

Bacteriological Studies of Water and Bottom Sediments of the Vistula River between Wyszogród and Toruń

W. Donderski, I. Wilk

Department of Water Microbiology and Biotechnology,
Nicolaus Copernicus University,
Gagarina 9, 87-100 Toruń, Poland

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Abstract

This paper deals with the sanitary conditions of the water and bottom sediments in the Lower Vistula river, between Wyszogród and Toruń. The contamination extent of the water and bottom sediments by easily decomposable organic matter and substances of faecal origin have been indirectly estimated by determining the total number of heterotrophic bacteria (TVC 20°C) and the occurrence of the faecal coliform (FC) and faecal streptococci (FS). Examination results enabled a classification of this water as moderately and moderate highly affected by the easily decomposable organic matter and faecal substances. The bottom sediments, however, contained a much greater load of psychophilic and faecal heterotrophic bacteria, yet they were polluted to a moderate extent. According to bacteriological results the examination site that revealed the greatest extent of easily decomposable organic matter and faecal matter, both in the water and bottom sediments, was the study site near Płock (site II). The least affected sites were those in the Włocławski Reservoir dam (site III) and near Nieszawa (site IV). The faecal contamination factor (FC:FS ratio), in majority cases being more than 4, indicated that it was human-borne faecal contamination that dominated the area.

Keywords: river, heterotrophic bacteria, coliform bacteria, faecal coliform, faecal streptococci.

Introduction

The Vistula river is the second greatest river (after the Neva) among the ones that make the catchment basin of the Baltic Sea. The 150 km section of the river referred to presently, between Wyszogród and Toruń, makes the representative section of the Lower Vistula. It starts with the Włocławski Reservoir (formed by dammed water of the Włocławek power plant) and the river section over the distance to Toruń. All the Lower Vistula (from the Narew mouth to the Baltic Sea) is 390 km long. It has been said that this is that section of the river that is responsible to the greatest extent for all the pollution dis-

charged by the Vistula into the Sea. Hence, a continuous monitoring of the water quality along that distance is of vital importance. Thus it is subject to constant physical and chemical, hydrobiological and microbiological examinations.

The sanitation of the river is assessed on the basis of the so-called microbiological factors. It takes an examining of the occurrence of psychophilic (TVC 20°C), mesophilic (TVC 37°C) heterotrophic bacteria and coliform bacteria, faecal coliform, faecal streptococci and sulphate reducing Clostridium rods. In the majority of cases, their presence indicates the existence of faecal contamination, which often contains pathogenic microflora.

The sanitary classification suggested by Kohl [13] and Kavka [12] and later modified by Albinger [1], allows for

