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Orchards for edible cities: Cadmium and lead content in nuts, berries, pome and stone fruits harvested within the inner city neighbourhoods in Berlin, Germany

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ABSTRACT

Today's urban gardening focuses mainly on vegetable production and rarely includes fruit trees. Health effects of consuming urban crops are questioned due to high local pollution loads. Here, we determined cadmium and lead content in the edible parts of nuts, berries, pome, and stone fruits harvested from fruit trees and shrubs within inner city neighbourhoods of Berlin, Germany. We analysed how local settings at sampling sites shaped the trace metal content. We revealed significant differences in trace metal content depending on species, fruit type, local traffic, and parameters related to barriers between the sampling site and neighbouring roads. Higher overall traffic burden and proximity to roads increased whereas buildings or vegetation as barriers reduced trace metal content in the edible biomass. We demonstrate, that the consumption of non-vegetable fruits growing in inner city sites in Berlin does not pose a risk on human health as long as the fruits are thoroughly washed and it is provided that site pollutions and impacts are considered in garden concepts and guidelines.

1. Introduction

Urban gardening is booming worldwide and enhances food security, particularly in developing countries (FAO (Food and Agriculture Organisation of the United Nations), 2007). The interest of city dwellers for producing their own fresh food is also rising in developed countries (Leake et al., 2009) and food production for low-income citizens is supported by self-organisation and local authorities (Hancock, 2001).

Beyond local food production, urban gardening provides a broad range of ecosystem services and is recognised as a key instrument in environmental education (Krasny and Bonney, 2005), for community building (Bendt et al., 2013; Glover et al., 2005), and for enhancing urban biodiversity (Galluzzi et al., 2010).

Fruit tree species have been used for ornamental purposes as a reminiscence of rural landscapes (Lenné, 1825) and fruit trees along urban roads or in parks have been leased to get financial support for street or park maintenance in the 19th century (Schmidlin, 1852). Currently, fruit trees remain unused although abundant in public urban green spaces (see Fig. 1A for Berlin) and the urban gardeners focus mainly on vegetable production (Bendt et al., 2013; Hough et al., 2004).

The effect on human health caused by the consumption of urban gardening products is discussed controversially, mainly due to the high pollution loads in urban areas (Alloway, 2004; Finster et al., 2004; Hough et al., 2004; Leake et al., 2009). Studies of vegetables demonstrated, that the uptake and accumulation of trace metals differed among crop type, species, and among plant parts (Alexander et al., 2006; Finster et al., 2004; Säumel et al., 2012). Few studies investigated the relation between trace metal content in the edible parts of vegetables and local traffic burden (Kloke et al., 1984; Säumel et al., 2012). Planting and building structures (i.e. hedges, shrubs, lead free painted houses or walls) can function as barrier between planting site and road, decreasing trace metal content in the crops (Säumel et al., 2012).

Yet, there are only few studies analysing trace metal content in fruit tree products growing in urban environments (Li et al., 2006; Rossini Oliva and Valdés, 2003; Rossini Oliva et al., 2008; Samsøe-Petersen et al., 2002). Consequently, the aim of this study was to analyse the cadmium (Cd) and lead (Pb) content in the edible parts of different non-vegetable fruit types and fruit tree species. We determined the influence of traffic burden (i.e. traffic burden of the nearest and the nearest main arterial road, distances from the planting site to nearest and nearest main arterial road, overall traffic burden at sampling site) on trace metal content in the fruits. We evaluated whether characteristics of the planting site (i.e. sampling height, presence or absence of barriers between planting site and roads, barrier width or height, degree of enclosure of the sampling site by barriers) influence the trace

