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ESTIMATION OF HEAVY METALS ACCUMULATION BY VEGETABLES IN AGROECOSYSTEMS AS ONE OF THE MAIN ASPECTS IN FOOD SECURITY

Serhii Razanov^{1*}, Antonina Piddubna², Galina Gucol³, Lyudmyla Symochko⁴,
Svitlana Kovalova⁵, Mykola Bakhmat⁶, Oleh Bakhmat⁷

^{1*,2,3}*Vinnitsia National Agrarian University, Soniachna Str.,3., Vinnitsia, Ukraine;*

⁴*Uzhhorod National University, Voloshyna Str.,32, Uzhhorod, Ukraine;*

⁵*Polissia National University, boulevard Stary, 7, Zhytomyr, Zhytomyr region, Ukraine*

^{6,7}*Higher Education Institution "Podillia State University", Shevchenko Str.,12., Kamianets-Podilskyi, Khmelnytskyi region, Ukraine;*

*Corresponding Author Razanov Serhii, email: razanovsergej65@gmail.com;

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ABSTRACT

The article is devoted to the study of the intensity accumulation of heavy metals (Pb, Cd, Zn, Cu) by vegetables in agricultural lands. Vegetable products play important role in human nutrition and requirements for quality and safety are very strict. The study was conducted on dark gray podzolic soils in the Tyvriv district of the Vinnitsia region. The fruits of the cucumber variety Dzherelo, the zucchini variety Chaklun, and the pea variety Geneva were used for the research. It is noted that the main indicators of climatic conditions during the study period were favorable for growing vegetables. It was determined that among vegetables (food peas, zucchini, cucumber) the highest content of heavy metals was observed in pea fruits. At the same time, it was found that the Cd content in pea fruits exceeded the PL (permissible level) by 1.61 times at a concentration of heavy metals in the soil below the TVL. Among heavy metals (Pb, Cd) higher migration and translocation were observed in the studied vegetables according to Cd, and among heavy metals-trace elements (Zn and Cu) - according to Cu. It was found that pea fruits were characterized by the highest coefficient of accumulation of heavy metals (Pb, Cd, Zn, Cu). The risk factor for heavy metals in the studied vegetables was lower than the threshold level of 0.1, except for Cd in peas, where this figure was 1.61 times higher.

Keywords: heavy metals, Pb, Cd, Zn, Cu, soil, pea, zucchini, cucumber, accumulation, agroecosystem, security.

INTRODUCTION

Vegetables are vital to the human diet, they provide the body with nutrients to maintain normal physiological functions. With vegetables, the body receives a large amount of potassium, calcium, sodium, magnesium and many other useful elements. These elements are important for all metabolic processes in the body and necessary for the normal functioning of the digestive, cardiovascular and nervous systems.

They also regulate water balance (Vdovenko et al., 2020; Symochko et al., 2021). The oldest and most widespread vegetable crop which are grown around the world, is cucumber. This is the perfect food for those who care about their well-being and keep fit. It contains many important nutrients such as vitamin A, vitamin B, vitamin C, vitamin K, manganese, copper and potassium. Including cucumbers in your daily diet has a positive effect on health (Verheles, 2021; Gograj Singh et al., 2021; Hassan et al., 2021).

Zucchini is a popular vegetable for home cultivation, which is widely used in cooking. In addition, it is very useful for the human body and is valued in folk medicine. Zucchini is a source of carotenoids lutein and zeaxanthin, extremely useful for eye health, which when used regularly reduce the risk of age-related vision loss and cataracts (Palamarchuk, 2020, 2021; Hassan et al., 2021). Among vegetable crops, peas are the richest source of protein, containing valuable amino acids: cystine, lysine, arginine, tryptophan, methionine. Green peas are characterized by nutritional value, digestibility and good taste. The agronomic significance of peas as a nitrogen accumulator in the soil due to nodule bacteria is known (Mazur et al., 2021; Mostovenko et al., 2021; Okrushko, 2021).

