ACCUMULATION OF HEAVY METALS IN RED BEETS (*BETA VULGARIS L.*) IN HOUSEHOLDS FROM THE COPȘA MICĂ AREA

Vera CARABULEA[1], Nicoleta Olimpia VRÎNCEANU[1], Dumitru-Marian MOTELICĂ[1], Mihaela COSTEA[1], Bogdan Ștefan OPREA[1], Georgiana PLOPEANU[1*]

(1)National Research and Development Institute for Soil Science, Agrochemistry and Environment, 61 Marasti Blvd, District 1, 011464, Bucharest, Romania, office@icpa.ro
**E-mail: oliicpa@yahoo.com*

Abstract
This study shows the accumulation of heavy metals (Cd, Pb, Zn and Cu) from the soil in the roots of beetroot (Beta Vulgaris L.) from individual gardens in the polluted area CopșaMică.
The estimation of heavy metal accumulation in beetroot grown in the area affected by historical pollution was carried out based on a data set collected from 18 individual households.
The content of heavy metals in the soil ranged for Cd between 0.52 mg/kg^{-1} and 19.52 mg/kg^{-1}, Pb had values from 19 mg/kg^{-1} to 530 mg/kg^{-1}, Zn ranged between 28 mg/kg^{-1} and 112 mg/kg^{-1} and Cu had values from 150 mg/kg^{-1} to 1136 mg/kg^{-1}.
The concentration of cadmium (Cd) in the root of red beet varied between 0.015 mg/kg^{-1} and 0.568 mg/kg^{-1}. The content of lead (Pb) and copper (Cu) registered values between 0.019 mg/kg^{-1} and 0.198 mg/kg^{-1}, respectively from 0.49 mg/kg^{-1}and 2.01 mg/kg^{-1}.Zinc content values was between 3.5 mg/kg^{-1} and 10.4 mg/kg^{-1}.
It is noted that for cadmium (r=0,839***), lead (r=0,667**) and zinc (r=0,624**) the values of the linear correlation coefficient differ significantly from zero indicating a close dependence between the considered variables. In the case of copper (r=0,213^{ns}), the value of the linear correlation coefficient does not significantly differ from zero, which requires the use of another stochastic model to describe the accumulation of this metal in beetroot.

***Key words**:heavy metals; soil; red beets; pollution; accumulation*

INTRODUCTION

Beetroot (*Beta vulgaris L.*) is part of the root vegetable family *Chenopodiaceae*. It is cultivated annually or biennially and is a species spread throughout the world.

It is a herbaceous, biennial, leguminous plant with therapeutic value, cultivated.

The red colour is given by anthocyanin pigments. The more potassium in the soil, the redder the bulbs and the better the taste. Contains carbohydrates, proteins, vitamins: A, B1, B2, B3, B5, B6, C, E, PP, folic acid, biotin, trace elements and mineral salts. *Beta vulgaris* is known as both food and medicine. (Stan and Munteanu, 2003; Bangar et al., 2022).

In Romania, beetroots are grown in all the counties of the country and, as evidence, also in the gardens of the area of Sibiu county under study.The main sources of pollution in the Copșa Mică area of Sibiu county are due to the industrial activities of two economic agents: SC SOMETRA SA, with a non-ferrous metallurgy profile which, before 1990, was considered the largest profile unit in the country and SC CARBOSIN SA with a profile chemical.

As a result of a historical country of over 60 years, the area of Copșa Mică is an area affected by atmospheric pollution, characterized by the unclean quality of the air, the area of surface waters, soil pollution, the qualitative degradation of plant pollution and the risk of the possibility of health of animals and people in the area (Vrîncenu et.al., 2009; Miclăușu C., 2019).

Heavy metals can cause serious problems for all organisms, and the bioaccumulation of heavy metals in the food chain can be very dangerous for human health.

In small amounts they are necessary for all metabolic activities of plants (Islam et. al., 2007; Škrbić, 2010;Osipova, et. al., 2014; Ez-zarhouny, et. al., 2015).

Among the heavy metals, lead, mercury, cadmium and chromium top the list of toxicity, the first three are called the “big three” because of their major impact on the environment (Sandeep, 2019).

Numerous authors show that the contents of Cd, Pb, Zn and Cu in the soils of the studied area are sometimes higher than the maximum allowed limits.