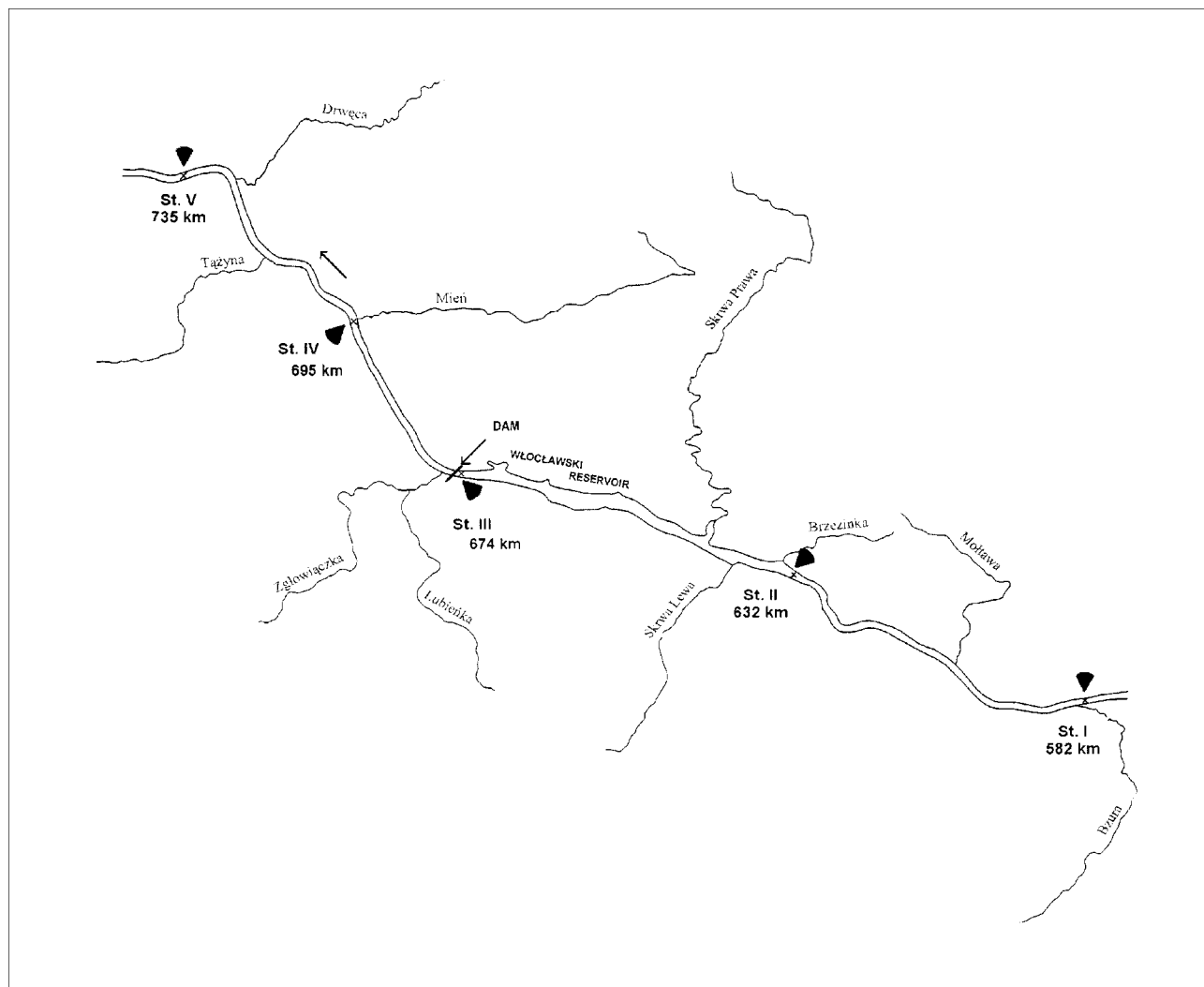


Fig. 1. Standpoint studies on the Lower Vistula on section Wyszogród – Toruń. Explanations: St. I, II ... V – sampling sites.

an assessment of water and bottom sediment contamination by easily decomposable organic matter and faecal bacteria. The total number of heterotrophic bacteria (TVC 20°C) reflects the contamination extent by the easily decomposable organic matter, while the faecal coliform bacteria number gives an idea of the contamination size by faecal substance. Based on the FC : FS (faecal coliform bacteria to faecal streptococci ratio), one may get information on the type and origin of the human-borne, animal-borne contamination as well as the mixed type of these substances [6, 20].

The sanitary qualification of water gives evidence of its hygienic condition only at the moment of sampling, whereas the bacteriological analysis of bottom sediments allows for more comprehensive information on the hygienic state of a water body over a longer time span, which comprises also the period prior to examination. It enables also an indication of the secondary pollution of water by substances and bacteria accumulated in the deposits following their shifting up to the water due to various phenomena occurring there [1]. The basic cause for bottom sediment resuspension in rivers and dam reservoirs is the turbulent flow of water masses [25]. That

process may also result from the changes within the organic matter concentration or salinity [7] and the release of decomposing gases, i.e. CH₄, H₂S [16] or an intense grazing by a large group of benthic fish [15]. Many authors [3, 18, 9] point out the fact that bottom sediments contain 100-1000 times more of enteric bacteria than the waters of the water bodies. Also, microorganism survival in bottom sediments is longer than in water [18].

