Health Risk of Heavy Metals to the General Inhabitants in Guilin, China via Consumption of Vegetables

Li-zhu Yuan[1], Bo Song[1], Yu-fei Huang[1],
Feng-yan Fu[1], Su-fen Lu[1]
[1]College of Environmental Science and Engineering,
Guilin University of Technology,
Guilin 541004

Xue-mei Zhong[2*]
[2]College of Earth Sciences,
Guilin University of Technology,
Guilin 541004
*Corresponding Author: zxm_glite@163.com

***Abstract*—To estimate the human health risk of heavy metals associated with consumption of vegetables, a total of 566 samples of vegetables were collected from Guilin to analyse heavy metals (As, Cd, Pb, Cu, Zn, and Ni) concentrations and the human risk. The average concentrations of As, Cd, Pb, Cu, Zn, and Ni in vegetables were 0.010, 0.026, 0.049, 0.315, 2.454 and 0.036 μg·g^{-1}(fw), respectively. The estimated daily intake (EDI) of heavy metals were less than the provisional tolerable daily intakes values (PTDI). Individual metal target hazard quotient (THQ) values and total metal THQ value indicated that it was still safe for the general population of Guilin to consume locally produced vegetables. As, Cd, and Pb were the major components contributing to the potential health risk for local inhabitants via consumption of vegetables.**

Keywords-heavy metals; human health risks; vegetable; Guilin

I. Introduction

With the rapid growth in industrialization, soil contamination with heavy metals is becoming an important environmental problem on a global scale[1]. Heavy metals present a risk for human health because they are non-degradable pollutants[2], having a range of effect, such as cardiovascular, nervous, kidney, and bone diseases, especially for young children who are more sensitive to these contaminants than adults. Vegetables are important constituents of human diet across the world, as vegetables are rich sources of vitamins, minerals, and fibers, and also have beneficial antioxidative effects [3]. Therefore, the safety of vegetables is a serious and current concern for government and regulatory bodies for environmental and human risk assessment, especially the consumption of vegetables for Chinese residents is increasing greatly with the food structural adjustment in recent years [4].The objectives of this study are to (1) investigating the concentrations of heavy metals in vegetable in different districts of Guilin; (2) assessing the health risks associated with these heavy metals via consumption of vegetables to general population by comparing EDI with PTDI recommended by FAO/WHO and using THQ.

II. Materials and methods

A. Sampling and pretreatment

A total of 566 fresh vegetable samples were collected in the thirteen counties of Guilin. Based on the edible part of the plant, samples were classified as leafy vegetables (LV) (62.7%), gourd and fruit vegetables (GFV) (29.2%), and stem and root vegetables (RSV) (8.1%). And 82.3% of vegetable samples were directly taken from farmlands, and others from markets for human consumption. The fresh vegetable samples were collected in clean polyethylene bags in the field, and transported to the laboratory. The vegetable samples then were washed with tap water to eliminate the air-borne pollutants and soil particles, and then rinsed with deionized water, dried with filter papers. The edible parts of each vegetable were weighed to get fresh weight, recording, and then oven dried at 80℃ to attain constant weight. Moisture contents was calculated by recoding the fresh and dry weights. The dried samples were crumbled and pulverized with a porcelain pestle and mortar.

B. Digestion and determination

The vegetable samples were digested using the method recommended by USEPA. The concentrations of Cu and Zn were measured using a flame atomic absorption spectrometer (AAS, PE AA-700) and the concentrations of Cd, Pb and Ni were measured using graphite furnaceatomic absorption spectrometry (GF-AAS, PE AA-700). The concentrations of As was measured using hydride generation atomic fluorescence spectroscopy (AFS-9605).

C. Statistical analysis

Statistical analysis was performed by using SPSS 18.0 program. It is necessary to describe the probability distribution characterization of the variables at first. And Statistical tests included ANOVA, t-test and a probability level of $P<0.05$ was considered statistically significant. The EDI and THQ of heavy metals was calculated based on the reference[5].

