Geology, Geophysics & Environment 2015, vol. 41 (2): 177–185

Anthropogenic sediments from facultative lagoons of the Konstancin-Jeziorna sewage treatment facility and their usability for soil recultivation

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Received: January 2015; accepted: May 2015

Abstract: The sewage treatment facility of a paper mill at Konstancin-Jeziorna was opened to process industrial and domestic wastewater. After closure of that mill, the sewage treatment facility had to be rebuilt and modernized. Therefore, it was necessary to analyse the chemical and phase composition of the sediments from facultative lagoons used for biological treatment of wastewater. Eight samples of sediments were taken to identify a general phase composition by X-ray diffraction and ten to determine concentrations of selected main and trace elements with the use of ICP-AES and AMA methods.

The analyses showed that the sediments consisted of over 90% of mineral fraction, mainly kaolinite, calcite, and quartz and also neomorphic smithsonite. They contained low quantities of Hg, Cd, Co and Mo, and elevated concentrations of Zn, Ba, Mn and Sr. Comparisons of the obtained mean values with admissible concentrations of metals, as defined by Regulation of the Minister of Environment of 9 September 2002, showed that the mean concentrations of As, Sn, Co, Mo and Ni (and also of Hg and Cr in the southern lagoon) met quality standards for soils in areas under protection (group A). Mean concentrations of Pb (both lagoons), Ba, Cu, Cd (northern lagoon) as well as Cr and Hg (southern lagoon) in sediments are higher. However, they still meet standards for areas usable for agricultural and other purposes (group B). The highest concentrations were recorded for Zn, Cd, Cu and Ba in samples from the southern lagoon. These continued to be lower than all the limits acceptable for industrial areas.

Keywords: anthropogenic soils, heavy metals, revitalization

INTRODUCTION

The history of the Konstancin-Jeziorna paper mill can be traced back to the 1780's and Johann Joseph Felix von Kurz known as Bernardon, a Viennese actor with outstanding managerial and supervisory skills. His vast business experience helped him to recognize and make use of business opportunities in the Warsaw region resulting from steady growth in demand for paper in offices, schools and print shops, accompanied by a lack of any large local producers to compete with. The key to success was his ability to make King Stanisław August Poniatowski interested in the project of establishing a paper mill at Jeziorna. The project proved to be very attractive, as it took on the production of good quality laid paper from rags collected by the poor, which provided them work from which they could earn money (Dąbrowski 2011). In result, King Poniatowski became a co-founder of

http://dx.doi.org/10.7494/geol.2015.41.2.177 ISSN 2299-8004 | e-ISSN 2353-0790 | Wydawnictwa AGH

this project and, this way, the dream of Johann J.F. Kurz became a reality. His paper mill got the status of a royal manufacturer and could place the King's coat of arms in the watermark of the produced laid paper.

The paper supplied by the Jeziorna paper mill played a significant role in the most important events in the history of Poland, in the last decades of the 18th century, being widely used in works of the Great Sejm, printing the text of The Constitution of 3rd May, 1791 as well as in the production of the first Polish paper currency. After further expansion and installation of modern Hollander beaters for production of cellulose containing plant fibers, the Jeziorna paper mill became one of the largest in Poland and the largest in the Warsaw region.

In the 19th century, whirlwinds of history and related changes in the market repeatedly put the future of the Jeziorna paper mill at risk. Nevertheless, the mill appeared capable to maintain its importance. The significant milestones being 1812, when the mill got the title of the Royal Paper Manufacturing Factory, as well as 1830, when it was taken over by the Polish Bank (Bank Polski). Finally in 1838, paper production became mechanized. The next important event in history of the paper mill took place at the start of the 20th century, when the Mirków Paper Manufacturing Joint-Stock Company became interested in the Jeziorna paper mill. This resulted in a merger of the enterprises and establishment of the Mirków Paper Manufacturing Company based at Jeziorna. The First World War significantly impeded successful operations of this new entity, leading to its temporary closure. The production was successfully recommenced in 1917, with reconstruction and modernization of the mill continuing for about 10 years.

