BALTIC COASTAL ZONE
Journal of Ecology and Protection of the Coastline
40th academic year of the University
Vol. 14 pp. 25-36 2010

ISBN 1643-0115

Original research paper

Received: **12.09.2009**
Accepted: **27.10.2009**

EVALUATION OF POLLUTION IN BOTTOM SEDIMENTS OF THE LOWER VISTULA ALONG THE SECTION WYSZOGRÓD-TORUŃ BASED ON BACTERIOLOGICAL INDICATORS OF THE SANITARY STATE

Iwona Wilk, Agnieszka Kalwasińska, Wojciech Donderski

Department of Environmental Microbiology and Biotechnology,
Nicolaus Copernicus University,
ul. Gagarina 9, 87-100 Toruń, Poland,
e-mail: wilk@umk.pl

Abstract

This paper deals with the evaluation of the sanitary state of bottom sediments of the Lower Vistula along the section from Wyszogród to Toruń. The contamination extent of bottom sediments by easily decomposable organic matter and substances of faecal origin was defined based, respectively, on the number of heterotrophic bacteria capable of growth at 22°C and the occurrence of faecal coli (FC) bacteria. Examination results enabled to classify the bottom sediments of the Lower Vistula in the studied section as little and moderately loaded with easily decomposable organic matter, as well as very little, little and moderately polluted with faeces. The highest contamination with faecal and easily decomposable organic matter was recorded in bottom sediments of the sites located in Wyszogród and Płock. Research point situated within the limnic part of the reservoir in the vicinity of Włocławek was the least contaminated site

Key words: river, heterotrophic bacteria, coliform bacteria, faecal coliform, faecal streptococci

INTRODUCTION

Bottom sediments constitute an integral part of each water reservoir. The bigger the amount of components accumulated in sediments returns to water and the larger the surface area of sediments in relation to water mass, the higher the significance of bottom sediments and their influence on the water (Starmach et al. 1976).
Bottom sediments are highly varied environments, inhabited by microorganisms in large numbers. The amount of easily decomposable organic matter, disintegrated at the bottom, much higher as compared to the amount of organic matter in water depths, is favourable to particular abundance and increased survivality of bacterial populations in bottom sediments. It was proved that muddy or clayey sediments,

more rich in organic matter, usually contain significantly more bacteria, as compared to sandy sediments (Niewolak 1998). Albinger (1992) proved that the number of bacteria in bottom sediments decreases together with the increased size of sediment particles. Bacteria adsorbed at sediment particles might be protected against the influence of UV radiation, high salinity (Ghoul et al. 1986), toxicity of heavy metals, attack of bacteriophages (Roper and Marshall 1979) or grazing by protozoan.

Bottom sediments are the place where accumulation and periodic deactivation of toxic substances take place, such as pesticides, detergents, radioactive elements or other products of anthropogenic origin (Olejnik et al. 2001, Arnason and Fletcher 2003). Many scientific studies prove that bacteria indicative of the sanitary state, pathogenic bacteria and viruses accumulate in bottom sediments (Pommepuy et al. 1992, Niewolak and Opieka 2000). Sorption of microorganisms at sediment particles suspended in the water, which then sediment at the bottom, creates favourable conditions for the aforementioned situation. Bottom sediments may contain from 100 up to 1 000 times more faecal indicators than the water itself (Irvine and Pettibone 1993). Until those bacteria are adsorbed at the bottom, they do not constitute a threat to human health. However, there is a continuous exchange between bottom sediments and the water. As a result of the release of decomposition gases, which induces the resuspension of sediments, changes in the salinity or concentration of organic matter, microorganisms adsorbed at the surface of mineral and organic particles can penetrate into the water phase, bringing about the secondary contamination of waters (Wiśniewski 1995, Niewolak 1998). Therefore, not only the extent of water pollution makes a very important issue, but also the contamination of bottom sediments, which constitute the integral element of each river or lake.

MATERIALS AND METHODS

Study area

The research subject comprised bottom sediments of the Vistula River along the section between Wyszogród and Toruń. This section constitutes a significant fragment of the Lower Vistula River from the mouth of the Narwia River up to the Vistula estuary into the Baltic Sea. Along this section, the Vistula River flows through the ice-marginal stream valley towards north-west and reaches the basin of Płock and Toruń, receiving additionally e.g. waters of the rivers: Bzura, Skrwa and Drwęca. Due to diverse extent of transformation and the development of the Lower Vistula valley, Babiński (1992) divided this river section into four main sections.

