Gorzysław POLESZCZUK^{1*}, Anna BUCIOR¹, Tymoteusz MILLER²
and Małgorzata TOKARZ²

POLLUTION OF THE ECOSYSTEM OF THE RUSALKA CITY LAKE WITH HEAVY METALS

ZANIECZYSZCZENIE EKOSYSTEMU ŚRÓDMIEJSKIEGO JEZIORA RUSALKA METALAMI CIĘŻKIMI

Abstract: In the vegetation season April-October 2010, the value of and the changes in Zn_{tot} , Cu_{tot} , Cd_{tot} and Pb_{tot} concentrations in the water of the Rusalka flow-through lake (with average water retention of ca 30 days) situated in the city centre of Szczecin were determined. Water temperature, pH, concentration of dissolved oxygen (with calculation of water saturation with O_2), COD-Cr and BOD_5 , total hardness, HCO_3^- concentration (as total alkalinity), Cl^- , SO_4^{2-} , Mn_{tot} and Fe_{tot} were also determined. The data collected may be used to evaluate the ecological and chemical status of the surface waters under investigation. As far as the ecological status of the Rusalka Lake is concerned, the investigated waters were found, based on the official criteria being in force in Poland in evaluation of the ecological and chemical status of surface waters, to conform to water quality classes I and II considering total zinc and copper concentrations, temperature and dissolved oxygen concentration (except water inflow to the lake in August) as well as BOD_5 , SO_4^{2-} and Cl^- concentrations and pH value; however, they were always worse than water quality class II while taking the COD-Cr values into account. Regarding the chemical status of the investigated waters, total cadmium and lead concentrations were the levels exceeding the admissible values according to the official criteria in Poland. Changes in the values of indices being investigated along water flow path allowed stating that the equilibriums between the sedimentation and the resuspension and the dissolution processes during the research period were shifted towards sedimentation in case of Zn and Cd only, as well as of the organic matter sedimenting in the form of divalent cation- and divalent anion-sorbing gels. Although three phytoplankton blooms occurred in the body of water, unfortunately weak ones, the dissimilation processes prevailed over assimilation.

Keywords: water pollution, metals in waters, city lakes, Rusalka Lake in Szczecin

Natural or artificial water reservoirs in urban agglomerations are usually included into municipal rainwater drainage systems where they function as storage reservoirs. Air and urban area surface pollution as well as the erosion processes within unbuilt areas of water catchment basin causes that the waters flowing from municipal rainwater drainage system

¹ Department of Chemistry and Aquatic Environmental Protection, Faculty of Biology, University of Szczecin, ul. Felczaka 3C, 71-412 Szczecin, Poland, phone +48 91 444 15 71

² Students' Society of Natural Aquatic Ecosystem Research and Protection, Department of Chemistry and Aquatic Environmental Protection, Faculty of Biology, University of Szczecin, ul. Felczaka 3C, 71-412 Szczecin, Poland

*Corresponding author: polesz@univ.szczecin.pl

are largely heavily polluted with the precipitation wastewater bringing in substantial quantities of various pollutants, particularly heavy metals and petroleum-derivative wastes [1]. Additionally, particularly in the city districts with older building development, effluents from combined sewerage system can enter into rainwater drainage system during the period of intensified precipitation through storm overflows. Sometimes, industrial or municipal sewage wasters are being directly discharged into rainwater drainage system. City water reservoirs included into municipal rainwater drainage networks frequently function not only as storage reservoirs but also as settling ponds and biological sewage treatment plants [2]. The Rusalka Lake in the Kasprowicz Park in Szczecin is an example of such a water reservoir (Fig. 1).

Fig. 1. Rusalka Lake in Szczecin - simplified diagram of inflow and outflow waters [3] - with some changes

Waters and bottom sediments of the Rusalka Lake were frequently investigated in the past. Basic parameters of the waters flowing through this lake were analysed [3-6], as well as its pollution of water and bottom sediments with heavy metals [7-9]. Also microbial contamination was analysed [10, 11], as well as changes in the activity of biochemical organic matter decomposition processes in its waters [12]. All quoted references showed that the waters and bottom sediments in the Rusalka Lake were considerably polluted.

