Sanitary and Bacteriological Evaluation of the Southern Part of Legiński Lake for Recreational Purposes

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Abstract

Evaluation of water in the southern part of Leginski Lake and its usefulness for recreation was carried out on the basis of the following criteria: Kohl 1975 and Kavka 1987 in Albinger's modification; U.S Department of the Interior, Federal Water Pollution Control Administration; and the European Committee for the Quality of Water for Bathing Purposes. Research work was aimed at determining the number of bacteria indicatory of pollution (Total Viable Count 20°C) and sanitary state (FC and FS). Samples of water and bottom sediments were examined at three different sites. The results revealed that water in the southern part of Leginski Lake can be used for recreational purposes. The majority of samples examined was classified as clean or little polluted. A higher degree of water loading was found only at the outlet of the stream coming from biological ponds of the local water-treatment plant.

Keywords; lake, water pollution, sanitary evaluation, indicator microorganisms, bacteria.

Introduction

The quality of stagnant water is influenced by two major factors: antropogenic, i.e. related to human activity, and natural, which can be divided into geochemical, morphometric-hydrographic-drainage and climatic categories [13, 4].

The nutrients, getting into water from the drainage area pointwise, areawise or bandwise, thus determine the process of eutrophication [13]. As a result, both autochtonous and allochtonous microflora are present in the water. There is a wide body of literature on qualitative and quantative examination of bacteria indicatory of sanitary state and alimentary tract pathogens in water and bottom sediments in lakes. Furthermore, numerous works deal with the impact of environmental factors on the lifespan of these bacteria. Among a wide range of physical and chemical factors, an important role is played by temperature [20, 17, 16, 19], light [18, 8, 2, 6] the quantity of organic substances [18, 5, 8], and aerobic or anaerobic conditions [21]. Also biological factors have a substantial influence on the lifespan of bacteria indicatory of sanitary state and alimentary tract pathogens [11,24,3,12].

The aim of this paper is to evaluate the usefulness of the southern part of Leginski Lake for recreational purposes on the basis of the following criteria:

a) Kohl [15] and Kavka [14] in Albinger's modification

b) U.S Department of Interior, Federal Water Pollution Control Administration [23].

c) EEC (European Committeee for the Quality of Water for Bathing Purposes [7].

Materials and Methods

Research Subject

Leginski Lake is a part of Leginski Lake group, which also includes Klawoj Lake, Mutek Lake, Pasterzewo Lake, Trzcinno Lake and Wydrynskie Lake.

Leginski Lake is situated at 21°08.3' longititude and 53°58.9' latitude. It occupies the southernmost location as compared to other lakes from the group and therefore receives all water courses coming from Leginski Lake complex. In addition, the southern part of the lake is supplied with treated wastewater coming from a three-stage treatment plant in Lezany opened in 1988 (it is an experimental object of Water Protection and Inland Fishery Department of Warmia and Mazury University in Olsztyn). Waters from Leginski Lake flow away from the northern part of the lake in a single water course, i.e. Leginka, to the Sajny river.

Water Sampling Sites

Three sampling sites were designated in the southern part of Leginski Lake:

- site I (st. I) - discharge of the stream flowing from the waste ponds of the three-stage treatment plant in Lezany (- 0.5 m deep).
- site II (st. II) - location chosen between site I and III. Situated 200 m from site I (lake's depth -10 m).
- site III (st. Ill) - location chosen 300 m from site I (lake's depth -15 m).

Sampling Material

a) water taken from:

- site I at 0.3 m depth below the surface in 1992 and 1993.
- site II and **III,** at 0.3 m depth under the surface and 0.5 m above the bottom in 1992 and 1993,

b) bottom sediments taken from sites I, II, and III from the surface layer in 1992 and 1993.

Sample Taking

Samples were taken in one to two week intervals in spring from 25.03 to 23.06.1992 and from 4.05 to 17.07. 1993.

a) water - surface water samples were taken directly into sterile glass bottles with ground stoppers, and near bottom samples - using Ruttner apparatus and then placed into sterile bottles as well.

b) bottom sediments - bottom sediment samples were taken from 5 cm surface layer with Kajak apparatus and placed into sterile glass containers.

