Detection and Analysis of Lead, Cadmium and Arsenic Content in Common Vegetables

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Abstract This study was carried out to detect content of heavy metals (Pb, Cd, and As) in vegetables, understand the current situation of heavy metal contamination in vegetables, and to provide scientific reference for further researches. It randomly selected 6 large vegetable markets and 6 supermarkets in Changsha City, selected 8 types of typical vegetables, and detected 96 samples. In accordance with maximum level of contaminants in foods in existing GB2762 – 2012 standard, Nemerow composite pollution index (P_t) and grading standards, it made evaluation: uncontaminated ($P_t \leqslant 1$), mildly contaminated ($1 < P_t \leqslant 2$), moderately contaminated ($2 < P_t \leqslant 3$), and highly contaminated ($P_t > 3$). Among 96 samples, range of content of Pb, Cd and As is (0.06 – 1.41), (0.06 – 1.26) and (0.00 – 0.91) mg/kg respectively; the over – limit rate of these metals exceeding the safety level is 78.13%, 45.83%, and 34.38% separately; the composite pollution index is in (0.90 – 6.05), the eggplant is 6.05 and hot pepper is 3.24; the content of Pb ($F = 23.908$, $P = 0.001$) and Cd ($F = 64.908$, $P = 0.000$) are significantly different between 8 types of vegetables and there is no significant difference between the content of As ($F = 4.634$, $P = 0.705 > 0.05$) in 8 types of vegetables. Study shows that common vegetables in Changsha City has problem of excess Pb, Cd and As, and the Pb over – limit rate is the highest. The composite pollution index indicates that most heavy metal contamination of vegetables is mild and moderate contamination, melon, fruit and vegetable contamination is high contamination, and Cd is the major factor leading to contamination of melons, fruits and vegetables.

Key words Heavy metals, Vegetable, Lead (Pb), Cadmium (Cd), Arsenic (As)

Vegetable is essential food for people. According to *Dietary Guideline for Chinese Residents* (2007), food should be diverse, cereal should be the major part with combination of coarse and fine grain, and it is recommended to take more vegetables, fruits, and tuber crops[1]. However, with the economic development, environmental pollution becomes increasingly serious. The pollution of heavy metals to soil and water is also worse and worse, which exerts certain influence on growth and development of plants. Heavy metals can enter into roots, stems and leaves of plants, store up, and finally enter into human body through the food chain, accordingly harming human health[2]. Vegetable intake accounts for a large part in daily food intake, thus content of heavy metals in vegetables should not be neglected. Many researches have indicated that vegetables in Changsha City are seriously contaminated by heavy metals, especially Lead (Pb) and Cadmium (Cd)[3-4]. However, researches in recent years are relatively few. Therefore, it is necessary to detect content of heavy metals in common vegetables sold at Changsha markets and make survey and evaluation of the contamination situation.

We randomly selected 8 types of common vegetables in 3 districts of Changsha City, detected content of Pb, Cd and As, and analyzed the detection results, in the hope of providing scientific reference for in-depth study and coming up with solutions.

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1 Materials and methods

1.1 Sample source We randomly selected 6 large vegetable markets and 6 supermarkets in Changsha City, collected 96 samples (8 for each market and supermarket) of 8 common vegetables. The weight of each sample of each type of vegetable is 1 kg.

1.2 Detection items and methods Pb and Cd were separately detected in accordance with existing standards GB/T5009.12 – 2010 and GB/T5009.15 – 2003 using Graphite furnace atomic absorption spectrometry (GFAAS); as was detected using silver diethyl-dithiocarbamate method as per the standard GB/T5009.11 – 2003.

1.3 Evaluation methods Heavy metal contamination of vegetables was evaluated using maximum limit of contaminants in food specified in existing GB2762 – 2012: Pb in vegetables (cormogenous vegetables and leafy vegetables, excluding edible fungus) ≤ 0.1 mg/kg; Pb in cormogenous vegetables and leafy vegetables ≤ 0.3 mg/kg; Cd in rhizome vegetables (except celery) ≤ 0.1 mg/kg, Cd in leafy, celery and edible fungus ≤ 0.2 mg/kg, Cd in other types of vegetables ≤ 0.05 mg/kg; As in vegetables ≤ 0.5 mg/kg. The evaluation method adopted Nemerow composite pollution index method[5] and grading standard (Table 1), using following formula:

$$P_t = \{[(C_i/S_i)^2 \max + (C_i/S_i)^2 \text{ave}]/2\} 1/2$$

where, P_t signifies composite pollution index, C_i is the measured concentration of the contaminant i, S_i is evaluation standard of contaminant i, (C_i/S_i)max stands for maximum value of pollution index in contaminants, (C_i/S_i) ave is average value of pollution index in contaminants, and single pollution index $P_i = C_i/S_i$.

1.4 Quality control Glass ware were firstly washed with cleaning solution, soaked in 10% nitrate solution for 24 hours, washed with distilled water, and then dried for use. Accuracy of the test: regression analysis was carried out for fitting curve of standard Pb, Cd and As solution (regression coefficient r is 0.997, 0.998 and 0.997 respectively). Precision of the test: standard substance was added to samples and the same methods were used to digest and detect. Through calculation, the Pb recovery rate is 97.47%, Cd recovery rate is 100.54%, and As recovery rate is 101.19%.

