# Assessing Urban Impacted Soil for Urban Gardening:

## Decision Support Tool
## Technical Report and Rationale

May, 2011

# Acknowledgments

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# Executive Summary

## Introduction

Urban gardening is gaining momentum in North America. Urban gardening can provide broad health, environmental, social and economic benefits. The City of Toronto recognizes that urban gardening plays an important role in making Toronto a healthier city. In 2007, City Council directed City staff to promote local food production and remove barriers to urban gardening (City Council Climate Change Action Plan, 2007), and in 2009, City Council adopted a recommendation to support strategies and initiatives that will achieve the overall goal of expanding opportunities for local food production and other urban agricultural activities in the City of Toronto (TEO, 2009).

Often the land available for increasing the urban land base for community gardening are lands that are vacant, abandoned, or previously used for purposes other than food production. As urban gardening expands in Toronto there will be a growing interest to garden on these lands. Previous and current activities on or next to these sites might have resulted in contamination of the soil.

Toronto Public Health (TPH) in collaboration with Parks, Forestry and Recreation (PF&R) and in consultation with the Toronto Environment Office (TEO) developed an urban gardening soil assessment guide to assist City staff in the assessment of potential sites for community and allotment gardens. The guide is a decision-support tool used to identify areas that may be contaminated but could be suitable for food production and to identify appropriate exposure reduction actions based on the condition of the site.

This report begins with a summary of the policy context and drivers supporting urban gardening in the City of Toronto. It outlines some of the potential challenges posed by gardening on urban impacted soils and the need for a decision support tool to guide the assessment, interpretation, selection and risk management for urban gardens. The report summarizes the purpose, scope, objectives and expected outcomes of the initiative. The report provides a step-by-step summary of the guide and a description of a pilot study that was conducted in 2009 to assess the feasibility of the soil sampling guidance. The report then discusses the expected outcomes of the application of the guide and the proposed next steps. Appendix A provides details on the process to develop the guide. Appendix B summarizes the review of the existing decision support tools and soil standards, guidelines and screening values to assess soil safety. Appendix C provides a summary of the evidence informing each step of the guide and Appendix D describes the derivation of Soil Screening Values for urban gardening. Appendix E summarizes a semi-quantitative case-example of the potential health benefits of implementation of this guide.

## Benefits of Urban Gardening

Urban gardening can increase food security and availability of low cost, nutritious, culturally appropriate food; increase physical activity; improve opportunities for small-scale food entrepreneurship; improve mental health and community cohesion; and reduce carbon footprints (Boettche et. al, 1995; de Zeeuw et al 2000; Mougoet 2000; Hancock, 2001; Baris, 2002; Schmelzkopf, 2002; De Sousa, 2003; Doyle and Krasny, 2003; Holland, 2004; PHAC, 2007; Wakefield et. al, 2007; Rideout, 2009; ven den Berg, 2010; UN FAO, undated). Nearly 10% of Canadians are food insecure, and urban areas have a higher prevalence of food insecure households than rural areas (Health Canada, 2007). 2/3rds of Toronto families in low income neighbourhoods are food insecure (Kirkpatrick and Tarasuk, 2009). Effort to increase urban food production has been identified as an important strategy to improve urban food security (Hancock, 2001; Schmelzkopf, 2002; Doyle and Krasny, 2003; Holland, 2004; PHAC, 2007). Studies have also demonstrated that access to community gardens can empower newcomers by supporting healthy and traditional food choices (Hyman et al., 2002).

## Public Health Importance of Developing a Decision Support Tool to Support Urban Gardening

The City of Toronto Parks, Forestry and Recreation (PF&R) Division currently manages 51 community gardens (about 3,000 sq. ft. per garden on average), 12 allotment gardens (comprising 1,674 plots), and a seven-acre urban farm. There is an increasing demand in the community for spaces to grow food: there are over 80 outstanding requests for new community gardens and 503 individuals on the waiting list for allotment plots (Boye, pers. comm. 2011).

While there are many expected health benefits from urban gardening, there are also some concerns about exposure to urban soil contaminants and the potential health risks that may arise from these exposures. Numerous studies show that urban soils have higher concentrations of many contaminants than rural soils (MOE, 1993; Pilgrim and Schroeder, 1997; Aelion et al., 2009). In addition, international public health agencies note safety concerns with urban gardening on soils with elevated concentrations of soil contaminants (IDRC, 1999; WHO, 1999; US Department of Agriculture, 2004; IDRC, 2006; ATSDR, 2007). Other studies have predicted unacceptable health risks from gardening on urban impacted soils (Kaufman and Bailkey 2000; Hynes et al. 2001; Hough et al. 2004; Devine, 2007; Clark et al. 2008; Aelion et al., 2009; Papritz and Reichard, 2009).

As urban gardening expands in Toronto there will be a need for the public to garden on vacant lands or other areas previously not used for gardening. Previous and current activities on or next to these sites might have resulted in contamination of the soil. There is very little information available on contaminant levels in Toronto’s soils. The available data suggest a wide range of potential soil contaminant levels. At the higher range of soil concentrations, Toronto Public Health has concerns about the public risks of gardening in these soils in the absence of measures to minimize their exposure to contaminants in the soil.

Concern about contamination, the associated cost for the evaluation of site conditions and the implementation of typical risk management measures have been identified as a major barrier to meeting the demand of Toronto residents for more community gardens in Toronto (Boye, pers.comm. 2009). Many people assume that it is too costly and complicated for urban gardeners to assess and manage potentially contaminated urban soils (Kaufman and Bailkey, 2000; Cole et al., 2008). Toronto residents note their frustration with the lack of clear information and resources to develop community gardens (TPH, 2010) and urban gardeners have indicated the need for tools and information that will allow them to inexpensively assess the safety of urban soils (Nasr et al., 2010).

The United States Environmental Protection Agency (USEPA, 2010) recently noted the urgent need for frameworks to assess the soils for urban gardens. They note that frameworks need to include risk-based soil quality standards, identification of the soil contaminants of most concern, sampling and analysis instructions and guidance on interpreting results. Moreover, gardeners and policy-makers need these frameworks to be flexible, reassuring and easy to communicate (USEPA, 2010).

## Purpose, Scope, Aims, and Goals of the Urban Gardening Soil Assessment Guide

The **purpose** of the urban gardening soil assessment guide is to provide a decision-support tool to guide City staff when choosing a site for a new community and allotment gardens. The guide directs staff to conduct an initial site assessment, soil testing and assessment (if required) and the selection of appropriate exposure reduction measures.

Many chemicals are common soil contaminants in the urban environment, and others are naturally occurring. It is important to note that the presence of a soil contaminant in the soil of an urban garden does not necessarily mean there is an *elevated* health risk from using the site for urban gardening (USEPA, 2007). When developing the guide, we addressed the following situations:

a) Urban soil contaminants present at levels above background [1], indicating a pollution source and a potential for *elevated* exposure due to urban gardening; and,
b) Soil contaminants levels where there are unacceptable health risks.

The guide addresses concerns related to gardening in urban soils that are potentially contaminated. Soil fertility is outside of the current **scope** of the guide.

The guide **aims** to:

1. Encourage urban food production while minimizing unnecessary soil assessment and exposure reduction measures;

[1] For the purposes of this report, background levels of soil contaminants are defined as the levels one would expect to find in urban parkland soil in the absence of a point source of pollution.

2. Address the questions, concerns and needs of communities relating to soil contaminants and urban gardening; and,
3. Remove barriers to urban gardening by providing a flexible tool that is relatively inexpensive to use.