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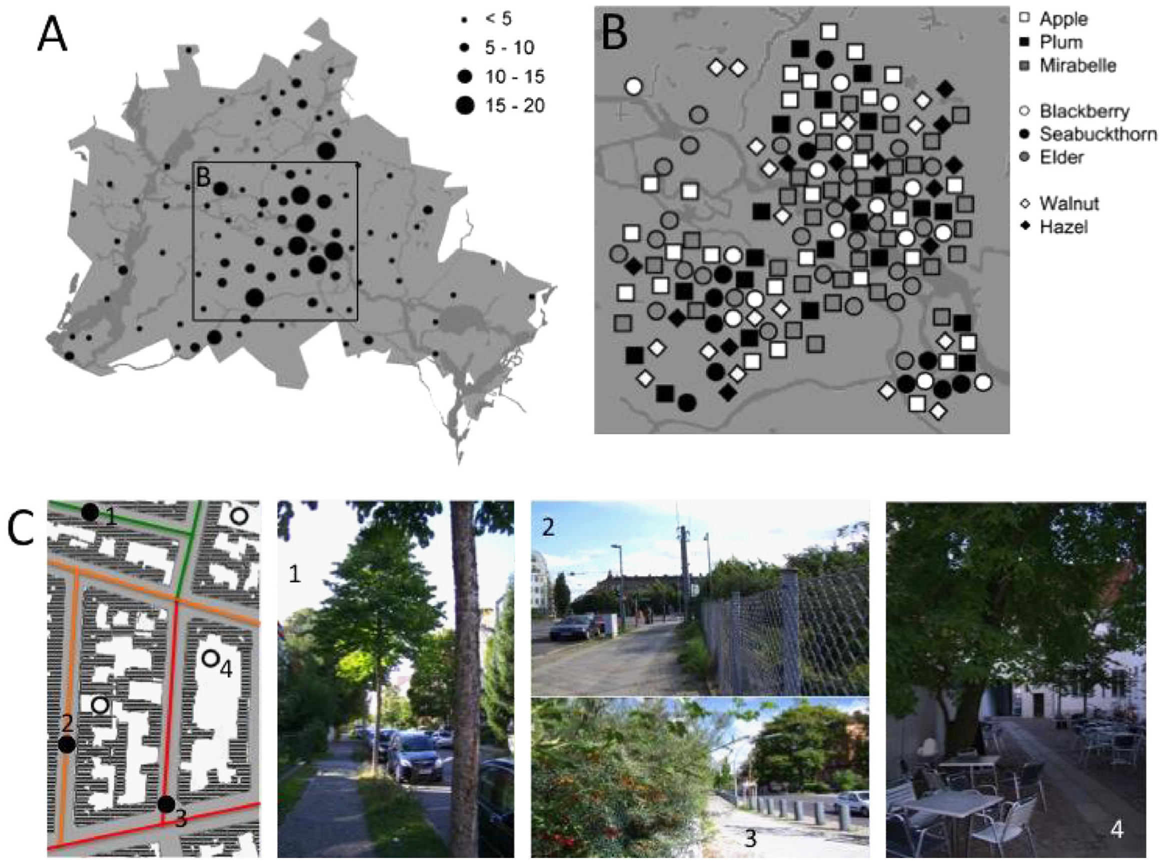

Fig. 1. (A) Number of fruit trees and shrubs in public green spaces in Berlin, Germany including pome and stone fruit trees (i.e. apple, apricot, cheery, mirabelle, pear, plum, quince, sloe), berries (i.e. blackberry, blueberry, currant, elder, juniper berry, mulberry, raspberry, sea buckthorn), and nuts (i.e. chestnut, hazel, walnut) according to Mundraub (2013) added by own survey data. Internet domains such as www.mundraub.org document fruit trees for a public use. (B) Sample sites per species in the inner city of Berlin, Germany (pome and stone fruits indicated by squares; berries indicated by circles and nuts indicated by diamonds). (C) Examples of different local conditions of the sample sites (black points: sampling sites with different distances to the nearest street or to the nearest arterial street and different traffic burden (red, orange or green line indicate high, medium or low traffic burden); open circles are sampling sites with a barrier between street and sampling site). Photos for typical sites are given (i.e., 1: sampling site along small street with low traffic burden; 2: sampling site along street with medium traffic burden; 3: sampling site along street with high traffic burden and 4 sampling site within a courtyard with a barrier between streets and sampling site; Photos taken by von Hoffen). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

metal content. Furthermore, we compared the trace metal content of the urban non-vegetable fruits with supermarket products to assess health risks by consuming these urban fruits.