The objective of this study was to continue earlier research works [7, 8], aiming at recognition of the contamination of the Rusalka Lake waters with heavy metals, in particular at determination of total Zn, Cu, Cd and Pb concentrations in the surface waters of this lake in the 2010 vegetation season (April-October). Comparison of the concentrations of heavy metals at the water inflow to the lake should make recognition of the equilibrium status between the deposition processes (precipitation of sediments and sorption on sedimenting suspended matter) and passing into the body of water (resuspension of suspended matter and dissolution) of the above-mentioned heavy metals along water flow path through the lake possible. The broadening of the study scope with additional water quality parameters, as expected, should make an attempt to learn what biohydrochemical processes have occurred in the lake ecosystem in that time period and to what extent these processes have affected the quality of waters flowing through the Rusalka Lake ecosystem possible.

Description of the water reservoir under investigation

The Rusalka Lake is a small water reservoir (with surface area of 2.9 ha) situated in the Kasprowicz Park within the Niemierzyn Valley in Szczecin (Fig. 1). It is an artificial water reservoir being formed due to damming and weiring the waters of the Osowka stream flowing from the hills in the Osow city district, being additionally supplied with the waters of the Warszawiec stream flowing from the Warszewo Hills. The lake is elongated in shape with a necking in its central part (length more than 600 m, width 25-60 m). In part of the lake, right before the water outflow from the lake, there is a weir (about 1.5 m height), differentiating the water level in two parts of the lake being isolated in that way. Maximum depth of the lake before sediment dredging was about 1.7 m, being about 3.0 m after it. Average depth before dredging was about 1.4 m, being about 2.0 m after it. Considering the volume of supplying water inflow, the Rusalka lake could have been seen rather as a stream water flood area but not a lake after estimation of the water retention time in it (on average ca 30 days) [13]. The beds of streams supplying the Rusalka Lake with water are greatly built over within the city area. The waters flowing out from the lake are drained to the Western Odra River through an underground canal, too. During the study period, the Osowka and Warszawiec streams, together with the Rusalka Lake, were included into municipal storm drainage system of the City of Szczecin where the lake functioned as a storage reservoir.

Material and methods

Water samples for analyses were drawn from the water surface layer (ca 0.5 m deep) at measuring stations 1 and 2 (Fig. 1), *ie* on the water inflow to and the water outflow from the lake during the time period from April to October 2010 with a monthly frequency. Attention was paid to the fact that intervals between successive water sample collection times was about 30 days, *ie* as much as the average water retention time in the lake.

The concentrations of heavy metals (Zn, Cu, Cd and Pb) in the analysed water samples were determined by the method of flame atomic absorption spectrometry [14].

Water temperature and pH as well as its total alkalinity were determined at the place of sample collection. Separate samples were collected in order to determine dissolved oxygen concentration, COD-Cr and BOD₅. In addition, water hardness, chloride and sulphate(VI) concentrations and total Mn and Fe concentrations were determined at the laboratory. All determinations were conducted according to the procedures given in literature [15].

Results and discussion

Results of total Zn, Cu, Cd and Pb concentration determination in the waters inflowing to and outflowing from the Rusalka Lake are presented in Figure 2, those of temperature, pH and water O₂ concentration determination and water O₂ saturation calculation, as well as COD-Cr and BOD₅ determination - in Figure 3, whereas those of total water hardness, HCO₃⁻ concentration (determined based on total alkalinity determination) and Cl⁻, SO₄²⁻ and Mn_{tot.} and Fe_{tot.} concentration determination - in Figure 4.

