Evaluation of Pollution and the Sanitary-Bacteriological State of Lake Wigry, Poland

Part II. Near-shore Waters of Lake Wigry

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Abstract

This paper presents the results of studies on the degree of pollution and the sanitary-bacteriological state of near-shore waters of Lake Wigry in three successive summer periods (1994-1996) in the region of bathing sites, sailing harbours and anchoring places for fishery and anglers' boats. TVC 20°C and TVC 37° were used as the indicators of pollution, while TC, FC and FS - as indicators of sanitary state. Near-shore waters of Lake Wigry showed a little higher degree of pollution than pelagic waters. The waters of Lake Wigry showed higher bacteriological pollution in the region of bathing sites, the sailing harbour and the camping-site in Stary Folwark and in the northern part of this reservoir, the lower one was observed in the middle part, while the lowest one was in the western part in the region of Uklei and Wigierki Bays. Higher bacteriological pollution was found in near-shore waters of Lake Wigry in the end of June, 1994 and 1996 and at the beginning of September, 1995. In 1994 and 1996 it was caused mainly by the activity of water fowl (high number of FS), in 1995 by human recreational activity (high number of TC and FC). The majority of the examined water samples of near-shore waters of Lake Wigry fulfilled the water conditions for recreation, including bathing.

Keywords: lake, National Park, beach pollution, sanitary evaluation, microbiological standards, indicator bacteria, recreation, bathing

Introduction

Near-shore waters of rivers, lakes and seas are a potential source of recreational waters. They are locally utilized as a source of water for domestic purposes. Besides typical water bacteria *(Pseudomonas, Achromobacter, Chromobacterium, Sphaerotilus)* they contain bacteria carried from soil *(Bacillus* sp.) during rainfalls or by wind and bacteria from alimentary tracts of people and animals that get into water with domestic sewage. Besides bacteria from the group of *Escherichia coli, Enterococcus, Bacteroides* and *Clostridium perfringens* (which are included in natural microflora of the lower part of alimentary tract of humans or warm-blooded animals) pathogenic microorganisms can pass in excrement sporadically. Pollution of near-shore waters with bacteria like *Salmonella* is of significant impor-

tance. Fortunately infectious doses of these bacteria (10^6) are too large to cause symptom infections in people while choking. It does not concern *Salmonella typhi* and *Salmonella paratyphi* B, whose minimal infectious doses for people are about 1000 CFU but not less and these numbers are very seldom reached. Symptom infections are only found in particularly sensitive individuals who bathe in near-shore waters [9]. Diseases of alimentary tract were found in people bathing in strongly polluted canals of Alabama (FC 10^7 MPN/100 ml), the rivers of Louisiana impacted by a broken sewer line in the United States, and other locations [5]. Near-shore waters may act as a vehicle carrying pathogenic bacteria such as *Shigella,* pathogenic strains of *Klebsiella, Vibrio parahaemolyticus, Pseudomonas aeruginosa, Staphylococcus aureus, Leptospira interrogans, Franciscella tularensis,* protozoa of *Giardia lamblia,*

Entamoeba histolytica, speciess of *Schistosoma,* pathogenic nematodes and flatworms, pathogenic fungi such as *Candida albicans* and numerous enteric viruses [11, 16, 20], However, symptom infections in those who bathe in near-shore waters are limited only to pathogens, whose infectious doses are minimal. Conjunctivitis trachoma, ringworm infections, sinus throat, middle ear infections, otitis externa, swimmer itch, leptospirosis, chronical granulomas of the skin, shigellosis, primary amoebic meningoencephalitis, possibly even hepatitis and very rare cases of tuberculosis and tularemia are mentioned in literature as far as the people bathing in near-shore waters are concerned [5, 20].

The most important element of monitoring the quality and safety of recreational waters is the detection of faecal pollutions because many pathogenic microorganisms carried by water come from alimentary tracts of people and animals. In practice this means detection and quantitative estimation of index bacteria TC, FC *(Escherichia coli),* FS *(Enterococci)* instead of time-consuming and impractical control and monitoring this quality of recreational waters of pathogenic bacteria of alimentary tract [6, 7, 20]. FS and *Escherichia coli* at a lower degree correlate the best with "morbidity rate of gastrointestinal symptoms".

The results of the degree of pollution and sanitary-bacteriological state of near-shore waters of Lake Wigry with particular attention to bathing sites in the summers of 1994, 1995 and 1996 are presented in this paper. The present work together with research on sanitary-bacteriological states of pelagic waters of this reservoir [14] is part of a wider study devoted to the estimation of pollution and sanitary-bacteriological states of surface and underground waters in the area of Wigry National Park in nort-eastem Poland.