At the outbreak of the Second World War, the Jeziorna paper mill had full production capability. After it was closed during the military operations of September 1939, production recommenced under control of the occupation authorities to continue until the autumn of 1944, when the Nazi Germans sent workers to concentration camps and began to loot the machinery of the mill leading to its systematic demolition. After the end of the war, the mill was rebuilt to be nationalized in 1947. Soon thereafter it was merged with 6 other enterprises to form the Warsaw Paper Manufacturing Factory. Following restructurisation and modernization, the Jeziorna paper mill reached its pre-war production levels in 1951. Subsequent investments led to dynamic growth of both the enterprise and the adjacent area.

When the Polish government began to implement the mass privatization programs of state-owned businesses in the mid-1990s, ownership shares of the Warsaw Paper Manufacturing Factory were passed to the Polish National Investment Funds, and, subsequently, the majority of shareholding went to a Finnish company, Metsä Tissue. This company was mainly interested in the hygienic and sanitary paper products market and, therefore, the parts of the paper mill with production lines of cardboard, writing paper and parchment were bought by Konstans Co. Ltd. The parts producing felt paper and paperboard were leased by Ecotex Polska Co. Ltd.

In 2010, the history of the Jeziorna paper mill came to an end after almost 250 years, when the Konstans Company decided to phase out production and closed its part of the mill, techinically considered obsolete. This decision was soon also taken by the Ecotex company as well as Metsä Tissue, which transferred its whole production from Jeziorna to its factory at Krapkowice by the end of 2012 (Gadomska, website).

The shutdown of the Jeziorna paper mill meant the simultaneous closure of its mechanical-biological wastewater treatment facility. Since its opening in 1961, the facility operated as an element of the technological line of the mill, designed to treat both process wastewater and domestic wastewater from neighboring areas. The biological section of this facility included a facultative lagoon, partly separated into two sections by an intermediate dyke. This was a type of stabilization pond used for biological treatment, in which biological sediment could accumulate. After the shutdown of the mill, and, before the start of revitalization, the dyke was extended to achieve full separation of the lagoon into two parts, the northern lagoon and the southern.

One of the main stages of revitalization was connected with the removal of sediments, accumulated on the floor of the lagoons. The sediments have to be treated as anthropogenic soils;

i.e. soils originating as a result of economic activity of people, created by people, or caused by human activity. They include solid waste and relocated and re-deposited natural soils" (Drągowski 2010). This approach was in accordance with the water-law permit obtained by the operator, who was obliged to periodically remove sediments accumulating on the facultative lagoon floor. Suspended matter originating as a result of the continuous work of aerators was pumped and removed for a few months every year, making it possible to stop classifying sediments accumulating on the lagoon floor as waste, under the code 19 08 12 (sludge from biological treatment of industrial wastewater other than those classified under the code 19 08 11). This interpretation was supported by the results of assessments of the total amount of carbon occurring in organic compounds (TOC), conducted in 2012. The data obtained showed that the content of organic matter in the sediments from the lagoon floor equals 7.32% on average (Bojakowska et al. 2012) and in wet sludge sediments – about 60% on average, ranging from 36% to 80% (Bień & Wystalska 2011). Therefore, the terms "sediments" and "anthropogenic soils" are used interchangeably later in the present paper.

FIELD WORKS

The field works on the northern and southern lagoons were carried out separately. They were conducted in stages comprising successive rounds of sampling of the lagoon floor sediments. In total, 8 samples were taken in 2012 and the next 10 samples in 2013 (7 samples from the southern lagoon and 3 from the northern). Figure 1 shows the location of sites sampled in the year 2013.

