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RELATIONS BETWEEN Pb, Zn, AND Cu CONTENT IN THE SOIL AND PLANTS OF ALLOTMENT GARDENS

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A b s t r a c t. Research was carried out in 1998 on the area of 10 allotments situated within the limits of the city of Lublin. Representative soil samples, as well as samples of white cabbage and carrot roots were collected. Content of lead, zinc, and copper were analysed in the samples. On the basis of chemical analysis, it was observed that quantities of lead and zinc were usually higher than average in the same type soils in non-polluted areas. Copper content in the soil did not exceed the average values. The natural content of metals was usually not exceeded in plants. However, samples of white cabbage taken from the "Nasza Zdobycz" and "Sygnał" allotments, where the amount of lead was higher than 1 mg kg^{-1} of dry mass were an exception.

K e y w o r d s: soil, plants, allotment gardens, heavy metals.

INTRODUCTION

Heavy metals have been used since 8,000 years BC. However, a rapid development of industry and transportation means in the 19th century caused progressing degradation of environment on vast areas as a result of pollution with those elements.

When compared to towns of Śląsk, Lublin is a weakly industrialised. However, information on the excessive air and soil pollution in this region is often announced [10,11]. Hence, studies were undertaken to determine the existing heavy metal pollution of soil and plants taken from different allotments situated within the administrative city limits, and relations between the content of heavy metals in various soil layers and in plants.

MATERIAL AND METHODS

In 1998, representative soil samples were taken from the area of 10 allotments situated in Lublin. Samples were taken with a soil auger from two layers of the

soil profile, i.e: 0-30 and 30-60 cm. Samples of white cabbage and carrot roots were also taken together with the soil samples. Content of lead, zinc, and copper was measured in the collected material. Heavy metal content in the soil was measured using the method of atomic absorption according to the Polish Standard - 92/c-04570/01 on the Varian Spectra AA 250+ apparatus. The content of Pb in plants was evaluated using the method of atomic absorption on the Perkin-Elmer apparatus, and the content of Zn in plants was calculated using the JCP-AES method. Copper was measured according to the standard mentioned above using an apparatus by Varian. Chemical analysis of the soil and plant material was carried out on the samples taken in four repetitions. Statistical elaboration was done at the Computer Centre of the Agricultural University of Lublin using the following methods: multi-factor variance analysis, the Tukey's multiple confidence intervals and correlations.

In the allotments of "Podzamcze", "Słonecznik", "Al. Warszawska", and "Słoneczne Wzgórze", the soil was described as medium carbonate, whereas in the rest of the allotments it was medium mineral. In the investigated objects soil reaction (pH in 1 n KCl) ranged from 5.8 to 7.1.

RESULTS AND DISCUSSION

Evaluation of the limit level of the harmful heavy metals content in the soil, is very difficult since it is related not only to the general content of elements but also on their availability for plants. Availability for plants depends on the soil reaction and formation of organic bonds. This is probably the source of significant differences quoted by various authors [1-3]. An average lead content in the upper layer (0-30 cm) of the investigated soil was somewhat higher than 30 mg kg^{-1} d.m., which is the limit for the non-polluted soils given by Gorlach [6]. In the lower layer of the soil profile (30-60 cm), an average amount of lead significantly decreased and was equal to 20.6 mg kg^{-1} d.m. only (Table 1). Assuming the limit level of 50 mg kg^{-1} d.m. given by Kabata-Pendias [7,8], it was observed that the soils of the following allotments showed the highest pollution with lead: the "Sygnał" (87.7 mg kg^{-1} d.m.) and the "Nasza Zdobycz" (73.6 mg kg^{-1} d.m.). The least polluted was the soil from the "Al. Warszawska" allotments (10.0 mg kg^{-1} d.m.). Analysing the lead content in plants, the highest content of that elements was found in white cabbage taken from the "Sygnał" (1.42 mg kg^{-1} d.m.) and "Nasza Zdobycz" allotments (1.13 mg kg^{-1} d.m.). The value of 0.1-1.0 mg kg^{-1} d.m. given by Wiatr *et al.* [11] was accepted as the standard of lead content in plants. This indicates that the lead content in the plants from other allotments remained within the range of the

Table 1. Reaction and average contents of Pb, Zn, and Cu in soil of allotment gardens in the area of Lublin city (mg kg^{-1} d.m.)

	Name of allotments	pH in KCl	Pb		Zn		Cu	
			A*	B**	A	B	A	B
1	Nasza Zdobycz	6.6	73.6	41.2	144.0	108.0	34.1	27.1
2	Podzamcze	6.8	48.6	35.8	335.0	196.0	31.8	24.7
3	Słonecznik	7.1	55.4	16.2	72.2	52.1	8.4	7.5
4	Al. Warszawska	6.9	10.0	8.4	30.0	29.7	7.6	7.7
5	Słoneczne Wzgórze	6.8	15.8	14.3	62.8	54.8	14.8	11.5
6	Zgoda	6.4	13.4	9.0	77.8	36.0	15.1	8.6
7	Puławski	6.2	16.8	17.5	80.9	89.2	11.0	13.6
8	Pionier	6.3	23.0	23.6	75.1	73.6	13.9	11.7
9	Sygnał	6.5	87.7	30.6	77.0	69.9	17.3	15.5
10	A. Mickiewicza	6.9	18.7	9.6	90.6	49.6	9.7	6.8
	Mean values		36.3	20.6	104.5	75.9	16.4	13.7
	LSD ($\alpha = 0.05$) allotments		13.9	8.3	18.7	12.1	10.3	7.4
	LSD ($\alpha = 0.05$) layers		-	5.3	-	6.2	-	2.3
	Variation coefficient (%)		43	35	46	38	31	24
	Coefficient of correlation between soil layers		-	0.3782^{***}	-	0.3142^{***}	-	0.2934^{***}

* 0-30 cm layer; ** 30-60 cm layer; *** significance $\alpha \leq 0.05$.

accepted standard but it underwent significant deviations and depended also on the kind of plant, which is also confirmed by the research of Kowalska-Pyłka [9]. Diffe-rences in the lead contents of white cabbage and carrot (allotments: "Nasza Zdobycz", "Podzamcze", "Pionier", "Sygnał") indicated a possibility of high lead absorption from air by the vegetables with edible upper parts.

