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PRESENCE OF MERCURY IN LAKE WATERS OF THE SUWAŁKI LANDSCAPE PARK

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Abstract: Hg concentration was studied in waters of 16 lakes in the Suwałki Landscape Park. The samples of lake water were collected from the surface zone and 1 m above the bottom, in the deepest site of the lakes. Apart from Hg concentration, the measurements included: the pH, soluble oxygen, water saturation with oxygen, electrolytic conductivity and total hardness of water. Hg concentration varied from lake to lake, but remained at the same levels in consecutive years. It has been found that Hg concentration in the bottom zone is higher than that in the surface zone. Significant differences were found between mean Hg concentrations in the bottom zone both during the summer and winter stagnation. No significant differences were found in mean Hg concentration in surface waters in different seasons of the year.

INTRODUCTION

Mercury belongs to those microcontaminants which adversely affect living organisms. It is commonly found in the environment because of its capability of translocation, but its concentration is usually very low. Several authors report that unpolluted rivers may contain from 0.01 to 0.1 μg of Hg per dm^3 [7, 9]. However, according to Kabata-Pendias [7], Hg concentration in the largest rivers of Poland is found to be within the range of 0.2–1.2 $\mu g \cdot dm^{-3}$. This is likely due to the condition of the so called "natural background" in which Hg concentration is commonly found beyond permissive levels. The lack of data on Hg levels in lakes may suggest that this issue has not been studied extensively. The data described in literature usually refer to incidental cases, where evident environmental pollution has occurred [3, 4, 13, 14]. Since lakes have the ability to accumulate mercury, and also due to the specificity of lake ecosystems, Hg levels are higher in lakes than in running waters. Natural emission increases Hg levels in the environment, so that its content accounts for about 66% (geogenic Hg), while 33% of total Hg comes from anthropogenic sources [9]. Precipitation is another important factor affecting Hg contents in the ecosystem [7, 9, 13]. The most important processes that occur in waters containing mercury are: complexation, adsorption and methylation. These processes depend on many biological and hydrochemical factors, such as: pH, ionic composition of water, contents of diluted organic matter, etc. In contrast to other metals, Hg solubility in water decreases with the decreasing pH, which usually results in saturation of insoluble mercuric sulphide [15].

The area of the Suwałki Landscape Park is relatively small, but rich in lakes of varied limnological conditions – from α-mesotrophic lake Hańcza, the deepest in Central Europe, through lakes of various levels of trophy until dystrophic ones [6]. Since the area described above is free of any point sources of industrial releases, it seems quite likely that the sources of mercury present in the waters of those lakes are primarily generated by the atmosphere, in which anthropogenic sources of mercury are represented by the so called "long-distance atmospheric transport" affecting the entire region to a relatively similar extent. This assumption, consequently leads to the thesis that Hg concentration in lake waters is comparatively at the same level in the entire region.

The purpose of the present study was to determine the differences and seasonal variations in Hg concentration of lake waters of the Suwałki Landscape Park, with respect to physical and chemical parameters of the aqueous environment and depths of lakes.

METHODS

Area of investigation

The Suwałki Landscape Park is situated in the north-east of Poland and belongs to the Lithuanian Lake District. It is located in the Niemen river-basin, with three smaller rivers: the Czarna Hańcza, the Szeszupa and the Szelmentka. The measurements were carried out in 16 lakes of the Suwałki Landscape Park: Kluczysk, Szurpiły, Jegłówek, Boczne, Jaczno, Linówek, Perty, Białe, Czarne, Udrynek, Szelment Wielki, Krejwelek, Hańcza, Sumowo, Kojle, and Kopane. Table 1 shows the morphometric data analyzed in the study.

