HEAVY METALS IN VEGETABLES AND POTENTIAL RISK FOR HUMAN HEALTH

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Abstract

Heavy metal contamination is a major environmental health challenge and is potentially dangerous because of bioaccumulation through the food chain, which arises from rapid industrial growth, advances in the use of agricultural chemicals, and the urbanising activities of man. Also, heavy metal accumulation depends on plant species, while the efficiency of plants in absorbing metals is determined by either plant uptake or soil to plant transfer factors of the metals. Consumer perception of better quality vegetables is subjective as they consider dark green and big leaves as characteristics of good quality. However, the external morphology of vegetables cannot guarantee wholesomeness because heavy metals rank high amongst the major contaminants of leafy vegetables.

This study aimed to investigate the concentrations of cadmium, cobalt, chromium, iron, lead, nickel and zinc, in vegetable samples (spinach, lettuce and red leaf lettuce) obtained from industrial soils in Elbasan and the accumulation factor (ratio in plant/soil). The concentration of Cr, Fe, Pb, Ni and Zn in vegetable samples with concentrations ranging from 21-86 mg/kg, 644-921 mg/kg, 25-42 mg/kg, 34-151mg/kg and 31-62 mg/kg, respectively. The heavy metal contents are comparing with the permissible limits established by WHO/FAO guideline and they were higher than the acceptable limits. Accumulation factors (AF) from soils to vegetables was AF < 1, the vegetable can be an excluder. Based on the results, there would be a significant health risk to the consumer associated with the consumption of spinach, lettuce and red leaf lettuce cultivated in ex industrial area. Consequently, the study area should be monitored regularly to avoid health risk of human being due to exposure of toxic level.

Keywords: contamination, heavy metals, transfer factor, bioaccumulation

1. INTRODUCTION

Heavy metals are natural constituents of the earth's crust and are persistent environmental contaminants; they are not degradable and enter the body through food, air, and water and bioaccumulate over a period of time (UNEP, 2004). They can be released into the environment by natural and anthropogenic sources. Anthropogenic sources of heavy metal contamination include agricultural activities, such as pesticide and herbicide application, contaminated irrigation water, municipal waste used for fertilization and even mineral fertilizer containing traces of heavy metals (Alloway and Jackson, 1999). Additional anthropogenic sources of heavy metals include direct waste disposal on farmland, mining activities, use of lead as antiknock in petrol, traffic emissions, cigarette smoking, metallurgy and smelting, aerosol cans, sewage discharge, and building materials, such as paints (Merian *et al*., 2004).

Vegetables are essential for human nutrition and health, particularly as source of vitamin C, folic acid, minerals, niacin, thiamine, pyridoxine and dietary fibres, their biochemical role and their antioxidative effects (Siegel *et al*., 2014). Emissions of heavy metals from the industries may be deposited on the vegetable surfaces during their production. Heavy metals can be readily adsorbed by vegetable roots, and can be accumulated in the edible parts of vegetables at high levels, regardless of the heavy metal concentration in the soil (Jolly *et al*. 2013). The prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992). The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety. Dietary intake of heavy metals also poses risk to animals and human health. Heavy metals such as Cd and Pb have been shown to have carcinogenic effects (Trichopoulos, 1997). High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer (Turkdogan *et al*., 2002). Nickel is an essential trace element in animals, and it is often implicated in chronic bronchitis, emphysema, impaired pulmonary function, and fibrosis (USDHHS, 2005). A recently published WHO/FAO report recommends consumption of minimum of 400 g of fruit and vegetables per day (excluding potatoes and other starchy tubers) for prevention of chronic diseases such as heart diseases, cancer, diabetes, and obesity, as well as for prevention and alleviation of several micronutrient deficiencies, especially in less developed countries.

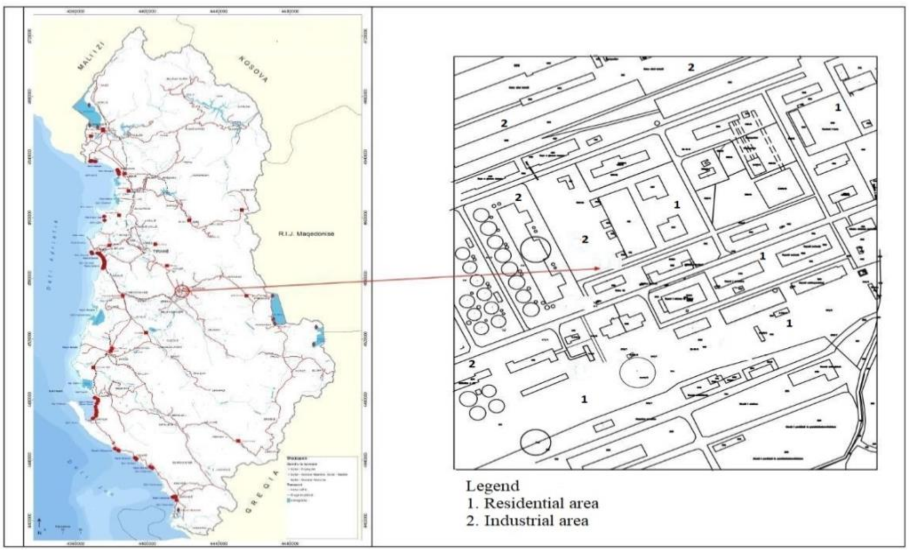
Absorption and accumulation of heavy metals in plant tissues depend upon temperature, moisture, organic matter, pH, and nutrient availability (Osmani *et al.*, 2018, Bani *et al.*, 2015). Heavy metal accumulation also depends on plant species, while the efficiency of plants in absorbing metals is determined by either plant uptake or soil-to-plant transfer factors of the metals ((Radulescu *et al.*, 2013).

