Heavy Metals Concentrations and Health Risk in Vegetables Grown in Xigu Industrial District in Lanzhou City

Jean Yves Uwamungu, Yufeng Jiang, Anne Marie Mukundwa, Hang Sun, and Xuefei Hu

***Abstract*—These experiments were carried out to analyze the content of heavy metals in 8 kinds of vegetables grown in Xigu Industrial District in Lanzhou city. The possible health risk associated with 4 metals in vegetables to local inhabitants via their consumption was assessed, based on target hazard quotients (THQ) and pollution indexes. The results showed that the measured vegetables do not contain Pb or maybe Pb content in vegetables is relatively small, it could not be measured in this experiment. For Cu elements, the most abundant content was in eggplant with a concentration of 0.067 mg/kg, then the least content was for cauliflower with a concentration of 0.015 mg/kg; for Cd elements, the most abundant content was in celery with a concentration of 0.067mg / kg, the content in cabbage was the least with a concentration of 0.023 mg/kg; and then for Zn elements, the most abundant content was in spinach with a concentration of 1.001 mg/kg, the least is pepper with a concentration of 0.274 mg/kg. Environmental health risk assessment showed that THQ values are less than 1, indicating the heavy metal content of most collected vegetables match with the requirements of safety and quality of agricultural products.**

***Index Terms*—Health risk, heavy metals, industrial district, vegetables.**

I. Introduction

Vegetables are important in people's daily diet, and provide to the body essential vitamins, minerals, fibers and many other nutrients [1]. With the rapid economic development, the people's living standards have known a corresponding increase, and there must be taken attention to the quality of vegetables. Due to the rapid development of China's urbanization, industrialization and agricultural intensification processes, environmental pollution, especially agricultural soil pollution, agricultural safety issues caused by the soil quality of the environment has increasingly become severe [2]. Heavy metal pollution has long-term cumulative effects and interactions, considering their environmental effects related to soil, water, plants, animals and humans [3].

Accumulation of heavy metals in vegetables may affect the growth and development of vegetables; enter the body through the food chain on the human health impact. Although soil heavy metal pollution has an important buffer, but the heavy metal content exceeds effect concentration, especially on crops accumulation of heavy metals in the food chain can produce unpredictable results [4]. Due to the impact of vegetables' pollution on human health, to carry out a risk assessment of heavy metals in vegetables, vegetable guide for safe consumption, promote the development of vegetable industry has an important significance [5].

Taking Xigu District of Lanzhou City, growing vegetables for the study were analyzed vegetable samples content Cu, Cd, Pb, Zn, and vegetable contamination by heavy metals in the analysis and evaluation of the health risks and safety of vegetables were discussed. Analysis and evaluation of potentially dangerous heavy metal contamination of soil vegetable grasp vegetable production soil environment, reducing the heavy metal content in vegetables, vegetables improve quality, and guarantee people's food security and the promotion of sustainable development of vegetable industry are of great significance.

II. Materials and Methods

A. The Main Instruments and Reagents

AA220Z atomic absorption spectrophotometer, lead, cadmium, copper, zinc and other elements of the hollow cathode lamp, electric stove, beakers, flasks, 50mL crucibles, pipettes and graduated cylinders,

Concentrated nitric acid (excellent pure); perchloric acid (pure); 30% hydrogen peroxide (pure), lead, cadmium, copper, zinc standard solution (concentration of 1000mg / l, National Research Center) ,Deionized water, etc.

B. Material Acquisition and Preprocessing

Fresh vegetables and edible parts as samples were chosen, the collected vegetables were immediately put into a plastic bag to prevent moisture loss, which could cause their moisture content determination become inaccurate. Samples were taken back to the lab, and immediately the leaves and roots were washed with tap water. When there is no water in the vegetable surface, vegetables were weighed each about 20g to determine the moisture content, all samples (including samples of vegetables used to measure water use) chopped on heated blast oven baked at 60 ℃ about two days, after the samples were then crushed prototype eleven pulverized, were placed in a sealed and labeled bag, the last saved backup for analysis in a dryer.

