CONCENTRATION OF CADMIUM IN VEGETABLES GROWN ON CONTAMINATED GARDENS AND IN PURCHASED VEGETABLES

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Self-supply with home-produced vegetables is very common in urban areas, where cadmium is a characteristic pollutant due to its anthropogenic origin. It has a harmful effect on human health. People are exposed to cadmium in different ways. One of the most common is through consumption of contaminated food, such as home-produced vegetables. However, different vegetables accumulate cadmium in different concentrations and as such pose different risk to human health. In this research 6 species of vegetables were sampled: endive, chicory, courgettes, tomato, onion and carrot. Vegetables (edible parts) were sampled in gardens of the Municipality of Celje, which is the third largest city in Slovenia. In some areas soils in the city and its vicinity are polluted with heavy metals (e.g. cadmium, lead, zinc) due to past industrial activities. Sampling area was stratified into 6 zones according to Slovenian legislation and the level of soil pollution with cadmium (mg/kg DW): <0.99, 1.00 - 1.99; 2.00 – 3.99; 4 – 7.99; 8 – 11.99; >12. Additionally, vegetables were purchased in local shops, markets and supermarkets in order to compare concentrations of cadmium in vegetables grown in gardens and in purchased vegetables. The main goal of this research was to determine whether purchased vegetables contain significantly lower concentration of cadmium than vegetables produced on gardens of the Municipality of Celje. Results showed that the significant difference between the average concentrations of cadmium in purchased and garden vegetables was observed in vegetables produced in gardens with soil cadmium content above 2 mg/kg DW. Therefore, the recommendation to purchase vegetable rather than to produce it at home garden is justified in areas where the contamination of soil with cadmium is above 2 mg/kg DW when producing carrot, chicory and endive or above 4 mg/kg DW when producing courgettes, tomato and onion.

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Introduction

Cadmium is a very toxic metal and has a harmful effect on human health, including promotion of osteoporosis, kidney damage, and lung cancer[13]. It occurs naturally in ores together with zinc, lead, copper and phosphorous. Cadmium compounds are used as stabilizers in PVC products, colour pigment, re-chargeable nickel–cadmium batteries and several alloys[8]. Due to its wide application in industry, cadmium is a characteristic pollutant in urban areas, where self-supply with home-produced vegetables is very common. Therefore, home gardeners are unknowingly exposed to cadmium through consumption of contaminated home-produced vegetables. However, different vegetables accumulate cadmium in different concentrations and as such pose different risk to human health. According to Pettersson[11] the order for accumulation of cadmium in vegetables was lettuce > carrot, tomato > rape, kale, radish > cucumber, peas, bean. Alexander et al.[2] reported the following order: lettuce > spinach > onion > carrot > pea >french bean. Zupan et al.[16] observed slightly different order: spinach > endive > carrot > red beet > lettuce > radish > tomato > potato > pea > Brussels sprouts > cabbage > kohlrabi.

The research area was the Municipality of Celje which is the third largest city in Slovenia. The population of the city is 37.834 people [14]. In some areas soils in the city and its vicinity are polluted with metals (e.g. cadmium, lead, zinc) due to past industrial activities (e.g. zinc smelters, brickworks, enamelware industry, heavy traffic and steel mills)[9,15]. Eržen et al.[4] concluded that increased concentrations of cadmium in soil in two areas of Municipality of Celje (Medlog and Teharje) presented a problem because surpluses of yields are sold on a market.

This research was conducted in the context of main research "Risk assessment of cadmium intake from home grown vegetables on the local population of the Municipality of Celje". The main goal was to determine whether purchased vegetables contained significantly lower concentration of cadmium than vegetables produced on gardens of the Municipality of Celje. Moreover, we wanted to determine if recommendation to buy vegetable is justified?

Materials and Methods

The sampling took place in August and September 2008. Vegetables were sampled on 59 home gardens of the Municipality of Celje and 222 samples of vegetables were collected. Purchased vegetables were sampled on 20 markets, where local population may buy vegetables and 100 vegetable samples were collected. Only edible parts were sampled.

Sampling garden area was stratified into 6 zones according to the level of soil pollution with cadmium (mg/kg DW): <0.99, 1.00 - 1.99; 2.00 – 3.99; 4 – 7.99; 8 – 11.99; >12. Slovenian legislation[3] determines three normative values of Cd concentration in soil (mg/kg DW after aqua regia dissolution): 1 - limit, 2 - warning and 12 - critical. However, the interval between warning and critical value of Cd in soil is quite wide, therefore we divided it to get more gradual transition from moderate to heavy polluted gardens in the sampling area.

