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Original Research

Bacterial Flora of Water Originating from Syrenie Stawy Municipal Lake in Szczecin

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Abstract

Our study is aimed at microbiological analysis of water samples originating from a small municipal lake in Szczecin, called Syrenie Stawy. The studies were conducted for a year in monthly intervals. The variables estimated in the water samples included the extent of contamination (TVC 20ºC and TVC 37ºC), content of sanitary status bacteria (coli group bacteria, TC), foecal-type coli group bacteria (FC), foecal streptococci (FS) and bacteria of physiological types (denitrification, amonification, sulphate- and sulphite-reducing bacteria). Results of the studies demonstrated high content of sanitary bacteria, which pointed to a significant contamination of the lake. High content of psychrophilic and mesophilic bacteria pointed to high amounts of organic substances in water. On the other hand, the high content of NPL, of coli group bacteria titres and of foecal type coli group bacteria provided evidence for drainage of communal sewage to waters of Syrenie Stawy. This was additionally proven by the presence of foecal streptococci. As far as physiological bacteria were concerned, the extensive differences in between mean values obtained for various sampling points may indicate unequal loading of Syrenie Stawy waters with contaminants in various points of their coastal zone.

Keywords: water, municipal lakes, microbiological analysis

Introduction

Small municipal lakes represent sites that enrich the landscape, provide towns with character, and form elements of green fields, parks and, therefore, offer the prospect for relax and rest of many town inhabitants. Consequently, the need arises for protecting the clean character of such places, not just for aesthetic reasons, but also to prevent their transformation to another epidemiological hazard [1-4]. In the area of Szczecin and in all of West-Pomerania Voivodship, several small water containers are present, which are not covered by the monitoring programme. The Programme of State Environmental Monitoring (2007-09) and implementation of the Framework Aquatic Directive monitor water purity in lakes of over 50 ha in area [5, 6]. A report on the condition of the environment in West Pomerania voivodship in 2004-05 [5] contains data on studies conducted on only 10 lakes (situated beyond municipal agglomerations) of area between 10 and approximately 42 ha. Interest in the lakes [5] reflected mainly the process of implementation of the Nitrate Directive[1]. Four lakes were selected for the study [5], situated in the catchment area of the Płonia River (Dołogie

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[1] The Nitrate Directive: No. 91/676/EEC, edited in 1991 by the European Council in order to restrict water contamination with nitrogen originating from agricultural sources. Excessive concentration of nitrates in drinking water directly endangers health of humans and animals, while in surface waters it may disturb biological equilibrium, resulting in eutrophization of the containers. Moreover, contamination with nitrates is frequently linked to contamination with various other noxious substances, providing a sort of index of hazards for the basic natural resources of water.

Mielęcińskie, Zaborsko I, Zaborsko II and Płonno lakes), and six lakes (Psarskie, Byszkowo, Machliny Małe, Baczyno, Baczynko and Czarnówek) potentially endangered by inflow of contaminations from regions fertilized with liquid manure from industrial pig farms [5]. The report claims [5] that the only examined index in the microbiological range involved foecal-type coli titre, and that the waters fitted the class I or II of purity. In 1993-2008 our Department conducted microbiological evaluations of water originating from small municipal lakes of Szczecin, including Rusałka [1, 7, 23, 24, 26-33], Syrenie Stawy [2, 7, 23-25, 33], Słoneczne [31-33, 38] and Głębokie [31, 33]. The studies pertained to sanitary bacteria (bacteria characterizing the extent of contamination, TVC 20ºC and TVC 37ºC, foecal-type coli group bacteria and foecal streptococci) and bacterial of physiological groups (denitrification, ammonification, sulphate- and sulphite-reducing bacteria). Analysis showed that water of the containers was extensively polluted and the evaluation pointed to the need and purposeful character of systematic monitoring, also of microbiological parameters that define the sanitary and ecological conditions of the containers.

Aim of Study

The studies aimed at microbiological analysis of water samples, related to their content of sanitary bacteria (bacteria which indicate the extent of contamination, TVC 20ºC and TVC 37ºC, coli-group bacteria, foecal-type coli-group bacteria and foecal streptococci) and of bacteria belonging to a physiological group (denitrification, ammonification, sulphate- and sulphite-reducing bacteria), originating from the small municipal lake Syrenie Stawy in Szczecin. The analysis was conducted in 2004, with water sampling every 4 weeks.

Material and Methods

Material for the studies involved water samples originating from Syrenie Stawy lake (Fig. 1), consisting of three containers linked by human-made inlets, the surface area of which amounts to, respectively, 4.5 ha, 0.22 ha and 0.20 ha. Depth of individual containers ranged between 1.5 m and 2.0 m, and municipal sewage is drained to all of them. Water samples were taken in four points of the lake, marked as SSI, SSII, SSIII and SSIV, respectively (Fig. 1). The studies were conducted in the entire year of 2004, in monthly intervals using the study model designed in the Chair of Microbiology and Immunology, FNSci, US [3, 34-37], but the variables estimated in the studies included bacteria characterizing the extent of contamination, TVC 20ºC and TVC 37ºC, coli group bacteria (TC), foecal type coli group bacteria (FC), foecal streptococci (FS) and bacteria of physiological groups (denitrification, ammonification, sulphate- and sulphite-reducing bacteria), using the earlier-described procedures [3, 34].