The **goal** of this initiative is to remove barriers to urban gardening and enable a greater number of people to grow produce because they have the required tools and information. The implementation of the guide is expected to:

1. Empower gardeners and City staff with tools and information about soil contaminants.
    a. Reduce gardeners' exposures to urban soil contaminants by providing exposure reduction guidance.
    b. Address the public's concerns about soil contamination and thus, encourage more gardeners to produce food.
2. Increase the number of Toronto residents able to grow food on City land by streamlining PF&R decision making.
3. Optimize the conversion of vacant urban land into productive use by guiding the selection of appropriate gardening activities and to identify areas in Toronto where the soil is appropriate for urban gardening using no- or low-cost exposure reduction measures.

## The Review of Health Evidence to Develop a Decision Support Tool for Urban Gardening

TPH followed best practices for using evidence in informed decision-making in public health developed by the National Collaborating Centre for Tools and Methods[2]. Figure E-1 provides a summary of the process used to develop the urban gardening soil assessment guide.

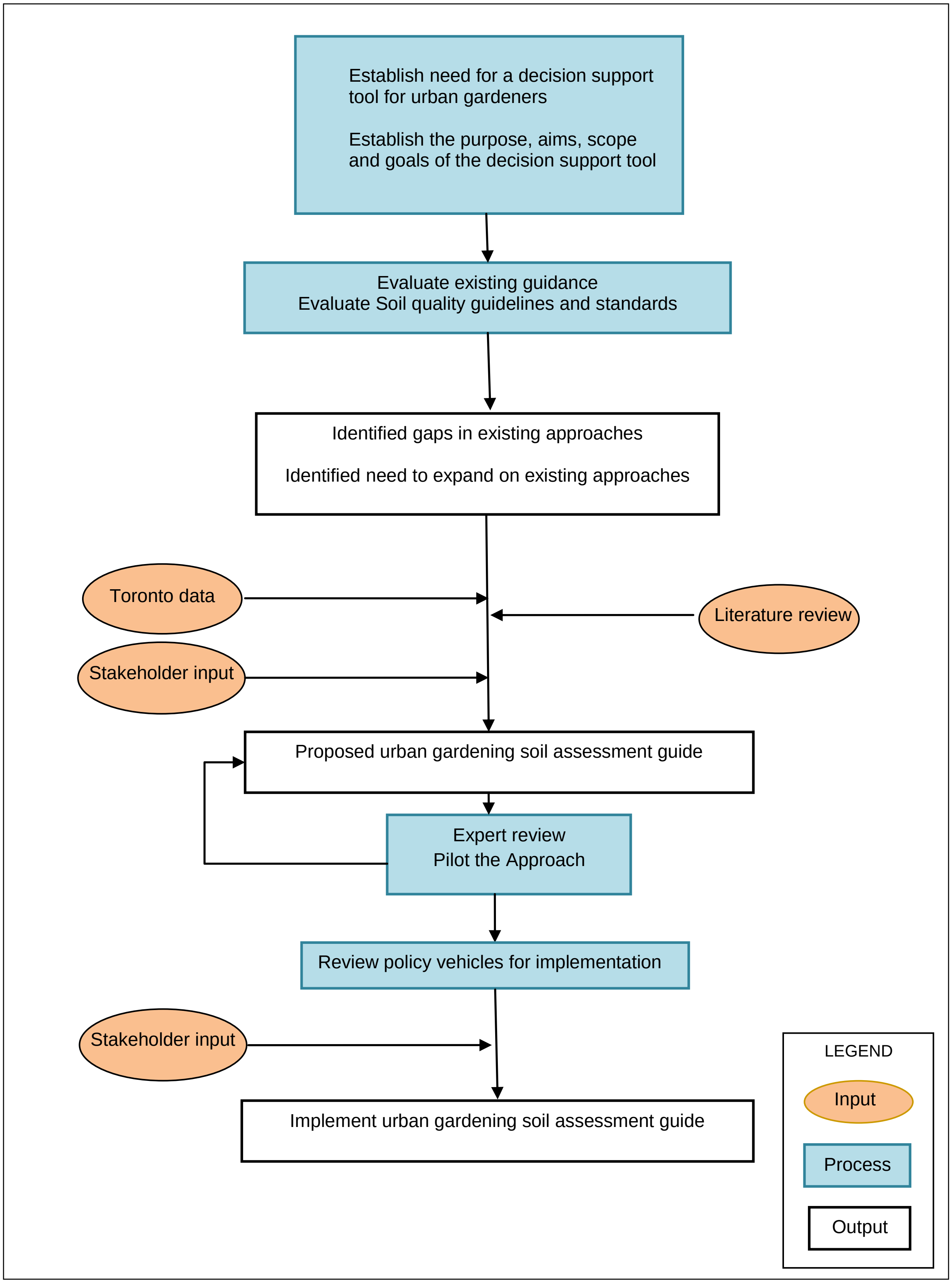
TPH reviewed the existing national and international guidance on assessing soils for urban gardening. The bodies of literature were reviewed, synthesized and assessed for application to urban gardening. Internal and external experts in public health, toxicology, contaminated sites risk assessment, urban agriculture policy development, and urban practice were consulted and asked to provide feedback on our proposed approach.

The following criteria were used to guide the development of the guide. The guide should:

- Be health-protective;
- Provide guidance on soil sampling, analysis and interpretation, all specifically targeted for urban gardening; and,
- Be flexible, easy and relatively inexpensive to implement.

[2] Available at: *www.ccnmo.ca*

**Figure E-1: Process used by Toronto Public Health to develop the urban gardening soil assessment guide**



We evaluated existing soil screening guidance (i.e., soil sampling and analysis) for urban agriculture in light of these requirements. TPH did not find any guidance that met these criteria. A summary of our findings is provided in Appendix B.

We also evaluated the existing soil screening values (i.e., soil standards, guidelines) that are used to interpret the soil concentrations to guide appropriate exposure reduction measures. We identified no appropriate soil screening values for urban gardening. The available soil screening values did not account for consumption of produce and enhanced soil exposure associated with urban gardening. Moreover, they included exposure pathways that are irrelevant to urban gardening. In short, none were developed to apply to urban gardening. A summary of our findings is provided in Appendix D.

Thus, we derived urban gardening-specific soil screening values (SSVs). These values were derived using the Ontario Ministry of the Environment formulae for calculating Site Condition Standards (MOE, 2009), exposure assumptions appropriate for urban gardening, and a method from New York Department of Environmental Conservation (NY DEC and NY DOH, 2006) for qualitatively accounting for the garden produce consumption.

Thus, TPH adapted aspects of existing soil screening guidance to create a guide that is suited to urban gardening in Toronto. Specifically, we adapted:

- The methods for Brownfields risk assessment developed by the Ontario Ministry of the Environment, and New York State Departments of Health and Environmental Conservation (MOE, 2009; NY DEC and NY DOH, 2006; US EPA, 2009);
- The garden soil sampling protocols recommended by the University of Minnesota, and Cornell University (Rosen, 2002; Shayler et al., 2009a, b, c); and,
- The exposure reduction measures recommended by the University of Minnesota, and Cornell University (Rosen, 2002; Shayler et al., 2009a, b, c).

