OSWER 9200.2-142
December 2013

TECHNICAL REVIEW WORKGROUP RECOMMENDATIONS REGARDING GARDENING AND REDUCING EXPOSURE TO LEAD-CONTAMINATED SOILS

Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

NOTICE

This document provides technical and policy guidance to the U.S. Environmental Protection Agency (EPA) staff on making risk management decisions for contaminated sites. It also provides information to the public and to the regulated community on how EPA intends to exercise its discretion in implementing its regulations at contaminated sites. It is important to understand, however, that this document does not substitute for statues those EPA administrators or their implementing regulations, nor is it a regulation itself. Thus, this document does not impose legally – binding requirements on EPA, states, or the regulated community, and may not apply to a particular situation based upon the specific circumstances. Rather, the document suggests approaches that may be used at particular sites, as appropriate, given site-specific circumstances.

U.S. ENVIRONMENTAL PROTECTION AGENCY
TECHNICAL REVIEW WORKGROUP FOR LEAD

The Technical Review Workgroup for Lead (TRW) is an interoffice workgroup convened by the U.S. EPA Office of Solid Waste and Emergency Response/Office of Superfund Remediation and Technology Innovation (OSWER/OSRTI).

MEMBERS

Region 1
Mary Ballew
Claire Willscher

Region 2
Mark Maddaloni
Julie McPherson

Region 3
Dawn Ioven
Linda Watson

Region 4
Kevin Koporec

Region 5
Andrew Podowski

Region 6
Ghassan Khoury

Region 7
Mike Beringer (advisor)
Todd Phillips

Region 8
Charles Partridge (co-chair)
Jim Luey

Region 9
Sophia Serda

Region 10
Marc Stifelman
Craig Cameron

OSRTI
Michele Burgess (co-chair)
Steve Jones (ATSDR Liaison)

ORD NRMRL – Cincinnati
Harlal Choudhury
Kirk Scheckel

ORD NCEA – RTP
Jim Brown

State of Utah DEQ
Scott Everett (co-chair)

Advisors
Karen Hogan (ORD NCEA)
Paul White (ORD NCEA)
Larry Zaragoza (OSRTI)
Michele Mahoney (OSRTI)

Overview

This document provides an overview of exposure to lead while gardening and consuming home-grown produce, and, based on currently available information, to provide Best Management Practices for Gardening in Lead Contaminated Areas to reduce lead exposure in contaminated soil (see Table 1). This document also seeks to identify key data gaps and uncertainties. These Best Management Practices are based on a review of the literature and best professional judgment to identify appropriate risk mitigating actions associated with the varying ranges of soil lead concentrations[1] in produce gardens. For further background information on lead risk assessment, refer to U.S. EPA Technical Review Workgroup for Lead (TRW) website (http://epa.gov/superfund/lead/trw.htm).

The Office of Solid Waste and Emergency Response (OSWER) recommends using the Integrated Exposure Uptake Biokinetic Model (IEUBK model) as a risk assessment tool to support environmental cleanup decisions for residential scenarios at Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites and at Resource Conservation and Recovery Act (RCRA) Corrective Action sites (U.S. EPA, 1994a, b). It is also useful to support environmental cleanup decisions for other types of sites too. For residential scenarios, OSWER has established 400 ppm as the screening level for lead in soil (U.S. EPA 1994c). Soil Screening Levels (SSLs) are not cleanup goals. SSLs are guidelines to determine which sites or portions of sites require further study. While residential areas with soil lead concentrations below 400 ppm generally require no further action, some actions may be appropriate in edible gardens at soil lead concentrations below 400 ppm to reduce the potential for increased lead exposure. The basis for the 400 ppm SSL is children playing in lead contaminated soil and some other exposures, with the predominant source of exposure from direct soil ingestion or ingestion of soil manifested as house dust. Scientific limitations when the SSL for lead was developed did not allow adequate accounting for consumption of home-grown produce. In some instances, States or tribal cleanup programs or local governments may established more stringent standards that require further action at soil lead concentrations below 400 ppm for cleanup activities they govern, fund, or oversee.

To address public health concerns of potential exposure to lead while gardening, the TRW extensively reviewed the literature and conducted a feasibility study (*i.e.*, the Spreadsheet Model, see Appendix A) to develop quantitative, risk-based recommendations for lead concentrations in garden soil for specific garden-related exposure pathways. The TRW identified the following four pathways of lead exposure that may be associated with gardening in contaminated soil and consuming produce as well as additional exposure risks from contaminated soil tracked into dwellings for inclusion in the model[2]:

- Direct ingestion of lead in the matrix of produce;
- Ingestion of lead in soil adhered to produce surfaces;
- Incidental ingestion of soil while gardening; and
- Incidental ingestion of soil tracked into residence.

[1]"Best professional judgment" reflects the collaborative technical expertise of the TRW, as well as other participating Federal and State Agencies.

[2]Inhalation and dermal absorption of lead from gardening are believed to be minor routes of exposure, and, consequently, not discussed in this document.

Data were not sufficient to derive quantitative, risk-based recommendations for lead concentrations in garden soil for specific garden-related exposure pathways (see Appendix A). Nonetheless, the TRW identified that the exposures associated with gardening (both as an activity and through the consumption of home grown produce) could result in greater exposure than typically considered as part of the traditional residential exposure pathway. Because of insufficient data limitations, the TRW recommends that that soil lead concentrations in Table 1 be used as guidelines to consider the associated Best Management Practices for Gardening in Lead Contaminated Areas to reduce lead exposure in contaminated soil.

