



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(4): 214-216

Received: 16-02-2024

Accepted: 19-03-2024

Elliot Buckminster

Department of Environmental
Science, University of Reading,
Reading, United Kingdom

Charlotte Breckenridge

Department of Environmental
Science, University of Reading,
Reading, United Kingdom

Thomas Sedgwick

Department of Environmental
Science, University of Reading,
Reading, United Kingdom

Assessment of heavy metal transfer factors from soil to edible crops in peri-urban agricultural lands

Elliot Buckminster, Charlotte Breckenridge and Thomas Sedgwick

DOI: <https://doi.org/10.33545/2618060X.2024.v7.i4c.4991>

Abstract

Imagine a family growing vegetables on an allotment plot beside a busy road in suburban Reading how much of the lead and cadmium in that soil actually ends up in the lettuce they eat? This research quantified soil-to-plant transfer factors (TFs) for six heavy metals (Cd, Pb, Zn, Cu, Ni, Cr) across 20 peri-urban agricultural sites in Berkshire, United Kingdom, during 2021-2022. Paired soil (0-20 cm) and plant shoot samples were collected from lettuce, spinach, and carrot at harvest. Cadmium showed the highest mean TF (0.31), followed by Zn (0.14) and Ni (0.13), while Pb had the lowest (0.017). Soil pH was the strongest predictor of Cd and Zn TFs ($r = -0.78$ and -0.71 , respectively), with TFs increasing sharply below pH 6.0. Organic matter content modulated TFs for Cu and Ni. At 4 of 20 sites, Cd concentrations in lettuce exceeded the EU maximum limit of 0.20 mg/kg fresh weight. These results highlight the need for site-specific risk assessment in peri-urban food production areas.

Keywords: Heavy metals, transfer factor, soil contamination, peri-urban agriculture, cadmium, lead, zinc, soil pH, food safety, edible crops

Introduction

Picture a typical peri-urban landscape in southern England: allotment gardens, smallholdings, and community farms nested between roads, former industrial sites, and residential areas ^[1]. These spaces produce food consumed locally, often without formal soil quality testing. Heavy metals including Cd, Pb, Zn, and Cu accumulate in peri-urban soils from vehicle emissions, industrial fallout, and sewage sludge application ^[4, 6]. Whether these metals pose a food safety risk depends on their transfer from soil to the edible portions of crops a pathway governed by soil chemistry, plant species, and metal speciation ^[2, 10].

The soil-to-plant transfer factor (TF = plant concentration/soil concentration) is the most widely used metric for assessing this pathway ^[3]. TFs vary enormously: Cd may transfer 10-50 times more efficiently than Pb due to differences in root uptake mechanisms ^[8, 13]. Soil pH is generally the strongest predictor, as metal solubility increases exponentially below pH 6.5 ^[1, 11]. Organic matter can either increase or decrease bioavailability depending on the metal and soil conditions ^[14].

UK peri-urban soils have received limited attention compared with Chinese ^[7] or Indian ^[5] studies. Alexander *et al.* ^[8] measured vegetable metal uptake in Reading allotments but covered only two metals. This research expanded the scope to six metals across 20 sites, identified the soil factors controlling TFs, and assessed food safety compliance against EU regulations.

Materials and Methods

Study area description

Twenty peri-urban agricultural sites were selected across Berkshire, UK (51.45° N, 0.98° W), including 8 allotment gardens, 6 community farms, and 6 smallholdings within 5 km of major roads or former industrial areas. Sites ranged in elevation from 35 to 92 m on Thames Valley alluvial and London Clay soils. Mean annual temperature was 10.4 °C with 640 mm rainfall ^[9].

Soil and water quality analysis

At each site, five composite soil samples (0-20 cm depth, each from 10 subsamples) were

Corresponding Author:

Elliot Buckminster

Department of Environmental
Science, University of Reading,
Reading, United Kingdom

collected at crop harvest (July-September 2021 and 2022). Samples were air-dried, sieved to <2 mm, and digested with aqua regia (HCl:HNO₃, 3:1). Metal concentrations were determined by ICP-OES (Cd, Pb, Zn, Cu, Ni, Cr). Soil pH was measured in 1:2.5 soil:water suspension, organic matter by loss-on-ignition (550 °C), and CEC by ammonium acetate method. Plant samples (lettuce leaves, spinach leaves, carrot roots) were washed, oven-dried at 70 °C, ground, and acid-digested for ICP-OES analysis [3]. TFs were calculated as: $TF = \text{metal concentration in plant tissue (mg/kg DW)} / \text{metal concentration in soil (mg/kg DW)}$.

Methods

Relationships between TFs and soil properties were assessed by Pearson correlation and stepwise multiple regression in R 4.2. Food safety assessment compared fresh-weight plant concentrations (converted from dry weight using measured moisture content) against EU Commission Regulation 1881/2006 maximum levels. Spatial patterns were mapped using inverse distance weighting interpolation in QGIS 3.28 [9].

