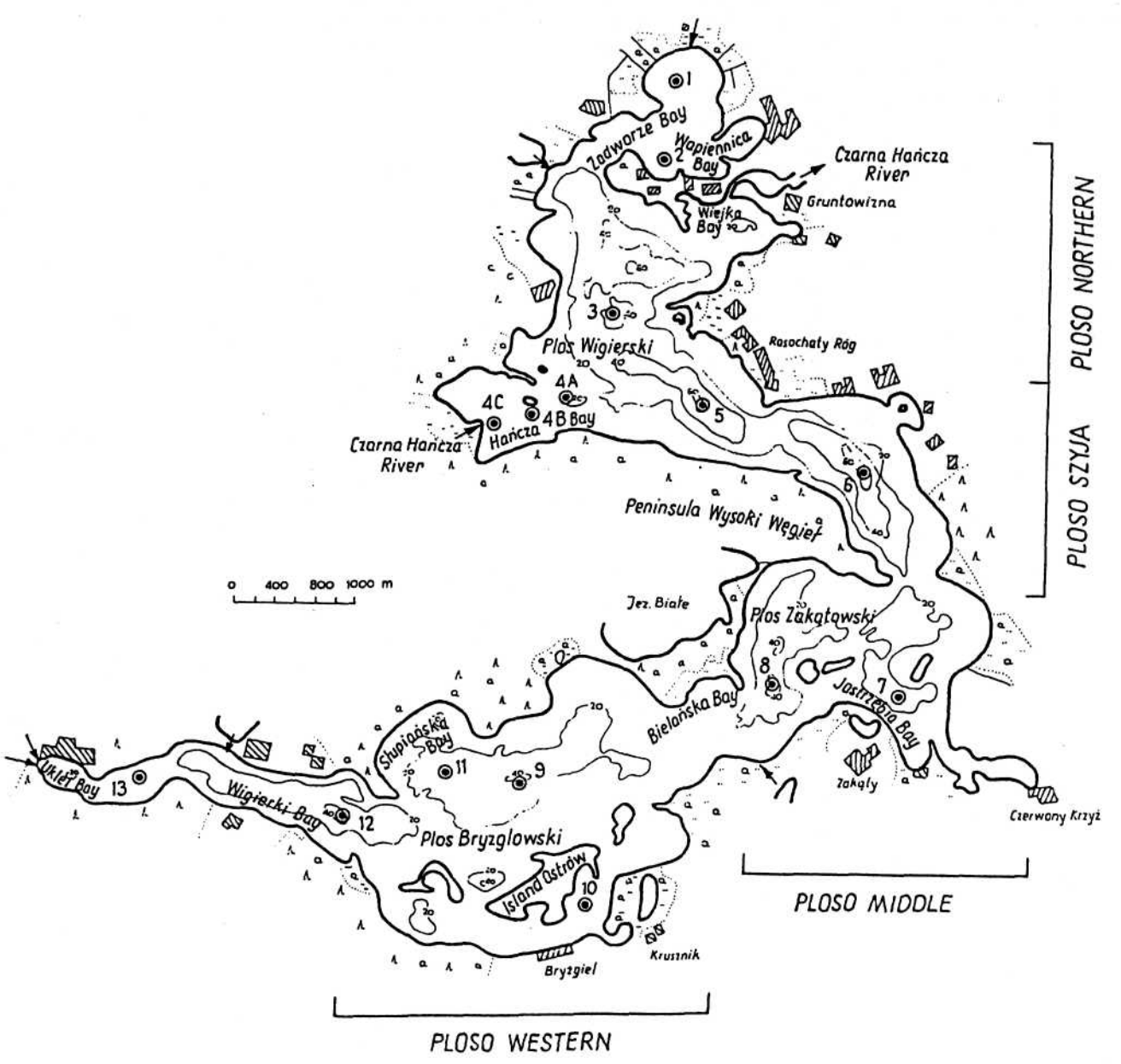

Fig. 2. Map of Lake Wigry and location of the sampling stations 1, 2, 3... 13.

Samle Wielkie being differentiated as far as their trophy [11] is concerned and these lakes are found in the northwestern part from lake Pierty. All larger lakes in Wigry are connected by watercourses and are included in the system of outflow of the Czarna Hancza River. The Czarna Hancza River brings purified waters from Suwalki and the watershed into Lake Wigry in the region of Hanczariska Bay. The second largest river is the Kamionka, conncecting lakes Kolesne and Krzywe with Lake Pierty. In the middle course it flows through the so-called Huclanskie Lakes (Dqbrowka, Krzywe, Zielone, Czarne, Kolesne). Numerous distrophic lakes called "suchar" are found in the middle part of the Kamionka Basin. The Wiatroluza River goes from the north through Lake Kr616wek to Lake Wigry from where Piertanka Trench through Lake Omutowek flows into Zadworze Bay in Lake Wigry. The Maniowka River flows into it two kilometers to the north. The Samlanka River outflowing from Lake Samle Male is a small inflow of Lake Pierty. Flowing towards Lake Pierty the river collects the waters from lakes Gateziste and Piercianskie. Two other short watercourses (irrigation ditches) flow into Lake Pierty from the east side. One of them irrigates the swamps near a village called Piertanie, the second one near the villages Krolowek and Wysoka Gora [3].

According to Zdanowski et al. [15] only larger lakes in the Park (Wigry, Pierty, Biate Wigierskie) and the deep ones of small area (Suchar II, Suchar IV, Samle Wielkie, Czarne near Bryzgiel, Biale, Galeziste, Mulaczysko) are characterized by typical thermal stratification in summer. Several lakes (Leszczewek, Suchar Wielki, Suchar Dembowskich, Suchar Rzepiskowy, Widnc, Sucharek, Postaw, Czarne near Gawrych Ruda, Suchar I, Suchar II, Okra.gle, Mulaczysko, Dlugie Wigierskie) area characterized by thermocline reaching the bottom or great differentiation of temperature without clear thermal stratification. In a few lakes (Klonek, Suchar VI, Omutowek) only little water temperature decrease at the bottom was found. The best oxygen conditions were observed in Lakes Biale Wigierskie, Biale Pierciafiskie, Samle Wielkie and Czarne near Bryzgiel. According to Sokolowski and Kot [11] Lake Biale Wigierskie (mezotrophic) shows the state very similar because of physico-chemical features of water. The other lakes transformed as a result of succession into eutrophic or distrophic lakes and they have a protective function for mezotrophic lakes Wigry and Pierty. Distrophic lakes have acid pH (below 6.5) and a lower content of calcium (below 6 mg/1) and other soluble ions. The basic feature of chemical composition of water in mezo- and eutrophic lakes is a hydrogen-carbon type.

Sampling

The samples of water for microbiological examinations were taken in July 1995, in the deepest parts of the lakes. In Lake Wigry there were 15 sites, in Lakes Dlugie Wigierskie, Muliczne, Suchar Wielki, Postaw - 2 sites, in Lakes Biale Wigierskie and Pierty - 3 sites, in the other lakes - 1 site (Tables 1 and 2, Figs. 1 and 2). Besides, the samples were taken from inflowing and/or outflowing canals which carried water from lakes. In each lake the samples were taken from the surface layer (0.3 m), in deeper lakes from the depth of 1 m, 5 m and 10 m and later in 10 meter interwals right to the bottom. The samples of near-bottom water were taken 20-30 cm from the bottom. From canals the samples were collected from the surface layer (0.3 m). At the water surface, samples were collected directly into sterile glass bottles (300 ml volume) with ground stoppers. Water samples from lower depths were collected by 5 1 Rutner device into the same sterile glasses. The samples were kept in dry ice, enabling temperature maintenance of 4-6°C for a least 24 h. The time from collecting the samples to carrying out analysis (sanitary-bacteriological) did not usually exceed 18 h.

Microbiological Studies

Bacteriological analyses comprised the following:

1. total number (CFU/1 ml) of bacteria on broth-agar after 72 h incubation at 20°C (TVC 20°C);
2. total number (CFU/1 ml) of bacteria on broth-agar after 24 h incubation at 37°C (TVC 37°C);
3. total number (MPN/100 ml) of bacteria from *Escheri chia coli* group (TC) on the Eijkman medium after 48 h incubation at 37°C;
4. number (MPN/100 ml) of faecal bacteria from *Escheri chia coli* group (FC) on the Eijkman medium after 24 h incubation at 44.5°C;
5. number (MPN/100 ml) of faecal streptococci (FC) on the Slanetz and Bartley medium with sodium azide and crystal violet after 72 h incubation at 37°C.

TVC 20°C and TVC 37°C were determined according to the bacteriological procedure used for drinking water. The most probable number TC, FC and FS was determined with the fermentation test-tube method and the dilution method according to Standard Methods [2].