The first (unregulated) section of the Lower Vistula, stretches between the town of Modlin (551 km) and Kępa Polska (606 km). This section is characterized by changeable water levels and braided features upstream from the Włocławek Reservoir.

Before the town of Włocławek, there is a dam built on the river together with a hydroelectric power plant, forming the flow-through Włocławek Reservoir. In respect of the area, it is the biggest (ca. 70.5 km^2) artificial reservoir in Poland and the second largest (after the Solina Reservoir) in respect of the total volume, which, with

the maximum damming up of water, amounts to 370 mln m^3 (Głogowska 2000, Kajak 2001). A regular shape of the reservoir, a considerable length (ca. 58 km) and small width emphasize its fluvial, river-bed character. Short water retention time – ca. 5 days with average flow of 900 m^3/s (70 times per year) – permits to classify this reservoir as super-rheolimnic. The Włocławek Reservoir was built as a multi-assignment object. It is also used for recreational purposes, it constitutes a water source, and the dam itself functions also as a road bridge (Banach 1995). However, its main assignment is to produce electricity. A hydro-electric power station is located on the dam, between a weir and a navigable lock. Its power amounts to 162 MW and it works in the intermediate operating mode, as well as in the intervention (discontinuous) system. Within the reservoir itself, one can distinguish two zones: the upper one and the lower one. The former stretches from Płock (the 632th km) to about 655th-657th km of the Vistula River's course (upstream from the town of Dobrzyń n/Wisłą). It definitely has rheolimnic (fluvial) characteristics, average current velocity amounting to ca. 1 m/s and basically sandy sediments. Whereas, the lower zone stretches from the town of Dobrzyń up to the dam (the 675th km of the Vistula River's course) and has limnic (lacustrine) characteristics with the average current velocity oscillating around 0.1-0.4 m/s. Muddy sediments predominate here.
Downstream from the stage of fall in the town of Włocławek, one can easily observe a highly narrowed fragment of the river with the length of ca. 20-25 km. This section, located in the vicinity of the Nieszawa town, has ravine characteristics at the regulation stage, where shores are only locally reinforced by embankments. It is characterized by the increased bottom erosion induced by the increased water energy after the water is released from the hydroelectric power plant, as well as by the fact that there is no traction in the river (Głogowska 2000).
Downstream from the mouth of the river Tążyna, from the 718th km of the Vistula River's course, the last fragment of the Lower Vistula stretches up to the 941st km of its course, that is up to the Vistula Delta. That fragment was defined by Babiński (1992) as engineered (regulated) at the end of the 19th century.

Sampling

Samples of bottom sediments for microbiological studies were collected at five research sites:
site I – in the vicinity of Wyszogród, downstream from the mouth of the Bzura River (at the 592nd km of the river's course),
site II – in the town of Płock, near the road bridge, situated within the rheolimnic part of the reservoir (at the 632nd km of the river's course),
site III – in the vicinity of Włocławek, about 500 m before the dam, situated within the limnic part of the reservoir (at the 674th km of the river's course),
site IV – in the town of Nieszawa, near the ferry passage (at the 695th km of the river's course),
site V – in the town of Toruń, near the road bridge (at the 736th km of the river's course).
Samples of sediments were collected from May 2002 to October 2003 from the central part of the river's course, by means of a tubular bucket. The upper layer of bot-

tom sediments, up to a depth of 5 cm, was aseptically transferred into sterile glass jars of the twist type. All samples meant for microbiological research were transported to a laboratory in heat-insulating containers with ice at a temperature not exceeding 7°C. The time from the moment of samples collection until the beginning of analyses, usually did not exceed 8 hours.

Microbiological studies

Microbiological studies included the evaluation of:

1. the number (CFU/g of wet sediment) of heterotrophic bacteria on broth agar after 72 h incubation at 22°C (CFU 22°C),
2. the number (CFU/g of w.s.)) of heterotrophic bacteria on broth agar after 24 h incubation at 37°C (CFU 37°C),
3. the number (MPN/100 g of w.s.) of total coliforms (TC) on Eijkman medium (BTL) after 48 h incubation at 37ºC,
4. the number (MPN/100 g of w.s.) of faecal coliforms (FC), a confirmatory study on the medium with brilliant green (BTL) after 24 h incubation at 44.5°C,
5. the number (CFU/100 g of w.s.) of faecal streptococci (FS) on Slanetz and Bartley medium (BTL) after 48 h incubation at 37ºC, a confirmatory study on the medium with bile and esculin.