Table 1. TRW Lead Committee Recommended Best Management Practices for Gardening in Lead Contaminated Areas

Soil-Lead Concentration (ppm)	Category	Recommendation: Gardening Practices	Recommendation: Choosing Plants[a]
<100	Low risk	• No specific remedial action needed. • Wash hands, produce, clothes (good gardening and housekeeping practices).	• No restrictions of crop types.
>100–400[b] -·-·-·-·-► 400–1200	Potential risk	• Increasing use of good gardening and housekeeping practices as described in Table 3. • Relocate garden to lower risk garden areas. • Increasing use of soil amendments (*e.g.*, compost, clean fill), barriers (*e.g.*, mulch), and other remedial measures (see Table 3) up to and including raised beds and containers. • Ensure gardeners wear gloves and use tools to reduce soil contact and ingestion.	• Decrease planting of root vegetables or relocate root crop planting to lower risk areas. • Increase use of soil amendments and barriers to reduce soil deposition onto leafy vegetables. • Increase planting of fruiting vegetables, vegetables that grow on vines, and fruit trees.
>1200	High risk	• All of the above good gardening and housekeeping practices. • Raised beds, soil containers, soil replacement (*i.e.*, excavate contaminated soil and replace with soil containing low lead concentrations) are strongly recommended.[c] • Consider finding other locations for garden. • Restrict child access to only established safe areas. • Restrict all gardening by or for children in contaminated soils.	• Select plants with shallow roots for raised beds or areas with replacement soil to ensure that roots do not reach contaminated soil that is left in place, if any, otherwise, no restrictions.

[a] Source: Hemphill et al., 1973; Moir and Thornton, 1989; U.S. EPA, 1995; U.S. DOE, 1998; Jorhem et al., 2000; Heinegg et al., 2000; Finster et al., 2003; Pichtel and Bradway, 2008; Shayler et al., 2009; Leake et al., 2009; Chaney et al., 2010; Nabulo et al., 2010; U.S. EPA, 2011a; U.S. EPA, 2011b; Säumel et al., 2012

[b] While 400 ppm lead in soil is considered an appropriate screening level for residential soil-lead, the TRW recommends that 100 ppm be used as the low end of the range of soil lead concentrations to mitigate exposure to lead in soil when gardening is an important exposure pathway. Lacking the information to support a quantitative approach for estimating risk for gardening scenario to support establishing acceptable concentration of lead in garden areas, best professional judgment was used to establish the low end of the range. This soil concentration is below the 400 ppm soil screening level for lead because the gardening exposure pathway includes other sources of lead exposure not sufficiently accounted for in the soil screening level. The basis for the Soil Screening Level (SSL) is children playing in lead contaminated soil and some other exposures, with the predominant source of exposure from direct soil ingestion or ingestion of soil manifested as house dust. Scientific limitations when it was developed did not allow the SSL for lead to adequately account for consuming home-grown produce. In developing an acceptable concentration of lead in soil for home garden exposures, the same child receptor would be exposed if accompanying the adult in the garden and also exposed through consumption of lead in and on the produce grown in the soil. Hence, the garden-based level is lower than the SSL and reasonable steps to mitigate exposure to lead while gardening in soil lead concentrations between 100–400 ppm would be appropriate. The TRW acknowledges that background soil lead concentrations in some communities may exceed the guidance values recommended for garden areas. Mitigation may be necessary for those communities.

[c] Twenty-four (24) inches of clean soil cover is generally considered adequate for gardening; however, site specific conditions should also be considered. A 24-inch barrier normally is necessary to prevent contact of contaminated soil at depth with plant roots, root vegetables, and clean soil that is mixed via deep rototilling. Raised garden beds could cost effectively add 24 inches of clean soil (U.S. EPA, 2003).

INTRODUCTION

The benefits of home- and community-based gardening are widely documented (Green Institute, 2006; Walsh et al., 2001; van den Berg et al., 2010; Leake et al., 2011; Alaimo et al., 2008; Burton et al., 1999), yet consuming home-grown produce creates a potential route of exposure to contaminants in soil (Nolan et al., 2012; U.S. EPA, 2011c; Roussel et al., 2010; Lima et al., 2009; Scheckel et al., 2009; Chaney et al., 2008; Douay et al., 2008; Alloway, 2004; SamsØe-Petersen et al., 2002; Heinegg et al., 2000).

Screening levels are defined as a level of contamination above which there may be enough concern to warrant site-specific study of risks. Screening levels provide health protection without knowledge of the specific exposure conditions at a site (U.S. EPA, 1994c). The Soil Screening Level (SSL) for lead is intended to represent children playing in lead contaminated soil; the predominant source of lead exposure coming from incidental soil ingestion. The current OSWER residential SSL for lead (400 ppm) was selected as a reasonable value in the range of candidate preliminary remediation goals (PRG) values and selected as a policy decision to give a round number for ease of calculations. This value, however, does not account for consuming garden produce. Thus, the SSL for lead may underestimate the risk of exposure to lead for garden-related activities and consumption of produce grown in contaminated soil. The 1994 OSWER Directive states (in the section entitled Derivation of Lead Screening Levels):

> *"For the purpose of deriving a residential screening level, the background lead exposure inputs to the IEUBK model were determined using national averages, where suitable, or typical values. Thus, the estimated screening level of 400 ppm is associated with an expected "typical" response to these exposures, and should not be taken to indicate that a certain level of risk (e.g., exactly 5% of children exceeding 10 µg/dL blood) will be observed in specific community (e.g., in a blood lead survey)."*

Historically, the TRW has cautioned against gardening in areas or consuming produce grown in areas of known soil contamination, but the TRW was unable to recommend specific soil lead concentrations to be avoided for garden areas due to a wide range of recommendations (see Appendix B). The TRW identified garden-specific exposure parameters that need to be considered when characterizing risk associated with exposure to lead contaminated soils and dusts[3] from the following exposure pathways:

- Direct ingestion of lead in the matrix of produce;
- Ingestion of lead in soil adhered to produce surfaces;
- Incidental ingestion of soil while gardening; and
- Incidental ingestion of soil tracked into residence.

The objective of this analysis is threefold: 1) review the available literature and determine the state of the science (*i.e.*, identify data gaps), 2) conduct a feasibility study to develop quantitative approach for estimating risk associated with and acceptable soil lead concentrations for gardening (*i.e.*, Spreadsheet Model, see Appendix A), and 3) provide evidence-based Best Management Practices for limiting potential exposure to lead while gardening.

---

[3] Inhalation and dermal absorption of lead from gardening are believed to be minor routes of exposure, and was neither discussed in this document nor included in the analysis.

TECHNICAL ANALYSIS

A literature search was conducted to identify data for estimating the garden-specific exposure parameters. PubMed, TOXLINE, and Agricola were searched using various strategies that incorporated the search terms: *lead*, *uptake*, *bioaccessible*, *garden*, *crops*, and *plants*. The literature search identified limited quantitative data for the four garden-specific exposure parameters.