Material and Methods

Study Area

The research was carried out on water and bottom sediments of the Lower Vistula along a 150 km long segment between Wyszogród and Toruń. The Vistula covers that distance moving along the proglacial stream valley heading for north-west and reaches the Płock and Toruń basins, receiving the water of the rivers Skrzywa and Drwęca on the way. Before Włocławek, there is a dam on the river and a water power plant, thus forming a flow-through Włocławski Reservoir. In terms of surface

size, it is the greatest artificial reservoir in Poland (750 km²), second largest after that in Solina in terms of total capacity, which reaches 408.0 million m³ water at maximum water damming [10].

Sampling

The water and bottom sediments were sampled at five sites:

Site I: located in Wyszogród, in the vicinity of an old wooden bridge (spring and summer samples – in 582 km of the Vistula flow); and a new bridge (autumn and winter samples – in 588 km of the Vistula flow).

Site II: located in Płock, in the vicinity of a road bridge – in 632 km of the Vistula flow.

Site III: located in the Zbiornik Włocławski (Włocławski Reservoir), about 500 km before the dam – in 674 km of the Vistula flow.

Site IV: located in Nieszawa, in the vicinity of a ferry across the river – in 695 km of the Vistula flow.

Site V: was located in Toruń, in the vicinity of a road bridge – in 735 km of the Vistula flow.

The sampling took place in spring (1st April 99), in summer (1st July 99), in autumn (4th Nov. 99) and in winter (22nd Feb. 00).

The water was sampled from mid-stream, from the surface layer (20-30 cm deep) directly into sterile flasks. The bottom sediments were sampled with the use of Eckman scoop, from which the samples were aseptically transferred into sterile glass containers. The samples were then placed in thermo insulated bags at about 7°C, and transported to the laboratory for analyses. Usually the time between sampling and analyses was not more than 12 hours.

Microbiological Study

The investigations comprised determination of the following: total number of heterotrophic bacteria (TVC 20°C), total coliform bacteria (TC), faecal coliform number (FC) and the number of faecal streptococci (FS).

Prior to the study, a series of 10 times dilutions of the sampled water and bottom sediments were made. A sterile solution of physiological salt (0.85% NaCl) was used as diluting substance.

Total Number of Heterotrophic Bacteria

Total number of heterotrophic bacteria (TVC 20°C – Total Viable Colony) in the water and bottom sediments of the Vistula was determined by means of cast plates. For this purpose, 1 ml of properly diluted water or sediment sample was poured into Petri plates and flooded in agar iron-peptone medium according to Ferrer at al. [5]. The plates containing the inoculations in three parallel replicates were incubated at 20°C for 72 hours and then the grown heterotrophic bacteria colonies were counted. The results were then converted into 1 ml of water or 1 g wet sediment.

Total Number of Coliform Bacteria

Total number of coliform bacteria (TC) were determined by means of the most probable number (MPN). The Eijkman medium by BTL was used for the determinations. The three-tube test system was used during the study. The medium was inoculated to 0.1, 1.0 and 10 ml of the sample under investigation. With 10 ml inoculations a double concentrated Eijkman medium was used. The incubation was carried out for 24 hours at 37°C. The result was deemed positive when gas occurred in the Durham tube, the medium became opaque and the purple colour became yellow. The results were read from the tables according to Polish Standard [23] and converted into 100 ml of water or 100 g wet sediment.

Number of Faecal Coliforms

Number of faecal coliform bacteria (FC) was determined by means of the most probable number (MPN). All positive and doubtful samples on Eijkman medium, which indicated coliform bacteria presence, were inoculated onto a medium containing brilliant green [23]. Then the samples were incubated for 24 h at 44°C. The result was deemed positive when the medium became opaque and simultaneously gas occurred in the Durham tube or in all the medium, when stirred. The results were read according to the tables included in the Polish Standard [23] and converted into 100 ml or 100 g wet sediment.

Number of Faecal Streptococci

The number of faecal streptococci (FS) were determined with the use of membrane filters. Having filtered respective sample volumes through membrane filters (Millipore of HA type, 0.45 µm pore diameter), they were put on top of SF Medium by Difco poured into Petri plates. The incubation was carried out for 48 h at 37°C. Then the grown faecal streptococci were counted. The results were converted into 100 ml or 100 g wet sediment, which was in accordance with the Polish Standard [24].