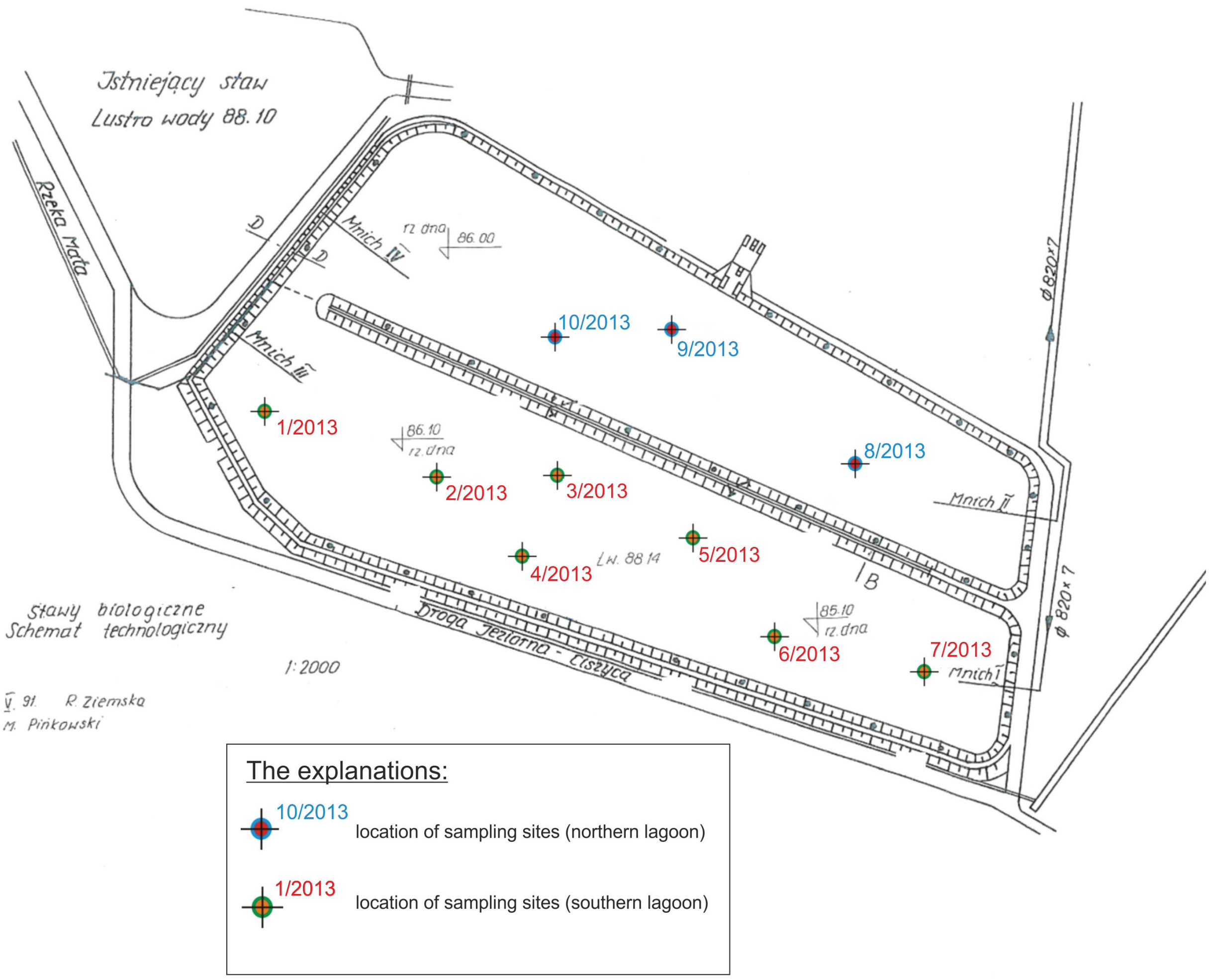

Fig. 1. *Location of sampling sites*

THE RANGE AND METHODS OF ANALYSES

Samples taken in 2012 were subjected to X-ray diffraction (XRD) analysis to identify their general phase composition. In turn, the material collected in 2013 was dissolved in aqua regia to determine contents of As, Ba, Cd, Cr, Co, Cu, Mo, Ni, Pb, Sn, Sr, V, Zn, Al, Ca, Fe, K, Mg, Mn, Na, P and S, with the use of atomic emission spectrometry, with an excitation in the inductively coupled plasma (ICP-AES). Moreover, contents of Hg were determined by absorption spectrometry, with the use of an amalgamator (AMA).

DISCUSSION OF RESULTS

X-ray diffraction (XRD) analyses showed that the lagoon bottom sediments consist of over 90% of mineral fraction. The X-ray diffractograms showed that the sediments mainly consist of kaolinite (with a share of 30%), calcite (about 25%) and quartz (about 15%). Moreover, neomorphic smithsonite was found to be present in trace amounts of two samples. Some admixtures of feldspars, dolomite, hematite and pyrite were also recorded.

Table 1 shows the results of the analysis of the general phase composition as established for individual samples. One should note that, the arrangement of minerals identified and listed in each sample in Table 1 is according to their decreasing percentage.

Table 2 shows concentrations of elements in the soil samples, Table 3 – statistical parameters (arithmetic mean, geometric mean and median, minimum and maximum values).

Analysis of data from Table 2 shows that all concentrations of Hg, Cd, Co, Mo and As in the studied sediments were lower than 10 mg/kg. Concentrations of Hg in sediments from both lagoons appeared to be lower than 1 mg/kg. In sediments from the southern lagoon they ranged from 0.405 to 0.902 mg/kg (being equal 0.716 mg/kg on average) and in those from the northern lagoon – from 0.382 to 0.582 