Soil conditions of Ukraine are favorable for growing vegetable products, as well as factors that positively affect the development of vegetable growing in Ukraine: good geographical location of the country; lack of state intervention in the formation of vegetable prices; moderate price for labor and natural resources (Vdovenko et al., 2020). Its implementation in fresh and processed form is an important direction in the country's economy. Despite all the difficulties in the agricultural sector, there has been a positive trend in the last decade in the vegetable sector: yields are rising, production is increasing (Volontyr, 2021). In the development of the vegetable production of Ukraine it is important to improve the quality of vegetables, reduce crop losses, expand the range, reduce production costs, increase the economic efficiency of the industry. Food quality and safety are probably the most important issues for human health. Vegetables available for consumption must be free of all chemical contaminants that pose a risk to the health of consumers. The concept of quality and safety of products in general and fruits and vegetables in particular is crucial in the life cycle: cultivation, processing, sale and consumption. According to the modern concept of sharing responsibility for product quality and safety, all food market operators are responsible for the processes they manage (Kovalchuk, 2021). The primary responsibility is usually borne by farmers and agricultural enterprises. It is during the cultivation of fruit and vegetables that its quality and safety are mainly formed. The characteristics of the quality of fruit and vegetable products include organoleptic and physico-chemical indicators that ensure compliance with the functional purpose and preferences of consumers. Among the indicators of quality of fruit and vegetable products determine the appearance, size, tolerances, as well as taste and smell. An important indicator of functionality is the energy and nutritional value of products. Quality indicators are regulated by regulatory documents for products (Rogach et al., 2019). Unlike quality indicators, safety indicators are regulated by law and are mandatory. Control and observance of safety indicators is a prerequisite for the introduction of fruit and vegetables and prevention of negative effects on the health of consumers. Safety indicators for the regulation, control and monitoring of fruit and vegetables include: microbial indicators, toxic elements, radionuclides, nitrates, mycotoxins and pesticides. All of these contaminants in fruits and vegetables can adversely affect the health of consumers.

Ukraine has certain standards identical to the European Economic Commission, but there is a low degree of compliance. In particular, the permissible doses of heavy metal contamination in European standards are much lower than in Ukrainian. Contamination of vegetables with mercury, copper, zinc and arsenic is not allowed at all according to European standards, while according to Ukrainian standards it is allowed. Today, the demand for organic vegetables is increasing, ie the cultivation of environmentally friendly products (without the use of fertilizers, chemicals, pesticides), almost a new direction in the economy of Ukraine. Such products are difficult to grow, but they are highly valued and in great demand for export (Honcharuk et al., 2020; Kaletnik et al., 2020). After all, chemical contamination of food poses a significant risk to consumers. The source of this risk is the consumption of products contaminated with heavy metals such as Cd, Pb, Zn and Cu (Antisari et al., 2015; Rasanov et al., 2017; Rasanov et al., 2018; Rasanov et al., 2020). The impact of heavy metals on humans has increased dramatically over the past 50 years. In today's world there is no escape from the effects of toxic chemicals and heavy metals. Entering the soil, heavy metals primarily affect its biological properties: changes in the total number of microorganisms, narrows the species composition of the microbial group, reduces the activity of soil enzymes, and only then can change more conservative features - humus, structure, pH, mobility of macronutrients and others (Bondar et al., 2019; Dursun et al., 2020; Tkachuk et al., 2021). Consumption of vegetables containing heavy metals is one of the main ways these elements get into the human body. Potentially harmful content of metals in the soil comes not only from rocks, but also from anthropogenic sources, such as solid or liquid waste, agricultural products, as well as industrial and urban emissions. Therefore, it is important to monitor the quality of raw materials, given that the uptake of plants is one of the main ways through which heavy metals enter the food chain. Vegetables

absorb heavy metals and accumulate them in edible and inedible parts in such quantities that can cause clinical problems in both animals and humans.

MATERIALS AND METHODS

Studies on the accumulation of heavy metals in vegetables (cucumber, zucchini, peas) were conducted on dark gray podzolic soils in the Tyvriv district of Vinnytsia region. The climate of the area is temperate continental with mild winters and warm humid summers. This region has periodic droughts and belongs to the area with unstable humidity. According to meteorological observations, the main indicators of climatic conditions during the research period (2020-2021) were favorable for growing vegetables. The fruits of the cucumber variety Dzherelo, zucchini - Chaklun and pea - Geneva were used for research. Vegetables were selected by spot sampling, soil sampling was performed by the envelope method. Determination of heavy metals in vegetables was performed by atomic absorption spectrophotometry in accordance with GOST 30178-96 (GOST, 2010).