III. Result and discussion

A. Concentration of heavy metals in vegetables

The result showed that the vegetables concentrations of Zn, Cd and Ni followed a lognormal distribution and Pb, Cu and As followed a Box-Cox normal distribution. The average concentrations and range of heavy metals (mg kg-1, fresh weight) in the vegetables collected from Guilin are shown in Table I. There were 7, 1, 2 and 11 samples below the detection limit of 0.001 mg/kg for As, Ni, Cd and Pb, respectively. According to the GB2762-2005 and Chinese temporary maximum level of Ni[6], the concentrations of Pb, As, Cd, and Ni in 8.7%, 1.6%, 4.4% and 2.1% of vegetable samples exceeded the maximum level (ML) of the tolerance limit of contaminants in foods from China, respectively. However, Cu and Zn were not regulated in China. Compared with the ML of contaminants set by FAO/WHO [7] and European Communities (EC)[8], the concentrations of Cu, Zn, and Ni were found to be greatly lower than the ML. 3% of the vegetable samples exceeded the ML for Pb set by FAO and EC, while 9.4% and 6.9% of vegetable samples exceeded the ML of FAO and EC set for Cd, respectively. In this study, 2 stem and root vegetables, 6 LV and 1 fruit vegetable samples exceeded the ML for As set by the FAO.