Prior to the evaluation, a series with 10 time dilutions of the sampled sediment was prepared. Sterile Ringer's solution (PN-EN ISO 8199: 2007) was applied as a diluent. The research was conducted according to the Polish Norm (PN-EN ISO 6222: 2004, PN-C-04615-05: 1975, PN-C-04615-07: 1977, PN-EN ISO 7899-2: 2004).

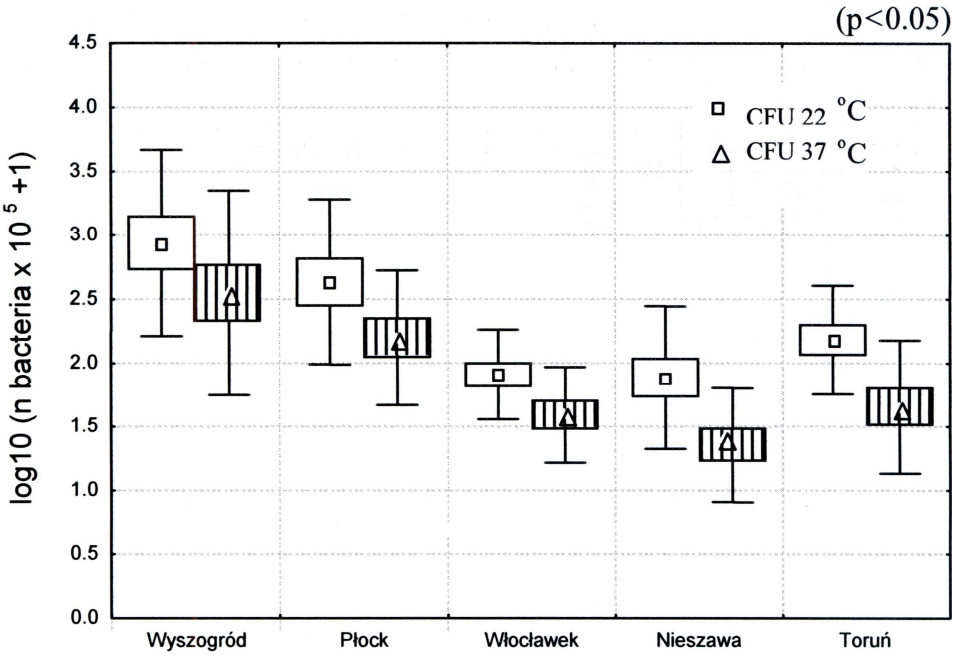
RESULTS

The number of bacteria indicating the degree of pollution

In the bottom sediments of the Lower Vistula along the section from the town of Wyszogród up to the town of Toruń, the number of heterotrophic bacteria capable of growth at 22°C (CFU 22°C), ranged from 1.5 x 10^5 to 16.1 x 10^7 CFU/g of wet sediment. Smaller fluctuations affected the number of heterotrophic bacteria capable of growth at 37°C (CFU 37°C), which ranged from 4.0 x 10^4 to 91.0 x 10^6 CFU/g of wet sediment. On average, the highest number of the studied bacteria in bottom sediments was recorded at site I in the town of Wyszogród, whereas the lowest numbers – at site III in the town of Włocławek and at site IV in the town of Nieszawa (Fig. 1). The highest reduction in the number of bacteria was observed within the Włocławek Reservoir. Between site II in Płock, located within the backwater area of the reservoir, and site III in Włocławek, located 500 m before the dam, there was observed a decrease in the number of heterotrophic bacteria capable of growth at 22°C on average from 91.2 x 10^5 to 10.1 x 10^5 CFU/g of wet sediment (88.9% reduction), in the number of heterotrophic bacteria capable of growth at 37°C on average from 33.9 x 10^5 to 5.6 x 10^5 CFU/g of wet sediment (83.3% reduction).

The analysis of variance proved that in case of bottom sediments of the Vistula River, the location of samples' collection had statistically significant influence ($p<0.05$)

on the number of heterotrophic bacteria capable of growth at 22°C (CFU 22°C) and 37°C (CFU 37°C).



