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ASSESSMENT OF THE LONG-TERM ANTHROPOGENIC IMPACT ON THE DEGREE OF HEAVY METAL CONTAMINATION OF ORGANIC ALLUVIA DEPOSITED IN THE AREA OF THE BIAŁOGOŃSKI POND

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Abstract: The study area is located in the southern part of the city of Kielce, in the district named Białogon, where metallurgical and machine-building industries have operated for more than 200 years. The immediate cause for creating the Białogoński Pond was power demand of the Alexander's Metalworks functioning in this area. In 1993, the Pond underwent drainage, whereas the soils formed on its ground still indicate significant enrichment in heavy metals. The content of heavy metals ($mg \cdot kg^{-1}$) in soils of the study area ranges from: 22.40 to 395.73 for Cr; 14.80 to 177.53 for Cu; 21.30 to 103.1 for Ni; 47.00 to 1617 for Pb; and 456.60 to 1646 for Zn. The largest exceedances among the analysed soil samples were noted for Zn, Pb and Cr, i.e. 100%, 85.7% and 42.9% of samples, respectively. At present, the physicochemical properties of developed mineral-organic and organic formations (pH 6.0-8.0 as well as high organic matter content) do not facilitate leaching and migration of deposited elements to environment, including ground and underground waters. Nevertheless, the location of the contaminated area within the protection zone of the largest municipal drinking water intake for Kielce requires conducting continuous monitoring.

Key words: heavy metals, contaminated soils, organic soils, metallurgical industry, Białogonski Pond

1. INTRODUCTION

The area of the former Białogoński Pond is a place where human economic activity has caused a major burden to environment. The 19th century was marked there by a rapidly developing metallurgical and machine-building plant, i.e. the Alexander's Metalworks. Its activity was characterized by substantial emission of metalliferous dusts which in turn led to their deposition and stabilization in the bottom sediments of the water reservoir. What is more, the Pond was flowed through by the River Bobrza carrying sanitary contamination, including heavy metals which had previously been accumulated in waters flowing into it by the River Silnica. After the flood of 1993, which had caused the destruction of the hydro-technical constructions, the Pond was drained (Świercz, 2010; Świercz & Prażak, 2014). From that moment, the area of the water reservoir was undergoing progressive degradation. The mineral-organic and organic soils were developed from the bottom sediments after the Pond's drainage. The studies of soil samples conducted in 2011 and 2012 indicated considerable quantities of heavy metals, including lead, zinc and chromium (Świercz & Prażak, 2014). This issue is important insofar as the study area is located within the protection zone of the largest municipal drinking water intake for Kielce of nearly 200,000 population. Therefore, heavy metals deposited in the soil pose a serious threat to the Devonian water resources.

In the present article, the selected physicochemical properties of soils formed in the area of the former water reservoir and its vicinity, including the content of selected heavy metals, were submitted for analysis. Also, the spatial variability of analysed characteristics as well as the correlations among particular indices were determined.

2. MATERIALS AND METHOD

The study involved 7 soil pits. The pits no. 1÷3 were located on the site of the Pond existing before 1920, whereas the pits no. 4÷7 were dug within the boundaries of the Pond existing until 1993 (Fig. 1). The samples for analysis, weighing 1000 g, were collected from the top soil layers to a depth of 30 cm below ground level (b.g.l.). After drying at ambient temperature (16-17°C), the samples were sieved through a nylon sieve with a mesh size of 2 mm. The samples were determined according to the methodology applicable to soil science i.e. pH in H_2O and 0.1 n KCl (pH-meter CP-103, Elmetron, Poland), the S1 cation exchange capacity by Kappen's method, the content of C_{org} by Tiurin's method, the content of $CaCO_3$ by Sheibler's method (Ostrowska et al., 1991). The air-dried soil samples were disaggregated with a Fritsch s blender to pass a < 0.06 mm sieve and were analysed in terms of the content of selected heavy metals. Samples were digested in *aqua regia* by weighing 1 g of sample in polyethylene tube and adding 6 ml HCl and 2 ml HNO_3. The samples were left for 15 minutes at room temperature before heating in an aluminum block at 95^{o}C for 60 minutes. After cooling, the samples were filtered and made up to 50 ml in a polyethylene flask. The soils samples were analyzed for 5 elements (Cr, Cu, Ni, Pb, Zn) by ICP-AES, using a J-Y 70 Plus Geoplasma ICP-AES instrument. The level of heavy metals was compared with the permissible values specified in the Ordinance of the Ministry of Environment of 9 September 2002 on soil quality standards and land quality standards (Journal of Laws of 2002, No. 165, item 1359 Environment, 2002) as well as the results of some archival studies (Świercz & Prażak, 2014). The contamination degree of the area for each of the elements was calculated according to the geoaccumulation index (I_{geo}) which is used for both assessment of bottom sediment contamination and extent of soil contamination on the basis of the formula (Faiz et al., 2009):