According to Galler [4] and Gambuś [5], agricultural soils that are not exposed to heavy metal pollution contain zinc in the amount of 5-100 mg kg^{-1} d.m. Brummer [1] claimed that there is toxic activity of zinc already when its content is 100-500 mg kg^{-1} d.m. of soil. The investigated samples presented a serious danger of an excessive zinc level in both soil horizons of the "Nasza Zdobycz" (144-108 500 mg kg^{-1} d.m.) and "Podzamcze" allotments (335-196 500 mg kg^{-1} d.m.). Generally speaking, there is much less zinc in the lower layer than in the arable layer. However, it is not always true (Table 1). Assuming Wiatr *et al.* [11] that the natural content of Zn in plants is 15-80 500 mg kg^{-1} d.m., no surplus was observed in any of the investigated plants (Table 2). However, significant differences in the content of zinc in the plants from different allotments, as well as significantly lower zinc contents in carrot than in white cabbage was found.

Table 2. Average contents of Pb, Zn, and Cu in white cabbage (*Brassica napus* var. *capitata*) and in carrot roots (*Daucus carota*) collected in allotment gardens in the area of Lublin city (mg kg^{-1} d.m.)

	Name of allotments	Pb (0.1-1.0)		Zn (15-80)		Cu (5-20)	
		X*	Y**	X	Y	X	Y
1	Nasza Zdobycz	1.13	0.62	49.1	26.6	4.4	6.3
2	Podzamcze	0.78	0.43	57.6	29.6	4.3	7.2
3	Słonecznik	0.10	0.24	17.9	14.3	3.4	5.2
4	Al. Warszawska	0.33	0.38	17.9	48.0	3.1	5.8
5	Słoneczne Wzgórze	0.46	0.38	14.5	18.3	2.6	4.8
6	Zgoda	0.25	0.58	13.8	13.3	2.6	3.9
7	Pułaski	0.17	0.22	24.5	15.3	5.9	4.3
8	Pionier	0.57	0.37	29.3	25.1	3.2	6.9
9	Sygnał	1.42	0.41	23.6	18.6	3.8	4.0
10	A. Mickiewicza	0.31	0.28	24.4	24.6	3.2	3.0
	Mean values	0.55	0.39	27.3	23.4	3.65	5.22
	LSD ($\alpha \leq 0.05$) for plants	0.11	0.13	5.6	4.5	1.2	1.3
	LSD ($\alpha \leq 0.05$) between plants	-	0.15	-	3.2	-	1.4
	Variation coefficient (%)	31.5	29.3	44.6	42.1	36.8	32.7
	Variation range	0.1-1.54	0.14-1.00	13.1-76.5	9.1-47.8	1.8-6.6	3.2-7.9
	Coefficient of correlation between	0.3214***	02745***	0.3018***	0.1958	0.1686	0.1945
	the element in soil and plant depending on soil layer	0.2836***	0.2578***	0.2315***	0.2003	0.1598	0.2013

* *Brassica napus* var. *capitata*; ** *Daucus carota*; *** significance $\alpha \leq 0.05$.

According to Kabata-Pendias [8], copper content in the light soils should not exceed 50 mg kg^{-1} d.m. Therefore, there was no excess of this element in the investigated soils. Significant differences were found in the copper contents relating to the place and depth from which soil samples were taken (Table 1). Considering the value of 5-20 mg kg^{-1} d.m. given by Wiatr *et al.* [11], the natural Cu content in plants, Cu shortage was observed in both of the investigated vegetables, especially in cabbage (Table 2). Similar results were also obtained by Turski *et al.* [10].

The calculated correlation coefficients indicated important relations between Pb, Zn, and Cu in both layers of the soil profile (Table 1). The influence of Pb and Zn content in the soil on content of these elements in the investigated plants was observed (Table 2). At the same time, it was observed that the surplus of zinc in

the soil was not necessarily accompanied by its surplus in the vegetables cultivated on these soils. Such an effect was probably related to the neutral reaction of the soil solution in the allotments of "Nasza Zdobycz" and "Podzamcze".

CONCLUSIONS

1. Excessive content of lead in the soil of the "Sygnał" and "Nasza Zdobycz" allotments was confirmed. It was followed by the excessive lead levels in white cabbage but did not affect the allowable limit in carrot. That might have been caused by the contact of cabbage leaves with polluted air.

2. Zn content that exceeded the standards was found in the "Podzamcze" and "Nasza Zdobycz" allotments. However, it did not result in the excessive levels of this element in the investigated vegetables, which might have been related to poor zinc uptake by plants in the conditions of neutral soil reaction.

3. The soil layer of 30-60 cm contained significantly less lead, zinc, and copper than the arable layer (0-30 cm). However, important relations between the investigated elements were observed in both soil layers.

4. Significant correlations between the content of lead and zinc in the soil, and in white cabbage and carrot were proved.

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