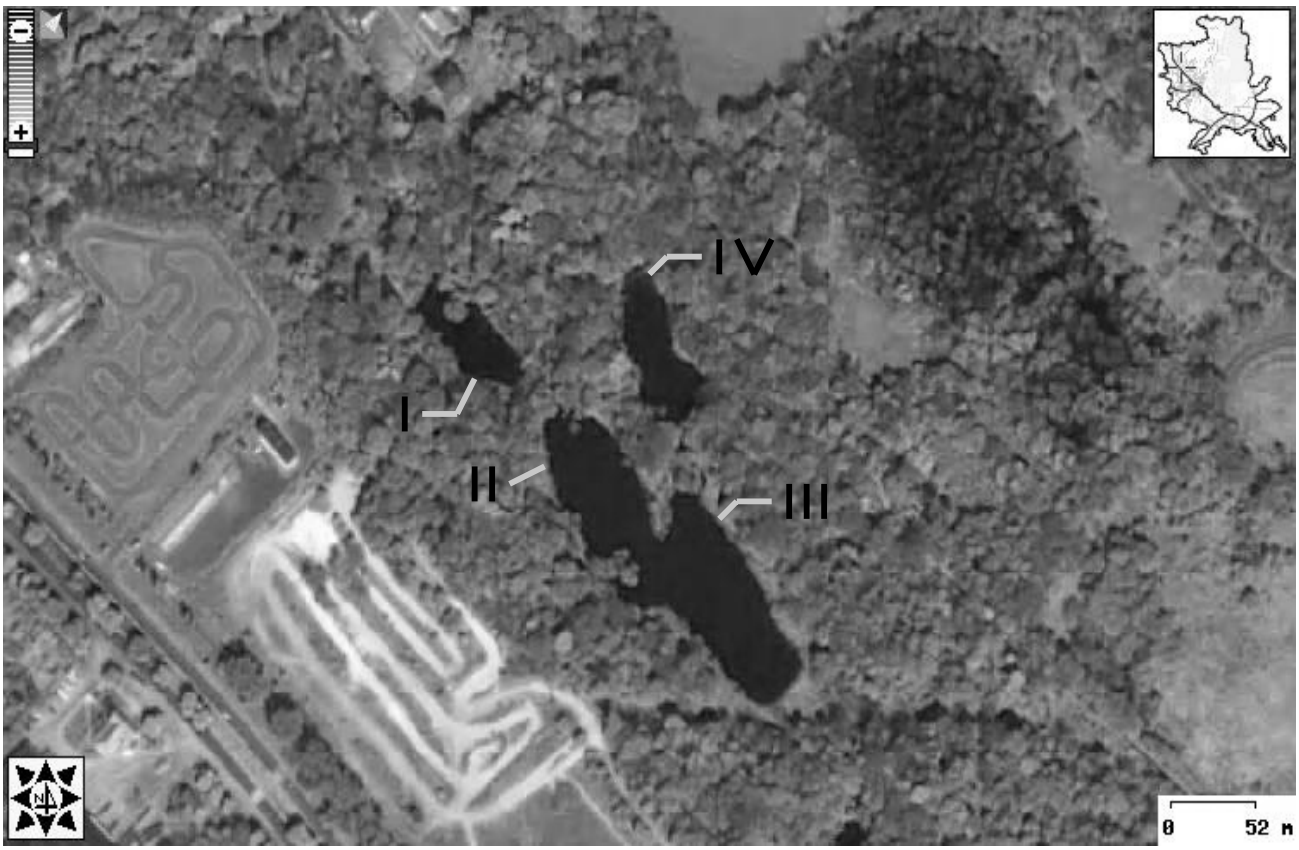

Fig. 1. Location of sampling site (SSI-IV) in Syrenie Stawy.

Table 1. Results of microbiological analysis of sampling site SSI in Syrenie Stawy.

Month of analysis	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
I	73	1.88	230	0.0004	62	0.002	10	2,300	0.00004	9,300,000	0.00001	9,3	present
II	40	2.8	62	0.002	62	0.002	700	9,300	0.00001	9,300,000	0.00001	2,3	not present
III	3.4	19	62	0.002	230	0.4	200	39,000	0.003	111,000,000	0.0000099	230	present
IV	3.4	46	<5	>20	<5	>20	0	6,400	0.00002	930	0.0001	4	not present
V	57	86	62	2	62	2	0	150	0.0007	930	0.0001	9	not present
VI	189	90	240	0.4	62	2	0	930	0.0001	430	0.0002	240	not present
VII	1.9	480	230	0.4	23	4	0	2,100,000	0.00005	240,000,000	0.0000004	43	not present
VIII	61	7	23	4	23	4	5	240,000,000	0.0000004	23,000	0.004	9	not present
IX	1.6	130	230	0.4	6	17	0	2,300,000	0.00004	1,500,000	0.00007	43	present
X	1.2	48	620	0.2	620	0.2	0	93	0.001	230	0.0004	23	not present
XI	1.37	45	2,3	0.04	2,3	0.04	300	23	0.004	150	0.0007	93	present
XII	235	32	23	4	23	4	0	43	0.002	230	0.0004	23	not present

TVC – the amount of pollution degree indicator bacteria, MPN – the most probable number.

Table 2. Results of microbiological analysis of sampling site SSII in Syrenie Stawy.