The Spreadsheet Model (see Appendix A) was developed to explore the feasibility of developing a quantitative risk model given the information available at this time. To simplify the calculations, daily lead intake rates were calculated for the following types/categories of produce: dark green leafy, lettuce, tomatoes, root vegetables, and other vegetables. Data sources, methods, and uncertainty for parameters that were estimated in the quantitative analysis of the four exposure pathways are provided in Appendix A.

RESULTS

In response to uncertainty and limitations of the available data, the TRW recommended as Best Management Practices for Gardening to reduce lead exposure in contaminated soil (see Table 1). The results from the feasibility study (*i.e.*, Spreadsheet Model) are provided in Appendix A.

In addition, four documents were identified that describe Best Practices for limiting potential exposure to lead while gardening and provide guidance on interpreting soil sample test results (Table 2). Note: these four well written guidance documents do not constitute an exhaustive representation of the literature on this subject matter. See table B-1 for a more extensive listing of guidance documents with accompanying interpretive soil lead values (which vary from document to document but, collectively, are generally concordant with the recommendations made in this report).

Table 2. Summary of Selected Guidance Documents that Address Gardening and Potential Lead Risk

Study	Lead Concentration (mg/kg)	Description	Study Overview
U.S. EPA, 2011a	400 mg/kg (residential) 1200 mg/kg (commercial)	Soil Screening Level	Provides best practices, bioavailability, and exposure pathways
U.S. EPA, 2011b	–	–	Provides best practices, interpreting soil sample results, and current data limitations
Heinegg et al., 2000*	70 mg/kg (Canada) 50 mg/kg (Quebec province)	Agricultural standards for Pb	Provides best practices, compares Canadian National agricultural soil standards to provincial standards (Quebec)
Shayler et al., 2009*	63 mg/kg (unrestricted use) 400 mg/kg (residential, restricted-residential use)	New York State Soil Cleanup Objectives	Discusses New York Department of Health and EPA standards

*While the TRW generally agrees with the best management practices in these documents, the TRW recommends different soil lead guideline values for garden areas and the recommendations may not be completely concordant.

RECOMMENDATIONS

While 400 ppm lead in soil is generally a protective screening level for residential soil-lead, it may not be adequate for intensive gardening activities and consumption of home grown produce. The TRW Lead Committee recommends that 100 ppm be used as the low end of the range of soil lead concentrations to initiate best management practices to mitigate exposure to lead in soil for gardening-related exposure pathways. Lacking sufficient data to support a quantitative approach for estimating risk for the gardening exposure pathways to support establishing acceptable concentration of lead in garden areas, a semi-quantitative weight-of-evidence and best professional judgment approach was used to establish the low end of the range. The recommended low-end soil lead concentration (100 ppm) is below the 400 ppm SSL for lead because the gardening exposure pathway includes other sources of exposure not sufficiently accounted for in the development of the SSL. The basis for the SSL is children playing in lead contaminated soil and other gardening exposures, with the predominant source of exposure from soil ingestion (though it includes contributions from other pathways such as tap water, air, and store-bought food). Thus, the existing SSL for lead does not explicitly account for exposure to lead from consuming home-grown produce or the potentially longer duration of soil contact and potential for ingestion of soil related to gardening activities. In developing an acceptable concentration of lead in soil for home garden exposures, the same child receptor would be exposed if accompanying the adult in the garden (and from secondary soil track-in) and also exposed through consumption of lead in and on the produce grown in the soil (which can be higher in lead content than store-bought food[4]). Hence, the garden-based soil recommendation is appropriately lower than the SSL, and reasonable steps to mitigate exposure to lead while gardening in soil lead concentrations between 100–400 ppm would be appropriate. The TRW also acknowledges that background soil lead concentrations in some communities may exceed the guidance values recommended for garden areas. Risk management decisions may be necessary for those communities.

Based on the literature review performed for this analysis, as well as utilizing best professional judgment, the TRW recommends the Best Management Practices for limiting potential exposure to lead while gardening (Table 1). These recommendations may be revisited when additional data are available.

During the literature search, the TRW identified a variety of additional techniques that could be used to reduce exposure to lead from garden-related exposure pathways (Table 3).

---

[4] See http://www.epa.gov/superfund/lead for the TRW Lead Committee's current recommendations regarding dietary exposure from store-bought food.

Table 3. Additional approaches to reducing exposure to lead while gardening

Techniques	Approaches
Behavioral	• Discard outer leaves of leafy vegetables • Wash produce to remove soil • Peel root crops • Discourage eating soil • Wash hands, toys, pacifiers • Wear gloves • Keep children from entering the garden if contaminant levels are unknown • Keep soil outside • Take off shoes, use doormats, and clean floors • Provide alternative safe areas, like a sandbox, for children's play • Locate gardens away from older painted structures, fences or sheds
Soil Remediation	• Request a soil sample test for metals and agronomic parameters before beginning gardening • Adjust soil pH to near neutral (~6.5-7.5), based on findings • Incorporate clean materials (*e.g.*, compost, manure) • Apply mulch to reduce dust and soil splash-back onto crops and reduce exposures • Add phosphate amendments where appropriate • Excavate contaminated soil, place geotextile barriers
Alternate Remediation	• Build raised beds with safe materials (*i.e.*, do not use treated lumber or salvaged painted wood) with a barrier (*e.g.*, landscape fabric) and fill with clean soil • Use containers to grow in clean soil (*e.g.*, 5-gallon buckets that do not leach metals) • Consider other land/location options

REFERENCES

Alaimo, K., E. Packnett, R. A. Miles, and D. J. Kruger. 2008. Fruit and vegetable intake among urban community gardeners. J Nutri Educ Behav 40: 94–101.

Alloway, B.J. 2004. Contamination of soils in domestic gardens and allotments: a brief overview. Land Contamin & Reclamation. 12 (3): 179-187.

Burton, L.C., Shapiro, S., German, P.S. 1999. Determinants of physical activity initiation and maintenance among community-dwelling older persons. Preventative medicine. 29 (5): 422-430.

