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**TOTAL CONTENT OF MERCURY  
IN ARABLE SOILS IN THE VICINITY  
OF LAFARGE-CEMENT POLAND SA PLANT  
("KUJAWY" BIELAWY)**

**CAŁKOWITA ZAWARTOŚĆ RTECI W GLEBACH UPRAWNYCH  
W OTOCZENIU ZAKŁADÓW LAFARGE-CEMENT POLSKA SA,  
ZAKŁAD „KUJAWY” W BIELAWACH**

**Abstract:** In the area of Kujawy-Pomerania province in Bielawy town the limestone is exploited which is the main resource in the production process carried out by Lafarge-Cement Plant. The alkaline reaction of emitted dusts caused excessive alkalinisation of the surrounding soils which are also simultaneously contaminated by trace metals (including mercury).

The aim of the study was to assess the impact of Lafarge-Cement Poland SA Plant ("Kujawy" Bielawy) activity on total content of mercury in arable soils in the vicinity of the plant.

As a research material served arable soil gathered at various distances from the plant. Samples were collected from surface (0–20 cm) and subsurface (20–40 cm) horizons. Moreover samples were also collected from two soil profiles classified as Haplic Luvisol (Piechcin) and Haplic Podzol (Krotoszyn). The total content of mercury was determined in solid samples by atomic spectrometry method using AMA 254 mercury analyser. The results were as follows: in the 0–20 cm horizons within the range of 11.20–27.09  $\mu\text{g} \cdot \text{kg}^{-1}$  and in 20–40 cm horizons – from 11.53 to 26.48  $\mu\text{g} \cdot \text{kg}^{-1}$ . In profile samples, the total mercury content was within the range of 3.89–27.15  $\mu\text{g} \cdot \text{kg}^{-1}$ . In the Haplic Luvisol the highest total content of Hg was detected at the C horizon, the lowest however at Eet horizon. In the case of the Haplic Podzol, the highest concentration of Hg was found in surface and subsurface horizons. The assessment of the total mercury content in soils surrounding Lafarge-Cement Poland SA Plant, did not confirm the influence of cement dusts on mercury contamination.

**Keywords:** soils, alkalinisation, mercury, dusts

From among various substances which have negative impact on the environment, mercury compounds are worthy of interest. This metal is transported from the sources mainly into the atmosphere, and from there it can cover large distances in the form of

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gas, dust or aerosols [1, 2]. In Poland the main sources of mercury are: combustion of fossil fuels, disposal of fluorescent lamps and batteries, production and application of mercury fungicides as well as the cement production [2–4].

Natural level of mercury content in environment is several times lower than the amounts initiated in anthropogenic way [2, 5, 6], that is why it is necessary to monitor the content of this metal in arable soils surrounding such plants as Lafarge.

In the area of Kujawy-Pomerania province in Bielawy town the limestone is exploited which is the main resource in the production process carried out by Lafarge-Cement Plant. The alkaline reaction of emitted dusts caused excessive alkalisation of the surrounding soils which are also simultaneously contaminated by trace metals, including mercury.

The aim of the study was to assess the impact of Lafarge-Cement Poland SA Plant (“Kujawy” Bielawy) activity on total content of mercury in arable soils in the vicinity of the plant.

## Material and methods

As a research material has served arable soil samples gathered at various distances from the Lafarge plant. The samples were taken from surface (0–20 cm) and subsurface (20–40 cm) horizons and additionally collected from two soil profiles classified as Haplic Luvisol (Piechcin) and Haplic Podzol (Krotoszyn) according to World Reference Base for Soil Resources.

In the dried and sieved material (diameter below 2 mm) the following soil properties were determined: pH in H<sub>2</sub>O and in 1 mol · dm<sup>-3</sup> KCl solution, the total content of organic carbon and the content of CaCO<sub>3</sub> using commonly applied methods in soil science. Soil texture was determined according to the Casagrande areometric method, modified by Proszynski. Interpretation of the texture results was performed according to USDA classification. The total content of mercury was determined in solid samples with atomic spectrometry method using AMA 254 mercury analyser [7]. The analysis was triplicated and the results are an arithmetic mean (SD below 5 %).