mg/kg (0.486 mg/kg on average). Concentrations of Cd ranged from 2.1 to 8.2 mg/kg in all the studied sediments, but in a narrower range in the case of those from the northern lagoon – merely from 2.1 to 2.7 mg/kg. Mean concentrations of Cd in sediments from the southern lagoon were equal 4.2 mg/kg and, in those from the northern lagoon, 2.4 mg/kg. Concentrations of Co in the studied sediments ranged from 2.0 to 8.0 mg/kg and from 3.0 to 7.0 mg/kg in sediments from the northern lagoon. Mean concentrations of Co in sediments from the southern lagoon were 4.0 mg/kg and in those from the northern lagoon – 5.0 mg/kg. Concentrations of the last of these elements, Mo, ranged from 3.3 to 6.7 mg/kg in sediments from the southern lagoon and from 2.9 to 4.5 mg/kg in those from the northern one, being 4.4 and 4.0 mg/kg on average, respectively. Concentrations of As were found to range from 4.0 to 8.0 mg/kg equal to 6.0 mg/kg on average in sediments from both lagoons.

Table 1
Crystalline phases identified in the soil samples

Sample number	The results of X-ray diffraction (XRD analysis)
1/2012	calcite, quartz, clay minerals (kaolinite, traces of illite and talc), admixture of feldspars, dolomite and trace of smithsonite
2/2012	calcite, quartz, clay minerals (kaolinite, traces of illite), admixture of feldspars, dolomite and traces of smithsonite and pyrite
3/2012	calcite, quartz, clay minerals (kaolinite)
4/2012	calcite, quartz, clay minerals (kaolinite), admixture of feldspars, dolomite
5/2012	calcite, quartz, clay minerals (kaolinite, illite/ muscovite), feldspars, trace of hematite
6/2012	quartz, calcite, clay minerals (kaolinite, illite/ muskovite), feldspars, traces of hematite
7/2012	calcite, quartz, clay minerals (kaolinite, traces of illite), trace of dolomite and pyrite
8/2012	quartz, calcite, clay minerals (kaolinite, traces of illite), admixture of feldspars, pyrite and dolomite