Month of analysis	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
I	110,000	2,250	62,000	0.002	62,000	0.002	18,000	430,000	0.00002	46,000,000	0.000002	9,300	present
II	10,000	86	2,300	0.04	620	0.2	0	2,300,000	0.00004	230,000	0.0004	93	not present
III	6,200	90	2,300	0.04	230	0.4	200	430,000	0.0002	15,000,000	0.000007	43	present
IV	64,000	125	1,300	0.08	620	0.2	100	230,000	0.0004	230,000	0.0004	230	not present
V	251	76	240	0.4	240	0.4	0	750,000	0.0001	930,000	0.0001	23	not present
VI	87	16	62	2	62	2	200	2,100,000	0.00005	230,000	0.0004	1,100	not present
VII	520	290	2,300	0.04	62	2	200	2,300,000	0.00004	240,000,000	0.0000004	240	present
VIII	1,320	500	620	0.2	620	0.2	4,000	2,300,000	0.00004	930,000	0.0001	11	not present
IX	4,900	300	62,000	0.002	620	0.2	0	280,000	0.0004	930,000	0.0001	93	present
X	950	19	62	2	60	1.7	0	300	0.03	93,000	0.001	93	not present
XI	2,200	1,310	2,100	0.05	2,100	0.05	2,500	2,300,000	0.00004	9,300,000	0.00001	1,500	present
XII	1,900	136	230	0.4	23	4	0	23,000	0.004	430,000	0.0002	23	present

TVC – the amount of pollution degree indicator bacteria, MPN – the most probable number.

Table 3. Results of microbiological analysis of sampling site SSIII in Syrenie Stawy.

Month of analysis	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
I	98,000	1,500	62,000	0.002	62,000	0.002	30,000	2,100,000	0.00005	24,000,000	0.0000004	430	present
II	14,200	1,160	230,000	0.0004	13,000	0.008	1,100	15,000,000	0.000007	24,000,000	0.000004	930	not present
III	980	102	2,300	0.04	62	2	300	230,000	0.0004	24,000,000	0.000004	93	present
IV	33,000	210	2,300	0.04	230	0.4	0	1,500,000	0.00007	2,300,000	0.00004	40	not present
V	52	40	1,300	0.08	1,300	0.08	0	390,000	0.0003	430,000	0.0002	43	not present
VI	91	42	2,400	0.04	2,400	0.04	400	24,000,000	0.000004	2,300,000	0.00004	240	not present
VII	830	310	620	0.2	<5	>20	0	2,300,000	0.00004	23,000	0.004	150	not present
VIII	1,560	206	23	4	23	4	4,500	240,000,000	0.0000004	43,000	0.002	460	not present
IX	350	140	6	17	6	17	0	9,300	0.01	430,000	0.0001	240	not present
X	196	19	23	4	23	4	0	75,000	0.001	2,300,000	0.00004	4	not present
XI	17,000	960	6,200	0.02	6,200	0.02	1,200	24,000,000	0.000004	2,300,000	0.00004	93	present
XII	210	39	230	0.4	230	0.4	0	39,000	0.003	23,000	0.004	23	present

TVC – the amount of pollution degree indicator bacteria, MPN – the most probable number.

Table 4. Results of microbiological analysis of sampling site SSIV in Syrenie Stawy.

Month of analysis	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
I	192,000	17,000	620,000	0.0002	6,200,000	0.0002	21,000	7,500,000	0.00001	9,300,000	0.00001	9,300	present
II	21,500	550	62,000	0.002	6,200	0.02	200	6,400,000	0.00002	12,000,000	0.000008	150	present
III	7,600	125	23,000	0.004	23,000	0.004	700	3,900	0.03	15,000,000	0.000007	230	present
IV	210,000	2,640	620,000	0.0002	230,000	0.0004	7,000	2,100,000	0.00005	24,000,000	0.000004	20,000	present
V	760,000	1,500	230,000	0.0004	230,000	0.0004	7,600	1,200,000	0.00008	240,000,000	0.0000004	930	not present
VI	700	72	2,400	0.04	2,400	0.04	100	46,000,000	0.000002	2,300,000	0.00004	240	not present
VII	12,000	320	230	0.4	23	4	0	230,000	0.0004	930,000	0.0001	150	not present
VIII	2,130	111	23	4	23	4	5,700	4,300,000	0.00002	230,000	0.004	240	not present
IX	1,800	400	2,300	0.004	50	2	0	1,500,000	0.00007	430,000	0.0002	93	not present
X	256	125	230	0.4	230	0.4	1	93,000	0.001	230,000	0.004	4	not present
XI	11,200	610	13,000	0.008	13,000	0.008	2,100	240,000,000	0.0000004	2,300,000	0.00004	240	present
XII	12,000	114	23,000	0.004	23,000	0.004	1	<3	>33	230,000	0.0004	43	present

TVC – the amount of pollution degree indicator bacteria, MPN – the most probable number.

Table 5. The average annual values of microbiological parameters within the range of the sanitary state of Syrenie Stawy Lake.

Sampling site	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci
SSI	10,534	472	32,521	1.0404	11,577	3.0585	1,350
SSII	16,861	433	11,293	0.4378	5,605	0.6460	2,100
SSIII	13,872	394	25,617	2.1519	7,770	2.5409	3,125
SSIV	102,599	1 964	133,015	0.4082	560,661	0.8731	3,700

TVC – the amount of pollution degree indicator bacteria. MPN – the most probable number.

Table 6. The average annual values of microbiological parameters within the range of physiological group bacteria in Syrenie Stawy Lake.

Sampling site	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
SSI	21,973,166	0.0009134	362,011	0.0005000	1,026	present
SSII	1,442,775	0.0031942	26,191,917	0.0002266	1,026	present
SSIII	25,803,608	0.0012396	24,887,417	0.0008724	229	present
SSIV	28,120,627	0.0028775	25,579,167	0.0001314	2,635	present

MPN – the most probable number.