Methods

The criteria worked out for domestic conditions by Cabejszek et al. [4] and Decree of the Cabinet dated 14th December, 1987 concerning the classification of waters and the latest data presented by Albinger [1, 15] about the loading of waters by organic substance easily decomposed by heterotrophic bacteria and human and animal excreta were taken into consideration while estimating the degree of pollution of near-shore waters of Lake Wigry. Cabejszek et al. [4] differentiate 4 classes of water purity (unpolluted, slightly polluted, significantly polluted, strongly polluted). Each class is attributed to a given range of the number of TVC 20°C, TVC 37°C and FC (coliform index). The Decree of the Cabinet dated 14th December 1987 about the classification of waters [15] differentiates 3 classes of water purity on the basis of a wide range of physico-chemical parameters and coliform index. Albinger [1] distinguishes 7 degrees of water loading (very little, little, moderate, high moderate, high, very high and extremely high) by organic substance easily decomposed by heterotrophic bacteria (TVC 20°C) and by human and animal excreta (FC).

Data obtained from the US Department of the Interior [18] and later conclusions by the US EPA [19] concerning recommended and maximum permissible numbers of TC, FC, *Escherichia coli,* enterococci for recreational waters utilized for bathing (primary contact) and other purposes (angling, canoeing, rowing, sailing, wind-surfing, water

skiing - secondary contact) and public water supply (aestetic) were used for the estimation of usefulness and safety of waters for recreational purposes (bathing). Recomendations concerning the number of TC, FC and FS and maximum values of TC and FC in the waters for bathing included in EC Directive 7/160 of the European Committee for the Quality of Water for Bathing Purposes (E.E.C. - [8]) were taken into consideration. The number of FC (or *Escherichia coli)* was an index of the estimation of surface waters for the usefulness of bathing purposes in all these Standards. US Department of Interior besides FC requires TC determination, US EPA - *Escherichia coli* and entero cocci. These standards differ acording to the frequency of sampling and carrying out bacteriological analysis of the water and statistical evaluation of the results. None of these standards guarantees total safety for the swimmers bathing in the water fulfiling requirements as far as the number of FC is concerned. The utilization of thermotolerant bacteria from the group of *Escherichia coli* as the main index of faecal water pollution is questionable [12].

Lake Wigry

Lake Wigry (Fig. 1) is one of the largest and deepest lakes in northeastern Poland. It is situated in the basin of the Czarna Hancza-Niemen rivers at latitude 54°02.5', longitude 23°04.4' and 131.9 m above the sea-level. Its area is 2,118.3 ha (island area - 68.4 ha). The maximum length of the lake is 15,500 m, maximum width is 3330 m, maximum depth is 73.0 m. The length of the shoreline is 72,225 (including the length of the lake basin - 59,850 m, islands - 12,375 m), its volume is 336,726 thousand m^3. The origin

Table 1. Sites of water sampling

Part of the lake	Site[1]
I. Ploso Northern Zadworze Bay Plos Wigierski	A. Bathing site – Stary Folwark B. Sailing harbour next to a camping site C. Anchorage for fishery/ anglers' boats in Rosochaty Róg D. Next to farm building in Cimochowizna opposite a camping site
II. Ploso Szyja	E. Anchorage place for fishery/ anglers' boats near Mikołajewo
III. Ploso Middle Plos Zakątowski Jastrzębia Bay	F. Bathing site in the region of Piaski G. Bathing site in Zakąty, next to a camping-site
IV. Ploso Western Plos Bryzglowski Wigierki Bay Uklei Bay	H. Bathing site in Bryzgiel I. Bathing site "Binduga" J. Opposite camping site in Gawrych Ruda K. Sailing harbour in Gawrych Ruda L. About 100 m from the bathing site in Gawrych Ruda M. Bathing site in Gawrych Ruda

[1] See Figure 1.

of the lake is channel-morainal and consists of 3 principal parts of different morphometric features. They are: Plos Wigierski in the northern part of the lake, Plos Zakatowski and Plos Bryzglowski in the southern part of the lake. Rich and various shoreline, numerous large islands in the southern part of the Lake and numerous "depths" and high woods over the surface of the lake create wounderful landscapes and attract many tourists [13]. More definite data concerning the morphometry of Lake Wigry and its location in northeast Poland were presented in the first part of the paper [14]. More data concerning this lake are given by Bajkiewicz-Grabowska [2, 3], Hillbricht-Ilkowska et al. [10], Sokolowski and Kot [17] and Zdanowski et al. [21].

Monitoring Sites

Thirteen sites were selected in the near-shore lake which were situated in the bathing areas, close to the harbours and other places used for recreation by local people. The localization of the sites was presented in Fig. 1 and their short characteristic was show in Table 1.

Sampling

The samples were taken in near-shore waters in Lake Wigry about 5 m from the shore, at depth 0.3 m at intervals of 1 month from July to September 1994, and from June to October 1995 and 1996 into 300 ml sterile glass bottles with ground stoppers. The samples of pelagial water and water flowing into the lake from the Czarna Hancza River [14] were taken at the same time. After taking the samples they were put into a containers with dry ice (4-5°C) and transported to a laboratory where they were bacteriologically analyzed. There was never more than 16 h difference between sample collection and their analysis.