Time lapse between sample taking and microbiological analysis did not exceed three hours. While transported, the samples were kept at about 4°C. **Microbiological determinations included:**

a) total number of bacteria in broth agar after 72h incubation at 20°C in 1 cm^3 water or lg w.w. of bottom sediments

b) total number of coliforms on Eijkman medium (MERCK) after 48h incubation at 37°C (MPL/100 cm^3 water)

c) total number of faecal coliforms on Eijkman me dium (MERCK) after 24h incubation at 44.5°C (MPL/100 cm^3 water or 1 g w.w. of bottom sediments)

d) number of faecal streptococci on Enterococci confirmatory broth (DIFCO) after 72h incubation at 37°C (MPL/100 cm^3 water)

Results

Following the criteria given by Kohl [15] and Kavka [14] in Albinger's modification [1] (Table 1), it can be concluded that 100% of the surface water samples examined at sites II and III in 1993, and at site III in 1992 revealed very little loading with organic substance easily decomposed by TVC 20°C bacteria. In 1992, 80% of the samples at site **III** in demersal water and at site II at both depths corresponded to this criterion, and the remaining 20% at site **III** showed little and, at site II, moderate, degree of loading. Site I differed from the other two. Only 40% of the samples examined in 1992 and 42.8% in 1993 conformed with the first degree of loading with organic substance. Examination of the percent share of the remaining samples revealed various degree of loading with easily decomposable organic substance, up to moderately high.

To recapitulate briefly, in both years and throughout the whole research period a substantial portion of the examined water samples showed very little loading with easily decomposable organic substance (TVC 20°C). In 1992, it was 76% (sites **I-III),** in 1993 (sites **Mil)** - 88.6%, and altogether in 1992 - 1993 - 83.3%.

Close examination of bottom sediment samples from all three sites throughout the whole research period showed little loading with organic substance easily decomposed by TVC 20°C bacteria (Table 2).

Taking into account numeric values of faecal coliforms in water samples (Table 1), it can be concluded that during the testing period at sites II and **III** the respective values of loading with faecal substance was very little for a substantial number of samples (from 60% to 100%), little for 0% to 28.6% of the samples and moderate for 0% to 20%.

The number of faecal coliforms at site I was higher. In 1992, 40% of water samples at this site revealed very little, 40% little and 20% high degree of loading with faecal substances. In 1993, the degree of loading was very little for 14.3% of the samples, little for 14.3% , moderate for 42.8% and very high for 28.6%.

The majority of samples tested showed very little loading with faecal substances both in the respective years (from 62.8% to 72%) and throughout the whole sampling period of 1992 - 1993 (66.7%).

In bottom sediments at sites II and III small quantities of faecal bacteria from the coliforms group were detected. In 1992, 60% of the samples from these sites showed minimal loading with faecal substances and the remaining 40% - little.

The number of faecal coliforms at site I was higher. In 1992, 40% of the samples had little loading and 60% - very little, while in 1993, 57.1% revealed little, 14.3% very little and 28.6% moderate loading (Table 2).

Following the criteria given by the U.S. Department of Interior, Federal Water Pollution Control Administration [23] (Table 3), and allowing for coliform frequency, 100% of water samples tested at sites II and **III** in 1992

Table 1. Water quality evaluation in the southern part of Legiński Lake according to criteria given by Kohl in 1975 and Kavka in 1987 in Albinger's modification (1992). Sample percentage per class.

Criteria of water quality evaluation		Water quality[3]	1992						1993						1992-1993
Microorganisms	Number of bacteria		st. I	st. II		st. III		st.I-III	st. I	st. II		st. III		st. I-III	
			s	s	n.b.	s	n.b.		s	s	n.b.	s	n.b.		
TVC 20°C[1]	≤ 500	1	40.0	80.0	80.0	100.0	80.0	76.0	42.8	100.0	100.0	100.0	100.0	88.6	83.3
	> 500 – 1000	2	0	0	0	0	20.0	4.0	14.3	0	0	0	0	2.8	3.3
	> 1000 – 10 000	3	40.0	20.0	20.0	0	0	16.0	28.6	0	0	0	0	5.8	10
	> 10 000 – 50 000	4	20.0	0	0	0	0	4.0	14.3	0	0	0	0	2.8	3.4
	> 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
			[4](5)	(5)	(5)	(5)	(5)	(25)	(7)	(7)	(7)	(7)	(7)	(35)	(60)
FC[2]	1 – 10	1	40.0	60.0	80.0	80.0	100.0	72.0	14.3	71.4	85.7	71.4	71.4	62.8	66.7
	> 10 – 100	2	40.0	20.0	20.0	20.0	0	20.0	14.3	28.6	0	28.6	28.6	20.0	20
	> 100 – 1000	3	0	20.0	0	0	0	4.0	42.8	0	14.3	0	0	11.4	8.3
	> 1000 – 5000	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	> 5000 – 10 000	5	20.0	0	0	0	0	4.0	0	0	0	0	0	0	1.7
	> 10 000 – 100 000	6	0	0	0	0	0	0	28.6	0	0	0	0	5.8	3.3
	> 100 000	7	0	0	0	0	0	0	0	0	0	0	0	0	0
			(5)	(5)	(5)	(5)	(5)	(25)	(7)	(7)	(7)	(7)	(7)	(35)	(60)

s – surface water

n.b – near bottom water

[1] – total number of bacteria on broth agar after 72 h incubation at 20°C in 1 cm^3 water