Results

Results of microbiological tests on water samples for 12 individual months and 4 sampling points are shown in Tables 1 to 4, and the mean annual values for the four sampling points are shown in Tables 5 and 6.

Analysis of results obtained for water samples originating from Syrenie Stawy Lake, related to bacteria which serve as an index of contamination extent examined at 20ºC, at the sampling point SSI demonstrated variation between 57 (May) and 73,000 bacteria per ml water (January), at the sampling point SSII between 87 (June) and 110,000 (January), at the sampling point SSIII between 52 (May) and 98,000 (January), and at the sampling point SIV between 256 (October) and 760,000 (May). Mean annual value of the parameter were as follows: in sampling point SSI: 10,534 bacteria per ml water; in SSII: 16,861; in SSIII: 13,872; and in SSIV: 102,599. Considering index bacteria for the extent of contamination examined at 37ºC, in sampling point SSI content of the bacteria ranged from 7 (August) to 2,800 (February), in SSII from 19 (October) to 2,250 (January), in SSIII from 19 (October) to 1,500 (January), in SSIV from 72 (June) to 17,000 (January). Annual means of the parameter were as follows: in sampling point SSI water contained 472 bacteria per ml, in SSII 433, in SSIII 394, and in SSIV 1,964 bacteria per ml (Tables 5 and 6).

In the studied period values of NPL and titres of coli group bacteria, in SSI NPL ranged from <5 cells per 100 ml water and their titre from >20 (April) to NPL of 230,000 bacteria per 100 ml water and titre of 0.0004 (January), in point SSII from NPL of 62 and titre of 2 (June, October) to NPL of 62,000 and titre of 0.002 (January, September), in point SSIII from NPL of 6 and titre of 17 (September) to NPL of 230,000 and titre of 0.0004 (February), in point SSIV from NPL of 23 and titre of 4 (August) to NPL of 620,000 and titre of 0.0002 (January, April). Mean annual values of NPL for coli group bacteria in the point SSI amounted to 32,521 bacteria per 100ml water, in SSII to 11,293, in SSIII to 25,617 and in SSIV to 133,015 bacteria per 100 ml water.

Analysis of the results obtained for NPL values and titre of foecal-type coli-group bacteria in the point of SSI ranged from NPL of <5 bacteria per 100 ml water and the titre of >20 (April) to NPL of 62,000, titre of 0.002 (January, February). At the point of SSII the results ranged from NPL of 23, titre of 4 (December) to NPL of 62,000, titre of 0.002 (January). In the point of SSIII the parameter values ranged from NPL of <5, titre of >20 (July) to NPL of 62,000, titre of 0.002 (January), and in the point SSIV from NPL of 23, titre of 4 (July, August) to NPL of 6,200,000, titre of 0.0002 (January). Mean annual values of NPL for foecal-type coli-group bacteria were as follows: in SSI the value amounted to 11,577, in SSII to 5,605, in SSIII to 7,770, and in SSIV to 560,661.

NPL for foecal type streptococci ranged in the sampling point of SSI from 0 bacteria per 100 ml water (April-July, September, October, December) to 10,000 (January); in SSII from 0 (February, May, September, October, December) to 18,000 (January); in SSIII from 0 (April,

May, July, September, October, December); in SSIV from 0 (July, September) to 21,000 (January). Mean annual values of the parameter were as follows: in the sampling point of SSI 1,350, in SSII 2,100, in SSIII 3,125 and in SSIV 3,700.

Analysis of the results obtained for bacteria of physiological groups showed that NPL values and titres of denitrification bacteria in SSI ranged from NPL of 23,000, titre of 0.004 (November) to NPL of 240,000,000, titre of 0.0000004 (August); in SSI from NPL 300, titre of 0.033 (October) to NPL of 2,300,000, titre of 0.00004 (February, July), in SSIII from NPL of 9,300, titre of 0.01 (September) to NPL of 240,000,000, titre of 0.000004 (August) and in SSIV from NPL <3, titre of >33 (December) to NPL of 240,000,000, titre of 0.0000004 (November). Mean annual value of the parameter amounted to 21,973,166 in SSI, to 1,442,775 in SSII, to 25,803,608 in SSIII and to 28,120,627 in SSIV. NPL values and titre of ammonification bacteria demonstrated variation in SSI from NPL of 23,000, titre of 0.004 (August) to NPL of 240,000,000, titre of 0.0000004 (July); in SSII from NPL of 93,000, titre of 0.001 (October) to NPL of 240,000,000, titre of 0.0000004 (July); in SSIII from NPL of 23,000, titre of 0.004 (July) to NPL of 24,000,000 , titre of 0.000004 (February, March); in SSIV from NPL of 230,000, titre of 0.004 (August, October) to NPL of 240,000,000, titre of 0.0000004 (May). The documented mean annual NPL for ammonification bacteria were as follows: in SSI 362,011, in SSII 26,191,917, in SSIII 24,887,417, and in SSIV 25,579,167 bacteria.

Discussion of Results

Few studies have dealt with microbiological tests on water samples originating from small municipal lakes in the area of Poland (Tables 7 and 8), except for our own reports on Szczecin municipal lakes: Rusałka [1, 7, 23, 24, 26-33], Syrenie Stawy [2, 7, 23-25, 33], Słoneczne [31-33, 38] and Głębokie [33]. Therefore, interpretation of present results is difficult since the results obtained now can mainly be compared just with our own earlier results.