Table 1. Basic morphometric data for explored lakes

Lake	Size [ha]	Capacity [thousand m^3]	Max. depth [m]	Mean depth [m]
Białe*	9.5	l.d.	10.5	l.d.
Bocznel	16.5	165	1.8	1.0
Czarne*	14.1	l.d.	4.5	l.d.
Hańcza	311.4	120364	108.5	38.7
Jaczno	41.0	4797	29.6	11.7
Jegłówek	19.2	1444	18.1	7.5
Kluczysk*	3.7	l.d.	13.6	l.d.
Kojle	16.1	1755	27.5	10.9
Kopane	14.5	1058	17.4	76.3
Krejwelek*	10.8	l.d.	6.0	l.d.
Linówek*	2.8	l.d.	6.8	l.d.
Perty	20.4	1019	31.0	5.0
Sumowo	30.0	661	8.0	2.2
Szelment Wielki	356.1	53492	45.0	15.0
Szurpiły	80.9	8168	46.2	10.0
Udrynek*	l.d.	l.d.	4.2	1.7

data according to [5], * – author's data, l.d. – lack of data

Methods

The water samples were collected three times: in August 1994 (summer stagnation), February 1995 (winter stagnation – all the lakes were covered with ice) and in October 1996 (at the end of summer stagnation). The samples of water were collected from the surface zone and about 1 m above the bottom, in the deepest part of the lakes under investigation. The samples of water were not filtered. The measurements included: Hg contents, pH, contents of soluble oxygen, water saturation with oxygen, electrolytic conductivity and total hardness of water. Hg content was measured using an ASA method with flameless amalgamation by the instrument TMA 254 (Tesla, Czech Republic). The results of the analyses were verified with certified reference material – RTC Trace Metals AA Ampule 1, QCI-049-1 (RT Corp., Laramie, USA). Certified values for the reference material was 0.0613 $\mu g \cdot dm^{-3}$ Hg (acceptance limits 0.0463–0.0760 $\mu g \cdot dm^{-3}$ Hg). However, the obtained concentrations were 0.059 $\mu g \cdot dm^{-3}$ Hg (5 repetitions). The accuracy of the method was understood as the difference between the real value of the studied indicator and the average value of the obtained measurement that was below 5%. Total mercury contents found in the water samples were determined in µg Hg per dm^3. Contents of dissolved oxygen and water saturation with oxygen were determined using an HI 9143 oxygen probe (Hanna Instruments). Electrolytic conductivity was measured using a Slandi CM 204 conductometer. Total hardness of water was measured by manual method with EDTA [12].

The data obtained were subjected to the analysis of variance and the significance of differences was explored by Duncan's multiple range test.

RESULTS

Table 2 shows Hg concentration of the lake waters under investigation. The highest Hg concentration (10.2 $\mu g \cdot dm^{-3}$) was found in the surface zone of lake Linówek (9.4 $\mu g \cdot dm^{-3}$ on average, during summer stagnation, while the lowest Hg concentration was found in the epilimnion of the lake Kopane (0.71 $\mu g \cdot dm^{-3}$ on average, during summer stagnation). During summer stagnation, Hg concentration in the surface zone of all the lakes under investigation averaged 2.16 $\mu g \cdot dm^{-3}$. Hg contents widely varied from lake to lake; therefore, the standard deviation was relatively high (either higher or close to the mean). In general, mean Hg levels of the water samples collected from the bottom of the lakes during summer stagnation were higher (2.16 $\mu g \cdot dm^{-3}$) than those found in the surface zone (3.28 $\mu g \cdot dm^{-3}$). The greatest difference between Hg concentration of the surface and bottom zones was found in the lake Kojle, where Hg concentration at the bottom was 6 times as high. The highest Hg concentration of the hypolimnion was found in the lake Kojle (8.46 $\mu g \cdot dm^{-3}$ on average), while the lowest concentrations were found in the lakes Szelment Wielki and Szurpiły (1.2 and 0.72 $\mu g \cdot dm^{-3}$, respectively). Only in the lakes Białe, Hańcza, Linówek and Szelment Wielki, the lowest Hg concentration was found at depths close to the bottom zone. No significant differences between Hg contents of surface waters of the lakes were observed in August 1994 and October 1996, but at the same time, the mean levels increased from 3.01 to 3.56 $\mu g \cdot dm^{-3}$ in the water samples collected from the bottom zone.

