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Bacteriological Monitoring of River Water Quality in the North Area of Wigry National Park

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Abstract

This paper comprises the results of examinations 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 the Kamionka, Maniowka, Wiatrotuza and Piertanka Rivers in the north area of Wigry National Park in 1996 and the number of these microorganisms taken to Wigry Lake. The investigations were carried out at 3 sites situated on the Kamionka River (in Okuniowiec, below a group of "hucianskie" lakes, before the tributary to Pierty Lake), at 2 sites situated on the Maniowka River (in Lipniak and before the mouth to the Wiatrotuza River), at 5 sites on the Wiatrotuza River (in Wiatrotuza, above and below the estuary of the Maniowka River, at the mouth to Krolowek Lake, between Krolowek Lake and Pierty Lake) and at 1 site situated on the Piertanka River (between Omutowek Lake and Wigry Lake). The obtained values of bacteriological indices of pollution degree and sanitary state were compared with the criteria of surface water purity estimation suggested in literature and their usefulness for recreation. The number of the examined indicator bacteria found in the present research shows significant water pollution (II and **III** class of purity) of the examined rivers in the region of rural areas and the improvement of purity degree along the river course. There were found leakages of pollution from cesspools in the rural areas (demonstrated by a significant number of FC in water of given sites) and flows from other arable-forestry-pasture-meadow catchment (which is expressed by a larger number of Streptococci than Escherichia coli) as a main source of water pollution of the examined rivers.

Keywords: rivers, water, pollution, survey, indicators, bacteria

Introduction

The Czarna Haricza River and the Wiatroluza River influence the pollution of Wigry Lake situated in Wigry National Park. Wigry Lake as well as the Czarna Hancza River were examined taking into consideration physico-chemical [2, 3, 17] and bacteriological aspects [9-14, 16]. There is a lack of data concerning the degree of pollution and sanitary-bacteriological state of the Wiatroluza River and its indirect tributaries (the Kamionka River) and direct tributaries (the Maniowka River) and the range of bacteriological pollution carried by the river into Wigry Lake. Knowledge about these problems is importance while planning reclamative actions and from the point of view of public health of people inhabiting the area of the catchment of this river. Sailing clubs, camping sites and bathing areas are found in the region of the effluent of the Wiatroluza River to Wigry Lake. These places are visited by many foreign and Polish tourists in summer. Therefore, the subject of this paper is the estimation of the degree of bacteriological pollution and sanitary state of this river and its utilization for recreation.

Materials and Methods

The Area of Research

The research was carried out in the north part of Wigry National Park, from May to November 1996. The

examination comprised waters from the Kamionka, Maniowka, Wiatroluza and Piertanka Rivers. The Kamionka River is the second largest one (after the Czarna Hancza River) in the Wigry National Park. Its spring is situated in Szwajcaria (a small village towards the northeast of Suwalki) in a forested and swampy area. It is a shallow watercourse, in the upper part resembling a drainage ditch, supplied by streams and numerous springs situated along a valley and on the slopes of Krzywe Lake basin. In the middle course it flows across Dabrowka, Krzywe, Czarne and Kolesne Lakes (so called Huciaiiskie lakes), then across forested areas with a beaver reserve. In the final part (near Leszczewo) it flows into Pierty Lake, the second largest lake (after Wigry) in Park. The total area of the Kamionka River is 99.4 km^2. In the north of the Kamionka River having its spring in Debowo. In the upper part of this river there are numerous drainage ditches, meadows and little ponds; in the lower course the river flows across the forested areas and another reserve of beavers, where it flows to the Wiatroluza River. The Wiatrofuza River collects water from a few springs in numerous lowerings to the north of Wiatrotuza. Near Kaletnik the parts combine in one stream which flows to Pierty Lake. After connecting with the Maniowka River it flows across numerous peatbogs and swamps inhabited by beavers in a protected reserve. It is supplied by water from drainage ditches. In its lower course it flows across Krolowek Lake, from where it flows to Pierty Lake. From Pierty Lake in the southern part it flows across Omulowek Lake and then to Wigry Lake in the region of Zadworze Bay. The total area of the catchment of the Wiatroluza River is 176.5 km^2. In a wide swampy valley of the Wiatroluza River there are fragments of mixed forests and dry-ground forests, fragments of low peatbogs and beavers which damm the water in this river. The Piertanka River is a short stream connecting Omulowek Lake with Wigry Lake.