The demonstrated total number of bacterial colonies in a 100 ml sample, cultured in a nutrient agar at 20ºC for 72 h, has been in the range of 52 to 760,000 and has proven higher than the bacterial content in most small aquatic containers in the area of Poland [Table 7, pos. 11-20, 31, 33], but lower than the results noted for Słoneczne Lake [31-33, 38], Rusałka Lake [1, 7, 23, 24, 26-33], or Syrenie Stawy Lake [2, 7, 23-25, 31, 33] in 1993 to 2003 (Table 7).

As far as the total number of bacterial colonies is concerned, per 100 ml sample cultured at 37ºC, in a nutrient agar for 24 hours, the results have ranged between 7 and 17,000, resembling the results obtained by Niewolak [15] in Jeziorak Mały Lake (Table 7) which, although located within a town, manifests a much higher surface area (26 ha). Results of the parameters we obtained have been higher than values recorded for most studied containers of a surface area ranging between 2 and 26 ha [11-19, 31, 33], but lower than those documented for the other municipal lakes of Szczecin, Słoneczne [31-33, 38] and Rusałka [1, 7, 23, 24, 26-33], or that found in Lake Długie, near Olsztyn [20].

In the scope of coli bacteria a wide range of values has been noted of the most probable number of the bacteria (NPL), ranging from <5 to 620,000, which has not been confirmed by other studies on small lakes (Table 7). However, it has been noted that the values have been higher than those obtained Starodworskie [13] and Mutek lakes, [14] or in Głębokie Lake [31, 33] but lower than the results obtained in other small lakes in Szczecin, Słoneczne [31-33, 38] and Rusałka [1, 7, 23, 24, 26-33].

Titres of coli-group bacteria in our own studies have ranged from 0.0002 to >20. Similar values within a similar range have been disclosed by our team in studies on Słoneczne [31-33, 38], and Głębokie lakes [31, 33], and also in the earlier conducted studies on Syrenie Stawy Lake [2, 7, 21, 23-25, 33]. The values have been noted to be higher than those obtained in Skrzynka Lake [12], Lipno [11], Rosnowskie-Małe [11], Budzyńskie [12] and Długie lakes near Olsztyn, and those documented by Niewolak and Donderski in Jeziorak Mały Lake [15-18] (Table 7).

NPL of foecal-type coli-group bacteria in our studies has ranged between less than 5 to 6,200,000, and the results have exceeded those recorded in Mutek [14] and Głębokie lakes [31,33], although they have been lower than those noted in Słoneczne [31-33, 38] and Rusałka lakes [1,7,23,24,26-33] or in earlier studies on Syrenie Stawy Lake [2, 7, 23-25, 31, 33] from 1993-2003.

Titres of foecal-type coli-group bacteria in our studies have ranged between 0.0002 and >20. The variable has been studied only in our investigations on other municipal lakes of Szczecin in 1993-2003: Słoneczne [31-33, 38], Rusałka [1, 7, 23, 24, 26-33], Głębokie [31, 33] and Syrenie Stawy lakes [2, 7, 23-25, 31, 33], and the values noted at present have been confirmed.

NPL of foecal streptococci in present studies has varied between 0 and 140,000. The value has been lower than the values obtained for Słoneczne lake [31-33, 38], Rusałka [1, 7, 23, 24, 26-33], and Syrenie Stawy lakes [2, 7, 23-25, 31, 33] in studies conducted in 1993-2006, but higher than the values noted in the out-of-town-situated Mutek Lake [14] or municipal Głębokie Lake [31, 33].

In evaluation of results within the range of physiological group bacteria it has to be noted that few studies have been performed on the group of bacteria in other water containers in Poland (apart from our own studies on lakes such as Rusałka, Syrenie Stawy or Słoneczne) and the studies have used to include just two indices: NPL of ammonification bacteria and NPL of denitrification bacteria.

The NPL of ammonification bacteria have fitted the range of 23,000 to 240,000,000, and the level has been confirmed also in Słoneczne [31-33, 38] and Rusałka lakes [1, 7, 23, 24, 26-33], and in the earlier studies on Syrenie Stawy Lake [2, 7, 23-25, 31, 33]. The remaining tested lakes [11, 12, 20, 22, 39], of surface area up to 32 ha (Table 8), had much lower values.

In our own studies the titre of ammonification bacteria showed the range of 0.0000004 to 0.004. Results of the index could have been compared only to values obtained by

Table 7. The sanitary state bacteria in water from lakes situated in Poland.