Microbiological Studies

Bacteriological anylyses comprised the following:
1. total number (CFTJ/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);
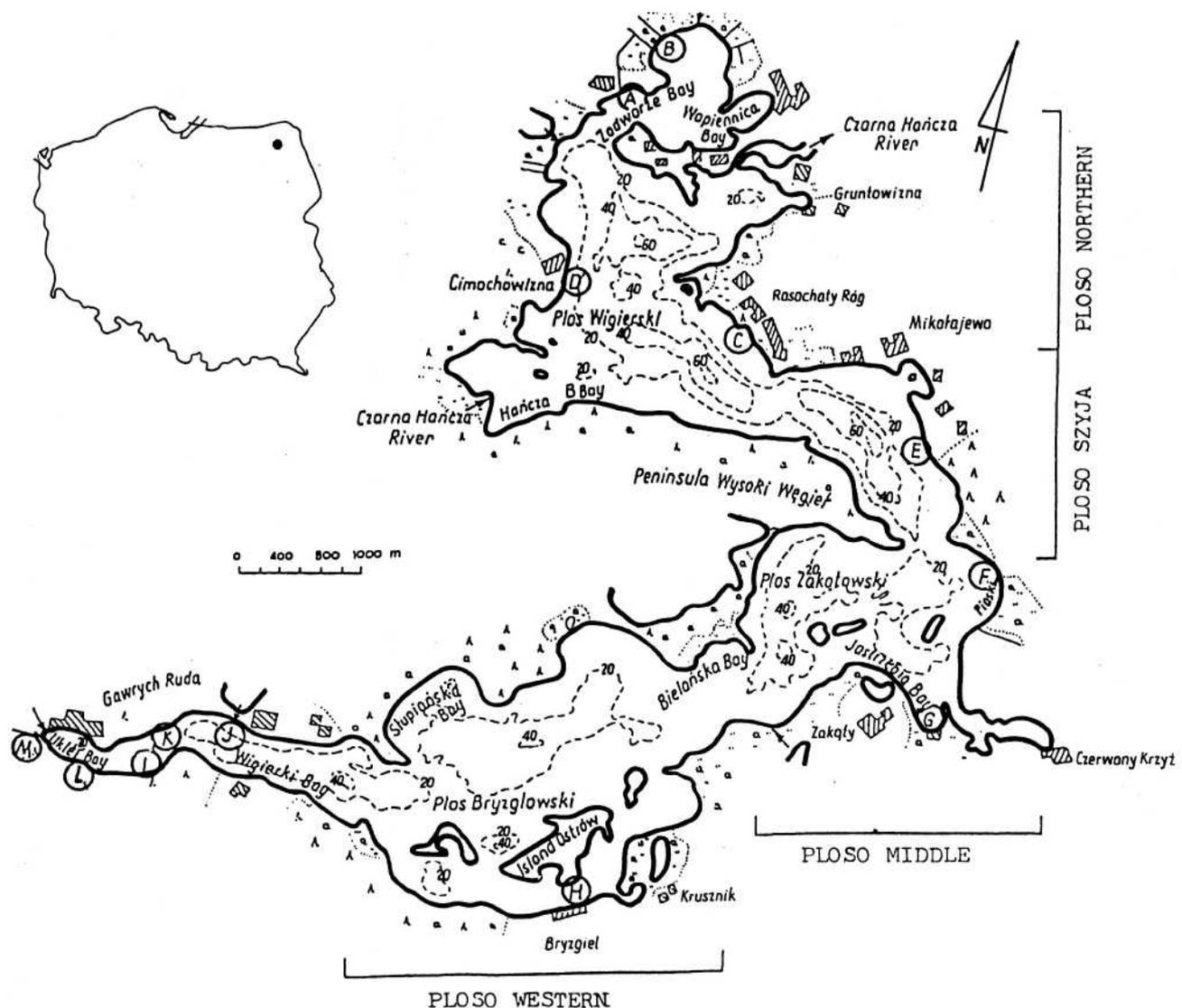

Fig. 1. Situational sketch of Lake Wigry. (A, B, C ... M - sampling sites).

3. number (MPN/100 ml) of total coliforms (TC) on Eijkman medium after 48 h incubation at 37°C;
4. number (MPN/100 ml) of faecal coliforms (FC) on Eijkman medium after 24 h incubation at 44.5°C;
5. number (MPN/100 ml) of faecal streptococci (FS) on Slanetz nad Bartley medium with sodium azide and cry stalline 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 methods of work on TC, FC and FS determination were the same as in the first part of the paper [14]. The same concerns research on the presence of *Escherichia coli* and faecal coliforms. The results of the examination of the number of bacteriological indexes of the degree of contamination (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) of the examined samples of near-shore waters of Lake Wigry referred to the criteria of the estimation of the degree of surface water purity presented in literature [1, 4, 15] and requirements for water for recreational purposes [8, 18, 19]. In this way 129 samples of near-shore water of Lake Wigry were examined.