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C. Determination of Heavy Metal Element Content

For the determination of heavy metal samples, the atomic absorption spectrometry method has been used in this experiment. The experiment measured four kinds of heavy metals in vegetables: zinc, copper, lead and cadmium. Specific heavy metal content determination method is: accurately weighed on the analytical balance of 1.0 g of plant sample powder, placed in a capacity of 50ml crucible, then add 20mL digestion solution (in the concentration ratio of nitric acid: perchloric acid = 5: 1),cover the crucible cover then soaked for 12 hours, and heated slightly on the heating plate until the sample particles melt, and then add 5-l0mL digestion, shaked, and gradually heated, the solution gradually thickens, the color becomes brown Red, paying attention to the process of heating to prevent ashing. Continue to add 5-10mL digestion, until when the sample color is no longer brown; turns to red , and then wait until the solution is digested until it becomes transparent (colorless), or light yellow, lowering the temperature to continue heating to the solution, taking a thick white smoke, and yellow-white residue so far. The cooling removal, with a filter into the 50mL volumetric flask, and diluted with deionized water to the mark, using atomic absorption spectrometry was determined.

D. Evaluation Method and Pollution Standards of Heavy Metals in Vegetables

The single factor pollution index method and Nemerow integrated pollution index method were used in the evaluation [6] and [7].

1) Single factor pollution index method

The single pollution index was used to evaluate the pollution degree of heavy metals in vegetables:

$$P_i = \frac{C_i}{S_i}$$

where, P is the single pollution index of pollutant i; C_i is the measured value (mg / kg) of pollutant i; S_i is the evaluation standard (mg / kg) of pollutant i.

2) Nemerow integrated pollution index method

As the single pollution index can only reflect the pollution of various pollutants, it cannot fully and comprehensively reflect the pollution of vegetables, and the pollution index that takes into account the single pollution index average and the highest value, can highlight the pollution of heavy pollutants effect.

The calculation formula is:

$$P_{综} = \sqrt{\frac{(P_i)^2_{\max} + (\frac{1}{n}\sum_{i=1}^{n} P_i)^2}{2}}$$

where, $P_{综}$ is the total mechanized heavy metal pollution index; (P_i) max contaminants in soil pollutant dye maximum index; $\frac{1}{n}\sum_{i=1}^{n} P_i$ as the average of pollutants.

TABLE I: HEAVY METAL POLLUTION INDICES AND THE CORRESPONDING POLLUTION DEGREES OF THE VEGETABLES

Classification	pollution index	Integrated pollution level	Pollution level
1	p≤0.7	safe	Safe
2	0.7＜P≤1.0	warn	Clean
3	1＜P≤2.0	light	Light
4	2＜P≤3.0	moderate	Moderate
5	P＞3	heavy	strong, severe

3) Human health risk assessment

(THQ) was used to assess the health risk of heavy metals in the Lanzhou area through the intake of vegetables, according to the health risk concentration proposed by the US Environmental Protection Agency (EPA) in 2000 [8]. The method is based on the US EPA (2000) proposed method for the adult and the average weight of children, which established the risk analysis method for different age groups of different parameters. The formula is:

$$THQ = \frac{E_F \times E_D \times E_{IR} \times C}{R_{FD} \times W_{AB} \times T_A} \times 10^{-3}$$

where E_F is the exposure frequency (365d / a); E_D is the exposure duration (70 a); E_{IR} for the exposure inhalation rate (g / (person • d)); C is the heavy metals content nutrients(mg / kg); R_{FD} as a reference dose (mg / (kg • d)), W_{AB} for the average human body weight to heavy metals (for adults 55.9kg, and for 32.7kg children); T_A is the average exposure time. The results THQ <1, indicating no pollutants affect human health (not obvious); THQ> 1, indicating that the contaminant can cause human health risks, large THQ value indicates that the risk on human health is high.

4) Data analysis

Data analysis and statistical analysis were performed using Excel 2010 and SPSS software.

III. RESULTS AND DISCUSSIONS

While analyzing vegetable samples, most of them matched with the pollution degree requirements shown in Table I, and below are some analyses done during the research:

A. Analysis of Water Content in Vegetables

As shown in Table II, the maximum water content in vegetables has been found in spinach, whereas the minimal water content has been found in peppers, the results showed that the water content of the selected experiments leafy vegetables is generally higher than the class roots, fruits and vegetables. Fruits and vegetables displayed content of heavy metals with high moisture content, consistent with the previous reports. Studies have shown that some of the short growth cycle of vegetables is due to the content of heavy metals in vegetables such as leeks, green onions, etc. Although not relatively low moisture content, but because of their growth cycle is short, thus leading to the enrichment of heavy metals in soil from a relatively short time, thus resulting in the accumulation of heavy metals in vegetables rather small [9].