Fig. 2. Total concentrations of Cu, Zn, Cd and Pb in Lake Rusalka waters at inflow (—◆—) and outflow (—■—) waters from the reservoir during the vegetation season in year 2010

Statistical characteristics of the collected data sets is presented in Table 1. Table 2 presents the data which can be used for evaluation of the ecological and chemical status of the Rusalka Lake waters according to the official criteria being in force in Poland [1]. It follows from Table 2 that the Zn_{tot.} and Cu_{tot.} concentrations were lower than the admissible values according to the criteria being applied for evaluation of the ecological status. On the other hand, the Cd_{tot.} and Pb_{tot.} concentrations exceeded the admissible values according to the criteria being designed for evaluation of the chemical status. As far as other water quality parameters which can be used for evaluation of the ecological status of the investigated ecosystem, *ie* temperature, dissolved oxygen concentration, BOD₅, COD-Cr, SO₄²⁻ and Cl⁻ concentrations and pH value, are concerned, the COD-Cr values and dissolved oxygen concentration at the water outflow from the lake in August 2010

corresponded to the waters of quality classes III-V or even to impaired waters (no appropriate criteria for evaluation of quality differences in literature [1]), whereas other water quality parameters investigated corresponded to surface water quality class I or II.

Fig. 3. Temperature, pH and O_2 diss concentrations and waters saturation by O_2 [%] Rusalka Lake in Szczecin at inflow (—◆—) and outflow (—■—) waters, and values of COD-Cr and BOD_5 characterizing the quality of these waters during the vegetation season in year 2010

Similarity of the values of water quality parameters being investigated at the inflow to and the outflow from the lake as well as that of the trends in changes in the values of water quality parameters being determined in successive water sample collection times (Figs. 2-4) are evidence of the fact that in case of the Rusalka Lake - being in fact a flow-through reservoir and even a stream water flood area - with short water retention time the quality of waters of that water reservoir depends first of all on the quality of waters inflowing there through the Osowka stream bed. For example, it was showed in the previous paper [8] that the amount of precipitation did not have any direct effect on changes in the water quality in that water reservoir. Such an effect is to be found when the water catchment basin is being characterised by large water retention and considerable soil and soil water buffering capacity. In order to document more exactly how and to what extent changes in the quality of the Osowka stream waters flowing through the Rusalka Lake varied, changes in the values of particular investigated water quality parameters being calculated as the differences between respective values of the successive parameters at the inflow to the lake in a given measurement site less the value of the same parameters in the outflowing waters after one month are presented in Figures 5-7. It follows from the data presented in Figure 5 that

changes in the Cu_{tot} and Zn_{tot} concentrations were very similar. From April to July, the concentrations of those heavy metals decreased along the water flow path, whereas they increased in summer (*ie* in July-August and August-September intervals), with the Zn_{tot} concentrations increasing in July-August interval only. On the other hand, the character of changes in the Cd_{tot} and Pb_{tot} concentrations was different. Most likely, a source of pollution with the respective heavy metals mentioned above was different. The equilibriums between the sedimentation and the resuspension and the dissolution processes were clearly shifted towards sedimentation in case of Zn_{tot} and Cd_{tot} only.

Fig. 4. Total hardness and concentrations HCO_3^- , Cl^- , SO_4^{2-} , Mn_{tot} and Fe_{tot} in Lake Rusalka waters at inflow (—◆—) and outflow (—■—) waters from the reservoir during the vegetation season in year 2010

As far as changes in the values of other examined parameters of the waters flowing through the lake are concerned, they were relatively small. Small but distinctive changes in water saturation with oxygen, pH and HCO_3^- concentration which consistently point to the fact that three weak phytoplankton blooms occurred during the vegetation season, the effect of which was water enrichment, in particular in July-August interval, with organic matter (according to COD-Cr), is conspicuous.

