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LEVEL OF SOIL POLLUTION BY HEAVY METALS IN SELECTED ORCHARDS OF WIELKOPOLSKA

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A b s t r a c t. The content of Cd, Pb, Cu, Ni and Cr was analysed in the soil layers of 0-20 and 21-40 cm originating from four fruit growing farms localised in the area of Wielkopolska. The analyses have shown that the content of all the investigated heavy metals both in the arable soil layer and in the subsoil, was lower than their natural content in the Polish soils. The phenomenon of decreasing Cd, Cu and Pb content, and increasing Ni values in the deeper soil layers as compared to the arable layer was observed.

K e y w o r d s: heavy metals, soil, washing out, pollution, orchards.

INTRODUCTION

Soil is very important in the environment decisive for plant growth and development. Soil provides a substrate in which plant roots are seated and supplies plants with water and nutritive mineral components. With increasing anthropopressure on the natural environment, there can be heavy metals among the chemical compounds taken up by plant roots. Accumulation of metals in the soil and in consequence in the plants, particularly in connection with other types of gaseous pollution can lead to a decrease in plant yields even by as much as 30% [9]. The presence of heavy metals in the soil, even in the amounts lower than the permissible limit, stops the activity of soil microorganisms, especially those that absorb atmospheric nitrogen [10].

The object of this work was to identify the actual content of five heavy metals: cadmium, lead, copper, nickel and chromium in two soil layers: an arable layer and subsoil originating from four fruit growing farms in the area of Wielkopolska, and to determine the differences occurring in the content of heavy metals at various levels of the soil profile.

MATERIALS AND METHODS

Studies on the content of five heavy metals were carried out in the soil samples taken from four fruit growing farms in Wielkopolska at the following sites: Opalenica, Przybroda, Komorzewo, and Białężyn. Separate analyses for the arable layer (0-20 cm) and the subsoil (21-40 cm) were carried out using an atomic absorption spectrophotometer and the flame technique in the solutions obtained by etching soil samples with a concentrated nitric acid (HNO_3) and perchloric acid ($HCLO_4$).

Additionally, in order to supplement the results of the above analyses, in the arable soil layer and in the subsoil, humus content, pH and granulometric composition were also determined.

Humus content was determined by the weighing method from a decrease in the sample mass during its combustion in a muffle furnace at 550 ^oC.

Soil acidity was determined by the potentiometric method. H_2 concentration was identified in the soil suspension in the potassium chloride solution (pH_{KCl}).

Granulometric composition was measured with the use of an areometer by measuring density of the soil suspension in water.

RESULTS AND DISCUSSION

The results obtained by the numerous authors who investigated heavy metal toxicity indicate that one of the factors deciding about phytotoxicity is soil pH. With an increase of the soil pH, phytoassimilation of metals decreases [4]. As shown by Szteke *et al.* [13], even with a high content of Cd in the soil (regarded as one of the most toxic elements) with a simultaneous increase of the soil pH, plants uptake of cadmium is twice lower than with a lower Cd content but with low pH. Decreases in heavy metal phytotoxicity together with a decrease in the soil pH, depend both on the plant species and on the particular metal. The impact of soil acidity is the highest in the case of Zn uptake by plant roots. Acidity limits also the Cu uptake but to a lesser degree. On the other hand, for Cd and Ni, plant species is decisive [5].

Soil analyses of the arable layers and the subsoil originating from the four selected fruit growing farms in Wielkopolska show that except for the farm in Przybroda (soil pH 6.6-6.8), acid and slightly acid soils with the pH level from 4.4 to 5.8 can be found (Tables 1 and 2).