Explanation: point – average
frame – average – standard error
average + standard error
whiskers – average – standard deviation
average + standard deviation

Fig. 1. The number of benthic heterotrophic bacteria capable of growth at 22°C (CFU 22°C) and 37°C (CFU 37°C) in bottom sediments of the Lower Vistula at individual research sites

The number of bacteria indicating the sanitary state

As it appears from the performed research on bottom sediments of the Lower Vistula along the section from Wyszogród up to Toruń, significant values and fluctuations of the number were recorded among bacteria from the total coliform group (TC), from 0.4 x 10^2 to 93.0 x 10^4 NPL/100 g of wet sediment. Bacteria from the faecal coliform group (FC) occurred in smaller numbers, reaching at the most 46.0 x 10^4 NPL/100 g of wet sediment. The number of faecal streptococci (FS) in bottom sediments fell within the range of 0.1 x 10^2 and 13.2 x 10^4 CFU/100 g of wet sediment. The highest values of all sanitary indicators were recorded at site I in Wyszogród, whereas the lowest at site III in Włocławek (Fig. 2). The highest decrease in the number of all the studied indicators of the sanitary state was recorded within the bottom sediments of the Włocławek Reservoir. The count of total coliforms (TC) changed on average from 19.0 x 10^4 (site II in Płock) to 41.4 x 10^2 NPL/100 g of

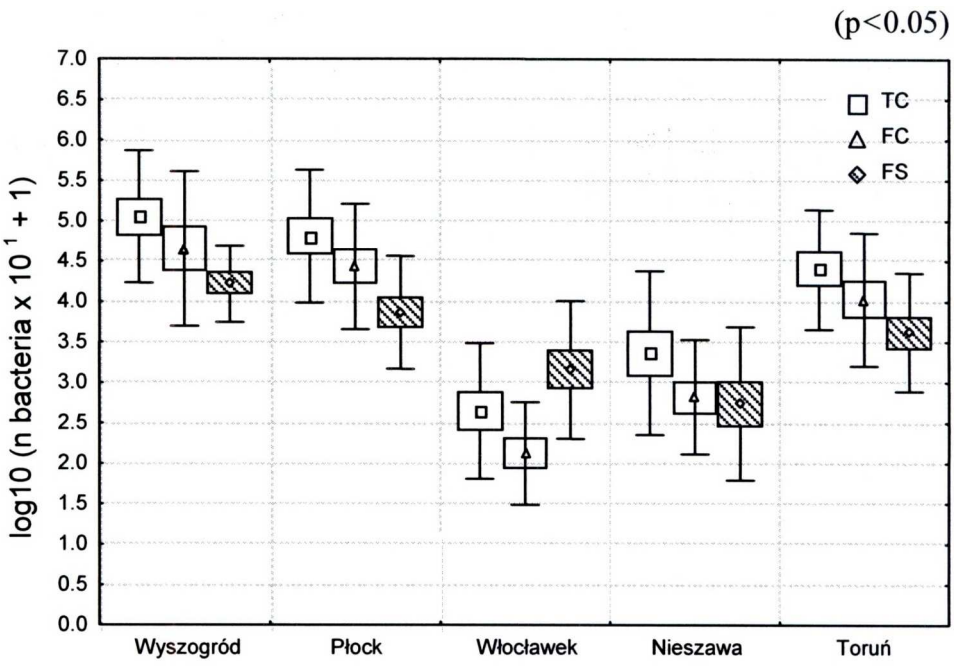


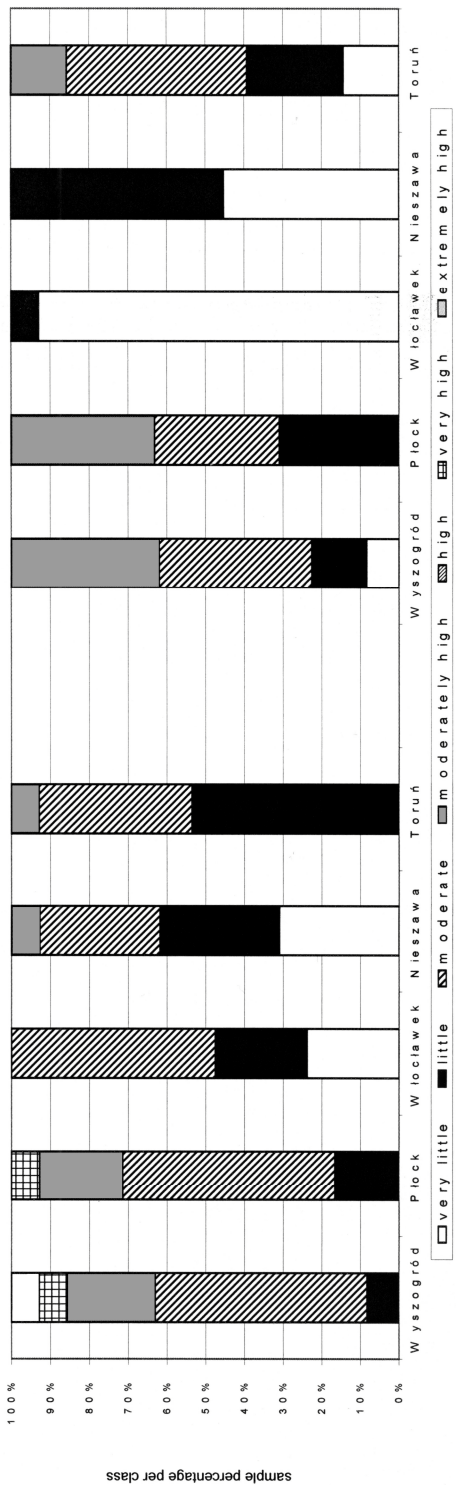
Fig. 2. The number of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) in bottom sediments of the Lower Vistula at particular research sites