Results

Numbers of Bacteria Indicatory of Pollution and Sanitary State in Near-shore Waters of Lake Wigry

Indicatory bacteria of the pollution degree. In near-shore waters of Lake Wigry the number of indicatory bacteria of the pollution degree (TVC 20°C, TVC 37°C) was generally higher than in pelagic waters in the respective parts of the reservoir. Total number TVC 20°C ranged from 5 CFU/1 ml in Piaski in October 1995 to 13,500 CFU/1 ml in a guarded bathing area in Gawrych Ruda, in July 1995. However, the total number TVC 37°C ranged from 2-5 CFU/1 ml at different sites in October 1995, in June, July and October 1996 to 3000 CFU/1 ml in Stary Folwark in June 1994. In the research season higher contamination was observed in summer months (Table 2).

Indicatory bacteria of sanitary state. Total number of faecal coliforms (TC) ranged from <3 do 1400 MPN/100 ml at different sites and in different research periods. The number of faecal coliforms (FC) only in August 1995 reached higher values(to 1,400 MPN/100 ml) in the water collected near the sailing harbour and a camping site in Stary Folwark, an anchoring place for fishery/anglers' boats in Rosochaty Rog, in a village Cimochowizna and an unguarded bathing site "Binduga". They were not often found in 100 ml water (particularly in autumn 1995 and 1996). The number of faecal streptococci (FS) ranged from <3 to 1400 MPN/100 ml. The largest number of them was observed in near-shore water at all sites in June 1996 (Table 3).

The Number of Indicatory Bacteria and the Degree of Near-shore Water Pollution in Lake Wigry

The presentation of the results of research on the number of TVC 20"C and FC in near-shore water of Lake Wigry with bacteriological criteria of water purity given by

Albinger [1] shows very little, little, moderate and/or moderately high loading by organic substance easily decomposed by heterotrophic bacteria and very little, little, especially moderate or moderately high loading by human and animal excrement. The samples of water moderately high loaded by organic substance easily decomposed by heterotrophic bacteria were taken near farm buildings in Cimochowizna, an anchorage in Mikolajewo and a bathing site in Zakaty, and in the area of a bathing site in Gawrych Ruda. The samples of water moderately high loaded by human and animal excrement were taken in the region of a sailing harbour and a camping site in Stary Folwark, at an anchorage in Rosochaty Rog (and close to farm building in Cimochowizna), and at an anchorage in Mikoiajewo (Table 4).

An approximate estimation of pollution degree of near-shore waters of Lake Wigry is obtained comparing the results of examination of the number TVC 20°C, TVC 37°C and faecal coliform index (FC) with the criteria of the estimation of water purity given for Polish conditions by Cabejszek et al. [5] presended in Table 5. According to these criteria the number TVC 20°C in 33-37% of the examined samples was in the class of unpolluted waters. The smallest number of such samples was found in the bathing sites and the sailing harbour in Stary Folwark and the bathing site "Binduga". The largest number was observed near the farm buildings in Cimochowizna, an anchorage in Mikolajewo, the bathing site Zakaty, and at a distance of 100 m from the bathing site in Gawrych Ruda. As far as the number TVC 37°C is concerned, 64-100% of the examined sample was in the class of unpolluted waters. The least number of such samples was found in the bathing site in Stary Folwark and close to the farm buildings in Cimochowizna, the largest number near the sailing harbour in Stary Folwark, the bathing site "Binduga" and the sailing harbour and the guarded bathing site in Gawrych Ruda. Coliform index of faecal type in 82-100% of the examined samples was in the class of unpolluted waters. The fewest samples of such water were found in the bathing site in Stary Folwark, the anchorage in Rosochaty Rog and the bathing site in Gawrych Ruda. Most of them were in the region of the anchorage in Mikolajewo, the bathing site in Zakaty, Bryzgiel, Binduga and opposite the camping site in Gawrych Ruda. According to the Decree of the Cabinet issued on 14th December 1987 [15], class I of water purity comprises 82-92% of water samples in the bathing site in Stary Folwark, Piaski and Gawrych Ruda; at the sailing harbours in Stary Folwark and Gawrych Ruda; at the anchorage in Rosochaty Rog; near the farm buildings in Rosochaty Rog and Cimochowizna; at a distance of about 100 m from the bathing site in Gawrych Ruda; and all the samples near the anchorage in Mikolajewo, the bathing site in Zakaty, the bathing site in Bryzgiel and "Binduga" and opposite the camping site in Gawrych Ruda.