Experimental Sites

There were 11 sites situated at a certain distance from one another taking into account technical possibilities of water sampling on the rivers and carrying out sanitary-bacteriological analysis within several hours from the moment of first sampling (1). They were:

a. on the Kamionka River:
   site 1 - in Okuniowiec;
   site 2 - below Kolesne Lake;
   site 3 - about 100 m below the mouth to Pierty Lake.
b. on the Maniowka River:
   site 4 - in Lipniak;
   site 5 - about 50 m before the mouth to the Wiatroluza River.
c. on the Wiatroluza River:
   site 6 - in Wiatroluza village;
   site 7 - about 100 m above the mouth of the Maniowka River;
   site 8 - by the bridge on the road from Lipniak to Piotrowa Dabrowa;
   site 9 - in Krolowek Lake about 50 m from the effluent of the Wiatroluza River;
   site 10 - between Krolowek Lake and Pierty Lake, d. on the Piertanka River:
   site 11 - between Omulowek Lake and Wigry Lake, by the bridge on the road Suwalki-Sejny.

A situational outline of the examined rivers and chosen sites were given in Fig. 1.

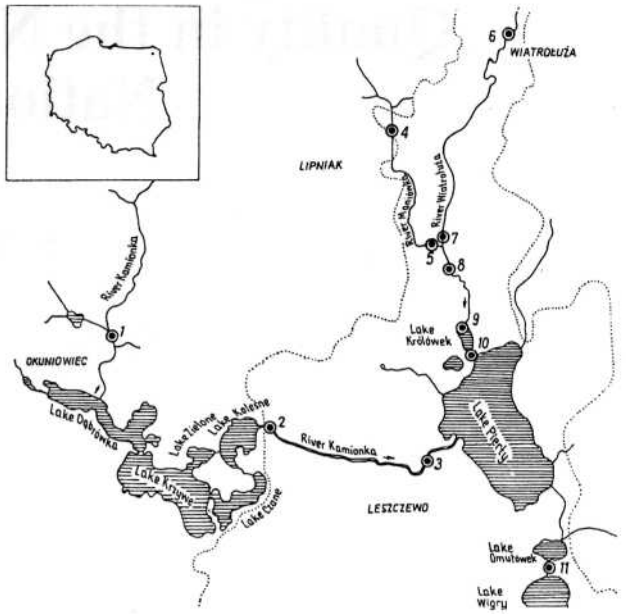

Fig. 1. Situational sketch of rivers Kamionka, Maniowka, Wiatroluza and Piertanka in the region of Wigry National Park 1, 2, 3 . . . 11 - sites for collecting water samples.

Sampling

The samples of river water were taken from a current and a surface layer by a special extensive arm where a sterile glass bottle was attached. The bottle had 300 ml capacity and a ground cork. Immediately after the sampling the water samples were carried to containers with dry ice to maintain the temperature 4-6"C for 24 h. The time from sampling to carrying out sanitary-bacteriological analysis did not exceed 18 h. The examinations were carried out at least at 1 month intervals from May to November 1996.

Microbiological Examinations

Microbiological examinations of the water samples taken from the rivers comprised the following determinations:

1. the total number (CFU/1 ml) of bacteria on broth-agar after 72 h incubation at 20°C (TVC 20°C);
2. the total number (CFU/1 ml) of bacteria on broth agar after 24 h incubation at 37°C (TVC 37°C);
3. the total number (MPN/100 ml) of coliforms (TC) on the Eijkman medium after 48 h incubation at 37°C;
4. the number (MPN/100 ml) of faecal coliforms (FC) on the Eijkman medium after 24 h incubation at 44.5°C;

5. the number (MPN/100 ml) of faecal streptococci (FS) on the Slanetz and Bartley medium with sodium azide and crystal violet after 72 h incubation at 37°C.

The total number of TVC 20°C and TVC 37°C was determined according to the accepted bacteriological technique for the investigation of drinking water. The most probable number (MPN) of TC, FC, FS was determined according to the Standard Methods [1]. All determinations were carried out in 3 parallel repetitions. The results of the investigation of TC, FC, FS numbers were read from McCrady's tables. A physiological solution of NaCl was used for sample dilutions. Positive results for the presence of coliforms in the fermentation test on the Eijkman medium were checked on the Endo medium, on the lauryl-tryptose broth, and in biologicals stained with Gram method. Positive results for the presence of streptococci in the Slanetz and Bartley medium were checked on the m-Enterococcus Agar. Typical colonies which grew on this medium were dark red and they were grafted into the broth determining growth ability at 44.5°C, at pH 9.6, with the presence of 6.5% NaCl and in milk with 0.01% methylene blue. Dry media produced by Difco and Merck were used in the research. The obtained values of bacteriological indicators of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) of the examined samples of river water were referred to the criteria suggested in literature [4, 5] concerning the estimation of degree of surface purity and their utilization for recreation and the Decree of the Ministry of Environmental Protection, Natural Resources and Forestry dated 5th November 1991 about water classification **[15].**

