

Ecological assessment of vegetable products grown in the city of Zhytomyr and its residential suburb

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The purpose of the given research was to carry out complex ecological assessment of vegetables grown in the city of Zhytomyr and in its residential suburb as to the content of nitrates and heavy metals in them. The results of the research showed that on the average from the whole amount of samples selected on the territory of the city the excess nitrate content was found in potatoes, bulb onion, green onion, garden radish and red beet. In the rest of vegetable and fruit samples the excess of the nitrate level was not found. In vegetables grown under the conditions of agroecosystems of suburban settlements the excess nitrate content was fixed in 44.6 % of the samples selected. Most often the excess of the norm was observed in potatoes (75 % of the samples). The comparative analysis of vegetable products grown under different conditions showed that vegetables grown in settlements of the residential suburb were more polluted with nitrates than those grown in urban ecosystems. It has been established that in the selected samples of vegetables grown under the conditions of the city higher content of heavy metals, especially lead and cadmium, is observed. From the total amount of the samples the most dangerous for human consumption proved to be leaf parsley in which the excess of lead, cadmium and zinc level was on the average 5.1, 7.3 and 3.2 times respectively, and the safest vegetable was garden carrot. As a result of the investigations into the content of heavy metals in vegetables grown in the residential suburb, it has been established that absolutely safe for man are garden carrot, red beet, cucumbers, tomatoes and onion in which the level of heavy metals is substantially lower than the maximum permissible one. Lead content in white head cabbage and parsley was fixed at the level of 1.25 and 3.45 mg/kg. Slight increase in cuprum content was found in white head cabbage, and in potatoes the content of zinc exceeding the norm was fixed. It has been proved that crop products grown under the conditions of urban ecosystems contain higher amount of heavy metals as compared with the same crops grown in the residential suburb. When conducting the investigations into the content of nitrates and heavy metals in different vegetable parts we found that distribution of pollutants among organs of plants was first of all determined by their species and biological characteristics of organs themselves.

Key words: nitrates, nitrates, cuprum, zinc, lead, cadmium, urban ecosystems, agroecosystems, maximum allowable concentration.

Introduction

Despite the downswing environmental pollution in Ukraine is still going on. Industrialization of even small towns is increasing at the expense of the growth of small-scale enterprises and the number of motor vehicles. The intensive development and functioning of agrarian, mainly stock-raising enterprises in the residential suburb is not controlled, and their waste products result in the pollution of the environment, specifically vegetable produce, with toxicants. In this respect the Zhytomyr residential suburb with actively functioning stock-raising and crop-growing complexes which deliver waste to agroecosystems of rural settlements is not an exception.

It is known that one of the factors determining the health of communities is the state of environment which, in its turn, is closely connected with man's ecological culture and consciousness. Today, under the conditions of economic crisis in Ukraine we can observe wide development of collective and individual gardening which gives people an opportunity to grow and consume vegetable products. This process is especially intensive in the residential suburb, in near-by villages and gardening cooperatives. Vegetables grown under the conditions of agroecosystems of the residential suburb are both consumed by local residents and sold at the city's spontaneous markets. This produce, however, at present is not controlled and may be dangerous for human consumption because of heavy metals and nitrates exceeding their maximum allowable concentration (MAC).

Nitrates are priority pollutants of vegetable produce. They are salts of nitric acid and make the essential part of plant nourishment (KrohalYova and Cherepanov, 2016). It is known that the largest amount of nitrates comes to human body with vegetable food (Velzen et al., 2008; Bahadoran et al., 2016; Gruszecka-Kosowska and Baran, 2017). The nitrate content in vegetables depends on many factors, such as conditions of growing (closed or open soil) (Kriger et al., 2013), fertilizer application (Ilic et al., 2014), biological features of plants (Fateme and Fathollah, 2013), climatic conditions, etc. The amount of nitrates coming to human body which exceeds maximum allowable concentration may cause methaemoglobinemia resulting in oxygen shortage in tissues (Chan, 2011, Mykaylo et al., 2013). Thus, monitoring investigations into the quality of vegetable produce grown within the boundaries of the city as well as outside its limits and sold in the city's spontaneous trading network is an acute and pressing problem.

The conducted research testifies to the unsatisfactory quality of vegetable produce concerning the content of heavy metals in it, its main pollutants being Pb, Cd, Cr, Cu, Zn and Ni (Antisari et al., 2015; Cherfi et al., 2016; Devetakovic et al., 2017; Fan et al., 2017; Li et al., 2017). The extra-standard amount of heavy metals in human body may result in acute chronic diseases. Some heavy metals belong to cancerogenic elements which may cause oncologic diseases. It is the consumption of food products with the high content of cancerogenes that directly influences the formation of diseases and mortality as a result of malignant neoplasms (Osipova et al., 2013; Zhou et al., 2016; Herasymchuk and Valerko, 2017). The analysis of the latest investigation results shows that the assessment of vegetable produce quality as to the content of heavy metals was mainly conducted in technologically intensive regions with the highly-developed industrial complex (Galal and Shehata, 2015; Nedelescu et al., 2015; Ye et al., 2015). But regions of agrarian orientation, including Zhytomyr oblast, were mainly disregarded by scholars (Myslyva, 2011; My`sly`va and Herasymchuk, 2011; Herasymchuk and Valerko, 2012; Herasymchuk and Valerko, 2014).

Taking into account all the above-stated, the goal we have set is the ecological assessment of the quality of vegetables grown within the boundaries of Zhytomyr and its residential suburb as to the content of nitrates and heavy metals in them.

To achieve this goal, it was necessary to perform the following tasks:

- to make a selection of vegetable produce within the boundaries of Zhytomyr and on the territory of settlements and gardening cooperatives of the city's residential suburb;
- to carry out an analysis of vegetable samples as to the content of heavy metals and nitrates;
- to carry out a comparative analysis of the quality of vegetables grown under different conditions;
- to find out the characteristics of pollutant accumulation in different parts of vegetable produce.