Contamination of heavy metals is of great concern in the environment and human health, in Elbasan city. As a result of industrial activity, this soil is contaminated with heavy metals (Shallari *et al.*, 1998; Sallaku *et al.*, 1999; Osmani *et al.*, 2015, Osmani *et al.*, 2018). The study aimed to investigate the concentrations of cadmium, cobalt, chromium, iron, lead, nickel and zinc, in vegetable samples (spinach, lettuce and red leaf lettuce) obtained from industrial soils in Elbasan and the accumulation factor (ratio in plant/soil).

Materials and Methods

The study area

The metallurgical plant is located in Elbasan, in the centre of Albania, near the Shkumbin River, about 60-km southeast from Tirana.



A B

Figure 1. A) The map of Albania with the location of the study area (Elbasani); B) Description of Ish-Uzina 12

It is the largest plant in the country with a surface of 155 hectares and a treatment capacity of 800 thousand tons/year of iron-nickel and produced an estimated 44.8 tons of toxic dust. The main plants, which have been operating (1967- 1990), are Nickel-Cobalt Plant (Ish-Uzina12), Metallurgy Electrolysis Plant and Ferro-Chrome Plant (Shehu, 2009). After the ‘90s, the population growth and the migration from villages towards cities, have transformed a part of this industrial area in residential area, like which now is called Former Plant 12 (Ish-Uzina 12). This is the place with the highest risk of pollution and toxins, and where at least 11 hectares of soil is spotted by the ferrochrome wastes (Shallari *et al.*, 1998; Sallaku *et al.*, 1999; Osmani *et al.*, 2015, Osmani *et al.*, 2018).

Preparation and metals determination of samples

The collected samples of vegetables were washed with distilled water to remove the dust particles. Then samples were dried in an oven at 100ºC and grinded into a fine powder using a commercial blender and stored in polyethylene bags, until used for acid digestion.

Samples (soil and vegetable) were mineralized with a microwave digester (Ethos One Pro-24), where 0.3 g of soil or plants sample was digested by adding 8 ml HNO_3 69% and 2 ml H_2O_2. Solutions were filtered and were adjusted to 50 ml with distilled water. Heavy metals were determined spectrochemically using atomic absorption spectrophotometer (Nov AA-350).

Accumulation factor

Heavy metal concentrations in the shoots and soil extracts were calculated on the dry weight basis. Shoots concentrations are often used for contaminant concentration in plants because soil to plant transfer is one of the major pathways for pollutants to enter the food chain (Yoon *et al.*, 2006). As total heavy metal concentration of soils is a poor indicator of metal availability for plant uptake, accumulation factor (AF) was calculated based on metal availability and its uptake by the plant as follows:

$$AF = \frac{Metal\ concentration\ in\ plant\ (mg\ kg^{-1})}{Metal\ concentration\ in\ soil\ (mg\ kg^{-1})}$$

The Accumulation Factor gives an idea of the ability of a plant to accumulate metals absorbed from the soil. In addition, AF quantifies the relative differences in the bioavailability of metals to plants (Radulescu *et al.*, 2013).

Results and Discussion

pH and heavy metal contents

Soil pH, determines the fate of substances in the soil environment. Most soils cultivated for crop production fall within the pH range of pH 6-8, where nutrient availability to the plant is optimal. Acid soils (pH <5.5) and alkaline soils (pH >8), however, fall outside this optimal pH range and pose challenges for the plant such as low nutrient availability, ion toxicities and nutrient imbalances (Läuchli and Grattan, 2012). In the study the soil pH is 7.9, so it is optimal for plant growing.