Table 2
Contents of the elements in anthropogenic soils collected from southern lagoon and northern lagoon in 2013

Element	Unit	Southern lagoon							Northern lagoon		
		Sample number									
		1/2013	2/2013	3/2013	4/2013	5/2013	6/2013	7/2013	8/2013	9/2013	10/2013
Arsenic	mg/kg	5	6	7	4	6	7	8	4	6	8
Barium	mg/kg	516	464	444	356	278	607	150	145	609	122
Chromium	mg/kg	43	47	67	37	43	57	65	25	43	45
Tin	mg/kg	9	10	13	6	16	12	14	7	9	7
Zinc	mg/kg	868	869	1390	671	1321	1084	1303	550	653	738
Cadmium	mg/kg	3.1	2.9	4.2	2.7	8.2	3.1	4.9	2.5	2.1	2.7
Cobalt	mg/kg	3	3	3	7	8	2	4	5	3	7
Manganese	mg/kg	313	292	254	357	568	198	195	319	342	286
Copper	mg/kg	177	178	185	126	378	169	250	169	141	133
Molybdenium	mg/kg	3.9	3.5	4.7	3.4	6.7	3.3	5.0	2.9	4.5	4.5
Nickel	mg/kg	16	15	15	26	29	14	18	17	15	27
Lead	mg/kg	76	80	122	49	62	105	111	39	78	79
Mercury	mg/kg	0.662	0.672	0.902	0.405	0.802	0.707	0.861	0.382	0.582	0.495
Strontium	mg/kg	245	193	125	199	301	106	119	130	220	111
Vanadium	mg/kg	9	10	10	21	12	8	10	9	10	25
Phosphorus	%	0.551	0.541	0.499	0.554	1.009	0.471	0.516	0.492	0.599	0.419
Aluminum	%	1.66	1.84	2.21	1.28	1.08	1.93	1.87	0.88	1.47	1.96
Magnesium	%	0.26	0.27	0.18	0.30	0.32	0.16	0.19	0.18	0.27	0.30
Potassium	%	0.069	0.075	0.071	0.090	0.057	0.064	0.067	0.053	0.062	0.110
Sulfur	%	0.971	0.748	0.750	1.226	2.793	0.597	1.003	0.996	0.727	0.940
Sodium	%	0.040	0.036	0.034	0.029	0.057	0.030	0.043	0.043	0.045	0.038
Calcium	%	14.3	12.9	8.0	9.9	13.5	6.2	6.7	6.15	13.77	5.67
Iron	%	1.08	0.97	0.76	2.48	3.07	0.65	1.13	1.22	0.78	1.71

Table 3
Statistical parameters of elements in sewage sludge collected from a southern lagoon and northern lagoon in 2013

Element	Unit	Southern lagoon					Northern lagoon				
		arith-metic mean	geo-metric mean	median	min.	max.	arith-metic mean	geo-metric mean	median	min.	max.
Arsenic	mg/kg	6	6	6	4	8	6	6	6	4	8
Barium	mg/kg	402	370	444	150	607	292	221	145	122	609
Chromium	mg/kg	51	50	47	37	67	38	36	43	25	45
Tin	mg/kg	11	11	12	6	16	8	8	7	7	9
Zinc	mg/kg	1 072	1 040	1 084	671	1 390	647	643	653	550	738
Cadmium	mg/kg	4.2	3.9	3.1	2.7	8.2	2.4	2.4	2.5	2.1	2.7