Table 1 Grading standard using Nemerow composite pollution index method

Grade	P_t	Pollution intensity
1	$P_t \leqslant 1$	Not contaminated
2	$1 < P_t \leqslant 2$	Mildly contaminated
3	$2 < P_t \leqslant 3$	Moderately contaminated
4	$P_t > 3$	Highly contaminated

1.5 Statistical analysis We used SPSS 19.0 statistical software to analyze data. Normal distribution adopted the single factor variance to compare average value of samples, and pairwise comparison adopted LSD test; abnormal distribution adopted rank sum test to compare difference between groups. The significance level $\alpha = 0.05$.

2 Results and analyses

2.1 General conditions of samples Detection results of Pb, Cd and As in vegetables were listed in Table 2. Table 2 indicates that the over-limit rate of Pb, Cd and As in samples is 78.13%, 45.83% and 34.38% respectively.

Table 2 Detection results of Pb, Cd and As in sample vegetables (n = 96)

Item	Quantity of samples	Concentration range//mg/kg	Quantity of samples exceeding standard	Over-limit rate//%
Pb	96	0.06 – 1.41	75	78.13
Cd	96	0.00 – 0.91	44	45.83
As	96	0.06 – 1.26	33	34.38

2.2 Detection results of Pb, Cd and As in sample vegetables

We used variance analysis and rank sum test to compare differences of 3 heavy metals between 8 types of vegetables. The detection results were listed in Table 3. Detection results indicate that the content of Pb (F = 23.908, P = 0.001) and Cd (F = 64.908, P = 0.000) are significantly different between 8 types of vegetables and there is no significant difference between the content of As (F = 4.634, P = 0.705) in 8 types of vegetables. Therefore, Pb content in leafy vegetables is higher than in other types of vegetables; Cd content in leafy vegetables, melons and fruits is higher than in rhizome vegetables, and there is no significant difference in As content.

2.3 Analysis of pollution index of samples The calculation results of composite pollution index of 3 heavy metals in samples and pollution index were listed in Table 4. It indicates that P_t of eggplants and peppers is higher than 3, P_t of lettuce and romaine lettuce is lower than 1, and P_t of other vegetables is in the range of 1 – 3. Single pollution index (Pi) of Cd has the largest contribution to the composite pollution index (P_t), followed by Pb, and As has the smallest contribution.

Table 3 Detection results of Pb, Cd and As in sample vegetables

Name of vegetable	Pb			Cd			Cd		
	$\bar{x} \pm s$ mg/kg	National standard (GB) mg/kg	Quantity of samples exceeding standard	$\bar{x} \pm s$ mg/kg	National standard (GB) mg/kg	Quantity of samples exceeding standard	$\bar{x} \pm s$ mg/kg	National standard (GB) mg/kg	Quantity of samples exceeding standard
Lettuce (n = 12)	0.28 ± 0.16	≤0.30	4	0.08 ± 0.04	≤0.10	2	0.45 ± 0.23	≤0.50	4
Eggplant (n = 12)	0.34 ± 0.12	≤0.10	12	0.38 ± 0.18	≤0.05	12	0.39 ± 0.20	≤0.50	3
White turnip (n = 12)	0.20 ± 0.13	≤0.10	10	0.25 ± 0.14	≤0.10	10	0.48 ± 0.25	≤0.50	5
Swamp cabbage (n = 12)	0.51 ± 0.40	≤0.30	7	0.36 ± 0.25	≤0.20	9	0.50 ± 0.28	≤0.50	4
Cauliflower (n = 12)	0.21 ± 0.12	≤0.10	10	0.02 ± 0.01	≤0.20	0	0.50 ± 0.33	≤0.50	2
Pakchoi (n = 12)	0.43 ± 0.22	≤0.30	8	0.19 ± 0.14	≤0.20	0	0.60 ± 0.28	≤0.50	8
Pepper (n = 12)	0.19 ± 0.06	≤0.10	12	0.20 ± 0.13	≤0.05	11	0.39 ± 0.22	≤0.50	3
Romaine lettuce (n = 12)	0.31 ± 0.25	≤0.30	12	0.16 ± 0.10	≤0.20	3	0.45 ± 0.22	≤0.50	4

Table 4 Analysis results of pollution index of sample vegetables

Name of vegetable	Single pollution index (P_i)			Composite pollution index (P_t)	Pollution intensity
	Pb	Cd	As		
Lettuce	0.93	0.80	0.90	0.90	Not contaminated
Eggplant	3.40	7.60	0.78	6.05	Highly contaminated
White turnip	2.00	2.50	0.96	2.19	Moderately contaminated
Swamp cabbage	1.70	1.80	1.00	1.66	Mildly contaminated
Cauliflower	2.10	0.10	1.00	1.67	Mildly contaminated
Pakchoi	1.43	0.95	1.20	1.32	Mildly contaminated
Pepper	1.90	4.00	0.78	3.24	Highly contaminated
Romaine lettuce	1.03	0.80	0.90	0.97	Not contaminated