wet sediments (site III in Włocławek) – 97.8% reduction. The count of bacteria from the faecal coliforms (FC) changed on average from 7.4 x 10^4 (site II in Płock) to 3.4 x 10^2 NPL/100 g of wet sediments (site III Włocławek) – 99.5% reduction of the count. The number of faecal streptococci (FS) in bottom sediments of the Włocławek Reservoir changed on average from 11.4 x 10^3 (site II in Płock) to 17.3 x 10^2 CFU/100 g of fresh sediment material (site III in Włocławek), which corresponds to 84.9% reduction.

The analysis of variance revealed statistically significant differences ($p<0.05$) in the count of indicators of the sanitary state between particular sites of samples' collection.

Quality evaluation

The evaluation of pollution extent in bottom sediments of the Lower Vistula, along the section between Wyszogród and Toruń, was performed based on the system of classification proposed by Kohl (1975) and Kavka (1987), and modified by Albinger (1992). The data included in Figure 3 indicate that a significant percentage of sedi-



number of bacteria	estimated contamination	number of bacteria	
CFU 22°C: - 500 000	very little	FC:	100 – 1000
>500 000 – 1 000 000	little		>1000 – 10 000
>1 000 000 – 10 000 000	moderate		>10 000 – 100 000
>10 000 000 – 50 000 000	moderately high		>100 000 – 500 000
>50 000 000 – 100 000 000	high		>500 000 – 1 000 000
>100 000 000 – 750 000 000	very high		>1 000 000 – 10 000 000
>750 000 000	extremely high		>10 000 000

Fig. 3. Sediment quality evaluation in the Vistula River along the section Wyszogród – Toruń according to criteria given by Kohl (1975) and Kavka (1987), with Albinger's modification (1992)

ment samples were polluted with easily decomposable organic matter to a moderate and little extent, as well as to a very little, little and moderate extent with the contaminant of faecal origin. Wyszogród was the site with the highest load of easily decomposable organic matter and the contaminant of faecal origin. Significant contamination of bottom sediments was also recorded at site II in Płock, situated within the rheolimnic part of the Włocławek Reservoir. Bottom sediments of site III were the least polluted in Włocławek, where 52.4% of the samples indicated moderate contamination with easily decomposable organic matter and 92.85% of the samples indicated very low contamination with the contaminant of faecal origin.

DISCUSSION

In the present paper, the bottom sediments of the Vistula River on the section from Wyszogród to Toruń were subject to bacteriological and sanitary assessment. When receiving the waters carried by the river from southern Poland and by its middle course, as well as domestic and industrial wastewater coming from towns situated along this section, the Lower Vistula River is responsible, to a large extent, for pollution brought into the Baltic Sea.

At present, only water is subject to bacteriological and sanitary analyses in routine laboratory investigations. Sometimes, bacteria of faecal origin occurred only in bottom sediments, while they were not detected in the water itself (Albinger 1992, Niewolak 1998). It is necessary to be aware that bottom sediments are innocuous until they are deposited at the bottom. However, due to resuspension they can get into the water depths and become a cause of its secondary pollution. It is a particularly dangerous phenomenon, since at least 100-1 000 times more bacteria of faecal origin are detected in the matter deposited at the bottom, as compared to water above sediments (Niewolak 1998). Moreover, as demonstrated by numerous scientific studies, the survival rate of those bacteria is much higher in bottom sediments than in the water (Niewolak 1998, Albinger 1992). And thus, there is a clear need for research on bottom sediments in waters of various types (rivers and dam reservoirs) in respect of faecal pollution.