Each time 10 ml, 1 ml, 0.1 ml and 0.01 ml of water were inoculated in 3 parallel repetitions. The results were obtained from McCrady's Tables. A physiological solution of NaCl was used as the diluent. Positive results for the presence of total coliforms and faecal coliforms in fermentation tests on Eijkman medium were checked on Endo medium, on lauryl-tryptone broth, and in preparates stained with the Gram method. Positive results for the presence of faecal streptococci in Slanetz and Bartley medium were checked in m-Enterococcus Agar medium. Typical dark-red colonies which developed in this medium were inoculated to broth medium and their growing ability was determined in 44.5"C, at pH 9.6, in presence of 6.5% NaCl and additionally in milk with an addition of 0.01% methylene blue. Dry media produced by DIFCO and MERCK were used in the study. The obtained values of microbiological indices of pollution (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) of lake water were related to the criteria adapted for the classification of surface waters [1, 5, 10] and for waters used for recreation purposes [6, 13]. A total of 81 samples were collected from Lake Wigry, 93 samples from 19 lakes in the direct watershed of this reservoir, 29 samples from 4 lakes in the watershed of the Wiatrotuza River, 22 samples from 7 distrophic lakes in the watershed of the Kamionka River, 17 samples from 5 lakes in the watershed of the Samlanka River, 22 samples from 5 "other" lakes in WNP, and 13 samples from canals flowing into or out of the lakes.

Table 1. Some morphometric data of Lake Wigry and lakes in watershed immediately Lake Wigry and their watersheds after Bajkiewicz-Grabowska et al. [4] and Zdanowski et al. [15].

No.	Lake	Lake						Watershed						
				Depth (m)						Percent surface area of immediately watershed				
		Total area (ha)	Volume (1000 m^3)	Max.	Average	Trophic type	Quality Class	Surface area of immediately watershed (km^2)	Watershed type	Cultivated	Meadow and swamps	Forests	Land development and highway	Water
1.	Wigry	2118.3	336,726.7	73.0	15.8	eu-me[1]	–	73.12	S[2]	15	3	56	0	24
Lakes in watershed immediately Lake Wigry														
2.	Czarne near Bryzgiel	7.8	786.1	32.0	10.1	eu-me	II	0.236	S-C	23	59	18	0	0
3.	Okrągłe	12.2	814.1	12.8	6.7	eu-me	II	0.228	S	50	0	28	12	0
4.	Długie Wigierskie	80.0	5227.6	14.8	6.4	eu-me	I	5.089	S	23	20	57	0	0
5.	Muliczne	25.7	1219.4	11.3	4.7	eu-me	II	1.332	S	0	7	93	0	0
6.	Białe Wigierskie	100.2	13193.3	34.0	13.2	eu-me	I	1.558	S	0	0	100	0	0
7.	Suchar Wielki	8.9	327.8	9.0	3.6	dis.	II	0.988	S	0	0	100	0	0
8.	Suchar Rzepiskowy	1.0	19.3	4.7	1.9	dis.	–	0.088	S	0	0	100	0	0
9.	Rzepiskowe	1.47	60.7	7.0	4.1	–	–	0.654	S	0	10	90	0	0
10.	Leszczewek	21.0	950.6	18.0	3.5	eu-me	II	2.837	S-C	76	17	7	0	0
11.	Suchar Zachodni	1.2	12.2	2.3	1.0	dis.	II	1.755	S	0	0	100	0	0
12.	Suchar Wschodni	1.0	17.9	3.1	1.8	dis.	II	0.118	S	0	0	100	0	0
13.	Suchar Dembowskich	3.3	144.0	7.5	4.3	dis.	II	0.396	S	0	0	100	0	0
14.	Czarne near Gawrych Ruda	6.4	145.3	10.0	2.3	eu-me	–	0.175	S	0	100	0	0	0
15.	Krusznik	26.8	950.6	18.0	3.5	eu-me	II	1.276	G-S	78	10	9	0	0
16.	Mulaczysko	18.3	1042.8	20.5	5.7	eu-me	II	0.642	G-S	96	1	3	0	0
17.	Klonek	4.5	66.5	3.3	1.5	eu-me	I	0.134	G-S	76	9	15	0	0
18.	Ślepiec (Wygorzele)	2.0	31.7	2.5	1.5	dis.	II	1.798	S	12	4	84	0	0
19.	Sucharek near Bryzgiel	0.7	5.2	6.0	0.8	dis.	III	0.255	S	0	19	81	0	0
20.	Ślepe Krzyżańskie	0.9	–	1.2	0.5	dis.	–	–	–	–	–	–	–	–

[1] – eutrophic - mezotrophic, distrophic

[2] – S - sandy, S-C - sandy-clayey, G-S - clayey-sandy

Table 2. Some morphometric data of lakes in watersheds River Wiatrołuża, River Kamionka, River Samlanka and "other" lakes in the area of Wigry National Park after Bajkiewicz-Grabowska et al. [4] and Zdanowski et al. [15].

No.	Lake	Lake						Watershed							
		Total area (ha)	Volume (1000 m^3)	Depth (m)		Trophic type	Quality Class	Surface area of immediately watershed (km^2)	Watershed type	Percent surface area of immediately watershed					
				Max.	Average					Cultivated	Meadow and swamps	Forests	Land development and highway	Water	
Lakes in watershed River Wiatrołuża															
21.	Pietronajcie	1.7	76.6	9.5	4.3	–	I	0.030	C[2]	0	0	100	0	0	
22.	Królówek	9.9	215.0	4.5	2.2	–	–	0.349	C	0	20	80	0	0	
23.	Pierty	228.2	23677.2	38.0	10.4	eu-me[1]	II	7.562	C-S	30	15	53	0	2	
24.	Omułówek	14.2	429.2	5.5	3.0	eu-me	I	0.409	C	57	42	0	1	0	
Lakes in watershed River Kamionka															
25.	Suchar I	0.9	23.9	4.0	2.5	dis.	II	0.157	C-S	0	0	100	0	0	
26.	Suchar II	2.6	93.2	9.5	3.6	dis.	II	0.082	C-S	0	0	100	0	0	
27.	Suchar III	0.33	6.3	4.0	1.9	dis.	II	0.205	C-S	0	0	94	0	6	
28.	Suchar IV	1.15	34.4	8.0	3.2	dis.	III	0.109	C-S	0	0	100	0	0	
29.	Suchar V	0.5	9.8	5.7	2.1	–	–	0.513	C-S	0	4	96	0	0	
30.	Suchar VI	0.2	2.2	2.0	1.0	dis.	II	0.142	C-S	0	0	100	0	0	
31.	Suchar VII	0.2	2.2	2.9	1.2	dis.	II	0.645	C-S	0	23	77	0	0	
Lakes in watershed River Samlanka															
32.	Wądołek	1.0	82.5	15.0	8.6	dis.	II	0.110	C-S	18	0	82	0	0	
33.	Samle Małe	0.8	–	10.0	–	–	–	0.485	C-S	54	0	46	0	0	
34.	Samle Wielkie	2.1	114.7	11.0	5.0	eu-me	II	0.371	C-S	70	0	30	0	0	
35.	Gałęziste	3.9	203.8	14.3	5.2	eu-me	II	0.119	C	8	0	92	0	0	
36.	Białe Pierciańskie	6.0	362.8	24.0	8.0	eu-me	II	0.093	C-S	59	7	34	0	0	
"Other" lakes in the area of Wigry National Park															
37.	Postaw	13.5	450.6	8.0	3.3	eu-me	II	1.095	C-S	46	45	5	0	4	
38.	Konopniak	1.73	53.3	6.7	3.1	–	I	0.597	P	0	0	100	0	0	
39.	Mozguć	–	–	–	–	–	–	–	–	–	–	–	–	–	
40.	Widne	2.1	–	5.7	2.5	dis.	–	–	–	–	–	–	–	–	
41.	Ślepe Zielone	–	–	–	–	–	–	–	–	–	–	–	–	–	

[1] – eutrophic - mezotrophic, distrophic
[2] – C – clayey, S-C - sandy-clayey, C-S - clayey-sandy

Results

Number of Indicatory Bacteria of Pollution and Sanitary State in Waters of Lakes in Wigry National Park