Results

Bacteria as Pollution Indicators

The total number of heterotrophic bacteria (TVC 20°C) in the Vistula water along the distance between Wyszogród – Toruń was variable; it oscillated between 2.3 x 10³ cells/ml at site IV in Nieszawa and 10.3 x 10³ cells/ml at site II in Płock. At site V in Toruń there were 6.7 x 10³ cells/ml. At other sites the number was more or less even and amounted to 9.1 – 9.7 x 10³ cells/ml. Having analysed Fig. 2, it was easy to state that the section of the river under study, between site III (Włocławski Reservoir close to the dam) and site IV (Nieszawa), underwent an intense self-purification process of the river. At site IV (Nieszawa) there were recorded by 76.3% less hetero-

trophic planktonic bacteria than at site III (Włocławski Reservoir).

In the bottom sediments, the total number of heterotrophic bacteria (TVC 20°C) was much more than in the water of the same river section that was analysed (Fig.2). The most abundant heterotrophs were found at site II in Płock (1213 x 10³ cells/g of wet sediment), as was the case with planktonic heterotrophic bacteria. The lowest number of these bacteria was recorded at site IV in Nieszawa (386 x 10³ cells/g of wet sediment). The sites at Wyszogród and Toruń (sites I and V) had a similar number of heterotrophic bacteria (780 and 850 x 10³ cells/g of wet sediment respectively). In bottom sediments at site III in the Włocławski Reservoir, the total number of heterotrophic bacteria was close to that recorded at site IV in Nieszawa and was 470 x 10³ cells/g of wet sediment. The greatest drop in the amount of heterotrophic bacteria (68.18 %) was noted in the bottom sediments in the Lower Vistula between sites II and IV.

Bacteria as Indicators of Sanitary State

Table 1 presents the study results of the total bacteria number of the coliform (TC), faecal coliform (FC) and faecal streptococci (FS).

Table 1. Number of total coliforms, faecal coliforms, faecal streptococci in water and bottom sediments the of Vistula River on the section Wyszogród – Toruń.

Site	Water			Sediments		
	TC ¹	FC ²	FS ³	TC ¹	FC ²	FS ³
	(x 10 ³ / 100 ml water)			(x 10 ³ / 100 g wet sediments)		
I	4.37	0.54	1.14	118.7	39.3	15.2
II	41.0	7.21	0.37	240.0	240	28.7
III	3.00	0.60	0.58	138.7	11.9	8.50
IV	5.45	1.04	0.10	91.10	11.9	1.83
V	25.6	7.82	0.76	140.0	54.7	12.17

Explanations:

¹ – total number of coliform bacteria

² – number of faecal coliform bacteria

³ – number of faecal streptococci

The total number of coliform bacteria (TC) found in the water of the Lower Vistula section under study oscillated between 41 x 10³ cells/100 ml at the research site in Płock (site II) and 3 x 10³ cells/100 ml at the site in Włocławski Reservoir before the dam (site III). It was that leg of the river where the greatest drop in the number of up to 92% of coliform bacteria was recorded. Both Wyszogród and Nieszawa (sites I and IV) presented coliform factor close to the minimum (4-5 x 10³ cells/100 ml). The site in Toruń (site V) was the second in terms of abundance of the bacteria found in the water (25.6 x 10³ cells/100 ml).

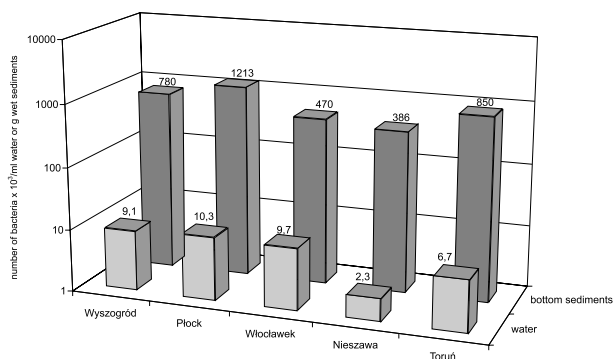


Fig. 2. Total number of heterotrophic bacteria (TVC 20°C) in the water and bottom sediments of the Lower Vistula on the section Wyszogród – Toruń.