The coefficient of accumulation (Cacc.) In vegetables was calculated by the formula: $Cacc. = C_m / C_n$

where m is the concentration of contaminants in vegetables, mg / kg;

C_n - concentration of pollutants in the soil, mg / kg.

The hazard factor (Chaz.) of heavy metals in vegetables was calculated by the formula: $Chaz = C_m / PL$

where C_m is the concentration of contaminants in vegetables, mg / kg; PL - permissible levels in vegetables: $Pb - 0.50$ mg / kg, $Cd - 0.03$ mg / kg, $Zn - 10.0$ mg / kg, $Cu - 5.0$ mg / kg.

RESULTS AND DISCUSSION

The results of studies of man-made impact on the soils of agricultural lands in the study region indicate a constant impact of chemicalization of the crop industry on the level of Pb , Cd , Zn and Cu in the soil. It was found that a high influx of heavy metals is observed with mineral fertilizers, which are the main source of recovery in the soil of essential plant nutrients, in particular, nitrogen, phosphorus and potassium.

Among all types of soil fertilization in the Forest-Steppe of the right-bank Ukraine, the use of mineral fertilizers reaches 98%. At the same time, it is necessary to note the growing level of Pb , Cd , Zn and Cu in the soil due to increased use of mineral fertilizers due to high levels of basic nutrients (NBL) for growing sunflower, corn and winter wheat - components of modern limited crop rotation. Over the last 10 years, the use of mineral fertilizers has increased 3.6 times. With each kilogram of ammonium nitrate enters the soil on average: Pb - up to 2 mg, Cd - up to 4 mg; with simple superphosphate: Pb - 4.4 mg, Cd - 0.8 mg; potassium chloride: Pb - 3.0 mg, Cd - 3.0 mg.

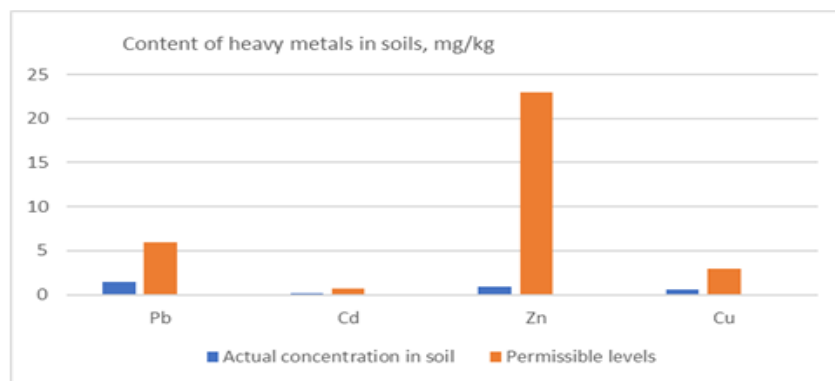


Figure 1. Content of heavy metals in soils, mg / kg

Analysis of the content of heavy metals in the soils in the study area showed that their concentrations were below permissible levels (PL). In particular, the content of Pb in soils was lower than the permissible level by 4.0 times, Cd - 3.2 times, Zn - 2.5 times and Cu - 5.0 times.

Table 1. Content of heavy metals in vegetables, mg / kg

Crop	Pb		Cd		Zn		Cu	
	Actual concentration	PL	Actual concentration	PL	Actual concentration	PL	Actual concentration	PL
Pea	0,2642±0,001	0,50	0,0485±0,001	0,03	7,927±0,022	10,0	2,412±0,013	5,0
Zucchini	0,0930±0,001	0,50	0,0173±0,0001	0,03	2,567±0,016	10,0	0,6022±0,002	5,0
Cucumber	0,1045±0,001	0,50	0,0191±0,001	0,03	3,462±0,025	10,0	0,4825±0,001	5,0