Chaney RL, et al. 2008. Element Bioavailability and Bioaccessibility in Soils: What is known now, and what are significant data gaps? Proc. SERDP-ESTCP Bioavailability Workshop, Aug. 20-21, 2008, Annapolis, MD. pp. B36 to B-72 in Workshop Report. http://www.serdp.org/content/download/8236/101212/version/1/file/Bioavailability_Wkshp_Nov_2008.pdf

Chaney, R. L., E. E. Codling, K. Scheckel, and M. Zia. 2010. Pb in carrots grown on Pb-rich soils is mostly without the xylem [Abstract]. American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA). 2010 International Annual Meetings; Long Beach, CA. Available online at: http://a-c-s.confex.com/crops/2010am/webprogram/Paper60451.html.

Douay, F., Roussel, H., Pruvot, C., Waterlot, C. 2008. Impact of a Smelter Closedown on Metal Contents of Wheat Cultivated in the Neighbourhood. Env Sci Pollut Res. 15(2): 162–169.

Finster, M. E., K. A. Gray, and H. G. Binns. 2003. Lead levels of edibles grown in contaminated residential soils: A field survey. Sci Total Environ 320(2-3): 245–257. Available online at: http://pursuitofresearch.org/wp-content/uploads/2011/01/binnspaper2003.pdf.

Green Institute. 2006. Multiple benefits of community gardening. Minneapolis, MN. Available online at http://www.communitygarden.org

Jorhem, L., J. Engman, L. Lindeström, and T. Schröder. 2000. Uptake of lead by vegetables grown in contaminated soil. Commun Soil Sci Plant Anal 31(11-14): 2403–2411.

Heinegg, A., P. Maragos, E. Mason, J. Rabinowicz, G. Straccini, and H. Walsh. 2000. Soil Contamination and Urban Agriculture: A Practical Guide to Soil Contamination Issues for Individuals and Groups. Quebec, Canada: McGill University, McGill School of Environment. Available online at: http://www.ruaf.org/sites/default/files/guide%20on%20soil%20contamination.pdf.

Hemphill, D. D., C. J. Marienfeld, R. S. Reddy, W. D. Heidlage, and J. O. Pierce. 1973. Toxic heavy metals in vegetables and forage grasses in Missouri's lead belt. J Assoc Off Anal Chem 56(4): 994–997.

Leake, J. R., A. Adam-Bradford, and R. Janette. 2009. Health benefits of 'grow your own' food in urban areas: Implications for contaminated land risk assessment and risk management? Environ Health 8 Suppl 1: S6.

Lima, F.S., Nascimento, C.W.A., Silva, F.B.V., Carvalho, V.G.B., Filho., M.R.R. 2009. Lead concentration and allocation in vegetable crops grown in a soil contaminated by battery residues. Horticultura Brasileira 27: 362-365.

Moir, A. M. and I. Thornton. 1989. Lead and cadmium in urban allotment and garden soils and vegetables in the United Kingdom. Environ Geochem Health 11: 113–120.

Nabulo, G., S. D. Young, and C. R. Black. 2010. Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils. Sci Total Environ 408(22): 5338–5351.

Nolan, G.A., McFarland, A.L., Zajicek, J.M., Waliczek, T.M. 2012. The Effects of Nutrition Education and Gardening on Attitudes, Preferences, and Knowledge of Minority Second to Fifth Graders in the Rio Grande Valley Toward Fruit and Vegetables. HortTechnology. 22(3): 299-304.

Pichtel, J. and D. J. Bradway. 2008. Conventional crops and organic amendments for Pb, Cd and Zn treatment at a severely contaminated site. Bioresour Technol 99(5): 1242–1251.

Roussel, H., Waterlot, C., Pelfrêne, A., Pruvot, C., Mazzuca, M., Douay, F. 2010. Cd, Pb and Zn Oral Bioaccessibility of Urban Soils Contaminated in the Past by Atmospheric Emissions from Two Lead and Zinc Smelters. Arch Environ Contam Toxicol. 58:945–954.

SamsØe-Petersen, L., Larsen, E.H., Larsen, P.B., Bruun, P. 2002. Uptake of Trace Elements and PAHs by Fruits and Vegetables from Contaminated Soils. Environ. Sci. Technol. 36: 3057-3063.

Säumel, I., I. Kotsyuk, M. Hölscher, C. Lenkereit, F. Weber, and I. Kowarik. 2012. How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighborhoods in Berlin, Germany. Environ Pollut 165: 124–132.

Scheckel, K.G., Chaney, R.L., Basta, N.T., Ryan, J.A. 2009. Advances in assessing bioavailability of metal(loid)s in contaminated soils. Adv Agron. 107: 10-52.

Shayler H., M. McBride, and E. Harrison. 2009. Guide to Soil Testing and Interpreting Results. Cornell Waste Management Institute, Cornell University. April 15, 2009. Available online at: http://cwmi.css.cornell.edu/guidetosoil.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1994a. Validation Strategy for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response: Washington, DC. EPA 540/R-94-039. Available online at: http://epa.gov/superfund/lead/products/valstrat.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1994b. Technical Support Document: Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic Model for Lead in Children. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response: Washington, DC. Available online at: http://www.epa.gov/superfund/lead/products/tsd.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1994c. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities, EPA/540/F-94/043, Office of Solid Waste and Emergency Response, Washington, D.C. Directive 9355.4-12.

U.S. Environmental Protection Agency (U.S. EPA). 1995. Sampling House Dust for Lead: Basic Concepts and Literature Review. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances: Washington, DC. EPA 747-R-95-007. Available online at: http://www.epa.gov/lead/pubs/r95-007.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1998. Short Sheet: IEUBK Model Mass Fraction of Soil in Indoor Dust (M_{SD}) Variable. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response: Washington, DC. EPA 540-F-00-008. Available online at: http://epa.gov/superfund/lead/products/ssmsdcol.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011a. Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices. U.S. Environmental Protection Agency, Region 5: Chicago, IL. EPA 560/S-11/001. Available online at: http://www.epa.gov/swerosps/bf/urbanag/pdf/bf_urban_ag.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011b. Reusing Potentially Contaminated Landscapes: Growing Gardens in Urban Soils. U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation: Washington, DC. EPA 542-F-10-011. Available online at: http://www.clu-in.org/download/misc/urban_gardening_fact_sheet.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011c. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, National Center for Environmental Assessment Office of Research and Development: Washington, DC. EPA/600/R-09/052F. Available online at: http://www.epa.gov/ncea/efh/report.html.