The bottom sediments were to a much greater extent contaminated with intestine bacteria than the water. The overall number of coliform bacteria (TC) in the bottom sediments oscillated between 91.1 and 240 x 10³ cells/100 g of wet sediment. The lowest amount was recorded at site IV in Nieszawa, while the greatest was at site II in Płock. At other sampling sites the coliform indicator in the bottom sediments was from 120 – 140 x 10³ cells/100 g of wet sediment. The greatest drop in coliform bacteria number in bottom sediment (42%) was recorded in the section of the river between Płock (site II) and Włocławski Reservoir (site III), as was the case with the bacteria number in the water. In terms of bottom sediments, a tendency to further reduction in number of the bacteria was noted in the section of the river before the dam (between sites III and IV) – 34%. An increase in the coliform bacteria number was then recorded in the section of the river near Toruń, where the reduction in number of the bacteria as compared to site II in Płock was 41.67%.

The number of faecal coliform bacteria (FC) in this water oscillated between 0.54 x 10³ and 7.82 x 10³ cells/100 ml. The average smallest number of the faecal coliform bacteria was found near Wyszogród (site I) and in Włocławski Reservoir (site III). The greatest number was recorded in Płock and Toruń (sites II and V). The faecal coliforms at site IV (Nieszawa) was 1.04 x 10³ cells/100 ml. In the body of the Włocławski Reservoir was the place, where the greatest reduction of the faecal coliform bacteria occurred in this water (about 91%).

The site that saw the greatest amount of those bacteria in the bottom sediments was site II in Płock (240 x 10³ cells/100 g of wet sediment). The least amount of faecal coliforms was recorded at site III in the Włocławski Reservoir and at site IV in Nieszawa (11.9 x 10³ cells/100 g of wet sediment each). The greatest reduction to the number of those bacteria in the river bottom sediments was recorded in the section below the dam (between sites III and IV), only to find an increase in the number of those bacteria in Toruń – site V (54.7 x 10³ cells/100 ml).

The number of faecal streptococci (FS) in the water of the section of the Lower Vistula under investigation oscillated between 0.10 x 10³ cells/100 ml at site IV in

Nieszawa to 1.14×10^3 cells/100 ml at site I in Wyszogród. At other sites the indicator of faecal streptococci remained within $0.76 - 0.37 \times 10^3$ cells/100 ml. A significant drop in the number of those bacteria (by 67.5 %) was recorded along the distance between site I in Wyszogród and site II in Płock.

In bottom sediments, the number of faecal streptococci was by one order of magnitude greater than in the water. A maximum number of those bacteria was recorded in Płock (site II – 28.7×10^3 cells/100 g of wet sediment) and a minimum was found near Nieszawa (site IV – 1.83×10^3 cells/100 g of wet sediment). Both in Wyszogród (site I) and Toruń (site V) the values of the faecal streptococci indicator was similar and were $12.17 - 15.2 \times 10^3$ cells/100 g of wet sediment respectively. In the Włocławski Reservoir bottom sediments (site III), a significant drop in the number of those bacteria was recorded (about 70%) in relation to the sediment at site II in Płock.

FC : FS Ratio in Water and Bottom Sediments

The indicator of faecal contamination expressed by the FC:FS ratio (Table 2) was usually greater than 4.0. It was mainly site I in Wyszogród that displayed the greatest variety of pollution in terms of the FC:FS ratio, where 25% of the samples had values less than 0.7 (which indicated that they were of animal origin) and 50% of the samples were more than 4.0 (human related faecal impurities). At sites III and IV, the indicator of faecal value was always higher than 4 (100% of the samples).

Table 2. Origin of faecal contamination of the water and bottom sediments of the Lower Vistula on section Wyszogród – Toruń.