3 Conclusions and discussions

Vegetable is essential food for human beings and its safety receives wider and wider concern. Heavy metal is a major factor harming vegetable safety. Once heavy metals enter into vegetables and store up, they will jeopardize human health through the food chain. Researches have shown that lead is one of major heavy metals increasing risks of non-cancerous diseases. For example, lead poisoning will interfere with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders, and also lead to thyroid gland diseases[6]. Cadmium is a major heavy metal increasing risk of cancers. A study in Japan has indicated that increase of daily intake of cadmium will greatly increase risk of breast cancer[7]. Excessive intake of arsenic will also lead to various health problems, including skin, respiratory track, cardiovascular, intestines and stomach, blood, liver, nerve, development, reproduction, immunity, gene diseases, and have certain carcinogenic action[8]. This study was carried out to detect content of heavy metals (Pb, Cd, and As) in vegetables, understand the current situation of heavy metal contamination in vegetables, and to provide scientific reference for further researches.

In recent years, United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO) of the United Nations, and World Health Organization (WHO) have taken heavy metal pollution of vegetables and foods as major project in the global food pollution monitoring program. There are also such reports one after another. Singh *et al* surveyed heavy metal pollution of vegetables in New Delhi and found that Cu, Zn, Pb and Cd in spinach exceeded the limit, and the over-limit rate was 13%, 95%, 78% and 100% respectively[9]; George *et al* detected heavy metal content in vegetables of 46 sampling points in 4 farms and found that Pb and Cd content in vegetables in Boolaroo exceeded the maximum limit of Pb and Cd specified in Australian food standard[10]. In this study, we measured 8 types of sample vegetables sold at markets of Changsha City. We found that the over-limit rate of Pb, Cd and As in sample vegetables was 78.13%, 45.83% and 34.38% respectively, indicating that vegetables sold in Changsha City have certain heavy metal pollution.

The problem of heavy metal pollution of vegetables also receives wide concern in China. It is reported that cultivated land suffered from heavy metal (such as Cd, As, Cr and Pb) pollution is near 20 million hectares, some countries and regions refuse to import agricultural and sideline products from China[11], which leads to huge loss to China's economy; on the other hand, people start to realize the importance of food security, thus locating reasons for heavy metal pollution of vegetables is of great significance. Some surveys indicate that heavy metal pollution of vegetables is possibly related with heavy metal content in soil. Salazar MJ *et al* measured and analyzed heavy metal content in Argentinean soybean and soil, and found that the heavy metal content in soybean has direct relationship with the heavy metal content in planting soil[12]. Data analysis results of Cui Xiaofeng *et al* also indicate that there is significant positive correlation between heavy metal content in vegetables and total content of Pb and Cd and their effective state content in soil, and no significant correlation with total content of As in soil[13]. However, the study of Liu X *et al* indicates that there is no direct statistical significance in heavy metal content in soil and vegetables. To guarantee soil quality and food security, they stated that additional environmental quality monitoring should also be given special attention[14], such as untreated water for irrigation[15] and heavy metal concentration in air[16]. Thus, it is necessary to make further research to make clear the influence of soil and other related factors on heavy metal content in vegetables.

Some researches show that different types of vegetables have great difference in absorbing and gathering heavy metals, while the same type of vegetable is also different in absorbing and gathering different heavy metals. Pb content in leafy vegetables is higher than in other types of vegetables; Cd content in leafy vegetables, melons and fruits is higher than in rhizome vegetables, and there is no significant difference in As content. It can be concluded that leafy vegetables have higher ability of absorbing and gathering Pb and Cd than other types of vegetables. Single pollution index (Pi) of Cd has the largest contribution to the composite pollution index (P_t), so it can be concluded that Cd is easier to be absorbed by leafy vegetables, melons and fruits. This also supports the above opinions to a certain extent.

In sum, vegetables in Changsha City has problem of excess Pb, Cd and As, and the Pb over-limit rate is the highest, up to 78.13%. The composite pollution index indicates that most heavy metal contamination of vegetables is mild and moderate contamination, melon, fruit and vegetable contamination is high contamination, and Cd is the major factor leading to contamination of melons, fruits and vegetables. In line with the above situations, we will continue studying related factors of vegetable and soil pollution. At the same time, we recommend that relevant departments should strengthen monitoring, enhance environmental control, and actively study causes for heavy metal pollution of vegetables.

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ment.

3.3 Enhancing market admission requirement and pushing forward structure adjustment of food industries Because small companies take up a large proportion in the food industry in China, it is difficult for government to supervise. In order to pursue the maximum interest, small food factories would prefer illegal production since the cost to enter and exit market is low, which indicates it is of great necessity to enhance companies' illegal cost and to force companies for safe production. Moreover, local government should update food industries and promote structure adjustment so that food factories can become stronger, larger and produce safer products[10].

Meanwhile, considering the scattered small factories in China, food and medicine departments should cooperate with each other to accelerate adjustment of agricultural structure. It is suggested that the new pattern "company + cooperation + farmers" can make companies and farmers become more intimate[14].

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