Food and Chemical Toxicology 113 (2018) 204–210

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Concentration of lead and mercury in collected vegetables and herbs from Markazi province, Iran: a non-carcinogenic risk assessment

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ARTICLE INFO

Keywords:
Food safety
Vegetable
Heavy metal
Non-carcinogenic risk
Target hazard quotient (THQ)
Hazard index (HI)

ABSTRACT

The current study was undertaken to determine the concentration of Hg and Pb in ten types of collected green leafy vegetables and herbs from different agricultural sites of Markazi province, Iran as well as the gathered water and soil around them using inductively coupled plasma-optical emission spectroscopy (ICP-OES). Also, the potential health risk assessment by using target hazard quotient (THQ) and hazard index (HI) parameters was estimated. Based on the accumulation order, *Artemisia dracunculus* L with 56.147 ± 17.30 μg/kg and *Spinacia oleracea* L with 1733.62 ± 2264.7 μg/kg can uptake and accumulate more concentration of Pb and Hg in their tissues, respectively. Regarding gathered soil around vegetables, the concentration of Hg and Pb were measured as 52.056 ± 16.25 μg/kg and 4993.83 ± 1287.8 μg/kg, respectively. The transfer factor (TF) demonstrated that vegetables and herbs could absorb a high amount of Hg from the soil while these plants uptake less concentration of Pb thought their green leaves. The non-carcinogenic risk assessment showed the minimum, and maximum THQ was related to 15–24 and 35–44 age groups in the urban and rural consumers. Also, HI in the urban and rural areas was calculated as 8.492 and 9.012, respectively. Since HI > 1, exposure of the urban and rural areas of Markazi province to non-carcinogenic risk by consuming the green leafy vegetables and herbs is a source of concern.

1. Introduction

Environmental pollutions such as contamination by heavy metal can affect the quality and safety of vegetables and herbs, which are remarked as the most commonly used plants in daily life. They could absorb and accumulate heavy metals in their tissues from contaminated soils, the irrigation water as well as deposited air pollution (Singh and Kumar, 2006). The ability to absorb the heavy metals from the environment by vegetables and herbs depends on different parameters such as soil type, the period of irrigation and the nature of vegetables as well as herbs (Intawongse, 2007). The toxic metals like Pb and Hg have no biological function in organisms or biochemical systems (Abtahi et al., 2017; Shahsavani et al., 2017). Moreover, they classified as the most toxic compounds or human carcinogens according to the U.S. Environmental Protection Agency (Tchounwou et al., 2012).

Pb is used in different industries such as cosmetics, pigments, coinage, building materials, batteries and gasoline (D'souza et al., 2011). It can be absorbed by inhalation and ingestion of food or water into the human body; therefore, the adsorbed Pb can interfere with a broad range of biochemical and biological functions. Pb enters into the bloodstreams, and it binds to low molecular weight proteins, analogues to metalloproteins (Apostoli et al., 1988). The Pb ions interact and displaced with sodium, zinc, copper, iron, potassium, manganese, magnesium and calcium ions from some functional enzymes involved in mitosis, meiosis, DNA and RNA function, cellular respiration, mitochondrial, ribosomal and lysosomal operation and membrane

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https://doi.org/10.1016/j.fct.2018.01.048
Received 28 November 2017; Received in revised form 11 January 2018; Accepted 27 January 2018
Available online 31 January 2018
0278-6915/

transport (Flora et al., 2012; Gillis et al., 2012). Moreover, various cells in different parts of the body like erythrocytes, leucocytes, pulmonary macrophages, fibroblasts, renal tubular epithelium, hepatocytes, osteoclasts, peripheral blood neutrophils, and glial cells of the brain are very susceptible to toxicity of Pb (Wani et al., 2015).

Ninety, and thirty-two percent of the entered Pb into an adult human and child body, respectively, are exerted within a couple of weeks. Majority of Pb is concentrated in bones and teeth. The gastrointestinal tract is a major route for Pb absorption and adults absorb approximately 10% of the lead content in food while children uptake 3 or 4 times more Pb. The toxicity at risk dose level of Pb can result in increased blood pressure, difficulties in the nervous system, and weakness in bone, nail, and ankles (Flora et al., 2012). The rapid turnover pool of Pb in the human body is a distribution in the soft tissues within days like spleen, kidney, liver, and lung while the slower turnover pool is skeletal bones and teeth (Maret, 2017).

Hg is toxic and non-essential heavy metal, possibly at second rank after Pb to being the most toxic among all heavy metals (Adel et al., 2016; Iqbal and Asmat, 2012). It can be used in wide range of applications in industrials and medicinal tools as well as Dentistry (Grigoletto et al., 2008). In the environment, it can be generated from combustion fossil fuels, electricity-generating power station, volcanic activity, manufacture of cement, waste material from industrial processes. Mercury has different forms of compounds like methyl, dimethyl (organic mercury) and ethyl via occupational or dental amalgam (WHO, 2007). Organic Hg can enter to the human body from biological sources such as fishes, fruits, and vegetables (Bernhoft, 2011). Hg in the form of mercuric Hg bonded to metallothioneins that can deposit in the liver, epithelial tissues, testes and choroidal plexus (Yasutake and Nakamura, 2011). Methylmercury as organic mercury react with sulfhydryl groups and interfere with DNA transcription and protein synthesis and make a mutation in an extended period, also impact on nervous system and brain (Bernhoft, 2011). The transmission of metals from soil to the plant is recognized as transfer factor (TF) which is shown the ability of the plant to uptake metal from soil (Laţo et al., 2012).