Materials and methods

The research was conducted in 2016-2017 in different seasons on the territory of the private sector of Urban Ecosystem of Zhytomyr and agroecosystems of its residential suburb. The urboecosystem is a natural urban ecosystem consisting of fragments of natural ecosystems surrounded with functional urban space (Gerasimova et al., 2003). The agroecosystems is an ecosystems artificially made by man with the aim of producing agricultural products (Smahlii et al., 2006). In this study the term 'agroecosystem' refers to fields, orchards, kitchen gardens, greenhouses and hotbeds in the residential suburb of the city of Zhytomyr. Vegetable samples were selected in accordance with N.A. Makarenko's methodological instructions (Makarenko, 2005).

The evaluation of nitrates in vegetable produce was carried out by the ionometric method based on the extraction of nitrates with the solution of alumopotassium sulphate and estimation of their concentration in the obtained extract with the aid of an ionoselective electrode. To accelerate the analysis it is possible to use vegetable sap diluted with the solution of alumopotassium sulphate. The measurement of nitrate-ion concentration in the obtained suspension was carried out with the ionometer pX 150 MI.

The content of heavy metals in plants was determined in solutions of their ashes by the method of atomo-absorption spectrometry with preliminary dry ashing of plant samples at the temperature of 500-550°C in a muffle furnace till getting white ashes, with obtaining ash solution (HNO₃ 1:2).

The assessment of the ecological condition of vegetables studied was conducted by comparison of actual content of nitrates and heavy metals with their maximum allowable concentration.

Results and their discussion

Ecologically clean produce is the basis of man's health. This is especially true of vegetable produce which contains large amount of vitamins, microelements, ferments, phytoncids and other substances important for human health. This produce, however, may be dangerous because of higher amount of nitrates and heavy metals in it. That is why regular monitoring of vegetable produce is an important and pressing task.

In recent years in Ukraine there have been a clear tendency to raise the cultivation of vegetable produce with nitrate content which exceeds possibly admissible standards. On the whole more than 30 per cent of agricultural produce in the country shows the excess of the above standards (Yaczuk et al., 2014). Nitrates come to human body by different ways: with food products of plant and animal origin, drinking water and medicines. Some part of nitrates may be formed in human body itself in the process of metabolism. The bulk of nitrates (40-80 % of daily amount) comes to human body with vegetable produce.

More than 20 factors are known that may bring about higher accumulation of nitrates in crop products. Among them are light scarcity, heat or cold in the period of vegetation, drought or constant overmoistening, large or small amount of nitrogen, potassium and phosphorus in soil, biological activity of soil, its acidity, disease and some others. But the key factors are irrational application of nitrogen fertilizers and violation of agrotechnology of farm crop treatment.

One of the characteristic features of Zhytomyr is preservation of individual development areas with small household plots next to modern buildings. Such plots are typical of both outlying parts of the city and its centre.

As a result of investigations into the quality of produce grown in the city's private sector the excess of nitrate content was registered in potatoes (1,8 MAC), red beet (1,6 MAC), bulb onion (1,9 MAC), green onion (2,4 MAC) and garden radish (1,6 MAC) (Fig. 1). The mean nitrate content in vegetable marrows was fixed at the level of maximum allowable concentration. The other species of vegetables were completely harmless for man's health.

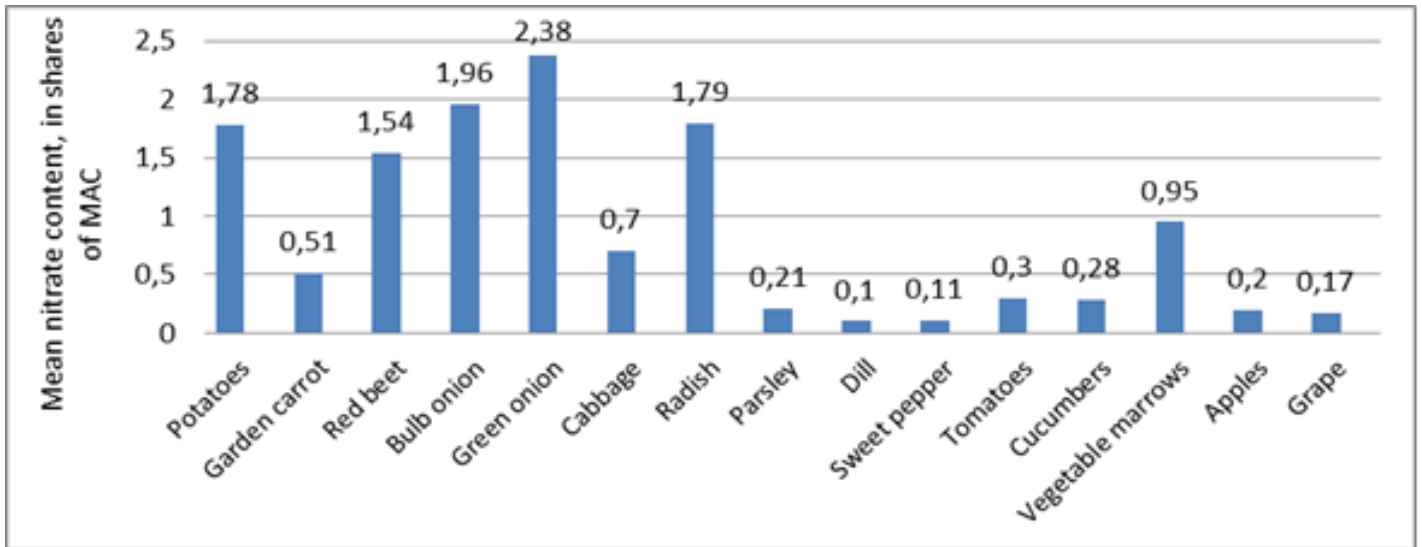


Fig. 1. Nitrate content in plant products grown within the limits of Zhytomyr's populated area

It is known that by the ability to accumulate nitrates vegetables and fruit are divided into 4 groups: with maximum, high, medium and low nitrate content (Table 1).

