biology and life sciences forum

MDPI

Proceeding Paper

Lead in Wild Edible Mushroom Species in Leicester, England †

Gurminderjeet S. Jagdev [1], Mark D. Evans [1], Tiziana Sgamma [1], María del Carmen Lobo-Bedmar [2] and Antonio Peña-Fernández [1,3,*]

1 Leicester School of Allied Health Sciences, Faculty of Health & Life Sciences, De Montfort University, Leicester LE1 9BH, UK
2 Departamento de Investigación Agroambiental, Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), Finca el Encín, Crta. Madrid-Barcelona, Km 38.2, 28800 Alcalá de Henares, Spain
3 Department of Surgery, Medical and Social Sciences, Faculty of Medicine and Health Sciences, University of Alcalá, Ctra. Madrid-Barcelona, Km. 33.600, 28805 Alcalá de Henares, Spain
* Correspondence: antonio.penafer@uah.es
† Presented at the 4th International Electronic Conference on Foods, 15–30 October 2023; Available online: https://foods2023.sciforum.net/.

Abstract: The aim was two-fold: to characterise the risks of lead (Pb) in *Agaricus bitorquis* collected in the city of Leicester (England), and to evaluate its presence in urban topsoils. Pb was monitored by ICP-MS in twenty-two homogenised mushroom samples (caps and stipes) mineralised with HNO_3/H_2O_2 [LoD = 0.872 mg/kg dry weight (dw)]. Moreover, 450 topsoil samples were collected from 18 urban parks across Leicester; Pb was also measured by ICP-MS after appropriate digestion (LoD = 0.698 mg/kg). Levels were significantly higher in the mushroom caps (p-value = 3×10^{-5}); median and ranges are provided in mg/kg dw: 2.461 (1.806–6.664) vs. 1.579 (0.988–4.223). Concentrations were much higher than those reported in sixteen *A. bisporus* (median < 1.0 mg/kg DW) specifically cultivated in high-traffic areas in the inner city of Berlin, suggesting some contamination by Pb. All caps monitored exceeded the established maximum concentration limit for Pb in cultivated mushrooms in the European Union (3 mg/kg dw), in line with the high accumulative metal capability described in the literature for *Agaricus* spp. Although non-carcinogenic risks characterised for Pb were negligible in the monitored mushrooms, a high consumption of wild green edibles in Leicester's city should be limited as there are multiple additional sources of Pb and other metals, and they should be substituted by cultivated edibles where possible.

Keywords: wild edible mushrooms; *Agaricus bitorquis*; Pb; risks; urban contamination

Citation: Jagdev, G.S.; Evans, M.D.; Sgamma, T.; Lobo-Bedmar, M.d.C.; Peña-Fernández, A. Lead in Wild Edible Mushroom Species in Leicester, England. *Biol. Life Sci. Forum* **2023**, *26*, 59. https://doi.org/10.3390/Foods2023-15035

Academic Editor: Vito Verardo

Published: 14 October 2023

1. Introduction

The consumption of urban garden products, including wild edible mushrooms, can contribute to local food security and is increasing all over the world, despite the risks that they can represent due to anthropogenic contamination [1,2]. There is comprehensive evidence highlighting that urban and garden topsoils can contain high amounts of metals and metalloids. Wild mushrooms can grow in these areas, including highly polluted substrates, and can show a dynamic accumulation of trace metals, which would require careful assessment owing to the non-biodegradable nature of these pollutants [2]. Although the European Union has established EU standards for maximum acceptable metal concentrations in soils to be used for horticulture [3], collecting wild edible mushrooms can represent a serious risk to human health. Thus, recent systematic reviews have reported a significant toxic risk to those that consume wild edible mushrooms, including adults and children [4], highlighting a potential public health risk in England that has been little explored.

Evidence of the impact of urbanisation, economic development and growth on wild edible mushrooms in the British urban media is scarce. As a result, the aim was to assess the risks from lead (Pb) present in wild edible mushrooms of the species *Agaricus bitorquis* collected in the city of Leicester (England), as well as in urban topsoils, to evaluate the environmental presence and distribution of this contaminant.