Table 1
Statistical characteristics collected results of the determinations water quality indices in Lake Rusalka in Szczecin investigated during vegetation season in 2010 years

No.	Statistical characteristics Water quality indices (units)	Inflow						Outflow					
		Min.	$\bar{x}$	$\tilde{x}$	Max.	SD	CV	Min.	$\bar{x}$	$\tilde{x}$	Max.	SD	CV
Heavy metals													
1	Cu _{tot.} [μg Cu · dm ⁻³]	8	19	20	30	8	0.41	12	20	18	29	7	0.35
2	Zn _{tot.} [μg Zn · dm ⁻³]	25	50	51	83	21	0.41	10	32	25	63	19	0.60
3	Cd _{tot.} [μg Cd · dm ⁻³]	0	1	0	2	1	1.33	0	1	0	3	1	1.98
4	Pb _{tot.} [μg Pb · dm ⁻³]	10	15	16	21	4	0.27	12	16	14	23	5	0.29
Physical and chemical water quality indices													
5	Temperature [°C]	10.5	14.7	15.0	18.6	3.2	0.22	11.0	15.5	13.2	21.5	4.8	0.31
6	pH [pH units]	7.01	7.49	7.46	8.30	0.42	0.06	7.15	7.53	7.53	8.26	0.36	0.05
7	O ₂ diss. [mg O ₂ · dm ⁻³]	4.8	7.1	6.8	9.3	1.7	0.23	5.2	6.9	6.9	9.7	1.7	0.24
8	Saturation waters by O ₂ [%]	51.9	71.1	68.6	101.4	16.9	0.24	49.2	72.7	69.9	94.3	15.6	0.22
9	COD-Cr [mg O ₂ · dm ⁻³]	48.7	128.0	135.6	176.7	41.1	0.32	49.6	114.8	118.7	146.0	32.2	0.28
10	BOD ₅ [mg O ₂ · dm ⁻³]	2.1	5.5	5.0	8.9	2.4	0.45	0.1	5.5	4.9	10.1	3.3	0.61
Mineralization water quality indices													
11	Total hardness [mg CaCO ₃ · dm ⁻³]	325	368	366	406	32	0.09	283	337	333	394	41	0.12
12	HCO ₃ ⁻ [mg HCO ₃ · dm ⁻³]	303	361	370	422	42	0.12	257	314	300	427	62	0.20
13	Cl ⁻ [mg Cl · dm ⁻³]	53	58	56	71	6	0.10	49	54	50	73	9	0.16
14	SO ₄ ²⁻ [mg SO ₄ · dm ⁻³]	99	116	120	128	11	0.10	93	115	115	136	15	0.13
15	Mn _{tot.} [mg Mn · dm ⁻³]	0.05	0.33	0.16	1.28	0.44	1.33	0.02	0.23	0.06	0.96	0.35	1.49
16	Fe _{tot.} [mg Fe · dm ⁻³]	0.08	0.25	0.32	0.45	0.14	0.55	0.12	0.26	0.14	0.58	0.19	0.72

Table 2

Data for the evaluation ecological and chemical status of Rusalka Lake waters investigated during April-October 2010