As part of the development of the guide we completed the following:

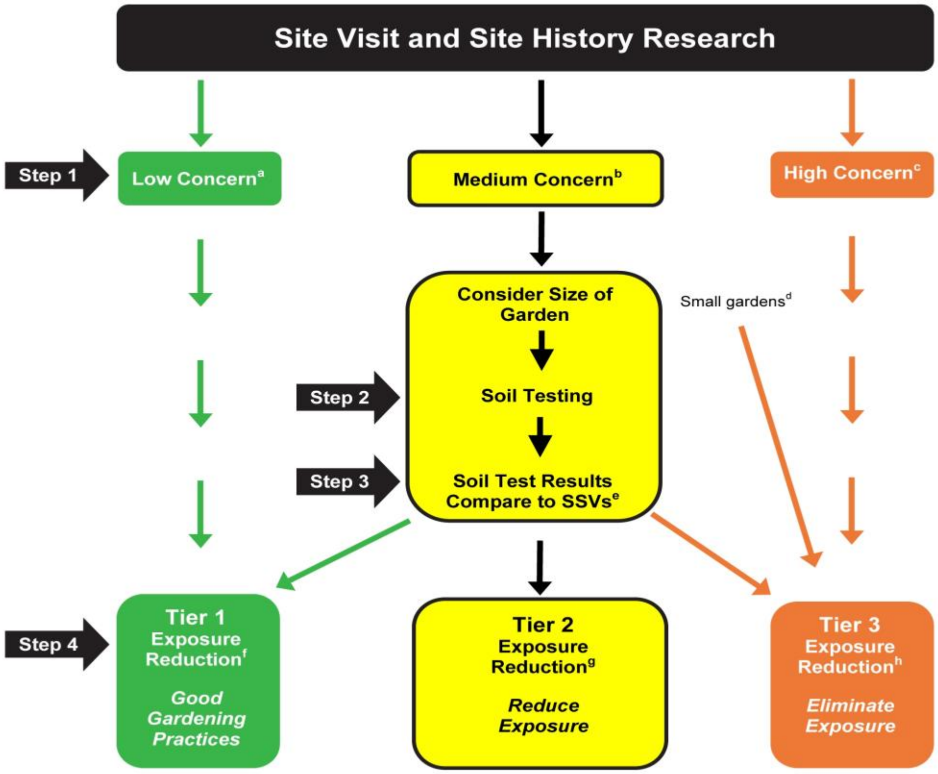
- An integrated risk/benefit approach;
- Uncertainty analysis of the approach;
- Sensitivity analysis of the Soil Screening Values;
- Semi-quantitative case-example of the potential health benefits of the implementation of the guide;
- Integrated consideration of costs of soil analysis and raised bed gardening and into the guide; and,
- Piloted the sampling and analysis components of the guide in five proposed community gardens.

## Overview of the Decision Support Tool

The guide is a step-wise process that starts with establishing a Level of Concern and concludes with developing an exposure reduction plan for a proposed garden site. The steps of the guide are summarized in Figure E-2. The steps in the guide are as follows:

Step 1 - Establish a Level of Concern
Step 2 - Sample and Test the Soil, if required
Step 3 - Interpret the Soil Tests
Step 4 - Mitigate the Risks

**Figure E-2: The Urban Gardening Soil Assessment Guide**




a *Low concern:* *Site is and has always been residential land, parkland (green space used for recreational purposes), farmland, child care centre, school land uses,* ***except for sites where any indicators of higher levels of concern apply.***

b ***Medium Concern:*** *Site is or has once been risk-managed park, orchard, hydro corridor, commercial land uses (excluding gas stations, dry cleaners, print and autobody shop), infill area, former landfill, former lead reduction zone, any land within 30 metres of a rail line or a major arterial road.*

c ***High Concern:*** *Site is or has once been industrial land uses, gas station, dry cleaner, printing and autobody shops, rail line or depot, lands with indications of dumping or burning, or, presence of smells or staining of the soil.*

d *Small garden: dimensions less than or equal to 4 x 4 m (13 x 13 ft), or total area less than or equal to 16 $m^2$ (170 $ft^2$). Larger gardens in the Medium Concern category should follow Step 2 and 3.*

e *Soil Screening Values (SSVs)*

f ***Tier 1 Exposure Reduction:*** *Use good gardening practices: Wash hands after gardening and particularly before eating and wash produce with soap and water.*

g ***Tier 2 Exposure Reduction:*** *Use good gardening practices (see above); and, reduce exposure pathways: dilute soil concentrations by adding clean soil and organic matter (compost and manure); lower bioavailability of contaminants by adding organic matter and raising pH; reduce dust by covering bare soil with mulch; peel root vegetables before cooking and eating; and, avoid or restrict growing of produce that accumulate contaminants.*

h ***Tier 3 Exposure Reduction:*** *Use good gardening practices (see above); and, reduce dust by covering bare soil surrounding garden with ground cover or mulch; and, eliminate exposure pathways**:** build raised bed gardens (minimum of 40 cm over a geotextile barrier), or use container gardens, and, add clean soil and organic matter annually (compost and manure); OR grow only nut and fruit trees (do not grow other types of produce).*

## Step 1 - Establish a Level of Concern

The initial step of the guidance is to assess the likelihood that the soil quality for a garden may be of concern due to contamination from past activities. The appropriate Level of Concern is identified by conducting a site visit and researching the land use history to determine if various indicators are present[3].

- A site visit is conducted by walking through and inspecting the site thoroughly. The site is walked through and checked for indications of illegal dumping or burning of garbage. The soil is turned over with a shovel in the areas intended for gardening and checked for soil staining (discolouration, usually dark patches) and odours (chemical and gasoline smells).
- A site history is researched by searching the City Archives, available City records[4], and asking local neighbours for information about the past and current use of the site and adjacent properties.

Each indicator is associated with a level of concern. The indicator of greatest concern defines the level of concern for the site as a whole. Table E.1 lists the various indicators, the appropriate Level of Concern, and the recommended next steps for the garden site.

In the Province of Ontario, brownfields are regulated by Ontario Regulation 153/04 (updated in 2009, O. Reg. 511/09), under Part XV.1 of the Environmental Protection Act. During Step 1 of the guidance, the site should be assessed for whether there are any requirements for the site under O.Reg 153/04. In addition to any provincial requirements, the guide is intended to be used on all lands that the City is considering for gardening and food production.

For sites that have been characterized as Medium Concern, go to Step 2. For all other gardens, go to Step 4.

[3] TPH developed a list of indicators for soil contamination for the City of Toronto based on a literature review of urban soil contaminants, the current limited information on Toronto's soil, and a pilot study on five proposed community and allotment gardens on Toronto parkland.

[4] Toronto Public Health developed the Historical Land Use Inventory; Parks, Forestry and Recreation has information on risk managed parks; Technical Services has information on former landfills.