When analysing the research results, one can observe common tendencies for spatial heterogeneity in the count of heterotrophic bacteria and indicators of the sanitary state. The highest numbers of those bacteria were recorded at the first two research sites, that is in Wyszogród and Płock, whereas the lowest number – mainly at site III in Włocławek. As stated by WIOŚ (the Provincial Inspectorate of Environmental Protection, Raport o stanie... 2002), one should search for the causes of such situation in the inflow of pollutants from the upper and middle reaches of the Vistula River and its tributaries, and particularly from the Bzura River, which is one of the most polluted rivers in Poland. This watercourse flows into the Vistula River in the vicinity of Wyszogród. The research carried out by WIOŚ (Raport o stanie... 2002) on the Włocławek Reservoir, also reveals some significant bacteriological contamination of bottom sediments occurring within the backwater area (near the town of Płock), as well as good conditions of bottom sediments collected near the dam. The construction of the Włocławek Reservoir affected some changes in the hydrological

regime of the river, both downstream and upstream from the dam. Within the reservoir, a significant reduction of the river flow occurs as compared to water velocity along the river section (site I in Wyszogród). Therefore, the water mixing rate is decreasing, which affects, among others, the aerobic conditions of the Włocławek Reservoir. In the vicinity of the dam (site III, Włocławek), periodic oxygen deficiencies are observed. Whereas, the oxygen deficit and the presence of decomposition gases in bottom sediments may significantly affect the reduction of the bacteria count. Additional slowdown of the Vistula River flow within the Włocławek Reservoir brings about the increased sedimentation of the matter carried by the river together with some microorganisms settled there. As quoted by Giziński and Falkowska (2003), the Włocławek Reservoir reduces the suspended matter carried by the Vistula River by 30 to 60%. A relatively high number of heterotrophic bacteria and indicators of the sanitary state is being recorded also at site II in Płock, where influence of the backwater area becomes distinct. Whereas, site III in Włocławek receives a smaller amount of matter together with microorganisms. The biggest drops in the count of both benthic heterotrophic bacteria, as well as indicators of the sanitary state were recorded within the Włocławek Reservoir. Between site II in Płock and site III situated in the vicinity of Włocławek, there was recorded 97.8% reduction in the count of bacteria from the total coliform group (TC), 99.5% reduction in the count of faecal coliform bacteria (FC) and 84.9% reduction in the count of faecal streptococci (FS). The significant reduction of indicators of the sanitary state (TC, FC, FS) in the bottom sediments of the Włocławek Reservoir was already observed by Donderski and Wilk (2002), who investigated the same section of the river.

Another increase in the counts of the majority of the studied indicators of pollution extent and the sanitary state observed in the bottom sediments upstream from the dam, was probably connected with the discharge of untreated storm waters into the Vistula River near the towns of Nieszawa and Toruń, as well as bringing the pollutants into the river by its tributaries (Tążyna, the Toruń Stream).

Based on bacteriological criteria for quality assessment of bottom sediments proposed by Kohl (1975) and Kavka (1987), and then modified by Albinger (1992), the evaluation of their pollution was performed. The conducted research revealed that a significant percentage of bottom sediment samples were polluted to a moderate or little extent with easily decomposable organic matter, as well as to a very little, little and moderate extent with the contaminant of faecal origin – Figure 3. As proved by the aforementioned research, the bottom sediments were polluted with the contaminant of faecal origin to a lesser extent as compared with easily decomposable organic matter. Wyszogród was the site with the highest load of easily decomposable organic matter and the contaminant of faecal origin. Considerable contamination of bottom sediments was also recorded at site II in Płock, situated within the rheolimnic part of the Włocławek Reservoir. Bottom sediments at site III in the vicinity of Włocławek were the least polluted.

The results discussed in the present paper do not entirely reflect the changes in the count of bacteriological indicators of the pollution extent and the sanitary state (TC, FC, FS) in the bottom sediments of the Vistula River along the section Wyszogród-Toruń. It is a very complex problem, which requires further research based on the constant monitoring of the quality of waters and bottom sediments. Especially taking

into consideration the places of wastewater discharge or outlets of all watercourses responsible for the contamination of the Lower Vistula.