Table 1. Distribution of plant produce by the ability to accumulate nitrates

No	Nitrate content, mg/kg	Crops
1.	Maximum content, 1500-5000	Lettuce, Pe-tsal savoy cabbage, leaf beet, spinach, radish in hotbed soil, melon, water-melon, parsley, celery
2.	High content, 700-1500	Early-maturing cauliflower and white head cabbage, red beet, branching cabbage, turnip celery, rooted turnip, kohlrabi, rhubarb, garden turnip, horseradish, open-sown garden and black radish, green onion in hotbed soil
3.	Medium content, 150-700	Cucumbers, late-maturing white head cabbage, open-sown green onion, pumpkin, vegetable marrows, bush pumpkins, leek, sorrel, early-maturing carrot, parsley roots, spring onion, cauliflower (in autumn)
4.	Low content, 10-150	Pea, tomatoes, sweet pepper, garlic, beans, potatoes, bulb onion, late-maturing carrot, fruit and berries

In our research we have established the declining series of vegetable crops grown in Zhytomyr by their ability to accumulate nitrates: green onion > bulb onion > potatoes > garden radish > red beet.

As to ecological safety of vegetables grown within the limits of agroecosystems of the city's residential suburb, it has been found that 44.6 % of the samples had nitrate concentration which exceed the established maximum permissible levels.

By nitrate content 75 % of potato samples, 50 % of white head cabbage, 40 % of red beet, 33 % of leaf parsley and 25 % of fresh cucumbers did not conform with sanitary norms and regulations (Table 2). The nitrate content within the limits of the norm was only observed in garden carrot. It has been found that in Zhytomyr's residential suburb the content of nitrate compounds in the mean exceed the established standards of maximum allowable concentration 1.4 times in potatoes, 2.2 times in white head cabbage, 1.5 times in red beet and 1.025 times in parsley.

Table 2. Nitrate content in crops grown in the residential suburb

Crop	Samples studied	Mean content, mg/kg	Content variation, mg/kg	Number of samples with the excess of MAC, %	MAC
Potatoes	15	249,75	150-350	75	180
Garden carrot	12	126,8	14,7-275	0	300
Red beet	10	2038	150-4500	40	1400
White head cabbage	10	879	150-3630	50	400
Cucumbers	12	115,15	62,9-248	25	200
Parsley	10	820	320-1490	33	800
Total	69	-	-	44.6	-

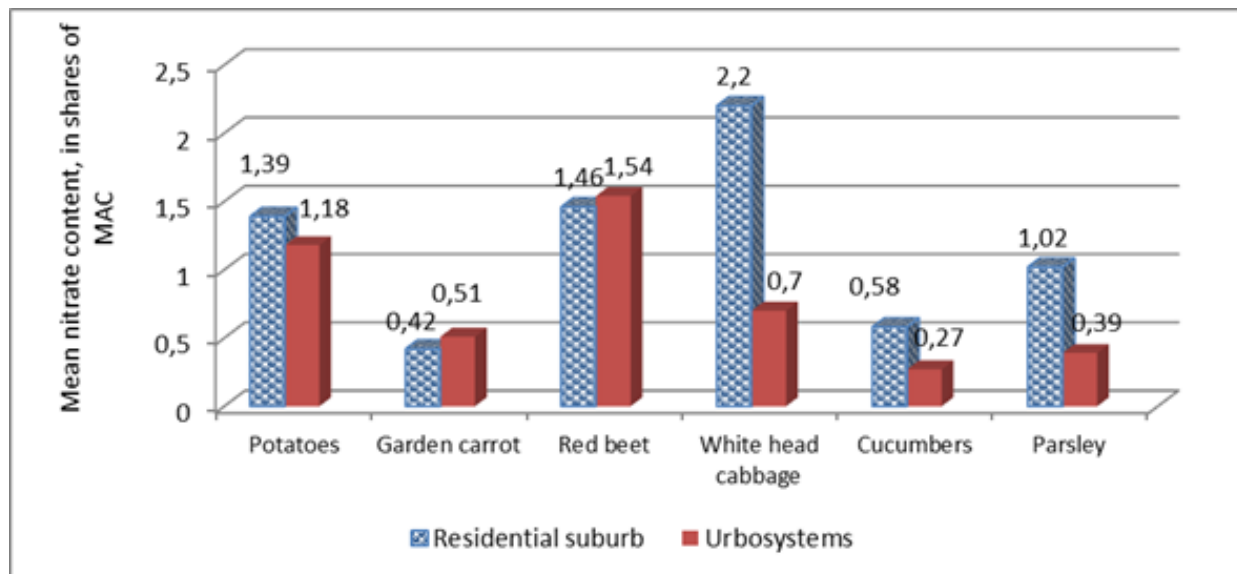
The largest number of the samples with the excess of maximum allowable level was fixed for potatoes: 11 out of 15 samples showed nitrate content exceeding the norm, though the excess in the mean makes 1.4 times. However, the problem of nitrate pollution of potatoes as such does not exist. Firstly, this is connected with the fact that potato belongs to root crops with low nitrate content. Secondly, before usage as food it is washed, peeled and then boiled which makes it absolutely safe to be consumed by man.

The substantial excess of nitrate content (1.5 and 2.2 times) was fixed in red beet and white head cabbage which is conditioned by their biological features.

As a result of the research we have determined the declining series of crops as to nitrate content which looks as follows: white head cabbage > red beet > potatoes > parsley.

In the course of studies of vegetable produce quality as to nitrate content in it we carried out a comparative analysis of the quality of vegetables grown under the conditions of urban ecosystems and in the residential suburb. We compared nitrate content in the crops which coincided when carrying out monitoring in the urban area and residential suburb. They are potatoes, garden carrot, red beet, white head cabbage, cucumbers and parsley.

The comparative analysis showed that vegetables grown under the conditions of agroecosystems of residential suburb settlements are more polluted with nitrates than those grown in urban ecosystems. The difference in nitrate content was as follows: potatoes (1.2 times), white head cabbage (3.2), cucumbers (2.1) and parsley (2.6 times) (Fig. 2).