The accumulation factor was also calculated as the ratio of Hg content in genetic horizon to its content in parent material.

## Results and discussion

The texture of the analysed soils (Table 1) allows to categorise them as light soils in the surface (0–20 cm) and subsurface horizons (20–40 cm) in which the texture of loamy sand was found (USDA). The exception was found for the samples taken from Wolice I and Wolice II, where in both places sandy loam occurred (Table 1). Profile samples were characterised by loamy sand, except for the Piechcin profile (Table 2) where the C horizon was classified as sandy loam (USDA).

Depending on the sampling site, pH varied within the range of pH<sub>H<sub>2</sub>O</sub> 5.88–8.17 and pH<sub>KCl</sub> 5.17–7.68 (Table 1). Alkaline pH was found in surface and subsurface samples in Sadlogoszcz (pH<sub>KCl</sub> 7.58 and 7.68) and in Piechcin (pH<sub>KCl</sub> 7.15 and 7.02) located

closest to the plant. Moreover, alkaline pH also occurred in surface samples ( $\text{pH}_{\text{KCl}}$  7.57) and subsurface samples ( $\text{pH}_{\text{KCl}}$  7.60) taken from the site in Dabrowka Chelminska located beyond the plant impact area, and which could be the result of lime application. However, in the profile samples the pH is quite levelled (Table 1). In the Haplic Luvisol the lowest value was found in the Bt horizon ( $\text{pH}_{\text{H}_2\text{O}}$  5.99 and 5.89), whereas in the Haplic Podzol – at the horizon of parent material ( $\text{pH}_{\text{H}_2\text{O}}$  6.29 and 6.29).

Table 1

## Physicochemical properties of soils

Sampling site	Depth [cm]	Share of fraction [%] with diameter [mm]			Organic C [g · kg <sup>-1</sup> ]	CaCO <sub>3</sub>	pH	
		2–0.05	0.05–0.002	< 0.002			H <sub>2</sub> O	KCl
Piechcin	0–20	79	6	15	4.1	n.d.*	7.32	7.15
	20–40	77	7	16	4.8	n.d.	7.32	7.02
Sadłogoszcz	0–20	85	10	5	5.2	102	7.98	7.58
	20–40	83	10	7	5.4	93	8.17	7.68
Krotoszyn	0–20	77	14	9	4.7	n.d.	6.28	5.74
	20–40	79	10	11	1.7	n.d.	6.44	5.88
Wolice I	0–20	63	20	17	4.5	n.d.	6.46	5.83
	20–40	60	21	19	5.2	n.d.	6.49	5.59
Wolice II	0–20	64	20	16	7.8	n.d.	6.43	5.74
	20–40	64	21	15	5.2	n.d.	6.40	5.56
Mamlicz	0–20	83	19	8	5.1	n.d.	5.88	5.21
	20–40	74	8	8	3.5	n.d.	6.20	5.17
Dabrowka Barcinska	0–20	78	15	9	16.0	51	7.64	7.57
	20–40	78	13	9	7.7	16	7.87	7.60

\* n.d. – not detected.

The content of organic carbon in surface horizons ranged from 4.1 to 16.0 g · kg<sup>-1</sup>, and in the humus horizons of the profile samples equalled to 4.5 g · kg<sup>-1</sup> in Haplic Podzol and 6.6 g · kg<sup>-1</sup> in Haplic Luvisol. These are typical values for the soils of this region [9]. In the majority of the studied samples no presence of CaCO<sub>3</sub> was detected, except for two sampling sites where CaCO<sub>3</sub> was found in surface and in subsurface horizons, 10.2 % and 5.1 % as well as 9.3 % and 1.6 %, respectively. In profile samples (Table 2) however, only in the Piechcin profile was the content of CaCO<sub>3</sub> detected in surface and subsurface horizons, and equalled to 5.9 % and 5.0 %, respectively. The parent material of the soils in the vicinity of the plant does not contain CaCO<sub>3</sub>, hence its presence in surface horizons is of anthropogenic origin.