The following 6 species of vegetables were included in research: endive, chicory, courgettes, tomato, onion and carrot. Samples of vegetables from gardens and markets were brought to the laboratory of the "Centre for Soil and Environmental Science", where they were cleaned with deionised water and cut with a stainless steel knife. Samples were than lyophilised and crushed in mill "Retsch ZM 100". The concentration of cadmium in vegetables was determined in "Acme Analytical Laboratories Ltd", Canada, after aqua regia dissolution by inductively coupled plasma mass spectrometry. Blanks, duplicates and standard reference materials were inserted in the sequences of analysed samples. As data of concentration of cadmium in vegetable was expressed in dry weight (DW), conversion to fresh weight (FW) was made based on literature data (Table 1).

Table 1. The water content of selected vegetables (bolded number refers to the number of reference)

Vegetables	The water content (%)					
	10	**7**	**12**	**6**	**1**	**Average**
Courgettes	94,7	91	91,3	94	91,6	92,5
Tomato	93,4	94	94,2	93,8	94,5	94,0
Onion	92,8	88	87,6	89	89,11	89,3
Carrot	89,9	90	89,7	89,2	88,29	89,4
Edive	93,7	94	94,3	93,8	93,79	93,9
Chicory	96,2	94	94,4	94,7	94,52	94,8

Allowed maximum levels of cadmium in vegetables according to European legislation[5] are set for tomato, onion and courgettes at 0.05 mg/kg FW; for carrot at 0.10 mg/kg FW; and for endive and chicory at 0.20 mg/kg FW.

Results and Discussion

The concentration of cadmium in garden vegetables exceeded the regulatory allowed maximum level in 39 samples (Figure 1). The most frequently exceeded concentration of cadmium was in carrot (27-times), followed by onion (4-times), chicory (3-times), endive (2-times) and once in tomato. However, bear in mind that the number of sampled vegetable species was different.

The concentration of cadmium in purchased vegetables was exceeded in two samples, in carrot (0,157 mg/kg FW) and chicory (1,203 mg/kg FW) (Figure 2). Both two samples were produced locally and bought in city market.

Figure 3 illustrates the response of garden vegetables to increase concentrations of cadmium in soil. The lowest response was noticed in courgette and the moderate response in tomato and onion. The highest responses were observed in carrot, chicory and endive, which also explain the high average concentrations of cadmium in their tissue (Table 2). The first main increase of cadmium concentration in carrot, chicory and endive occurs at the level of garden pollution between 2.00-3.99 mg/kg DW of cadmium in soil and in courgette, tomato and onion at the level between 4.00-7.99 mg/kg DW.

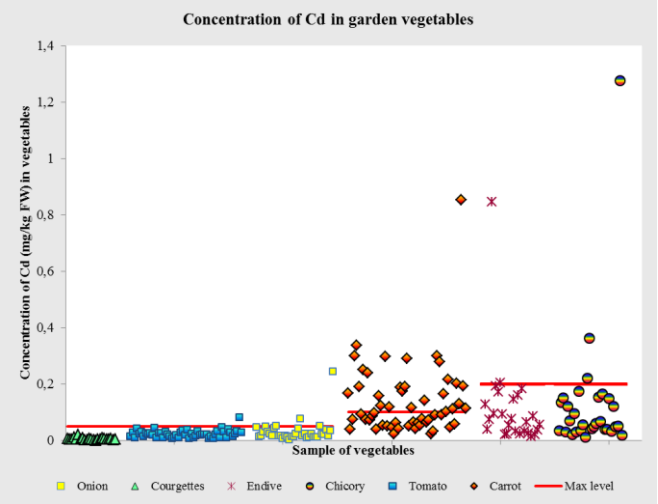

Figure 1. The concentrations of cadmium in a garden vegetable samples with maximum levels (mg/kg FW)[5]

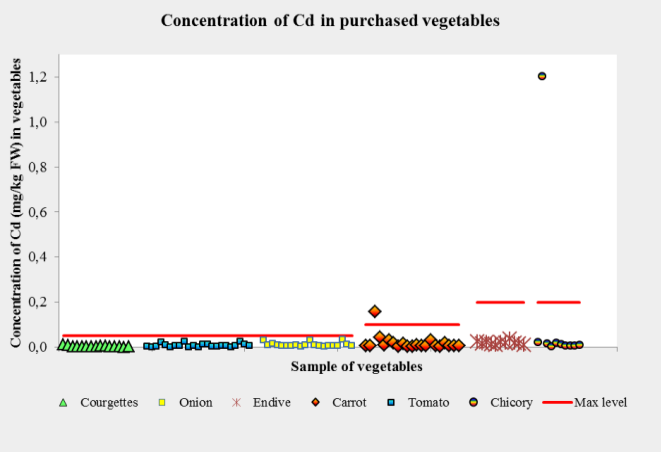

Figure 2. The concentration of cadmium in purchased vegetable sample, with maximum levels (mg/kg FW)[5]

Table 2 depicts the basic descriptive statistics for garden and purchased vegetables. The concentrations of cadmium in garden vegetables mostly varied in endive, chicory and carrot. The latter two also varied the most in purchased vegetables.