No.	Indices (units)	The limited values indices by Decree (2008)	The values indicated in this work (<i>vide</i> Table 1 and Fig. 2)	Waters quality indices on basis of the indicator	Notices
CONCENTRATIONS OF HEAVY METALS					
1	Zn [mg Zn · dm ⁻³]	1.000	inflow: max: 0.083 outflow: max: 0.063	The limit values by criterion used for the assessment of ecological status	The assessment of ecological status of waters stream, flux, brook, river and lakes after Annex No. 5 to [1]
2	Cu [mg Cu · dm ⁻³]	0.050	inflow: max: 0.030 outflow: max: 0.029	as above	as above
3	Cd and its compounds [μg · dm ⁻³]	max: 0.45÷1.50 *	inflow: max: 2.0 outflow: max: 3.0	Exceeding the limit values by criterion used for the assessment of chemical status	The assessment of ecological status of surfaces waters after Annex No. 8 to [1]
4	Pb and its compounds [μg · dm ⁻³]	max: 7.2 **	15.0 (average)	as above	as above
Other investigated indices ***					
5	Water temperature [°C]	≤ 22°C (I class) 24°C (II class) III-V class – there is no fixed limited values	inflow: max: 18.6 outflow: max: 21.5	I quality class	The assessment of ecological status of waters stream, flux, brook and river after Annex No. 1 to [1]
6	O ₂ dissolved [mg O ₂ · dm ⁻³]	≥ 7 (I class) 5 (II class) III-V class - there is no fixed limited values	> 7.0 (April and May) otherwise 5.0 < c _{O₂} < 7.0 apart from: inflow: max: 4.8 (August) outflow: max: 5.2 (August)	I class – April-May. otherwise always II class, apart from inflow Walters in August: III-V quality class	as above
7	BOD ₅ [mg O ₂ · dm ⁻³]	≤ 3 (I class) 6 (II class) III-V class - there is no fixed limited values	inflow: max: 2.1 (May) outflow: max: 0.1 (May) always 3 < BOD ₅ < 6	In May I quality class, otherwise always II quality class	as above ****
8	COD-Cr [mg O ₂ · dm ⁻³]	≤ 10 (I class) ≤ 20 (II class) III-V class - there is no fixed limited values	inflow: within the limits around 50÷180 outflow: within the limits around 50÷250	Waters was always III-V quality classes or outside classification	as above
9	SO ₄ ²⁻ [mg SO ₄ · dm ⁻³]	≤ 150 (I class) 250 (II class) III-V class - there is no fixed limited values	inflow: always ≤ 150 outflow: always < 250	Inflow: I quality class Outflow: II quality class	as above

10	Cl^- [mg $\text{Cl}^- \cdot \text{dm}^{-3}$]	≤ 200 (I class) 300 (II class) III-V class - there is no fixed limited values	inflow: always ≤ 200 outflow: always ≤ 200	Water I quality class	as above
11	pH [pH units]	6.0÷8.5 (I class) 6.0÷9.0 (II class) III-V class - there is no fixed limited values	Always within the limits ok. 7.0÷8.3	as above	as above

* after Annex No. 8 to [1] forming in the legislation, that in the hardness of waters $\geq 200 \text{ mg CaCO}_3/\text{dm}^3$ (corresponding of waters V class quality) this is like in the waters of Rusalka lake in all waters samples taken during the period research - it should be as limited concentrations of general cadmium accept value $1.5 \mu\text{g}/\text{dm}^3$.

** after Annex No. 8 to [1] value $7.2 \mu\text{g}/\text{dm}^3$ is the criterion for assessing average values of the total concentrations of lead in samples water in the calendar year.

*** it was considered that Rusalka lake, because waters retentions time is short (≈ 30 days), may be considered as pool of Osowka stream [13].

**** in May slump of BOD_5 most probably supply as a result of toxic substances for microorganisms mineralizing organic matter. Supported for that large „nontypical” relations between BOD_5 and COD-Cr values (see: [16] p. 303). Unfortunately independently of these, according to [1], investigated waters are classified as waters I class quality according to BOD_5 .

Fig. 5. Differences in the total concentrations of heavy metals $\Delta M = [M]_{\text{outflow } i+1} - [M]_{\text{inflow } i}$, ie in month $i+1$ for the outflow and i inflow. $\Delta M > 0$ (■) means the enrichment deep waters during the flow waters in data metal, $\Delta M < 0$ (■) means the impoverishment deep waters in the data metal

When compared with changes in pH, those in the BOD_5 value illustrating technically the changes in the water richness in biodegradable organic matter, although in that case reflecting rather those in the activity of biochemical processes of organic matter decomposition, point to the occurrence of increase in water richness, or more properly in

the activity of organic matter decomposition processes in late spring and autumn, although the effects being observed were small.