Lake Wigry

Microbiological examinations of Lake Wigry water were carried out at 15 sites situated in the most characteristic places (Fig. 2.). TVC 20°C ranged from 20 to 6050 CFU/1 ml, depending on the site and depth (Table 3). The lowest fluctuations of their numbers were in water at site 1 (200-790 CFU/1 ml), the highest at site 7 (80-5330 CFU/ 1 ml). On average for the whole surface the least number was found at site 11 (290 CFU/1 ml), the highest number at sites 7 and 13 (2385 and 2395 CFU/1 ml, respectively). TVC 37°C ranged from 5 to 14200 CFU/1 ml. The lowest fluctuations of their number were in water at site 4B (75-240 CFU/1 ml), the highest at the site 7 (20-14,200 CFU/ 1 ml). On average for the whole surface the lowest number was found at sites 4A and 4C (10-20 CFU/1 ml), the highest at site 13 (540 CFU/1 ml). TC ranged from 4 to 1100 (at sites 1,4B and 8) and up to 4000 MPN/100 ml (at 4A site). On the average above 100 MPN/100 ml of these bacteria was found in the water at sites 1, 2, 3, 4 (A, B, C), 8 and 10. The number of FC did not exceed 460 MPN/100 ml in the water at site 1 and 150 MPN/100 ml at site 2. In most samples of water at particular sites these bacteria were not found. The number of FS reached the maximum values in water at site 4C(up to 14000 MPN/100 ml) and 10 (up to 1100 MPN/100 ml); they were not often found in inoculated volumes of water. On average it did not exceed 100 MPN/100 ml for the whole surface. Vertical stratification of indicatory bacteria in Lake Wigry was differentiated at particular sites. TVC 20°C at sites 1,9-13 appeared more numerous on the surface layer of water; at 1 m depth their number decreased and increased in deeper layers of water and in near-bottom water. At sites 3 and 5 it was smaller in surface water and increased at 1 m and in deeper layers of water. At sites 4A and 4B it was the same in surface water and at the depth of 1 m, it increased insignificantly at the depth of 5 m and decreased at the bottom. TVC 37°C at almost all sites decreased in water at 1 m depth and increased at 5 m, at some sites at near-bottom water as well. The number of TC, FC and FS at sites 1-4A and 9 and 10 decreased at 1 m depth and increased at 5 and/or 10 m. At 4B and sites 5-10 it decreased at 1 m and increased at 5 and/or 10 m; their larger number was seldom observed in bottom waters (Fig. 3).

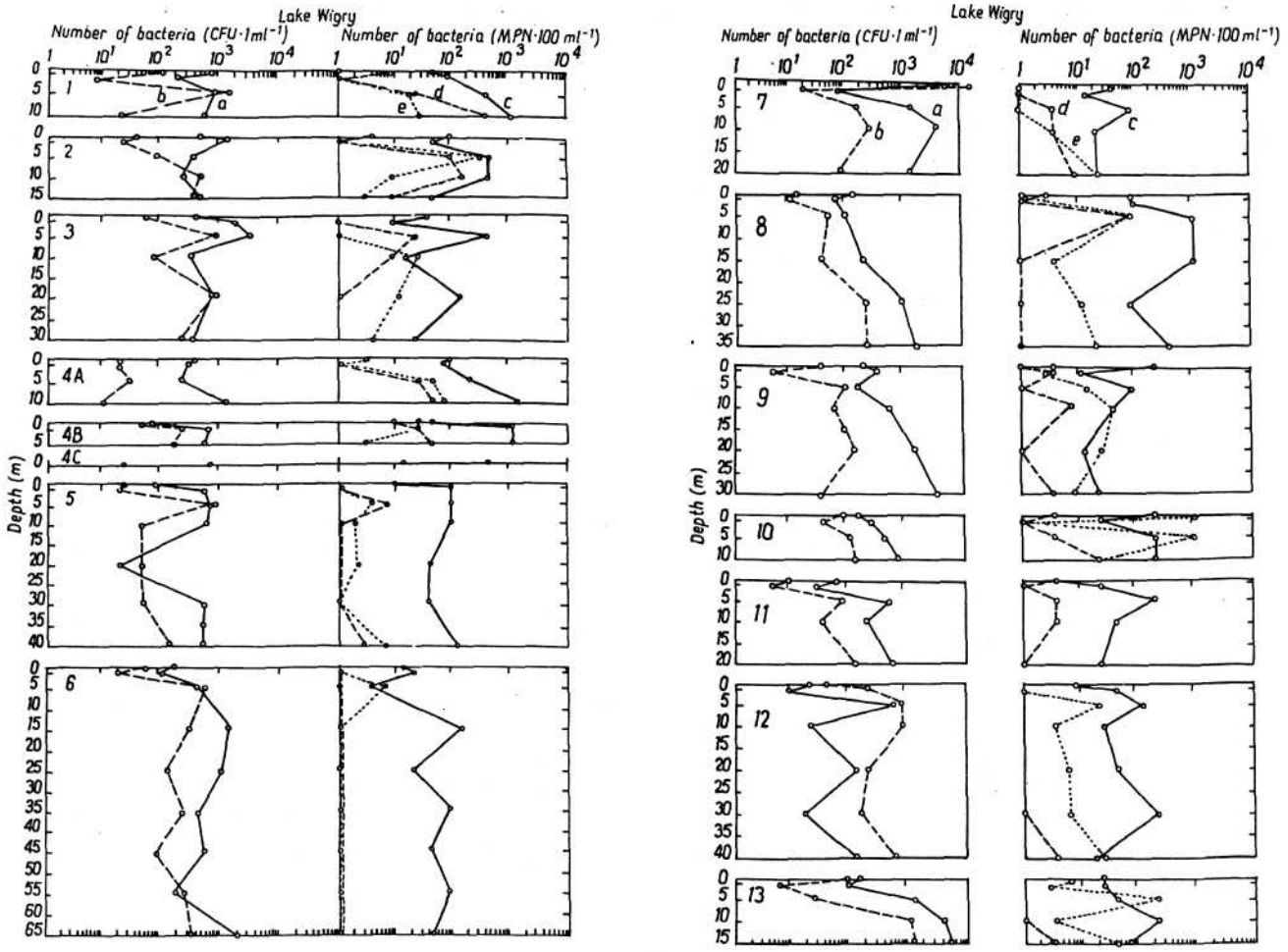

Fig. 3. Vertical stratification of the numbers of TVC 20°C (a), TVC 37°C (b), TC (c), FC (d) and FS (e) in the water of the Wigry Lake. 1, 2, 3 ... 13 sampling stations.

Lakes in the Direct Watershed uf Lake Wigry

19 lakes of different sizes in the direct watershed of Lake Wigry were examined (Table 1). TVC 20°C and TVC 37°C was generally higher than the observed one at the same time in Lake Wigry (Table 4). It was from 35 (Lake Slepiec-Wygorzele) to 55,125 (Lake Rzepiskowe) CFU/ 1 ml and from 2 (Lake Slepiec-Wygorzele) to 18,600 (Lake Suchar Dembowskich) CFU/1 ml, respectively. On average the lowest number was found in the water of Lake Slepiec-Wygorzele (115 and 7 CFU/1 ml, respectively), the highest number was in lakes Rzepiskowe and Biaie Wigier-skie (TVC 20°C 22640 and 11,700 CFU/1 ml, respectively) and lakes Suchar Wielki and Suchar Dembowskich (TVC 37"C 6350 and 6800 CFU/1 ml, respectively). The number of TC and FS fluctuated from < 3 to 1400 MPN/100 ml in water of different lakes; the number of FC was from < 3 to 240 MPN/100 ml (Table 4). On average the number of TC reached the lowest values in lakes Okra.gle, Biate Wigierskie and Slepe Krzyzanskie (6-13 MPN/100 ml), the highest values were found in Lake Leszczewek (600 MPN/100 ml). The number of FC was the lowest in lakes Okra.gte, Dlugie Wigierskie, Biale Wigierskie, Rzepiskowe, Suchar Zachodni, Krusznik, Mulaczysko, Klonek, Slepiec-Wygorzele and Slepe Krzyzanskie (< 3-11 MPN/100 ml), the highest number was found in lakes Leszczewek, Suchar Wschodni and Suchar Dembowskich (up to 75 MPN/100 ml). They were not found in Lake Okrqgle. The number of FS reached the lowest mean values in lakes Okrqgle, Dlugie Wigierskie and Biale Wigierskie (4-62 MPN/100 ml) the higest values were in lakes Suchar Dembowskich, Czarne near Gawrych Ruda, Suchar Zachodni and Suchar Wschodni (800, 825, 930 and 1300 MPN/100 ml, respectively). Vertical stratification of the examined indicatory bacteria in this group of lakes was differentiated (Fig. 4.). TVC 20°C and TVC 37°C in lower quantities were found in surface water (0.3 m), in larger quantities at 1 m depth (lakes Czarne near Gawrych Ruda, Dlugie Wigierskie, Biale Wigierskie, Suchar Wielki, Rzepiskowe, Suchar Wschodni, Krusznik, Mulaczysko), in others they were more numerous in surface water, in lower quantities at 1 m depth (lakes Suchar Rzepiskowy, Leszczewek, Suchar Zachodni, Czarne near Bryzgiel, Klonek, Slepiec-Wygorzele). In deeper layers of water their number generally decreased and increased more or less at the bottom. The numbers of TC and FS generally reached lower values in surface waters (0.3 m), higher ones at 1 m depth; in some lakes at the bottom as well.