$$I_{geo}= \log_2(C_n/1.5B_n)$$

where: C_n – the concentration of the analysed metal in the soil, B_n – the geochemical background for the analysed metal, 1.5 – the natural variation of the content of a particular metal in environment resulting from some slight differences in a geological structure. The obtained results were referred to seven classes of land contamination in the range of I_{geo} from 0 (uncontaminated area) to <5 (extremely contaminated area). There is also the contamination factor (CF) which was calculated for the study area on the basis of the formula:

$$CF= C_1/C_n$$

where: C_1– the arithmetic mean of the concentration of an analysed element on the basis of at least five measurement points, C_n – the concentration of the analysed element from the pre-industrial period (geochemical background). The contamination degree (C_{deg}) was determined by adding up the values of CF according to the same categories as for CF. The accumulation index (AI), as a quotient of the geometric mean of the content of a particular metal and its content in parent rocks, was in turn used to assess the contamination degree (geochemical background) (Czarnowska, 1996).

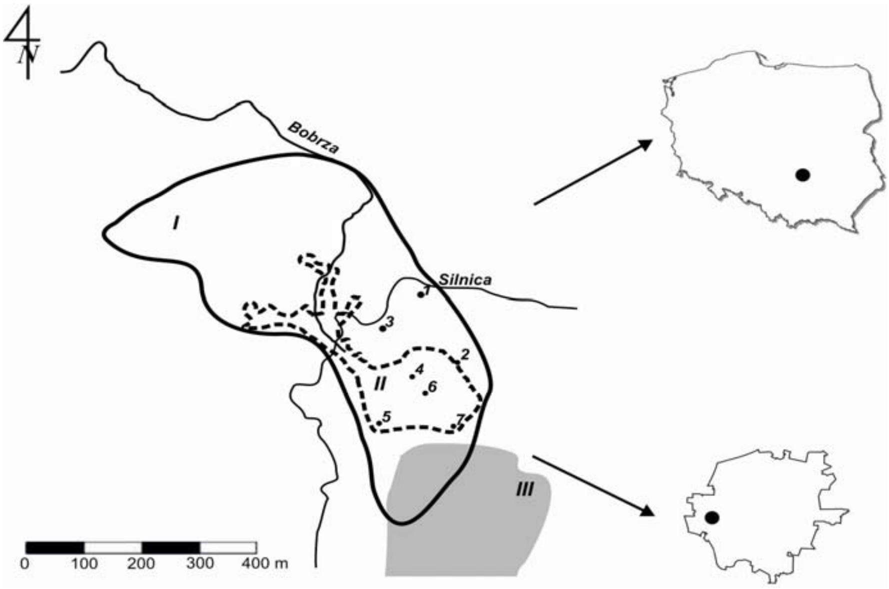

Figure 1. Distribution of soil pits in the area of the Białogoński Pond on the background of Poland and Kielce
Explanations to Figure 1.: I – the outline of the Pond before 1920, II – the outline of the Pond before 1993, III – the Alexander Metalworks' buildings.

The data were analysed statistically, and by using the Surfer v. 10 program was presented the spatial variability of distribution of the analysed determinations. The figures concerning the spatial variability of the content of heavy metals in the soils of the former Białogoński Pond should be considered illustrative due to limited number of soil samples.

3. RESULTS AND DISCUSSION

It was claimed that the formations developed in the area of the Białogoński Pond belong to mineral-organic and organic soils. Due to oxygen deficiency in the drained, but soggy alluvia there were initially marsh and peat formation processes. Over time, the progressive aeration stimulated the moorshing process of the soil material (Świercz & Prażak, 2014). The result of this process was development of the post-marsh peat-moorsh soils (profiles no. 1÷6) and the moorshed soils (profile no. 7) in the medium as well as the loamy and silty sands. The soils are characterized by the high content of silt and clay fractions (<0.02 mm) in the range of 23-54% and the high proportion of organic matter (Table 1). They create habitats for some eutrophic communities, mainly meadow and riparian ones. The basin of the former water reservoir has become overgrown with pioneer vegetation, such as: reed, common yarrow, wormwood, common nettle, thistle, wild carrot, and white nettle.