2. Materials and Methods

Twenty-two *A. bitorquis* mushrooms were collected from an open green area close to St Augustine Road, a high-traffic area within the inner Leicester city centre. Mushrooms were manually washed with tap water to remove soil and dust, rinsed with deionised and Milli-Q water, and split into caps and stipes to gain insight into the variability of Pb concentrations along the mushroom tissue [5]. Then, mushroom samples were individually oven dried at 70–80 °C for 1 day [6]. The dried mushrooms' samples were ground into a fine powder using a ceramic mortar [7], sieved through a 200-mesh sieve, and finally homogenised and stored in polyethylene bags. Species identification was confirmed by DNA barcoding using internal transcribed spacer 1/4 primers after extracting DNA from 100 mg of frozen, homogenised, ground mushroom material using a DNeasy Plant Mini Kit® (Qiagen Inc., Germantown, MD, USA), according to previous methods described by Sgamma et al. [8]. Pb was monitored by ICP-MS in cleaned, dried, and homogenised mushroom caps, and stipes were mineralised with HNO_3/H_2O_2 [LoD = 0.872 mg/kg dry weight (dw)] following previous methods [1].

Moreover, 450 topsoil samples were collected from 18 urban parks and green areas across Leicester, which were appropriately prepared, pulverised, pooled together and thoroughly homogenised on a motorised rotating mixer to be further processed as composite samples per park in duplicate. Pb was also measured in duplicate in each of the 36 composite samples by ICP-MS after acid digestion with nitric acid (69%) and chlorohydric acid (37%) in a microwave system [9].

Certified reference material for mushrooms (NIST1570a trace elements in spinach leaves; Darmstadt, Germany, Sigma-Aldrich) and topsoils (CRM059 trace elements in loamy clay 2; Darmstadt, Germany, Sigma-Aldrich) were used to assess the quality of the measurements.

Non-carcinogenic human risks were assessed for exposure to Pb through the ingestion, dermal absorption, and inhalation of topsoils, following the US EPA Risk Assessment Guidance for Superfund (RAGs) methodology [10] and the dosimetry methodology [11]. Further equations and information can be found in Rovira et al. [12,13].

Statistical analyses were performed using the free software R, version 3.3.2. A Peto–Prentice test was used to evaluate the differences between areas and to investigate tissue distribution. The levels of significance for statistical analyses were set at 0.05.

3. Results and Discussion

Pb was found in all topsoil composites examined (LoD = 0.698 mg/kg) and in the collected mushrooms. Percentages of recovery for the reference materials used for mushrooms and topsoils were 107% and 120%, respectively, indicating that the data obtained were accurate.

Levels of this metal were significantly higher in the mushroom caps (p-value = 3×10^{-5}); median and ranges are provided in mg/kg dw: 2.461 (1.806–6.664) vs. 1.579 (0.988–4.223). Concentrations were, in general, lower than those recently reported in different species of the genus *Agaricus*, collected in urban habitats in Berlin (Germany; <0.1–51.0 mg/kg dw) [1]. However, the levels of Pb detected were much higher than those reported in sixteen *A. bisporus* (median < 1.0 mg/kg dw) specifically cultivated in high-traffic areas in the inner city of Berlin reported by these authors, suggesting that Leicester's St Augustine Road presents a heavy volume of traffic that should be further explored to prevent risks of Pb exposure. Despite the ban of alkyl Pb motor fuel additives at the end of 1999 [14], road and traffic continue to be finite sources of Pb in the environment, which could include road runoff, corrosion of crash barriers, and the wear of tyres and engine pieces [15]. Moreover, diesel, biodiesel and unleaded gasoline can have ultra-trace amounts of Pb [16], which could contribute to the presence of this metal in the monitored environment owing to its high environmental persistence. Thus, Resongles et al. [14] have recently observed a strong link between the Pb deposited during the 20th century in London with its high presence in particulate matter in the current atmosphere of the city.

Higher levels of Pb were found in the urban area [102.805 (84.335–110.625) vs. 62.080 (35.781–68.140); data presented as median and 95% CI, in mg/kg], which did not show statistical differences, perhaps due to the wide dispersion observed, which is characteristic of Pb and is well described in the literature. Leicester soils are less contaminated by Pb than in other, larger British cities, such as London (180.1 mg/kg) [17]. The urban region was subdivided into four ordinal directions to study the distribution of this metal. Significant differences (p-value = 0.02) were detected, which revealed the following pattern for Pb: NW > SE > SW > NE, reflecting the wide distribution of this metal in Leicester.