Fig. 6. Differences in the values of water quality indices $\Delta X = [X]_{\text{outflow } i+1} - [X]_{\text{inflow } i}$, *ie* in month *i+1* for the outflow and *i* inflow. $\Delta X > 0$ (■) means the enrichment deep waters during the flow waters, $\Delta X < 0$ (■) means the impoverishment deep waters in the data indices

Changes in total water hardness point to the occurrence of Ca^{2+} deposition in the lake, and possibly of Mg^{2+} , in its sediments, most likely together with the organic matter gels depositing in the lake sediments, which is also indicated by changes in the values of SO_4^{2-} concentrations. On the other hand, changes in the HCO_3^- concentrations point to the shift of equilibrium in the carbonate system connected with changes in the dissolved CO_2 concentrations (desorption to atmosphere and fixation in the assimilation process).

Fig. 7. Differences in the values of water quality indices $\Delta X = [X]_{\text{outflow } i+1} - [X]_{\text{inflow } i}$, ie in month $i+1$ for the outflow and i inflow. $\Delta X > 0$ (■) means the enrichment deep waters during the flow waters, $\Delta X < 0$ (■) means the impoverishment deep waters in the data indices

As far the Fe_{tot} concentrations are concerned, they changed quite considerably, starting with an increase in its concentrations in spring (is it a resuspension during the meltwater flow time?), through concentration decreases in summer (deposition), to their increases in autumn induced by autumn wind water mixing. The Mn_{tot} concentrations were definitely stabilised over the whole research period.

Conclusions

1. In the vegetation season April-October 2010, the Osowka stream waters flowing through the Rusalka Lake in Szczecin, when being analysed according to the official criteria being designed for evaluation of the ecological and chemical status of aquatic ecosystems in Poland, carried small quantities of zinc and copper, corresponding to

- good ecological status of the lake ecosystem; unfortunately, they contained cadmium and lead in the quantities exceeding the admissible values according to the criteria being designed for evaluation of the chemical status of waters.
2. Only changes in the $Zn_{tot.}$ and $Cd_{tot.}$ concentrations in the waters flowing through the lake pointed to the fact that the sedimentation processes of these heavy metals prevailed over resuspension and dissolution of sediments practically over the whole research period.
 3. Due to changes in the values of other water quality parameters in the Rusalka Lake in the research period which can be used for evaluation of the ecological status of that water reservoir, *ie* temperature, dissolved oxygen concentration, BOD_5 , $COD-Cr$, SO_4^{2-} , and Cl^- concentrations and pH value, the $COD-Cr$ values and dissolved oxygen concentration at the water outflow from the lake in August 2010 corresponded to the waters of quality classes III-V or even to impaired waters (no appropriate criteria for evaluation of quality differences in literature [1]), whereas results of dissolved oxygen concentration determination in other time periods and those of other parameters determination corresponded to water quality class I or II.
 4. The waters investigated in the research period were characterised by statistically significant variation in the values of water quality parameters ($CV > 20\%$), whereas in successive measurement months the values of respective water quality parameters of the inflowing waters differed from those of the outflowing waters only to small extent, thus the quality of waters in the this water reservoir depended on the value of the Osowka stream water inflowing to the Rusalka Lake.
 5. Changes in pH, water saturation with oxygen, $COD-Cr$ and BOD_5 the waters flowing through the Rusalka Lake pointed to the occurrence of three weak phytoplankton blooms during the research period, which most probably favoured the increase of water richness in organic matter.
 6. Changes in the $COD-Cr$ values as well as those in the values of divalent cation and divalent anion concentrations pointed to the fact that the sedimentation processes of coagulating organic matter gels occurred in that water reservoir, with the equilibrium between the coagulation and the peptisation processes shifted, being favoured by the observed periodic enrichment of the waters flowing through the Rusalka Lake with some heavy metals under determination.