The study results show that the soils are characterized by the reaction from slightly acid to alkaline, where as much as 70% of soils have pH_{KCl} > 7.02. The obtained values referred to some results of the archival studies (Świercz & Prażak, 2014) indicate that the analysed soils' pH remains over the years 1996-2012 at the similar level. The migration and solubility of heavy metals in a soil profile depend, *inter alia*, on a pH value of a soil solution (Lenartowicz & Bartkowiak, 2012; Saint-Laurent et al., 2013).

The analysed soils are characterized by the organic matter content in the range of 192.2-630 $g{\cdot}kg^{-1}$ (Table 1). Such high proportion of organic matter explains the tendency of grounds to increase the degree of complexation of heavy metals (Sammel & Niedźwiecki, 2006; Kabata-Pendias & Pendias, 2010).

The formation of soil humus is positively influenced by calcium compounds. The content of $CaCO_3$ in the analysed soils varies in a wide range and adopts the maximum value in the central part of the drained Pond. This element stimulates soil organic matter decomposition and acts as a buffer with respect to a change of reaction (Sammel & Niedźwiecki, 2006).

The obtained values of the S1 cation exchange capacity varied in the range of 7.00-147.5 with the average mean 46.77 $cmol(+)kg^{-1}$ (Table 1). This is a typical value for mineral-organic soils (Sammel & Niedźwiecki, 2006).

The studies reveal that there are considerable quantities of heavy metals deposited in the soils of the Białogoński Pond. The elevated concentrations of heavy metals in the study area were also pointed out by other authors (Świercz & Prażak, 2014).

The production profile of the former Alexander's Metalworks (lead sulphide processing – galena ores) caused a significant enrichment of the soil in lead 47.00-1617 $mg{\cdot}kg^{-1}$ (Fig. 2). The substantial exceedances for this metal were noticed in six soil samples (Table 2), whereas the geochemical background value was exceeded in all analysed soil samples. Lead, due to the high bioaccumulation index, belongs to the elements of high toxicity (Al-Farraj et al., 2013; Du et al., 2013). It is found in each part of environment and in all biological systems (Guo et al., 2013). The largest anthropogenic source of origin for this metal is industry, including metallurgy (Olafisoye et al., 2013).

Table 1. Selected properties of the top soil layers (to 30 cm b.g.l.)

Number of soil pit	pH		C_{org}	$CaCO_3$	S1 cation exchange capacity
	H_2O	KCl	$g{\cdot}kg^{-1}$	%	$cmol(+)kg^{-1}$
1	6.55	6.15	252.3	1.50	24.80
2	7.53	7.27	498.0	0.69	7.00
3	7.63	7.13	426.0	1.81	10.00
4	7.34	7.02	192.2	1.91	19.60
5	8.18	7.50	510.0	9.03	49.00
6	7.63	7.35	630.0	14.03	49.50
7	7.40	6.94	267.7	1.51	167.50

Table 2. Concentration of heavy metals in accumulation layers of the analysed soils

Number of soil pit	Cr	Cu	Ni	Pb	Zn
	(mg·kg^{-1})				
1	39.60	20.20	21.30	1617.00	456.60
2	143.73	177.53	71.84	883.27	911.11
3	186.24	163.91	60.40	903.50	930.39
4	100.30	134.00	31.20	1428.00	639.00
5	395.73	117.38	97.71	459.23	1392.20
6	176.75	119.39	103.1	581.84	1482.00
7	22.40	14.80	28.20	47.00	1646.00
Permissible values according to soil quality standards (Journal of Laws of 2002, No. 165, item 1359)	150.00	150.00	100.0	100.0	300.00
Average statistical content in all Polish soils (Lis & Pasieczna, 1995)	4.00	4.00	4.0	13.00	35.00
Geochemical background (Czarnowska, 1995)	27	7.1	9.8	9.8	30

