EDIBLE PRODUCTION ON ROOFTOP GARDENS IN PARIS? ASSESSMENT OF HEAVY METAL CONTAMINATION IN VEGETABLES GROWING ON RECYCLED ORGANIC WASTES SUBSTRATES IN 5 EXPERIMENTAL ROOFGARDENS

[1]MOHAMAD RAHMANIAN, [2]ANNE-CECILE DANIEL, [3]BAPTISTE GRARD, [4]ANTOINE JUVIN, [5]STEPHANE BESANCON, [6]ALICE BOSCH, [7]CHRISTINE AUBRY, [8]PHILIPPE CAMBIER, [9]NASTARAN MANOUCHEHRI

[1]Ph.D student of Soil Science, College of Agriculture, ShahrekordUniversity, Iran
[2]Chaire Eco-conception VINCI, Agroparistech, Paris, France
[3,6,7]UMR SADAPT, AgroParisTech, Inra, Université Paris-Saclay, Paris, France
[4]Cultures en Ville, ARCUEIL, France
[5,9]UMR Ingénierie Procédés Aliments, AgroParisTech, Inra, Université Paris-Saclay, 91300 Massy, France [8]UMR ECOSYS, AgroParisTech, Inra, Université Paris-Saclay, Paris, France.
E-mail: [1]M.rahmanian10@yahoo.com, [2]anne-cecile.daniel@agroparistech.fr, [3]baptiste.grard@agroparistech.fr, [4]antoine.juvin@culturesenville.fr, [5]stephane.besancon@agroparistech.fr, [6]alice.bosch@yahoo.fr, [7]christine.aubry@agroparistech.fr, [8]philippe.cambier@grignon.inra.fr, [9]nastaran.manouchehri@agroparistech.fr

Abstract— The growing proportion of humans living in cities has led to urban sprawl and thus to the increasing need for space dedicated to food production within cities. Rooftops offer a high potential in terms of available space, sun exposure and consumer proximity. However, urban agriculture raises many questions about health risks associated with production in high traffic areas. 4 experimental roofgardens installed in different peri-urban zones of Paris were investigated in this work using a mixture of topsoil, green waste compost and coffee grounds with mycelium as growing substrates. Trace metal (TM) concentrations (Pb, Cd, Hg, Cu and Zn) were measured in five growing crops (tomato, parsley, salad, carrot and strawberry) of these roofgardens. TM's levels were below the health-based guidance values (EU standards) for virtually all fruits and vegetables. TM's concentration varied by crop type i.e. parsley and salad contained higher level compared to tomato, strawberry and carrot. Atmospheric fallout seemed to be the major source of TM's in crops especially in the case of parsley. Significant difference was observed between TM's level in washed and unwashed vegetables dealing with the importance of consumer good practice like as washing and peeling before consumption.

Keywords— Urban Agriculture, Roofgarden, trace metal, growing crops, atmospheric fallout.

I. INTRODUCTION

The growing proportion of humans living in cities has led to urban sprawl and thus to the increasing need for space dedicated to food production within cities. However, urban expansion and relative alterations in the physical environment due to the human activity (Chen, 2007) caused a lack of suitable land for agriculture (Nabulo, 2009). Rooftops offer a high potential in terms of available space, sun exposure and consumer proximity.

Mayor of Paris made a political promise in relation with urban agriculture[1]. By 2020, she wants to count on its territory 100 hectares of green roofs and facades, including 30 productive hectares. A city as dense as Paris (seventh densest city in the world), hopes to conquer roofs belonging to the public and private spheres with various objectives like as food restoration, direct selling, workshop, individual hobby,...).

However, in urban sites generally arises the question of potential health risk for consumer related to the presence of contaminants like as Trace Metals (TM's) in products. The growing crops are necessarily exposed to the direct urban pollution (atmospheric fallout in high traffic areas) or to the contamination by TM's transfer from the growing medium (Yujing et al., 2005; pruvot et al., 2006; Zheng et al., 2007; Säumel et al., 2012; Pelfrêne et al., 2012; Szolnoki et al., 2013; Mitchelle et al., 2014; Ferri et al., 2015; Warming et al., 2015).

Since 2012, Bertrand Ney roofgarden of AgroParisTech is the support of a Productive Roofgarden Pilot Project testing the production on various substrates made from waste organic materials. These substrates contain very low level of TM's and the rhizospheric transfer of metals is not significant (Grard et al., 2015). Pb and Cd contents in salads and tomatoes grown on this roofgarden were below the European guidance values[2].

Based on these insights, this work studied the feasibility of the production of edible crops at 4 peri-urban sites in Paris area which could potentially host a roofgarden using the organic waste substrates as growing medium. The main objective is to estimate the contamination of vegetables crops by TM's (Cd, Pb, Hg, Cu and Zn) during a short period of production (3 months). The impact of environmental

[1]Urban agriculture (UA) is defined according Foeken and Owuor (2000) as any agricultural activity within the administrative boundary of an urban center.