References

- [1] Rozporządzenie Ministra Środowiska z dnia 20 sierpnia 2008 roku w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych, DzU 2008, Nr 162, poz. 1008 [In Polish; Regulation of the Minister of Environment of 20 August 2008 on the method for classification of the condition of uniform surface water parts, Official Journal of Laws of 2008, No. 162, item 1008].
- [2] Osmulka-Mróż B. Prognozowanie i ochrona jakości wód powierzchniowych na terenach miejskich [In Polish; Forecasting and protection of the surface water quality in urban areas]. Warszawa: Wyd Inst Ochr Środow; 1992.
- [3] Hłyńczak AJ, Poleszczuk G, Możdżer A, Słupińska A, Deptuła W. Ekologiczne znaczenie zbiorników wodnych w aglomeracjach miejskich na przykładzie Rusalki w Szczecinie [In Polish; Ecological importance of water reservoirs in urban agglomerations on the example of the Rusalka Lake in Szczecin]. *Aura*. 1995;2:9-11.
- [4] Poleszczuk G, Hłyńczak AJ, Możdżer A, Deptuła W. Dynamika zmian wybranych parametrów chemicznych w wodach jeziora Rusalka i Syrenich Stawów (cz. II) [In Polish; Dynamics of the changes in selected

- chemical parameters of the Rusalka Lake and the Syrenie Stawy Ponds (Part 2)]. Mater. Symposium: Succession Municipality Gardens and Historical Landscape, 18 June 1992 Warszawa. Warszawa: Wyd SGGW; 1994.
- [5] Poleszczuk G, Hłyńczak AJ, Możdżer A, Garbaruk K. Zbiornik zaporowy Rusalka w Szczecinie - wybrane chemiczne i biochemiczne wskaźniki jakości [In Polish; The Rusalka dammed reservoir in Szczecin - selected chemical and biochemical water quality parameters]. Mater Konf US. 1996;19:181-198.
- [6] Poleszczuk G, Wawrzyniak W. Jezioro Rusalka w Szczecinie - badania jakości wód w cztery lata po wybagrowaniu osadów dennych [In Polish; The Rusalka Lake in Szczecin - water quality examination after four years from bottom sediment dredging]. Stud Mater Inst Badań Ekspertyz Nauk Ser Ekologia Pogranicza. 2002;163-167.
- [7] Hłyńczak AJ, Baranowska-Bosiacka I, Janeczko A. Występowanie niektórych metali ciężkich w wybranych zbiornikach wodnych Szczecina [In Polish; The occurrence of certain heavy metals in selected water reservoirs in Szczecin]. Arch Ochr Środow. 1998;24:57 - 67.
- [8] Hłyńczak AJ, Poleszczuk G, Bucior A, Rutkowska M, Janeczko A, Draszawka-Bolzan B. Heavy metals in water of the Rusalka lake in Szczecin following dredging of bottom sediments. Advances in Agricult Sci. 2008;12:77-90.
- [9] Niedźwiecki E, Wojcieszczuk T, Poleszczuk G, Meller E, Malinowski R, Sammel A. Skład chemiczny osadów dennych zbiorników wodnych Rusalka i Słoneczne aglomeracji szczecińskiej i możliwości ich wykorzystania [In Polish; The chemical composition of bottom sediments in the Rusalka and Słoneczne water reservoirs in the Szczecin agglomeration and possibilities of their employment]. Zesz Probl Postęp Nauk Roln. 2007;520:353-362.
- [10] Nahurska A, Deptuła W. Sanitary studies on water of selected lakes in Szczecin, Polish J Environ Stud. 2004;13:693-702.
- [11] Stapf D, Deptuła W. Dynamika zmian ilości bakterii w wodach jeziora Rusalka i Syrenich Stawów (cz. I) [In Polish; Dynamics of the changes in the quantity of bacteria in The Rusalka Lake and the Syrenie Stawy Ponds (Part 1)]. Mater. Symposium: Succession Municipality Gardens and Historical Landscape, 18 June 1992 Warszawa. Warszawa: Wyd SGGW; 1994:76-82.
- [12] Poleszczuk G, Bucior A. Biodegradation of organic substances in the waters of Lake Rusalka in Szczecin agglomeration in autumn and winter 2004/2005, Bulletin VURH Vodnany (Uniw. Ceskie Budejovice). 2009;45(4):44-51.
- [13] Giercuskiewicz-Bajtlik M. Prognozowanie zmian jakości wód stojących [In Polish; Forecasting of the changes in lentic water quality]. Warszawa: Wyd Inst Ochr Środ; 1990.
- [14] PN-ISO 8288. Jakość wody. Oznaczanie kobaltu, niklu, miedzi, cynku, kadmu i ołowiu. Metody atomowej spektrometrii absorpcyjnej z atomizacją w płomieniu [In Polish; Polish Standard PN-ISO 8288. Water quality. Cobalt, nickel, copper, zinc, cadmium and lead determination. Flame atomic absorption spectrometry methods].
- [15] Hermanowicz W, Dojlido J, Dożańska W, Koziorowski B, Zerbe J. Fizyczno-chemiczne badanie wody i ścieków [In Polish: Physicochemical examination of water and wastewater]. Warszawa: Wyd Arkady; 1999.
- [16] Pitter P. Hydrochemie. Praha: Vydavatelství VŠCHT; 1999.