The average concentration of cadmium in vegetable was only exceeded in garden carrot (0,139 mg/kg FW). All other average concentrations of cadmium in vegetables were below the regulatory allowed maximum level. The lowest average concentration of cadmium in purchased vegetables was in courgettes (0,0034 mg/kg FW), followed by tomato (0,0074 mg/kg FW), onion (0,0104 mg/kg FW), carrot (0,0182 mg/kg FW), endive (0,0185 mg/kg FW) and chicory (0,1295 mg/kg FW). Similar order was observed in garden vegetables, with the difference in carrot being in the last place.

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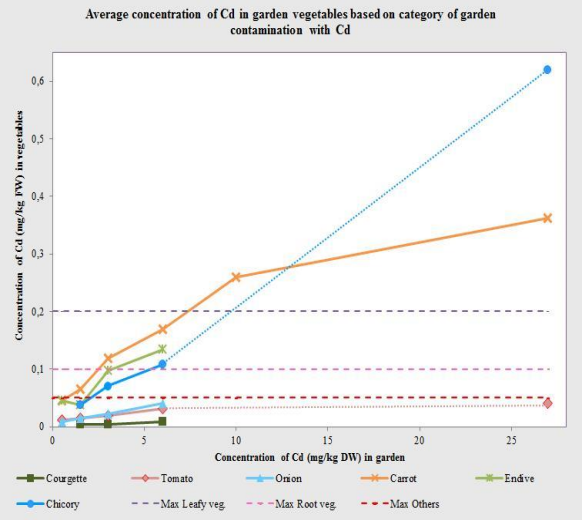

Figure 3. The average concentration of cadmium in vegetables grown on gardens with different soil cadmium content and regulatory allowed maximum levels of cadmium in vegetables. Dotted line refers to the lack of data of the average concentration of cadmium in chicory and tomato at level of soil pollution between 8.00 and 11,99 mg/kg DW of cadmium in garden.

The lowest concentration of cadmium in a sample was detected in fruit vegetables: in courgettes (0,0008 mg/kg FW) in garden vegetables and in tomato (0,0003 mg/kg FW) in purchased vegetables. The highest concentration of cadmium in a sample was detected in purchased and garden chicory (1,2028 mg/kg FW and 1,2761 mg/kg FW, respectively). Moreover, the highest difference between average value and median was noticed in chicory, but average values between purchased and garden chicory were similar (0,1295 and 0,1284 mg/kg FW, respectively).

Generally, the average concentrations of cadmium were lower in purchased vegetables than in garden vegetables. The average concentration of cadmium in courgettes was 1,7 times higher than in purchased, 3-times higher in tomato and onion, 6-times higher in endive and 7,6-times higher in carrot than in purchased ones. Likewise, the average concentration of cadmium in purchased vegetables was lower than average concentration of cadmium in garden vegetables, which were stratified in 6 garden categories, with the exception of chicory. In general, the significant difference between average concentrations of cadmium in purchased and garden carrot, chicory and endive were detected in gardens with soil cadmium content more than 2 mg/kg DW and in courgette, tomato and onion at gardens with soil cadmium content above 4 mg/kg DW.

The ratio between medians of garden and purchased courgettes, tomato and onion was similar compared to the ratio between average values of garden and purchased vegetables. However, the median of garden endive was 3,8-times higher compared to purchased, the median of chicory was 6,2-times higher and the median of carrot was 15,3-times higher compared to purchased ones.

Table 2. Descriptive statistics for vegetable samples from markets, gardens and according to category of garden contamination with Cd (mg/kg DW)