Results

Number of Indicatory Bacteria of Pollution Degree and Sanitary State in Water of Rivers in the North Areas of Wigry National Park

The Kamionka River

In water of the Kamionka River the number TVC 20°C ranged from several dozen to a few thousand CFU/1 ml. Generally fewer were found in water at site 2 situated below Kolesne Lake (70-2070 CFU/1 ml), more in water at site 1 in Okuniowiec (350-2700 CFU/1 ml) and at site 3 near Leszczewo before the mouth to Pierty Lake (650-4400 CFU/1 ml). In the research season the fewest number of these bacteria was found in November (70-650 CFU/1 ml), the largest amount was observed in August (2070-4400 CFU/1 ml). The number TVC 37°C was generally lower in water at site 1 in Okuniowiec (40-700 CFU/1 ml), higher at site 3 in the region of Leszczewo (25-3150 CFU/1 ml). In the research season the lowest pollution of water by these bacteria was found in November (at all 3 sites) and in September (at sites 1 and 2), the highest one was observed in August (at all 3 sites) and in July (at site 3). The ratio of TVC 20°C: TVC 37°C ranged from 0.4 in July at site 2 up to 47.6 in September at site 1 (Table 1). The total number of coliforms (TC) ranged from < 3 in November at sites 1 and 2 up to 15,000-110,000 MPN/100 ml in August at all 3 sites. On average in the research season lower pollution was found at site 1 (3475 and 7750 MPN/100 ml, respectively), higher at site 3 (18600 CFU/100 ml). The number of faecal coliforms (FC) ranged from < 3 in August and November at all 3 sites up to 150, 240 and 93 MPN/100 ml in May at sites 1, 2 and 3. Their mean number in the research season was almost the same in water at all 3 sites and reached 41-48 MPN/100 ml. The number of faecal streptococci (FS) ranged from 43-93 MPN/100 ml in July at all 3 sites up to 140,000 MPN/100 ml in October at sites 1 and 2 and 150,000 MPN/100 ml in August and September at site 3. On the average lower number in the research season was found in water at site 3 (7160 MPN/100 ml), more in water at sites 1 and 2 (32,000 i 38,350 MPN/100 ml, respectively) (Table 2). The ratio FC:FS ranged from 0.00002 and 0.00004 (at sites 1 and 2, respectively) in October up to 0.4 (at sites 1 and 3) in July (Table 3).

The Maniowka River

In water of the Maniowka River TVC 20"C ranged from 200 up to 17,000 CFU/1 ml depending on the site and the date of sampling. Generally, lower quantities were found at site 5 before the mouth to the Wiatroluza River (200-17,000 CFU/1 ml), more in water at site 4 in Lipniak (1025-36,900 CFU/1 ml). In the research season the lowest number was observed in August at site 4 and in November at site 5 (1025 and 200 CFU/1 ml, respectively), the highest quantities were observed in September at site 4 in Lipniak (36900 CFU/1 ml) and in July at site 5 at the mouth to the Wiatroluza River (17,000 CFU/1 ml). The number TVC 37°C ranged from 245 to 17,880 CFU/1 ml in water at site 4 in Lipniak and from 115 to 2990 CFU/1 ml in water at site 5 at the mouth to the Wiatroluza River. In the research season the lowest pollution of water was found at site 4 in September and November (245 and 265 CFU/1 ml, respectively), at site 5 in November (115 CFU/1 ml), the highest at site 4 in July (17,880 CFU/1 ml) and at site 5 in August (2990 CFU/1 ml). The ratio TVC 20°C: TVC 37°C ranged from 0.8 to 150.6 in water at site 4 and 1.7 to 65.7 at site 5 (Table 1). The number of total coliforms (TC) ranged from < 3 in August at both sites and in November at site 5 to 15,000 MPN/100 ml in water at both sites in August. Their mean number in the research season was 3190 MPN/100 ml at site 4 and 3045 MPN/100 ml at site 5. The number of faecal coliforms (FC) ranged from < 3 in water at both sites in August and at site 5 in November to 1400 MPN/100 ml at site 4 and 460 MPN/100 ml at site 5 in May. Their mean number in the research season was 80 MPN/100 ml at site 5 and 835 MPN/100 ml at site 4. The number of faecal Streptococci ranged from 1100 MPN/100 ml in July to 140,000 MPN/100 ml in October at site 4 and from 150 MPN/100 ml in November to 30,000 MPN/100 ml in September at site 5. On the average in the research season a lower number was found at site 5 (9980 MPN/100 ml), a higher number at site 4 (24,585 MPN/100 ml) (Table 2). The ratio FC:FS ranged from 0.0002 and 0.0004 in October to 0.4 and 1.0 in July at sites 4 and 5, respectively (Table 3).

