Accumulation of heavy metals in the fruit and leaves of plum *(Prunus domestica* L.*)* in the Tuzla area

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Preliminary communications

Summary

Introduction: The term heavy metals imply all metals of specific density greater than 5 g/cm^3. Anthropogenic emissions of heavy metals affect the ongoing pollution of the Tuzla area. Cultivated plants acquire large amounts of heavy metals and therefore there is a real possibility of their involvement in the food chain. *Goals:* The basic objective of this paper is to determine the content and dynamics of heavy metals: cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn) in the fruit and leaves of plum *(Prunus domestica* L.) in the Tuzla area in order to obtain information about their impact on the environment. *Materials and methods:* Research consisted of fieldwork and laboratory analysis. Plant material was sampled at nine sites in the Tuzla area and prepared for chemical analysis of heavy metals. The content of heavy metals: chromium (Cr), cadmium (Cd), copper (Cu), zinc (Zn), in solutions of plant material samples was determined by atomic absorption spectrophotometry (AAS method), with the instrument "Perkin-Elmer" 3110 and graphite cuvette "Perkin-Elmer" HGA-440. Determination of heavy metals was carried out according to ASTM-E 1812-96 standard. *Results:* The determined values of cadmium and copper content in plum leaves were higher than the natural content for plants in non-polluted environments in most localities. Cadmium concentration in the fruit of plum on most sites exceeded natural values of 0.8 mg/kg. The content of zinc in the fruit of plum at all locations was within the limits of the average value. In plum leaves the identified concentrations at the site of Donji Bistarac were 2.5 times higher than the average value which is 30 mg/kg. The highest concentration of chromium in leaves of plum was found at the site Donji Bistarac (2.25 mg/kg), and lowest at the site Donji Pasci. Plum fruit has a much smaller amount of the mentioned metal than a leaf, except at the site Donji Pasci where the determined values were 3 times higher than the average. *Conclusion:* The highest concentrations of heavy metals were found on sites that are located near industrial plants. Therefore, in the industrial-urban areas there should be provided continuous monitoring of heavy metals content in order to produce healthy food and improve the quality of life of people.

Keywords: Prunus domestica, cadmium, copper, zinc, chromium

Introduction

Tuzla area is contaminated with heavy metals as a result of continuous environmental pollution by high immissions of dust containing heavy metals and other harmful pollutants.

Large amounts of heavy metals are accumulated by cultivated plants too, so there is a real possibility of their involvement in the food chain. The fruits of plum *(Prunus domestica* L.) are consumed in fresh and processed forms, and it is important to determine the contamination of the site from which they are harvested. This fruit is rich in vitamins, minerals and phenolic compounds that contribute to its antioxidant activity (Walkowiak-Tomczak et al., 2008). In addition, they are a significant source of carbohydrates, organic acids, vitamin A, vitamin B, potassium, calcium, magnesium, zinc, selenium and fiber. The content of total fiber in the plum fruit increases with drying processes (Siddiq, 2006).

Iqbal and Khan, 2010 suggest that plants that are grown in polluted areas have a higher concentration of heavy metals than those grown in unpolluted environment. Among the heavy metals Cd, Cr, Cu and Zn occupy a special place because they belong to the so-called harmful elements. The greatest amount of heavy metals plants absorb by roots. Adoption and accumulation of heavy metals in plants depends on a number of environmental factors of habitats: soil pH, absorption capacity, the amount of $CaCO_3$, the distance from the source of emission of pollutants, exposure time, etc. (Kataba-Pendias and Pendias, 1984; Csintalan and Tuba, 1992; Goletić 1998, Goletić and Redžić, 2003). If heavy metals by precipitation land on leaf surfaces, the plant then adopts them directly through stomata (Reimann et al., 2001, Lokeshwari and Chandrappa, 2006).

The basic objective of this paper is to determine the content and dynamics of heavy metals: cadmium (Cd),

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chromium (Cr), copper (Cu) and zinc (Zn) in the fruit and leaves of plum *(Prunus domestica* L.) of Tuzla area in order to obtain information about their impact on the environment, because it is known that at higher concentrations heavy metals become included in the food chain and lead to various disorders in ecosystems.

Materials and methods

Research consisted of fieldwork and laboratory analysis. Fieldwork implied sampling of plant material at nine sites in Tuzla area. Laboratory work consisted of preparation of plant material for chemical analysis and chemical analysis of heavy metals in plant material. Samples of plant material for chemical analysis were prepared as follows: 1 g of plant material was dissolved in nitric acid (HNO_3, p.a.) and hydrochloric acid (HCl, p.a.) with heating. After decomposition of the sample (clarifying the contents of the flask), the flask of 25 ml was supplemented with perchloric acid ($HClO_4$, p.a.), and the sample was heated until the occurrence of perchloric vapors and their rising to the neck of the flask. The flask content was cooled down to room temperature, and then the flask was supplemented with distilled water up to a mark and the content was well mixed. Thus the sample solution was prepared to measure the concentrations of heavy metals.
Content (concentration) of heavy metals: chromium (Cr), cadmium (Cd), copper (Cu), zinc (Zn), in solutions of plant material samples was determined by the method of atomic absorption spectrophotometry (AAS method), with the instrument "Perkin-Elmer" 3110 and graphite cuvette "Perkin-Elmer" HGA-440. Determination of heavy metals was carried out according to ASTM-E 1812-96 standard. Measuring parameter was the absorbance and the results were read from the calibration curve, which is constructed on the basis of the absorbance readings and the given concentration in solutions for calibration. Parameters at which the absorbance measurement was performed were set according to the manufacturer's instructions. Cathode lamps (Hollow Cathode Lamps) were used for the determination of each metal separately.