[2]EC 1881/2006, December 19, 2006

conditions (atmospheric deposition or physico-chemical properties of substrates) and consumer practices will also be considered.

II. MATERIALS AND METHODS

2.1. Sites

Four urban sites (shopping centres) were selected to install the experimental gardens. The different sites are all located near major highways with traffic burden of 105000 to 1100000 per day.A fifth site (Bertrand Ney roofgarden) served as control due to low levels of TM's measured in its products (Grard et al. 2015). It is located on Bertrand Ney roof of AgroParisTech school in the centre of Paris.

2.2. Growing Medium

The used substrate was a mixture of topsoil (Distrisoil), green waste compost from a composting platform (BioYveline Services) and coffee grounds with mycelium. The proportions were 40: 40: 20 respectively.

2.3. Garden installation

Given the very short period of experimentation (one crop cycle), easily installable and removable gardens were implanted using containers in geotextile (122 L). They were positioned in locations the most exposed to potential sources of contamination (near highways), avoiding the barriers (walls, hedges etc.). Three containers were installed on each experimental garden (3 replicates).

2.4. Crop species

Crop choice for this experiment was based on following criteria: (i) edible species commonly grown in urban agriculture, (ii) vegetables with different edible parts (leaf, root, fruit), (iii) crop cycle (maximum of 15 weeks like as carrots).

2.5. Sample preparation and analysis

100 g of fresh matter were collected from each container. To comply with good consumer practices, all the samples were washed (carrots were peeled). The washed samples were dried at 40°C during at least one week for the salad and parsley and about three weeks for carrots, tomatoes and strawberries. The fresh and dry matters were weighted in order to estimate the water content in fruit and vegetables. They were then mineralized using a digestion block (DigiPREP SCP SCIENCE). Five TM's (Cd, Pb, Cu, Zn and Hg) were analyzed using a Polarized Zeeman Atomic Absorption spectrophotometer model Z5000 (HITACHI).

III. RESULTS AND DISCUSSION

Mean value of TM's (Pb, Cd, Hg, Cu and Zn) concentrations in five studied vegetables grown on 5 experimental gardens are illustrated on Table 1 (n=3). There are three replicates (three containers) for each vegetable. The measurement of TM's was effected in two replicates.

Vegetables of Bertrand Ney roofgarden serves as control because the levels of TM's present in the washed and unwashed vegetables do not exceed regulatory thresholds (Grard et al., 2015).

For all experimental gardens, Pb, Cd and Hg contents were below the regulatory values (European Commission, 2006) except for Pb in parsley samples of Bertarnd Ney roofgarden. Pb, Cd and Hg contents were below the concentrations reported by Mench and Baize (2004) for some supermarket vegetables. Cu and Zn concentrations were mostly below the reference values commonly used in the literature (Mench and Baize, 2004; Tremel and Feix, 2005) with some exceeding values for parsley samples. Generally, TM's concentrations were higher in leafy vegetable compared to root and fruit. Results are discussed basing on two major exposure pathways of vegetables to TM's *e.i.* foliar absorption via atmospheric fallout and soil/plant transfer.

3.1. Substrate to vegetable transfer:

Use of recycled organic waste with metal concentrations below the French applied standards values (AFNOR, 2002) limited the metal contamination via this pathway. Generally, low transfer rates of substrate to vegetable were observed. Physicochemical properties of substrates (alkaline pH and high organic matter contents related to the substrate composition of compost/topsoil) could explain this behaviour. However, leafy vegetables, known for their ability to accumulate TM's via soil/plant transfer, showed higher concentrations than fruit and root vegetables.

3.2. Foliar absorption:

Fine particulate matter deposition is reported as a real source of contamination of vegetables by TM's in urban area. It concerns mostly the leafy vegetables like as salad and more specifically aromatic herbs due to their large surface of exposure (Schreck et al., 2012; Mombo et al., 2015). The relative high level of Pb, Cu and Zn in parsley samples could be explained by this specific behaviour of leafy vegetables. The mechanism of uptake via foliar absorption is not well known. Different pathways are proposed in the literature like as cuticular retention or leave incorporation depending on the metal speciation on the surface of tissues (Uzu et al., 2010; Shreck et al., 2012).

Table 1. Mean values (n=3) of TM's contents (mg.kg-1 of fresh weight) in salad, tomato, strawberry, carrot and parsley grown on 5 experimental roofgardens. The uncertainty of all measurements expressed as RSD did not exceed 8% (n=3).