**Fig. 2.** Comparative analysis of nitrate pollution of vegetables grown under the conditions of urbosystems and agroecosystems of residential suburb (mg/kg)

Such tendency, in our opinion, testifies to the fact that rural dwellers much more often apply mineral and organic fertilizers, as crop growing areas in rural settlements are far larger than those on urban plots.

To achieve our goal, we carried out an analysis of nitrate content in different parts of vegetables. It is known that specific differences between plants as to accumulation of nitrates is often conditioned by their localization in individual parts of crops. In generative organs nitrates are absent or their content is less as compared with vegetative organs of plants, and in root, stem and leaf stalks their amount is considerably larger (1.5-4 times) than in leaf plate. Different content of nitrates is not only connected with individual speed of movement by vascular-conducting system to the place of restoration but also with the ability of these substances to actively redistribute themselves into the surrounding system of tissues.

The amount of nitrates is different in different parts of plants. Vascular-passing systems of plants which are the richest in nitrates are located nearer to the root. Their amount increases from leaf plate to leaf stalk and then to stem. For instance, in parsley, celery and dill leaves the amount of nitrates is 50-60 % less than in stems.

Thus, knowing zones of different parts of plants with higher nitrate amount, one may essentially reduce it in products of raw material processing. And consuming those parts of plants which contain the smallest amount of nitrates it is possible to reduce practically twice their entry to human body (Demidenko, 2015).

We investigated nitrate localization in different anatomical parts of white head cabbage, cucumber, parsley, sorrel and green onion, since their significance from the point of view of using them as food is not equal, and their specific weight is different (Fig. 3).

Tissues in which we determined the content of nitrate-ions differ by their functions. In this connection they are characterized by different anatomical structure as well as different intensity and character of metabolic processes.

In white head cabbage the highest nitrate concentration is observed in the upper part of the head. Upper leaves contain twice more nitrates than inner ones. Especially large content of nitrates is in leaf stalks and cabbage stump. More or less safe for human consumption are middle leaves from which fibres are preliminarily to be removed.

On the basis of experimental data we can draw a conclusion about differential accumulation of nitrates by anatomical parts of edible cucumber. Nitrates are mainly found in cucumber peel and the excess of their content as compared with pulp was 3.6 times.

The largest accumulation of nitrates is observed in the parts which contain large amount of xylemic tissues and in the cells where vacuoles are well developed, that is in the parts which serve for transportation of nutrients in plants. That is why nitrate concentration in parsley stalks is 4.65 times higher than in its leaves.

The similar situation is also observed with sorrel – nitrate content in stalks is 3.4 times higher than in leaves.

As to green onion, the excess of nitrate content in bulb was 4 times in comparison with green part (pinna). That is the part of vegetable which is in the soil will always accumulate larger amount of nitrates than its upper part.

Considerable danger for human body may be created by double contamination of food products with heavy metals and nitrates, since in this case one may observe the intensification of negative effect of both pollutants (summation effect).

The interest in the study of heavy metals in food products of plant origin is first of all conditioned by the fact that plants actually start the chain of migration of chemical elements in biosphere according to the scheme “soil-plant-animals-man” and are one of the most important ways of their coming to human body. This turned to be especially topical in the latest decades, since the accumulation of various pollutants and xenobiotics including heavy metals in biosphere takes place on account of uncontrolled anthropogenic and constantly intensifying influence on environment.

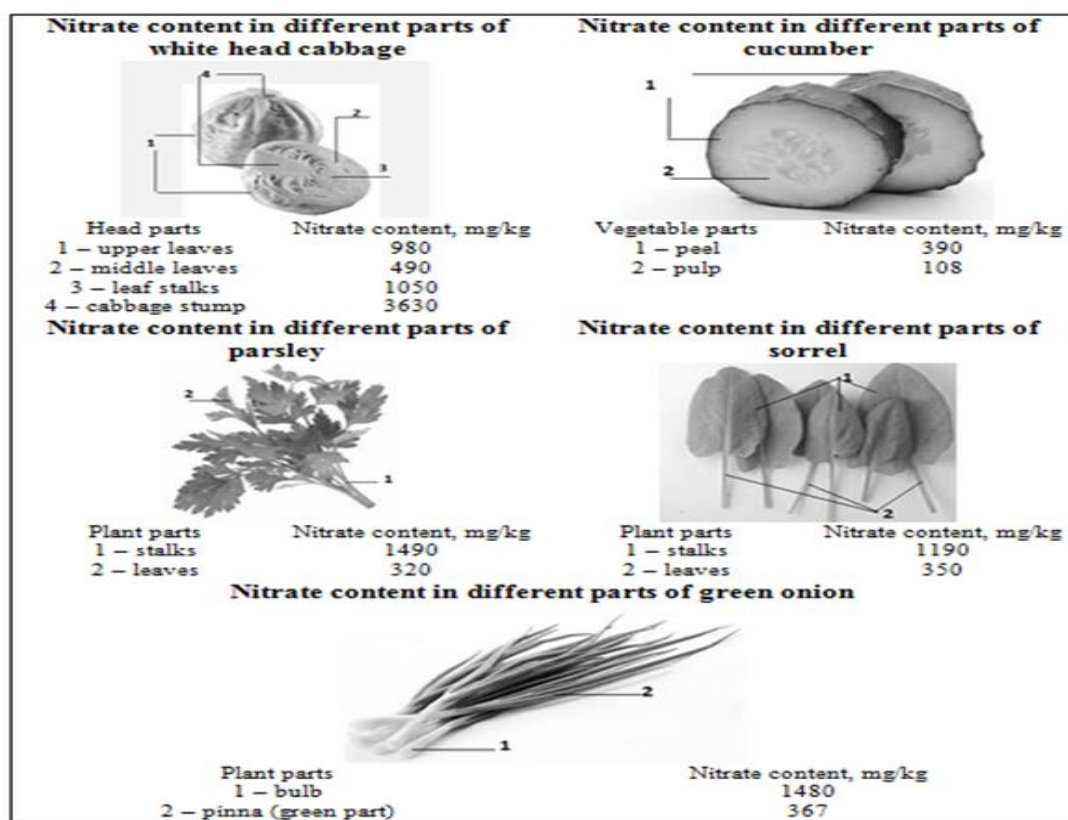


Fig. 3. Nitrate content in different vegetable parts

This results in substantial extension of diseases in etiology and pathogenesis of which one may observe disequilibrium of ions of metals and their compounds in human body. Today in many regions of Ukraine, especially in industrially developed cities, there arises a real threat of forming artificial, anthropogenous biogeochemical provinces with specific soil, water and air composition which is the cause of endemic disease development. Especial danger comes from the pollution of environment with heavy metals the substantial part of which in higher concentration has toxic influence on human organism and causes the disturbance of the course of metabolic processes both on the level of tissues and on the cell level.