Markazi province is recognized as an industrial zone in Iran with high level of air/water/soil pollution due to presence of several important industries such aluminum and chemical factories (Dobaradaran et al., 2009; Ghadimi and Ghomi, 2013; Ghiyasi et al., 2010; Hani and Karimineja, 2010; Solgi et al., 2012). Therefore, this study aimed to determine the dry matter level of Hg and Pb in soil, water and fresh tissues of ten types of green parts of vegetables and herbs that more produced by farmers and more consumed in Iranian dishes in by using of ICP-OES technique. The collected data were analyzed and compared with the recommended levels by WHO/FAO. Also, non-carcinogenic risk assessment by estimated target hazard quotient (THQ) and hazard index (HI) were calculated.

2. Material and methods

2.1. Experimental sites and its description

The experimental site (Markazi province-Iran) is considered as an important point of agricultural-industrial sites, which are, located at a latitude and longitude 34° 05′ 30.26” N and 49° 41′ 20.98” E northwest of Iran. Markazi province has different main factories like, steel melting, petroleum, Aluminum Company and automotive industry that make a high level of air pollution into the atmosphere.

2.2. Chemical and reagent

All chemicals and standards or stock solutions in analytical grade were obtained from Merck (Darmstadt, Germany) and the elements standard solutions were prepared by diluting them. Double-deionized water was used in all dilutions.

2.3. Vegetable and herb samples collection

Allium ampeloprasum L, *A. wakegi* L, *Artemisia dracunculus* L, *Coriandrum sativum* L, *Lepidium sativum* L, *Mentha arvensis* L, *Petroselinum crispum Nyman* Consp, *Raphanus sativus* L, *Spinacia oleracea* L and *Trigonella foenum-graecum* L. were collected in spring to summer (May to August 2014) (because of some of vegetables like *Spinacia oleracea* L and *Lepidium sativum* L only growing in spring). They collected separately from five different agricultural sites by using vinyl gloves (in each agriculture sites about 1 kg of each), totally 100 samples, were gathered, then packed into the polyethylene bags and transferred to the laboratory. Vegetable and herb samples in the laboratory were washed with tap water then two times with deionized water to remove all unwanted pollutions. All samples were oven dried at 60–70 °C for 24 h. Then they crushed to the small size and stored in polyethylene bags for analyses (for maximum 6–12 months) (McCurdy et al., 2009).

2.4. Soil sampling

The soil around vegetable and herb samples from 30 (five agricultural sites × six sample plots) sampling plots was gathered by shovel and transferred by using clean bags. The depth of soil sampling was 10–15 cm. Different soil samples were taken in the same manner from various sites. Unwanted things like weed or grass, trash, rubbish, and stone were discarded.

Soil samples were oven dried in 60–70 °C for 12–24 h. Soil powder was maintained in the container for next step.

2.5. Water sampling

Water samples, which were used for field irrigation, were collected from different agricultural sites in pre-cleaned polyethylene bottles. These bottles were soaked in 10% HNO_3 overnight then two times washed with deionized water (Chary et al., 2008). The water samples injected to ICP-OES to measure the amount of Hg and Pb in samples (30 samples in triplicate). The metal concentration of aquatic ecosystem is increasing. Because of industrialization and urbanization. Water molecules can solve various elements in various concentration and also undergo a frequent change in the solution, dissolution, precipitation and sorption of elements or different metals and materials in water, that can uptake by plants. The investigation of heavy metals in water could be used to find the effect of polluted water on plant and also the health of consumers like humans (Ali et al., 2016).

2.6. Preparation and treatment of vegetable and herbs samples

About 1 g of vegetable and herb powder were digested by adding 15 mL of a mixture of acids (HNO_3 (70%), H_2SO_4 (65%), and $HClO_4$ (70%) in 5:1:1 ratio) to the test tubes or acid digested to obtain a mixture for analyses (Shakya and Khwaounjoo, 2013).

2.7. Preparation and treatment soil samples

The powdered soil was digested with 6 $mol \cdot L^{-1}$ HNO_3 (Merck, Darmstadt, Germany), solutions and rinsed with deionized water. Samples were filtered under vacuum (using Whatman No.42 filter paper) to eliminate turbidity or suspended substances. Prepared samples were maintained to the clean bottle prior analysis and further injection to ICP-OES (Shakya and Khwaounjoo, 2013).

2.8. Instrumental analysis (ICP-OES)

Inductively coupled plasma atomic emission spectroscopy (ICP-OES EOP, Spectroacros, Varian Vista-MPX, Germany) was used for analyses Hg and Pb in this research. ICP-OES has an excellent limit for detection,