***Table 3** cont.*

Element	Unit	Southern lagoon					Northern lagoon				
		arith-metic mean	geo-metric mean	median	min.	max.	arith-metic mean	geo-metric mean	median	min.	max.
Cobalt	mg/kg	4	4	3	2	8	5	5	5	3	7
Manganese	mg/kg	311	292	292	195	568	316	315	319	286	342
Copper	mg/kg	209	197	178	126	378	147	147	141	133	169
Molybdenium	mg/kg	4.4	4.2	3.9	3.3	6.7	4.0	3,9	4,5	2,9	4,5
Nickel	mg/kg	19	18	16	14	29	20	19	17	15	27
Lead	mg/kg	86	83	80	49	122	66	62	78	39	79
Mercury	mg/kg	0.716	0.696	0.707	0.405	0.902	0.486	0.479	0.495	0.382	0.582
Strontium	mg/kg	184	172	193	106	301	154	147	130	111	220
Vanadium	mg/kg	11	11	10	8	21	15	13	10	9	25
Phosphorus	%	0.592	0.573	0.541	0.471	1.009	0.503	0.498	0.492	0.419	0.599
Aluminum	%	1.70	1.65	1.84	1.08	2.21	1.43	1.36	1.47	0.88	1.96
Magnesium	%	0.24	0,23	0.26	0.16	0.32	0.25	0.24	0.27	0.18	0.30
Potassium	%	0.070	0.070	0.069	0.057	0.090	0.075	0.071	0.062	0.053	0.110
Sulfur	%	1.155	1.016	0.971	0.597	2.793	0.888	0.880	0.940	0.727	0.996
Sodium	%	0.038	0.037	0.036	0.029	0.057	0.042	0.042	0.043	0.038	0.045
Calcium	%	10.19	9.69	9.88	6.20	14.25	8.53	7.83	6.15	5.67	13.77
Iron	%	1.45	1.24	1.08	0.65	3.07	1.24	1.18	1.22	0.78	1.71

The elements occurring at the higher than 100 mg/kg concentrations in all the studied sediments included Zn, Ba, Mn, Sr and Cu. Concentrations of Zn were found to range from 671 to 1,390 mg/kg in sediments from the southern lagoon and from 550 to 738 mg/kg in those from the northern one, equal to 1,072 mg/kg and 647 mg/kg on average, respectively. Similarly high variability in concentrations was recorded in the case of Ba. Concentrations of that element ranged from 150 to 607 mg/kg in sediments from the southern lagoon and from 122 to 609 mg/kg in those from the northern one, equal to 402 mg/kg and 292 mg/kg on average, respectively. In turn, concentrations of Mn were found to range from 195 to 568 mg/kg. These concentrations appeared similar in sediments from both lagoons, amounting to to 311 mg/kg and 316 mg/kg in those from the southern and northern lagoon. Concentrations of Sr were found to be lower, equal to 184 mg/kg and 154 mg/kg on average in sediments from the southern and northern lagoon, respectively. Concentrations of Cu were found to have a wide range in sediments from the southern lagoon, from 126 to 378 mg/kg (209 mg/kg average), and in somewhat narrower range in those from the northern lagoon, from 133 to 169 mg/kg (147 mg/kg average).

Of the remaining parameters used in this study, concentrations of Cr ranged from 25to 67 mg/kg, being 38 an 51 mg/kg on average in sediments from the northern and southern lagoon, respectively. Concentrations of Sn ranged from 6 to 16 mg/kg in sediments from the southern lagoon and from 7 to 9 mg/kg in sediments from the northern lagoon, equal to 11 and 8 mg/kg on average, respectively. Concentrations of Ni ranged from 14 to 29 mg/kg (from 15 to 27 mg/kg in sediments from the northern lagoon), equal to 19 and

20 mg/kg in sediments from the southern and northern lagoon, respectively. Concentrations of Pb were found to range from 49 to 122 mg/kg in sediments from the southern lagoon and from 39 to 79 mg/kg in those from the northern lagoon, equal to 86 and 66 mg/kg on average, respectively. In turn, concentrations of V ranged from 8 to 21 mg/kg in sedimnts from the southern lagoon and from 9 to 25 mg/kg in those from the northern lagoon, equal to 11 and 15 mg/kg on average, respectively.