During winter stagnation, Hg contents were lower both in the surface and bottom zones. Besides, the variations in Hg concentration were smaller, and the standard deviation was half the average. The lowest Hg concentration of the bottom zone was found in the lake Sumowo (0.81 $\mu g \cdot dm^{-3}$), while the highest was that found in Linówek (0.82 $\mu g \cdot dm^{-3}$). The comparison of surface and bottom zones during winter stagnation shows

Table 2. Hg concentration in lake waters of the Suwałki District [$\mu g\ Hg \cdot dm^{-3}$]

	August 1994			February 1995			October 1996		
Lake	epi.	hypo.	z	epi.	hypo.	z	epi.	hypo.	z
Białe	1.70	1.35	79	1.31	0.91	70	1.70	1.53	90
Bocznel	1.60	4.15	259	0.85	0.84	99	1.68	4.74	282
Czarne	1.00	1.70	170	0.91	0.92	101	1.00	1.78	178
Hańcza	2.05	1.35	66	1.73	1.35	78	2.01	1.42	71
Jaczno	3.65	5.45	149	1.83	2.86	156	3.64	6.20	170
Jegłówek	4.17	6.75	162	1.94	2.82	145	4.07	7.42	183
Kluczysk	0.73	1.35	185	0.90	1.33	147	0.75	1.46	194
Kojle	1.35	8.00	593	0.82	2.73	333	1.37	8.92	651
Kopane	0.71	1.35	190	1.71	3.28	192	0.72	1.45	200
Krejwelek	1.02	5.60	549	1.20	1.85	154	1.03	6.08	589
Linówek	10.20	3.40	33	3.38	3.86	114	8.63	7.94	92
Perty	2.07	2.40	116	0.92	0.92	100	2.14	2.41	112
Sumowo	1.33	1.35	102	0.81	1.31	161	1.31	1.43	109
Szelment Wielki	1.35	1.20	89	0.85	1.77	207	1.37	1.41	103
Szurpiły	1.00	1.35	135	1.36	0.82	61	1.01	1.40	139
Udrynek	1.35	1.35	100	1.36	1.31	96	1.35	1.43	106
Mean	2.21	3.01	186	1.37	1.81	138	2.11	3.56	204
Deviation	2.34	2.28	193	0.66	0.99	67	1.98	2.80	171
min	0.71	1.20	189	0.81	0.82	61	0.72	1.40	71
max	10.20	8.00	190	3.38	3.86	333	8.63	8.92	651

epi. – Hg concentration in the epilimnion (surface zone),
hypo. – Hg concentration in the hypolimnion (bottom zone),
z – difference [%] between Hg concentration in surface and bottom zone

that higher Hg concentration was usually at the bottom. However, the differences were smaller than those observed during summer stagnation. It is worth noting that in five lakes, Hg concentration was higher in the surface zone (Fig. 1). Since Hg concentration of the lake Linówek was much higher than the levels found in other lakes, the parameters obtained in this lake significantly affected the variability and the mean value. For this reason, the median was always lower than the mean value; 1.36 for surface waters and 1.62 for bottom waters during summer stagnation and 1.25 for surface and 1.34 for bottom zone during winter stagnation. The values higher than the median suggest that Hg concentration in some lakes must have been much higher than the mean.

Table 3 shows the contents of oxygen dissolved in water and oxygen saturation. The epilimnion during summer stagnation exhibited similar, relatively high concentrations of dissolved oxygen. In August 1994 the amounts were slightly higher than in October 1996 and saturation was usually > 100%. The highest quantities of oxygen in the surface zone were found in lake Perty (11.64 mg $O_2 \cdot dm^{-3}$ – 138.9% saturation), while the lowest levels were in lake Sumowo (7.51 mg $O_2 \cdot dm^{-3}$ – 89.4% saturation). In August 1994 no oxygen was found in five lakes, while in October 1996 oxygen disappeared from the bottom zone of the majority (12) of lakes under investigation. The highest oxygen concentration in the bottom zone of the lakes was observed in lake Boczne (7.88 mg $O_2 \cdot dm^{-3}$ – 98.4% saturation), but since the lake is not deep, it seems quite likely that it had not been stratified