CONCLUSIONS

Based on the results presented in this paper, one can express the following conclusions:

1. Watercourses and untreated storm waters, supplying a considerable load of easily decomposable organic matter and bacteria of faecal origin, had a significant impact on the level of pollution in bottom sediments of the Lower Vistula along the section Wyszogród-Toruń. The highest counts of bacteriological indicators of pollution level and of the sanitary state were recorded at site I in Wyszogród, located downstream from the mouth of the Bzura River and at site II in Płock, located within the "backwater area" of the Włocławek Reservoir. Whereas, the lowest counts of the studied bacteria were recorded in bottom sediments of site III located in the vicinity of Włocławek (within the limnic part of the reservoir, about 500 m before the dam).
2. The Włocławek Reservoir had a significant influence on the improvement of microbiological quality of bottom sediments, within the area of which, 88.9% reduction was observed in the count of heterotrophic bacteria capable of growth at 22°C, indicating the load size of easily decomposable organic matter, as well as 99.5% reduction in the number of bacteria from the faecal coliform group, indicating the faecal contamination.
3. Bottom sediments were polluted to a lesser extent with the contaminant of faecal origin as compared to easily decomposable organic matter. In accordance with the evaluation criteria presented by Albinger (1992), it was recognized that bottom sediments were polluted with easily decomposable organic matter to a little and moderate extent and very little, little and moderate extent with the contaminant of faecal origin.

REFERENCES

Albinger O., 1992. Bacteriological investigation of water and sediment of the River Danube between streamkilometers 16 and 1868 from March, 13rd-17th, 1988. *Arch. Hydrobiol. Suppl.*, 84(2-4), 115-130.

Arnason J.G., Fletcher B.A., 2003. A 40+ year record of Cd, Hg, Pb, and U deposition in sediments of Patroon Reservoir, Albany Coutry, NY, USA. *Env. Pollution*, 123, 383-391.

Babiński Z., 1992. Współczesne procesy korytowe Dolnej Wisły. (Present-day fluvial processes of the Lower Vistula Channel). Pr. Geogr. UMK Toruń, 157, 1-27, (in Polish).

Banach M., 1995. Hydrologiczne i geomorfologiczne problemy Zbiornika Włocławskiego. Akumulacja osadów i pokrywy lodowej w zbiorniku. (Hydrological and geomorphological issues of Włocławek Reservoir. Accumulation of bottom sediments and ice cover). 44 Zjazd Polskiego Towarzystwa Geograficznego, Toruń, (in Polish).

Donderski W., Wilk I., 2002. Bacteriological Studies of Water and Bottom Sediments of the Vistula River between Wyszogród and Toruń. *Pol. J. Env. St.*, 11(1), 33-40.

Ghoul M., Bernard T., Cormier M., 1986. Evidence that Escherichia coli accumulates glycine betaine from marine sediment. *Appl. Environ. Microbiol*., 56, 551-554.

Giziński A., Falkowska E., 2003. Hydrobiologia stosowana: ochrona wód powierzchniowych. (Applied hydrobiology: protection of surface waters). WSH-E Włocławek, (in Polish).

Głogowska B., 2000. Hydrobiology of the Lower Vistula River between Wyszogród and Toruń. An assessment of the influence of the Włocławek dam on the structure and functions of the river ecosystem. Part II. A geographical and hydrological profile of the study area. AUNC *Limnol. Papers*, 21, 11-21.

Irvine K.N., Pettibone G.W., 1993. Dynamics of indicator bacteria populations in sediment and river water near a combined sewer outfall. *Environ. Technol*., 14, 531-542.

Kajak Z., 2001. Hydrobiologia – limnologia. Ekosystemy wód śródlądowych (Hydrobiology – limnology. Inlands water ekosystem). PWN, Warszawa, (in Polish).

Kavka G., 1987. Die bakteriologische Wasserbeschaffenheit der österreichischen Donau. (Bacteriological state of waters of Austrian Danube). *Wasser und Abwasser*, 31, 305-344, (in German).

Kohl W., 1975. Über die Bedeutung bakteriologischer untersuchungen für die beurteilung von fließgewässern, dargestellt am beispiel der österreichischen Donau. (About significance of bactteriological investigations at estimation of rivers, introduced on examole of Austrian Danube). *Arch. Hydrobiol., Suppl*., 44, 392-461, (in German).

Niewolak S., 1980. Badania porównawcze nad przeżywalnością niektórych bakterii jelitowych w wodzie i osadach dennych jezior różnych typów. (Comparative investigation above survivality of some intestinal bacteria in water and bottom sediments of lakes of different types). *Zesz. Nauk. ART Olsztyn*, 10, 59-69, (in Polish).

Niewolak S., 1998. Total viable count and concentration of enteric bacteria in bottom sediments from the Czarna Hańcza River, Northeast Poland. *Pol. J. Environ. Stud*., 7(5), 295--306.

Niewolak S., Opieka A., 2000. Potentially pathogenic microorganisms in water and bottom sediments in the Czarna Hańcza River. *Pol. J. Environ. Stud*., 9(3), 183-194.