As a result, vegetables, including beetroot, accumulate higher amounts of metals (Lăcătușu and Lăcătușu, 2008; Vrîncenu et. al., 2009; Vrîncenu et.al., 2022).

The paper presents results regarding the accumulation of heavy metals in the edible part of sugar beet.

MATERIALS AND METHODS

This paper presents a study carried out in the period 2021–2022 regarding the accumulation of heavy metals in the root of beetroot (*Beta vulgaris L.*) in correlation with the polluted soil in the Copșa Mică area.

The recognized area with a high degree of historical pollution of the Copșa Mică industrial platform.

The estimation of the accumulation of heavy metals in the beetroot root (*Beta vulgaris L.*) was carried out based on a set of data collected from 18 individual households in seven localities: Axente Sever, Agârbiciu, Copșa Mică, Bazna, Micăsasa, Șoala and Tarnava.

Soil samples were collected from the top 0–20 cm layer, then dried at room temperature, mortared and passed through a 0.2 mm sieve.

From these samples, the content of heavy metals (Cd, Pb, Cu and Zn) was determined by atomic absorption spectrometry, after extraction by the aqua regia - microwave digestion method.

Post-harvest plant samples were cleaned of wilted and decayed parts and then washed thoroughly 2 times before being minced and frozen.

The samples were treated with nitric acid in a microwave digestion system. Atomic absorption spectrometry (Flame GBC 932AA or graphite furnace GBC SavanatAAZ) was used to determine the heavy metal content.

Microsoft Excel 2002 was used for the statistical processing and graphical representation of data.

RESULTS AND DISCUSSIONS

The results of the study carried out in the Copșa Mică area, regarding the accumulation of heavy metals in the soil, are presented in table 1.

The soil cadmium content at the depth of 0–20 cm varies between 0.52 $mg \cdot kg^{-1}$ (minimum value) and 19.52 $mg \cdot kg^{-1}$ (maximum value) with a coefficient of variation of 80.8%.

Lead values range from 19 $mg \cdot kg^{-1}$ to 530 $mg \cdot kg^{-1}$, with a mean of 136.5 $mg \cdot kg^{-1}$ and a coefficient of variation of 78.9%.

The zinc content has values between 150 mg·kg-1 and 1136 $mg \cdot kg^{-1}$, with a geometric mean of 391.4 $mg \cdot kg^{-1}$ and a coefficient of variation of 60.7 %.

Total soil Cu content ranges from 28 $mg \cdot kg^{-1}$ to 112 $mg \cdot kg^{-1}$, with a mean of 66.0 $mg \cdot kg^{-1}$ and a coefficient of variation of – 28.5%.

Beetroot is one of the root vegetables found in the individual households included in the study.

Characterization of heavy metals in beetroot harvested from the 18 individual households is shown in Table 2.

The cadmium content of beetroot root ranges from 0.015 to 0.568 $mg \cdot kg^{-1}$ with a coefficient of variation of 96.6%.

Lead ranges from 0.019 $mg \cdot kg^{-1}$ to 0.259 $mg \cdot kg^{-1}$, with a mean of 0.120 $mg \cdot kg^{-1}$ and a coefficient of variation of 47.2%.

The zinc content varies from 3.5 $mg \cdot kg^{-1}$ to 10.4 $mg \cdot kg^{-1}$ and with a coefficient of variation of 31.5%.

The content of Cu in beetroot root varies between 0.49 $mg \cdot kg^{-1}$ and 2.01 $mg \cdot kg^{-1}$, and the coefficient of variation is 36.0%.