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

According to data obtained from the US Department of the Interior [18] the numbers of TC and FC in surface waters utilized for bathing purposes (direct contact of a man's body with water) should not exceed 1000 and 200 MPN/100 ml, respectively; for all the waters used for recreational purposes except bathing (canoeing, sailing, etc.,

Table 2. Numbers of total viable counts at 20°C (TVC 20°C) and 37°C (TVC 37°C) in the water of coast Lake Wigry (1994-1996).

Sampling site	1994 July 20°C	July 37°C	Aug. 20°C	Aug. 37°C	Sept. 20°C	Sept. 37°C	1995 June 20°C	June 37°C	July 20°C	July 37°C	Aug. 20°C	Aug. 37°C	Oct. 20°C	Oct. 37°C	1996 June 20°C	June 37°C	July 20°C	July 37°C	Aug. 20°C	Aug. 37°C	Sept. 20°C	Sept. 37°C	Oct. 20°C	Oct. 37°C
A. Stary Folwark	200	95	1850	160	3900	1320	9200	3000	1750	1100	1600	40	425	380	80	15	310	35	85	45	65	15	85	8
B. Stary Folwark	125	15	700	100	1100	220	850	30	1960	20	950	60	25	15	90	25	60	10	310	15	100	35	115	9
C. Rosochaty Róg	135	60	700	20	1100	305	1730	1650	1975	45	205	40	15	40	93	5	350	5	270	115	–	–	75	5
D. Cimochowizna	–	–	–	–	–	–	–	–	–	–	520	90	170	20	135	10	400	5	70	45	40	25	85	5
E. Mikołajewo	–	–	–	–	–	–	–	–	380	85	225	105	45	30	45	15	1300	12	265	325	–	–	85	3
F. Piaski	180	330	400	440	3240	310	1160	50	120	50	55	15	5	2	140	140	72	3	550	480	–	–	85	5
G. Zakęty	225	55	2120	170	440	45	1030	115	80	55	65	30	25	25	165	130	60	100	125	25	–	–	95	30
H. Bryzgiel	700	285	1060	290	930	115	190	25	1000	190	60	35	35	3	175	60	50	10	445	110	–	–	190	80
I. Binduga	–	–	–	–	–	–	–	–	415	50	135	20	15	10	400	65	85	5	2000	30	–	–	–	–
J. Gawrych Ruda	1700	415	245	135	1180	300	250	30	–	–	90	35	93	2	190	75	60	5	240	55	–	–	190	80
K. Gawrych Ruda	290	240	850	130	1835	10	–	–	750	225	545	225	430	10	200	90	110	5	775	50	–	–	180	15
L. Gawrych Ruda	315	60	950	115	835	110	–	–	1750	30	200	55	40	2	875	165	105	5	1460	35	–	–	90	35
M. Gawrych Ruda	285	45	225	75	950	255	–	–	13500	2400	120	40	110	5	1745	200	180	10	2650	95	–	–	105	10

Table 3. Numbers of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) in the water of coast Lake Wigry (1994-1996).

Sampling site	1994 July TC	FC	FS	Aug. TC	FC	FS	Sept. TC	FC	FS	1995 June TC	FC	FS	July TC	FC	FS	Aug. TC	FC	FS	Oct. TC	FC	FS	1996 June TC	FC	FS	July TC	FC	FS	Aug. TC	FC	FS	Sept. TC	FC	FS	Oct. TC	FC	FS
A. Stary Folwark	43	3	<3	<3	4	1100	1100	93	<3	1400	140	43	43	3	4	210	20	4	340	23	4	23	<3	1100	9	<3	<3	150	9	64	43	4	11	<3	<3	<3
B. Stary Folwark	4	<3	<3	4	<3	43	150	25	<3	15	9	4	11	4	4	1400	1400	4	9	9	4	23	<3	460	75	<3	<3	9	<3	23	75	9	11	3	<3	<3
C. Rosochaty Róg	9	9	4	4	<3	15	240	93	<3	460	23	4	23	4	3	1400	1100	9	23	23	9	4	23	1400	9	<3	9	4	<3	39	–	–	–	3	<3	<3
D. Cimochowizna	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1400	1100	9	23	23	11	23	<3	460	9	<3	4	9	<3	3	43	–	11	<3	<3	<3
E. Mikołajewo	–	–	–	–	–	–	–	–	–	–	–	–	93	3	–	1400	150	15	9	<3	7	4	3	1400	9	<3	4	15	3	23	–	–	–	<3	<3	<3
F. Piaski	43	3	11	7	23	150	75	9	150	43	9	3	23	3	4	9	11	<3	20	<3	<3	3	<3	1100	<3	<3	<3	23	3	23	–	–	–	4	<3	<3
G. Zakęty	4	<3	4	9	<3	15	15	4	15	23	9	3	23	3	43	43	43	9	15	<3	93	14	<3	1100	23	<3	4	23	<3	4	–	–	–	4	<3	<3
H. Bryzgiel	150	43	240	–	–	75	460	9	75	240	150	4	460	9	75	210	43	93	240	4	4	240	150	1100	15	<3	9	23	<3	93	–	–	–	4	<3	<3
I. Binduga	–	–	–	–	–	–	–	–	–	–	–	–	240	9	3	1400	1400	15	15	<3	3	23	4	460	9	<3	3	23	<3	43	–	–	–	–	–	–
J. Gawrych Ruda	240	9	4	9	<3	93	23	<3	3	15	4	460	–	–	–	23	23	9	93	<3	3	43	4	1400	9	<3	14	64	<3	23	–	–	–	4	<3	<3
K. Gawrych Ruda	150	9	93	9	15	93	240	23	43	–	–	–	150	9	23	1100	43	43	410	43	43	9	<3	1400	43	<3	<3	93	<3	9	–	–	–	9	3	3
L. Gawrych Ruda	23	3	75	4	7	7	150	<3	4	–	–	–	21	3	20	93	4	23	460	<3	<3	75	<3	1400	9	<3	<3	15	<3	<3	–	–	–	<3	<3	<3
M. Gawrych Ruda	43	23	23	9	7	43	460	4	15	–	–	–	75	3	7	93	15	9	93	<3	9	43	<3	1400	23	<3	<3	23	<3	3	–	–	–	3	<3	<3

