Effects of different air pollution levels in Berlin on lettuce production in various locations

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1. Introduction, Knowledge, Objectives

Cities account for around two thirds of the worldwide energy consumption and global emissions (UNFCCC, 2015). The United Nations Food and Agriculture Organization (FAO, 2008) identified the availability of safe and affordable food as the most pressing issue of the world. Urban agriculture takes this development into account (Whittinghill and Rowe, 2011). However, because of potential soil contamination and air pollution, urban agriculture is also associated with contamination of food with heavy metals and particulate matter. On the one hand, according to the Berlin Senate Department for the Environment, Transport and Climate Protection (SenUVK, 2017) the air content of various heavy metals is below legal limits and ever decreasing. On the other hand, Säumel et al. (2012) found considerable amounts of heavy metals in some vegetables harvested in different places in the urban area of Berlin. In this context, it was not ascertained if soil or air pollution was responsible for these undesirable accumulations. Therefore, this work aims at identifying the risks of heavy metal accumulations in food due to atmospheric deposition by producing edible crops within the city.

2. Material and Methods

Lettuce was chosen as it is a common urban produced vegetable. Furthermore, investigations identify leafy vegetables as predestined for accumulation of some heavy metals (Kuboi et al., 1986). In order to have a broad variety of measurement locations, 20 sites with different air pollution levels according to the Berlin senate (SenSW, 2019) were chosen for the cultivation of lettuce (Figure 1). As such, the locations were grouped and coloured according to their pollution level indices as shown in Figure 1. In total, 40 flower boxes with four lettuce heads each were placed at the mentioned 20 spots, especially on window sills and balconies of buildings. Based on this placement, the flower boxes with plants were exposed to different cardinal points.

In order to exclude heavy metal uptake due to soil contamination and to avoid cultivation error, a standard potting substrate was used, and an irrigation schedule was defined. The plant growth period started on the 15th of May and ended on the 18th of June in 2018. Fresh and dry weight of lettuce heads were measured, and composite samples of washed and unwashed lettuces freeze dried. Afterwards the amount of heavy metals was analyzed by inductively coupled plasma optical emission spectrometry according to Dannehl et al. (2012). The results were compared with legal limits and tolerable daily intakes of heavy metals according to Verordnung-(EG)-Nr.-1881/2006 (2006), WHO (1973), EFSA (2014), and EFSA (2015).

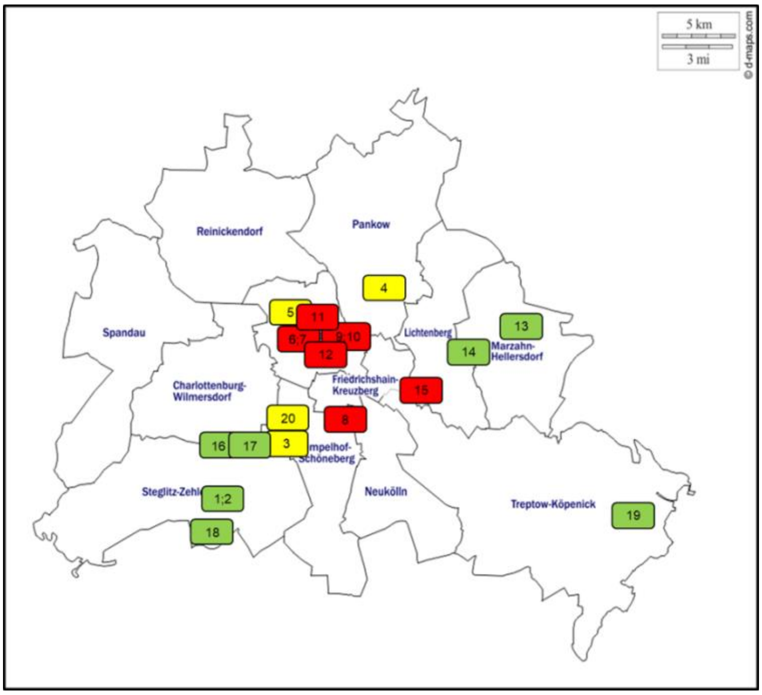

Figure1: Map of the city of Berlin showing cultivation places (numbered flower boxes from 1-20) and recorded air pollution levels (NOx and PM) according to SenSW (2019): red = elevated, yellow = moderate, green = low.