FC:FS ratio	Site									
	Water					Sediments				
	I	II	III	IV	V	I	II	III	IV	V
< 0.7	25 *	25	0	0	0	0	0	25	0	25
0.7 – 4.0	25	0	0	0	25	25	0	0	100	0
> 4.0	50	75	100	100	75	75	100	75	0	75

Explanations:

FC : FS ratio < 0.7 – animal origin

0.7 – 4.0 – mixed origin

> 0.4 – human origin

* – sample percentage per class

In bottom sediments the contamination was less varied. Site III (Włocławski Reservoir) and site V (Toruń) had 25% samples each that came within less than 0.7 of animal related contamination and 75% within the group of more than 4.0 which indicated human origin of the contamination. In Wyszogród (site I), 25% of the samples showed faecal contamination of mixed origin (within 0.7 – 4.0) and 75% of samples pointing to human-related contamination (FC:FS > 4.0). Site IV (Nieszawa)

displayed 100% of the results pointing to mixed origin of the faecal contamination (FC:FS = 0.7 – 4.0). It was only at site II in Płock that human-related faecal contamination dominated in bottom sediments. For 100% of the samples the indicator (FC:FS) was always higher than 4.0.

Number of Bacteria Indicatory Pollution Versus the Extent Easily Decomposed Organic Matter and Human or Animal Faeces Load in Water and Bottom Sediments

Following classification criteria by Albinger [1], the waters of the Vistula along the section under investigation were classified as contaminated to a moderate and moderately high degree by an easily decomposing organic matter and faecal substance (Tab. 3). As much as 40% of the samples indicated the 3rd, and 40% of them indicated the 4th degree of contamination by easily decomposing organic matter (total number of heterotrophic bacteria – TVC 20°C). As few as 10% of samples each pointed to the water being loaded to little and very little extent. Until 35% of the samples were polluted to a moderate degree and 30% moderately high, 20% indicated the 2nd degree of water contamination of faeces. Only 5% of the samples accounted for a high and 10% of them for a very high degree of water contamination. Site II in Płock turned out to be most contaminated with easily decomposing organic matter (75% samples indicated the 4th degree of contamination) and faeces (50% samples indicated the 4th and 25% the 6th degree on the scale of load). The site in Nieszawa (site IV) happened to be the purest place in terms of easily decomposing organic matter (25% samples indicated the 1st and 75% the 3rd degree on the load scale), whereas in terms of faeces, (FC) it was site III in the Włocławski Reservoir (25% indicated the 2nd; 50% indicated the 3rd and 25% indicated the 4th degree of contamination).

The bottom sediments along the distance of Lower Vistula under investigation were moderately contaminated by easily decomposing organic matter and faeces (Tab.4). The total number of heterotrophic bacteria (TVC 20°C) in 46.6% of the samples indicated the 3rd degree of contamination of the bottom sediments by easily decomposing organic matter, about 27% of the samples indicated the 1st and the 2nd degree of contamination. The bottom sediment contamination by faeces was also moderate to 53.2% and little to 26.8%.

The bottom sediments of sites II and V (Płock and Toruń respectively) were most contaminated by easily decomposing organic matter as 67% of the samples indicated the 3rd degree of contamination. The purest sites were site III and IV (Włocławski Reservoir and the area off Nieszawa) where 67% of the samples accounted for the 1st degree of contamination. In terms of faeces, Płock was the dominant site (site II), as all the samples indicated the 4th degree of load. The least faeces occurred in sites III and IV (Włocławski Reservoir and Nieszawa respectively) where 67% of the samples accounted for the 2nd degree on the contamination scale. The bottom sediments of sites I and V (Wyszogród and Toruń respectively) indicated the 3rd degree of contamination.

Table 3. Water quality evaluation in the Vistula River on section Wyszogród – Toruń according to criteria given by Kohl [13] and Kavka [12] in Albinger's modification [1].