The total content of Hg in soils layers varied in similar ranges as follows: in the 0–20 cm horizons from 11.20 to 27.09 μg · kg<sup>-1</sup> and in 20–40 cm horizons – from 11.53 to 26.48 μg · kg<sup>-1</sup> (Table 3).

Table 2

## Physicochemical properties of soils

Sampling site	Horizon	Depth [cm]	Share of fraction [%] with diameter [mm]			Organic C [g · kg <sup>-1</sup> ]	CaCO <sub>3</sub> [%]	pH	
			2–0.05	0.05–0.002	< 0.002			H <sub>2</sub> O	KCl
Piechcin	Ap	0–38	84	10	6	4.1	n.d.*	6.26	6.44
	Eet	38–93	93	2	5	4.8	n.d.	5.21	5.39
	Bt	93–120	81	7	12	5.2	n.d.	5.99	5.89
	C	> 120	68	16	16	5.4	n.d.	6.21	6.29
Krotoszyn	Ap	0–35	89	6	5	4.7	5.9	6.22	6.40
	Ees	35–50	88	6	6	1.7	5.0	6.02	6.51
	Bhfe	50–120	96	3	1	4.5	n.d.	5.99	5.89
	C	120–135	84	5	11		n.d.	6.29	5.29

\* n.d. – not detected.

Table 3

## Total extractable Hg content in soils

Sampling site	Depth	
	0–20 cm	20–40 cm
	Hg content [µg · kg <sup>-1</sup> ]	
Piechcin	16.87	18.02
Sadlogoszcz	11.20	11.53
Krotoszyn	21.93	13.98
Wolice I	23.79	25.58
Wolice II	27.09	26.48
Mamlicz	15.80	14.36
Dabrowka Barcinska	21.58	23.43

These values were quite levelled and did not confirm higher content of this metal in surface samples, as observed by other researchers [9, 10]. Higher total Hg content was found in samples rich in clay fraction ( $\varnothing < 0.002$  mm), which should be related to this metal being bound by clay minerals [9, 10].

In profile samples (Table 4), the total mercury content was within the range of 3.89–27.15 µg · kg<sup>-1</sup>. In Haplic Luvisol the highest total content of Hg was detected at the C horizon, the lowest however at Eet horizon, which could result from its lessivage and binding by mineral colloids [11]. Accumulation of Hg in deeper horizons, with lower humus content and higher clay fraction content, may lead to absorption of Hg in exchangeable form [12]. In Haplic Podzol the highest concentration of Hg was found in surface horizons, which could result from binding this metal by organic matter [9, 10].

Table 4

Total Hg content in soil profiles (SD &lt; 5 %)

Sampling site	Horizon	Depth [cm]	Hg [ $\mu\text{g} \cdot \text{kg}^{-1}$ ]	Accumulation factor
Piechcin	Ap	0–38	11.51	0.52
	Eet	38–93	3.89	0.17
	Bt	93–120	12.01	0.54
	C	> 120	22.25	
Krotoszyn	Ap	0–35	26.07	1.66
	Ees	35–50	27.15	1.73
	Bhfe	50–120	4.14	0.26
	C	> 120	15.66	

In order to illustrate the sources of Hg pollution of the analysed soils, Hg accumulation factors in soil profile were calculated (Table 4) (the ratio of Hg content in genetic horizon to its content in parent material). In Haplic Luvisol these factors were highest in Bt (0.54) and Ap horizons (0.52), whereas in the Haplic Podzol, in Ees (1.73) and Ap horizons (1.66). The values of these factors in surface horizons of the Haplic Podzol, indicate significant participation of anthropogenic Hg in the total content of this element [13].

The average content of Hg in the analysed soils is below its natural content in the soils of Poland, which is within 50–300  $\mu\text{g} \cdot \text{kg}^{-1}$  [4] and is also lower than its permissible level in soils used for ecological cultivation (1000  $\mu\text{g} \cdot \text{kg}^{-1}$ ) and the borderline level for agricultural areas (2 mg  $\cdot \text{kg}^{-1}$ ) [13, 14]. That is why the analysed soils were qualified as non contaminated by this metal.