Table 1. Number of total viable count at 20°C and 37°C and temperature ratio test (TVC 20°C:TVC 37°C) in the water of rivers Kamionka, Maniówka, Wiatrołuża and Piertanka in the region of Wigry National Park in 1996.

River	[1]Site	17 May			24 July			27 Aug.			26 Sept.			25 Oct.			29 Nov.			Average		
		[2](CFU/1 ml)																				
		20°C	37°C	Ratio	20°C	37°C	Ratio	20°C	37°C	Ratio	20°C	37°C	Ratio	20°C	37°C	Ratio	20°C	37°C	Ratio	20°C	37°C	Ratio
Kamionka	1	1750	500	3.5	1500	290	5.2	2700	700	3.8	2000	40	47.6	2400	220	11.0	350	70	5.0	1785	305	–
	2	325	130	2.5	100	270	0.4	2070	900	2.3	300	60	4.8	330	375	0.9	70	70	1.0	530	300	–
	3	1925	220	8.7	2250	3150	0.7	4400	1600	2.7	3200	155	20.6	1100	140	7.8	650	25	26.0	2255	880	–
Maniówka	4	2120	1200	1.7	15500	17880	0.8	1025	425	2.4	36900	245	150.6	15500	585	26.5	1650	265	6.2	12100	3450	–
	5	1550	180	8.6	17000	1980	8.5	6000	2990	2.0	13800	210	65.7	9200	170	54.0	200	115	1.7	7960	940	–
Wiatrołuża	6	1700	230	7.4	1150	370	3.1	3050	805	3.8	12100	1080	11.2	2200	730	3.1	6500	175	37.1	4450	565	–
	7	1610	1500	1.0	450	125	3.6	160	35	4.5	1170	2620	0.4	550	93	5.9	1150	40	27.3	850	735	–
	8	2065	355	5.8	2850	215	13.2	580	90	6.4	715	155	4.6	1500	90	16.6	2815	140	19.8	1755	175	–
	9	550	90	6.5	120	325	0.3	9050	780	11.6	300	8	37.5	590	175	3.7	[3]NT	NT	–	2120	275	–
	10	800	600	1.3	150	175	0.8	3700	1155	3.2	120	10	12.0	550	30	18.3	2150	55	39.0	1245	335	–
Piertanka	11	1080	270	5.4	1100	525	2.1	2025	485	4.2	400	13	30.7	665	70	9.5	120	60	2.0	900	235	–

[1] See Figure 1, [2] CFU – Colony Forming Unit, [3] NT – Not Tested.

Table 2. Numbers of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) in the water of rivers Kamionka, Maniówka, Wiatrołuża and Piertanka in the region of Wigry National Park in 1996.

River	[1]Site	17 May			24 July			27 Aug.			26 Sept.			25 Oct.			29 Nov.			Average		
		[2](MPN/1oo ml)																				
		TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS
Kamionka	1	4500	150	14000	23	43	93	15000	< 3	15000	1100	93	20000	240	4	140000	< 3	<3	1100	3475	48	32000
	2	210	240	14000	4	4	43	45000	< 3	45000	9	7	30000	93	4	140000	< 3	< 3	1100	7750	41	38350
	3	1100	93	1500	23	93	43	110000	< 3	15000	240	23	15000	240	39	11000	4	< 3	460	18600	41	7160
Maniówka	4	1400	1400	11000	1100	460	1100	15000	< 3	1400	1100	460	45000	1100	230	140000	75	9	7500	3190	535	24585
	5	2000	460	14000	93	4	240	15000	< 3	4500	93	4	30000	1100	4	11000	< 3	< 3	150	3045	80	9980
Wiatrołuża	6	11000	1400	14000	240	43	150	4500	< 3	20000	1100	460	1100	460	150	14000	240	93	1100	2920	355	8390
	7	4500	240	14000	43	23	11	7500	< 3	23	23	21	14000	460	3	140000	9	9	4500	2085	50	28750
	8	4500	240	14000	9	9	150	1100	< 3	1400	23	21	1500	240	9	11000	23	7	460	980	50	4750
	9	1100	23	2500	4	3	15	4	< 3	150	3	3	14000	93	4	45000	[3]NT	NT	NT	240	5	10275
	10	240	150	14000	9	3	75	240	< 3	45000	3	4	2100	240	4	4500	7	9	140000	125	28	34280
Piertanka	11	93	23	14000	9	15	150	93	< 3	140000	43	9	140000	23	23	20000	< 3	< 3	93	45	12	52375

[1] See Figure 1, [2] MPN – Most Probable Number, [3] NT – Not Tested.