It has been found that in the selected samples of plant products higher content of heavy metals is observed (Table 3).

Table 3. The content of heavy metals in vegetable crops grown on household plots in Zhytomyr, mg/kg

Crop, sampling volume	Cu	Pb	Cd	Zn
	<u>M±m*</u>	<u>M±m</u>	<u>M±m</u>	<u>M±m</u>
	lim V	lim V	lim V	lim V
Red beet, 12	<u>2,74±0,5</u>	<u>1,25±0,095</u>	<u>0,11±0,06</u>	<u>14,8±6,5</u>
	1,67-3,05	0,3-32	0,03-0,20	8,4-26,5
Parsley, 7	<u>1,8±0,29</u>	<u>2,55±1,67</u>	<u>0,22±0,07</u>	<u>31,65±1,4</u>
	1,32-2,09	0,2-4,3	0,16-0,35	7,8-44,2
Potatoes, 14	<u>5,85±0,15</u>	<u>1,015±0,07</u>	<u>0,045±0,003</u>	<u>11,9±2,3</u>
	1,4-12,6	0,5-2,0	0,04-0,06	10,2-17,0
Carrot, 5	<u>2,6±0,13</u>	<u>0,4±0,02</u>	<u>0,026±0,0013</u>	<u>9,24±0,96</u>
	0,75-4,3	0,16-0,65	0,02-0,03	7,6-10,2
Cabbage, 14	<u>6,36±0,6</u>	<u>1,25±0,08</u>	<u>0,06±0,002</u>	<u>7,45±0,6</u>
	4,5-8,0	0,4-2,3	0,02-0,15	9,2-10,8
MAC	5,0	0,5	0,03	10,0

Note: * - M - mean content of heavy metals, mg/kg; m - error of mean value; lim V - interval of values.

Higher amount of cuprum was fixed in potato and white head cabbage samples. The excess of lead content norm was registered practically in all vegetables except carrot. Its largest amount was found in leaf parsley with the excess of 5.1 times. The excess of lead in red beet and white head cabbage samples was established at the level of 2.5 MAC and in potatoes at the level of 2.03 MAC. The similar situation was also with cadmium, the excess admissible amount of which was fixed in all vegetables except carrot. By cadmium excess we have formulated the following declining vegetable series: leaf parsley (7.3 MAC) > red beet (3.7 MAC) > white head cabbage (2.0 MAC) > potatoes (1.5 MAC).

The largest amount of zinc was fixed in leaf parsley which exceeded MAC 3.2 times. Its MAC excess in red beet samples was 1.48 times and in potatoes it was 1.2 times. Thus, we have established that from the whole amount of the selected samples of vegetables grown on the territory of the private sector in Zhytomyr leaf parsley proved to be the most dangerous food product for human consumption, and the safest vegetable was garden carrot. To achieve our goal we selected samples of widely used vegetable products, namely potatoes, garden carrot, white head cabbage, red beet, cucumbers, tomatoes, onion and parsley grown in populated landscapes of the city's residential suburb.

As a result of the investigation into the content of heavy metals in vegetables we have established that completely safe for usage by man are garden carrot, red beet, cucumbers, tomatoes and onion in which the level of heavy metals is much lower than the maximum permissible one. In white head cabbage and parsley lead content was fixed at the level of 1.25 and 3.45 mg/kg which exceeded the norm 2.5 and 6.9 times respectively. The excess of cadmium MAC in cabbage and parsley was 2 and 3.3 times respectively. Small increase in cuprum content was found in white head cabbage, and zinc content exceeding the norm was fixed in potatoes (Fig. 4). It should especially be pointed out that cadmium accumulated in crop products in high concentration polluted them more frequently than other metals. Practically all vegetables grown within the limits of agropopulated landscapes of Zhytomyr residential suburb were polluted with this element, its content ranging between 1.3 and 3.3 MAC. In our opinion, this is caused by the fact that cadmium possesses high mobility; it is mobile in soil, dissolves quite well in water, is easily absorbed by plants and can substitute zinc in many biochemical processes as it is very similar to zinc by its chemical properties. Besides, on Zn-deficient lands cadmium accumulation in plants takes place even when its content in soil is low. Considerable geochemical similarity between Zn and Cd also conditions the similarity in transport of these elements into plants. Under such circumstances cadmium pollution of organs of assimilant storing in most crops becomes almost inevitable.

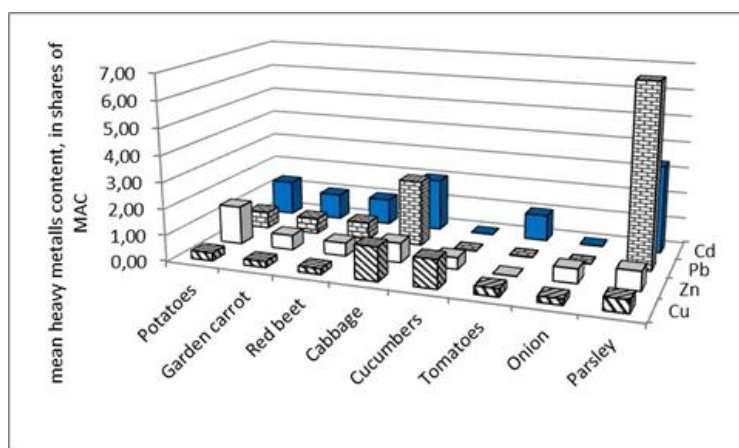


Fig. 4. The level of heavy metals accumulation in vegetables selected on household plots in rural settlements of the city's residential suburb

Representatives of Cucurbitae genus as well as bulb onion grown on agropopulated landscapes of the residential suburb accumulate the minimum quantity of cadmium in comparison with other botanical families, and maximum amount of this element is concentrated in white head cabbage and parsley. Zinc was not found as the priority pollutant of crop products, since its higher amount was only accumulated by potatoes.