No.	Lake name	Year of analysis	Area (ha)	TVC 20°C	TVC 37°C	MPN · 100ml^{-1} total coliforms	Coli titre	MPN · 100ml^{-1} fecal coliforms	Fecal coliforms titre	MPN · 100ml^{-1} fecal streptococci
1	Słoneczne [31-33, 38]	1993-2006	2	123-1,210	40-680,000	>5- 24,000,000	0.000004->20	>5-2,400,000	0.00004->20	0-476,500
2	Skrzynka [12]	1974	2.24	60-100	3-19	-	1-10	-	-	-
3	Rusałka [1, 7, 23, 24, 26-33]	1993-2006	3.7	26-4,200,000	0-300,000	6-240,000,000	0.0000004-17	0-240,000,000	0.0000004->20	0-520,000
4	Kociołek [12]	1974	4.32	63-660	8-240	-	10	-	-	-
5	Syrenie Stawy [2, 7, 23-25, 31, 33]	1993-2006	4.92	0-3,600,000	6-1,486,000	<5-240,000,000	0.000004->20	0-50,000,000	0.00002->20	0-750,000
6	Starodworskie [13]	1986-1988	6.7	0-3,100	2-3,050	0-1,400	-	-	-	-
7	Mutek [14]	1993	7.0	75-24,500	15-2,000	4-11,000	-	<3-1,100	-	3-4,500
		1994		80-2,440	13-230	4-460	-	<3-23	-	21-11,000
8	Lipno [11]	1974	9.0	100 - 6,400	45-360	-	0.1-10	-	-	-
9	Rosnowskie-Małe [11]	1974	9.84	55-1,860	12-1,030	-	0.1-10	-	-	-
10	Budzyńskie [12]	1974	17.3	46-920	6-360	-	10	-	-	-
11	Jeziorak Mały [15-18]	1960-1963	26.0	-	>10,000	-	0.01-1	-	-	-
		1967-1972		160-20,500	10-2,670	-	0.01-1	-	-	-
		1968		500-5,000	-	-	-	-	-	-
		1996		14,300-30,000	-	-	-	-	-	-
12	Długie near Olsztyn [20]	1972-1973	26.8	780-90,000	500-45,000	-	0.0001-0.1	-	-	-
13	Głębokie [31, 33]	1996	31.3	36-300,000	0-13,700	<5-62,000	0.002->20	<5-62,000	0.002->20	0-15,300

TVC – the amount of pollution degree indicator bacteria. MPN – the most probable number

Table 8. The phisiological types of bacteria in water from lakes situated in Poland.

No.	Lake name	Year of analysis	Area (ha)	MPN · 100ml^{-1} Denitrification bacteria	Denitrification bacteria titre	MPN · 100ml^{-1} Amonification bacteria	Amonification bacteria titre	MPN · 100ml^{-1} Sulphate-reducing bacteria	Presence of sulphite-reducing bacteria
1	Wądołek [39]	1998-2000	1.0	2-2,930	-	<3-1,400	-	-	-
2	Suchar IV [39]	1998-2000	1.15	3-1,870	-	7-300	-	-	-
3	Suchar Zach. [39]	1998-2000	1.2	10-3,720	-	3-40	-	-	-
4	Konopiak [39]	1998-2000	1.73	25-3,025	-	7-50	-	-	-
5	Słoneczne [31, 32, 33, 38]	1993-2006	2.0	23,000-240,000,000	0.0000002-0.007	210-240,000,000	0.0000004-0.04	3-150,000	present
6	Wygorzele [39]	1998-2000	2.0	10-1,685	-	3-200	-	-	-
7	Skrzynka [12]	1974	2.24	9-80	-	70-800	-	-	-
8	Rusałka [1, 7, 23, 24, 26-33]	1993-2006	3.7	3-240,000,000	0.0000004-33	3-240,000,000	0.0000004-33	0-4,600	present
9	Kociołek [12]	1974	4.32	25-80	-	70-430	-	-	-
10	Syrenie Stawy [2, 7, 23-25, 31, 33]	1993-2006	4.92	3-240,000,000	0.000000004-7	3-150,000,000	0.000002-33	3-43,000	present
11	Smolak [22]	1970-1971	7.0	3,000-306,900	-	-	-	-	-
12	Lipno [11]	1974	9.0	25-70	-	25-430	-	-	-
13	Rosnowskie- Małe [11]	1974	9.84	25-4,300	-	70- 800	-	-	-
14	Czarna Kuta [22]	1970-1971	25.5	5,000-1,205,000	-	-	-	-	-
15	Długie near Olsztyn [20]	1972-1973	26.8	1,000-90,000	-	-	-	-	-

MPN – the most probable number

our team in studies on Syrenie Stawy Lake [2, 7, 23-25, 31, 33] in 1993 to 2003, and on Słoneczne Lake [31-33, 38] (in which the results have slightly diverged from present ones), and on Rusałka Lake [1, 7, 23, 24, 26-33], where the values have exceeded those obtained in present investigations.

NPL of denitrification bacteria in our own studies has reached values fitting the range <3 to 240,000,000, which has been confirmed in investigations conducted on Słoneczne Lake [31-33]. Results of the index have been demonstrated to exceed the results obtained in the lakes of Wądołek [39], Suchar IV [39], Suchar Zachodni [39], Konopiak [39], Wygorzele [39], Skrzynka [12], Kociołek [12], Lipno [11] and Rosnowskie-Małe [11].

Similarly to ammonification bacteria, the titres of denitrification bacteria have been examined only by our team in Słoneczne [31-33, 38], Rusałka [1, 7, 26-33] and Syrenie Stawy [2, 7, 23-25, 31, 33]. It has been recorded that similar values of the variable have been noted in the containers.

NPL of sulphite-reducing bacteria has ranged from 4 to 20,000. Also, this index has not been tested in other lakes with surface area up to 32 ha (Table 8), except of our investigations on lakes such as Słoneczne [31-33, 38], Rusałka [1, 7, 23, 24, 26-33] and earlier-conducted studies on Syrenie Stawy lake [2, 7, 23-25, 31, 33]. In present studies values of the index have been lower than those obtained in the above-mentioned water containers.

Similarly to most indices related to bacteria of physiological groups, the presence of sulphate-reducing bacteria has not been tested with the exception of our investigations, which usually have disclosed the presence of the bacteria group in studied water containers.