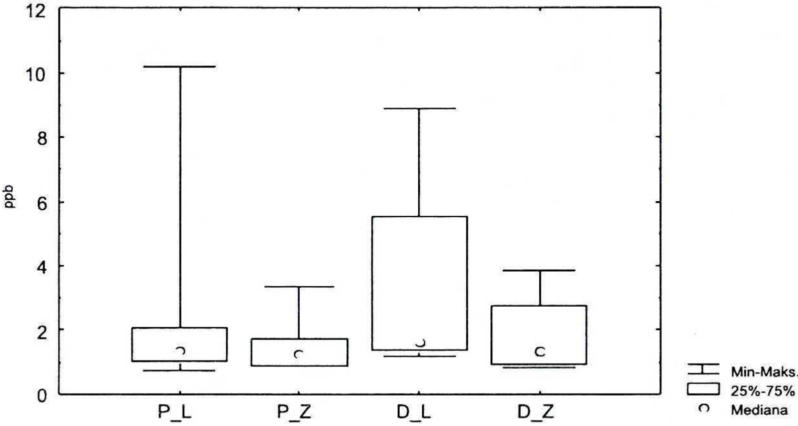

Fig. 1. Hg concentration in lake waters of the Suwałki Landscape Park [μg Hg·dm^{-3}]: P_L – surface zone, summer stagnation; P_Z – surface zone, winter stagnation; D_L – bottom zone, summer stagnation; D_Z – bottom zone, winter stagnation; (median values: 1.36; 1.25; 1.62; 1.34 μg Hg·dm^{-3}, respectively)

throughout the entire season. The highest percentage of oxygen in the hypolimnion was found in lake Hańcza (10.66 mg O_2·dm^{-3} – 87.9% saturation). As for the surface zone during winter stagnation, the majority of the lakes covered with ice were high in oxygen (12.54 mg O_2·dm^{-3} – 90.94% saturation, on average), but no oxygen was present in the bottom zone of nine lakes. The highest levels of oxygen were noted in lake Hańcza (6.55 mg O_2·dm^{-3} – 52.2% saturation).

Table 4 shows the pH, hardness and electrolytic conductivity of the lake waters. During summer stagnation, the mean pH values of the epilimnion were significantly higher than those of the hypolymnion and in each lake the pH value was higher (or much higher) than neutral. The pH in the bottom zone was usually close to neutral and slightly acidic in two lakes (Białe and Czarne). During winter stagnation, the pH of both surface and bottom zones was slightly basic. The differences in the pH between the lakes in the limnic zones and periods of investigation were insignificant.

Great differences were observed in total hardness of lake waters during summer stagnation; from 3.2°dH in lake Boczne to 19.5°dH in Jaczno. Total hardness of bottom waters was higher than that of the surface waters; from 3.8°dH in Boczne to 25.4°dH in Jaczno. During winter stagnation total hardness of the surface zone was lower than that observed during winter stagnation and amounted to 2°dH in Boczne and 15.42°dH in Udrynek. In winter the total hardness of waters ranged from 1.8°dH in Czarne to 15.8°dH in Udrynek.

Great differences were observed in the electrolytic conductivity of lake waters during summer stagnation, from 66 μS·cm^{-1} in Czarne to 455 μS·cm^{-1} in lake Kluczysk. The electrolytic conductivity of bottom waters was higher than that of surface waters and amounted from 72 μS·cm^{-1} in Czarne to 608 μS·cm^{-1} in lake Kluczysk. The electrolytic conductivity of the surface zone in winter ranged from 59 μS·cm^{-1} in Czarne to 326 μS·cm^{-1} in Kojle. The electrolytic conductivity of the bottom zone ranged from 68 μS·cm^{-1} in Czarne to 410 μS·cm^{-1} in lake Jaczno.