Table 4. Analysis of water quality of coast Lake Wigry using criteria given by Albinger [1]. Percent distribution of samples relevant to the given class

Water quality criteria		Water quality level[4]	Site[1]												
Microorganisms	Number of bacteria		A	B	C	D	E	F	G	H	I	J	K	L	M
[2]TVC 20°C (CFU/1 ml)	0 – 500	1	50	60	63	71	83	70	80	60	67	78	56	34	60
	500 – 1000	2	0	20	10	15	0	10	0	30	33	0	33	44	10
	1000 – 10,000	3	50	20	27	0	0	20	10	10	0	22	11	22	20
	10,000 – 50,000	4	0	0	0	14	17	0	10	0	0	0	0	0	10
	50,000 – 100,000	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	100,000 – 750,000	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	> 750,000	7	0	0	0	0	0	0	0	0	0	0	0	0	0
			[5](10)	(10)	(11)	(7)	(6)	(10)	(10)	(10)	(3)	(9)	(9)	(9)	(10)
[3]FC (MPN/100 ml)	1 – 10	1	64	73	70	66	83	70	80	70	100	89	66	100	78
	10 – 100	2	27	18	10	17	0	30	20	20	0	11	34	0	22
	100 – 1000	3	9	0	10	0	0	0	0	10	0	0	0	0	0
	1000 – 5000	4	0	9	10	17	17	0	0	0	0	0	0	0	0
	5000 – 10,000	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	10,000 – 100,000	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	> 100,000	7	0	0	0	0	0	0	0	0	0	0	0	0	0
			(11)	(11)	(10)	(6)	(6)	(10)	(10)	(10)	(3)	(9)	(9)	(9)	(9)

Explanations:
[1] - See Figure 1
[2] - Total viable count at 20"C (saprophytic bacteria)
[3] - Number of faecal coliforms
[4] - 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
[5] - In brackets number of samples investigated

Table 5. Analysis of bacteriological water quality of Lake Wigry using criteria given by Cabejszek et al. [4]. A - unpolluted, B - insignificantly polluted, C - distinctly polluted, D - heavily polluted. Percent distribution of samples relevant to the given class.

Water quality criteria		Water quality	Site[1]												
Microorganisms	Number of bacteria		A	B	C	D	E	F	G	H	I	J	K	L	M
[2]TVC 20°C CFU/1 ml	< 300	A	42	50	55	71	71	64	73	55	50	80	40	40	57
	300 – 5000	B	50	50	45	29	29	36	27	45	50	20	60	60	30
	5000 – 10,000	C	8	0	0	0	0	0	0	0	0	0	0	0	0
	> 10,000	D	0	0	0	0	0	0	0	0	0	0	0	0	0
			[5](12)	(12)	(11)	(7)	(7)	(11)	(11)	(11)	(6)	(10)	(10)	(10)	(10)
[3]TVC 37°C CFU/1 ml	< 200	A	66	92	82	100	86	64	100	82	100	80	70	100	80
	200 – 1000	B	9	8	18	0	14	36	0	18	0	20	30	0	10
	1000 – 5000	C	25	0	0	0	0	0	0	0	0	0	0	0	0
	> 5000	D	0	0	0	0	0	0	0	0	0	0	0	0	0
			(12)	(12)	(11)	(7)	(7)	(11)	(11)	(11)	(6)	(10)	(10)	(10)	(10)
[4]Coli titre	> 1	A	42	50	55	66	86	63	64	45	50	60	50	80	60
	1 – 0.1	B	25	33	18	34	14	10	18	27	37	30	20	20	20
	0.1 – 0.01	C	25	8	9	0	0	27	18	18	17	10	30	0	20
	< 0.01	D	8	9	18	0	0	0	0	10	0	0	0	0	0
			(12)	(12)	(11)	(6)	(7)	(11)	(11)	(11)	(6)	(10)	(10)	(10)	(10)