[2] – number of faecal coliforms (MPL/100 cm^3 water)

[3] – degree of loading with easily decomposable organic substance (TVC 20°C) and faeces:
1 – very little, 2 – little, 3 – moderate, 4 – modarately high, 5 – high, 6 – very high, 7 – extremely high

[4] – number of samples examined given in brackets

and 1993, and only 60% and 14.3% at site I in 1992 and 1993, respectively, can be classified as acceptable for bathing purposes.

Taking into account numeric values of faecal coliforms, it can be concluded that 100% of the samples from site III throughout the whole research period; 80% in surface water and 100% in demersal layer at site II in 1992; 100% in surface water, and 85.7% in demersal in 1993; 80% and 42.8% at site I in 1992 and 1993 respectively, met the requirements of water used for bathing purposes.

Regarding the aforementioned groups of indicatory organisms, it was concluded that 100% of the samples at site II and III fulfilled the conditions set for waters used for recreational purposes and allowed for direct contact with human body. As concerns the number of coliforms, 60% of the samples from 1992 and 57.1% from 1993 could be classified into this class of water from site I only, and considering faecal coliforms, the values would be 80% and 71.4% respectively. The results of bacteriological quality analysis for public water resources were the same as for class 2 of recreational waters.

Throughout the whole research period and in successive years, the prevailing majority of samples examined could be classified as water permitted for bathing purposes.

Adopting estimation criteria given by European Commiteee for the Quality of Water for Bathing Purposes [7], it can be stated that these were the samples fulfiling the requirements that constituted a high percentage share of water samples tested (Table 4). Considering general numbers of coliforms group (TC), the figures were 100% for the samples at sites II and III in 1992 and 1993; 60% and 14.3% at site I in 1992 and 1993.

Employing the faecal coliform (FC) count as an index, the criteria were satisfied by 100% of the samples at site III taken from the two depths during the whole sampling period, at site II from demersal layers in 1992 and surface water in 1993. In 1992, 80% of the samples at sites I and II in surface water, and in 1993, 85.7% at site II in demersal waters and, finally, 28.6% at site I, fulfilled water requirements for bathing purposes.

Taking faecal streptococci into account, a high percentage of samples was found to have met the EEC criteria, yet the percentage was slightly lower as compared with TC and FC index, namely from 80% to 100% at sites II and III in 1992 and from 71.4% to 100% in 1993. The highest numbers of faecal streptococci were found at site I, where 40% of the samples in 1992 and only 14.3% in 1993 were compatible with the EEC directives.

The majority of water samples from all monitoring sites throughout the whole research period and in the consecutive years as well, fulfilled the EEC criteria of waters used for bathing purposes.

Table 2. Evaluation of bottom sediments quality in the southern part of Leginski Lake according to criteria given by Kohl in 1975 and Kavka in 1987 in Albinger's modification (1992). Sample percentage per class.

Evaluation criteria for bottom sediments		Bottom sediments quality[3]	1992				1993				1992-1993
Microorganisms	Number of bacteria		site I	site II	site III	sites I-III	site I	site II	site III	sites I-III	
TVC 20°C[1]	≤ 500 000	1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	> 500 000 – 1 000 000	2	0	0	0	0	0	0	0	0	0
	> 1 000 000 – 10 000 000	3	0	0	0	0	0	0	0	0	0
	> 10 000 000 – 50 000 000	4	0	0	0	0	0	0	0	0	
	> 50 000 000 – 100 000 000	5	0	0	0	0	0	0	0	0	0
	> 100 000 000 – 750 000 000	6	0	0	0	0	0	0	0	0	0
	> 750 000 000	7	0	0	0	0	0	0	0	0	0
			[4](5)	(5)	(5)	(15)	(7)	(7)	(7)	(21)	(36)
FC[2]	1 – 10	1	0	60.0	60.0	40.0	57.1	100.0	100.0	85.7	66.7
	> 10 – 100	2	40.0	40.0	40.0	40.0	14.3	0	0	4.8	19.4
	> 100 – 1000	3	60.0	0	0	20.0	28.6	0	0	9.5	13.9
	> 1000 – 5000	4	0	0	0	0	0	0	0	0	0
	> 5000 – 10 000	5	0	0	0	0	0	0	0	0	0
	> 10 000 – 100 000	6	0	0	0	0	0	0	0	0	0
	> 100 000	7	0	0	0	0	0	0	0	0	0
			(5)	(5)	(5)	(15)	(7)	(7)	(7)	(21)	(36)