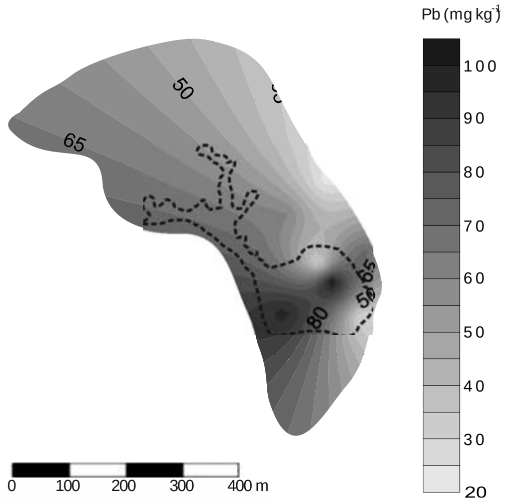

Figure 2. Spatial variability of the content of lead (mg·kg^{-1}) in the study area

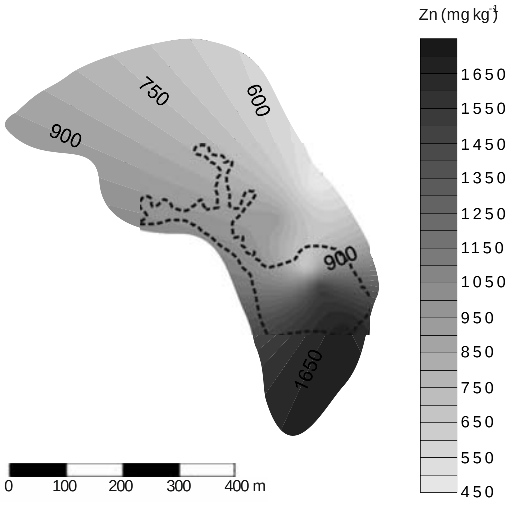

Figure 3. Spatial variability of the content of zinc (mg·kg^{-1}) in the study area

By contrast, in sediments of rivers, which are industrial wastewater receivers, over 90% of lead derives from contamination, and its concentration is inversely proportional to the distance from a place of wastewater discharge (Szalińska et al., 2010). Lead deposited in analysed soil samples derives from the historically anthropogenic accumulation as well as the modern accumulation related to the Rivers Bobrza and Silnica which flow into the area of the former Pond.

The total content of zinc in the analysed soil samples is significant and remains at the level of 456.60-1646 mg·kg^{-1} (Table 2, Fig. 3). The standard values were exceeded in all analysed soil samples. The high values of zinc in these samples indicate that it is an active migrant and is easily leached, what is additionally facilitated by the neutral and alkaline pH of the analysed soils.

The abnormal values were also noticed in relation to chromium. The results ranged between 22.40-395.73 mg·kg^{-1} (Table 2, Fig. 4). Three of all analysed samples showed standard exceedances, whereas one of them oscillated on the edge of the permissible value (Table 2). The content of chromium is strongly correlated with a type of soil – formations which contain more silt and clay fractions indicate the higher concentration of this element (Kołodziejczyk et al., 2011; Elbagermi et al., 2013; Salah et al., 2013). The analysed soil samples are rich in silt and clay fractions (23-54%), what facilitates its higher concentration as well.

Nickel and copper belong to the elements whose enrichment in the soils of the Białogoński Pond is the least in comparison to all analysed heavy metals. The total content of nickel oscillated at the level of 21.3-103.1 mg·kg^{-1} (Table 2. Fig. 5), whereas its permissible value was exceeded in one of the analysed samples.

In the case of the content of copper, the results of analyses ranging between 14.8-177.53 mg·kg^{-1} (Table 2. Fig. 6) reveal the abnormal values in two samples. Copper in soil environment is precipitated in the form of weakly mobile sulphides, sulphates and carbonates (Elbagermi et al., 2013). The risk of activating copper ions, which is generally considered to be a weak migrant, is thus less probable.

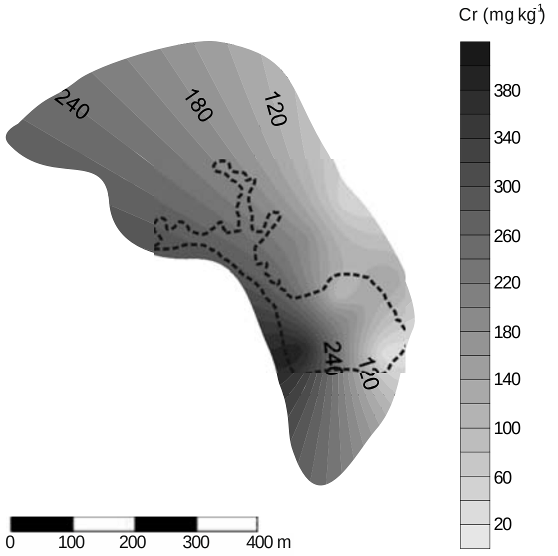

Figure 4. Spatial variability of the content of chromium (mg·kg^{-1}) in the study area