2. Materials and methods

We collected nuts, berries, pome and stone fruits of nine different species at 172 randomly chosen sites of the inner city of Berlin, Germany (Fig. 1B). The sampling sites represented different urban conditions (Fig. 1C) and were characterised by the following parameters: distance to nearest road (d1) and to nearest main arterial road (d2) in meters, traffic burden on the nearest road (tb1) and on the nearest main arterial road (tb2) according to the number of vehicles per day ($1 \leq 5000$; $2=5001$–10000; $3=10001$–15.000; $4=15001$–20000; $5=20001$–30000; $6=30001$–40000; $7= \geq 40001$; Berlin Department for Urban Development, 2009), presence and absence of barriers between planting sites and nearest roads (b); height of barrier (bh) and width of barrier (bw) in meters; the degree of enclosure of the sampling site by barriers (eb), and sampling height in meters (sh). Furthermore, we classified the overall traffic burden (otb) within a radius of 250 m around the planting sites (low: low traffic burden, existing barriers or high distance between planting site and nearest street; medium: low to medium traffic burden and lacking barriers between planting sites and streets, lower distance to the nearest street; high: high traffic burden and lacking barriers, small distance between planting site and nearest street).

All fruits were collected in 2012 at the usual harvest time of each fruit species. We classified fruit types as follows: 'nuts' (dry fruits with a hard woody shell including almond nuts); 'berries' (fleshy fruits including aggregate fruits such as blackberries or strawberries); 'stone fruits' (drupes with an outer edible fleshy part surrounding a seed containing shell); and 'pome fruits' (fruits with an outer edible fleshy part surrounding cores). In total, we sampled nuts: walnut (*Jugland regia*, $N=18$), hazel (*Corylus avellana*, $N=13$), ginkgo (*Ginkgo biloba*, $N=3$); berries: blackberry (*Rubus fruticosus agg*, $N=16$), seabuckthorn (*Hippophae rhamnoides*, $N=12$), elder (*Sambucus nigra*, $N=27$); and pome and stone fruits: apple (*Malus domestica*, $N=29$), mirabelle (*Prunus domestica* subsp. *syriaca* $N=28$), plum (*Prunus domestica subsp. domestica*, $N=26$). For each fruit species, we collected mixed samples of common supermarket fruits ($N=3$) except for ginkgo, elder, and seabuckthorn. Elder and seabuckthorn were not available in supermarkets; therefore we harvested samples from rural sites far away from potential pollution sources. In gingko, no trace metals were detected. We used these samples to compare the potential dietary exposure to trace metals of someone consuming urban horticulture products versus supermarket products.

Directly after the harvest, the edible parts of the berries, pome and stone fruits were thoroughly washed and afterwards frozen similar to the supermarket samples. The nuts were stored dry in their nutshells. Edible parts of all fruits were dried at a temperature of 60 °C for 72 h to 14 d depending on sample size and fruit species. After drying, the samples were ground ($<100\ \mu m$) and stored in a dehydrator. Then the samples were dried at a temperature of 105 °C for 48 h. Approximately 500 mg dry fruit powder and creamy nut powder was digested in 10 ml HNO_3 (69 percent) in a drying chamber at a temperature of 185 °C. After the digestion, the samples were filled up to a volume of 40 ml with ultrapure water. The determination of the trace metal content in the biomass was made with an atomic absorption spectroscopy using the Atomic Absorption Spectrometer AA880Z (Varian, Australia). The used wave lengths/ detection limits of the elements were 228.8/2.0 mg/l for Cd and 217.0/3.0 mg/l for Pb. We used a melon powder (IPE 950) as standard to assess the quality of our measurement (reference/measured values in mg/kg DW for $N=20$: Cd: 1.03/1.34; $N=28$: Pb: 3.50/3.55).

We used analysis of variance (ANOVA) for data analysis. Cd or Pb content in the dried biomass is the response variables and species, fruit type, and the parameters characterising local settings at sampling site (overall traffic burden, distance to the nearest road and number of vehicles of the nearest road, distance to the nearest arterial road and the number of vehicles per day of the nearest arterial road, presence and absence of a barrier and type, height, width and degree of enclosure