Table 3. FC:FS ratio in the water of rivers Kamionka, Maniowka, Wiatrohiza and Piertanka in the area of Wigry National Park in 1996.

River	[1] Site	17 May	24 July	27 Aug.	26 Sept.	25 Oct.	29 Nov.
Kamionka	1	0.01	0.4	[2] –	0.004	0.00002	–
	2	0.017	–	–	–	0.00004	–
	3	0.06	0.4	–	0.001	0.003	–
Maniówka	4	0.03	1.0	–	0.01	0.00016	0.001
	5	0.12	0.4	–	–	0.0004	–
Wiatrołuża	6	0.1	1.6	–	0.4	0.01	0.008
	7	0.17	4.0	–	–	0.00002	0.002
	8	0.17	–	–	0.01	0.0008	0.02
	9	0.01	–	–	–	0.0015	0.00006
	10	0.0016	–	–	–	0.00008	0.0015
Piertanka	11	0.009	–	–	–	0.0008	–

[1] – See Figure 1, [2] – FC < 3.

The Wiatroluza River

In the Wiatroluza River TVC 20°C ranged from 120 to 12,100 CFU/1 ml depending on the site and the date of sampling. Their minimum and maximum number at every 5 examined sites (sites 6-10) was different at different seasons and without regularity. On the average in the research season their lowest number was found at site 7 above the effluent of the Maniowka River (850 CFU/1 ml), the highest number was at site 6 in Wiatroluza village (4450 CFU/1 ml). The number of TVC 37°C ranged from 8-10 CFU/1 ml at sites 9 and 10 at the mouth to Krolowek Lake and between Krolowek Lake and Pierty Lake up to 2620 CFU/1 ml at site 7 above the effluent of the Maniowka River in September. On average in the research season their lowest number was at site 8 by the bridge on the road connecting Lipniak and Piotrowa Gora (175 CFU/1 ml), whereas the highest number was at site 7 above the effluent of the Maniowka River (735 CFU/1 ml). In the research season the lowest number was found at site 6 in November (175 CFU/1 ml), at sites 7 and 8 in August (35 and 90 CFU/1 ml, respectively) and in October (93 and 90 CFU/1 ml, respectively), at sites 9 and 10 in September (8 and 10 CFU/1 ml, respectively), the highest number was observed at sites 6 and 7 in September (1080 and 2620 CFU/1 ml, respectively), at site 8 in May (355 CFU/1 ml), at sites 9 and 10 in August (780 and 1155 CFU/1 ml, respectively) The ratio TVC 20°C:TVC 37°C ranged from 0.3 and 0.8, respectively in water at sites 9 and 10 in July and 0.4 at site 7 in September up to 39.0 at site 10 in November (Table 1). The number of total coliforms (TC) ranged from few MPN/100 ml at different sites in different research season up to 11,000 MPN/100 ml at site 6 in May. On average the lowest numbers were at sites 9 and 10 (240 and 125 MPN/100 ml, respectively), the highest at sites 6 and 7 (2920 and 2085 MPN/100 ml, respectively). At all sites, generally, the lowest in July and November, the highest in May and August. The number of faecal coliforms (FC) ranged from < 3 at all sites in August to 1400 MPN/100 ml at site 6 in May. On average the lowest number was at sites 9 and 10 (5 and 28 MPN/100 ml, respectively), the highest at site 6 (355 MPN/100 ml). The highest number was in May at all sites. The number of faecal streptococci (FS) ranged from 11 and 15 (at sites 7 and 9 in July, respectively) up to 140,000 MPN/100 ml (at site 7 in October). On the average the lowest number was at site 8 (4750 MPN/100 ml), the highest number at site 7 and 10 (28,750 and 34,280 MPN/100 ml, respectively). In the research season the lowest number was found at all sites in July (11-150 MPN/100 ml), the highest number was in October (4500-140,000 MPN/100 ml). The same number was found at site 10 in November (140,000 MPN/100 ml) (Table 2). The ratio FC:FS ranged from 0.00002 at site 5 in October to 4.0 at site 7 in July (Table 3).