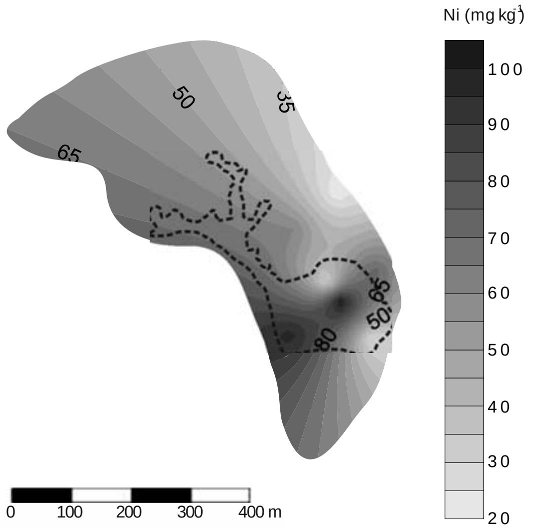

Figure 5. Spatial variability of the content of nickel (mg·kg^{-1}) in the study area

The results of studies concerning heavy metal deposition in the Białogoński Pond in Kielce can be referred to studies on the soil environment state of other Polish and world cities (Wei & Yang, 2010; Xia et al., 2011; Sudip et al., 2011; Chen & Xia, 2010; Chudecka, 2013; Elbagermi et al., 2013; Hu et al., 2013; Obeidy & Mashhadi, 2013; Salah et al., 2013). As they show, the obtained values in the range of Pb, Cr and Zn are much higher than the values reported not only for urban soils of Edinburgh, Szczecin, Bagdad, Beijing, and Hong Kong, but also for those noted by Świercz et al. (2011) for urban soils analysed around twenty petrol stations in Kielce. Nowadays, the high concentrations of some elements in the alluvia of the Pond do not pose a threat; however, the processes occurring in natural environment are variable in character.

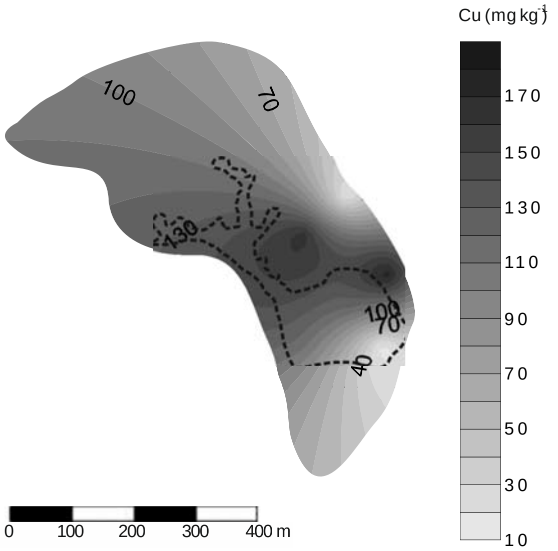

Figure 6. Spatial variability of the content of cooper (mg·kg^{-1}) in the study area

When the pH value or the content of organic carbon decreases, the solubility of heavy metal compounds clearly increases (Bhattacharya et al., 2013). Such situation may occur in the study area periodically, especially during retention of snowmelt water acidified by sulphur compounds deriving from stack emissions. The high values of $pH_{KCl} > 6.15$ observed in the analysed samples are a factor that buffers the mobility of metals in the soil. In these conditions, with substantial content of soil humus (Table 1), the solubility of elements' chemical bonds decreases and the sorption on soil colloids increases (Elbagermi et al., 2013, Obeidy & Mashhadi, 2013).

The groundwater quality tests conducted over several years in the holes of the nearby "Nałęczów" Hydrologic Station of the Polish Geological Institute in Kielce and wells of the Kielce-Białogon drinking water intake show that the reaction of water in the Quaternary sands varies in the range of 6.0-7.0, and oscillates at the level of 7.0-8.0 in the lower lying Middle-Upper Devonian limestones (Świercz & Prażak, 2014). This fact explains, *inter alia*, why heavy metals deposited in soils in the close vicinity of the former Alexander's Metalworks did not contaminate water in the nearby wells of the Kielce-Białogon municipal drinking water intake. The conducted correlation analyses (Table 3) indicated significant relationships between the content of heavy metals and the pH value as well as the organic matter content and carbonates.