Monitoring of the accumulation of heavy metals (Table 1) showed that in the conditions of dark gray podzolic soils in Vinnytsia exceeded the permissible levels of the studied crops only in pea fruits on Cd, in which this figure was higher than the permissible level of 1.61 times. Whereas in the fruits of zucchini and cucumbers, the Cd content was below the permissible level 1.73 times and 1.57 times, respectively. The content of Pb in the studied vegetables was lower than the permissible level, in particular, in peas - 1.89 times, zucchini - 5.37 times and cucumbers - 4.78 times. The Zn content in the fruits of peas, zucchini and cucumbers was below the permissible level 1.26 times, 3.89 times and 2.88 times. The Cu content in peas, zucchini and cucumbers was also below the permissible level 2.09 times, 8.30 times and 10.36 times, respectively. Among the studied fruit fruits, the highest levels of Pb, Cd, Zn and Cu were found in food peas. Thus, the Pb content in pea fruits was 2.84 times higher than in zucchini fruits and 2.52 times higher than in cucumber fruits. The Cd content in peas was 2.80 times higher than in zucchini and cucumbers. There is also a higher difference between the studied vegetables of Zn and Cu content. In particular, the content of Zn and Cu in the fruits of peas was higher than the fruits of zucchini 3.08 times and 4.0 times and cucumbers - 22.8 times and 4.99 times. The highest difference in Cu content in comparison with Pb, Cd, Zn between fruits of peas, zucchini and cucumbers was 1.5 - 2 times. Among heavy toxic metals (Pb, Cd) the highest content in vegetables was observed for Pb. Thus, the content of Pb in the fruits of peas, zucchini and cucumbers was higher than Cd by 5.44 times, 5.37 times and 5.47 times, respectively.

The content of heavy metals - trace elements (Zn, Cu) in the studied vegetables was higher in Zn. In particular, the Zn content was 3.28 times higher in pea fruits, 4.26 times higher in zucchini fruits and 7.17 times higher in cucumber fruits compared to Cu.

Table 2. The coefficient of accumulation of heavy metals in vegetables

Crop	Pb	Cd	Zn	Cu
Pea	0,176	0,222	8,616	4,053
Zucchini	0,062	0,079	2,790	1,012
Cucumber	0,069	0,087	3,763	0,810

The coefficient of accumulation of heavy metals in vegetables (Table 2) showed that it was highest in peas. In particular, the coefficient of accumulation in pea fruits was 2.83 times higher compared to zucchini fruits and 2.55 times higher compared to cucumber fruits. The coefficient of Cd accumulation in pea fruits was 2.81 times and 2.55 times higher compared to zucchini and cucumber fruits. Regarding the coefficient of accumulation in the fruits of peas Zn and Cu, this figure was 3.08 times and 4 times higher than the fruits of zucchini and 2.28 times and 5 times higher than the fruits of cucumbers. The highest difference in the coefficient of accumulation of heavy metals in vegetables was observed for Cu, which reached up to 5 times.

Table 3. Risk factor of heavy metals in vegetables

Crop	Pb	Cd	Zn	Cu
Pea	0,528	1,616	0,792	0,482
Zucchini	0,186	0,576	0,256	0,120
Cucumber	0,209	0,636	0,346	0,0965

The risk factor for heavy metals (Table 3) shows that among the studied vegetable crops, the highest figure was found in peas. In particular, the risk factor was higher in peas than in cucumbers and zucchini in Pb 2.83 times and 2.52 times, Cd - 2.8 times and 2.54 times, Zn - 3.09 times and 2.28 times and Cu - 4.01 times and 1.24 times. At the

same time, it should be noted that the risk factor Pb, Cd, Zn and Cu in the fruits of zucchini and cucumbers was lower than the maximum allowable value (0,1), which indicates the safety of these vegetables. The risk factor Cd in peas was 1.61 times higher than 1.0. The risk factors for Pb, Cd, Zn and Cu were 5.37 times, 1.73 times, 3.90 times and 8.33 times lower than the maximum level, respectively, and 4.78 times lower than in cucumbers. , 57 times, 2.89 times and 10.36 times, respectively.

CONCLUSION

- The study of heavy metals accumulation by vegetables in agroecosystems is a necessary aspect of managing food security in agroecosystems.
- Our results showed that among vegetables (food peas, zucchini, and cucumber) the highest content of Pb, Cd, Zn, and Cu was observed in pea fruits. At the same time, it should be noted that the Cd content in pea fruits exceeded the permissible level by 1.61 times, despite the fact that the content of this toxicant in the soil was 3.2 times lower than the PL.
- Among heavy metals (Pb, Cd) higher migration and translocation were observed in the studied vegetables according to Cd, and among heavy metals-trace elements (Zn and Cu) - according to Cu.
- It was found that the highest coefficient of accumulation of heavy metals (Pb, Cd, Zn, Cu) was characterized by pea fruits.
- The risk factor for heavy metals in the studied vegetables was lower than the threshold level of 0.1, except for Cd in peas, where this figure was 1.61 times higher.

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