The Piertanka River

In the Piertanka River the number TVC 20°C and TVC 37°C ranged from 120 to 2025 CFU/1 ml, respectively and from 13 to 525 CFU/1 ml. The lowest number was found in September, the highest number in July and August. The ratio TVC 20°C:TVC 37°C ranged from 2.1 in July and 2.0 in November to 30.7 in September (Table 1). The number of total coliforms (TC), the number of faecal coliforms (FC) and the number of faecal streptococci (FS) ranged from < 3 to 93; < 3 to 23 and from 93 to 140,000 MPN/100 ml, respectively. The lowest pollution was found in November, the highest one was observed in May and June (TC), in May and October (FC) or in August and September (FS) (Table 2). The ratio FC.FS ranged from 0.0008 to 0.009 (Table 3).

The Number of Indicatory Bacteria and Degree of Water Pollution of the Rivers in Northern Area of Wigry National Park

The comparison of the results of number TVC 20°C, TVC 37°C and faecal coli titre (FC) in the water of the Kamionka River at all 3 sites with criteria of surface water purity given by Cabejszek et al. [4] and presented in Table 4 shows its pure character or little pollution. Only single water samples contained TVC 37°C showing significant pollution. According to the same criteria of

Table 4. The analysis of bacteriological water quality of the rivers Kamionka, Maniowka, Wiaroluza and Piertanka in the area of Wigry National Park using criteria given by Cabejszek et al. [5], A - unpolluted; B - insignificantly polluted; C - distinctly polluted; D - heavily polluted.

Bacteriological water quality criteria		Water quality	River										
			Kamionka			Maniówka		Wiatroluża					Piertanka
Microorganisms	Number of bacteria		[1] Site										
			1	2	3	4	5	6	7	8	9	10	11
[2]TVC 20°C (CFU/1 ml)	< 300	A	0	33	0	0	17	0	17	0	20	33	17
	300 – 5000	B	100	67	100	50	17	67	83	100	60	67	83
	5000 – 10000	C	0	0	0	0	33	17	0	0	20	0	0
	> 10000	D	0	50	0	50	33	16	0	0	0	0	0
[3]TVC 37°C (CFU/1 ml)	< 200	A	33	50	50	0	50	17	67	67	60	67	50
	200 – 1000	B	67	50	17	67	17	67	0	33	40	17	50
	1000 – 5000	C	0	0	33	17	33	16	33	0	0	16	0
	> 5000	D	0	0	0	16	0	0	0	0	0	0	0
Faecal Coli titre	> 1	A	67	83	67	50	67	17	83	83	100	83	83
	1 – 0.1	B	33	17	33	17	33	67	17	17	0	17	17
	0.1 – 0.01	C	0	0	0	33	0	16	0	0	0	0	0
	< 0.01	D	0	0	0	0	0	0	0	0	0	0	0

[1] – see Figure 1, [2] – Total viable count at 20°C, [3] – Total viable count at 37°C.

estimation the water of the Maniowka River can be included in pure and insignificantly polluted, depending on the site and the water used for the estimation of a group of indicatory bacteria. The water of the Wiatroluza River at all sites showed a character of pure or insignificantly polluted water; at site 6 in Wiatroluza - significant or even heavy pollution depending on the research period. The water in the Piertanka River is shown to be pure or insignificantly polluted. Comparing the values of faecal coli titre (FC) for water of the examined rivers (data concerning the values of faecal coli titre are found at the author of this paper) with the data included in the Decree of the Minister of Environment Protection, Natural Resources and Forestry dated on 5th November 1991 concerning the water classification (15) 67-83% water samples of the Kamionka River, 50-67% of the Maniowka River, 17% of the Wiatrotuza River at site 6 in Wiatroluza village and 83-100% of water samples of this river at sites 8-10 and 83% of the Piertanka River can be included in class I purity. All the remaing samples of the Kamionka River, 17-33% of the samples taken from the Maniowka River, 67% of samples of the Wiatroluza River at site 6 in Wiatroluza village, and 17 % of samples at sites 7-10 of this river and 17% of samples from the Piertanka River at site 11 are included in purity class II. Class III of purity comprises 33% of samples taken from the Maniowka River at site 4 in Lipniak and 16% of the Wiatroluza River in Wiatroluza village (Table 4).