Table 3. Significant correlation coefficients for selected pairs of variables

Correlations for particular pairs of variables	Correlation coefficient with p=95%
pH_{KCl} - C_{org}	0.607
pH_{KCl} - $CaCO_3$	0.512
C_{org} - $CaCO_3$	0.676
Cr-Cu	0.505
Cr-Ni	0.802
Cr-$pH_{(KCl)}$	0.711
Cr-C_{org}	0.591
Ni-$CaCO_3$	0.557
Cu-Ni	0.559
Cu-$pH_{(KCl)}$	0.674
Ni-Zn	0.506
Ni-$pH_{(KCl)}$	0.807
Ni-$CaCO_3$	0.795
Zn-$pH_{(KCl)}$	0.608
Zn-C_{org}	0.514
Zn-$CaCO_3$	0.550
Zn-(S1)	0.717

The above-mentioned relationships may indicate the common source of origin for contamination. Similar relationships among elements from the group of heavy metals concerning soils in urban areas were also pointed out in other studies (Jumbe & Nandini, 2009).

The reference of the obtained values of heavy metals to the archival studies shows a slight variation of the analysed parameters. The increase was observed in the case of maximum values: for Pb (noticeable increase from 1143 $mg{\cdot}kg^{-1}$ to 1428 $mg{\cdot}kg^{-1}$), Zn (noticeable increase from 1287 $mg{\cdot}kg^{-1}$ to 1646 $mg{\cdot}kg^{-1}$) as well as Cr (noticeable increase from 138 $mg{\cdot}kg^{-1}$ to 396 $mg{\cdot}kg^{-1}$). The soil enrichment in Ni and Cu is permanent in character. The obtained minimum values for all elements coincide with the values from the archival studies (Świercz & Prażak, 2014).

The assessment of the contamination degree of the study area was conducted using some geochemical indices, such as the geoaccumulation index (I_{geo}), the contamination factor (CF) as well as the accumulation index (AI) (Table 4). Moreover, adding up the particular values of CF was used to determine the contamination degree (C_{deg}).

The calculated values of I_{geo} show slight variations. The highest class of land contamination was indicated for lead – 14.4% of the analysed samples reached the index value of >3 (contamination in the range from moderate to strong). More than 2/3 of the analysed samples showed the moderate soil contamination with lead. The moderate contamination was also observed in the case of zinc (100% of samples) as well as copper (71.4%). The condition 0 <Igeo <1, which determines the soil as "uncontaminated to moderately contaminated", was fulfilled with regard to nickel (100%) and partially copper (28.6%), chromium (71.4%), and lead (14.3%). Chromium is the only one among the analysed heavy metals for which geoaccumulation index indicates lack of soil contamination (28.6%).

The values of CF clearly demonstrate the strong soil contamination in the study area with the majority of analysed heavy metals (CF range of 15.03 - 86.30). The contamination was determined as significant only in the case of Cr (5.63). The distribution tendencies coincide with the obtained values of I_{geo}, which also prove the domination of Pb and the least influence of Cr on the contamination degree of the study area. The sum of all calculated values of CF determines the contamination degree (C_{deg}) which in the case of the analysed soils of the Białogoński Pond adopts the range of <32, what means that the area is highly contaminated. The anthropogenic enrichment of the study area in heavy metals is confirmed by the high values of AI: Cr (3.98), Cu (10.9), Ni (5.13), Pb (59.6), Zn (32.5). Similarly with regard to other geochemical indices, the highest degree of enrichment in relation to the background was observed in the case of Pb (Table 4).

The high content of heavy metals in the bottom sediments was also pointed out by other authors (Barbusiński & Nocoń, 2013, Bąk at al., 2013). It was demonstrated that the enrichment of the area of the former Białogoński Pond in heavy metals is a couple or even several times higher than the enrichment of bottom sediments of reservoirs or streams which were also previously subjected to anthropopressure from municipal sources.

Table 4. Classification of the contamination degree of the analysed soils

	Cr	Cu	Ni	Pb	Zn
Class	Geoaccumulation index I_{geo} (% of samples)				
0	28.6	-	-	-	-
1	71.4	28.6	100	14.3	-
2	-	71.4	-	71.4	100
3	-	-	-	14.3	-
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
	Contamination factor CF				
Category	Significant contamination	Very strong contamination			
Accumulation index AI					
	(3.98)	(10.9)	(5.13)	(59.6)	(32.5)

Such environmental state of the soils of the Białogoński Pond shows the accumulated and long-term deposition of heavy metals, which was also directly affected by pollutants emitted during the past activity of the Metalworks.