Table 3. Contents of oxygen dissolved in water [mg $O_2 \cdot dm^{-3}$] and oxygen saturation [%] in lakes under investigation

Dates of sample collection	August 1994				February 1995				October 1996			
	epi.		hypo.		epi.		hypo.		epi.		hypo.	
Lake	O_2	%	O_2	%	O_2	%	O_2	%	O_2	%	O_2	%
Białe	8.36	100.7	0.00	0.0	14.03	99.4	0.00	0.0	9.66	90.5	0.00	0.0
Bocznel	7.99	100.6	7.88	98.4	10.15	71.2	0.00	0.0	8.97	83.1	0.00	0.0
Czarne	8.97	110.2	3.88	45.5	14.53	101.4	0.00	0.0	10.52	96.8	4.26	38.3
Hańcza	9.21	114.3	10.66	87.9	11.54	109.4	6.55	52.2	10.63	95.9	6.47	50.8
Jaczno	11.27	136.3	0.36	2.9	12.05	86.8	0.00	0.0	11.54	109.4	0.00	0.0
Jegłówek	10.42	130.3	0.86	6.8	11.47	79.2	2.65	20.6	9.91	93.5	0.00	0.0
Kluczysk	9.45	118.7	0.00	0.0	13.56	95.3	0.00	0.0	10.65	98.4	0.00	0.0
Kojle	11.57	137.0	0.00	0.0	14.92	102.4	3.89	29.0	9.23	83.4	0.00	0.0
Kopane	11.20	112.0	0.73	6.8	12.53	88.2	0.00	0.0	10.38	89.5	0.00	0.0
Krejwelek	11.27	137.6	0.48	5.0	11.24	80.3	0.00	0.0	10.87	103.0	0.00	0.0
Linówek	9.88	118.6	9.94	45.6	11.27	87.1	0.00	0.0	8.23	79.8	0.00	0.0
Perty	11.64	138.9	0.00	0.0	6.84	47.5	2.10	16.3	8.96	83.6	0.00	0.0
Sumowo	7.51	89.4	0.00	0.0	16.50	115.0	0.00	0.0	8.75	79.5	0.00	0.0
Szelment Wielki	11.51	138.8	6.42	55.4	14.77	105.4	5.43	42.3	10.65	96.3	4.98	39.7
Szurpiły	10.35	128.6	2.06	17.4	13.08	96.6	4.87	37.8	9.69	86.4	0.00	0.0
Udrynek	9.45	113.8	4.60	54.9	12.22	89.9	2.16	17.1	9.21	85.7	1.56	12.5
Mean	10.00	120.36	2.99	26.66	12.54	90.94	1.73	13.46	9.87	90.93	1.08	8.83
Deviation	1.36	15.65	3.78	33.36	2.28	16.45	2.30	18.02	0.92	8.62	2.14	17.38
min	7.51	89.40	0.00	0.00	6.84	47.50	0.00	0.00	8.23	79.50	0.00	0.00
max	11.64	138.90	10.66	98.40	16.50	115.00	6.55	52.20	11.54	109.40	6.47	50.80

epi. – concentration in the epilimnion (surface zone),
hypo. – concentration in the hypolimnion (bottom zone)

Table 4. The pH, hardness and electrolytic conductivity of lake waters in the Suwałki District