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

According to data from the European Commission for Water Quality for Recreational Purposes [5] the number of total coliforms (TC), the number of faecal coliforms (FC) and the number of faecal streptococci (FS) in water for bathing purposes outdoors should not exceed 500, 100 and 100 MPN/100 ml (Guide values), recpectively. However, the numbers of TC and FC not exceeding 10,000 and 2000 MPN/100 ml, recpectively in at least 95% of the examined samples (Mandatory values) at a complete lack of Salmonella in 1 1 water and enteropathogenic viruses in 10 1 water. The examination for the presence of the last groups of microorganisms is required only in the case when there is suspicion of a possibility of their occurrence in water. Mandatory values do not take into account the examination for the presence of FS. Guide values in the Kamionka River were fulfilled at site 1 (in Okuniowiec) by 50; 83 and 17% of the examined water samples, respectively; at site 2 (below Kolesne Lake) 83; 83 and 17% of the examined water samples; at site 3 (before the mouth to Pierty Lake) 67; 100 and 17% of the examined water samples. In the Maniowka River at site 4 (in Lipniak) the requirements were fulfilled by 33; 33 and 0%, respectively of the examined water samples; at site 5 (before the mouth to the Wiatroluza River) by 50; 33 and 0% of the examined water samples. The percent of water samples fulfilling requirements of Guide values increased with the course of the river and at site 10 between Krolowek Lake and Pierty Lake was 100; 83 and 17%, respectively. In the Piertanka River at site 11 between Omulowek and Wigry Lakes it was 100;100 and 17%, respectively. Mandatory values requirements were fulfilled in the Kamionka and Maniowka rivers and Wiatroluza River at site 6 in Wiatroluza village by 83% samples, at sites 7-10 of the last river and the Piertanka River by 100% samples (Table 5). According to EEC Guidelines [5] waters of class I purity containing not more than 100 MPN/100 ml FC, which corresponds to faecal coli titre 1 and above [15] are recommended for bathing purposes.

Table 5. The analysis of water quality of the rivers Kamionka, Maniowka, Wiatrotuza and Piertanka in the area of Wigry National Park using criteria given by EEC [6]. Percent distribution of samples fulfilling guide and mandatory values for bathing water.

River	[1]Site	Guide values			Mandatory values		
		TC	FC	FS	TC	FC	[2]S/E
		MPN/100 ml			MPN/100 ml		
		500	100	100	10000	2000	0
Kamionka	1	50	83	17	83	100	–
	2	83	83	17	83	100	–
	3	67	100	17	83	100	–
Maniówka	4	33	33	0	83	100	–
	5	50	83	0	83	100	–
Wiatrołuża	6	50	33	0	83	100	–
	7	67	87	33	100	100	–
	8	67	83	0	100	100	–
	9	80	100	20	100	100	–
	10	100	83	17	100	100	–
Piertanka	11	100	100	17	100	100	–

[1] - See Figure 1
[2] - S - Salmonella/1 1; E - Enteroviruses/10 1
S/E measurement is only required when an inspection in the bathin area shows that the parameter may be present, or when water quality has deteriorated.

Discussion

The number of indicatory bacteria of pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in the water of the examined rivers undergoes significant fluctuations (from typical for waters class I to II and even class III of purity) depending on a site of water sampling, bacteria group and research season. In the Kamionka River numerous TVC 20°C occurrence at site 1 (in Okuniowiec) may be connected with the effluent of pollutants easily decomposed by these bacteria from building areas, leakages from cesspits and drainage catchments. The decrease of their number at site 2 below a sequence of lakes: Dabrowka, Krzywe, Czarne and Kolesne, is a result of diluting pollutants and accompanied bacteria in the water of these lakes. It also concerns the TC and FC numbers, which can also be decreased due to natural decaying and under the influence of different physico-chemical and biological factors in rivers and lakes [9]. Repeated increase of TVC 20°C, TVC 37°C and TC in the water of this river at site 3 (near Leszczewo) before the mouth to Pierty Lake may be attributed to the increase of the amount of pollution from drainage catchment and arable-forestry-pasture-meadow areas. In this region there is a reserve of beavers whose activity may be one of the factors influencing the worsening of sanitary-bacteriological state of waters in the final part of the Kamionka River. The pollution of the Kamionka River is shown not only by the number of the abtioned bacteria but also the ratio TVC 20°C:TVC 37°C lower than 10 in the majority of water samples. According to English data [7] this ratio ("differential temperature ratio test") in pure waters is 10:1 or more, in polluted waters is lower than 10:1. The influence of rural areas on the number of the examined indicatory bacteria of the pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) is observed from the examination carried out on the Maniowka and Wiatroluza Rivers. In case of the Maniowka River a higher number of these microorganisms found at site 4 are due to pollution getting from Lipniak and springs of this river in Debowo where there are drainage ditches, little ponds and meadows. Animal origin of these pollutions is proved by a higher number of FC and FS. According to Geldreich [6] the ratio FC:FS lower than 0.7 points to pollution originating from animals, the ratio FC:FS 0.7-0.4 points to pollution from people and animals, while an FC:FS ratio higher than 4.0 points to pollution from people. It is caused by the fact that in the excrements of warm-blooded animals faecal streptococci are more numerous than faecal coliforms, in human excrements faecal coliforms occur in larger quantities than faecal streptococci. At site 5 (in the region of the mouth to the Wiatroluza River) the number of the examined indicatory bacteria in the Maniowka River decreases although it still reaches the values typical for waters evidently polluted or even significantly polluted (class II and III of purity). It concerns mainly the number TVC 20°C and TVC 37°C. Higher quantities of FS at a complete lack of FC prove the pollution of this part of the river by wild animals, including beavers inhabiting the reserve.