TABLE I. MEAN AND RANGE OF HEAVY METALS CONCENTRATIONS (MG/KG FW) IN VEGETABLES COLLECTED FROM GUILIN

Vegetable species	Number	As		Pb		Cd		Cu		Zn		Ni	
		range	BCM	range	BCM	range	GM	range	BCM	range	GM	range	GM
Chinese cabbage	77	ND-0.125	0.009	ND-0.419	0.052	0.003-0.592	0.024	0.075-0.419	0.214	0.173-10.774	1.936	0.002-0.191	0.025
Cabbage	10	0.002-0.021	0.006	ND-0.194	0.022	0.003-0.033	0.009	0.136-0.325	0.189	1.031-3.063	1.817	0.019-0.130	0.049
Spinach	18	0.005-0.048	0.018	0.033-0.255	0.088	ND-0.161	0.034	0.305-1.005	0.552	0.950-11.697	4.262	0.014-0.216	0.064
Tender flower stalk	55	0.003-0.037	0.011	ND-0.408	0.047	0.007-0.150	0.032	0.197-0.896	0.397	1.001-8.688	3.590	0.003-0.205	0.033
Scallion	23	0.002-0.057	0.008	ND-0.473	0.022	0.006-0.272	0.030	0.173-0.814	0.358	0.896-6.841	2.225	0.011-0.471	0.046
Carrot	13	0.002-0.025	0.008	ND-0.270	0.033	0.012-0.317	0.038	0.148-0.757	0.290	0.503-5.582	1.698	0.011-0.222	0.058
Cauliflower	8	0.001-0.042	0.007	0.001-0.145	0.015	0.003-0.046	0.014	0.274-0.943	0.447	3.001-10.761	5.161	0.031-0.141	0.065
Mustard	12	0.005-0.024	0.011	0.026-0.228	0.093	0.013-0.117	0.040	0.164-0.409	0.270	0.961-7.233	2.473	0.013-0.113	0.034
Chives	9	0.002-0.030	0.009	0.043-0.184	0.092	0.008-0.216	0.030	0.137-0.713	0.368	1.248-5.631	2.641	0.012-0.135	0.040
Capsicum	16	0.004-0.039	0.018	0.005-0.599	0.090	0.005-0.219	0.038	1.493-3.530	2.286	2.268-8.017	4.147	0.031-0.374	0.132
Radish	68	0.001-0.160	0.005	0.001-0.091	0.014	0.003-0.081	0.011	0.032-0.545	0.126	0.382-12.179	1.568	0.001-0.173	0.021
Aubergine	3	0.002-0.006	0.003	0.002-0.037	0.011	0.003-0.057	0.011	0.193-0.583	0.395	1.265-1.481	1.389	0.008-0.038	0.021
Celery	21	0.002-0.024	0.010	0.002-0.271	0.064	0.009-2.290	0.057	0.193-0.646	0.349	1.048-7.911	3.351	0.008-0.280	0.038
Lettuce	21	0.002-0.040	0.009	0.001-0.315	0.083	0.016-0.289	0.044	0.158-0.468	0.288	0.058-7.035	1.871	0.004-0.194	0.018
Garlic	26	0.004-0.054	0.014	ND-0.187	0.036	ND-0.319	0.026	0.201-0.760	0.427	1.550-8.585	2.939	0.016-0.489	0.046
Garland Chrysanthemum	12	0.009-0.093	0.027	0.035-0.338	0.129	0.006-0.145	0.027	0.231-2.600	0.596	1.464-18.603	3.371	0.009-0.465	0.048
Garden Pea	6	0.002-0.007	0.004	0.005-0.354	0.045	0.001-0.087	0.012	0.446-1.812	0.919	3.330-18.268	6.183	0.062-0.289	0.182
Asparagusplettuce	39	0.001-0.038	0.010	0.004-0.280	0.074	0.004-0.167	0.032	0.125-0.492	0.268	0.596-6.325	1.811	0.004-0.436	0.026
Tomato	6	0.001-0.050	0.004	0.004-0.173	0.018	0.008-0.023	0.016	0.243-0.446	0.321	0.657-1.666	0.902	0.002-0.042	0.017
Coriander Herb	4	0.013-0.085	0.039	0.054-0.108	0.078	0.029-0.071	0.047	0.475-0.621	0.534	2.282-4.970	2.946	0.049-0.133	0.073
Pakchoi	33	0.005-0.030	0.012	0.009-0.342	0.065	0.009-0.141	0.033	0.154-0.589	0.294	1.117-13.320	2.652	0.015-0.469	0.039
Baby bokchoi	28	0.002-0.032	0.011	0.004-0.763	0.094	0.012-0.283	0.051	0.050-0.709	0.303	0.499-7.190	2.370	0.003-0.116	0.026
Taro	7	0.002-0.037	0.013	0.042-0.361	0.105	0.019-0.293	0.041	0.722-2.458	1.342	4.844-20.031	9.770	0.046-0.457	0.108
Other vegetables[A]	51	0.001-0.178	0.013	ND-1.425	0.057	0.001-0.264	0.016	0.073-2.260	0.495	0.843-20.620	2.734	0.008-0.981	0.059
LV	354	ND-0.133	0.011	ND-1.425	0.062	ND-2.290	0.032	0.050-2.600	0.326	0.058-20.620	2.604	0.002-0.981	0.034
RSV	165	0.001-0.160	0.008	ND-0.361	0.031	ND-0.319	0.019	0.032-2.458	0.235	0.382-20.031	2.043	0.001-0.489	0.032
GFV	47	0.001-0.178	0.009	0.001-0.599	0.038	0.001-0.219	0.016	0.073-3.530	0.743	0.657-18.268	2.999	0.002-0.374	0.075
All vegetables	566	ND-0.178	0.010	ND-1.425	0.049	ND-2.290	0.026	0.032-3.530	0.315	0.058-20.620	2.454	0.001-0.981	0.036

[A]: Other vegetables included Eleocharisdulcis, PatriniascabiosaefoliaFisch, Lotus fréimhe, Sagittariasagittifolia, Zingiberofficinale, Lyciumchinense, Beta vulgaris var. cicla, shamplapéacáin pea, sweet potato, Solanumtuberosum, shoots bambú, Pea Sweet, Cucurbitapepo L., Momordicacharantia, Pachyrhizuserosus, Cucumissativus Linn, crisiumsetosum.

GM: geometrical mean; BCM: Box-Cox mean. ND: concentration < 0.001 mg/kg.

B. Health risk of heavy metals from vegetable consumption

The results in this study showed that the EDI of As from consumption of vegetables were 2.68 and 4.03 μg/person/d for adults and children, respectively. According to the reported [9], we assumed that the percentage of inorganic As in vegetables was 83%. So the EDI of inorganic As was determined to be 0.040 and 0.064 μg/kgbw for adults and children, respectively. In China, a total of 17.8% of the total daily dietary intake of inorganic As comes from vegetable consumption [10]. So we can estimate that the EDI of As from total dietary consumption in Guilin was 0.225 and 0.360 μg/kgbw/d for adults and children, respectively, which were lower than the PTDI established by the FAO/WHO[11].