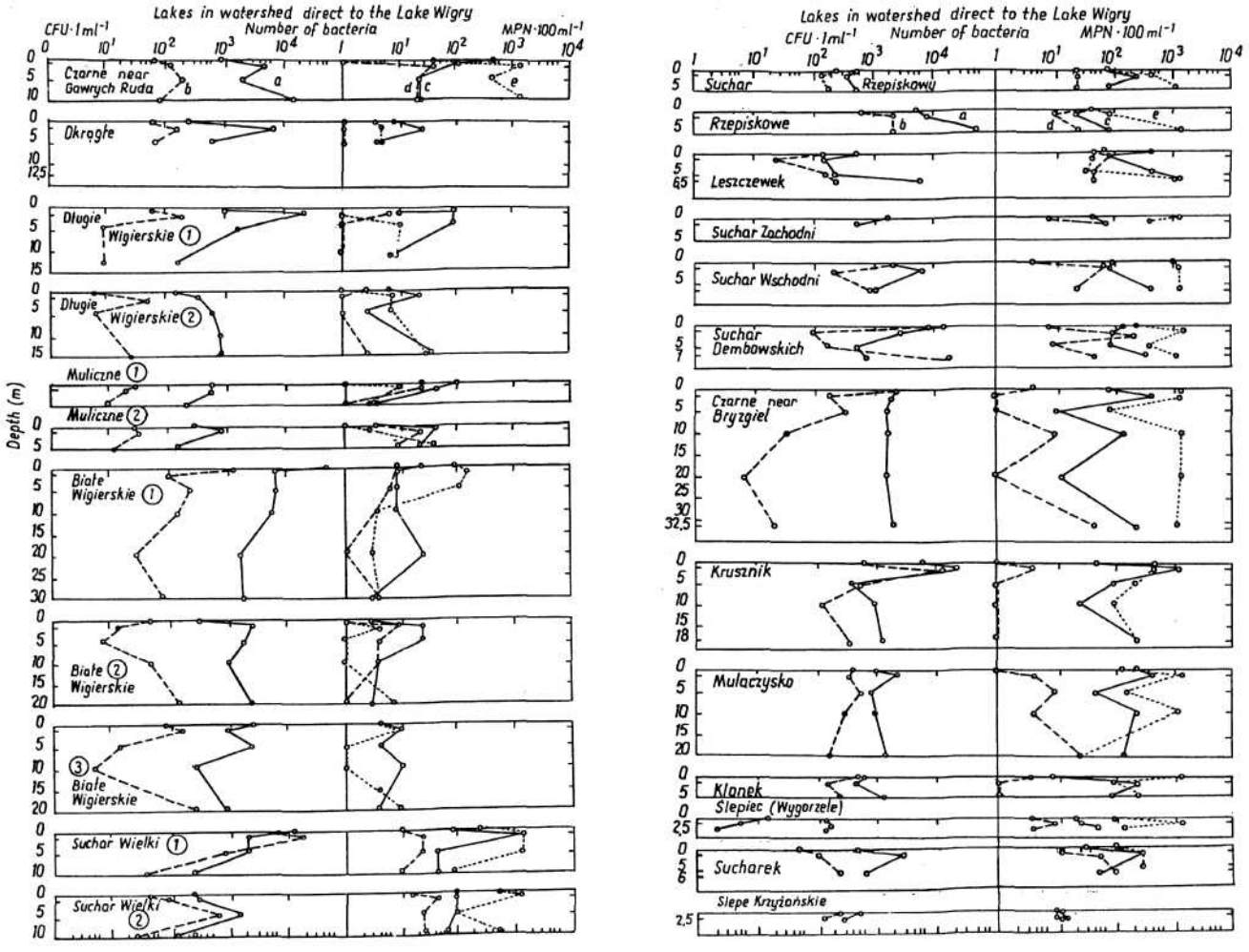

Fig. 4. Vertical stratification of the numbers of TVC 20°C (a), TVC 37°C (b), TC (c), FC (d), and FS (e) in the water of lakes in watershed immediately Lake Wigry. 1, 2, 3 sampling stations.

Lakes in the Wiatrotuza River Watershed

There are 4 lakes in the watershed of the Wiatroluza River which differ in depth and size (Table 2). TVC 20°C and TVC 37°C in the water of the lakes varied from 210 to 8640 CFU/1 ml and from 20 to 9950 CFU/1 ml, respectively. On average for the whole surface TVC 20°C appeared in the least quantities in Lake Pietronajcie; in the largest amounts in Lake Pierty (320 and 3870 CFU/1 ml, respectively). TVC 37°C were found in the least quantities in Lake Pierty at site 3, in the largest amounts in the same lake at site 2 (220 and 1670 CFU/1 ml, respectively). The number of TC and FC varied from < 3 to 460 MPN/100 ml and from < 3 to 120 MPN/100 ml, respectively. On average, for the whole surface the lowest number was observed in lakes Pietronajcie and Pietry (up to 20 MPN/100 ml) the largest number was in the water of Lake Krolowek (460 and 55 MPN/100 ml, respectively). The number of FS varied from 3 to 1400 MPN/100 ml. On the average for the whole surface the lowest number was found in lakes Pietronajcie and Omulowek (18 and 25 MPN/100 ml, respectively); the largest number was in Lake Pierty at site 2 (635 MPN/100 ml) (Table 5). Vertical stratification of TVC 20"C was characterized by smaller values in surface water, and larger ones at 1 m depth (lakes Sucharek near Bryzgiel, Krolowek, 0mul6wek) or inversely - lower at 1 m depth, larger in surface water and at the bottom (lakes Pietronajcie and Pietry). TVC 37°C were generally found in smaller quantities in surface water, and in larger ones at 1 m depth and in deeper layers as well as at the bottom. This also concerns the number of TC, FC and FS (Fig. 5).

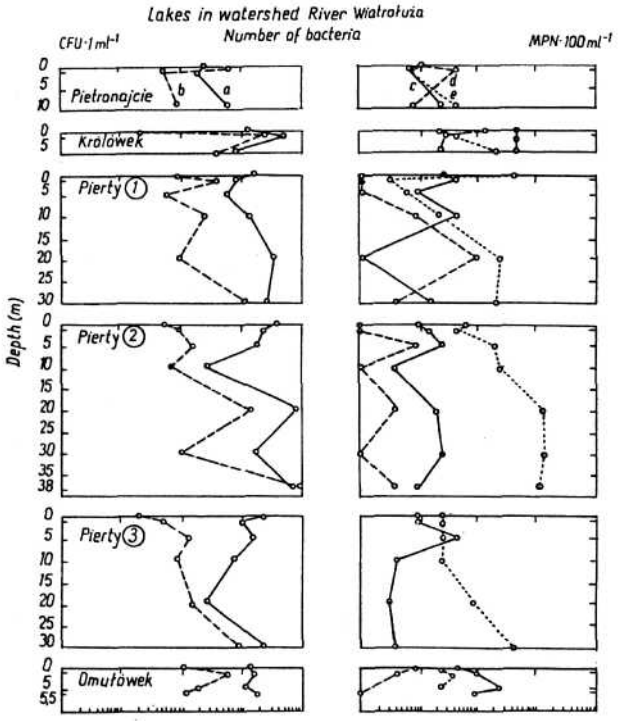

Fig. 5. Vertical stratification of the numbers of TVC 20°C (a), TVC 37°C (b), TC (c), FC (d), and FS (e) in the water of lakes in watershed River Wiatroluza. 1, 2, 3 sampling stations.

Lakes in the Kamionka River Watershed

There are 7 distrophic lakes called "suchar" in the Kamionka River watershed (Table 2). TVC 20°C in the water of these reservoirs ranged from 90 (Suchar IV) to 2250 (Suchar II) CFU/1 ml. On the average for the whole surface, their lowest number was found in lakes Suchar III, V and VII (from 200 to 275 CFU/1 ml), the largest number was in lakes Suchar I and II (1060 and 1115 CFU/1 ml, respectively). TVC 37°C varied from 30 (Suchar III and IV) to 8300 (Suchar I) CFU/1 ml. On the average for the whole surface the lowest number was found in Lake Suchar V (80 CFU/1 ml), the largest in Lake Suchar I (2820 CFU/1 ml). The number of TC ranged from < 3 (Suchar VI) to 460 MPN/100 ml (Suchar IV). Average for the whole surface ranged from 6 (Suchar VI) to 310 MPN/100 ml (Suchar IV). The number of FC varied from < 3 (in water of different lakes) to 150 MPN/100 ml (in lakes Suchar IV and Suchar V). They were not found in Lake Suchar II. On the average for the whole surface the largest amounts were in lakes Suchar IV and Suchar V (85 and 100 MPN/100 ml, respectively). The numbers of FS ranged from < 3 in lakes Suchar IV and Suchar V to 1400 in Lake Suchar I. On the average for the whole surface it was from 2 to 9 MPN/100 ml in lakes Suchar III, IV, V and VI up to 510 MPN/100 ml in Lake Suchar I (Table 6). Vertical stratification of TVC 20°C and TVC 37°C in the examined lakes was charac terized either by a decrease in depth (lakes Suchar I, II, III and VII) or an increase at 1 m and a decrease at deeper layers (Suchar IV, V, VI). Vertical stratification of the number of TC, FC and FS was characterized by a decrease at 1 m (Suchar I, II, IV) and deeper, or an increase at 1 m and decrease in deeper layers of water (Suchar III, IV, V, VI, VII) (Fig. 6).