Explanations:
[1] - See Figure 1
[2] - Total viable count at 20°C Colohy Forming Unit/1 ml
[3] - Total viable count at 37°C Colony Forming Unit/1 ml
[4] - Faecal coliforms titre
[5] - In brackets number of samples investigated

including direct contact of a man's body with water) maximum TC is up to 5,000 MPN/100 ml and 1,000 MPN/100 ml FC. Later recommendations of the US EPA [19] suggest maximum accepted mean geometric values of 23/100 ml *E. coli* and 33/100 ml enterococci. The comparison of the results of the examination concerning the numbers of TC and FC presented in Fig. 2 with the above mentioned American data shows that 83-100% samples of near-shore waters of Lake Wigry fulfilled the requirements for the waters used for the waters used for bathing purposes as far as the numbers of TC and FC are concerned. All the samples contained below 5,000 MPN/100 ml TC, 83-100% samples also contained below 1,000 MPN/100 ml FC maximum accepted for the waters utilized for recreational purposes other than bathing. Besides, all samples contained below 10,000 MPN/100 ml TC and below 2,000 MPN 100ml FC maximum accepted for public water supply (aestetic). The values for FC *(Escherichia coli)* and FS (enterococci) were higher than the maximum accepted for surface waters utilized for bathing by the US EPA [19]. These were most frequently observed in September 1994, in August 1995 and in June and August 1996 (Table 3). Data of the European Committee for Water Quality for Bathing Purposes [8] advises that numbers of TC and FC should not exceed

Fig 3. Percentage of water samples which meet sanitary and bacteriological requirements for recreational (swimming) water, given by EEC [8].
(A, B, C ... M - sampling sites)
TC - *total coliforms* FC - *Faecal coliforms* FS — *Faecal streptococci*

500 and 100 MPN/100 ml, respectively (at least in 80% of samples), numbers of FS - 100 MPN/100 ml (at least in 90% samples) (guide values). However, numbers of TC and FC may not exceed 1,000 and 2,000 MPN/100 ml, respectively, in at least 95% of examined samples (mandatory values) when there is a total lack of *Salmonella* in 1 l of water and enteropathogenic viruses in 10 l of water can be accepted (Table 6). Examination of the presence of *Salmonella* and enteropathogenic viruses are required if there is suspicion that these viruses are present at bathing sites. The modified European Standard (revised imperative) requires that the number of *Escherichia coli* in 95% samples not exceed 1000 MPN/100 ml. In contrast to earlier criteria, the EEC [8] does not require determination of the number of TC and FC. Comparison of the results of TC and FC (Fig. 3) with the above mentioned data of the European Committee for Water Quality for Bathing Purposes [8] shows that 83-100% of near-shore waters of Lake Wigry fulfilled the requirement guide values, all samples fulfilled mandatory requirements (imperative) values. As far as FS is concerned, guide value requirements were fulfilled by 80-90% samples. Only 6 samples (of a total of 129, 4.5%) taken in August 1995 near the sailing harbour in Stary Folwark and Gawrych Ruda, the anchorages in Rosochaty Rog and Mikotajewo, and opposite the farm buildings in Cimochowizna contained over 1000 MPN/100 ml FC recommended by the revised imperative of the Modified European Standard.
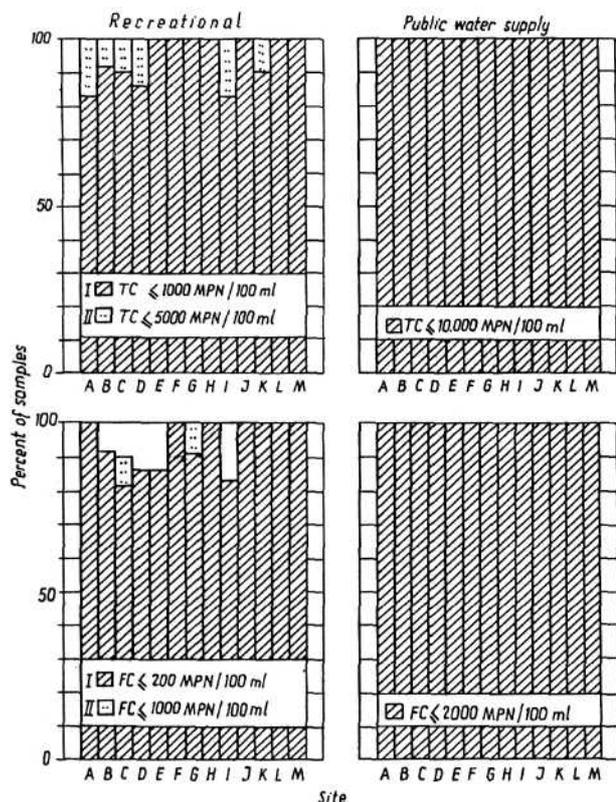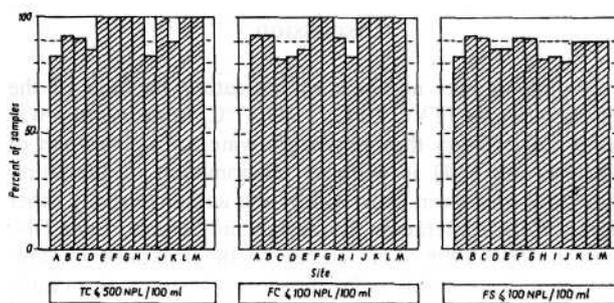