Walsh, J.M.E., Pressman, A.R., Cauley, J.A., Browner, W.S. 2001. Predictors of physical activity in community-dwelling elderly white women. J. Gen Intern Med. 16 (11): 721-727.

APPENDIX A. THE SPREADSHEET MODEL

OVERVIEW

The objective of the Spreadsheet Model is threefold: 1) Review the available literature and determine the state of the science (*i.e.*, identify data gaps), 2) examine the feasibility of applying a quantitative approach for estimating risk and acceptable soil concentrations for gardening, and 3) provide evidence-based Best Management Practices for limiting potential exposure to lead while gardening.

TECHNICAL ANALYSIS

A literature search was conducted to identify data for estimating the uptake of lead from soil by plants. PubMed, TOXLINE, and Agricola were searched using various strategies that incorporated the search terms: *lead*, *uptake*, *bioaccessible*, *garden*, *crops*, and *plants*. Citations in the Spreadsheet Model were also taken from existing EPA risk assessment models. An EndNote database includes the complete list of relevant citations.

Daily lead intakes were calculated for adults and children (0–7 years of age). Childhood exposures were calculated for the age-specific groups that are used in the IEUBK model. Estimates of average moisture content for different types of produce were required because most of the data on lead concentration in vegetables is provided on a dry-weight basis, while the consumption data from What We Eat in America (WWEIA) is reported on a wet-weight basis. Moisture contents were taken from Table 9-37 of the Exposure Factors Handbook (U.S. EPA, 2011).

The Spreadsheet Model does not make assumptions, nor is intended to, regarding the use of soil amendments or management strategies to neutralize and control pH, or improve soil structure or soil covers (such as mulch) that prevent soil deposition on crops.

The literature search identified limited data for the four exposure pathways that are needed to estimate risk related to gardening in and consuming produce from contaminated soils:

- Direct ingestion of lead in the matrix of produce (including consumption rates for various types or categories of produce);
- Ingestion of lead in soil adhered to produce surface (*e.g.*, leafy vegetables);
- Incidental ingestion of soil while gardening; and
- Incidental ingestion of soil tracked into residence.

DIRECT INGESTION OF LEAD IN THE MATRIX OF PRODUCE (PBI_{UP})

Ingestion of lead via uptake from soil by produce was estimated as the concentration of lead in produce multiplied by the average daily consumption rate for the type of produce. For the purposes of the preliminary risk assessment, daily lead intake rates were calculated for the following types/categories of produce: dark green leafy, lettuce, tomatoes, root vegetables, and other vegetables using Equation 1:

$$PbI_{Up} = Ing_{veg} \times UF \times PbS \qquad \text{Equation 1}$$

PbI_{Up} = daily intake of lead (µg Pb/day) from ingestion of vegetables that absorbed lead from the soil
Ing_{veg} = daily ingestion rate (g/day) of vegetables
UF = uptake factor (unitless; *e.g.*, ppm Pb in vegetable/ppm Pb in soil)
PbS = concentration of lead in garden soil (µg Pb/g soil) (site-specific)

The daily ingestion rates for garden vegetables were estimated using all respondents in the 2003–2008 National Health and Nutrition Examination Survey (NHANES) 24-hour recall dietary recalls [What We Eat in America (WWEIA) Survey] where recalls were determined to be reliable and complete (U.S. CDC, 2010a, 2010b, 2011). Estimates were calculated with the SurveyMeans procedure in SAS (SAS Institute) using the sampling weights, domains, and strata provided in the WWEIA data files. Daily ingestion rates were also calculated using the National Cancer Institute's (NCI) non-linear mixed model (Tooze et al., 2006; Parsons et al., 2009). The NCI estimates for individual vegetable groups (*e.g.*, dark-green leafy vegetables) differed from the SurveyMeans estimates by less than 10%; on average, estimates by the two methods differed by approximately 2%.

Estimates of lead uptake in vegetables were calculated with data from sources identified through the literature search described above. The uptake factors used in the preliminary lead intake estimates were estimated using the data from the Sudbury Urban Soil Study (MOE, 2004) for all produce except lettuce. The uptake data for lettuce from Sudbury was at the higher end of the range of uptakes that were identified from the literature search.

INGESTION OF LEAD IN SOIL ADHERED TO PRODUCE SURFACE (PBI_{ON})

Ingestion of lead present in soil adhered to the surface of produce was estimated as the concentration of lead in produce multiplied by the average daily consumption rate for the type of produce. To simplify the calculations, daily lead intake rates were calculated for the following types/categories of produce: dark green leafy, lettuce, tomatoes, root vegetables, and other vegetables using Equation 2:

$$PbI_{On} = Ing_{veg} \times AdF \times PbS \qquad \text{Equation 2}$$

PbI_{On} = daily intake of lead (µg pb/day) from incidental ingestion of soil adhered to surface of vegetables
Ing_{veg} = daily ingestion rate (g/day) of vegetables (see above)
AdF = soil adherence factor (unitless; *e.g.*, mass of soil / mass of vegetable)
PbS = concentration of lead in garden soil (µg pb/g soil) (site-specific)

Data for estimating the adherence factor was provided by Hettiarachchi et al. (2011). As described by Hettiarachchi et al. (2011), the adherence factor was estimated using the concentration measured in produce after "ordinary kitchen cleaning methods" were used to wash the produce as compared to the concentration measured after the produce were washed with a more rigorous "laboratory cleaning method". Differences in measured lead concentrations observed between methods were attributed to soil lead adherence. The difference in these measured concentrations was divided by the concentration of lead in the soil to estimate of the mass of soil that remained on the produce after the kitchen cleaning using Equation 3:

$$AdF = (C_{Kit} - C_{Lab})/PbS \qquad \text{Equation 3}$$

AdF = soil adherence factor (unitless; *e.g.*, mass of soil / mass of vegetable)
C_{Kit} = concentration of lead in/on produce after kitchen cleaning methods
C_{Lab} = concentration of lead in/on produce after laboratory cleaning methods
PbS = concentration of lead in garden soil (μg Pb/g soil) (site-specific)

INCIDENTAL INGESTION OF SOIL WHILE GARDENING (PBI_{ING})

The range of lead intake values for children from the incidental ingestion of soil while gardening (0.05–0.2 g/day) was taken from Table 5-1 of the Exposure Factors Handbook (U.S. EPA, 2011c). The values represent the central tendency (low) and upper percentile (high) values for the general population; the values do not vary between the age groups. For adults, the range of values (0.05–0.1 g/day) was based on personal communication with EPA personnel (Moya, 2011); the range (exposure for typical vs. soil-intensive activities) was also suggested by the TRW Lead Committee (U.S. EPA, 2003).