Lakes in the Samlanka River Watershed

Five lakes of this group have a low degree of bacteriological pollution (Table 7). TVC 20°C ranged from 60 (lakes Wcidolek and Galeziste) to 1030 (Lake Galeziste) and 1340 (Lake Biale Piercianskie) CFU/1 ml. On the average for the whole surface the lowest number was found in Lake Samle Male (165 CFU/1 ml), the highest number was in Lake Biale Piercianskie (640 CFU/1 ml). TVC 37°C fluctuated from 5 (Lake Galeziste) to 370 (Lake Samle Wielkie) CFU/1 ml. On the average for the whole surface the lowest number was in Lake Samle Wielkie (160 CFU/1 ml). The number of TC, FC and FS did not exceed 240 MPN/100 ml; they were often not found there. TVC 20°C and TVC 37°C increased at 1 m depth and decreased in deeper layers of water. The numbers of TC, FC and FS on the contrary - increased at 1 m depth and decreased in deeper layers of water (Fig. 6).

"Other" Lakes in Wigry National Park

Five lakes which were not connected with any watershed in the WNP showed a differentiated degree of bacteriological pollution (Table 8). TVC 20°C ranged from 55 CFU/1 ml (Lake Konopniak) to 2600 CFU/1 ml (Lake Postaw). On the average for the whole surface the lowest

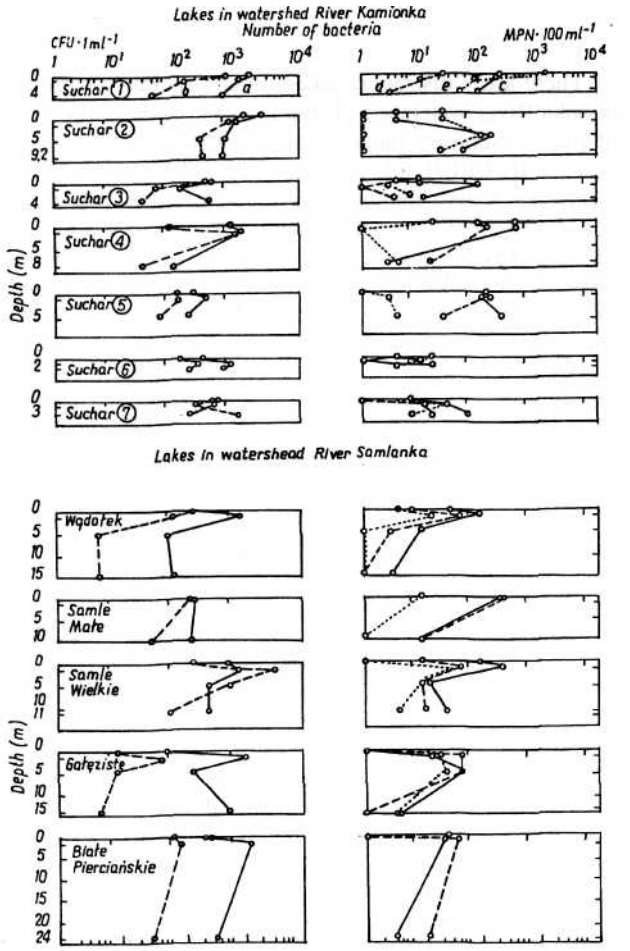

Fig. 6. Vertical stratification of the numbers of TVC 20°C (a), TVC 37"C (b), TC (c), FC (d), and FS (e) in the water of lakes in watershed River Kamionka and Samlanka.

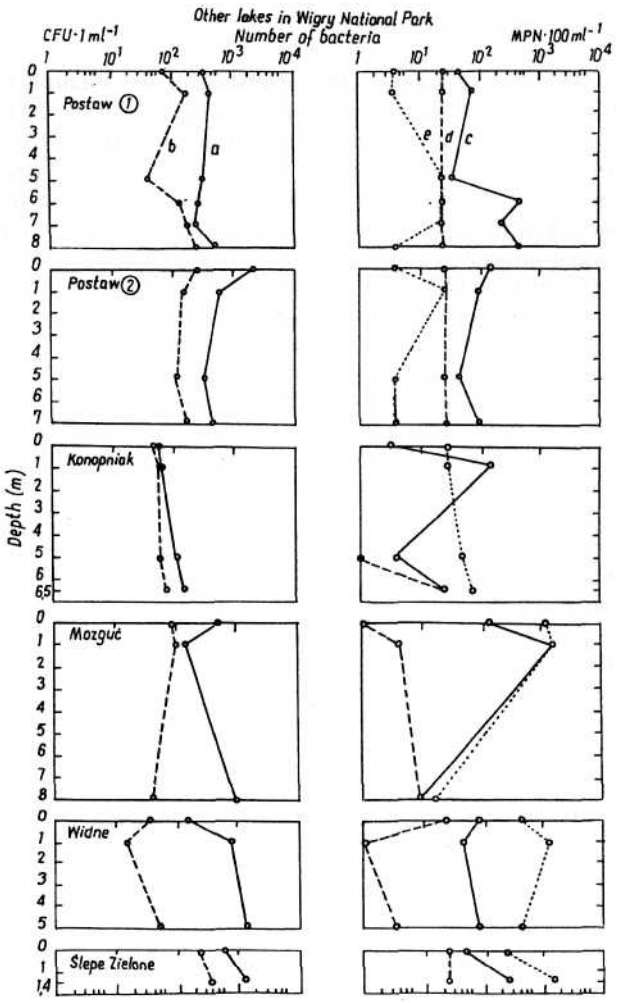

Fig. 7. Vertical stratification of the numbers of TVC 20°C (a), TVC 37°C (b), TC (c), FC (d), and FS (e) in the water of "other" lakes in Wigry National Park. 1, 2 - sampling stations.

number was found in Lake Konopniak (95 CFU/1 ml), the largest in Lake Slepe Zielone (940 CFU/1 ml). TVC 37°C ranged from 1 CFU/1 ml in Lake Widne to 240 CFU/1 ml in Lake Slepe Zielone. On the average for the whole surface it was from 35 CFU/1 ml (Lake Widne) to 290 CFU/1 ml (Lake Slepe Zielone). The numbers of TC ranged from 4 MPN/100 ml in Lake Konopniak to 1400 MPN/100 ml in Lake Mozguc. On the average it was from 45 (Lake Konopniak) to 510 MPN/100 ml (Lake Mozguc). The number of FC ranged from < 3 MPN/100 in lakes Widne, Konopniak and Mozguc and 4-15 MPN/100 ml in lake Postaw up to 23 MPN/100 ml in lakes Slepe Zielone, Widne, Konopniak and Postaw. The number of FS ranges from 4 MPN/100 ml in Lake Postaw up to 1400 MPN/100 ml in lakes Mozguc and Slepe Zielone. On the average for the whole surface their lowest number was in Lake Postaw, whereas the largest number was found in lakes Slepe Zielone and Widne. Vertical stratification of the examined indicatory bacteria was differentiated in the same lake on different sites (Fig. 7). For instance, in Lake Postaw at site 1 TVC 20°C and 37°C increased at 1 m depth but decreased at site 2. This also concerns the numbers of TC. The numbers of FC in water on both sites was the same from surface to bottom. The number of FS on site 1 increased in deeper layers, on site 2 their number increased at 1 m and decreased in deeper layers. In lakes Konopniak, Mozguc and Widne the number of the examined indicatory bacteria increased at 1 m depth and/or in deeper layers and at the bottom or they decreased at 1 m depth and increased at the bottom. In Lake Slepe Zielone a bit larger numbers of the examined indicatory bacteria were found at the bottom.

Flows

In flows (canals) connecting some lakes in the WNP TVC 20"C and TVC 37°C ranged from 200 to 8800 and from 45 to 7720 CFU/1 ml, respectively. Among indicatory bacteria of sanitary state FS were the most numerous (up to 1400 MPN/100 ml), whereas FC were the least numerous (up to 43 MPN/100 ml). The number of TC reached 1100 MPN/100 ml (Table 9).

Number of Indicatory Bacteria and Degree of Water Pollution of Lakes in Wigry National Park

The comparison of the results of the examination of TVC 20°C and the number of FC in lakes in Wigry National Park examined in the summer of 1995 with the bacteriological criteria of water quality estimation given by Albinger [1] and presented in Table 10 enables the evaluation of loading degree of organic substance easily decomposed by heterotrophic bacteria and human and/or animal excrement as follows:

1. Most samples taken from Lake Wigry, lakes in the watershed of the Kamionka, Samlanka rivers and "other" lakes in the WNP showed very little or little loading by organic substances easily decomposed by heterotrophic bacteria and human and/or animal excrement.