## Conclusions

The texture of the analysed soils allows to classify them as light soils, with the content of organic carbon typical for these soils. The pH varied, depending on location of the sampling sites. Alkaline pH was found in surface and subsurface horizons of samples located closest to the plant. The detected  $\text{CaCO}_3$  in several samples is of anthropogenic origin.

Total content of Hg in soils was as follows: in 0–20 cm horizons it ranged between 11.20 and 27.09  $\mu\text{g} \cdot \text{kg}^{-1}$  and in 20–40 cm horizons – 11.53 and 26.48  $\mu\text{g} \cdot \text{kg}^{-1}$ . In profile samples, the values ranged between 3.89 and 27.15  $\mu\text{g} \cdot \text{kg}^{-1}$ . The content allows to qualify the soils as non-contaminated.

The assessment of total mercury content in soils in the vicinity of the plant in Bielawy did not reveal the influence of cement dusts on Hg contamination in soils of the area.

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### CAŁKOWITA ZAWARTOŚĆ RTĘCI W GLEBACH UPRAWNYCH W OTOCZENIU ZAKŁADÓW LAFARGE-CEMENT POLSKA SA, ZAKŁAD „KUJAWY” W BIELAWACH

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**Abstrakt:** Celem podjętych badań była ocena wpływu Zakładów Cementowo-Wapienniczych „Lafarge” Zakład w Bielawach na całkowitą zawartość rtęci w glebach uprawnych w okolicy Zakładów.

Materiał badawczy stanowiły próbki gleb uprawnych, zlokalizowane w różnej odległości od Zakładów, które pobrano z dwóch głębokości oraz próbki pochodzące z dwóch profili glebowych, które zaklasyfikowano (wg PTG) jako: glebę płąwą typową (Piechcin) i bielicową właściwą (Krotoszyn). Całkowitą zawartość rtęci oznaczono metodą spektrometrii atomowej z wykorzystaniem analizatora AMA-254.

Badane gleby zaliczono do piasków gliniastych (PN-R-04033). Odczyn gleb był zróżnicowany w zależności od lokalizacji punktu badawczego –  $pH_{KCl}$  wahało się od 5,21 do 7,68. Zawartość C-organicznego mieściła się w zakresie 4,1–16,0 g · kg<sup>-1</sup>. W większości badanych próbek nie stwierdzono obecności CaCO<sub>3</sub>, z wyjątkiem dwóch punktów badawczych, w których CaCO<sub>3</sub> występował w poziomach wierzchnich, odpowiednio 10,2 % i 5,1 % oraz 9,3 % i 1,6 %. Natomiast jedynie w próbkach profilowych z Krotoszyna stwierdzono obecność CaCO<sub>3</sub> w wierzchnich poziomach: 5,9 i 5,0 %.

Całkowita zawartość Hg w glebach kształtowała się następująco: w poziomach 0–20 cm mieściła się w zakresie 11,20–27,09 µg · kg<sup>-1</sup>, a w poziomach 20–40 cm – 11,53–26,48 µg · kg<sup>-1</sup>. W próbkach profilowych, zawartości te wahały się w zakresie 3,89–271,50 µg · kg<sup>-1</sup>. W większości badanych próbek większe całkowite zawartości Hg występowały w poziomach powierzchniowych, co może wynikać z zaabsorbowania tego metalu przez substancję organiczną i minerały ilaste. Średnia zawartość Hg w badanych glebach mieściła się poniżej zawartości naturalnej tego pierwiastka w glebach Polski, która wynosi 0,05–0,30 mg · kg<sup>-1</sup>. Ocena całkowitej zawartości Hg w glebach z okolicy Zakładów w Bielawach nie wykazała wpływu pyłów cementowych na zanieczyszczenie rtęcią okolicznych gleb.

**Słowa kluczowe:** gleba, alkalizacja, rtęć, pyły