3. Results

In the present study, plant growth was mainly influenced by light differences, which were mainly caused by the direction of the solar radiation and shadows caused by other buildings and asociated lower light intensities. Therefore, the plants were grouped according to the cardinal point to which the flower boxes on the buildings were aligned. Plants grown in flower boxes on the south and east side of the buildings had the highest fresh weight (Figure 2). The ranking of the mean fresh weight of lettuce heads was as follows: east side (172.17 g) > south side (154.23 g) > west side (132.32 g) > north side (86.86 g). There were no significant differences between plants grown in flower boxes on the south and east side or those grown on the south and west side of the buildings. However, the fresh weight (FW) of lettuce heads harvested from flower boxes fixed on the north side of the buildings was significantly lower compared to all other plants (Figure 2). The same applies to dry weight of lettuce heads which varied between 0.89 and 1.67 g (data not shown). After harvest, elements, such as Pb, Cd, Zn, Cr, Cu, and Ni, were analysed in washed and unwashed lettuce heads. It was detected that most of them correlated positively with air pollution levels

(Table 1). In this context, it doesn't matter if lettuce heads were washed or not and if the elements were calculated on a fresh or dry weight basis. In washed plants the amount of all heavy metals was lower than in unwashed plants. Significant differences exist concerning Pb, Zn, Cr, Cu and Ni in fresh lettuce heads, but these were only found for unwashed plants and when calculated on a fresh weight basis. Except for Zn, the same significant differences were measured for Pb, Cr, Cu and Ni when these heavy metals were calculated on a dry weight basis. However, in washed samples no significant differences were found when calculated on a fresh and dry weight basis.

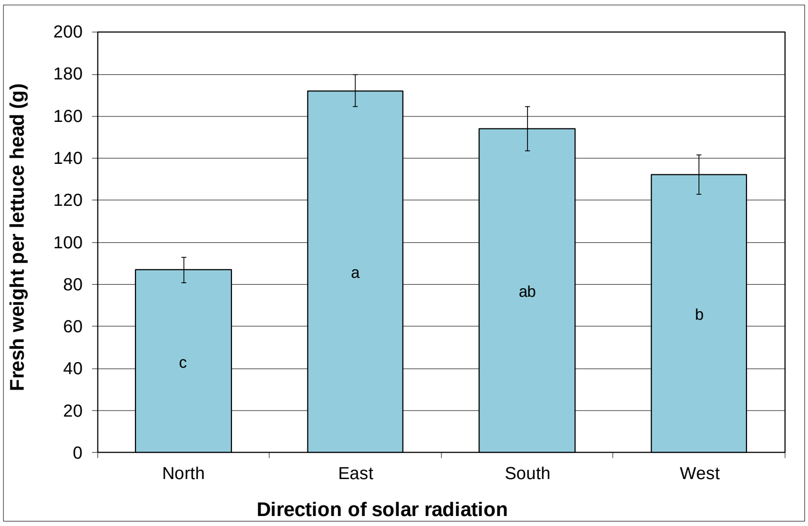

Figure 2: Fresh weight of lettuce heads depending on the direction of solar radiation. Results represent mean values of lettuce heads (n=153). Significant differences were calculated using Tukey-tests ($p < 0.05$). Different letters indicate significant differences.