Table 1. Content of humus and soil pH on the area of four fruit growing farms of Wielkopolska

Site	Soil layer (cm)	Soil acidity		Humus content (%)
		pH KCl	Reaction	
Białężyn	0-20	4.9	acid	1.50
	21-40	4.4	very acid	0.82
Komorzewo	0-20	5.8	slightly acid	1.97
	21-40	5.8	slightly acid	0.57
Opalenica	0-20	5.8	slightly acid	1.87
	21-40	6.3	slightly acid	1.45
Przybroda	0-20	6.8	neutral	1.45
	21-40	6.8	neutral	0.88

Table 2. Granulomertic soil composition in the area of four fruit growing farms of Wielkopolska

Site	Soil layer (cm)	Content of mechanical fraction (ϕ mm), (%)			Soil kind	Soil texture
		1.0-0.1	0.1-0.02	<0.02		
Białężyn	0-20	63	23	14	pgl	light
	21-40	66	23	11	pgl	light
Komorzewo	0-20	42	37	21	gpp	medium-heavy
	21-40	35	33	32	gpp	medium-heavy
Opalenica	0-20	61	20	19	pgm	light
	21-40	63	19	18	pgm	light
Przybroda	0-20	57	23	20	pgm	medium-heavy
	21-40	63	30	17	pgm	medium-heavy

pgl - light loamy sand, gpp - sand-silty loam, pgm - strong loamy sand.

Another factor that modifies accessibility of heavy metals to plant, is the soil content of organic matter. Despite the fact that soils with higher humus content also have a greater amount of Cu, Cd and Zn [6], it does not create any danger of excessive uptake of these elements. As shown by Podlešakova and Némeček [12], in the soil with high humus content, metal ions are bound by soil particles decreasing the number of metal mobile fractions. This limits translocations of these compounds to the overground plant parts. The authors of the present study believe that with high humus content in the soil and the resulting low content of mobile forms of heavy metals in the soil, the content of Cu and Pb (exceeding even the level of 300 ppm) does not drastically decrease plant yield.

As has been shown by the present analyses, soil humus content in the soils from the four fruit growing farms in Wielkopolska ranged from 1.97% (Komorzewo) to 1.45% (Przybroda) in the arable soil layer decreasing gradually in the 21-40 cm layer to 0.82% - Białężyn (Table 1).

The analyses of Cd content, showed that the amount of this element varied from 0.05 mg/kg d.m. (Białężyn) to 0.17 mg/kg d.m. (Opalenica). According to the IUNG soil classification in reference to heavy metal pollution [7], this amount is lower than the natural Cd content in the soils: 0.3 and 1.0 mg/kg d.m. depending on the amount of very fine sand fraction and soil reaction (Tables 3 and 4, Fig. 1).

The highest lead (1.3 mg kg d.m.) and copper values (9.0 mg/kg d.m.) found in the soil of Opalenica did not exceed the level of 30 mg/kg d.m. for lead and 15 mg/kg d.m. for copper. According to the IUNG classification the above levels are regarded as the natural content of these compounds in slightly acid soils with very fine sand fractions from 10 to 20% (Fig. 1, Table 4).

A similar conclusion can be drawn from the analysis of the nickel content. It ranged from 3.17 mg/kg d.m. (Białężyn) to 6.77 mg/kg d.m. (Komorzewo). This amount is lower than the value of 10 mg/kg d.m. regarded as the natural Ni content in the soils [7] (Fig. 1, Table 4).

The natural Cr content in the Polish soils ranges from 2 to 60 ppm for sandy soils, and from 14 to 80 ppm for loamy soils [8]. The analyses of Cr content in the soils of four fruit growing farms of Wielkopolska indicates that it is within the limits of the natural content (Fig. 1).

Analyses of the trace element content carried out separately for the two soil layers, allowed to study their possible displacement down the soil profile. The results obtained so far showed differentiated views on this problem. According to Cieśliński [2] and Andruszczak *et al.* [1], Cd, Pb and Cu have the greatest difficulties with displacing. Also our studies have confirmed this conclusions. From among the 5 investigated heavy metals, the greatest differences in their contents in different soil levels occurred in the case of Cd, than in Cu and Pb (Table 3).

On the other hand, no differences were found in Cr content in two layers of the soil profiles, and the Ni content in the subsoil sometimes was even by 38% (Komorzewo) higher than the content in he arable layer. This suggest that Cr is a mobile metal that gets washed out from the deeper soil layers.