[1] - total number of bacteria in broth agar after 72 h incubation at 20°C in 1 g of fresh bottom sediments mass
[2] - number of faecal coliforms (MPL/g of dry mass of bottom sediments)
[3] - degree of loading with easily decomposable organic substance (TVC 20°C) and faeces:
1 - very little, 2 - little, 3 - moderate, 4 - moderately high, 5 - high, 6 - very high. 7 - extremely high
[4] - number of samples examined given in brackets

Discussion

The character of microbiological pollution of the southern part of Leginski Lake is mainly affected by its drainage area. The reservoir is surrounded by mixed forest, with some parts of its sides occupied by fields and meadows. Apart from Lezany, there are no other human settlements in the direct vicinity of Leginski Lake, which eliminates a high inflow of domestic waste causing sanitary-bacteriological pollution of surface waters. In 1988, the three-level sewage-treatment plant was opened in Lezany, which considerably decreased the inflow of nutrients to the lake. Domestic wastes are treated by means of biofilters and then further treated in two stabilization ponds from where they follow a short stream section before entering Leginski Lake in approximate quantities of 100 m^3 per day. Generally, the treated sewage complied with requirements concerning waste disposed into natural receivers (Decree of Ministry of Environmental Protection, Natural Resources and Forestry from 05.02. 1991). ChZT levels ranged from 10 to 92 and BZT_5 from 1 to 17.6. The sewage treated contained from 280 to 15000 facultative psychrophilic bacteria per 1 cm^3, from 80 to 3200 mesophilic ones, from 5 to 140 *Escherichia coli* bacteria, from 2 to 140 faecal coliform bacteria and from 1 to 75 faecal streptococci. *Clostridium perfringens* was not detected [9].There were short spells, however, when these norms were exceeded. This could have taken place, for example, during an uncontrolled manure dump into a stabilization pond or during periodical failures of biofilter functioning as happened in April 1992. Identification based on EPL tests of 21 bacterial strains isolated from treated wastewater confirmed the presence of pathogens such as *Pseudomonas aeruginosa, Shigella desynteriae, Shigella boydii,* and *Klebsiella pneumoniae* [10]. This situation was undoubtedly affected by waterfowl that settle in the oxidation pond and cause secondary pollution of the already treated waste. The elimination of bacteriological pollution from sewage, according to the type of equipment employed, can range from 70 to over 90% of its initial value. It can therefore be concluded that outlets - even of an effective waste-treatment plant, yet receiving waste containing high numbers of microorganisms - can still exhibit an increased percentage of various organisms, including pathogenic bacteria and viruses. Poland has not yet established uniform criteria which would specify the permitted number of indicatory bacteria in outflows from treatment plants. The Directive from 1991 [22] specifies only that waste introduced to surface and sea waters cannot contain, for example, pathogenic microbes from places designated for treating people with infectous diseases or convalescents recovering from them. This was not the case with waste treated in Lezany. Higher counts of indicatory microorganisms found at the very estuary of the stream

Table 3. Bacteriological evaluation of water quality in the southern part of Leginski Lake according to U.S. Department of Interior Federal Water Pollution Control Administration (1968). Sample percentage per class.

Year	Site		Number of tested samples	Standards of bacteriological water quality					
				A – total number of coliforms (MPL/100 cm^3)			Number of faecal coliforms (MPL/100 cm^3)		
				Recreation		Public water resources	Recteation		Public water resources
				I	II		I	II	
				1000	**5000**	**10000**	**200**	**1000**	**2000**
1992	St. I	s	5	60.0	60.0	60.0	80.0	80.0	80.0
	St. II	s	5	100.0	100.0	100.0	80.0	100.0	100.0
		n.b	5	100.0	100.0	100.0	100.0	100.0	100.0
	st. III	s	5	100.0	100.0	100.0	100.0	100.0	100.0
		n.b	5	100.0	100.0	100.0	100.0	100.0	100.0
	st. I-III		25	92.0	92.0	92.0	92.0	96.0	96.0
1993	St. I	s	7	14.3	57.1	57.1	42.8	71.4	71.4
	St. II	s	7	100.0	100.0	100.0	100.0	100.0	100.0
		n.b	7	100.0	100.0	100.0	85.7	100.0	100.0
	st. III	s	7	100.0	100.0	100.0	100.0	100.0	100.0
		n.b	7	100.0	100.0	100.0	100.0	100.0	100.0
	st. I-III		35	82.8	91.4	91.4	85.7	94.3	94.3
1992-1993			60	86.7	91.7	91.7	88.3	95	95