The EDI was 7.50 and 6.56 μg/person/d for adults and children, respectively. Approximately 32.0% of the total daily dietary intake of Cd comes from vegetable consumption in China[10]. Similarly, the EDI of Cd from total dietary consumption in Guilin was 0.391 and 0.625 μg/kgbw/d for adults and children, respectively, which accounted for 39.1% and 62.5% of the PTDI of this element for adults and children, respectively. In China, approximately 39.6% of the total daily dietary intake of Pb comes from vegetable consumption[12]. For adults and children, the EDI of Pb from vegetable consumption in Guilin was 14.16 and 12.30 μg/person/d, respectively. We can estimate that the EDI of Pb from total dietary consumption in Guilin was 0.596 and 0.952 μg/kgbw/d for adults and children, respectively. Compared with the PTDI of 3.57 μg/kgbw/d was established for Pb[11], the EDI of Pb from total dietary intake accounted for 16.7% and 26.7% of the PTDI for adults and children, respectively. The EDI of Ni via vegetable consumption in Guilin was found to be 13.38 and 9.08 μg/person/d, representing 0.87% and 1.39% of the RfD of Ni for adult and children, respectively. The EDI of Cu and Zn from vegetable consumption in

Guilin were 91.08 and 709 μg/person/d for adults, 79.51 and 615 μg/person/d for children, respectively. According to the reported[13], we assumed that the EDI of Cu and Zn via vegetable consumption was responsible for 8.4% and 7.8% of the total dietary intake for adults, respectively. Then the EDI of Cu and Zn from the total dietary intake in Guilin were 18.07 and 151.5 μg/kgbw/d for adults, 28.86 and 242.1 μg/kgbw/d for children, respectively.

The THQ values of studied metals were 0.153 and 0.246 for As, 0.120 and 0.192 for Cd, 0.063 and 0.101 for Pb, 0.038 and 0.060 for Zn, 0.036 and 0.058 for Cu, 0.008 and 0.013 for Ni, respectively (Figure 1). As shown in Figure 1, the individual THQ value of each heavy metal for children were higher than that for adults. It shown that the exposure risk of heavy metals to children through vegetable consumption was higher than to adults. The individual THQ of each metal was less than the criteria value of 1, indicating that intake of a single metal through consumption of vegetables did not pose a potential health risk. Health risks to adult and children from As was highest, followed by, in descending order of risk, Cd, Pb, Zn, Cu, and Ni. The total THQ was treated as the mathematical sum of each individual THQ, which have been widely used [14]. The total THQ via consumption of vegetables from Guilin were 0.418 and 0.670 for adults and children, which were lower than 1, indicating that it was still safe for the general population with consumption of vegetables Guilin at present. As, Cd, Pb, Cu, Zn and Ni contributed 36.60%, 28.71%, 15.07%, 8.61%, 9.09% and 1.91% to the total THQ for adults, respectively, and 36.72%, 28.66%, 15.07%, 8.66%, 8.96% and 1.94% for children, respectively.

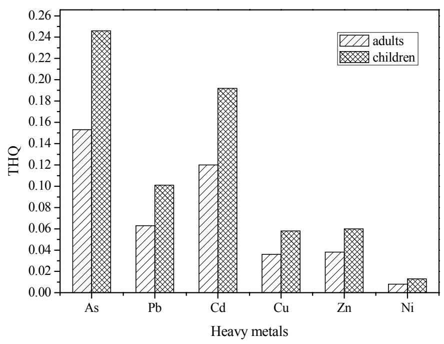

Figure 1. The THQ values of heavy metals from vegetables for adults and children in Guilin

IV. Conclusion

The Pb, As, Cd, and Ni concentration in 8.7%, 1.6%, 4.4% and 2.1% of vegetable samples exceeded the Chinese National Standards. Compared with the ML of contaminants set by FAO/WHO and EC, the concentrations of Cu and Zn levels in all samples were within the ML. The EDI of studied metals through consumption of vegetables for adults and children from Guilin were significantly lower than the PTDI. The individual THQ of each heavy metal and the total THQ via consumption of vegetables for both adults and children from Guilin were lower than 1, indicating the relative absence of health risks associated with consumption of vegetables.

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