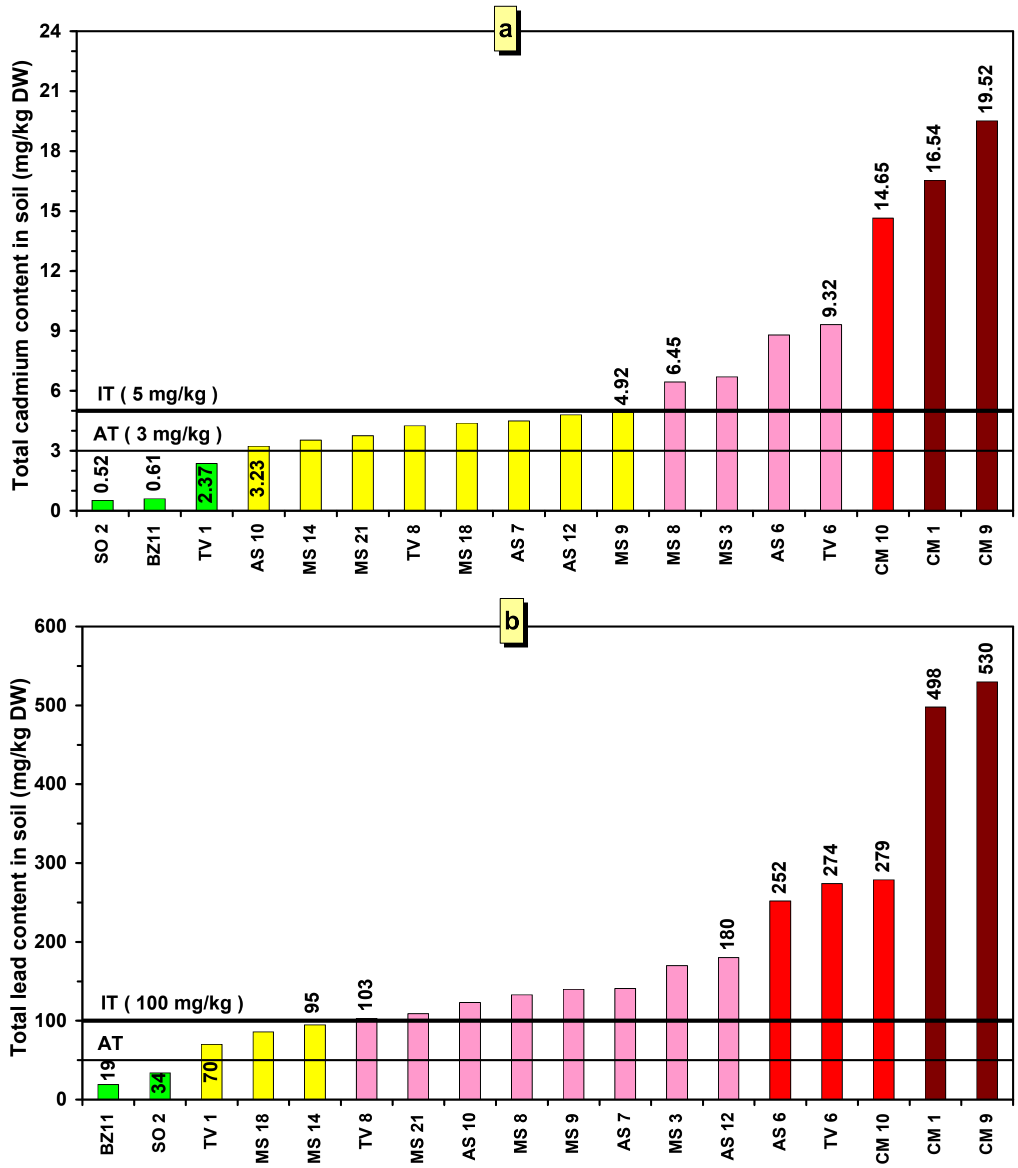
According to Ministerial Order 756/1997, the normal values of Cd content are in the localities of Șoala2(0.52$mg \cdot kg^{-1}$) and Bazna11 (0.61$mg \cdot kg^{-1}$) (Figure 1a).

As can be seen from figure 1a, in 8 localities, of those studied, the cadmium content is between 3.23–4.92mg·kg^{-1} and does not exceed the alert threshold for less sensitive types of use.

Table 1.Values of statistical parameters that characterize the central tendency and the variability of the total cadmium, lead, zinc, copper contents in soil (n=18)

Variable	Minimum	Maximum	Median	Geometric mean	Arithmetic mean	Standard deviation	Coefficient of variation
	- mg/kg DW -						
Cd_{soil}	0.52	19.52	4.66	4.66	6.60	5.33	80.8%
Pb_{soil}	19	530	136.5	134.5	179.8	141.9	78.9%
Zn_{soil}	150	1136	350.0	391.4	454.1	275.7	60.7%
Cu_{soil}	28	112	66.0	62.9	65.5	18.7	28.5%

DW - Dry Weight



IT - **I**ntervention **T**hreshold for sensitive use of land* **DW** - **D**ry **W**eight

AT - **A**lert **T**hreshold for sensitive use of land*

* **Ministry Order 756/1997**

Notes: **AS** - Axente Sever, **SO** - Şoala (villages of Axente Sever commune)
BZ - Bazna, **MS** - Micăsasa, **TV** - Târnava (communes in Sibiu County)
CM - Copşa Mică (town in Sibiu County)

Figure 1. Cadmium and lead contents in soil (layer 0-20 cm).