The mechanical soil composition allows to modify intensity with which heavy metals are washed out into deeper layers of the soil profile. As shown by other authors,

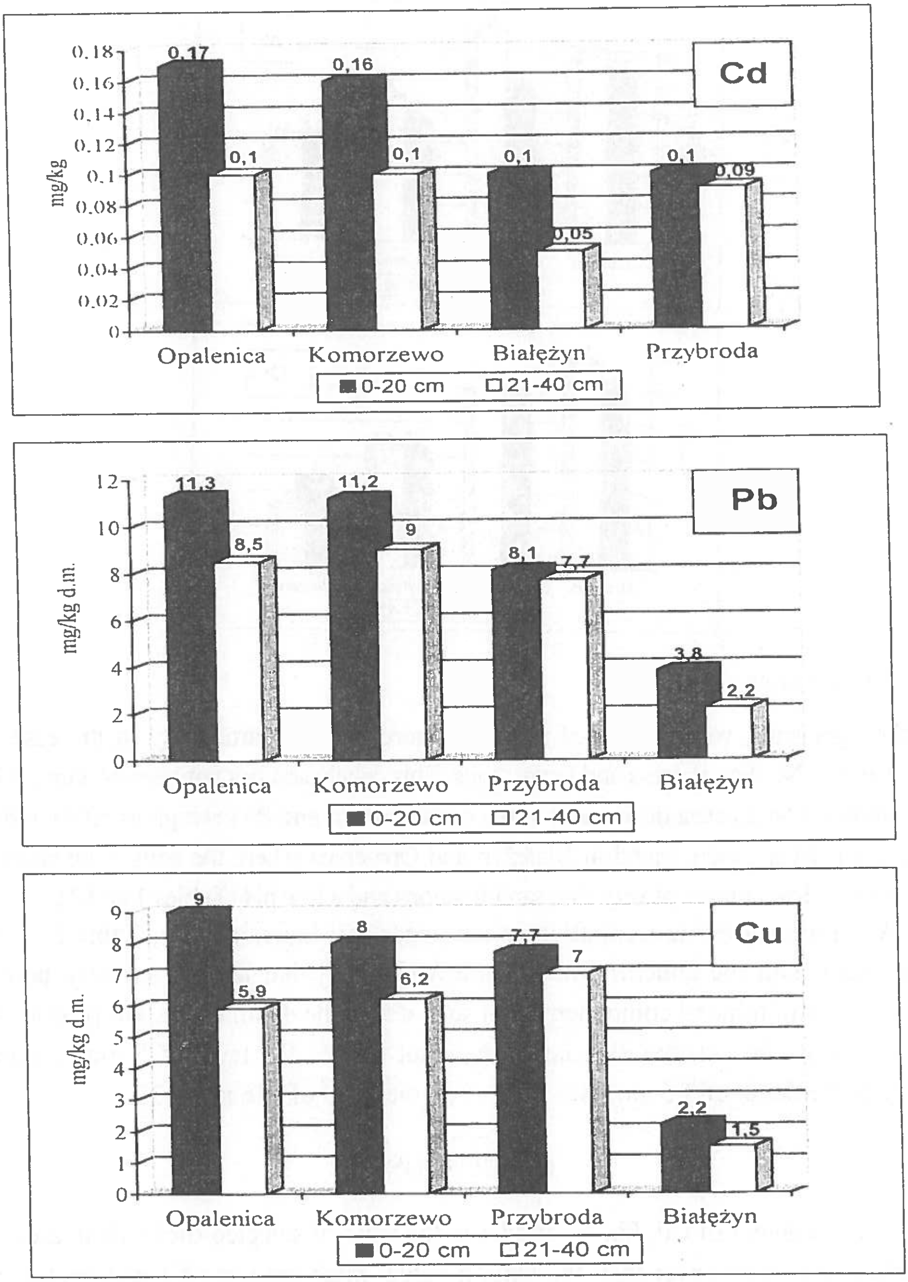

Fig. 1. Cd, Pb, Cu, Ni and Cr content (mg/kg d.m.) in the arable soil layer and in the subsoil from the area of the selected fruit growing farms in Wielkopolska.