Summary

As compared to results obtained with water of other lakes with surface area of approximately 30 ha in the area of Poland (Table 8), values of studied variables were markedly higher but resembled values obtained in the other municipal lakes of Szczecin (Rusałka, Słoneczne, Głębokie), studied by our team in 1993-2008 (Table 7). The high values of NPL and the high titres of coli-group bacteria and of foecal-type coli-group bacteria in water samples taken for the studies provide proof for draining of municipal sewage to Syrenie Stawy lake. In addition, the conclusion is corroborated by the presence of foecal streptococci. Moreover, we detected in the samples high numbers of psychrophilic and mesophilic bacteria point to high content of organic substances in the water. In addition, the high differences between mean values of physiological group bacteria noted between water sampling points of the studied water container may indicate an unequal burden of water contamination in Syrenie Stawy, at various points of its coastal zone. The high values of studied parameters in water samples obtained from Syrenie Stawy Lake not only corroborate the fact that the water container is contaminated, but also demonstrate lack of interest of municipal authorities in small lakes situated within the town of Szczecin.

References

1. NAHURSKA A., DEPTUŁA W., STOSIK M. Sanitary and ecological characteristics of water in the municipal lake of Rusałka in Szczecin. Pol. J. Environ. Stud., **16**, 853, **2007**.
2. NAHURSKA A., DEPTUŁA W. Microbiological analysis of water samples from Syrenie Stawy lake. "Man and Natural Environment of Western Pomerania". I Biotic environment. Edited by Rogalska S., Domagała J. Oficyna INPLUS, pp. 193-198, **2003** [In Polish].
3. NAHURSKA A. Microbiological analysis of water in selected municipal lakes of Szczecin town. Doctoral thesis. WNP US. Szczecin **2006** [In Polish].
4. OLEJNICZAK M., KULIŃSKA A., DEPTUŁA W. Small municipal lakes: beauty of source of a risk. Centaur Lubuski, 62, 12, **2004** [In Polish].
5. Report on environmental status in West-Pomerania voivodship in 2004-2005. Biblioteka Monitoringu Środowiska, Szczecin **2006** [In Polish].
6. Programme of National Environmental Monitoring in 2007-2009. Główny Inspektor Ochrony Środowiska, Warszawa **2006** [In Polish] .
7. NAHURSKA A., DEPTUŁA W. Sanitary studies on water of selected lakes in Szczecin. Pol. J. Env. Stud., **13**, 693, **2004**.
8. STRZELCZYK E., DONDERSKI W., STOPIŃSKI M. Studies of physiological properties of heterotrophic bacteria isolated from water and mud of three lakes. Acta Universitatis Nicolai Copernici, Prace Limnologiczne **9**, 27, **1976**.
9. DONDERSKI W., STRZELCZYK E. Bacteriological studies of the mesotrophic lake Jasne. Acta Universitatis Nicolai Copernici, Nauki matematyczno-przyrodnicze, Prace limnologiczne **10**, 15, **1977**.
10. DONDERSKI W., NOWACKA B. Production of B-vitamins by planctonic bacteria isolated from the mesotrophic lake Jasne. J. Islamic Acad. Sci., **5**, 32, **1992**.
11. DĄBSKA I., BURCHARDT L., HŁADKA M., NIEDZIELSKA E., PAŃCZAKOWA J. Hydrobiological studies on lakes of Wielkopolski National Park. Part II. Lakes of Witobelsko-Dymaczewo gully and Lipno lake. Part III. Lakes of Rosnowo-Jarosławiec gully. Poznańskie Towarzystwo Przyjaciół Nauk, Wydział Matematyczno-przyrodniczy, Prace Komisji Biologicznej, vol. 60, Wyd Nauk. PWN, Warszawa-Poznań **1981** [In Polish].
12. DĄBSKA I., HŁADKA M., NIEDZIELSKA E., PAŃCZAKOWA J., SZYSZKA T. Hydrobiological studies on lakes of Wielkopolski National Park. Part I. Lakes of zne badania jezior Wielkopolskiego Parku Narodowego, część I Jeziora Rynny Górecko-Budzyń gully. Poznańskie Towarzystwo Przyjaciół Nauk, Wydział Matematyczno-przyrodniczy, Prace Komisji Biologicznej, vol. 60, Wyd Nauk. PWN, Warszawa-Poznań **1981** [In Polish].
13. NIEWOLAK S. Sanitary and bacteriological survey of an artificially aerated eutrophic Starodworskie lake, Poland. Pol. J. Env. Stud., **6**, 33, **1997**.
14. NIEWOLAK S., FILIPKOWSKA Z., NOWAK A., POWĄZKA E. Evaluation of the sanitarny and bacteriological state of a polytrophic lake ten years after discounting its recultivation by the aeration metod. Acta Universitatis Nicolai Copernici, **110**, 207, **2003**.
15. NIEWOLAK S. Sanitary evaluation of surface waters in Iława lakes in 1960-1963. Z.N. WSR Olsztyn **21**, 91, **1966** [In Polish].
16. NIEWOLAK S. Sanitary evaluation of selected municipal lakes in Mazury Lake Region in 1967-1971 Gaz, woda i technika sanitarna **46**, 10, **1972** [in Polish] .