Dates of sample collection	August 1994						February 1995						October 1996					
Lake	epi.			hypo.			epi.			hypo.			epi.			hypo.		
	pH	TH	con.	pH	TH	con.	pH	TH	con.	pH	TH	con.	pH	TH	con.	pH	TH	con.
Białe	8.20	12.8	123	6.80	14.0	137	7.27	3.0	115	7.03	4.2	156	8.11	12.8	134	6.75	15.1	150
Bocznel	7.92	3.2	165	7.20	3.8	212	7.64	2.0	60	7.53	6.4	175	7.71	3.4	177	7.23	4.1	228
Czarne	8.57	6.0	66	6.94	6.2	72	7.82	2.4	59	7.33	1.8	68	8.23	5.9	69	6.97	6.4	75
Hańcza	8.68	4.8	249	8.09	5.2	277	8.30	6.6	204	8.03	7.2	234	8.67	4.7	268	8.07	5.6	299
Jaczno	8.24	19.5	351	7.47	23.5	408	8.22	9.8	303	7.89	13.3	410	8.20	19.5	382	7.34	25.4	447
Jegłówek	8.14	6.4	410	7.46	6.8	351	7.65	4.4	118	7.35	12.4	340	7.72	6.2	434	7.36	7.2	372
Kluczysk	7.31	6.6	432	7.11	9.1	576	7.76	10.2	287	7.67	14.2	391	7.35	6.8	455	7.15	9.5	608
Kojle	8.39	16.6	310	7.42	19.9	365	8.22	9.5	326	7.66	10.4	350	8.34	16.9	335	7.30	21.4	397
Kopane	8.20	17.8	221	7.52	20.7	319	7.48	12.8	169	7.39	12.0	345	8.28	18.5	296	7.42	23.2	349
Krejwelek	8.37	18.3	341	7.44	22.7	408	7.94	10.6	299	7.92	12.5	347	8.50	18.5	356	7.45	23.7	427
Linówek	8.53	4.1	197	7.73	4.4	207	7.56	4.6	130	7.30	8.2	239	8.10	4.3	213	7.45	4.7	225
Perty	8.45	18.1	315	7.45	20.9	358	7.95	6.0	210	7.65	10.1	330	8.17	17.5	341	7.46	22.5	389
Sumowo	8.20	16.0	283	7.43	17.1	325	8.10	8.3	231	7.79	11.0	303	8.18	15.6	290	7.87	17.5	333
Szelment Wielki	8.82	16.0	281	7.74	17.4	324	8.15	4.0	245	8.00	5.4	318	8.53	16.2	285	7.54	17.7	329
Szurpiły	8.31	7.7	366	7.45	10.6	384	7.95	7.8	211	7.80	11.4	323	8.11	7.8	385	7.34	11.1	405
Udrynek	8.36	18.2	292	7.82	14.2	296	7.89	15.4	263	7.56	15.8	276	8.10	17.6	311	7.32	15.1	317
Mean	8.29	12.01	275	7.44	13.53	314	7.87	7.33	202	7.62	9.77	288	8.14	12.01	296	7.38	14.38	334
Deviation	0.34	6.14	101	0.32	6.99	119	0.29	3.88	86	0.28	3.89	92	0.33	6.11	105	0.31	7.52	125
min	7.31	3.20	66	6.80	3.80	72	7.27	2.00	59	7.03	1.80	68	7.35	3.36	69	6.75	4.05	75
max	8.82	19.50	432	8.09	23.50	576	8.30	15.40	326	8.03	15.80	410	8.67	19.47	455	8.07	25.42	608

epi. – concentration in the epilimnion (surface zone), hypo. – concentration in the hypolimnion (bottom zone), TH – total hardness [°dH], con. – electrolytic conductivity of lake waters [$\mu S \cdot cm^{-1}$]

DISCUSSION

Since Hg levels found in the lake Linówek were much higher than in other lakes, the median was considered to be a parameter better characterizing the average result than the mean values. In the periods under investigation (summer and winter stagnation) the median was > 1 μg Hg·dm^{-3} (Fig. 1), that is above the permissive contamination standards for surface lake water quality [2], in which 1 μg Hg·dm^{-3} is considered class 1 purity. In this situation a question arises whether Hg levels found in the lakes of the Suwałki Landscape Park are high as compared to other lakes in Poland. There are many discrepancies in the data reported in literature. Presumably, some data showing the presence of mercury in the environment (obtained using old analytical methods, which are not in use today) are not in compliance with modern standards, therefore, they should be unaccounted for [7]. For example, the data obtained in the studies of lake Sławskie and other water reservoirs in the vicinity show Hg concentration within the range of 0–8 μS·cm^{-1} (2 μg Hg·dm^{-3} on average) [11], but Zerbe *et al.* [17] who studied lake waters of 11 lakes in the Wielkopolski National Park found that Hg levels in the lakes of that region ranged from 0.0 to 0.5 μg·dm^{-3} [17]. According to Merian's reports [9], Hg levels in the lakes of Switzerland reach 4 μg·dm^{-3} [9]. High Hg concentrations were also found in Scandinavian lakes [7, 9]. It can be assumed that Hg in open lakes is easily discharged from the ecosystem, whereas Hg concentration can reach high levels in those water courses, in which water exchange and deposition are hardly possible due to unfavorable conditions, saturation or floating.