TABLE II: RESULTS OF WATER CONTENT OF VEGETABLE SAMPLES

Species	eggplant	pepper	cabbage	celery	squash	radish	spinach	Cauliflower
Water content	94.23%	92.67%	94.13%	95.28%	94.98%	92.81%	96.43%	93.39%

B. Analysis of Heavy Metals in Vegetables

Experimentally, in eight kinds of vegetables, Cu, Cd, Pb, Zn (four heavy metals) contents have been measured. The results showed that the content difference between the measured heavy metals in vegetables is greater for Cu element, its content size relationship is in the order of eggplant> spinach> celery> cabbage> pepper> radish> squash> cauliflower, its content in the range 0.015-0.067mg / kg, an average of 0.04mg / kg; as it is noticed from Table III, for Cd elements, the content in a decreasing order of celery> spinach> cauliflower> eggplant> pepper> squash> radish> cabbage, its content in the range 0.023-0.067mg / kg, an average of 0.044mg / kg; for Zn element, the content of the relationship between the size of the order of spinach> celery> squash> cauliflower> radish> eggplant> cabbage> pepper amount ranging from 0.274-1.001mg / kg, an average of 0.483mg / kg, none of Pb is detected, it may be considered that Lanzhou xigu area greenhouses do not contain the Pb elements or Pb content is too small, it has been below the standard limit of detection in this experiment which explains that it cannot be harmful as it is shown in Table IV.

TABLE III: THE CONTENTS OF HEAVY METALS IN DIFFERENT VEGETABLES (MG/KG)

	eggplant	pepper	cabbage	celery	squash	radish	spinach	cauliflower
Cu	0.067	0.025	0.049	0.056	0.022	0.023	0.064	0.015
Cd	0.044	0.042	0.023	0.067	0.039	0.029	0.060	0.049
Pb	nd	nd	nd	nd	nd	nd	nd	nd
Zn	0.353	0.274	0.316	0.543	0.515	0.406	1.001	0.455

nd: not detected.

In comparison with the standards of national food hygiene standards, only the cadmium (Cd) was exceeded in the standard of the national food hygiene standards, the celery (0.067mg / kg) and the spinach (0.060mg / kg) exceeded the standards, and other vegetables were also close to the safety requirements of the free-pollution vegetables (Cauliflower in the Cd element content), the standard requirements of 0.050mg / kg, so that the long-term consumption of foodstuffs, such as cauliflower, eggplant and pepper, are more than 0.040mg / kg, and some even reached 0.049mg / These vegetables may have a certain impact on human health.

TABLE IV: MAXIMUM LEVELS OF CONTAMINANTS IN VEGETABLES

Heavy metal	Vegetable limit standards (mg kg^{-1})	Standard code
Cu	10	GB 15199-1994
Zn	20	GB 13106-1994
Pb	0.2	GB 2762-2005
Cd	0.05	GB 2762-2005

C. Heavy Metal Pollution Degree in Different Vegetables

The heavy metal pollution degree in different vegetables was different, and Table V lists the evaluation results of 8 kinds of heavy metal pollution in vegetables. According to the analysis of the status of heavy metal pollution on different vegetables in the sample, it can be obtained: Vegetables of different types, different conditions of the same heavy metal absorption, and the absorption of different heavy metals in vegetables are all different. This may be due to a variety of factors such as; the absorption of heavy metal elements in the process of vegetables to be affected [10], the size of a soil heavy metal content of heavy metals in vegetables, the degree of pollution and the nature of heavy metal elements, on the other hand, each vegetable itself has specific absorption characteristics on different heavy metals. He Jianghua, Liu Yong and other studies have shown that, in different vegetables, little enrichment coefficient of Pb, the poor mobility and lead in soils, and the mobility of Cd in soil is strong, and the absorption capacity of plants to cadmium is also strong [11]. Therefore, this experiment measured the Cd element content as relatively high, Pb element content is too low, and before the relevant report is consistent with.

As it can be seen from Table V, apart from celery and spinach, other vegetables heavy metal content of single pollution index and integrated pollution evaluation are in a clean range; meaning it has been found that the pollution level is safe and clean as it has been explained in Table 1; Cd content exceed the standard 1.34 times; evaluation of spinach single pollution index for light pollution can also be dangerous.

D. Human Health Risk Assessment of Heavy Metals Intake by Local Residents

In order to further analyze the health risk of heavy metals to the human body, the THQ method was used to evaluate the health risk of heavy metals in local residents (adults and children) by means of edible vegetables [12] and [13].