2. Lakes in the direct watershed of Lake Wigry and in the watershed of the Wiatroluza River most often show a moderate loading by organic substances easily decomposed by heterotrophic bacteria and very little or little loading by human and/or animal excrement.

On the other hand, a comparison of the results of the examined TVC 20°C, TVC 37°C and FC titre (data concerning FC titre are at the author of the paper) in Lake Wigry, lakes in the direct watershed of the reservoir, lakes in the watershed of the Wiatroluza, Kamionka, Samlanka rivers and "other" lakes in the WNP with the data presented by Cabejszek et al. [5] point at pure character and/or slight pollution. Only a small percentage of the examined samples can be regarded as significantly polluted. Comparing their FC values for the water of the examined lakes in the WNP and the values of FC titre given in the Decree of the Cabinet of Polish People's Republic dated 14th December,

Table 3. Mean (for total depth) and range for the numbers of total viable counts at 20°C and 37°C and total coliforms, faecal coliforms and faecal streptococci in the water of Lake Wigry in summer stratification.

Site[1]	Depth (m)	Number of samples	TVC 20°C	TVC 37°C	TC	FC	FS
			CFU/1 ml		MPN/100 ml		
1	10	4	550 200-790	470 10-1535	425 43-1100	123 < 3-460	12 < 3-28
2	15	5	570 230-1400	205 25-460	220 43-460	50 < 3-150	95 < 3-460
3	30	6	1130 330-3170	350 55-850	115 9-460	5 < 3-23	5 < 3-23
3[a]	10	4	1940 270-5500	135 50-350	55 4-93	11 < 3-23	50 23-75
4A	10	4	615 215-1260	10 10-30	445 75-1400	17 < 3-43	30 < 3-75
4B	5	3	405 45-625	165 75-240	750 43-1100	25 9-43	15 3-23
4C	0.3	1	720	25	460	15	14000
5	40	7	440 20-685	165 20-825	70 9-120	1 < 3-7	2 < 3-7
6	60	9	730 110-2000	230 20-525	55 4-150	3 3	0.7 < 3-7
7	20	5	2385 80-5330	2955 20-14200	39 15-93	3 < 3-9	5 < 3-23
8	30	6	535 70-1775	105 10-250	490 93-1100	15 < 3-93	20 3-93
9	30	6	1075 175-3450	65 5-130	70 11-240	3 < 3-9	17 3-43
10	10	4	420 180-800	100 40-135	190 23-240	8 < 3-23	555 < 3-1100
11	20	5	290 30-600	60 5-145	65 4-240	2 < 3-4	5 < 3-23
12	40	7	430 45-865	145 10-675	75 9-240	0.5 < 3-4	9 < 3-23
13	15	5	2390 110-6050	540 7-1200	80 23-240	0.8 < 3-4	53 3-210

[1] – as in Figure 2.

Table 4. Mean (for total depth) and range for the numbers of total viable counts at 20°C and 37°C and total coliforms, faecal coliforms and faecal streptococci in the water of lakes in watershed immediately lake Wigry in summer stratification.

No.	Lake[1]	Site	Number of samples	TVC 20°C	TVC 37°C	TC	FC	FS
				CFU/1 ml		MPN/100 ml		
2.	Czarne near Bryzgiel	1	6	2095 1750-2650	475 7-2275	155 9-460	9 < 3-43	1130 75-1400
3.	Okrągle	1	3	2375 230-6260	105 60-185	12 4-23	< 3 < 3	4 3-4
4.	Długie Wigierskie	1	4	6960 165-25650	255 9-950	50 4-93	3 < 3-9	5 < 3-11
		2	4	535 130-990	25 7-60	20 3-43	1.5 < 3-3	14 < 3-39
5.	Muliczne	1	4	530 200-915	45 10-125	45 4-93	19 < 3-25	63 < 3-240
		2	3	415 150-800	35 13-35	23 4-43	13 4-25	16 < 3-43
6.	Białe Wigierskie	1	6	11720 1375-48375	320 30-1350	13 3-23	6 < 3-9	62 3-150
		2	6	7885 310-39230	405 8-2200	13 3-23	6 < 3-23	4 < 3-11
		3	5	1340 275-2480	110 5-280	6 4-9	0.8 < 3-4	4 < 3-9
7.	Suchar Wielki	1	4	4040 215-11850	6350 40-1880	320 43-1100	16 9-23	625 93-1100
		2	4	545 120-1550	205 30-685	90 75-93	25 15-43	530 93-1100
8.	Suchar Rzepiskowy	1	3	470 385-520	175 120-245	130 75-240	23 23	550 93-1100
9.	Rzepiskowe	1	3	22640 5800-55125	1715 675-2320	53 23-93	6 9-43	510 43-1400
10.	Leszczewek	1	4	1865 170-6500	150 25-250	600 93-1400	55 43-93	315 39-1100
11.	Suchar Zachodni	1	2	1235 575-1900	215 210-225	60 43-75	6 < 3-11	930 460-1400
12.	Suchar Wschodni	1	3	3785 1000-7800	1215 200-2440	210 75-460	40 4-93	1300 1100-1400
13.	Suchar Dembowskich	1	4	4400 560-12500	6800 90-18600	190 75-460	75 9-240	800 240-1400
14.	Czarne near Gawrych Ruda	1	4	5575 805-15250	110 65-195	145 23-450	22 < 3-43	825 39-1400
15.	Krusznik	1	5	5910 410-21000	3190 115-14300	300 23-1100	0.8 < 3-4	293 93-460
16.	Mulaczysko	1	5	1390 860-2450	380 190-575	225 43-460	8 < 3-23	560 23-1400
17.	Klonek	1	3	4700 500-13000	310 160-525	115 9-240	1 < 3-4	580 93-1400
18.	Ślepiec (Wygorzele)	1	3	115 35-170	7 2-15	28 20-43	6 4-9	550 93-1400
19.	Sucharek near Bryzgiel	1	3	1245 480-2550	139 50-240	100 23-240	35 23-240	190 93-240
20.	Ślepe Krzyżańskie	1	2	435 355-510	185 125-245	12 9-15	9 9/9	590 75-1100

[1] – as in Figure 1.

1987 for different classes of water purity, it can be stated that 71.2% of the examined water samples taken from lakes in the watershed of the Wiatroluza River to lake Pierty, 81.2% of the examined water samples taken from lakes in the watershed of the Kamionka River, 94,1% of the examined water samples taken from lakes in the watershed of the Samlanka River and 95-100% of the examined water samples taken from Lake Wigry, lakes in the direct watershed of this reservoir, lakes in the watershed of the Wiatroluza River from Lake Pierty to Lake Wigry and "other" lakes were included in class I of purity.

Number of Indicatory Bacteria of Sanitary State and Requirements for Water for Recreational Purposes

The evaluation of bacteriological quality of lake water in Wigry National Park carried out on the basis of criteria given by the US Department of the Interior [13] shows that at least 92.6% of the water samples taken from lakes in the direct watershed of Lake Wigry 85.7% of the samples of water in lakes in the watershed of the Wiatroluza River to Lake Pierty, and 94.1% of the samples from lakes in the

Table 5. Mean (for total depth) and range for the numbers of total viable counts at 20°C and 37°C and total coliforms, faecal coliforms and faecal streptococci in the water of lakes in watershed River Wiatroluza in summer stratification.

No.	Lake[1]	Site	Number of samples	TVC 20°C	TVC 37°C	TC	FC	FS
				CFU/1 ml		MPN/100 ml		
21.	Pietronajcie	1	3	320 210-610	280 60-690	14 7-23	20 9-43	18 7-43
22.	Królówek	1	3	2530 950-5230	1060 425-2700	460 150-460	55 23-120	90 21-210
23.	Pierty	1	6	1865 630-3615	340 65-1100	20 < 3-43	18 < 3-93	155 3-460
		2	7	3870 285-8600	1670 50-9950	15 4-23	2 < 3-9	635 43-1400
		3	6	1440 280-2440	220 20-900	10 3-43	< 3 < 3	110 23-460
24.	Omułówek	1	4	1320 1010-1790	230 100-515	120 43-240	3 < 3-9	25 23-39

[1] – as in Figure 1.

Table 6. Mean (for total depth) and range for the numbers of total viable counts at 20°C and 37°C and total coliforms, faecal coliforms and faecal streptococci in the water of lakes in watershed River Kamionka in summer stratification.