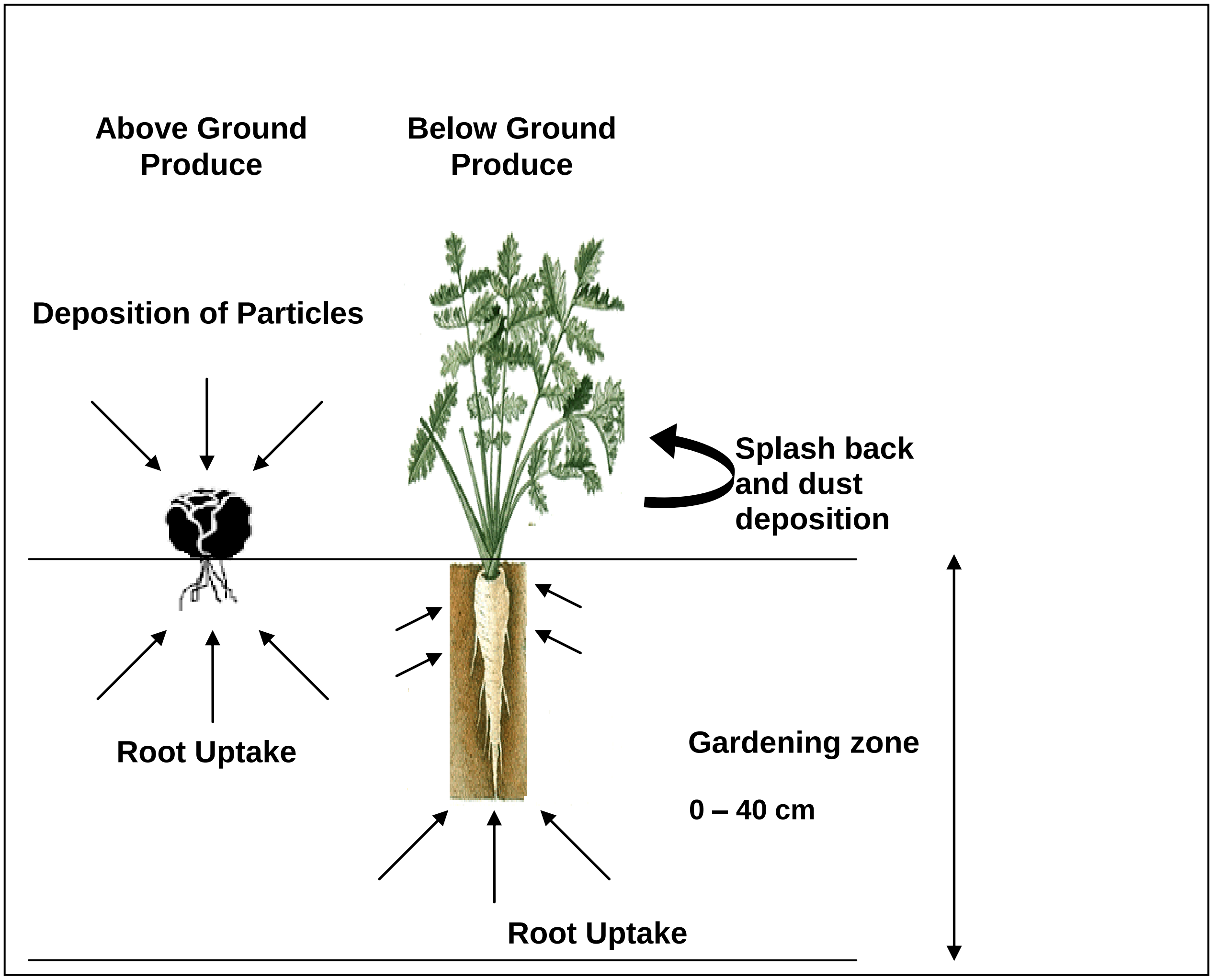
**Table E.1: Land Use and other Indicators for Establishing the Level of Concern for Urban Garden**

| Level Of Concern | Indicators | Next Step/ Soil Testing |
|---|---|---|
| **Low Concern** | Site is and has always been:<br>• Residential;<br>• Parkland;<br>• Farmland; or,<br>• Child care centre or school.<br><br>And, site is not located within:<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road.<br><br>And, site visit does not reveal:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | Soil testing not required.<br><br>**Go to Step 4 - Tier 1 Exposure Reduction.**<br><br>Use good gardening practices. |
| **Medium Concern** | Site is or has once been:<br>• Risk-managed park;<br>• Orchard;<br>• Hydro corridor;<br>• Infill area; or,<br>• Commercial land uses (excluding gas station, dry cleaner, printing or autobody shop- see High Concern).<br><br>Or, site is located within:<br>• Former landfill;<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road. | If the garden is small (less than 16 $m^2$ or 170 $ft^2$) it is not cost effective to conduct soil sampling, instead adopt exposure reduction strategies to eliminate exposure pathways. **Go to Step 4 (Tier 3 Exposure Reduction).**<br><br>For gardens larger than 16$m^2$ **Go to Step 2.** Sample and analyze the soil; the results of the soil testing will then indicate the appropriate exposure reduction measures to be taken. |
| **High Concern** | Site is or has once been:<br>• Gas station;<br>• Dry cleaner;<br>• Printing shop;<br>• Autobody shop;<br>• Rail line or rail yard; or,<br>• Industrial land uses.<br><br>Or, site visit reveals:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | **Eliminate exposures.**<br><br>**Go to Step 4 -Tier 3 Exposure Reduction** |

## Step 2 - Sample and Test the Soil

If the planned garden on a Medium Concern site is larger than 16 $m^2$ (170 $ft^2$) or 4 by 4 m (13 by 13 ft), TPH recommends that the soil be tested to determine the concentrations of soil contaminants. The cost of a raised bed garden of this size is less than soil sampling, thus it is not cost effective to conduct soil testing for gardens that are smaller than this size. TPH recommends that small gardens in the Medium Concern category go to Step 4. Figure E-3 depicts the depth of soil to be sampled is (0 to 40 cm), and the potential movement of soil contaminants into and onto garden produce.

**Figure E-3: Gardening Zone Depth of Soil and Movement of Contaminants into and onto Urban Garden Produce**




Sampling strategies should reflect how the gardeners use the garden. Community gardeners have unrestricted movement in the whole garden, whereas, allotment gardeners are restricted to a small garden plot within the larger garden area. In order to reflect these differences in the way that people use gardens, TPH recommends different sampling strategies for allotment and community gardens:

- For an allotment garden, nine individual sub-samples are taken in an X or Z pattern for every 10 by 10 metre area. Each sub-sample is combined and mixed into one composite sample. This composite sample is placed in a clean, labelled container.
- For a community garden, nine individual sub-samples are taken in an X or Z pattern for every 15 x 15 metres of land. Each sub-sample is combined and mixed into one composite sample. This composite sample is placed in a clean, labelled container.

The Ontario Brownfields Regulation O. Reg 153/04 provides a list of over 300 potential soil contaminants of concern (COCs)[5]. It is neither economically feasible nor necessary to analyze the urban impacted soils for this entire list of contaminants. TPH developed a streamlined list of COCs for the Medium Concern sites (see Table E.2). The cost to analyze each composite sample for all the parameters listed in Table E.2 is approximately $250. The number of required composite samples is determined by the size of the garden. For a community garden 1 to 2 sample covers 225 to 450 $m^2$, respectively. The average community garden is 280 $m^2$. Thus, most community gardens will require 2 samples at a cost of approximately $500.

**Table E.2: Chemicals of concern for Medium Concern garden sites**

| Metals: | Polycyclic Aromatic Hydrocarbons (PAHs): |
|---|---|
| Arsenic (As) | Acenaphthene |
| Cadmium (Cd) | Acenaphthylene |
| Cobalt (Co) | Anthracene |
| Chromium, total (Cr) | Benz(a)anthracene |
| Chromium, VI (Cr VI) | Benzo(a)pyrene |
| Copper (Cu) | Benzo(b)fluoranthene |
| Mercury (Hg) | Benzo(g,h,i)perylene |
| Molybdenum (Mo) | Benzo(k)fluoranthene |
| Nickel (Ni) | Chrysene |
| Lead (Pb) | Dibenz(a,h)anthracene |
| Selenium (Se) | Fluoranthene |
| Zinc (Zn) | Fluorene |
| | Indeno(1,2,3-c,d)pyrene |
| | Phenanthrene |
| | Pyrene |

If the indicators identified during the site visit and site history suggest that the soil might be contaminated by other soil contaminants not on TPH's streamlined list of COCs, then the site should be treated as a site of *High Concern* (Go to Step 4). Guidance on how to find an appropriate laboratory to conduct the soil analysis is being developed in consultation with PF&R staff.

[5] http://www.ene.gov.on.ca/envision/land/decomm/condition.htm

# Step 3 - Interpret the Soil Tests

In Step 3, the Exposure Reduction Tier for the garden is determined by comparing the soil concentration of each COC with the Soil Screening Values (SSVs) (see Table E.3). A summary of the basis, derivation and comparison of the SSVs to available soil screening values is provided in Appendix D.