4. CONCLUSIONS

The results of conducted analyses confirmed the contamination of the study area with heavy metals, as indicated in the archival studies, which still remain at the similarly high level. The origin of metal deposition dates back to the activity of the Alexander's Metalworks and destructive impact of contaminated waters of the River Bobrza.

The analysis of the scale of soil contamination using such geochemical indices as I_{geo}, CF, C_{deg}, and AI proved the contamination of the analysed soils with heavy metals, among which Pb and Zn have the largest contributions. In these cases, the geochemical background values were exceeded even several dozen times. The exceedances of the permissible values specified in the Ordinance of the Ministry of Environment (Journal of Laws of 2002, No. 165, item 1359) were observed with regard to all analysed elements. The exceedances were the largest and comprised all and six of the analysed samples in relation to Zn and Pb, respectively.

The analysed mineral-organic and organic formations developed from the alluvia and bottom sediments of the former water reservoir are characterized by the high content of silt and clay fractions, the pH value in the range from slightly acid to weakly alkaline as well as the high content of organic carbon and carbonates, what significantly reduces the bioavailability of heavy metals to plants. Heavy metals are characterized by a very long period of persistence in environment. A potential disturbance of the existing balance in the basin of the Pond by changing some environmental conditions may result in their inclusion into the biological circulation as well as their leaching and further migration to underground waters. With regard to the direct vicinity of the municipal drinking water intake, this area requires conducting continuous monitoring which will provide reliable information about any changes occurring in the area of the historical Białogoński Pond.

REFERENCES

Al-Farraj A.S., Al-Sewailem M., Aly A., Al-Wabel M. & El-Maghraby S., 2013. *Assessment and Heavy Metal Behaviors of Industrial Waste Water: A Case Study of Riyadh City, Saudi Arabia*. Proceedings of the International Academy of Ecology and Environmental Sciences, 3(3), 266-277.

Barbusiński K. & Nocoń W., 2013. *Heavy Metal Compounds in the Bottom Sediments of the River Klodnica. Environmental Pollution Control*, 33 (1), 13-17 (In Polish).

Bąk Ł., Górski J., Rabajczyk A. & Szwed M., 2013. *Content of Heavy Metal Compounds in the Bottom Sediments of the Suchedniów Water Reservoir*. Proceedings of Opole, 7 (1), 287-294 (In Polish).

Bhattacharya T., Chakraborty S., Tuteja D. & Patel M., 2013. *Zinc and Chromium Load in Road Dust, Suspended Particulate Matter and Foliar Dust Deposits of Anand City, Gujarat*. Open Journal of Metal, 3, 42-50.

Chen X. & Xia X., 2010. *Heavy Metal Concentrations in Roadside Soils and Correlation with Urban Traffic in Beijing, China*. Journal of Hazardous Materials, 181, 640-646.

Chudecka J., 2013. The Content of Zn, Cu, Pb and Salinity of Soils of Green Areas Located in the Center of Szczecin. Folia Pomer. Univ. Technol. Stetin. Agric., Aliment., Pisc., Zootech, **304(26)**, 5-12,

Czarnowska K., 1995. *Soils and Plants in an Urban Environment*. Advances of Agricultural Sciences

Problem Issues. 418, 11-115, (In Polish).

Czarnowska K., 1996. The Total Heavy Metal Content in Parent Rocks as the Geochemical Background of Soils. Soil Science Annual, 47, 43-50 (In Polish).

Du Y., Gao B., Zhou H., Ju X., Hao H. & Yin S., 2013. *Health Risk Assessment of Heavy Metals in Road Dusts in Urban Parks of Beijing, China*. Procedia Environmental Sciences, 18, 299-309.

Elbagermi M., Edwards H. & Alajtal A. 2013. *Monitoring of Heavy Metals Content in Soil Collected from City Centre and Industrial Areas of Misurata, Libya*. International Journal of Analytical Chemistry, 1-5.

Faiz Y., Tufail M., Tayyeb Javed M., Chaudhry M.M. & Siddique N., 2009. *Road dust pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan*. Microchemical Journal, 92, 186-192.