Olejnik G., Świątecki A., Górniak D., Kacprzycka-Nowicka M., 2001. Struktura i funkcja bakteriobentosu w jeziorach o różnej trofii. (Structure and function of bacteriobentos in lakes with different trophy). *Słupskie Pr. Przyr.*, 1, 141-152, (in Polish).

Polska Norma (PN-EN ISO 8199: 2007). Jakość wody. Ogólne wytyczne oznaczania liczby bakterii metodą hodowli. (General guide to the enumeration of micro-organisms by culture), (in Polish).

Polska Norma (PN-C-04615-05: 1975). Woda i ścieki. Badanie mikrobiologiczne. Oznaczanie bakterii grupy *coli* metodą fermentacyjną probówkową. (Water and wastes. Microbiological tests. Determination of the coliform by the fermentative test-tube method), (in Polish).

Polska Norma (PN-C-04615-07: 1977). Woda i ścieki. Badanie mikrobiologiczne. Oznaczanie bakterii grupy *coli* typu kałowego (fekalnego) metodą fermentacyjną probówkową, (Water and wastes. Microbiological tests. Determination of the fecal coliform by the fermentative test-tube metod), (in Polish).

Polska Norma (PN-EN ISO 6222: 2004). Jakość wody. Oznaczanie ilościowe mikroorganizmów zdolnych do wzrostu. Określanie ogólnej liczby kolonii metodą posiewu na agarze odżywczym. (Quality of water. Quantitative assay of culturable micro-organisms. Determination of the colony count by inoculation in a nutrient agar culture medium), (in Polish).

Polska Norma (PN-EN ISO 7899-2: 2004). Wykrywanie i oznaczanie ilościowe enterokoków kałowych. Część 2: Metoda filtacji membranowej. (Detection and quantitative assay of intestinal enterococci. Part 2: Membrane filtration method), (in Polish).

Pommepuy M., Guillaud J.F., Dupray E., Derrien A., Le Guyader F., Cormier M., 1992. Enteric bacteria survival factors. *Wat. Sci. Technol*., 12, 93-103.

Raport o stanie środowiska województwa mazowieckiego w 2001 roku. (Report about state of environment of Mazowieckie Province in 2001), 2002 Bibl. Monit. Środ., WIOŚ Warszawa, (in Polish).

Roper M.M., Marshall K.C., 1979. Effects of salinity on sedimentation and of particulates on survival of bacteria in estuarine habitation. *Geomicrobiol. J*., 1, 103-116.

Starmach K., Wróbel S., Pasternak K., 1976. Hydrobiologia. Limnologia. (Hydrobiology. Limnology). PWN, Warszawa, (in Polish).

van Donsel D.J., Geldreich E.E., 1971. Relationships of salmonellae to facal coliform in bottom sediments. *Water Res*. 5, 1079-1087.

Wiśniewski R., 1995. Rola resuspensji osadów dennych w funkcjonowaniu ekosystemów wodnych. (Role of bottom sediments resuspension in functioning of water ecosystems). UMK, Toruń, (in Polish).

OCENA ZANIECZYSZCZENIA OSADÓW DENNYCH DOLNEJ WISŁY NA ODCINKU WYSZOGRÓD-TORUŃ NA PODSTAWIE WSKAŹNIKÓW BAKTERIOLOGICZNYCH STANU SANITARNEGO

Streszczenie

Praca ta dotyczy oceny stanu sanitarnego osadów dennych Dolnej Wisły na odcinku od Wyszogrodu do Torunia. Stopień skażenia osadów dennych substancją organiczną łatwo rozkładalną oraz substancją pochodzenia kałowego określono odpowiednio na podstawie liczebności bakterii heterotroficznych zdolnych do wzrostu w 22ºC oraz występowania bakterii z grupy coli typu kałowego (FC). Wyniki badań pozwoliły zaklasyfikować osady denne Dolnej Wisły na badanym odcinku jako nisko i umiarkowanie obciążone substancją organiczną łatwo rozkładalną oraz bardzo nisko, nisko i umiarkowanie zanieczyszczone fekaliami. Największym zanieczyszczeniem substancją organiczną łatwo rozkładalną i fekalną odznaczały się osady denne stanowisk usytuowanych w Wyszogrodzie oraz Płocku. Stanowiskiem najmniej obciążonymi zanieczyszczeniami był punkt badawczy znajdujący się w części limnicznej zbiornika w okolicy Włocławka.