**Table E.3: Urban Gardening Soil Screening Values (mg/kg)**

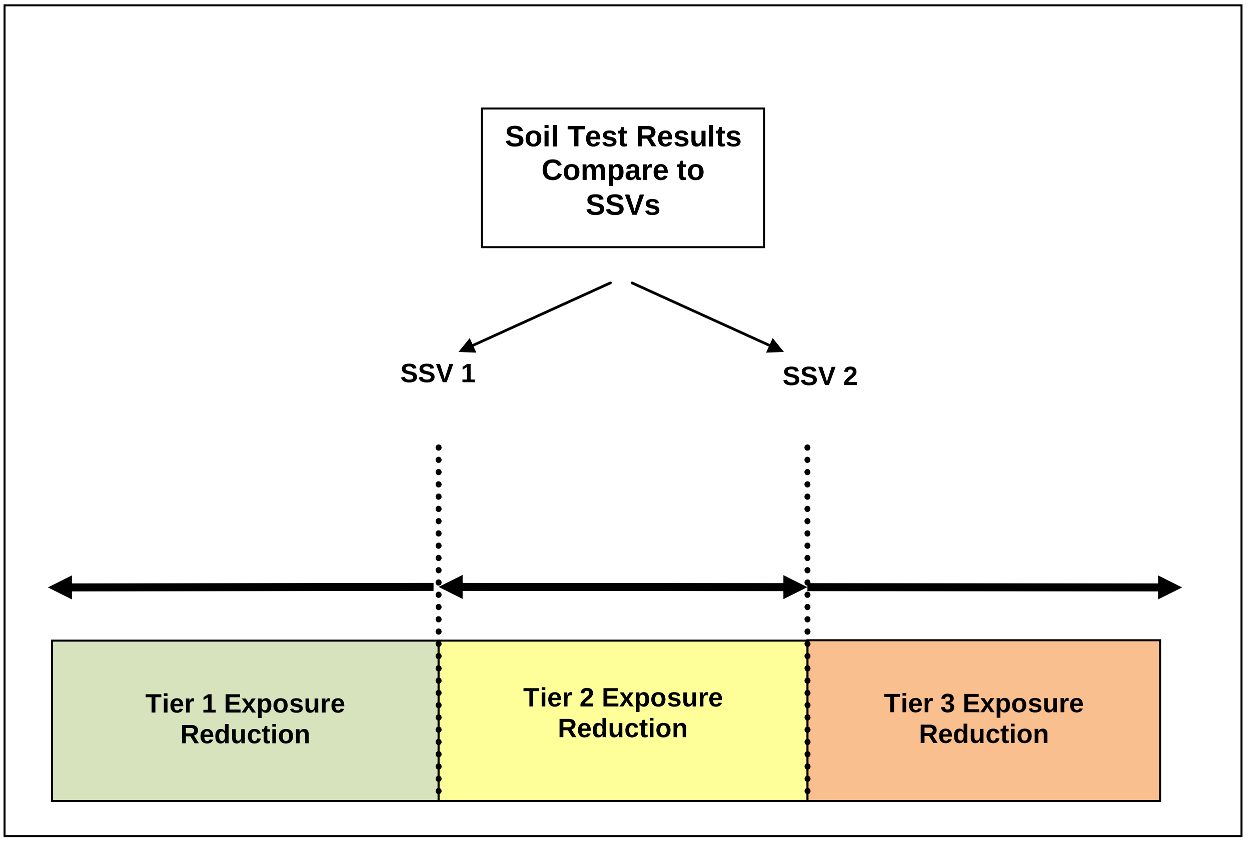
| | **Soil Screening Value (SSV)** | |
|---|---|---|
| Metals | **SSV 1** | **SSV 2** |
| Arsenic | 11 | 110 |
| Cadmium | 1.0 | 10 |
| Cobalt | 23 | 170 |
| Chromium, total | 390 | 630 |
| Chromium, VI | 5.0 | b |
| Copper | 180 | 660 |
| Mercury | 2.7 | b |
| Molybdenum | 13 | b |
| Nickel | 34 | 340 |
| Lead | 34 | 340 |
| Selenium | 10 | 11 |
| Zinc | 500 | 1800 |
| PAHs | | |
| Acenaphthene | 0.050 | 0.32 |
| Acenaphthylene | 0.093 | 0.47 |
| Anthracene | 0.58 | 0.58 |
| Benz(a)anthracene | 0.23 | 2.3 |
| Benzo(a)pyrene | 2.3 | 3 |
| Benzo(b)fluoranthene | 0.23 | 2.3 |
| Benzo(g,h,i)perylene | 0.10 | 1.0 |
| Benzo(k)fluoranthene | 0.23 | 2.3 |
| Chrysene | 0.099 | 0.99 |
| Dibenz(a,h)anthracene | 0.77 | b |
| Fluoranthene | 0.14 | 1.4 |
| Fluorene | 0.39 | b |
| Indeno(1,2,3-c,d)pyrene | 0.23 | 2.3 |
| Phenanthrene | 3.1 | b |
| Pyrene | 0.11 | 1.1 |

b Only Level 1 SSV was derived for this parameter. The human health intermediate value of this SSV is greater than 10 times urban background – the maximum value allowed in the guidance. Thus, the only SSV for this parameter is based on 10 times urban background.

The SSVs define the three risk levels, and are used to interpret the soil test data as follows (Figure E-4):

- If the concentrations of *all of the COCs* are below the respective SSV 1, then the site requires Tier 1 Exposure Reduction;
- If the concentration of *any COC* is above the SSV 1 but does not exceed the SSV 2, then the site requires Tier 2 Exposure Reduction; or,
- If the concentration of *any COC* is above the SSV 2, then the site requires Tier 3 Exposure Reduction.

**Figure E-4: Determining the Risk Level for the garden by comparing the soil concentrations to the SSVs**




## Step 4: Mitigate the Risks

There are many simple and inexpensive actions gardeners can easily take to reduce their exposure to urban soil contaminants depending on the risk level for the site. Table E-4 summarizes the recommended exposure reduction measures for the gardens that are required for Tier 1, 2 or 3 Exposure Reduction.

**Table E-4: Recommended Actions to Reduce Gardeners' Exposures to Soil Contaminants**

| Risk Level | Recommended Actions |
|---|---|
| **Tier 1 Exposure Reduction** | **Use good gardening practices:**<br>• Wash hands after gardening and particularly before eating; and<br>• Wash produce with soap and water. |
| **Tier 2 Exposure Reduction** | Use good gardening practices (see above); and,<br>**Reduce exposure pathways:**<br>• Dilute soil concentrations by adding clean soil and organic matter (compost and manure);<br>• Lower bioavailability of contaminants by adding organic matter and raising pH;<br>• Reduce dust by covering bare soil with ground cover or mulch;<br>• Peel root vegetables before eating or cooking; and,<br>• Avoid or restrict growing produce that accumulate contaminants. |
| **Tier 3 Exposure Reduction** | Use good gardening practices (see above); and,<br>• Reduce dust by covering bare soil surrounding the garden with ground cover or mulch; and,<br><br>**Eliminate exposure pathways:**<br>• Build raised bed gardens (minimum of 40 cm over a landscape fabric), or use container gardens, and,<br>• Add clean soil and organic matter annually (compost and manure).<br>OR<br>• Grow only nut and fruit trees (do not grow other types of produce). |

## Existing Gardens

Through regular gardening practices gardeners already do many of the activities outlined in Tier 1 and 2 Exposure Reduction risk levels. For example, gardeners add soil and organic matter to their gardens on an annual basis to improve the yield of their garden. These behaviours, year after year, result in a reduction in both the concentration and bioavailability of soil contaminants (Appendix C, Step 4). In addition, gardeners turn over their soil at least twice a year, aerating their soils and exposing deeper soil to sunlight (two mechanisms that degrade and reduce organic soil contaminants). These practices over many years significantly reduce the concentration and the bioavailability of soil contaminants.

Existing gardens on lands that are in the Low Concern category should continue to use Tier 1 Exposure Reduction measures. Existing gardens in the Medium Concern category should use Tier 2 Exposure Reduction measures, with the exception of avoid or restrict growing produce. There is no need to test the soils. Existing gardens in the High Concern category should follow the soil testing indicated for Medium Concern sites.