Guo Y., Feng H., Chen CH., Jia CH., Xiong F. & Lu Y., 2013. *Heavy Metal Concentrations in Soil and Agriculturial Products Near an Industrial District*. Pol. J. Environ. Stud, **5**, 1357-1362.

Hu Y., Liu X., Bai J., Shih K., Zeng E. & Cheng H., 2013. *Assessing Heavy Metal Pollution in the Surface Soils of a Region that Had Undergone Three Decades of Intense Industrialization and Urbanization*. Environ Sci Pollut Res, 20. 6150-6159.

Jumbe A.S. & Nandini N. 2009. *Heavy Metals Analysis and Sediment Quality Values in Urban Lakes*. Amer. J. Environ. Sci, 5(6), 678-687.

Kabata-Pendias A. & Pendias H., 2010. *Trace Elements in Soils and Plant*. CRC Press, 432 p.

Kołodziejczyk K., Tomaszewska K. & Pieprzka R., 2011. *The Content of Chromium in Organic Soil Horizons in the Legnica Region*. Environmental Protection and Natural Resources, 48, 204-209 (In Polish).

Lis J. & Pasieczna A., 1995. *Geochemical Atlas of Poland* 1:2500 000. Polish Geological Institute, Warsaw (In Polish).

Lenartowicz J. & Bartkowiak A., 2012. *Diagnosis of the Content of Selected Heavy Metals in the Soils of the Pałuki Region against their Enzymatic Activity*. Archives of Environmental Protection, 39, 23-32.

Obeidy A. & Mashhadi A., 2013. *Heavy Metal Contaminations in Urban Soil within Baghdad City, Iraq*. Journal of Environmental Protection, 4, 72-82.

Olafisoye O.B., Adefioye T. & Osibote O.A. 2013. *Heavy Metals Contamination of Water, Soil, Plants around an Electronic Waste Dumpsite*. Pol. J. Environ. Stud, 5, 1431-1439.

Ostrowska A., Gawliński S. & Szczubiałka Z., 1991. *Methods of Analysis and Evaluation of Properties of Soils and Plants*. EPI Catalogue: Warsaw, 1991 (In Polish).

Saint-Laurent D., Gervais-Beaulac V., Baril F., Matteau C. & Berthelot J.S., 2013. *Spatial Variability of Heavy Metal Contamination in Alluvial Soils in Relation to Flood Risk Zones in Southern Québec, Canada*. Air, Soil and Water Research, 6, 1-13.

Salah E., Turki A. & Noori S., 2013. *Heavy Metals Concentration in Urban Soils of Fallujah City, Iraq*. Journal of Environment and Earth Science, 3(11), 100-112.

Sammel A. & Niedźwiecki E., 2006. *The Content of Macro- and Microelements in Muckous Soils within the Odra Floodplain*. Water-Environment-Rural Areas, 6 (2), 293-304 **(**In Polish).

Sudip K. P., Wallis S.G. & Scott A., 2011. *Assessment of Heavy Metals Emission from Traffic on Road Surfaces*. Cent. Eur. J. Chem, 9, 314-319.

Szalińska E., Koperczak A. & Czaplicka-Kotas A., 2010. *Heavy Metals in the Bottom Sediments of Lake Goczalkowickie Tributaries*. Environmental Protection, 32 (1), 51-56 (In Polish).

Świercz A., 2010. Cultural Heritage (In) A. Świercz (ed) *The Monograph of the Chęcińsko-Kielecki Landscape Park. Jan Kochanowski University*. KTN Publishing House: Kielce, 319-343 (In Polish).

Świercz A., Stolicka K. & Sykała E., 2011. *Assessment of the Quality of Lands Adjacent to Petrol Stations in Kielce*. Scientific and Didactic Equipment, 4, 43-90.

Świercz A. & Prażak J., 2014. *The Pollution of Heavy Metals Soil-Aquatic Environment in the Former Alexander Smelter Area in Kielce*. Geological Bulletin, 457, 87-102.

The Ordinance of the Ministry of Environment of 9th September 2002. Journal of Laws of 2002, No. 165, item 1359 (In Polish).

Wei B. & Yang L., 2010. *A Review of Heavy Metal Contaminations in Urban Soils, Urban Road Dusts and Agricultural Soils from China*. Microchemical Journal, 94, 99-107.

Xia X., Chen X., Liu R. & H. Liu., 2011. *Heavy Metals in Urban Soils with Various Types of Land Use in Beijing, China*. J. Hazard. Mater, 186, 2043-2050.

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