17. NIEWOLAK S. Microbiological study of hyponeuston of Iława lakes during summer Acta Hydrobiol. **13**, 295, **1971** [In Polish].
18. DONDERSKI W., WALCZAK M., MUDRY Z., KOBYLIŃSKI M. Neustonic bacteria of lake Jeziorak Mały. Pol. J. Env. Stud., **7**, 125, **1998**.
19. DONDERSKI W., WALCZAK M., MUDRY Z., KOBYLIŃSKI M. Neustonic bacteria number, biomass and taxonomy. Pol. J. Env. Stud., **8**, 137, **1999**.
20. ZMYSŁOWSKA I., SOBIERAJSKA M. Microbiological characteristics of Długie lake in Olsztyn, polluted by communal-industrial sewage. Z.N. ART. Olsztyn, Ochrona Wód i Rybactwo Śródlądowe **10**, 39, **1980** [In Polish].
21. NIEWOLAK W. Sanitary and bacterial analysis of water and bottom sediments of a heavily polluted, hypertrophic lake. Ekologia Polska **37**, 3, **1989**.
22. NIEWOLAK S. Manifestation of microbes in water of some lakes in Węgorzewo region. Acta Hydrobiol. **17**, 371, **1975** [In Polish].
23. STAPF D., DEPTUŁA W. Dynamics of changes in bacterial contents of waters in Rusałka and Syrenie Stawy lakes (Part I). Proceedings of a Symposium on Heritage of municipal gardens and a historical landscape. Wyd. SGGW W-wa, Ursynów, pp. 76-82, **1994** [In Polish].
24. MARKIEWICZ D., DEPTUŁA W., BĄCZKOWSKI M. Results of microbiological studies on water samples from selected lakes in the area of Szczecin town. Proceedings of II Scientific-Technical Conference on Protection and Recultivation of lakes and water containers. Międzyzdroje, pp. 87-98, **1996** [In Polish].
25. NAHURSKA A., DEPTUŁA W., STOSIK M. Sanitary bacteria in water samples originating from Syrenie Stawy lake. Chemia i Inżynieria Ekologiczna **10**, 110, **2003** [In Polish].
26. NAHURSKA A., DEPTUŁA W. Microbiological tests of water samples from Rusałka Lake. Acta Universitatis Nicolai Copernici. Prace Limnologiczne XIII. Zeszyt **110**, 257, **2003**.
27. NAHURSKA A., DEPTUŁA W. Microbiological studies based on our own model of a small municipal lake. Księga konferencyjna Proceed. ECOpole`03, pp. 251, **2003** [in Polish].
28. NAHURSKA A., SAWICKA J., DEPTUŁA W. Our own model for microbiological evaluation of water in small municipal lakes exemplified by Rusałka Lake. UFZ-Bericht, **18**, 267, **2004**.
29. NAHURSKA A., DEPTUŁA W. Microbiological evaluation of water samples from municipal lake of Rusałka in Szczecin town. Trudy VII Mieždunarod. Naucznoj-prakticzeskoj konf. mołodych uczenych studentow i aspirantow, Sankt-Petersburg, pp. 117-125, **2006**.
30. SAWICKA J., NAHURSKA A., DEPTUŁA W. Bacteriological analysis of the waters of small municipal lake. Pol. J. Nat. Sci. **21**, 917, **2006**.
31. MARKIEWICZ D., DEPTUŁA W. Microbiological studies on water samples originating from selected lakes of Szczecin town. Mat. Nauk. XXIII Zjazdu Pol. Tow. Mikrobiol. Łódź, pp. 119, **1996** [In Polish].
32. MATUSIAK M., DEPTUŁA W., STOSIK M., MARKIEWICZ D. Microbiological evaluation of water samples originating from Słoneczne lake. Mat. XVII Zjazdu Hydrobiologów Polskich, Poznań, pp. 76, **1997** [In Polish].
33. MARKIEWICZ D., DEPTUŁA W., STOSIK M. Selected microbiological parameters of water samples originating from lakes of Szczecin town. Materiały XVII Zjazdu Hydrobiologów Polskich. Poznań, p. 75, **1997** [In Polish].
34. DEPTUŁA W., STOSIK M., HŁYŃCZAK A., MARKIEWICZ D., POLESZCZUK G., ZIELIŃSKI R., WESOŁOWSKA A. New model for studies on aquatic environment. Chemia i inżynieria Ekologiczna **5**, 1113, **1998** [In Polish] .
35. DEPTUŁA W., STOSIK M., POLESZCZUK G., HŁYŃCZAK A., ZIELIŃSKI R. An attempt to develop new model for evaluation of surface waters. Mat. I Krajowej Konf. „Biomarkery stanu środowiska wodnego". Zielona Góra, pp. 6-15, **1998** [In Polish].
36. DEPTUŁA W., HŁYŃCZAK A., POLESZCZUK G., STOSIK M., ZIELIŃSKI R. Our own model for evaluation of aquatic environment. Aura **9**, 16, **1993** [In Polish].
37. HŁYŃCZAK A., DEPTUŁA W., BRZEZIŃSKA M., ZIELIŃSKI R., STOSIK M., POLESZCZUK G. New model for studies. EkoBałtyk **5**, 8, **1993** [In Polish].
38. NAHURSKA A., SAWICKA J., DEPTUŁA W. Sanitary evaluation of water in two small municipal lakes. Proceedings of the III All-Polish Conference of Hydromicrobiology: Methods of molecular biology in hydromicrobiological studies Zielona Góra /Łagów, pp. 47, **2004**. [In Polish].
39. KUCZYŃSKA A., NIEWOLAK S. Seasonal alterations in numerical force of bacteria of nitrogen turnover in waters of dystrophic lakes in the area of Wigry National Park [In Polish] (on line). www.wigry.win.pl/sesja/kucz.htm