# Conclusions

This guidance will help the City assess urban soils for sites identified for new urban gardening initiatives. The guidance provides a framework for identifying sites that require no and low cost exposure reduction measures. The guidance will optimizes the use of City resources by streamlining the information required to make decisions about urban gardening while improving the protection of public health by reducing exposures to soil contaminants. The guidance will be updated periodically, as required, due to stakeholder feedback and changes in the evidence.

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# Glossary of Terms

**Soil Contaminant**: a substance present in soils due to human activity; a substance not naturally occurring in soils, or one present in soils at concentrations above naturally occurring levels substances found in soils that are from human-sources.

**Urban Environment**: refers to a geographic area that is densely populated and where there are mixed land uses in close proximity. Urban environments include green space, however, the majority of land cover is not vegetated (e.g., roads, houses, businesses, industry).

**Urban Gardening**: generally refers to all activities related to growing ornamental plants and food (vegetables, fruit, herbs and grains) in the urban environment. For the purposes of this document, urban gardening refers to those activities that result in direct exposure to urban soils and consumption of urban produce.

**Background Soil Concentrations**: Background levels of soil contaminants are generally defined as the levels one would expect to find in the soil in the absence of a pollution source. For the purposes of this report, the upper limit of normal ($98^{th}$ percentile of Ontario soil samples) in urban parkland is considered a reasonable approximation of an uncontaminated or background level of contaminant in the soil for the City of Toronto.

**Elevated Soil Concentrations**: Contaminant concentrations in soil that are above background levels, indicating a pollution source and a potential risk of *elevated* exposure.

**Contaminants of Concern**: Contaminants that may be elevated in urban soils (see Elevated Soil Concentrations).

**Major Arterial Road:** Roadways with traffic frequencies greater than 20,000 vehicles per day, speed limits of 50 to 60 km/h, no stop signs (traffic lights control intersections), and frequent use by city buses. The City of Toronto Road Classification System is available at: http://www.toronto.ca/transportation/road_class/index.htm.

**Exposure Reduction Measures:** Behavioural changes, gardening practices, and garden construction design features that reduce and/or eliminate gardeners' exposure to contaminants in urban soils while gardening and consuming garden produce.

**Urban-Impacted Soil**: Urban soil that has been adversely impacted by years of human activity, and is expected to have elevated soil concentrations of a number of soil contaminants.

**Risk-Managed Park**: Parkland where there is active risk mitigation (e.g., soil cap) in order to ensure the park is safe for use by the public. Risk-managed parks may have activity restrictions in place. For example, tree planting or gardening may not be allowed on that site.

# 1.0 Introduction

## 1.1 Background

The City of Toronto's support for urban gardening and food production has existed for over a decade with the development of the Community Garden Action Plan (1999) and the Environmental Plan – "Clean, Green and Healthy: A Plan for an Environmental Sustainable Toronto" (2000). In 2001, the Food and Hunger Action Committee developed an action plan to address food insecurity in Toronto. In 2004, City Council approved Parks, Forestry and Recreation's Strategic Plan, reinforcing the division's role in providing opportunities for community gardening and urban food production. In 2007, City Council unanimously adopted the Climate Change, Clean Air and Sustainability Energy Action Plan, which directed the City to promote local food production and remove barriers to urban gardening. In 2008, the Toronto Environment Office (TEO) led the establishment of the Urban Agriculture Interdivisional Working Group, with a mandate to explore and address barriers to increasing local food production. In 2008, the City of Toronto embarked on a major city-wide initiative to develop a sustainable food system in Toronto. In May 2010, the Medical Officer of Health's report "Cultivating Food Connections: Toward a Healthy and Sustainable Food System for Toronto" identified providing residents with urban gardening skills and information as a priority area for action.

In August of 2009, City Council adopted the recommendation outlined in the TEO report "Identifying Urban Agriculture Opportunities in the City of Toronto:" to support strategies and initiatives that will achieve the overall goal of expanding opportunities for local food production and other urban agricultural activities in the City of Toronto. A key issue raised during the consultation process was a need for consideration of human health and safety, in particular regarding concern about urban impacted soils and food production. The City of Toronto is currently investigating the feasibility of using publicly owned spaces (i.e., surplus city property, school board properties, hydro corridors and institutional lands) for urban food production.

The City of Toronto Parks, Forestry and Recreation Division (PF&R) currently manages 51 community gardens (with an average size of about 3,000 sq. ft. per garden), 12 allotment gardens (comprising 1,674 plots, ranging from 20 ft x 10 ft to 20 ft x 20 ft. per plot), and a seven-acre urban farm[6]. There is an increasing demand in the community for spaces to grow food with over 80 outstanding requests for new community gardens (Boye, pers. comm. 2011). PF&R provides community outreach, technical support, and training in urban agricultural practices to numerous community organizations. Many City divisions, including Toronto Public Health (TPH), support community programs that encourage urban gardening[7]. For example, TEO is working in

[6] Parks, Forestry and Recreation provides information on community gardens by ward (www.toronto.ca/parks/engagement/community-gardens). Toronto Community Garden Network provides information on 44 community gardens (*www.tcgn.ca* ).

[7] For a summary of urban gardening initiatives in the City of Toronto see TEO and PF&R Staff Report, 2009.

partnership with the Toronto District School Board and York University to identify the feasibility of using school lands for food production.

## 1.2 The Urban Gardening Movement

Urban gardening can provide broad health, environmental, social and economic benefits. These benefits include: increased food security and availability of low cost, nutritious, culturally appropriate food; increased physical activity; improved opportunities for small-scale food entrepreneurship; improved mental health and community cohesion; and reduced carbon footprints (Baris, 2002; Boettche et. al, 1995; De Sousa, 2003; de Zeeuw et al 2000; Doyle and Krasny, 2003; Hancock, 2001; Holland, 2004; Martin and Marsden 1998; Mougoet 2000; PHAC, 2007; Rideout, 2009; Schmelzkopf, 2002; UN FAO, undated; ven den Berg, 2010; Wakefield et. al, 2007).

Nearly 1 in 10 Canadians are food insecure, and urban areas have a higher prevalence of food insecure households than rural areas (Health Canada, 2007). 2/3rds of Toronto families in low income neighbourhoods are food insecure (Kirkpatrick and Tarasuk, 2009). Effort to increase urban food production has been identified as an important strategy to improve urban food security (PHAC, 2007; Holland, 2004; Doyle and Krasny, 2003; Hancock, 2001; Schmelzkopf, 2002). Studies have also demonstrated that access to community gardens can empower newcomers by supporting healthy and traditional food choices (Hyman et al., 2002).

Policies to support urban gardening are being considered in many cities in North America. In 2009, Vancouver developed urban gardening guidelines that recommend developers include shared gardening spaces for 30 percent of all residential units without access to private outdoor space (Groc, 2009). Montreal recently set a goal of providing gardening sites for at least 1 percent of its city's 1.6 million people (Groc, 2009). The City of Edmonton has rapidly expanded their community garden network from 3 to 60 gardens in the last few years (VIPIRG, 2007). Philadelphia and Chicago promote urban gardening as part of their overall sustainability agenda (Flisram, 2009), and Milwaukee is exploring the idea of setting aside 10 percent of vacant city-owned land for urban gardening (Flisram, 2009).

Public interest in local food and urban agriculture is growing rapidly and there is increasing demand to allocate additional City lands, particularly parkland, for the purposes of gardening and food production (TEO and PF&R, 2009).

## 1.3 The Issue

While the benefits of urban gardening are generally accepted and lauded by public health agencies (PHAC, 2007; UN FAO, undated), the expansion of urban gardening activities generally requires the public to garden in vacant lands or areas previously not used for gardening. These urban soils may be impacted by various stressors including past industrial and commercial activities, presence of older homes, and proximity to major roadways (Papritz and Reichard, 2009; Aelion et al., 2009; Kaufman and Bailkey 2000; Devine, 2007; De Sousa, 2003; Hynes et al. 2001; Clark et al. 2008).