It seems inappropriate to use the same standards for rivers and lakes, since the latter are able to accumulate higher amounts of microcontaminants in the ecosystem. Wildlife values (WV) have been used in the USA since Great Lakes Water Quality Initiative, 1994, when 1.30 μg Hg·dm^{-3} was determined for total Hg in non-filtered water. In 1997 another WV was determined for Hg, in which the ability of mercury to bioaccumulate was taken into account. The level was determined as methylated fraction of mercury at the level of 0.05 μg·dm^{-3} Hg [10]. It can, therefore, be concluded that Hg concentration at the level > 1 μg·dm^{-3} is by no means hazardous to natural environment. The basic criterion taken into consideration while assessing threat to the environment due to Hg bioaccumulation should be the level of methylated Hg (or dissolved Hg fraction).

Great differences in Hg accumulation in the lakes under investigation require further study, especially lake Linówek, in which Hg accumulation was extremely high. Linówek is a small, close lake surrounded by grassland. Although no accidental pollution was noted, it cannot be unanimously excluded, but it seems obvious that the only source of pollution was precipitation (wet and dry). This assumption leads us to the conclusion that the differences in Hg accumulation in the lakes resulted from Hg conversion and migration rate. Lake Linówek is characterized by low total hardness of water and high contents of humic compounds. The Xu and Allard [16] studies show that a large portion of Hg can be permanently bound to humic compounds dissolved in water. Mercury in such a form, although in aqueous solution, is not so toxic to living organisms as it is in methylated form. Another factor affecting the presence of mercury in lake waters is high pH, which improves mobility of this metal (in contrast to other heavy metals) [13, 15]. Jaczno and Jegłówek were two other lakes of the Szeszupy-basin in which Hg concentration of the surface and bottom zones was > 3 μg·dm^{-3}. In both of these lakes permanent stratification occurs, water exchange is at low levels (0.63 and 0.18, respectively), the depth is 10 m on average [1], the pH and oxygen level in the epilimnion are high. High Hg concentration in the two lakes was noted both during winter and summer stagnation (2.8 μg Hg per dm^3 was noted during the latter). The conditions prevailing in the two lakes favor long-term presence of mercury in water. It was characteristic that Hg concentration was almost twice lower in winter than in summer, which can account for the predominance of deposition processes in winter. In contrast, the lowest Hg concentrations were found in lakes Kopane, Kluczysk, Czarne, Szurpiły and Sumowo. Water exchange in these lakes is also insignificant, which may suggest that the processes of Hg deposition in these lakes are efficient. The parameters selected for the study do not allow us to indicate unanimous causes of the differences in Hg concentration. However, it is worth noting that the lakes Hańcza, Szelment and Szurpiły, described by Bajkiewicz-Grabowska [1] as highly resistant to the influx from the basin, exhibited low Hg concentrations in water.

The results of the study on Hg concentration in the surface and bottom zones show that the latter are significantly higher in Hg. Similar results were reported by Kirkwood *et al.* [8] who studied vertical Hg distribution in stratified lakes. According to Kirkwood *et al.* [8] Hg was accumulated in the hypolimnion at the end of the season as a result of sedimentation of phytoplankton, which absorbed mercury in the euphotic zone. Increased concentrations of methylated Hg were observed in the hypolimnion after remineralization [8]. A large portion of Hg is also adsorbed on the suspension [3], and besides, Hg levels can be augmented in the bottom zone after sedimentation. These processes must have occurred in the majority of the lakes under investigation. However, this rule was not observed in four lakes, especially two: Hańcza and Szelment Wielki – the deepest, with extremely low water exchange (0.07 and 0.09), in which Hg concentration at the bottom was lower than in the surface zone. This was likely due to permanent deposition of mercury in the bottom sediment accompanied by small inflow from the basin and low mercury content in precipitation (in relation to water capacity of the lake).