The analysis of vegetable samples as to heavy metals content gives us the possibility to determine ranked series of heavy metals for each plant (Table 4).

The table data show that biophylic elements such as cuprum and zinc are in the first place as to their accumulation by plants. Plumbum and cadmium take the second place, but they remain the priority pollutants of vegetable produce because of their toxicity.

Table 4. Ranked series of heavy metals

Plant name	Ranked series of heavy metals
Potatoes	Zn>Cu>Pb>Cd
Garden carrot	Zn>Cu>Pb>Cd
Red beet	Zn>Cu>Pb>Cd
White head cabbage	Zn>Cu>Pd>Cd
Cucumbers	Cu>Zn>Pb>Cd
Tomatoes	Cu>Cd>Zn>Pb
Bulb onion	Zn>Cu>Pb>Cd
Parsley	Zn>Pb>Cu>Cd

As to the comparative analysis of vegetables grown under the conditions of urban ecosystems and agroecosystems of the city's residential suburb, we have found that the content of all heavy metals in the crops grown in the city's private sector except white head cabbage was higher than in the suburb. Red beet showed the increase in the content of all the elements in urban ecosystems as compared with agroecosystems (Fig. 5).

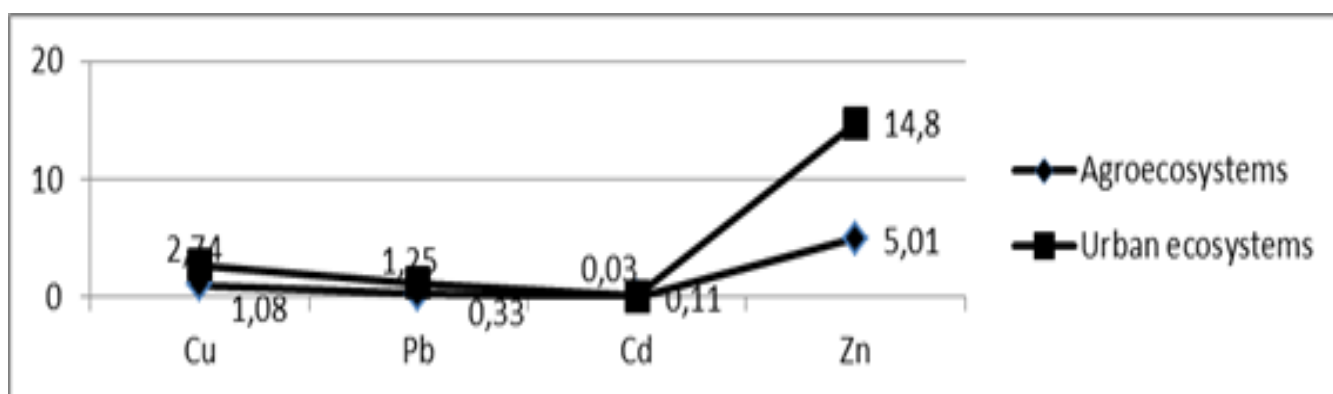


Fig. 5. The average content of heavy metals in red beet grown in urban and agroecosystems, mg/kg

In parsley grown under urban conditions the increase in heavy metals content was only fixed for cadmium and zinc (2.2 and 4.4 times respectively) as compared with rural territories. The reduction of cuprum and lead level was found in urban produce (Fig. 6).

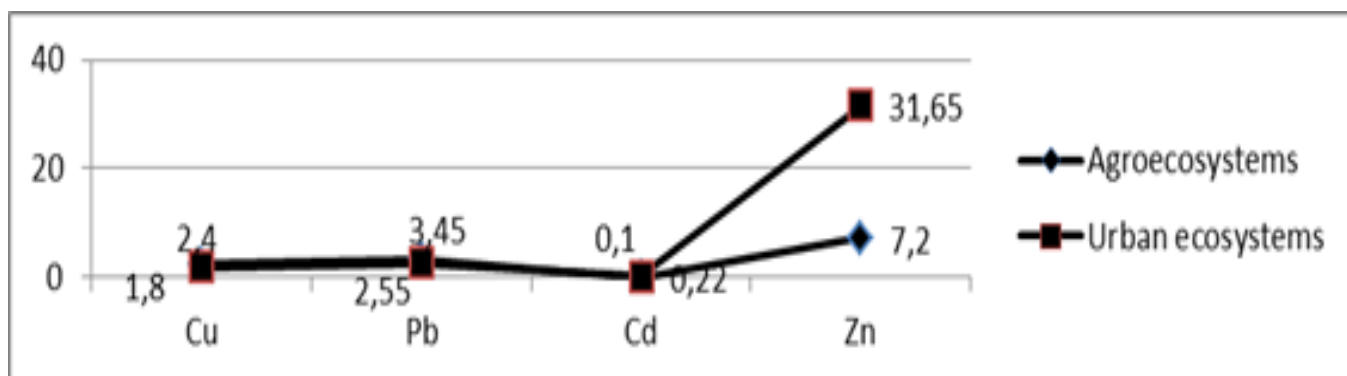


Fig. 6. The average content of heavy metals in parsley grown in urban and agroecosystems, mg/kg

The increase in the content of all the elements except zinc in potatoes was registered in urban ecosystems (Fig. 7). Carrot grown in the city's private sector accumulated smaller amount of cadmium in comparison with carrot grown on populated territories of the residential suburb. The content of the other elements in carrot was higher in the city than in its residential suburb (Fig. 8).