In North America, urban soils typically have higher concentrations of contaminants than rural soils (MOE, 1993a; Pilgrim and Schroeder, 1997; Aelion et al., 2009). Numerous international agencies note safety concerns regarding urban gardening when soil contaminants are elevated in urban soils (WHO, 1999; US Department of Agriculture, 2004; IDRC, 2006; IDRC, 1999; ATSDR, 2007; Rosen, 2002), and studies have predicted unacceptable health risks from gardening on urban impacted soils (Papritz and Reichard, 2009; Aelion et al., 2009; Kaufman and Bailkey 2000; Devine, 2007; Hynes et al. 2001; Hough et al. 2004; Clark et al. 2008).

While some researchers conclude that urban soils with some degree of contamination can be used safely for gardening if adequate precautions are taken (Puschenreiter et al., 1999), others argue that little is known about the chronic health effects of consuming small amounts of heavy metals over long periods of time, and that further research on the safety of urban gardening is needed (Birley and Lock, 1999). In addition, researchers argue that the assessment and management of urban soils is too costly and complicated for urban gardeners to undertake (Kaufman and Bailkey, 2000; Cole et al., 2008).

Typically, the process used to assess urban impacted soil is a screening-level risk assessment. A screening-level risk assessment uses worst-case scenarios to screened out sites (or exposure pathways) as not posing a health risk and those that need further study. If a site cannot be screened out using worst case scenario assumptions, then more detailed assessment is conducted in which uncertainty is reduced by collecting and evaluating site-specific data. Often a site-specific risk assessment is not conducted because this additional study takes time and money. However, planning risk mitigation based on the results of a worst-case assessment can have unintentional negative consequences (Boyd et al., 1999; Leake et al., 2009), for example:

- healthy and beneficial behaviours (e.g., outdoor activity, gardening, etc.) may be unnecessarily restricted; or,
- expensive exposure reduction measures (e.g., replacement of garden soil) may be undertaken with little or no health benefits.

## 1.4 The Need for a Decision-Support Tool

Concern about urban impacted soils and lack of knowledge and assessment tools has been identified as a barrier to enhancing urban gardening in the City of Toronto. Typical assessments and mitigation of urban soil contaminants require significant time, knowledge, expertise and financial resources. Communities weigh priorities between food security and concerns about soil contamination. For people with limited resources, alleviating hunger and increasing access to nutritious food may be a higher priority than addressing concerns about exposure to urban soil contaminants (Lee-Smith and Cole, 2008). In contrast, other communities may unnecessarily limit their food production because of perceived risks from soil contamination (Leake et al, 2009).

In the autumn of 2010, the United States Environmental Protection Agency (US EPA) held a special webinar series on reusing brownfields for urban gardening that highlighted the urgent need for a user-friendly assessment framework for urban gardens[8]. Assessment frameworks

[8] Copies of presentations and video recordings of the two webinars in the series (Webinar #1 The State of Scientific Knowledge and Research Needs and Policy Barriers, and Webinar #2 Incentives to Reusing Brownfields for

include risk-based soil quality standards, identification of the soil contaminants of most concern, sampling and analysis instructions and guidance on interpreting results. It was noted that gardeners and policy-makers need these frameworks to be flexible, reassuring and easy to communicate. This webinar series highlighted that assessment frameworks for urban gardening do not currently exist in North America.

The need to support gardeners in addressing soil contamination was also highlighted in the Metcalf Foundation report: "Scaling up Urban Agriculture in Toronto: Building the Infrastructure" (Nasr et al., 2010). The report notes that knowledge sharing, support, and development of strategies to inexpensively assess soil quality is a priority issue for Toronto gardeners. In 2010, the Toronto urban gardening community noted that they lack the skills and information they need to assess food safety (TPH, 2010) [9]. Moreover, many residents expressed frustration with the lack of clear information and resources to develop community gardens (TPH, 2010). In recent years, various City Divisions and community partners have sought advice from TPH on the suitability of gardening in urban impacted soils (Campbell, pers.comm. 2010). PF&R staff note that the limited resources available to assess the appropriateness of soils are a key barrier to opening new community gardens (Boye, pers comm. 2011).

## 1.5 Alternative Approaches Analysis

Several approaches were explored to address the concerns with gardening on potentially contaminated urban soils. These included:

Option 1: Adopt or adapt existing soil assessment guidance and compare the results to readily available soil quality standards.

Option 2: Restrict gardening to raised bed or container gardening regardless of site history and site conditions.

Option 3: Follow guidance designed specifically for urban gardening in Toronto.

Option 1 was not considered the best approach because of the following disadvantages:

- Soil testing and analysis using standard soil assessment guidance for an average-sized community garden are cost prohibitive (greater than $5,000 per garden);
- The standard guidance used to assess the degree of contamination does not consider all of the relevant exposure pathways and thus does not accurately reflect the risks to a gardener from exposure to the soil and from eating food grown on the site;

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Community Gardens and Urban Agriculture) are available online at: http://www.epa.gov/brownfields/urbanag/present.htm.

[9] The consultation report, "Food Connections: Toward a Healthy and Sustainable Food System for Toronto", formed the basis of discussions with residents, community organizations, business, farmers, City staff and other levels of government. A more detailed summary of the process and feedback is provided in the "What We Heard" report, available on the Food Strategy website (toronto.ca/foodconnections).

- Soil quality standards and guidelines that are used in Canada and elsewhere have been developed for different purposes. Therefore they cannot be used directly when assessing potential health risks when assessing soils in urban gardens in Toronto.

Option 2 applies the most restrictive mitigation measures on all potentially contaminated lands that would be used for urban gardening. The cost of creating a raised-bed or container garden for an average-sized community garden is estimated at $4,000 – $12,500. Therefore this approach would increase the cost of setting up new community and allotment gardens even in areas where such measures are not needed and would unnecessarily reduce the number of new gardens in the City.

To address the high cost of Options 1 and 2, TPH developed a guide for assessing soils in urban gardens, designed to facilitate urban gardening in Toronto and reduce gardeners' exposure to soil contaminants. The use of the guide will reduce the cost of soil analysis ($250 to $500, based on the size of the garden) and optimize the use of City resources by streamlining the data collected and the analysis required to make decisions on the appropriate actions to be taken on a specific parcel of land. The recommended approach is Option 3, the development of an urban gardening soil assessment guide.

## 1.6 Decision-Support Tool for Assessing Urban Impacted Soils for Urban Gardening

In order to support City staff and urban gardeners, TPH developed an evidence-informed guide for the assessment of potential risks from urban impacted soils for urban gardening. TPH consulted the literature, stakeholders and experts to develop the urban gardening soil assessment guide (process is described in Appendix A). This tool is specific to urban gardening, follows a health-based approach, and integrates input from the urban gardening community in Toronto. The urban gardening soil assessment guide supports communities by providing them with information, tools and resources to design exposure reduction measures to fit the specifics of their soil and garden site.

Guided by the frameworks outlined by Cole et al. (2008), TPH integrated the benefits of urban gardening into the assessment of risks. We developed a reasonable worst-case urban gardening scenario in order to ensure that the approach was health-based, without creating unnecessary barriers to urban gardening. The following assumptions and principles guided the development of the risk assessment:

1. There are health benefits associated with urban gardening;
2. There are *unknown* health risks associated with urban gardening on urban impacted soil; and,
3. Precaution[10] is used to address these unknown health risks as part of a risk/benefit approach.

[10] We used reasonable worst case exposure scenarios. Considerable professional judgement was used in the selection of each parameter. Section 4 of the report provides more detail.