INCIDENTAL INGESTION OF SOIL TRACKED INTO RESIDENCE (PBI_{TR})

Daily lead intake from the incidental ingestion of dust containing soil that has been tracked in from the garden is estimated using the soil/dust ingestion rates and soil dust ingestion ratio from the IEUBK model (U.S. EPA, 1994b, 1999), a track-in factor that represents the fraction residential dust lead concentration that is attributable to the lead in the garden soil. The track-in factor is analogous to the mass fraction of soil in indoor dust (M_{SD}) of the IEUBK model (U.S. EPA, 1994b); however, the track-in factor only represents the contribution of lead via track-in of soil from garden on shoes and clothes while the M_{SD} represents the contribution of nearby soil via all transport pathways (*e.g.*, including airborne transport of nearby soil (Equation 4).

$$PbI_{Tr} = IR_S \times PbS \times TF \times (1 - SD_{IR}) \qquad \text{Equation 4}$$

PbI_{Tr} = Daily intake of lead (μg Pb/day) from incidental ingestion of dust containing soil that is tracked-in from the garden
IR_S = Soil ingestion rates for children are from the IEUBK model (USEPA, 1994b, 1999); the rate for adults is from the Adult Lead Methodology (USEPA, 2003)
PbS = Concentration of lead in garden soil (μg Pb/g soil) (site-specific)
TF = Track-in factor (unitless); converts concentration of lead in soil to concentration of lead in residential dust
SD_{IR} = Soil/dust ingestion ratio (USEPA, 1994b)

RESULTS AND UNCERTAINTIES

The literature provided data that were used to estimate one or more of the parameters included in the Spreadsheet Model, or provided information that was used to inform the estimates or the uncertainty in the estimates. In general, the literature search identified data to produce a reliable estimate, with sufficient precision, for uptake of lead in tomatoes and root vegetables (*e.g.,* carrots and radish). The data for uptake in lettuce and dark-green leafy vegetables exhibited much more variability. It is very likely the lead concentrations for lettuce and dark-green leafy vegetables represented soil adhered to the surface of the vegetables rather than uptake (Sterrett et al., 1996; Finster et al., 2003; SARA Group, 2008; Nabulo et al., 2010).

Limited data or analyses were found that would provide a basis for estimating the amount of soil that adheres to the surface of vegetables. Estimates for adherence for dark-green leafy, lettuce, carrots, and tomatoes are based on unpublished data (Hettiarachchi et al., 2011). Estimates of daily lead intake are provided in Table A-1.

Table A-1. Current Range in Spreadsheet Estimates of Total Daily Lead Intake (All Exposure Routes) (µg/day)

Age Group (years)	IEUBK with Soil = 400 ppm[a]	Gardening	
		Low	High
0.5–1[b]	29	23	1153
1–2[b]	46	35	1532
2–3	46	37	1578
3–4	46	41	1763
4–5	34	45	1820
5–6	31	47	1852
6–7	29	44	1791
>7	–	88	–

[a]Provided for comparison purposes. Calculated with IEUBK model for soil and dust ingestion pathway only; diet (market basket), water and air not included and assumed to be minor compared to soil and dust ingestion.

[b] These young children would be exposed while accompanying the adult in the garden and also exposed through consumption of lead in and on the produce grown in the soil.

DIRECT INGESTION OF LEAD IN THE MATRIX OF PRODUCE (PbI_{UP})

On average this pathway currently represents approximately 20–25% of the central tendency (low) total daily lead intake estimated by the spreadsheet model. Along with other data provided by various published and unpublished study results (Davies, 1978; Chaney et al., 1984; PHD, 1986; Nwosu et al., 1995; Sterrett et al., 1996). The Sudbury Urban Soil Study (MOE, 2004) identified data to produce estimates with reasonable certainty (*i.e.,* sufficiently high precision) for uptake of lead by tomatoes and root vegetables (*e.g.*, carrots, potatoes and radish). Although there is much variability, there is a general trend suggesting that uptake in the matrix of produce is greater in root vegetables that in the foods where the plant shoots or fruits are consumed.

In general, the uptake data exhibited high variability. The lettuce uptake data was the most variable for this data set. A substantial amount of the observed variability may be explained by the nonlinear relationship between uptake and soil concentration. The data show uptake tends to decrease with increasing soil concentration. Much of the Sudbury data for uptake is from vegetables grown in soil with relatively lower lead concentrations; therefore, the spreadsheet very likely overestimates uptake for soil concentrations that are encountered in urban areas.

Another significant source of uncertainty in estimating uptake for leafy vegetables may be due to the difficulty in removing all soil from the surface of the vegetables before analysis. Hettiarachchi et al. (2011) measured approximately 0.4% soil by mass, adhered to the surface of Swiss chard, lettuce, and carrots after standard kitchen washing; approximately four times more than they found adhered to tomatoes. These amounts may seem small; however, as discussed below, the ingestion of lead contained in soil adhered to the surface of vegetables may account for more than half of the total lead ingestion associated with the gardening scenario.

INGESTION OF LEAD IN SOIL ADHERED TO PRODUCE SURFACE (PBI_{ON})

On average this pathway currently represents approximately 60–65% of the total daily lead intake estimated by the spreadsheet model for the central tendency estimates. The literature search did not find published data or analyses that provided a basis for estimating the amount of soil that adheres to the surface of vegetables. Estimates for adherence for dark-green leafy vegetables (*e.g.*, chard), lettuce, carrots, and tomatoes are based on unpublished data (Hettiarachchi et al., 2011). Hettiarachchi et al. (2011) measured approximately 0.4% soil by mass, adhered to the surface of Swiss chard, lettuce, and carrots after standard kitchen washing; approximately 4 times more than they found adhered to tomatoes.