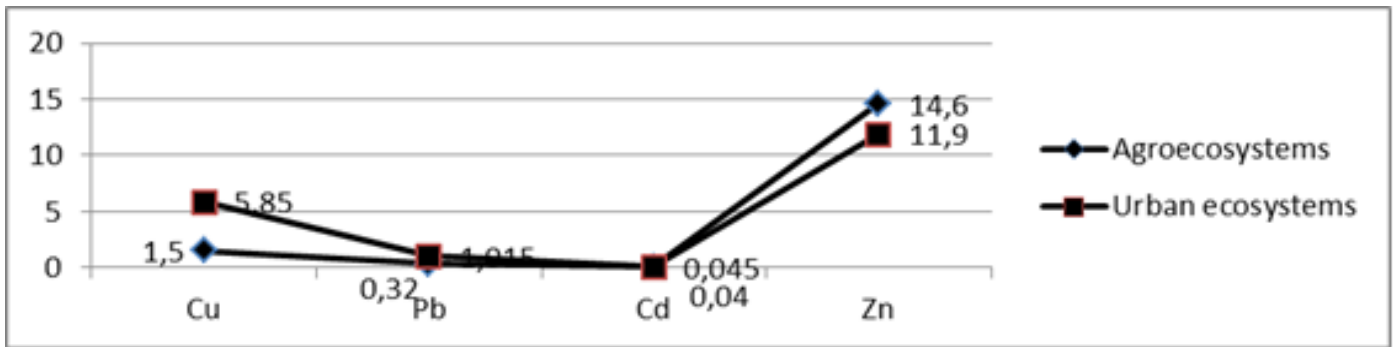


Fig. 7. The average content of heavy metals in potatoes grown in urban and agroecosystems, mg/kg

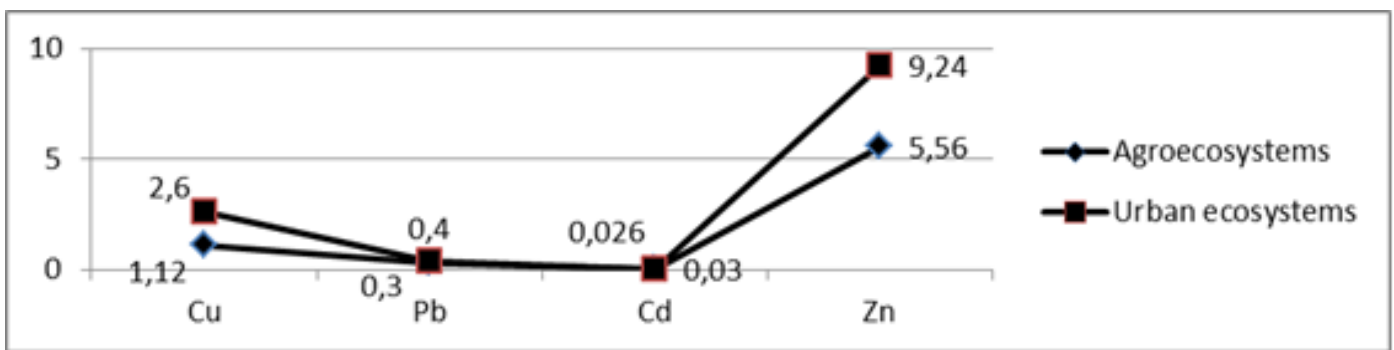


Fig. 8. The average content of heavy metals in garden carrot grown in urban and agroecosystems, mg/kg

Practically the same content of heavy metals was fixed in white head cabbage grown under different conditions (Fig. 9).

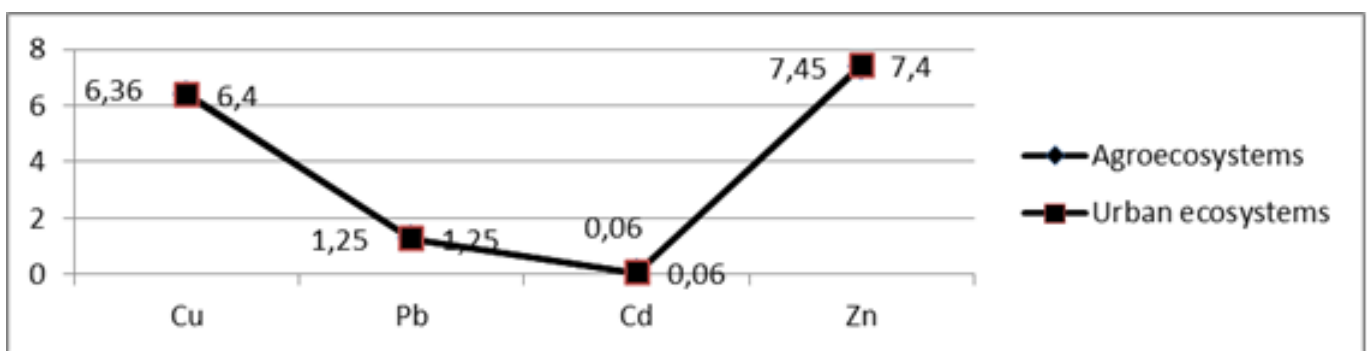


Fig. 9. The average content of heavy metals in white head cabbage grown in urban and agroecosystems, mg/kg

Thus, crops grown in urban ecosystems contain larger amount of heavy metals as compared with those grown in the residential suburb. This is most probably connected with airborne pollution of vegetables, since aeration in the city is much lower than in the suburb because of the large amount of multistorey buildings in it.

The knowledge of the peculiarities of heavy metals distribution in individual zones and tissues of different organs of vegetable crops gives an opportunity to assess their danger depending on the volume they occupy in a single organ, which will allow to make mechanical removal of its dangerous part (Myslyva, 2011).