Fig 2. Percentage of water sample which meet sanitary and bacteriological requirements for recreational water, given by U.S. Department of Interior (Federal Water Pollution Control Administration, [18]).
(A, B, C ... M - sampling sites)
TC — *total coliforms* FC - *Faecal coliforms*
I - Primary contact
II - Secondary contact

Table 6. European Economic Community (1976) Quality Requirements (microbiological) for Bathing Waters

Microbiological Parameter	Guide	Mandatory	Minimum sampling frequency
1. *Total Coliforms*/100 ml	500	10,000	Fortnightly
2. *Faecal Coliforms*/100 ml	100	2,000	Fortnightly
3. *Faecal Streptococci*/100 ml	100	–	(x)
4. *Salmonella*/litre	–	0	(x)
5. Enteroviruses PFU/10 litres	–	0	(x)
(x) Concentration to be checked by the competent authorities when an inspection in the bathing area shows that the substance may be present or that the quality of the water has deteriorated			

Discussion

Slightly higher numbers of indicatory bacteria of the pollution degree (TVC 20°C, TVC 37°C) in near-shore waters of Lake Wigry than in pelagic water of a given part of this reservoir [14] is a know phenomenon in literature. They have also been observed by the author in many other lakes in East-Pomeranian, Mazurian and Suwalki Lake Districts in 1960-1998. This is due to the leakgage of contamination from arable soils, meadows, pastures, farm buildings, etc., during story precipitation, in shallow parts of the lake from the bottom and snores, and aquatic vegetation during stormy weather. Avifauna can play a very important part. Although the number of these bacteria from this source can be little in comparison to their number getting into the lake from the Czarna Hancza River, their influence on near-shore water pollution may be disproportionately high. In the region where there are cormorants, near-shore waters may contain larger quantities of indicatory bacteria of sanitary state (TC, FC, FS) - sometimes even exceeding the values recommended for bathing waters [8, 18]. The influence of avifauna on the pollution of near-shore waters of Lake Wigry seemed to be particularly strong in June 1996 when FS exceeded 1,000 MPN/100 ml. On the contrary, larger numbers of TC and FC in near-shore waters of Lake Wigry in the region of bathing sites (Stary Folwark) at minimal number FS in August 1995 at all experimental sites and in June and August 1995 in the region of the bathing site and sailing harbour in Stary Folwark may be connected with recreational utilization of these fragments of the Lake by tourists and water sports enthusiasts. The number of these bacteria exceed (at some sites) recommended values [8] for the waters for recreational purposes. The fluctuations of the number of indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in the range of 2-3 order as far as the amount is concerned in particular research periods (summer 1994, 1995 and 1996) could be caused by seasonal changes of atmospheric conditions particularly temperature, insolation, wind strength, precipitation, rate of discharge of bacteria, recreation utilization of near-shore waters of Lake Wigry, avifauna activity. Larger amounts of indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in near-shore waters of Lake Wigry in the region of bathing sites and sailing harbour in Stary Folwark as well as in pelagial water of particular fragments of this lake can be explained by closeness of farm buildings, camping-sites and the larger populations of people living in these places. This also concerns near-shore waters of Lake Wigry nearby Gawrych Ruda.

Conclusions

1. Near-shore waters of Lake Wigry generally contain slightly higher numbers of index bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) than pelagic waters of respective parts of the reservoir. The number of the last ones seldom is above the maximum values recommended for the waters utilized for recreation purposes.

2. The maximum number of FS observed in June 1994 and 1996 with a lack or minimum number of TC and FC might be due to the activity of waterfowl, whereas the maximum number of TC and FC observed in September 1995 with minimum number FS is due recreational utilization of near-shore waters by the surrounding population and tourists during the final days of bathing season.

3. It is recommended that local sanitary services introduce constant bacteriological monitoring of near-shore waters of Lake Wigry during summer, particularly in frequently visited areas. Sanitary-bacteriological examination of these waters should be carried out at least once every second week according to the recommendations of the European Committee for Water Quality for Recreationd Purposes.

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