The mean concentrations of elements recorded in the sediments from the lagoons' floors were subsequently compared with admissible concentrations, as defined in the Regulation of the Ministry of Environment, 9th September, 2002, on the standards of soil quality (Journal of Laws No. 165, item 1359). Table 4 shows results of these comparisons.

Mean concentrations of As, Co, Mo and Ni recorded for sediments from both lagoons fall within the limits of those mentioned above in the Regulation of the Ministry of Environment as admissible for soils in areas protected under the Water Law and Environmental Law and relevant regulations (Group A). The same is the case of Cr and Hg concentrations in sediments from the northern lagoon. In turn, mean concentrations of these elements in sediments from the southern lagoon exceed values admissible for soils in areas of the Group A, falling within the limits of values admissible for soils in areas of the Group B in theRegulation mentioned above (agricultural areas, forests and urban areas). In addition, mean concentrations of Pb (equal 86 and 66 mg/kg for sediments from the southern and northern lagoon, respectively) match values admissible for soils in areas of the Group B.

Table 4
A comparison of average metal content in the samples collected from northern and southern lagoons with the limit values set out in the legislation

Item number	Pollutant	Unit	Arithmetic mean		Group A	Group B					Group C		
						Depth [m bgs]							
						0–0.3	0.3–15.0		>15		0–2	2–15	
							Permeability of soil [m/s]						
							to	less than	to	less than		to	less than
			Southern lagoon	Northern lagoon			$1\cdot10^{-7}$		$1\cdot10^{-7}$			$1\cdot10^{-7}$	
1.	Arsenic	mg/kg dry weight	**6**	**6**	**20**	20	20	25	25	55	60	25	100
2.	Barium		**402**	**292**	200	200	250	320	**300**	**650**	1 000	300	3 000
3.	Chromium		**51**	**38**	**50**	**150**	150	190	150	380	500	150	800
4.	Tin		**11**	**8**	**20**	20	30	50	40	300	350	40	300
5.	Zinc		**1 072**	**647**	100	300	350	300	300	**720**	1 000	300	**3 000**
6.	Cadmium		**4.2**	**2.4**	1	**4**	**5**	6	4	**10**	15	6	20
7.	Cobalt		**4**	**5**	**20**	20	30	60	50	120	200	50	300
8.	Copper		**209**	**147**	30	**150**	100	100	100	**200**	**600**	200	1 000
9.	Molybdenium		**4,4**	**4,0**	**10**	10	10	40	30	210	250	30	200
10.	Nickel		**19**	**20**	**35**	100	50	100	70	210	300	70	500
11.	Lead		**86**	**66**	50	**100**	100	200	100	200	600	200	1 000
12.	Mercury		**0.716**	**0.486**	**0.5**	**2**	3	5	4	10	30	4	50

In the case of the remaining pollutants (Ba, Zn, Cd and Cu), the situation appears more complex. Comparison of mean concentration values of Cd with the admissible levels showed that the value obtained for sediments from the northern lagoon (2.4 mg/kg) is lower than admissible for that pollutant in soils in areas of the Group B. In turn, mean concentration of that pollutant in sediments from the southern lagoon (4.2 mg/kg) is lower than admissible for soils in areas of the Group C (industrial areas, mining operations, communication traffic areas) as defined in the Regulation. At the same time, this value matches requirements set for soils in areas of the Group B in depth intervals of 0.3–15.0 m below the ground surface (bgs) and over 15 m, when soil permeability is below 10^{-7} m/s. It should be noted, that the admissible concentrations are exceeded in the remaining cases (depth intervals 0.0–0.3 m and over 15 m bgs when soil permeability is up to $1 \cdot 10^{-7}$ m/s).