With cadmium values between 6.45mg·kg^{-1} and 9.32mg·kg^{-1}, there are 4 localities that do not exceed the intervention threshold for types of sensitive use. In CopșaMică 10 the cadmium content is 14.65mg·kg^{-1}, and in CopșaMică1 – 16.54mg·kg^{-1} and CopșaMică2 it is 19.52mg·kg^{-1}, which exceeds the intervention threshold for less sensitive uses.

According to figure 1b, the total lead content in the soil has values below the alert threshold in the localities of Bazna 11 (19mg·kg^{-1}) and Șoala 2 (34mg·kg^{-1}). There are 3 localities between the alert threshold and the intervention threshold, with valuesbetween 70mg·kg^{-1} and 95mg·kg^{-1}. In 8 localities out of 18, the lead content is between 103–180mg·kg^{-1} and does not exceed the alert threshold for less sensitive types of use. In 4 localities, the intervention threshold for sensitive types of use is exceeded, with values between 252mg·kg^{-1} and 279mg·kg^{-1}. In CopșaMică 1 and CopșaMică 9, the total lead content is 498mg·kg^{-1} and 530mg·kg^{-1}, respectively and exceeds the intervention threshold for sensitive use of land.It is observed that the closer we get to the source of pollution, the higher the content of cadmium and lead in the soil.

According to EU Regulation 2021/1323, the maximum allowed level of cadmium in beetroot root is 0.06 mg·kg^{-1}. For the evaluation of the quality of beetroot roots, the cadmium content varies between 0.015 mg·kg^{-1} (minimum value) and 0.588 mg·kg^{-1} (maximum value) in the CopșaMică area (Figure 1a). In 4 localities, the cadmium values are below the maximum allowed limit, between 0.015mg·kg^{-1} and 0.044mg·kg^{-1}. In the following 6 localities it varies between 0.062mg·kg^{-1} and 0.120mg·kg^{-1}, above the maximum allowed limit. In Târnava 6, the cadmium content is 0.120mg·kg^{-1} to 0.198mg·kg^{-1} in Micăsasa 21, here the values are twice above the maximum allowed limit. In CopșaMică, a sudden increase in cadmium values up to 0.568mg·kg^{-1} was observed.

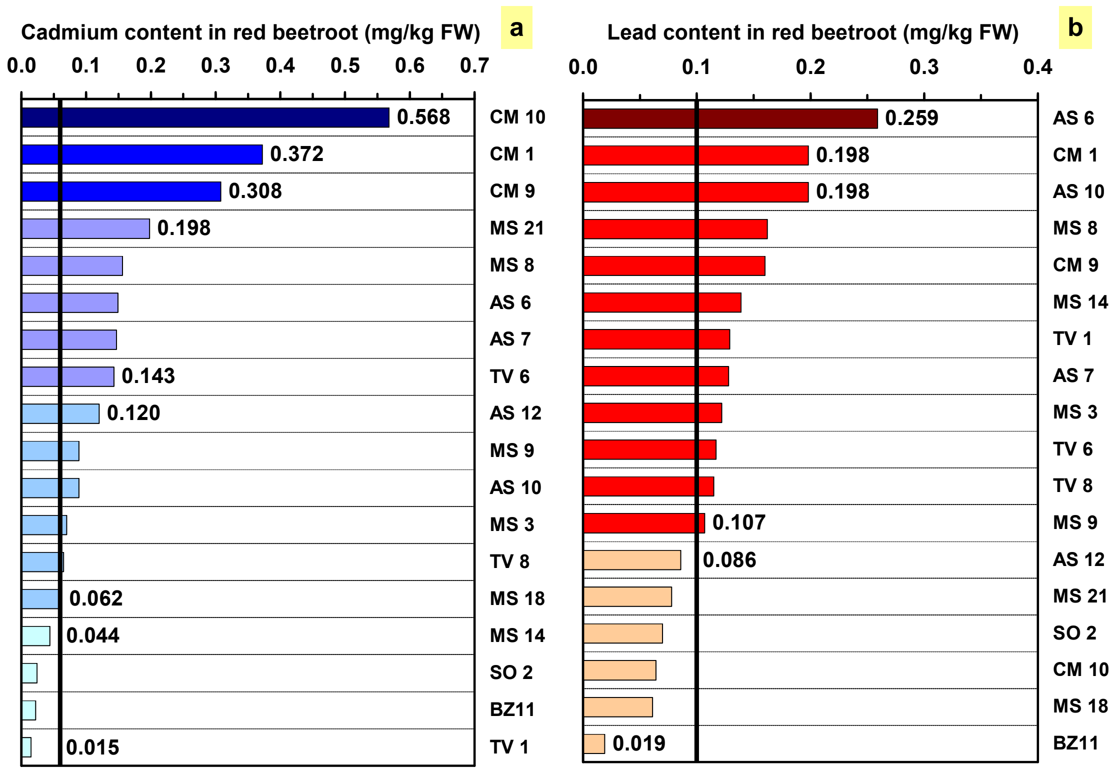
The maximum allowable limit of lead content in roots and tubers is 0.10 mg·kg^{-1} according to EU Regulation 2021/1317. From figure 1b, it can be seen that in 6 localities the data varies between 0.019 mg·kg^{-1} in Bazna 11 and0.086 mg·kg^{-1}in Axente Sever 12 and are below the maximum allowed limit. In the following 11 localities, cadmium varies between 0.107mg·kg^{-1} and 0.198mg·kg^{-1}, and in Axente Sever 6 the maximum value is 0.259 mg·kg^{-1}.