The comparison of the two seasons: summer and winter stagnation shows that Hg concentration in the bottom zone is lower in winter (significant level $p \leq 0.05$). The mean Hg concentrations in the surface zone were also lower in winter, but the difference was not always statistically significant ($p \leq 0.05$). Presumably, after autumn mixing, when Hg concentration in the vertical profile is at comparative levels, the ice cover cuts off the influx of mercury from precipitation. The load of mercury present in snow and ice can, of course, reach the lake water, but one season later, that is in spring. Unfortunately, no measurements of Hg concentration in precipitation and ice were carried out; therefore it is hard to determine the influence of these factors on mercury balance. However, this confirms the thesis that mercury present in the lakes under investigation comes mainly from precipitation.

A correlation of Hg concentration in water was analyzed in combination with other parameters. However, the levels of significance of the correlation coefficients were too low ($p \leq 0.05$). Heavy metals usually affect the pH, water hardness and oxygen conditions, but none of these relations have been found in the present study. The pH did not increase Hg mobility in the lakes under investigation, since basic reaction was noted in almost all of the lakes (although slight differences occurred). It can, therefore, be expected that the parameters determined in the study were not decisive as far as Hg levels are concerned. For a better understanding of the presence of mercury in lake waters, it is necessary to study the suspension and to determine Hg concentration in plankton, and the percentage of dissolved and methylated Hg in total Hg contents.

CONCLUSIONS

1. Hg concentration in the lake waters under investigation varied from lake to lake, but it was similar in consecutive years.
2. Mean Hg concentrations in lake waters of the Suwałki Landscape Park are similar to those found in the lakes of other regions of Poland.
3. It has been found that Hg concentration in the bottom zone is much higher than that in the surface zone.
4. Significant differences in mean Hg concentrations were found between summer and winter stagnation, but seasonal differences were not significant in the surface zone.
5. No significant correlations were found between the presence of total Hg in lake waters and other parameters.
6. It is necessary to determine the basic forms of mercury in order to obtain a more comprehensive picture of mercury presence in lake waters.

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WYSTĘPOWANIE RTĘCI W WODZIE JEZIOR SUWALSKIEGO PARKU KRAJOBRAZOWEGO

Przeprowadzono badania zawartości rtęci w wodzie 16 jezior Suwalskiego Parku Krajobrazowego: Kluczysk, Szurpiły, Jegłówek, Bocznel, Jaczno, Linówek, Perty, Białe, Czarne, Udrynek, Szelment Wielki, Krejwelek, Hańcza, Sumowo, Kojle i Kopane. Badania przeprowadzono trzykrotnie: w sierpniu 1994, lutym 1995 i październiku 1996. Analizy przeprowadzono w próbkach wody pobranej z warstwy powierzchniowej i około 1 m nad dnem w najgłębszym miejscu jezior. Rtęć oznaczono metodą zimnych par ASA z zastosowaniem amalgamacji bezpłomieniowej. Oprócz rtęci w próbkach wody oznaczono odczyn, zawartość tlenu rozpuszczonego i nasycenie wody tlenem, przewodnictwo elektrolityczne oraz twardość ogólną. Stężenia rtęci w warstwie powierzchniowej wahały się od 0,71 µg Hg·dm^{-3} w jeziorze Kopane do 10,2 µg Hg·dm^{-3} w jeziorze Linówek. Natomiast w wodach naddennych od 0,82 µg Hg·dm^{-3} w jeziorze Szurpiły do 8,92 µg Hg·dm^{-3} w jeziorze Kojle. Jeziora porównywane między sobą charakteryzowały się wysoką zmiennością występowania rtęci, jednocześnie zachowując podobny poziom tego pierwiastka w kolejnych latach. Stwierdzono, że stężenia rtęci w wodach naddenych są wyższe od stężeń spotykanych przy powierzchni. Wykazano istotne statystycznie różnice pomiędzy średnimi stężeniami rtęci przy dnie podczas stagnacji letniej i zimowej oraz brak istotnych statystycznie różnice w średnich stężeniach rtęci w różnych sezonach w wodach przypowierzchniowych. Nie stwierdzono statystycznie istotnych korelacji między obecnością rtęci w wodzie, a innymi oznaczanymi parametrami.