INCIDENTAL INGESTION OF SOIL WHILE GARDENING (PBI_{ING})

On average this pathway currently represents approximately 10–15% of the central tendency estimates of total daily lead intake estimated by the spreadsheet model for adults and all but the youngest age group for children estimates. The model estimates this pathway accounts for approximately 20% for children between 6 months and 1-years old.

INCIDENTAL INGESTION OF SOIL TRACKED INTO RESIDENCE (PBI_{TR})

On average this pathway currently represents just 1–2% of the total daily lead intake estimated by the spreadsheet model. Given the low contribution and the difficulty with estimating the track-in factor, additional research is required to better estimate this pathway.

The TRW identified several areas of uncertainty in the data used for the Spreadsheet Model. According to the current model for estimating daily lead intake for the gardening scenario, the amount of lead taken up by vegetables and the amount of soil adhered to the surface of vegetables account for as much as 85% of total daily lead intake. These pathways should be the focus of best practice recommendations, intervention efforts, and additional research.

The current spreadsheet model considers uptake as a constant fraction of soil lead concentration. Some data support a non-linear relationship between the concentration of lead in vegetables and the concentration in soil. Along with additional uptake data, future work should include developing non-linear models for uptake that allow the uptake rate to vary with soil concentration.

The dietary estimates are conservative, preliminary estimates that are biased high because they do not use recipe files that would provide more accurate consumption estimates. The estimates should be revised to incorporate recipe files that are available for the 2003–2006 WWEIA (U.S. CDC, 2010a,b). Additional research could be used to identify approaches for estimating produce consumption that better reflect the population that consumes garden vegetables (*e.g.*, WWEIA provides at least one variable that we have used to identify respondents who consume local produce).

These areas of uncertainty could be considered as areas where additional research is needed. Research on the uptake of lead in plants should focus on collecting more data on the uptake of lead by produce that is grown in soils containing lead (and possibly other metals) at the range of soil lead concentrations that are typically encountered in urban areas. Also additional information on soil management and gardening best practices as well as food handling that can reduce exposures is needed. Additional data are also needed to estimate the amount of soil that remains adhered to the surface of vegetables before and after they are washed using typical residential food preparation methods and based on whether the specific vegetable is commonly eaten raw or cooked and the nature of cooking. Data are also needed to measure the reduction of soil contaminants achieved by peeling vegetables (for vegetables that are commonly peeled).

Data that could be used to model the effect of soil pH and soil amendments on uptake would also be useful. If sufficient, such information could help develop improved models of uptake, as well as, allow for prediction of efficacy of these as strategies for mitigating exposure. Uncertainty associated with the Spreadsheet Model is outlined in Appendix A.

REFERENCES

Chaney, R. L., S. B. Sterrett, and H. W. Mielke. 1984. The potential for heavy metal exposure from urban gardens and soils. In: J.R. Preer (ed.) Proc. Symp. Heavy Metals in Urban Gardens. Univ. Dist. Columbia Extension Service, Washington, DC. pp 37-84. Available online at: http://www.indytilth.org/Links/Chaney_Exposure.pdf.

Davies, B. E. 1978. Plant-available lead and other metals in British garden soils. Sci Total Environ 9: 243–262.

Finster, M. E., K. A. Gray, and H. G. Binns. 2003. Lead levels of edibles grown in contaminated residential soils: A field survey. Sci Total Environ 320(2-3): 245–257. Available online at: http://pursuitofresearch.org/wp-content/uploads/2011/01/binnspaper2003.pdf

Hettiarachchi, G. 2011. K-State Project: Gardening Initiatives at Brownfields Sites. Kansas State University: Manhattan, KS.

Ministry of Environment (MOE). 2004. City of Greater Sudbury 2001 Urban Soil Survey: Main Study. Ontario Ministry of Environment. Available online at: http://www.sudburysoilsstudy.com/EN/media/support/reports/2001SoilsData/VOL_I/MOE_Report.pdf.

Moya, J. 2011. Personal Communication. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington Division.

Nabulo, G., S. D. Young, and C. R. Black. 2010. Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils. Sci Total Environ 408(22): 5338–5351.

Nwosu, J. U., A. K. Harding, and G. Linder. 1995. Cadmium and lead uptake by edible crops grown in a silt loam soil. Bull Environ Contam Toxicol 54(4): 570–578.

Parsons, R., Munuo, S.S., Buckman, D.W., Tooze, J.A. and Dodd, K.W. 2009. User's Guide for Analysis of Usual Intakes. May.

Panhandle Health District (PHD). 1986. Kellogg Revisited-1983. Childhood Blood Lead and Environmental Status Report. Panhandle District Health Department, Idaho.

SARA Group. 2008. Sudbury Area Risk Assessment, Volume II. Appendix E: Vegetable Garden Survey Data Report. Ontario Ministry of the Environment. Available online at: http://www.sudburysoilsstudy.com/EN/media/volume_II.asp.

Sterrett, S. B., R. L. Chaney, C. H. Gifford, and H. W. Mielke. 1996. Influence of fertilizer and sewage sludge compost of yield and heavy metal accumulation by lettuce grown in urban soils. Environ Geochem Health 18: 135–142.

Tooze, J.A., Midthune, D., Dodd, K.W, Freedman, L.S., Krebs-Smith, S.M., Subar, A.F., Guenther, P.M., Carroll, R. J. and Kipnis, V. 2006. A New Statistical Method for Estimating the Usual Intake of Episodically Consumed Foods with Application to their Distribution. J. Amer. Diet. Assoc. 106(10): 1575-87.

U.S. Centers for Disease Control and Prevention (U.S. CDC). 2010a. National Health and Nutrition Examination Survey. 2003-2004 Examination, Dietary, and Demographics Files. Retrieved October 4, 2010 from http://www.cdc.gov/nchs/nhanes/nhanes2003-2004.