Criteria of water quality evaluation		Water quality ³	Sample percentage per class					Average
micro-organisms	number of bacteria		site I	site II	site III	site IV	site V	
TVC 20°C ¹	– 500	1	0	0	0	25.0	25.0	10.0
	> 500 – 1000	2	0	0	25.0	0	25.0	10.0
	> 1000 – 10 000	3	50.0	25.0	25.0	75.0	25.0	40.0
	> 10 000 – 50 000	4	50.0	75.0	50.0	0	25.0	40.0
	> 50 000 – 100 000	5	0	0	0	0	0	0
	> 100 000 – 750 000	6	0	0	0	0	0	0
	> 750 000	7	0	0	0	0	0	0
FC ²	1 – 10	1	0	0	0	0	0	0
	> 10 – 100	2	0	25.0	25.0	25.0	25.0	20.0
	> 100 – 1000	3	75.0	0	50.0	25.0	25.0	35.0
	> 1000 – 5000	4	25.0	50.0	25.0	50.0	0	30.0
	> 5000 – 10 000	5	0	0	0	0	25.0	5.0
	> 10 000 – 100 000	6	0	25.0	0	0	25.0	10.0
	> 100 000	7	0	0	0	0	0	0

Explanations:

¹ – total number of heterotrophic bacteria (TVC 20°C); ² – number of faecal coliforms; ³ – degree of loading with easily decomposable organic substance and faeces: 1 – very little, 2 – little, 3 – moderate, 4 – moderately high, 5 – high, 6 – very high, 7 – extremely high.

Table 4. Sediment quality evaluation in the Vistula River on section Wyszogród – Toruń according to criteria given by Kohl [13] and Kavka in [12] in Albinger's modification [1].

Criteria of water quality evaluation		Sediment quality ³	Sample percentage per class					Average
micro-organisms	number of bacteria		site I	site II	site III	site IV	site V	
TVC 20°C ¹	– 500 000	1	0	0	66.67	66.67	0	26.67
	> 500 000 – 1 000 000	2	66.67	33.33	0	0	33.33	26.66
	> 1 000 000 – 10 000 000	3	33.33	66.67	33.33	33.33	66.67	46.67
	> 10 000 000 – 50 000 000	4	0	0	0	0	0	0
	> 50 000 000 – 100 000 000	5	0	0	0	0	0	0
	> 100 000 000 – 750 000 000	6	0	0	0	0	0	0
	> 750 000 000	7	0	0	0	0	0	0
FC ²	100 – 1000	1	0	0	0	0	0	0
	> 1000 – 10 000	2	0	0	66.67	66.67	0	26.67
	> 10 000 – 100 000	3	100	0	33.33	33.33	100	53.33
	> 100 000 – 500 000	4	0	100	0	0	0	20
	> 500 000 – 1 000 000	5	0	0	0	0	0	0
	> 1 000 000 – 10 000 000	6	0	0	0	0	0	0
	> 10 000 000	7	0	0	0	0	0	0

Explanations:

¹ – total number of heterotrophic bacteria (TVC 20°C); ² – number of faecal coliforms; ³ – degree of loading with easily decomposable organic substance and faeces: 1 – very little, 2 – little, 3 – moderate, 4 – moderately high, 5 – high, 6 – very high, 7 – extremely high.

Discussion

In order to be able to determine the contamination extent of the initial section of the Lower Vistula, a sanitary and biological study was carried out at site I (Wyszogród). This revealed that the water at that site contained the lowest FC, a medium TVC 20°C and TC and the highest FS over the sections under investigation. The high amount of faecal streptococci (FS) indicated that the contamination was of animal origin, which might have come from the field and pasture runoff nearby, because those bacteria occur more frequently in animal faeces than in human ones. Some of them, e.g. *Streptococcus equinus* and *Streptococcus bovis* occur only in animals [19]. The fact that there was no sewage discharge facility in the vicinity of the sampling sites may only suggest that it is the nearby catchment basin and the river bank that affect the composition and micro-organism amount relations. As it turns out to be evident from our study, the bottom sediments at that site contained almost 50 times more bacteria (TVC 20°C) that indicated the contamination by easily decomposing organic matter and by 13 to 73 times more indicator bacteria (TC, FC, FS). Those data confirmed the results by Donsel [3], Niewolak [18], Albinger [1] and Irvin [9], who said that bottom sediments of water bodies usually contain much more heterotrophic and intestine bacteria than the water above them. Albinger [1] and Niewolak [18, 21] explain the phenomenon by greater contents of bioelements included in the organic matter that are found in the bottom sediments. Also, the survival of such microorganisms is better in bottom sediments than in water. Thus, bottom sediments may make a reservoir of those bacteria.