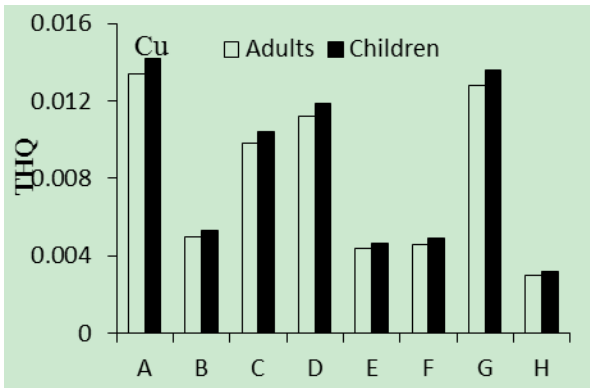

Fig. 1. Evaluation of local residents' (adults and children) health risk of heavy metals in edible vegetables using target hazard quotients for Cu.

Local residents (adults and children) into the body through the vegetable exposure to exposure to heavy metals Cu, Cd and Zn THQ values were expressed in Fig. 1-Fig. 3 respectively. From the graphs, the value of THQ of heavy metal in children is higher than that of adults, indicating that children eat more vegetables than adults. We can also see the Cd THQ value is the highest, in 0.195 to 0.568, less than 1, while the Cu and Zn value of THQ is small, is far less than 1, indicating the health risk of such heavy metals produced by the way of vegetables is not obvious. This shows that the health risk of heavy metals in vegetables in Lanzhou City, Xigu District, caused by the low consumption of these vegetables is relatively safe.

TABLE V: EVALUATION RESULTS OF HEAVY METAL POLLUTION BY USING SINGLE FACTOR INDEX AND NEMEROW INTEGRATIVE POLLUTION INDEX IN VEGETABLES

Project	Single pollution index				Single pollution index Assessment result	Integrated pollution index	Integrated pollution index Assessment result
	Cus	Zn	Pb	Cd			
Eggplant	0.007	0.018	—	0.88	Safe, clean	0.658	Safe, good
Pepper	0.003	0.014	—	0.84	Safe, clean	0.627	Safe, good
Cabbage	0.005	0.016	—	0.46	Safe, good	0.344	Safe, good
Celery	0.006	0.027	—	1.34	Light, less contaminated	1.06	Light, less contaminated
Squash	0.002	0.026	—	0.78	Safe, clean	0.583	Safe, good
Radish	0.002	0.020	—	0.58	Safe, good	0.434	Safe, good
Spinach	0.006	0.050	—	1.20	Light, less contaminated	0.898	Warning line
Cauliflower	0.005	0.023	—	0.98	Warn	0.733	Warn

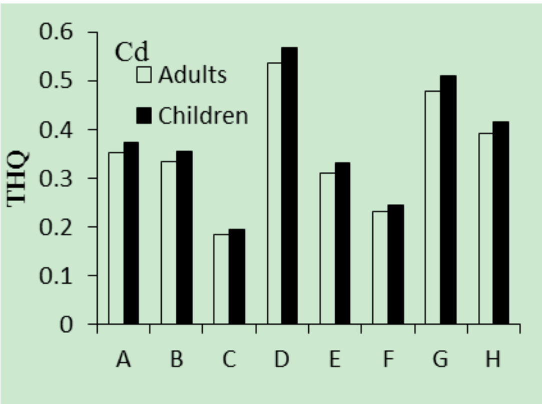

Fig. 2. Evaluation of local residents' (adults and children) health risk of heavy metals in edible vegetables using target hazard quotients for Cd.

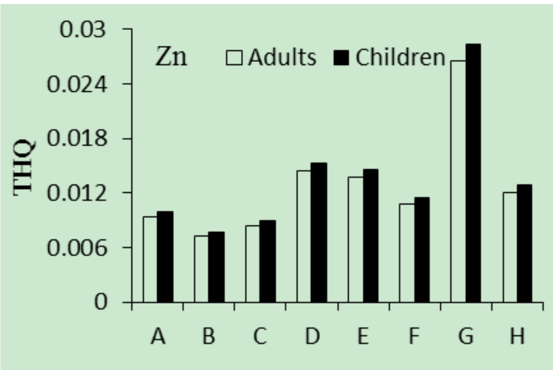

Fig. 3. Evaluation of local residents' (adults and children) health risk of heavy metals in edible vegetables using target hazard quotients for Zn, where A: Eggplant, B: Pepper, C: cabbage, D: Celery, E: Squash, F: Radish, G: Spinach and H: Cauliflower.

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