U.S. Centers for Disease Control and Prevention (U.S. CDC). 2010b. National Health and Nutrition Examination Survey. 2005-2006 Examination, Dietary and Files. Retrieved October 4, 2010 from http://www.cdc.gov/nchs/nhanes/nhanes2005-2006.

U.S. Centers for Disease Control and Prevention (U.S. CDC). 2011. National Health and Nutrition Examination Survey. 2007-2008 Laboratory File. Retrieved 12/8/11 from http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/lab07_08.htm

U.S. Environmental Protection Agency (U.S. EPA). 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities, EPA/540/F-94/043, Office of Solid Waste and Emergency Response, Washington, D.C. Directive 9355.4-12.

U.S. Environmental Protection Agency (U.S. EPA). 1994b. Technical Support Document: Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic Model for Lead in Children. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response: Washington, DC. Available online at: http://www.epa.gov/superfund/lead/products/tsd.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 1999. Short Sheet: IEUBK Model Soil/Dust Ingestion Rates. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response: Washington, DC. EPA 540-F-00-007. Available online at: http://epa.gov/superfund/lead/products/ssircolo.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2003. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. U.S. Environmental Protection Agency: Washington, DC. EPA-540-R-03-001. Available online at: http://www.epa.gov/superfund/lead/products/adultpb.pdf.

U.S. Environmental Protection Agency (U.S. EPA). 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, National Center for Environmental Assessment Office of Research and Development: Washington, DC. EPA/600/R-09/052F. Available online at: http://www.epa.gov/ncea/efh/report.html.

APPENDIX B. SOIL-LEAD CONCENTRATIONS AND RECOMMENDATIONS FOR CONTAMINATED GARDEN SOILS

Table B-1. Recommendations for Soil-Lead Concentrations for Contaminated Garden Soils

Soil Lead Concentration (ppm)	Recommendation	Source
0–499	Low risk	Traunfeld and Clement, 2001, Lead in Garden Soils: http://www.hgic.umd.edu/_media/documents/hg18.pdf
500–999	Medium risk	
1000–3000	High risk	
>3000	Very high	
5000	Replace soils with clean soils	University of Rhode Island, 2004, Lead in Garden Soils: http://www.uri.edu/ce/factsheets/sheets/lead.html
<150	Lead-free standard	Brown University, 2000, Soil & Lead: http://www.brown.edu/Research/EnvStudies_Theses/summit/Briefing_Papers/Soil_and_Lead/index.htm
150–1000	Lead-safe standard	
1000–10,000	Significant environmental lead hazard standard	
>10,000	Excavation is required	
600	"Safe" minimized health effects	Madhavan et al., 1989: recommended maximum permissible levels
>100 <300	Should not be used for gardening due to bare soil exposure to children through hand-to-mouth activity If soil exposure to children is not a concern	Rosen, 2010, Lead in the Home Garden and Urban Soil Environment: http://www.extension.umn.edu/distribution/horticulture/DG2543.html. In MN, bare soil standard is 100 ppm, and does not have to be removed
300	Health-based investigation levels for residential exposure	Australian Government, 2001, Health-based Soil Investigation Levels: http://www.health.gov.au/internet/main/publishing.nsf/content/66E7D805C1C1AD69CA2573CC0013EA68/$File/env_soil.pdf
400 1200	Residential soil screening levels Commercial soil screening levels	U.S. EPA, 1996, Soil Screening Guidance: http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg496.pdf
<300	Safe for growing vegetables	National Gardening Association, 2009, Lead Contamination in Urban Gardens: http://www.garden.org/urbangardening/index.php?page=sept-lead
100–400	Moderately contaminated sites – used for gardening with precautions	Pettinelli, 2013, Lead in Garden Soils: http://soiltest.uconn.edu/factsheets/LeadGardenSoils.pdf
>400	Should not be used for growing vegetables or herbs	

<100	Safe range	NIH, 2012, Lead Safe Gardening: http://www.niehs.nih.gov/health/assets/docs_f_o/pamphlet_lead_safe_gardening_english.pdf
100–400	Level of concern, use Best Practices	
400–2000	No gardening before contacting professional gardening group	
>2000	Gardening not recommended	
<50	Little to no lead – no precautions needed	Angima and Sullivan, 2008, Evaluating and Reducing Lead Hazard in Gardens and Landscapes: http://www.deq.state.or.us/lq/cu/nwr/MultnomahMetals/OSUEvaluatingReducingLeadHazardInGardensLandscapes.pdf
50–400	Some lead present, grow any vegetable crops, choose best practices to reduce dust and soil consumption	
400–1200	Do not grow leafy vegetables or root crops – choose best practices	
>1200	Not recommended for vegetable gardening – use clean soil, raised beds, or containers	
63–200	Unrestricted use	Shayler et al., 2009, Guide to Soil Testing and Interpreting Results: http://cwmi.css.cornell.edu/guidetosoil.pdf
≥400	Restricted use	
70 (Canada) 50 (Quebec)	Agricultural Standards: acceptable levels	CCME, 1999, Canadian Environmental Quality Guidelines: http://ceqg-rcqe.ccme.ca/
<50	Normal background: no precautions	Hoskins, 2008, General Guidelines for Soil Lead Contamination: http://anlab.umesci.maine.edu/soillab_files/under/lead%20guidelines.pdf
50–300	Slight: wash all vegetables, peel root crops	
300–500	Moderate: fruiting vegetables acceptable, avoid leafy and root vegetables, wash all produce, maintain a soil pH (6.5–7.0), organic matter 8–10%	
>500	Heavy: relocate garden area or put a barrier and bring in clean soil for a new raised bed garden	
<65	Very low: No precautions	Buob et al., 2012, Lead Screening for NH Soils: Minimizing Health Risks University of New Hampshire: http://extension.unh.edu/resources/files/Resource002038_Rep3025.pdf
65–180	Low: wash hands, maintain soil pH (6.5–7.0), high level of organic matter, wash vegetables, peel root crops (remove all soil)	
180–450	Medium: do not grow leafy or root vegetables, wash fruiting crops, grow leafy or root vegetables in containers with tested clean soil	
450–900	High: limit child's direct contact, maintain soil pH, edible plants are not recommended, limit plants to flowers or ornamentals	
≥900	Very high: consider child blood lead testing	