ZANIECZYSZCZENIE EKOSYSTEMU ŚRÓDMIEJSKIEGO JEZIORA RUSALKA METALAMI CIĘŻKIMI

Katedra Chemii i Ochrony Środowiska Wodnego, Wydział Biologii, Uniwersytet Szczeciński

Abstrakt: W sezonie wegetacyjnym kwiecień-październik 2010 oznaczano wielkość i zmiany stężeń ogólnych Zn, Cu, Cd i Pb w wodach przepływowych (średni czas retencji wód ok. 30 dni) jeziora Rusalka w centrum miasta Szczecina. Oznaczano także temperaturę, pH, stężenie rozpuszczonego tlenu (oraz obliczano natlenienie wód), ChZT-Cr i BZT₅, twardość ogólną, stężenie HCO₃⁻ (jako alkaliczność ogólna), Cl⁻, SO₄²⁻, Mn_{og} i Fe_{og}. Zgromadzone dane mogą być wykorzystane do oceny stanu ekologicznego i chemicznego badanych wód powierzchniowych. Jeżeli chodzi o stan ekologiczny jeziora Rusalka, to, zgodnie z kryterium urzędowym stosowanym w Polsce do oceny stanu ekologicznego i chemicznego wód powierzchniowych, stwierdzono, że

badane wody ze względu na stężenia ogólne cynku i miedzi, a także temperaturę, stężenie tlenu rozpuszczonego (oprócz wód na dopływie do jeziora w miesiącu sierpniu) oraz BZT₅, stężenia SO_4^{2-} , Cl^- i pH miały wartości odpowiadające I lub II klasie jakości, natomiast ze względu na wartości ChZT-Cr badane wody były zawsze gorszej niż II klasa jakości. Jeżeli chodzi o stan chemiczny badanych wód, to stężenia ogólne kadmu i ołowiu według tych kryteriów były stężeniami przekraczającymi wartości dopuszczalne. Zmiany wartości badanych wskaźników wzdłuż drogi spływu wód pozwoliły stwierdzić, że w okresie badawczym równowagi pomiędzy procesami sedymentowania oraz resuspendowania i rozpuszczania jedynie w przypadku Zn i Cd oraz materii organicznej sedymentującej w postaci żeli sorbujących jony dwudodatnie i dwuwartościowe były przesunięte w stronę sedymentowania. Pomimo wystąpienia trzech - niestety słabych - zakwitów fitoplanktonowych w toni wodnej procesy dysymilacji przeważały nad asymilacją.

Słowa kluczowe: zanieczyszczenie wód, metale w wodach, jeziora śródmiejskie, jezioro Rusalka w Szczecinie