No.	Lake[1]	Site	Number of samples	TVC 20°C	TVC 37°C	TC	FC	FS
				CFU/1 ml		MPN/100 ml		
25.	Suchar I	1	3	1060 500-1650	2820 40-8300	180 93-240	12 4-23	510 43-1400
26.	Suchar II	1	4	1115 600-2250	645 220-1250	70 4-240	< 3 < 3	40 23-93
27.	Suchar III	1	3	265 110-350	120 30-290	35 4-93	4 < 3-9	5 3-7
28.	Suchar IV	1	3	615 90-1050	385 30-1050	310 3-460	85 15-150	5 < 3-15
29.	Suchar V	1	3	200 150-265	80 50-95	190 110-240	100 23-150	2 < 3-4
30.	Suchar VI	1	3	525 225-750	150 100-185	6 < 3-14	6 4-9	9 4-14
31.	Suchar VII	1	3	275 130-375	540 195-1000	33 7-64	9 < 3-15	11 4-21

[1] – as in Figure 1.

watershed of the Samlanka River fulfilled the requirements for water for bathing purposes. In lakes of the Wiatroluza River watershed in the part from Lake Pierty to Lake Wigry, the Kamionka River and "other" lakes the requirements for water for recreational purpose were fulfilled by all the examined samples of water. Practicing water sports (canoeing, sailing, windsurfing) when the contact of body with water is rather indirect - is acceptable at least 97.5% of the samples taken from Lake Wigry, 96.7% of the samples taken from the direct watershed of this reservoir, 85.7% of the samples taken in the watershed of the Wiatrołuża River to Lake Pierty, and 94.1% of the samples taken from the Samlanka River watershed. In lakes in the Wiatroluza River watershed from Lake Pierty to Lake Wigry, the Kamionka River and "other" lakes of the examined area such requirements were fulfilled by all the examinated water samples.

Table 13 presents the values of the number of TC, FC and FS recommended and maximum accepted by European Committee for Quality of Water for Bathing Purposes [6] and the percent of water samples of the examined lakes in the WNP fulfilling the requirements of this institition. The data show that at least 92.6% of the water samples of Lake Wigry, 57.7% of the samples in the Wiatrohiza River watershed to Lake Pietry, and 89.2% of the water samples in the Wiatroluza River watershed from Lake Pierty to Lake Wigry, 86.4% of the water samples in the Kamionka River watershed and 63.6% of the samples of "other" lakes in WNP fulfilled the requirements for bathing waters. All the samples taken in the Samlanka River watershed contained these bacteria in amounts not exceeding the values recommended for bathing waters. In all examined samples of water lakes in the WNP the number of indicatory bacteria of sanitary state were lower than the maximum recommended by this institution.

Discussion

Dimensions and Sources of Pollution

The results of examination of bacteriological indexes of pollution degree (TVC 20°C, TVC 37°C) in water of lakes in Wigry National Park show very little, little or at least moderate loading by organic substance easily decomposed by heterotrophic bacteria, most often of autochtonic origin (TVC 20°C), seldom of allochtonic origin (TVC 37°C). Only a few samples of water were characterized by higher loading by organic substance easily decomposed by heterotrophic bacteria, they were collected from Lake Wigry in Zadworze Bay (site 1), Wapiennica Bay (site 2), Plos Wigierski (site 3), Jastrzebia Bay (site 7), Plos Bryzglowski

Table 10. The analysis of water quality of lakes in the area of Wigry National Park using criteria given by Albinger [1], Per cent distribution of samples relevant to the given class

Water quality criteria		Water quality level[1]	Lake Wigry	Lakes in watershed immediately Lake Wigry	Lakes in watershed River Wiatrołuża to Lake Pierty	Lakes in watershed River Wiatrołuża from Lake Pierty to Lake Wigry	Lakes in watershed River Kamionka	Lakes in watershed River Samlanka	„Other" lakes in the area of Wigry National Park	Total lakes in the Wigry National Park
Microorganisms	Number of bacteria (CFU · 1 ml^{-1})									
			1	2	3	4	5	6	7	8
TVC 20°C[2]	– < 500	1	51	26	50	9	55	65	59	39
	500 – 1000	2	29	32	16	31	36	24	32	28
	1000 – 10,000	3	20	33	34	60	9	11	9	29
	10,000 – 50,000	4	0	9	0	0	0	0	0	3
	50,000 – 100,000	5	0	0	0	0	0	0	0	1
	100,000 – 750,000	6	0	0	0	0	0	0	0	0
	> 750,000	7	0	0	0	0	0	0	0	0
			(70)[4]	(95)	(6)	(22)	(22)	(17)	(22)	(254)
FC[3]	1 – 10	1	83	66	17	95	59	53	36	68
	10 – 100	2	14	33	66	5	27	41	64	28
	100 – 1000	3	3	1	17	0	14	6	0	3
	1000 – 5000	4	0	0	0	0	0	0	0	1
	5000 – 10,000	5	0	0	0	0	0	0	0	0
	10,000 – 100,000	6	0	0	0	0	0	0	0	0
	> 100,000	7	0	0	0	0	0	0	0	0
			(71)	(93)	(6)	(23)	(22)	(17)	(22)	(254)

[1] - Degree of loading with organic substances, which can be well decomposed by bacteria (TVC 20°C) and degree of loading with faecal substances (FC): 1 - very little, 2 - little, 3 - moderate, 4 - moderate high, 5 - high, 6 - very high, 7 - extreme high

[2] - Total viable count at 20°C (heterotrophic bacteria as CFU • 1 ml^{-1})

[3] - Number of faecal coliforms (MPN • 100 ml^{-1})

[4] - In brackets number of samples investigated

Table 11. The analysis of bacteriological water quality of lakes in the area of Wigry National Park using criteria given by Cabejszek et el. [5]. A - unpolluted; B - insignificantly polluted; C - distinctly polluted; D - heavily polluted. Per cent distribution of samples relevant to the given class.

Bacteriological water quality criteria		Water quality	Lake Wigry	Lakes in watershed immediately Lake Wigry	Lakes in watershed River Wiatrołuża (to Lake Pierty)	Lakes in watershed River Wiatrołuża (from Lake Pierty to Lake Wigry)	Lakes in watershed River Kamionka	Lakes in watershed River Samlanka	„Other" lakes in the area of Wigry National Park	Total lakes in the Wigry National Park
Microorganisms	Number of bacteria (CFU · 1 ml^{-1})									
			1	2	3	4	5	6	7	8
TVC 20°C[1]	< 300	A	34.1	16.8	28.5	7.1	31.8	58.8	29.2	25.7
	300 – 5000	B	62.2	64.2	57.1	82.1	68.2	41.2	70.8	65.2
	5000 – 10,000	C	3.7	10.5	14.4	10.8	0.0	0.0	0.0	5.8
	> 10,000	D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
			(81)[4]	(95)	(7)	(28)	(22)	(17)	(24)	(274)
TVC 37°C[2]	< 200	A	70.3	65.3	42.8	53.6	54.5	94.1	79.2	66.5
	200 – 1000	B	24.7	23.2	28.6	28.6	31.4	5.0	20.8	24.3
	1000 – 5000	C	5.0	6.3	28.6	10.7	9.1	0.0	0.0	6.3
	> 5000	D	0.0	5.2	0.0	7.1	4.6	0.0	0.0	6.3
			(81)	(95)	(7)	(28)	(22)	(17)	(24)	(274)
Coli titre[3]	> 1	A	95.0	31.5	71.2	100	81.8	94.1	100	95.6
	1 – 0.1	B	5.0	33.7	14.4	0.0	18.2	5.9	0.0	4.0
	0.1 – 0.01	C	0.0	34.8	14.4	0.0	0.0	0.0	0.0	0.4
	< 0.01	D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			(80)	(95)	(7)	(28)	(22)	(17)	(24)	(273)

[1] - Total viable count at 20°C
[2] - Total viable count at 37°C
[3] - Faecal coliforms titre
[4] - In brackets number of samples investigated

Table 12. The analysis of bacteriological water quality of lakes in the area of Wigry National Park using criteria given by U.S. Department of Interior (Federal Water Pollution Control Administration - [13]). Percent distribution of samples relevant to the given class.

Lakes	Number of samples investigated	Bacteriological water quality standards					
		Total coliforms (MPN · 100 ml^{-1})			Faecal coliforms (MPN · 100 ml^{-1})		
		Recreational		Public water supply	Recreational		Public water supply
		I	II		I	II	
		1000	5000	10000	200	1000	2000
1. Lake Wigry	81	92.6	100.0	100.0	97.5	98.8	100.0
2. Lakes in watershed immediately Lake Wigry	95	96.7	100.0	100.0	98.9	100.0	100.0
3. Lakes in watershed River Wiatrołuża (to Lake Pierty)	7	100.0	100.0	100.0	85.7	85.7	100.0
4. Lakes in watershed River Wiatrołuża (from Lake Pierty to Lake Wigry)	28	100.0	100.0	100.0	100.0	100.0	100.0
5. Lakes in watershed River Kamionka	22	100.0	100.0	100.0	100.0	100.0	100.0
6. Lakes in watershed River Samlanka	17	100.0	100.0	100.0	94.1	100.0	100.0
7. „Other" lakes in the area of Wigry National Park	22	100.0	100.0	100.0	100.0	100.0	100.0
Total lakes in the area of Wigry National Park	274	98.2	100.0	100.0	98.5	99.2	99.6

I - Primary contact (swimming)
II - Secondary contact (sealing, windsurfing, boating...)