The logarithmic diagrams for power-type regression curves estimating the stochastic dependence between the total contents of cadmium, lead, zinc and copper in the soil and the contents of cadmium, lead, zinc and copper in the beet root are shown in figure 3.

Table 2.Values of statistical parameters that characterize the central tendency and the variability of the cadmium, lead, zinc, copper contents in the red beetroot (n=18)

Variable	Minimum	Maximum	Median	Geometric mean	Arithmetic mean	Standard deviation	Coefficient of variation
	- - - - - - - - - - - -	- - - - - - - -	- - - - - - - -	mg/kg FW	- - - - - - - -	- - - - - - - -	- - - - - - - - - - - -
$Cd_{beetroot}$	0.015	0.568	0.105	0.097	0.147	0.142	96.6%
$Pb_{beetroot}$	0.019	0.259	0.120	0.108	0.123	0.058	47.2%
$Zn_{beetroot}$	3.5	10.4	6.55	6.52	6.86	2.16	31.5%
$Cu_{beetroot}$	0.49	2.01	1.02	1.04	1.11	0.40	36.0%

FW - Fresh Weight



Maximum level of cadmium*/lead in red beetroot** **FW -** **F**resh **W**eight

* **Commission Regulation (EU) 2021/1323 of 10 August 2021**

** **Commission Regulation (EU) 2021/1317 of 9 August 2021**

Notes: **AS** - Axente Sever, **SO** - Şoala (villages of Axente Sever commune)
BZ - Bazna, **MS** - Micăsasa, **TV** - Târnava (communes in Sibiu County)
CM - Copşa Mică (town in Sibiu County)

Figure 2. Cadmium and lead contents in the red beetroot harvested from the Copşa Mică area.

It is noted that for cadmium, lead and zinc the values of the linear correlation coefficient differ significantly from zero indicating a close dependence between the considered variables.

The value of the linear correlation coefficient obtained for the dependence between the total cadmium content in the soil and in the plant is statistically significantly different from zero indicating a close correlation between the two variables, the value of the linear correlation coefficient (r = 0.839***).In addition, for lead, the linear correlation coefficient (r = 0.667**) and zinc (r = 0.624**), simple power regressions were found to be the best for estimating the bioaccumulation of these elements in beetroot roots.

In the case of copper, the value of the linear correlation coefficient does not significantly differ from zero, which requires the use of another stochastic model to describe the accumulation of this metal in beetroot. The value of the linear correlation coefficient (r = 0.213^{ns}) is not significantly different from zero.