s - surface water; n.b - near bottom water
Recreation: I class- for bathing purposes (direct physical contact with water) - TC-1000, FC-200
II class - canoeing, water sports (indirect physical contact with water) - TC-5000, FC-1000
Public water resources - TC-10000, FC-2000

taking the treated waste to Leginski Lake, higher than in the outflow of the other pond to the lake could have been caused by secondary pollution. Most probably, the reasons could be tracked down to local fowl, both wild and domestic, cow drinking, the stream being shallow (which means good mixing of the water with bottom sediments and its quick warming), and also the influence of decayed vegetable and animal fragments.

In the southern part of the lake, apart from the stream coming from the biological waste-treatment plant, there is also an outlet of a small tributary from Mutek Lake as well as a tributary collecting water from the farm building area in Lezany village. The latter is capable of supplying the lake's water with biogenic substances.

The results of sanitary - bacteriological analysis conducted in the southern part of Leginski Lake reveal a low degree of water pollution. Following the classifications given by Kohl [15] and Kavka [14] in Albinger's modification [1], U.S. Department of Interior, Federal Water Pollution Control Administration [23] and the European Committeee for the Quality of Water for Bathing Purposes [7], a substantial portion of examined samples belongs to the class of clean and little loaded waters.

Employing the first of the above mentioned classifications, a substantial portion of water samples and sediments at sites II and III could be regarded as having very little loading of easily decomposable organic substance and faeces. A much higher degree of loading was observed at site I.

Similar results of bacteriological quality of the southern part of Leginski Lake were obtained using the criteria given by the U.S. Department of the Interior, Federal Water Pollution Control Administration [23] and the EEC [7]. The former classification included TC and FC indexes, and the latter - TC, FC and FS. Taking into account the total number of coliforms and faecal coliforms at sites II and III, the examined samples generally conformed 100% with the requirements set for waters used for recreational and bathing purposes. The numbers of faecal streptococci was higher as compared with the sanitary indexes discussed; however, even in this case almost half of the samples at sites II and III fulfilled the requirements set for water used for bathing purposes. Site I differed distinctly from the others in having a higher degree of loading due to its being situated near the outlet of the treated sewage.

Conclusions

1. Using three different criteria for estimating the sanitary-bacteriological state of water (classification given by Kohl and Kavka in Albinger's modification; U.S. Department of Interior, Federal Water Pollution Control Administration and European Committeee for the Quality of Water for Bathing Purposes), it can be concluded that a substantial portion of water samples and bottom sediments at sites II and III can be classified as clean and little polluted water, a higher degree of water contamination having been observed only at site I.

2. The results obtained reveal that the southern part of Leginski Lake can be used for recreation.

Table 4. Bacteriological evaluation of water quality in the southern part of Leginski Lake according to EEC criteria (European Committee for the Quality of Water for Bathing Purposes, 1976). Percentage of samples complying with established requirements for water used for bathing purposes.

Year	Site		Number of tested samples	MPL/100 cm^3		
				500	100	100
				TC %	FC %	FS %
1992	st. I	s	5	60.0	80.0	40.0
	st. II	s	5	100.0	80.0	80.0
		n.b	5	100.0	100.0	100.0
	st. III	s	5	100.0	100.0	80.0
		n.b	5	100.0	100.0	80.0
	st. I-III		25	92.0	92.0	76.0
1993	st. I	s	7	14.3	28.6	14.3
	st. II	s	7	100.0	100.0	100.0
		n.b	7	100.0	85.7	71.4
	st. III	s	7	100.0	100.0	85.7
		n.b	7	100.0	100.0	85.7
	st. I-III		35	82.8	82.8	71.4
1992 – 1993			60	86.7	86.7	73.3

s - surface water; n.b - near bottom water

Criteria: TC - total number of coliforms - 500; FC - total number of faecal coliforms - 100; FS - number of faecal streptococci - 100

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