Human Health Risks

All caps monitored exceeded the established maximum concentration limit for Pb in cultivated mushrooms in the European Union (0.3 mg/kg wet weight, approximately 3 mg/kg dw) [18], in line with the high accumulative metal capability described in the literature for *Agaricus* spp. [1]. However, the range of Pb found was lower than the maximum concentration limit established for wild fungi by the European Commission (0.8 mg/kg wet weight, about 8 mg/kg dw) [18]. Moreover, the consumption of the monitored wild mushrooms represents a minimal risk to Pb, as the hazard quotients were much lower than the established threshold in both adults (5.72×10^{-8}) and children (2.67×10^{-7}).

In addition to this, the levels of Pb detected in Leicester urban topsoils would not represent a toxic risk to the population for any route (oral, inhalation and dermal), as all the risk quotients (4.17×10^{-2}, 1.50×10^{-4}, 2.03×10^{-1}) were lower than the established threshold (unit). However, although the concentration range of Pb observed was similar to the England ambient background concentration [29.30–476.92 vs. 40.1–387 mg/kg] [19], some areas within the city of Leicester could require remediation, as the levels of this metal exceed the upper range of the provisional Category 4 Screening Levels (pC4SLs) of Pb of residential land use (130–330 mg/kg) [17,20].

4. Conclusions

Although non-carcinogenic risks characterised for Pb were negligible in the monitored mushroom, the high consumption of wild green edibles in Leicester's city centre should be limited as there are multiple additional sources of Pb and other metals, and they should be substituted by cultivated edibles when possible.