Table 1. The concentration of heavy metals in soil (mg kg^{-1})

pH	Cd	Co	Cr	Fe	Ni	Zn	Pb
7.9	56	40	340	1954	582	65	45

Based on the results obtained it is observed that the concentrations of Zn and Pb are below the recommended level for heavy metals in soil, according to the Directive 86/278/EEC. The typical range of iron concentrations in soils is from 0.2% to 55% (20,000 to 550,000 mg kg^{-1}) according to Bodek *et al.*, (1988), so it is below the recommended level. In basalt, Co concentrations are in the range 40-50 mg kg^{-1}, while much lower concentrations, between 1 and 10 mg kg^{-1} are found in granite (Barceloux, 1999), so it is in the recommended level. According to Denneman and Robberse (1990) intervention values of heavy metals in soil (mg kg^{-1}) when remedial action is necessary are for Ni (210 mg kg^{-1}), Cd (12 mg kg^{-1}) and Cr (360 mg kg^{-1}). As a result of the industrial activity, iron-nickel plant and other plants around, the soil is contaminated with heavy metals elements, such as Ni and Cd.

Table 2. The concentration of heavy metals in vegetables (mg kg^{-1})

Vegetable	Cd	Co	Cr	Fe	Ni	Zn	Pb
Spinach	Nd	Nd	21	671	34	48	25
Lettuce	Nd	Nd	86	921	151	31	42
Red leaf lettuce	Nd	Nd	34	644	84	62	28

Nd - Not detected (Cd<12 mg kg^{-1}, Co<16 mg kg^{-1})

The concentrations of Cr, Ni and Pb in vegetable samples are higher in lettuce, than in red leaf lettuce and lower in spinach. Concentration of Fe in vegetable samples degree is from lettuce, to spinach and then to red leaf lettuce. The concentration of Zn in vegetable samples is higher in red leaf lettuce, than in spinach and lower in lettuce.

According FAO/WHO, normal range of heavy metals in vegetables for Cr, Pb, Zn, Fe and Ni are normally <1, 0.5-30, 20-100, 400-500 and 0.2-50 mg kg^{-1}, respectively. In lettuce, only the concentration of Zn is below the safe limit. In spinach, the concentration of Ni, Zn and Pb are below the limit. In red leaf lettuce, only the concentration of Pb is below the safe limit. Although the levels of this metal are within normal range for plants, however continual consumption could lead to accumulation and adverse health implication.

Accumulation factor

According to Radulescu *et al.*, (2013) if the accumulation factor is greater than 1 the plants can be accumulators; if is 1 there is no influence and if is less than 1 the plant can be an excluder. The accumulation factor (AF) of heavy metals from the soil to vegetables, are presented in (Figure 1).

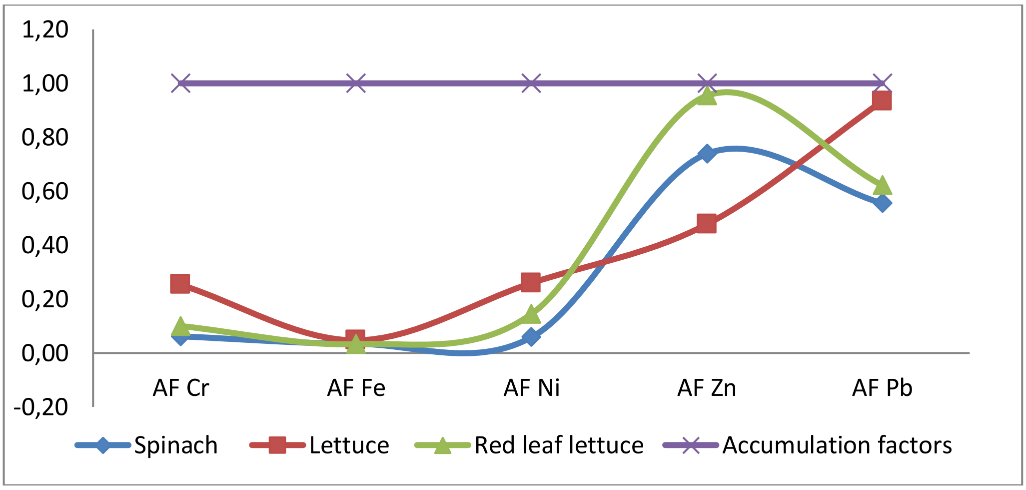


Figure 1. The accumulation factors in vegetable

The accumulation factors of all elements are within normal range in vegetable, smaller than one (<1). So, the vegetable are metal excluders. Metal excluders are plants which effectively limit the levels of heavy metal translocation within them and maintain relatively low levels in their shoot over a wide range of soil levels; however, they can still contain large amounts of metals in their roots (Baker and Walker, 1990).

Conclusions

Based on the results, some sample are within the permissible limits while some samples fell were above the limits stipulated by FAO/WHO. There would be a significant health risk to the consumer associated with the consumption of spinach, lettuce and red leaf lettuce cultivated in ex industrial area. Contaminated food is one of the main sources of exposure to heavy metals and an increased dietary heavy metal intake may contribute to the development of various disorders. Consequently, the study area should be monitored regularly to avoid health risk of human being due to exposure of toxic level. It is necessary to monitor the levels of these metals in food and in the body.

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