Results and discussion

The content of cadmium (Cd) in the investigated plant species

Natural cadmium content in plants varies in the range from 0.02 to 0.50 mg/kg of dry matter (Ward, 1995), while the average values of cadmium tolerance in plants are from 0.1 to 0.8 mg/kg (Bohn et al., 1985). From the shown results (Fig. 1) it is evident that the determined values of cadmium content in the leaf of plum are larger than the natural content for plants in unpolluted environments, which is within the range of 0.02-0.5 mg/kg (Ward, 1995). The values obtained were above the limit value of cadmium in plants at the following locations: Puračić (3.5 times higher than the limit value), Donji Bistarac (3.5 times higher), Crveno Brdo (3 times higher). These sites are generally closest to the dominant sources of heavy metals and therefore suffer the greatest impacts. This confirms that the industry and the burning of fossil fuels have influence on the increased absorption and accumulation in plants, which can be risky for consumers.
The concentration of cadmium in the fruit of plum on most sites exceeded the natural value of 0.8 mg/kg. The minimum values were registered at the site Donji Bistarac (0.27 mg/kg) and the highest at the site Donja Lipnica (2 times greater than natural values) (Fig. 1).
Analyzing the determined concentrations we can conclude that in most plants the maximum value was determined at locations that are closer to industrial zones, and the least was at remote locations. Many authors have ascertained the same in the environment of different factories (Kataba-Pendias i Pendias, 1984; Yanyu and Wang 1996; Elezi, 1998; Goletić and Redžić, 2003).

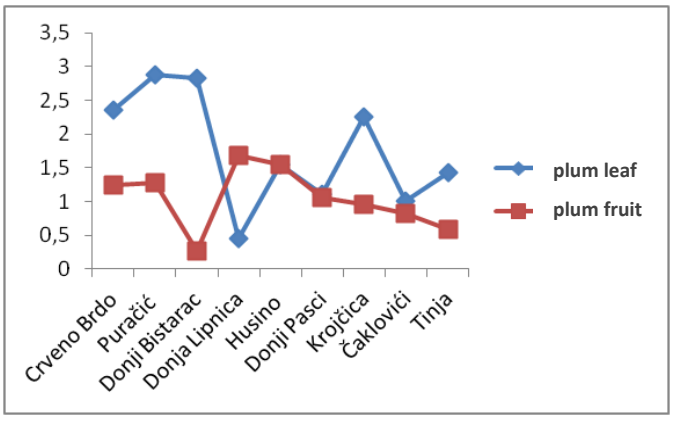

Fig. 1. The content of cadmium (Cd) in leaf and fruit of plum (mg/kg dry matter) at the investigated sites

The content of chromium (Cr) in the investigated plant species

The average chromium content in plants is in very small concentrations which vary in the range of 0.2-0.4 mg/kg of dry matter (Bogdanović et al., 1997). The highest concentration of chromium in the leaf of plum was found at the site Donji Bistarac (2.25 mg/kg), and lowest in the locality of Donji Pasci (Fig. 2). The plum fruits had a much smaller amount of the said metal than the leaves, except at the site Donji Pasci where the determined values were three times higher than the average (Fig. 2). As justification for the found condition in the above localities we may indicate the pH value of the soil. Values of soil pH indirectly affect the adoption of heavy metals, because the accessibility of certain elements in the soil depends on the pH of the soil (Kastori, 1998; Osmanovic et al., 2011).

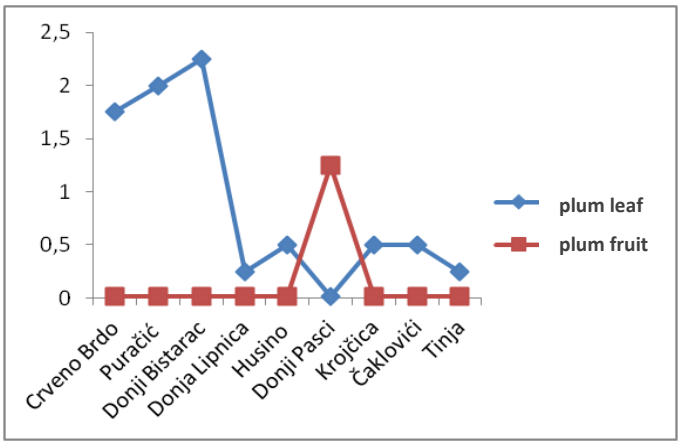

Fig. 2. The content of chromium (Cr) in leaf and fruit of plum (mg/kg dry matter) at the investigated sites