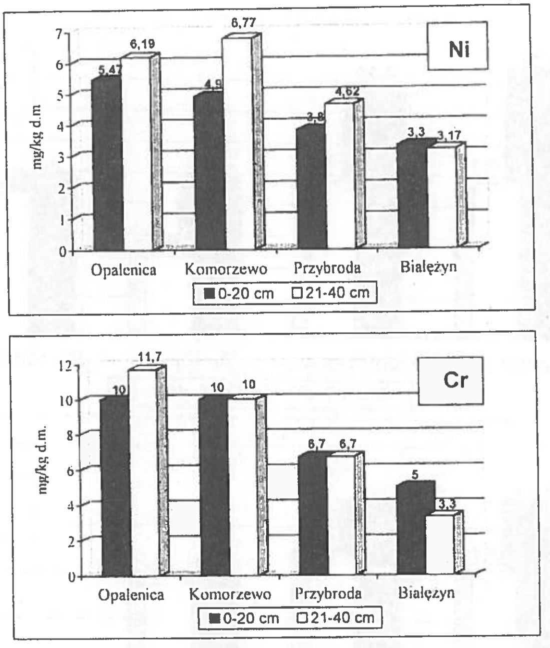

Fig. 1. Continuation.

in the light soils, washing out of metals is more intense, particularly in the case of Zn, Cu and Ni, than in loess and loamy soils. This conclusion has not been confirmed by our studies. The greatest differences in the content of Cd and Pb (as high as 50%) in different soil layers, were found in Białężyn and Opalenica where the soils were characterised by a low content of very fine sand fractions and a low pH (Tables 1 and 2).

A significant Pb concentration in the upper soil layers (Fig. 1, Table 3) is in agreement with the conclusions by Piotrowska [11] that lead is strongly bound with other soil mineral components that shift it into the depth of the soil profile. At the depth of 100 cm, the Pb content does not exceed the level of 5 mg/kg d.m., while at the depth of 3-5 cm, this value is on the level of 136 ppm [3].

CONCLUSIONS

1. The content of Cd, Pb, Ni and Cr in the soils of selected orchards in area of Wielkopolska was lower than the natural value. Such amount of heavy metals in the soii does not create any danger for the excessive amount of these compounds to be taken up by the roots of orchard plants.

T a b l e 3. Changes in the content of 5 heavy metals in the 21-40 cm soil layer in relation to the 0-20 cm soil layer

Places	Heavy metals	Content of heavy metals (mg/kg d.m.)		Scale of changes in content of heavy metals	
		0-20 (cm)	21-40 (cm)	mg/kg d.m.	%
Białężyn	Cd	0.10	0.05	-0.05	-50.0
	Pb	7.50	3.80	-3.70	-40.3
	Cu	2.20	1.50	-0.70	-31.8
	Ni	3.30	3.17	-0.13	-3.90
	Cr	5.0	3.3	-1.70	-34.0
Komorzewo	Cd	0.16	0.10	-0.06	-37.5
	Pb	11.2	9.0	-2.2	-19.6
	Cu	8.0	6.2	-1.8	-22.5
	Ni	4.9	6.77	+1.87	+38.2
	Cr	10.0	11.7	+1.7	+17.0
Opalenica	Cd	0.17	0.10	-0.07	-41.2
	Pb	11.3	8.5	-2.8	-24.8
	Cu	9.0	5.9	-3.1	-34.4
	Ni	5.47	6.19	+0.72	+13.2
	Cr	10.0	10.0	0	0
Przybroda	Cd	0.10	0.09	-0.01	-10.0
	Pb	8.1	8.1	0	0
	Cu	7.7	6.7	-1.0	-13.0
	Ni	3.8	4.6	+0.82	+21.6
	Cr	6.7	6.7	0	0

T a b l e 4. Natural Cd, Pb, Cu and Ni content (mg/kg d.m.) in different types of soil [8]

Hevy metals	Natural content (mg/kg d.m.)		
	light soil	medium-heavy soil	heavy soil
Cadmium	0.3	0.5	1.0
Lead	30	70	100
Copper	15	25	40
Nickel	10	25	50

2. In the deeper layers of the soil profile, where there is a majority of tree root systems, the Cd, Cu and Pb content decrease.

3. Ni concentration in the deeper soil layers was higher than in the surface layers.

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