Author Contributions: Conceptualization, A.P.-F.; methodology, G.S.J., M.D.E., T.S., M.d.C.L.-B. and A.P.-F.; validation, G.S.J. and A.P.-F.; formal analysis, G.S.J., T.S., M.d.C.L.-B. and A.P.-F.; investigation, G.S.J., M.D.E., T.S., M.d.C.L.-B. and A.P.-F.; resources, A.P.-F. and M.d.C.L.-B.; data curation, G.S.J., M.D.E., T.S. and A.P.-F.; writing—original draft preparation, A.P.-F.; writing—review and editing, G.S.J., M.D.E., T.S., M.d.C.L.-B. and A.P.-F.; visualization, G.S.J., M.D.E., T.S., M.d.C.L.-B. and A.P.-F.; supervision, M.D.E., T.S., M.d.C.L.-B. and A.P.-F.; project administration, M.D.E., T.S. and A.P.-F.; funding acquisition, T.S., M.d.C.L.-B. and A.P.-F. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been funded through the program EIADES: "Technology Assessment and Remediation of Contaminated Sites" S0505/AMB-0296 and S2009/AMB-1478. Consejería de Educación, Comunidad de Madrid, Spain.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to further processing for a future submission as a manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Schlecht, M.T.; Säumel, I. Wild growing mushrooms for the Edible City? Cadmium and lead content in edible mushrooms harvested within the urban agglomeration of Berlin, Germany. *Environ. Pollut.* **2015**, *204*, 298–305. [CrossRef] [PubMed]
2. Mleczek, M.; Budka, A.; Siwulski, M.; Budzyńska, S.; Kalač, P.; Karolewski, Z.; Niedzielski, P. Anthropogenic contamination leads to changes in mineral composition of soil-and tree-growing mushroom species: A case study of urban vs. rural environments and dietary implications. *Sci. Total Environ.* **2022**, *809*, 151162. [CrossRef] [PubMed]
3. Säumel, I.; Kotsyuk, I.; Hölscher, M.; Lenkereit, C.; Weber, F.; Kowarik, I. How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany. *Environ. Pollut.* **2012**, *165*, 124–132. [CrossRef] [PubMed]
4. Dowlati, M.; Sobhi, H.R.; Esrafili, A.; FarzadKia, M.; Yeganeh, M. Heavy metals content in edible mushrooms: A systematic review, meta-analysis and health risk assessment. *Trends Food Sci.* **2021**, *109*, 527–535. [CrossRef]
5. Fiket, Ž.; Medunić, G.; Furdek Turk, M.; Ivanić, M.; Kniewald, G. Influence of soil characteristics on rare earth fingerprints in mosses and mushrooms: Example of a pristine temperate rainforest (Slavonia, Croatia). *Chemosphere* **2017**, *179*, 92–100. [CrossRef] [PubMed]
6. Wang, Y.; Wang, R.; Fan, L.; Chen, T.; Bai, Y.; Yu, Q.; Liu, Y. Assessment of multiple exposure to chemical elements and health risks among residents near Huodehong lead-zinc mining area in Yunnan, Southwest China. *Chemosphere* **2017**, *174*, 613–627. [CrossRef] [PubMed]
7. Agnan, Y.; Séjalon-Delmas, N.; Claustres, A.; Probst, A. Investigation of spatial and temporal metal atmospheric deposition in France through lichen and moss bioaccumulation over one century. *Sci. Total Environ.* **2015**, *529*, 285–296. [CrossRef] [PubMed]
8. Sgamma, T.; Masiero, E.; Mali, P.; Mahat, M.; Slater, A. Sequence-specific detection of Aristolochia DNA—A simple test for contamination of herbal products. *Front. Plant Sci.* **2018**, *9*, 1828. [CrossRef] [PubMed]
9. Gil-Díaz, M.; Pinilla, P.; Alonso, J.; Lobo, M.C. Viability of a nanoremediation process in single or multi-metal (loid) contaminated soils. *J. Hazard Mater.* **2017**, *321*, 812–819. [CrossRef] [PubMed]
10. US EPA. *Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part A)*; US EPA: Washington, DC, USA, 1989.
11. US EPA. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*; US EPA: Washington, DC, USA, 2009.
12. Rovira, J.; Nadal, M.; Schuhmacher, M.; Domingo, J.L. Environmental levels of PCDD/Fs and metals around a cement plant in Catalonia, Spain, before and after alternative fuel implementation. Assessment of human health risks. *Sci. Total Environ.* **2014**, *485*, 121–129. [CrossRef] [PubMed]
13. Rovira, J.; Vilavert, L.; Nadal, M.; Schuhmacher, M.; Domingo, J.L. Temporal trends in the levels of metals, PCDD/Fs and PCBs in the vicinity of a municipal solid waste incinerator. Preliminary assessment of human health risks. *Waste Manag.* **2015**, *43*, 168–175. [CrossRef] [PubMed]
14. Resongles, E.; Dietze, V.; Green, D.C.; Harrison, R.M.; Ochoa-Gonzalez, R.; Tremper, A.H.; Weiss, D.J. Strong evidence for the continued contribution of lead deposited during the 20th century to the atmospheric environment in London of today. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2102791118. [CrossRef] [PubMed]
15. MacKinnon, G.; MacKenzie, A.B.; Cook, G.T.; Pulford, I.D.; Duncan, H.J.; Scott, E.M. Spatial and temporal variations in Pb concentrations and isotopic composition in road dust, farmland soil and vegetation in proximity to roads since cessation of use of leaded petrol in the UK. *Sci. Total Environ.* **2011**, *409*, 5010–5019. [CrossRef] [PubMed]
16. Chen, F.Y.; Jiang, S.J. Determination of Hg and Pb in fuels by inductively coupled plasma mass spectrometry using flow injection chemical vapor generation. *Anal. Sci.* **2009**, *25*, 1471–1476. [CrossRef]
17. Meng, Y.; Cave, M.; Zhang, C. Identifying geogenic and anthropogenic controls on different spatial distribution patterns of aluminium, calcium and lead in urban topsoil of Greater London Authority area. *Chemosphere* **2020**, *238*, 124541. [CrossRef]
18. EC (European Commission). Commission Regulation (EU) 2023/915 on Maximum Levels for Certain Contaminants in Food and Repealing Regulation (EC) No 1881/2006; pp. 103–157. Available online: https://eur-lex.europa.eu/eli/reg/2023/915/oj (accessed on 13 October 2023).
19. Barraclough, D. *UKSHS Report No.1, UK Soil and Herbage Pollutant Survey: Introduction and Summary*; Environment Agency: Bristol, UK, 2007.
20. CL:AIRE. Category 4 Screening Levels (C4SLs). Available online: https://www.claire.co.uk/projects-and-initiatives/category-4-screening-levels (accessed on 7 September 2023).