The content of copper (Cu) in the investigated plant species

Natural copper content in plants varies in the range of 1-15 mg/kg (Bašić et al., 1998) or 1-12 mg/kg (Ward, 1995), and the average content in herbaceous plants between 4 and 15 mg/kg (Bohn et al., 1985), or 2-20 mg/kg (Kastori, 1998). Copper content in the leaf of plum was higher than the limit value (20 mg/kg of dry matter) in most localities. The highest value was recorded in Donji Bistarac (27.7 mg/kg), and lowest at the site Krojčica (18 mg/kg). In the plum fruit were found significantly lower concentrations of copper than in the leaf (Fig. 3). This can be explained by the fact that copper accumulates significantly in leaves, where it accumulates most in chloroplasts, tied for plastocyanin which participates in the process of photosynthesis (Kataba-Pendias and Pendias, 1984; Udris and Neiland, 1990).

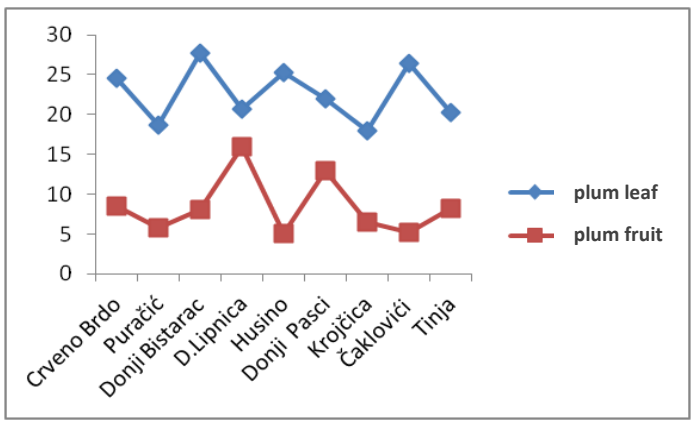

Fig. 3. The content of copper (Cu) in leaf and fruit of plum (mg/kg dry matter) at the investigated sites

The content of zinc (Zn) in the investigated plant species

The content of zinc in plants of unpolluted environments varies between 20 and 100 mg/kg (Kastori, 1998), and the average value is 30 mg/kg of dry matter (Ward, 1995). In organs of plants it occurs in an amount of 2-200 mg/kg of dry matter (Gračanin and Ilijanić, 1977), and its phytotoxic threshold is 200 mg/kg (Ivetić et al., 1991). Harmful effects on plants occur when the content exceeds 100 to 300 mg/kg (Kastori, 1998). Zinc content in the fruit of plum at all locations is within the limits of the average value. In the leaves of plum the determined concentrations at the site of Donji Bistarac are 2.5 times larger than the average value which was 30 mg/kg. The lowest concentration was registered at the site Donja Lipnica (20.5 mg/kg) (Fig. 4).

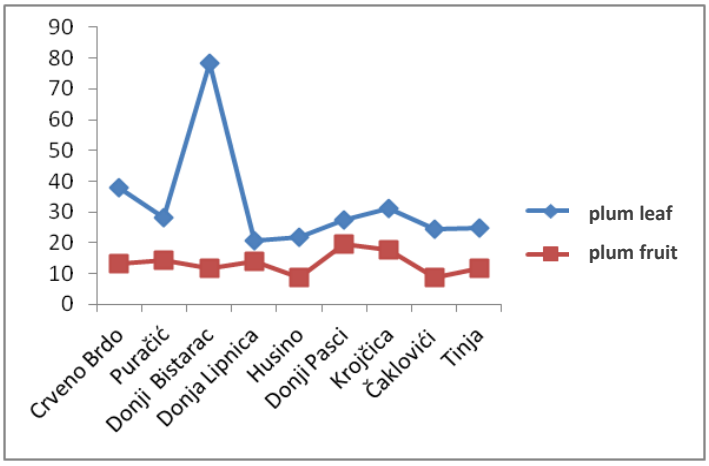

Fig. 4. The content of zinc (Zn) in leaf and fruit of plum (mg/kg dry matter) at the investigated sites

Conclusions

Based on the conducted studies during the realization of this work we came to the following conclusions:
The determined values of cadmium content in leaves and fruit of plum on most sites exceeded the natural values.
The determined chromium content in the leaf of plum did not exceed the limit values except in the locality of Donji Bistarac. The fruit of plum has a much smaller amount of chromium than the leaf, except at the site Donji Pasci where the determined values were three times higher than the average.
Copper content in the leaf of plum was higher than the threshold value at most locations. The determined value of copper in the fruit of plum was much lower than the limit value.
Zinc concentrations in plum leaves at most sites were higher than the average value. Zinc content in the fruit of plum in all localities exceeded the average value.
The highest concentrations of heavy metals were found at sites that are located near industrial plants. This should be borne in mind, especially due to the fact that environmental pollution by heavy metals can cause direct effects on human health.
By organized monitoring it is possible to control the intensity of accumulation and adoption of heavy metals, in order to create optimal conditions for the growth and development of plants, production of healthy food and improvement of the quality of people's lives because this way they consume health safer products.

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