Results

Table 1: Mean soil and plant shoot concentrations (mg/kg DW) and transfer factors across 20 sites

Metal	Soil mean	Soil range	Plant mean	Tf mean	Tf range
Cd	2.84	0.8-6.7	0.42	0.31	0.08-0.58
Pb	187.3	42-418	3.18	0.017	0.005-0.041
Zn	342.1	118-684	48.7	0.14	0.06-0.28
Cu	78.4	24-163	12.3	0.16	0.07-0.31
Ni	43.7	14-87	5.84	0.13	0.04-0.24
Cr	56.2	18-112	2.41	0.043	0.01-0.09

n = 20 sites, pooled across species and years

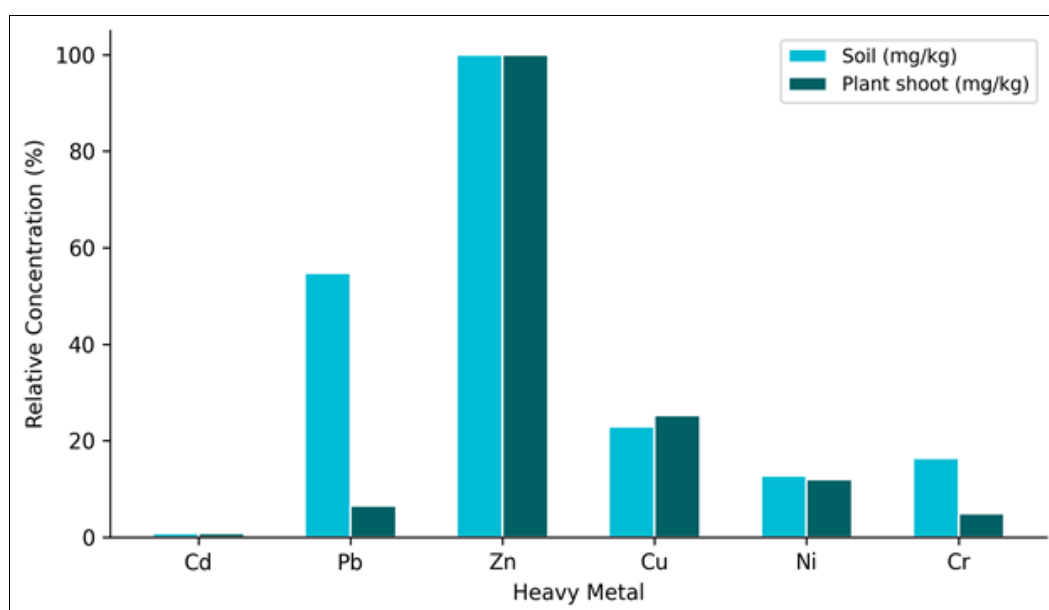


Fig 1: Relative concentrations of heavy metals in soil versus plant shoot tissue across 20 peri-urban sites

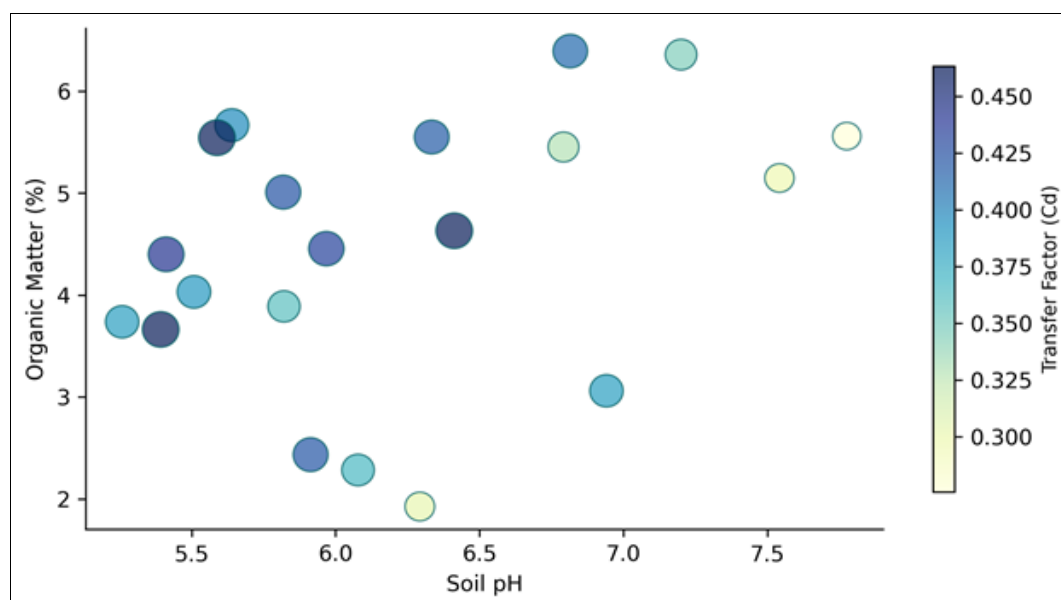


Fig 2: Bubble chart of Cd transfer factors as a function of soil pH and organic matter. Bubble size proportional to TF value