The site where occurrence of most heterotrophic bacteria (TVC 20°C), total coliform bacteria (TC) and faecal coliforms (FC) was site II in Płock. This means the greatest discharge of contaminating substances into that section of the Vistula under investigation. A high number of faecal (FC) and heterotrophic bacteria (TVC 20°C) in the bottom sediments may result from their great number occurring in water [1]. According to Niewolak [21], faecal coliform may be detected in bottom sediments even when there are no such bacteria recorded in the water at the same time.

The self-purification process in a river is a phenomenon that has been noted in waters contaminated by sewage [11, 4, 8, 17]. It is a complex process running in many stages. As our study on this water suggest, the process was most intense along the section of the river that runs below the dam (site IV near Nieszawa) where the reduction of the heterotrophic bacteria number (TVC 20°C) amounted to 76%. Within the Włocławski Reservoir a significant reduction in the amount of coliform bacteria (92%) and faecal coliform (91%) were recorded. Such a great reduction in the amount of those microorganisms must have resulted from an intensive self-purification process in the river and lack of major pollution that makes the source of food substances and intestine bacteria. In bottom sediments, the total number of heterotrophic bacteria (TVC 20°C), coliforms (TC) and faecal coliform bacteria (FC) number dropped significantly in the Włocławski Reservoir. Most probably, the reason lies in the changing hydrological conditions that are present

along that section of the river. As one may suppose, there may occur a shortage of oxygen in the bottom sediments of the reservoir when the flow of water changes.

A composition of faecal coliform bacteria (FC) and faecal streptococci (FS) indicator enables finding out the sources of that faecal contamination [14]. Following the investigation, many of the samples taken from both the water and the bottom sediments of that section of the river, had a FC:FS ratio greater than 4, which may indicate the human origin of the faecal bacteria. A greatest variety of the sources of the contamination (human, mixed: human/animal, and only animal) was noted at site I near Wyszogród. The least, mainly those of human origin – at site II in Płock and site V in Toruń.

Taking into consideration the bacteriological criteria of estimation for water and bottom sediments suggested by Kavka [12] and Kohl [13], later modified by Albinger [1], it is possible to estimate the contamination extent by easily decomposing organic matter and human and animal related faeces basing on the total number of heterotrophic bacteria (TVC 20°C) and faecal coliform (FC). Following those criteria, the said Vistula section were loaded with the easily decomposing organic matter and faeces to a moderate and slightly moderate extent. Niewolak [20] received at similar results while examining the extent of pollution in the Czarna Hańcza river near Suwałki (Wigry National Park, NE Poland) and determined the river water as moderately contaminated by easily decomposing organic matter and moderately high by faeces. As our present study has shown, the bottom sediments (despite a much greater number of heterotrophic and faecal bacteria) were to a lesser extent (moderately) loaded with easily decomposing organic matter than the water. Also fewer differences in heterotrophic bacteria (TVC 20°C) and faecal coliforms (FC) number were noted which might have resulted from great supplies of easily decomposing organic matter accumulated in the bottom sediments and a longer survival period for intestine bacteria that otherwise might be found in that environment [18, 2]. Similar dependence was shown by Niewolak [20, 21] in the case of the study of the water and bottom sediments in the Czarna Hańcza.

Conclusions

1. According to bacteriological studies both in the water and in the bottom sediments of the Lower Vistula, the greatest concentration of organic matter and faeces were recorded at site II in Płock.
2. The most intense process of river self-purification along the examined section was noted between site III in Włocławski Reservoir and site IV in Nieszawa.
3. A significant reduction in coliform bacteria (TC) number and faecal coliform (FC) number were recorded in the dam reservoir.
4. The water of the examined section of the Vistula River between Wyszogród and Toruń is to be deemed moderately and moderately high charged with easily decomposing organic matter and faeces.
5. Bottom sediments had fewer oscillations in heterotrophic bacteria number (TVC 20°C) and faecal coliforms (FC) than water.

6. The value of the indicator FC:FS factor for majority of the samples was over 4, which points out to a domination of human faecal contamination.

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