	N	Average (mg/kg FW)	±95% Conf.interval	Median	Min	Max	SD	SE	Max level (mg/kg FW)
Courgette									
MARKET	15	0,0034	0,0016	0,0023	0,0008	0,0113	0,0029	0,0007	**0,05**
GARDEN	23	0,0057	0,0018	0,0045	0,0008	0,0203	0,0041	0,0009	
Category of garden									
under 1	1	/	/	/	/	/	/	/	
between 1-1,9	6	0,0044	0,0010	0,0045	0,0008	0,0098	0,0032	0,0013	
between 2-3,9	9	0,0043	0,0025	0,0038	0,0015	0,0083	0,0023	0,0008	
between 4-7,9	6	0,0090	0,0027	0,0075	0,0038	0,0203	0,0060	0,0025	
between 8-11,9	0	/	/	/	/	/	/	/	
above 12	1	/	/	/	/	/	/	/	
Tomato									
MARKET	23	0,0074	0,0031	0,0060	0,0003	0,0258	0,0072	0,0015	**0,05**
GARDEN	52	0,0225	0,0037	0,0210	0,0060	0,0804	0,0133	0,0018	
Category of garden									
under 1	3	0,0116	0,0228	0,0066	0,0060	0,0222	0,0092	0,0053	
between 1-1,9	13	0,0145	0,0100	0,0132	0,0060	0,0288	0,0076	0,0021	
between 2-3,9	20	0,0199	0,0161	0,0210	0,0084	0,0330	0,0081	0,0018	
between 4-7,9	10	0,0317	0,0240	0,0306	0,0144	0,0456	0,0107	0,0034	
between 8-11,9	1	/	/	/	/	/	/	/	
above 12	5	0,0407	0,0124	0,0348	0,0240	0,0804	0,0227	0,0102	
Onion									
MARKET	20	0,0104	0,0044	0,0070	0,0032	0,0342	0,0094	0,0021	**0,05**
GARDEN	36	0,0304	0,0135	0,0193	0,0032	0,2429	0,0399	0,0066	
Category of garden									
under 1	3	0,0093	0,0031	0,0107	0,0064	0,0107	0,0025	0,0014	
between 1-1,9	10	0,0148	0,0094	0,0134	0,0032	0,0289	0,0075	0,0024	
between 2-3,9	14	0,0218	0,0151	0,0161	0,0118	0,0514	0,0115	0,0031	
between 4-7,9	6	0,0408	0,0326	0,0412	0,0310	0,0514	0,0078	0,0032	
between 8-11,9	0	/	/	/	/	/	/	/	
above 12	2	/	/	/	/	/	/	/	
Carrot									
MARKET	21	0,0182	0,0153	0,0064	0,0021	0,1569	0,0336	0,0073	**0,10**
GARDEN	55	**0,1386**	0,0350	0,0975	0,0223	0,8544	0,1296	0,0175	
Category of garden									
under 1	4	0,0451	0,0207	0,0498	0,0233	0,0572	0,0153	0,0076	
between 1-1,9	13	0,0650	0,0489	0,0636	0,0223	0,1177	0,0266	0,0074	
between 2-3,9	21	0,1183	0,0839	0,1018	0,0318	0,3000	0,0755	0,0165	
between 4-7,9	9	0,1696	0,1144	0,1654	0,0731	0,2979	0,0718	0,0239	
between 8-11,9	3	0,2593	0,0766	0,2502	0,1908	0,3371	0,0736	0,0425	
above 12	5	0,3623	0,0137	0,2904	0,1738	0,8544	0,2808	0,1256	
Endive									
MARKET	11	0,0185	0,0053	0,0183	0,0098	0,0378	0,0080	0,0024	**0,20**
GARDEN	26	0,1117	0,0654	0,0698	0,0128	0,8473	0,1618	0,0317	
Category of garden									
under 1	3	0,0460	0,0994	0,0250	0,0207	0,0921	0,0400	0,0231	
between 1-1,9	7	0,0377	0,0227	0,0329	0,0207	0,0659	0,0162	0,0061	
between 2-3,9	10	0,0980	0,0495	0,0808	0,0128	0,1928	0,0677	0,0214	
between 4-7,9	5	0,1348	0,0677	0,1269	0,0738	0,2056	0,0541	0,0242	
between 8-11,9	0	/	/	/	/	/	/	/	
above 12	1	/	/	/	/	/	/	/	
Chicory									
MARKET	10	0,1295	0,2698	0,0094	0,0042	1,2028	0,3772	0,1193	**0,20**
GARDEN	30	0,1284	0,0858	0,0580	0,0104	1,2761	0,2298	0,0419	
Category of garden									
under 1	0	/	/	/	/	/	/	/	
between 1-1,9	8	0,0383	0,0230	0,0372	0,0104	0,0671	0,0183	0,0065	
between 2-3,9	11	0,0708	0,0386	0,0499	0,0291	0,1659	0,0478	0,0144	
between 4-7,9	7	0,1080	0,0549	0,1217	0,0177	0,1732	0,0574	0,0217	
between 8-11,9	1	/	/	/	/	/	/	/	
above 12	3	0,6198	1,4230	0,3635	0,2200	1,2761	0,5728	0,3307	

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Conclusion

Due to basic statistics parameters and the fact that the average concentration of cadmium in garden vegetables was at least two times higher than in purchased vegetables, with the exception of chicory, the purchased vegetable contribute less cadmium in food chain than garden vegetables. However, the significant difference between the average concentrations of cadmium in purchased and garden vegetables was observed in vegetables produced in gardens with soil cadmium content above 2 mg/kg DW. Therefore, the recommendation to purchase vegetable rather than to produce it at home garden in contaminated areas is justified in areas where the contamination of soil with cadmium is above 2 mg/kg DW when producing carrot, chicory and endive or above 4 mg/kg DW when producing courgettes, tomato and onion.

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