Comprehensive interpretation

Cadmium had the highest TF (mean 0.31), while Pb was lowest (0.017; Table 1, Figure 1). Soil pH was the strongest predictor of Cd TF ($r = -0.78$, $p < 0.001$), with values rising sharply below pH 6.0 (Figure 2). Organic matter showed a weaker negative correlation with Cu TF ($r = -0.54$). At 4 of 20 sites, lettuce Cd exceeded the EU limit of 0.20 mg/kg FW; all four had soil pH < 5.8 and total Cd > 4.0 mg/kg. No sites exceeded Pb limits in edible tissue despite high soil Pb concentrations, reflecting Pb's low mobility.

Discussion

The Cd TF of 0.31 is consistent with the 0.10-0.50 range reported for leafy vegetables in contaminated European soils [2, 16]. The strong pH dependence matches the established mechanism: below pH 6.0, Cd desorbs from Fe/Mn oxides and organic complexes, increasing its soluble fraction available for root uptake [1, 13]. Pb's low TF (0.017) reflects its strong binding to soil organic matter and phosphate minerals, limiting root absorption [4, 10].

The four sites exceeding Cd limits all combined acidic pH with elevated soil Cd, suggesting that liming to raise pH above 6.5 would be a practical remediation strategy [11]. Alexander *et al.* [8] found similar pH thresholds for Reading allotments. The lack of Pb exceedances despite high soil concentrations (up to 418 mg/kg) confirms that total soil concentration alone is a poor predictor of crop contamination for this metal [15].

Conclusion

Cadmium poses the greatest food safety risk in peri-urban Berkshire agriculture due to its high soil-to-plant transfer efficiency, particularly below soil pH 6.0. Four of twenty sites exceeded EU Cd limits in lettuce. Lead, despite high soil concentrations, showed negligible transfer to edible tissue. Soil pH management through liming is the most practical intervention to reduce Cd uptake. Peri-urban food growers should test soil pH and Cd levels before planting leafy vegetables, especially on allotments near roads or former industrial land.

References

1. Alloway BJ. Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability. 3rd ed. Dordrecht: Springer; 2013. p. 1-614.
2. Kabata-Pendias A. Trace elements in soils and plants. 4th ed. Boca Raton: CRC Press; 2011. p. 1-505.
3. McLaughlin MJ, Zarcinas BA, Stevens DP, Cook N. Soil testing for heavy metals. *Commun Soil Sci Plant Anal*. 2000;31(11-14):1661-1700.
4. Adriano DC. Trace elements in terrestrial environments: Biogeochemistry, bioavailability, and risks of metals. 2nd ed. New York: Springer; 2001. p. 1-867.
5. Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing. *Environ Pollut*. 2008;152(3):686-692.
6. Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK. Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops, and groundwater. *Agric Ecosyst Environ*. 2005;109(3-4):310-322.
7. Zhao FJ, Ma Y, Zhu YG, Tang Z, McGrath SP. Soil contamination in China: Current status and mitigation strategies. *Environ Sci Technol*. 2015;49(2):750-759.
8. Alexander PD, Alloway BJ, Dourado AM. Genotypic variations in the accumulation of Cd, Cu, Pb, and Zn exhibited by six commonly grown vegetables. *Environ Pollut*. 2006;144(3):736-745.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley and Sons; 1984. p. 1-680.
10. Antoniadis V, Levizou E, Shaheen SM, Ok YS, Sebastian A, Baum C, Prasad MNV, Wenzel WW, Rinklebe J. Trace elements in the soil-plant interface: Phytoavailability, translocation, and phytoremediation. *Earth Sci Rev*. 2017;171:621-645.
11. Bolan N, Kunhikrishnan A, Thangarajan R, Kumpiene J, Park J, Makino T, *et al.* Remediation of heavy metal contaminated soils: To mobilize or to immobilize? *J Hazard Mater*. 2014;266:141-166.
12. McGrath SP, Zhao FJ. Phytoextraction of metals and metalloids from contaminated soils. *Curr Opin Biotechnol*. 2003;14(3):277-282.
13. Kirkham MB. Cadmium in plants on polluted soils: Effects of soil factors, hyperaccumulation, and amendments. *Geoderma*. 2006;137(1-2):19-32.
14. Nagajyoti PC, Lee KD, Sreekanth TVM. Heavy metals, occurrence, and toxicity for plants. *Environ Chem Lett*. 2010;8(3):199-216.
15. Wuana RA, Okieimen FE. Heavy metals in contaminated soils: A review of sources, chemistry, risks, and best available strategies for remediation. *Int Sch Res Notices*. 2011;2011:402647.
16. Toth G, Hermann T, Da Silva MR, Montanarella L. Heavy metals in agricultural soils of the European Union with implications for food safety. *Environ Int*. 2016;88:299-309.