A high degree of bacteriological pollution is observed at site 6 in the Wiatroluza River (in Wiatroluza village). The source of pollution of this part of the river could be leakage from cesspits, decay ditches (cow dung, liquid manure) and others washed away during storm rainfalls (excrement of farm animals and wild animals fed in pastures and meadows). A significantly high number of FC and FS in the examinated water samples [6] shows human and animal pollution of this part of the river. With the course of the river water quality improves, which is shown by the decrease of TVC 20°C, TVC 37°C, TC, FC, sometimes FS at site 7 (above the tributary of the Maniowka River). A more or less significant increase of

TVC 20°C in the Wiatroluza River at site 8 (below **the** tributary of the Maniowka River) was associated **with** a higher number of bacteria inflowing with this river. A significant decrease of TVC 20°C, TVC 37°C (except the water samples taken in August) and TC and FC in the Wiatrotuza River at sites 9 and 10 (in the region of the tributary to Krolowek Lake and between Krolowek Lake and Pierty Lake) is explained by diluted pollution and accompanied by indicatory bacteria in Krolowek Lake. The improvement of the bacteriological state of the water in the Wiatroluza River in this region is shown by the ratio TVC 20°C: TVC 37°C higher than 10, especially in summer and autumn. The increase of the number of TVC 20°C and FS and the ratio TVC 20°C: TVC 37°C lower than 10 in almost all water samples taken in the Piertanka River at site 11 (between Omuiowek Lake and Wigry Lake) can be explained by a localization of this site at a bridge in the neighbourhood of a water hostel, Folwark village and recreational utilization of these waters.

Conclusions

1. The number indicatory bacteria of the pollution degree (TVC 20°C, TVC 37°C) and the sanitary state (TC, FC, FS) in the water of the examinated parts of the Kamionka, Maniowka, Wiatroluza and Piertanka Rivers are the most typical for the water streams draining ar able-forestry-pasture-meadow catchments. The values of faecal coliforms titre correspond to the values accepted for class I and II of purity (the Kamionka and Piertanka Rivers, the Maniowka River before the inflow to the Wiatroluza River and a part of the Wiatroluza River be low the village Wiatroluza), exceptionally of class **III** pu rity (the Maniowka River in Lipniak and the Wiatroluza River in the village called Wiatroluza).

2. The decrease of the number of the examined indi catory bacteria in the Kamionka River below Dąbrowka, Krzywe, Czarne and Kolesne lakes and in the Wiatroluza River below Krolowek Lake is caused by dilution of pol lution and accompanied microorganisms. In case TC, FC and FS as well as natural decaying and under the influ ence of different physico-chemical (UV radiation, sun light, toxic secretion of algae) and biological (fed by pro tozoans and zooplankton, lytic activity of bacteriophages and some other bacteria).

3. The minimum number or the lack of FC in majority of the examined water samples (except the samples taken in the region of rural settlements) at high numbers of FS (the ratio FC:FS < 0.7) suggests the participation of ani mal excrement in their pollution, washed away from ar able-forestry-pasture-meadow catchments during rain fall. The high number of FC in the water samples taken in the region of Okuniowiec, Lipniak, Leszczewo and Wiatroluza village on the Kamionka, Maniowka and Wiatroluza rivers may be attributed to leakage from cess pits where there is a high number of these bacteria.

4. Fluctuations of the number of the examined indi catory bacteria of the pollution degree (TVC 20°C, TVC 37°C) and sanitary state (TC, FC, FS) in the water of **the** examined rivers from autumn may be connected with atmospheric conditions, especially waterfalls of a storm character and washed away from arable-forestry-pasture-meadow catchment earlier sedimented by people and farm animals (cattle grazing) and wild living (deer, beavers, migrating birds, stags etc.).

5. The Wiatroluza River (by the Piertanka River) takes to Wigry Lake TVC 20°C, TVC 37°C and FC typical for pure waters and/or insignificantly polluted with faecal coliforms titre corresponding to class I and/or II of water purity.

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