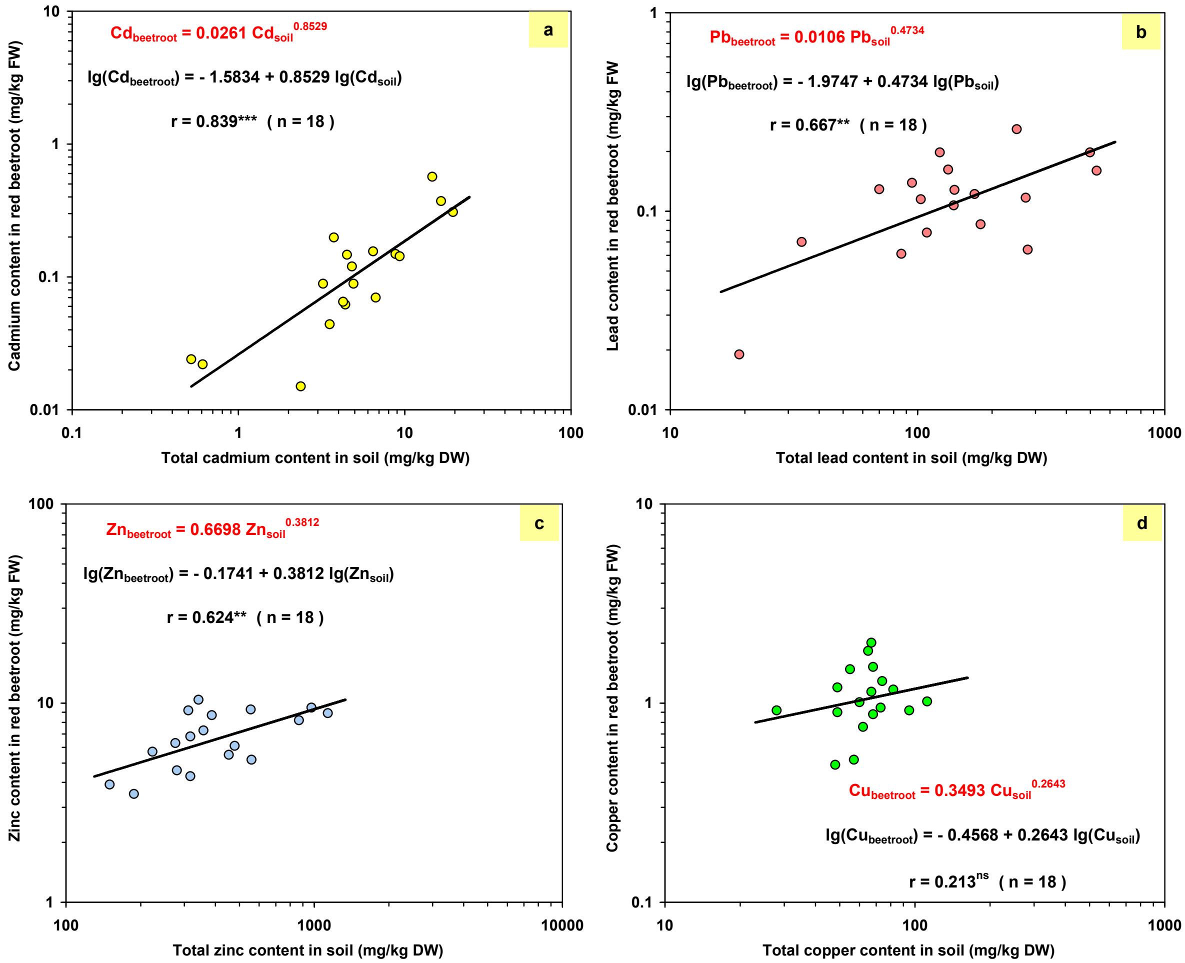


Figure 3. Log-log diagrams for power regression curves that estimate the stochastic dependency between thetotal cadmium, lead, zinc, copper contents in soil (layer 0-20 cm) and the cadmium, lead, zinc, coppercontents in the red beetroot.

CONCLUSIONS

This study shows the accumulation of heavy metals (Cd, Pb, Zn and Cu) from soil in beetroot (*Beta Vulgaris L.*) roots from individual gardens in the study area. The consumption of vegetables from individual gardens poses a risk to the population because they are not subject to quality control according to EU rules. For the content of cadmium, lead and zinc the values of the linear correlation coefficient differ significantly from zero indicating a close dependence between the considered variables.

The value of the linear correlation coefficient obtained for the dependence between the total cadmium content in the soil and in the plant is statistically significantly different from zero indicating a close correlation between the two variables. For lead and zinc simple power regressions were found to be the best for estimating the bioaccumulation of heavy metals in beetroot roots.

For copper, the value of the linear correlation coefficient does not significantly differ from zero, which requires the use of another stochastic model to describe the accumulation of this metal in beetroot.

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