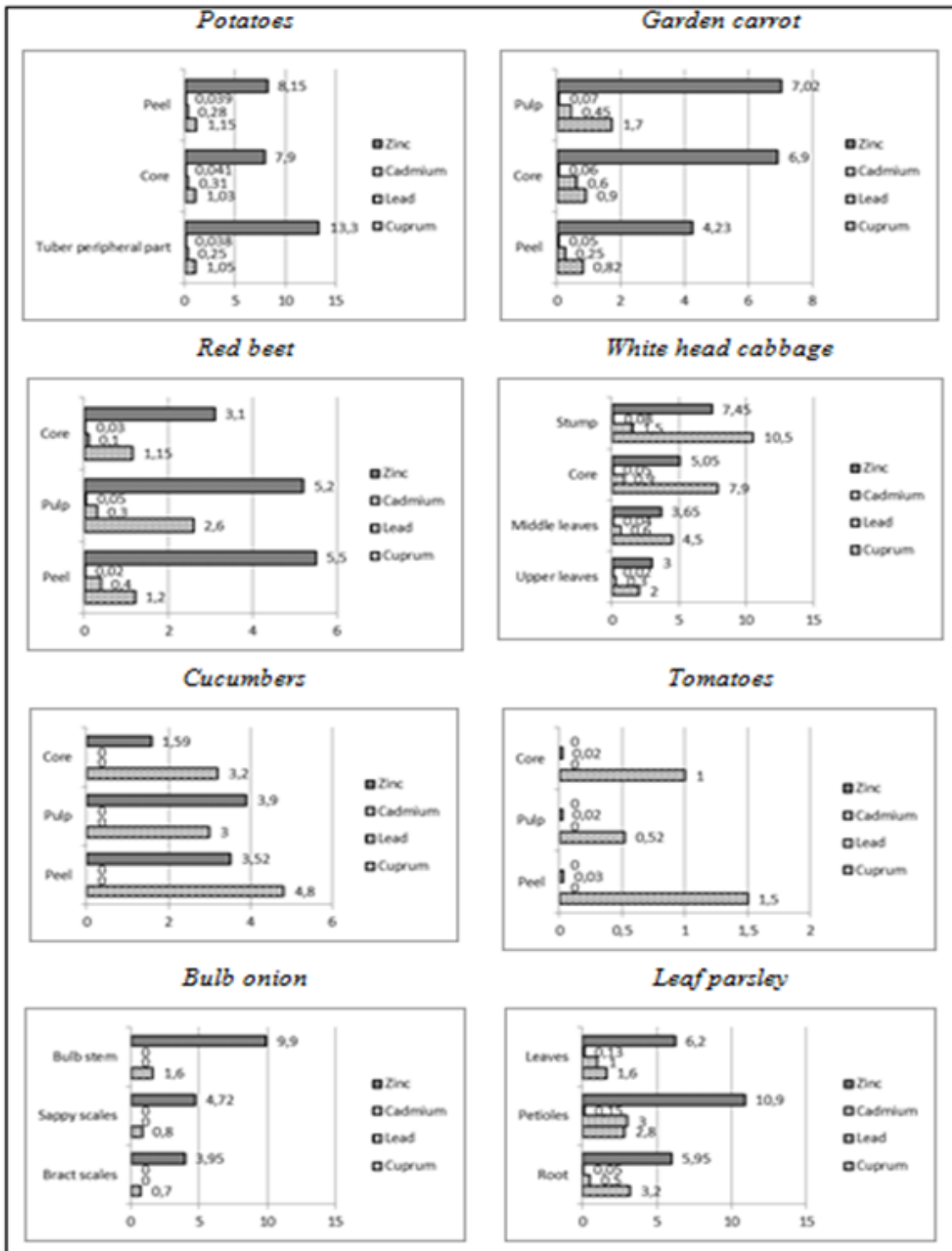


Fig. 10. Heavy metals distribution in vegetable crop organs, mean content, mg/kg

It has been established that in potato cuprum is evenly distributed in all tuber parts, and zinc maximum is concentrated in the peripheral zone. Lead and cadmium are found approximately in equal quantities in the peel and peripheral zone of the root crop. The maximum content of cuprum and cadmium was registered in carrot pulp, whereas lead and zinc mainly concentrated in its core. As to red beet the basic amount of cuprum and cadmium is concentrated in the root pulp, while lead and zinc maximum is in its peel. Besides, it has been found that the maximum amount of zinc, lead and cadmium is accumulated in the lower part of the root crop. The content of practically all elements under study in white head cabbage increases approximately 1.5-5.0 times from outer leaves to cabbage stump. All parts of cabbage head are notable for higher lead content and as to cuprum its higher content is observed in the core and stump. The largest amount of cuprum is concentrated in cucumber peel, whereas its pulp and core contain approximately equal amount of this element. Lead and cadmium were generally absent in this vegetable. Zinc was approximately equally accumulated in cucumber peel and pulp, and its minimum amount was in the core. The peel of tomatoes contained the maximum cuprum and cadmium amount permitted. In bulb onion Cu concentrates in sappy scales and Zn in bulb stem. Concerning greens the accumulation of heavy metals in leaf petioles was larger than in leaves. In particular, heavy metals accumulation in parsley stalks exceeded that in leaves 1.1-3 times depending on the pollutant (Fig. 10).

Conclusions

Carrying out the complex assessment of the quality of vegetable products grown within the limits of urban ecosystems of Zhytomyr and agroecosystems of its residential suburb gives us every reason to make a conclusion that not always these products satisfied the standards as to the content of nitrates and heavy metals in it. It has also been established that the conditions of growing vegetables influence their quality. In particular, vegetables grown in the city are safer concerning the content of nitrates in them than the same ones grown in the residential suburb. They also differ in quality as to the content of heavy metals in them. Urban produce is under stronger anthropogenic pressing, and therefore, the content of heavy metals in it substantially exceeds maximum allowable concentration; this especially concerns lead and cadmium.

The investigations concerning the accumulation of pollutants in different vegetable organs are important for human health because the knowledge of organs that accumulate more toxicants makes it possible to essentially reduce their coming to man's body. It has been established that distribution of pollutants among organs of plants is first of all determined by their species as well as by morphological and biological features of organs themselves.

Thus, the results of the research give us every reason for working out recommendations as to growing ecologically clean crop products on household plots in Zhytomyr and its suburban private sector under the conditions of intensified anthropogenic pressing.

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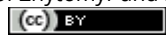
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