Table 1: Heavy metal content in lettuce plants grown under different air pollution levels

		Air pollution level											
		Low				Moderate				Elevated			
Element	Treatment	(mg/kg DW)	Sig.	(mg/kg FW)	Sig.	(mg/kg DW)	Sig.	(mg/kg FW)	Sig.	(mg/kg DW)	Sig.	(mg/kg FW)	Sig.
Pb	unwashed	0.953	b	0.042	b	1.015	a	0.048	a	2.003	a	0.114	a
	washed	0.351	a	0.016	a	0.372	a	0.017	a	0.650	a	0.031	a
Cd	unwashed	0.135	a	0.007	a	0.156	a	0.007	a	0.151	a	0.008	a
	washed	0.132	a	0.007	a	0.144	a	0.007	a	0.146	a	0.007	a
Zn	unwashed	53.141	a	2.546	b	61.129	a	2.768	a	75.492	a	3.805	a
	washed	75.492	a	2.637	a	54.498	a	2.452	a	61.733	a	2.867	a
Cr	unwashed	0.893	b	0.042	a	0.607	b	0.028	b	2.118	a	0.126	a
	washed	0.984	a	0.027	a	0.338	a	0.015	a	0.618	a	0.028	a
Cu	unwashed	4.377	b	0.211	b	5.372	b	0.240	b	7.225	a	0.368	a
	washed	4.955	a	0.239	a	6.340	a	0.283	a	6.766	a	0.311	a
Ni	unwashed	0.307	b	0.014	b	0.181	b	0.008	b	0.862	a	0.050	a
	washed	0.900	a	0.009	a	0.115	a	0.004	a	0.273	a	0.012	a

Air pollution levels are determined according to SenSW (2019). All data are mean values of three different mixed samples. Significant differences were calculated using Tukey-tests. Different letters indicate significant differences at a significance level of $p < 0.05$.

4. Discussion

In order to verify chances and potential risks of urban farming, a cultivation test of lettuce was carried out located inside the boundaries of Berlin City. Although the highest solar irradiation is not to be expected in the eastern direction, lettuce heads grown under these conditions lead to highest fresh and dry weights. This means, growth of plants is not only influenced by direction of solar radiation, but also by reduced light intensity caused by buildings and associated shades. This was demonstrated for plants grown in flower boxes, which were fixed on the south side of the building.

Regarding accumulations of heavy metals, higher values were detected in unwashed samples. Consequently, most of the analyzed elements were accumulated on the leaf surface. However, heavy metals are also deposited in leaf tissue as with rising air pollution level the amount of heavy metals increased in washed lettuce heads, as well (Table 1). The maximum permissible value for Pb is 0.3 mg/kg fresh weight of lettuce and that of Cd 0.2 mg/kg (Verordnung-(EG)-Nr.-1881/2006, 2006). These values were not exceeded. In fact, even in the highest polluted sites, the Pb amount was threefold and tenfold lower in unwashed and washed lettuce heads, respectively. If the amount of Zn and Cu exceeds 1 mg and 0.5 mg per kg body weight, respectively, the tolerable daily intake (TDI) is reached (WHO, 1973). Following the analytic results (Table 1), 15.8 kg and 81.5 kg of lettuce would have to be consumed to exceed the maximum level in terms of Zn and Cu, respectively. The level of consumption would have to be even higher concerning the TDI of Cr (EFSA, 2014) as for a toxic effect at least 184 kg of lettuce per day would have to be consumed. To reach the TDI regarding Ni (2.8 µg/kg body weight) legally consolidated by EFSA (2014), the daily intake would have to exceed 3.4 kg of lettuce, which is still a lot.

Furthermore, it could not be proven whether the accumulation of heavy metals had a negative effect on plant growth. According to the results obtained, it seems that not the heavy metals, but the light intensity had the greatest inlfuence on plant growth.

5. Conclusions

Due to light conditions, cultivation of lettuce on the south side of the buildings is preferable. With regard to heavy metals, our study did not reveal any health risk due to consumption of lettuce produced under urban conditions with different air pollution levels. Nevertheless, the accumulation of heavy metals increased in unwashed and washed samples with rising air pollution levels. Obviously, washing of produce reduces the amount of elements which are mainly accumulated on the leaf surface. Further investigations should analyze the differences in heavy metal content in samples cultivated under open and closed greenhouse conditions, where the greenhouses should be placed on roof tops of buildings in Berlin. This could be one solution to produce plant material in cities without contaminations with heavy metals because plants under closed greenhouse conditions are not so strong exposed to polluted air.

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6. Literature

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