Mean content of Cu in sediments from the southern lagoon (209 mg/kg) is lower than admissible for soils in areas of the Group C, in depth intervals 0–2 m and 2–15 m (when soil permeability is less than $1 \cdot 10^{-7}$ m/s), and exceeds admissible limits as defined by the Regulation for the remaining cases. In turn, the average concentration of Cu in sediments from the northern lagoon (147 mg/kg) was lower than those admissible for Group C as well as the depth interval 0.0–0.3 m in soils of Group B.

Mean concentrations of Ba in sediments from the southern lagoon (402 mg/kg) falls within the interval of various limits established for soils in the areas of Group C. The recorded value is higher than admissible for the depth interval 2–15 m bgs with soil permeability up to $1 \cdot 10^{-7}$ m/s, not exceeding the remaining limits. In turn, the mean concentration of that pollutant in sediments from the northern lagoon (292 mg/kg) is lower than those for soils of Group C as well as those for Group B in the interval 0.3–15.0 (under conditions of soil permeability below $1 \cdot 10^{-7}$ m/s) and at depths >15 m bgs (under various conditions of soil permeability).

Mean concentrations of Zn in samples from both lagoons fall within the interval of various limits established for soils of areas of Group C. However, it should be noted that concentrations recorded in most samples of sediments from the northern lagoon are up to two times higher than the limit for the Group C levels in the case of the depth interval 2–15 m bgs and under soil permeability up to $1 \cdot 10^{-7}$ m/s. Concentrations in most samples from the southern lagoon, on the other hand,exceed two lower limits for soils of areas of Group C except for the limit for the depth interval 2–15 m bgs and soil permeability below $1 \cdot 10^{-7}$ m/s.

CONCLUSIONS

Sediments sampled from the floor of the facultative lagoons originated as a result of human activity and are connected with several decades of treatment of industrial and domestic wastewater. The analyses of the authors show that the lagoon bottom sediments consist of over 90% of mineral fraction, mainly kaolinite, calcite and quartz. The high share (over 30%) of kaolinite is the direct result of the operations of the paper mill, as kaolinite was used for paper mass infill, to ensure gloss on some grades of paper. Zn oxide, in turn, was used to make the (cellulose) coating of paper whiter, brighter and more stable. The presence of neomorphic smithsonite (although in trace amounts) along with zinc occurring in higher concentration than the remaining pollutants further confirm the anthropogenic origin of the pollution. Zinc oxide is widely used in the cellulose and paper-making industry due to its whitening, matting and coating properties.

The work of this study has demonstarted that the southern lagoon was exposed to much stronger anthropopression. This is well proven by markedly higher concentrations of individual pollutants in samples from that lagoon than in those recorded in sediments from the northern lagoon. This regularity may be explained by the fact that industrial wastewater was first discharged to that part of the original facultative lagoon.

Comparisons of the recorded mean concentrations with admissible values, as defined in the Regulation of the Ministry of Environment, 9th September, 2002, on the standards of soil quality (Journal of Laws No. 165, item 1359) showed that those of As, Sn, Co, Mo and Ni fall within the limits admissible for soils in areas of the Group A (areas under protection). In turn, mean concentrations of Pb and also Hg and Cr (in sediments from the northern lagoon) meet the standards defined for soils in areas of the Group B (agricultural lands, forests, urban areas). Mean concentrations of Cu and Ba in the southern lagoon as well as of Zn in both lagoons fall within the interval of various limits established for soils in areas of Group C (industrial areas), while mean concentrations of Cu and Ba in the northern lagoon and of Cd in both lagoons do not exceed any of them.

These data demonstrate that anthropogenic sediments removed from the facultative lagoons of the former industrial and domestic wastewater treatment plant at Konstancin-Jeziorna, near Warsaw, generally match current environmental standards, making it possible to use them in in the process of land reclamation and similar purposes.

The authors would like to thank prof. dr hab. Bogusław Wiłkomirski and dr Rimante Zinkute for their comments that greatly improved the manuscript.

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