(site 9) and Uklei Bay (site 13), most lakes in direct watershed of Lake Wigry, Lake Kr616wek and Lake Pierty in the Wiatroluza watershed and some flows (canals) between lakes. Higher loading by faecal pollutants (most often of animal origin) was found in Lake Wigry in Zadworze Bay (site 1) and Wapiennica Bay (site 2), Hanczanska Bay (sites 4A, 4B, and 4C), between Ostrow Island and places like Bryzgiel and Krusznik (site 10) and in Uklei Bay (site 13), besides in Lake Kr616wek in the Wiatroluza River watershed and in lakes: Zielone, Widne, Konopniak, Mozguc and Postaw from the group of "other" lakes in the WNP and in some flows (canals) discharging water to Lake Wigry. Higher numbers of TVC 20°C and TVC 37°C in Jastrzebia Bay in Lake Wigry (where TC, FC and FS numbers were relatively small) could be attributed to strongly developed water plants in this more eutrophic part of the lake, giving the carbon source for heterotrophic bacteria as well as to recreational utilization of this bay [3, 4]. In the nearest neighbourhood of the bay there are farm buildings in Zaka.-ty, in summer season there are camping-sites and a sailing harbour being used by water sports fans. The superiority of FC over FS in Zadworze Bay (Site 1) and higher number of FC in Wapiennica Bay (site 2) in Lake Wigry are explained by the close proximity of rural districts, swimming areas, sailing harbours, and camping sites. Close to Wapiennica Bay from one side and Wiejka Bay from the other in Wigry on Klasztorny Peninsula there is a complex of monastery buildings which is now a hotel. Much higher numbers of FC than FS in lakes Suchar IV and Suchar V in the Kamionka River watershed, Samle Male and Lake Gateziste in the Samlanka River watershed have not been explained to the end. Higher numbers of FC in outflow from Lake Krusznik into Lake Wigry are attributed to recreational utilization of waters. Varness et al. [14] quotes many authors (Karalekas and Linch, Minkus et al., Dietrich et al.) from the last 30 years who said that recreation could have a negative influence of bacteriological quality of surface waters or they found a significant positive correlation between recreational utilization of waters and FC density in water. A factor modifying the degree of water pollution in Lake Wigry and other lakes in the WNP can be an activity of water fowls. The participation of this factor in pollution is explained by higher numbers of FS in Lake Wigry between Ostrow Island and places like Krusznik and Bryzgiel (site 10), as well as the majority of FS numbers over FC on Lake Czarne near Bryzgiel, Muliczne, Suchar Wielki, Suchar Rzepiskowy, Rzepiskowe, Leszczewek, Suchar Zachodni, Suchar Wschodni, Suchar Dembowskich, Czarne near Gawrych Ruda, Krusznik, Mulaczysko, Klonek, Slepiec-Wygorzele, Sucharek near Bryzgiel, Slepe Krzyzanskie in the direct watershed in Lake Wigry. It can also be observed in Lake Pierty in the Wiatrotuza River watershed, Lake Suchar I in the Kamionka River watershed, lakes Slepe Zielone, Widne and Mozguc" from the "other" lakes group in the Wigry National Park and in flows (canals) from lakes Czarne near Bryzgiel, Leszczewek and Krusznik to Lake Wigry, tributary of the Wiatroluza River to lakes Kr616wek and Pierty. Gustafson and Dille [7] quote the results of Fair and Morrison's research from 1967 and Stuart from 1971 according to which larger water pollution in closed areas (national parks) than in open ones for people is a result of wild animal activity.

Vertical Stratification of Indicatory Bacteria

In the research period in 1995 density of the examined indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in lakes in the WNP was different not only in different lakes but even in the same lake at different sites. In some lakes they were more numerous in the water layer at 0.3 m, in others at 1 m in metalimnion and/or at the bottom. The last one concerned especially TC, FC and FS. Lower numbers of these bacteria in the surface layer of water, higher at 1 m are explained by bacteriocidal activity of ultraviolet rays of sunlight on

Table 13. The analysis of water quality of lakes in the area of Wigry National Park using criteria given by EEC [6]. Per cent distribution of samples fulfilling guide and mandatory values for bathing waters

Lakes	Number of samples investigated	Guide values			Mandatory values		
		TC	FC	FS	TC	FC	S/E[1]
		500	100	100	10000	2000	0
		MPN/100 ml					
1. Lake Wigry	81	91.3	97.5	93.8	100	100	–
2. Lakes in watershed immediately Lake Wigry	95	96.8	98.9	54.7	100	100	–
3. Lakes in watershed River Wiatrołuża (to Lake Pierty)	7	100	85.7	85.7	100	100	–
4. Lakes in watershed River Wiatrołuża (from Lake Pierty to Lake Wigry)	28	100	100	89.2	100	100	–
5. Lakes in watershed River Kamionka	22	100	86.4	95.4	100	100	–
6. Lakes in watershed River Samlanka	17	100	100	100	100	100	–
7. „Other" lakes in the area of Wigry National Park	22	91.0	95.4	63.6	100	100	–
Total lakes in the area of Wigry National Park	27	96.2	97.0	78.5	100	100	–

[1] S - Salmonella/1 1; E - Enteroviruses PFU/10 1 (PFU - plaque forming units); S/E measurement is only required when an inspection in the bathing area shows that the parameter may be present, or when water quality has deteriorated.

allochtonic microflora of waters. It is known from literature that Gram-negative bacteria (especially *Escherichia coli)* are sensitive to sunlight and this factor is one of the most significant ones in the process of self-purification of waters being polluted by sewage [9].

More equal vertical stratification of the examined indicatory bacteria in small and shallow lakes can be attributed to deep mixing of waters. In deeper lakes the increase of their number in metalimnion and at the bottom could be attributed to temperature differences, specific weight of water, and the collection of larger amounts of dead plant and animal parts sedimenting from the surface layer or getting into bottom water from the surface layer of the bottom. Modifying influence on vertical stratification of the examined indicatory bacteria could have plant organisms (especially algae) releasing toxic substances and plankton animals. There are know examples of the decrease of bacteria number in water at the depths where *Crustacea* and *Rotatoria* were in larger amounts and their abundance at depths where the number of these crustaceans was lower **[8].**

Conclusions

1. The number of indicatory bacteria of the pollution degree (TVC 20°C, TVC 37°C) in a majority of water samples of the examined lakes in Wigry National Park shows pure character or only slight pollution of these reservoirs. Only a small percent of water samples taken from Lake Wigry in the direct watershed of this reservoir, lakes in watershed rivers Wiatroluza and Kamionka shows significant pollution.

2. Number of indicatory bacteria of sanitary state, particularly TC and FC shows usefulness for bathing purposes of all the water samples taken from the examined lakes in watershed rivers Wiatroluza (from Lake Pierty to Lake Wigry), Kamionka and a group of "other" lakes in Wigry National Park and a majority of water sample from Lake Wigry, lakes in the direct watershed rivers Wiatroluza (to Lake Pierty) and Samlanka.

3. The lowest counts of the examined indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) appeared in Lake Pietronajcie in watershed River Wiatromza, lakes Suchar **III,** IV, V, VI, VII in watershed River Kamionka, lakes Wadolek, Samle Male, Samle Wielkie, Galeziste and Piercianskie in watershed River Samlanka and Lake Konopniak from "other" lakes group in the WNP, the highest ones were observed in lakes: Biale Wigierskie, Czarne near Bryzgiel, Suchar Wielki, Rzepiskowe, Suchar Wschodni, Suchar Dembowskich, Czarne near Gawrych Ruda, Krusznik and Klonek in direct watershed Lake Wigry.

4. Minimum counts or FC lack in the majority of water samples and large FS count (ratio FC:FS below 0.7) suggest major participation of water fowl and/or wild animals in the pollution of these reservoirs; only in a few cases were they polluted by animals and people (ratio FC:FS 0.7-4.0), only by people (ratio FC:FS above 4).

5. Spatial distribution of indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in waters of larger lakes (Wigry, Dtugie Wigierskie, Biale Wigierskie, Suchar Wielki in the direct watershed Lake Wigry, Lake Pierty in watershed River Wiatroluza and Lake Postaw from "other" lakes group) in the WNP was different at particular sites depending on local sources of pollution. Only in Lake Muliczne was it indentical at both sites. Their vertical stratification was characterized by their lower number in surface water, higher at 1 m depth, in some lakes in metalimnion and at the bottom as well.

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