Site	Species	Pb	Cd	Hg	Zn	Cu
		Guidance value (EC, 2006): 0.3 mg.kg^{-1} for leafy vegetables and 0.1 mg.kg^{-1} for fruit and root vegetables	Guidance value (EC, 2006): 0.2 mg.kg^{-1} for leafy vegetables, 0.1 mg.kg^{-1} for root vegetables and 0.05 for fruits	Guidance value (EC, 2006) 0.5 mg.kg^{-1} in fishery products	Reference value (Mench and Baize 2004): 9 mg.kg-1	Reference value (Mench and Baize 2004): 1 mg.kg^{-1}
Bertrand Ney roofgarden	Carrot	0.02	0.003	<0.001	2.88	0.55
	Parsley	**0.53**	0.004	0.005	8.32	**1.54**
	Salad	0.02	0.006	0.001	3.15	0.65
	Strawberry	0.05	0.001	<0.001	1.56	0.85
	Tomato	0.003	0.001	<0.001	1.27	0.52
Site 1	Carrot	0.02	0.003	<0.001	1.95	0.58
	Parsley	0.18	0.007	0.005	**9.15**	**2.43**
	Salad	0.02	0.004	<0.001	2.37	0.66
	Strawberry	0.04	0.001	<0.001	1.25	0.58
	Tomato	0.004	0.002	<0.001	1.61	0.67
Site 2	Carrot	0.01	0.002	<0.001	1.84	0.61
	Parsley	0.09	0.002	0.003	5.98	**3.59**
	Salad	0.02	0.008	0.001	4.15	0.83
	Strawberry	0.06	0.001	<0.001	1.34	0.91
	Tomato	0.005	0.002	<0.001	2.15	0.68
Site 3	Carrot	0.02	0.003	<0.001	1.82	0.48
	Parsley	0.11	0.007	0.003	**11.2**	**1.37**
	Salad	0.02	0.009	0.002	3.1	0.69
	Strawberry	0.02	0.001	<0.001	1.82	0.83
	Tomato	0.003	0.002	<0.001	1.73	0.69
Site 4	Carrot	0.02	0.002	<0.001	1.98	0.55
	Parsley	-	-	-	-	-
	Salad	0.03	0.007	0.001	4.88	0.79
	Strawberry	-	-	-	-	-
	Tomato	0.005	0.001	<0.001	1.52	0.65

Figure 1 shows the levels of TM's in washed and unwashed salad samples grown on one of the studied sites. Significant differences were observed between Pb and Cd contents in washed and unwashed salad.

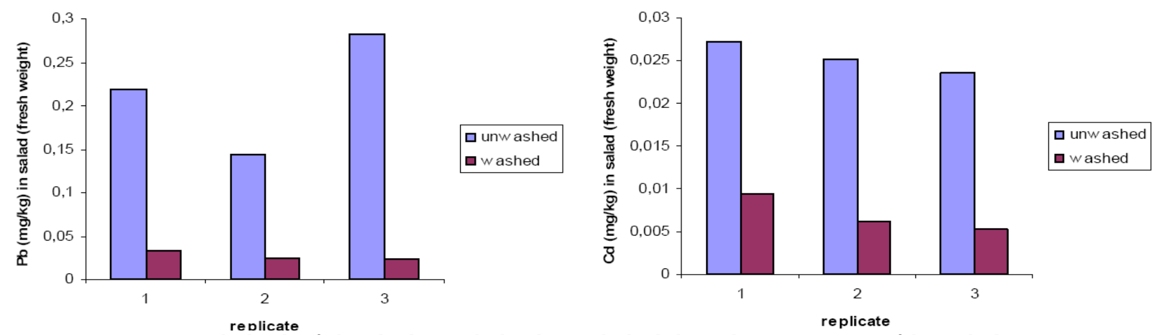

Fig. 1. the levels of Pb and Cd in washed and unwashed salad samples grown on one of the studied sites

Whatever the pathway of contamination, TM's contents in the vegetables grown on these experimental roofgardens, were below those reported by different authors in European cities. Saumel et al. (2012) reported TM's concentrations exceeding the permissible levels for Pb, Cd, Zn and Cu in leafy, root and fruit vegetables grown in the inner city of Berlin. Italian researchers (Ferry et al., 2015) reported also much higher levels for vegetables grown in urban areas (north of Italy) compared to Parisian vegetables.

Researches in this field are numerous (China, USA, Canada and Australia). The majority of these works use urban and peri-urban soils often contaminated by TM's. The advantage of the experimental gardens proposed in this work is the use of recycled organic substrates as a clean growing medium. However the atmospheric fallout remains a real issue to investigate for this type of garden.

CONCLUSION

Pb, Cd, Hg, Zn and Cu were measured in different types of crops growing on 4 experimental roofgardens installed in peri-urban zone of Paris. TM's levels were below the health-based guidance values (EU standards) for virtually all fruits and vegetables. TM's concentration varied by crop type. Considering the low level of TM's in growing substrates (mixture of green waste compost, topsoil and ground of coffee), the major source of TM's in crops was related to the atmospheric fallout. In this way, leafy vegetables (particularly parsley samples) contained higher levels of Pb, Zn and Cu compared to root and fruit crops. Hence, particular attention must be paid to the environmental conditions surrounding the crops more sensitive to atmospheric fallout like as aromatic herbs. Results indicated also the importance of good practice of consumption like as peeling and washing. The assessment of health risk associated to the consumption of urban crops is site-specific. Several parameters like as exposure pathways, type of crop, characteristics of growing medium, land use and finally exposed population are to be considered for giving appropriate recommendations to different actors participating in such sustainable gardening projects.

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