## 1.7 Purpose

The **purpose** of the guide is to provide a decision-support tool to guide City staff and residents through selecting a site that is suitable for a new community or allotment garden, determining the need for a soil assessment, and identifying the appropriate exposure reduction measures for the selected site. The guide outlines a process to follow to assess the potential risk from exposure to urban soil contaminants through urban gardening activities[11], and to develop an exposure reduction plan. Many chemicals are ubiquitous soil contaminants in the urban environment, and others are naturally occurring. The presence of a soil contaminant in the soil of an urban garden does not necessarily indicate an *elevated* health risk due to urban gardening (US EPA, 2007). When developing the guide, we addressed the following situations:

a) Urban soil contaminants present at levels above background [12], indicating a pollution source and a potential for *elevated* exposure due to urban gardening; and,

b) Soil contaminants present at levels associated with unacceptable health risks.

## 1.8 Scope

The guide addresses concerns related to gardening in urban soils that are potentially contaminated. Other aspects, like soil fertility[13], are outside of the current scope of the guide. The possible issue of electromagnetic field (EMF) exposures while gardening in hydro corridors is not addressed in this guide since PF&R currently follows the City of Toronto EMF Prudent Avoidance Policy[14].

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[11] Participating in urban gardening results in increased exposure to soil (via skin contact, ingestion of soil, inhalation of soil dust and consumption of garden produce, and increased exposure to areas of the city that a resident may not normally access, like vacant land.

[12] For the purposes of this report, background levels of soil contaminants are defined as the levels one would expect to find in urban soil in the absence of a point source of pollution. Background levels for the City of Toronto were defined as the Ministry of the Environment old urban parkland background values. Further explanation is provided in Appendix D.

[13] Information on other soil quality parameters like phosphorous, magnesium, nitrogen, potassium, pH, organic matter is available from the Ontario Ministry of Agriculture, Food and Rural Affairs.
http://www.omafra.gov.on.ca/english/crops/soils/fertility.html see “Sampling and Testing” section.

[14] In July 2008, City Council adopted a prudent avoidance policy that seeks to minimize children's electromagnetic fields (EMF) exposures. When planning new gardens in hydro corridors, the policy requires that the City measure EMF levels and predict the average time children might spend in the corridor so as to determine the best location for the garden. The EMF protocol is available at: http://www.toronto.ca/health/hphe/pdf/emf_backgrounder.pdf.

## 1.9 Key Aims and Goals

The guide **aims** to:

1. Encourage urban food production while minimizing unnecessary soil assessment and exposure reduction measures;
2. Address the questions, concerns and needs of communities relating to soil contaminants and urban gardening[15];
3. Be easily understood, and relatively inexpensive to use;
4. Be transparent and flexible, so that exposure reduction measures can be tailored to the specific risks at the site and the needs of the urban gardeners.

The **goal** of this initiative is to increase the number of people who will grow produce because they have the tools and information they require to make healthy choices about growing food on urban impacted soils. The implementation of the guide is expected to:

1. Empower gardeners and City staff with tools and information about soil contaminants.
   a. Reduce gardeners' exposures to urban soil contaminants by providing exposure reduction guidance.
   b. Address their concerns about potential soil contamination, thereby encouraging more gardeners to produce food.
2. Increase the number of Toronto residents able to grow food on City land by streamlining PF&R decision making.
3. Optimize the conversion of appropriate vacant urban land into productive use by guiding the selection of appropriate gardening activities[16].

# 2.0 The Urban Gardening Soil Assessment Guide

The following section outlines the urban gardening soil assessment guide. The methods, rationale and evidence that informed the development of the guide are summarized in the Appendices. More detailed instructions and guidance are being developed in consultation with Parks, Forestry and Recreation staff.

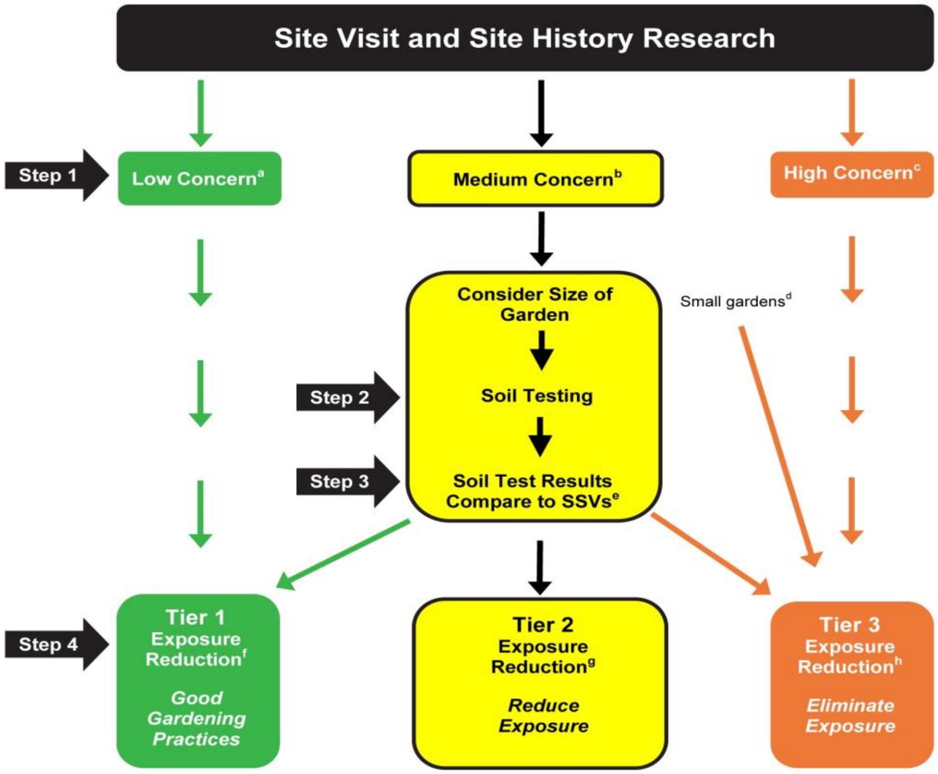
[15] TPH acknowledges the autonomy of the public and recognizes that individuals and families consider the information received from many sources, and make their own choices about the risks of soil contamination versus food security. Cole et al. (2008) notes that the public, and in particular those with the greatest need for urban gardening, benefit from knowledge inputs from others in order to help them make informed choices.

[16] That is, to identify areas in Toronto where the soil is appropriate for urban gardening given no- or low-cost exposure reduction measures, and to guide the conversion of vacant or under-used land into productive use.

The guide is a step-wise process that starts with establishing a Level of Concern and concludes with developing an exposure reduction plan for a proposed garden site. The steps of the guide are summarized in Figure 2-1. The steps in the guide are as follows:

Step 1 - Establish a Level of Concern
Step 2 - Sample and Test the Soil, if required
Step 3 - Interpret the Soil Tests
Step 4 - Mitigate the Risks

**Figure 2-1: The Urban Gardening Soil Assessment Guide**




a *__Low concern:__ Site is and has always been residential land, parkland (green space used for recreational purposes), farmland, child care centre, school land uses, __except for sites where any indicators of higher levels of concern apply.__*

b *__Medium Concern:__ Site is or has once been risk-managed park, orchard, hydro corridor, commercial land uses (excluding gas stations, dry cleaners, print and autobody shop), infill area, former landfill, former lead reduction zone, any land within 30 metres of a rail line or a major arterial road.*

c *__High Concern:__ Site is or has once been industrial land uses, gas station, dry cleaner, printing and autobody shops, rail line or depot, lands with indications of dumping or burning, or, presence of smells or staining of the soil.*

d *Small garden: dimensions less than or equal to 4 x 4 m (13 x 13 ft), or total area less than or equal to 16 $m^2$ (170 $ft^2$). Larger gardens in the Medium Concern category should follow Step 2 and 3.*

e *Soil Screening Values (SSVs)*

f *__Tier 1 Exposure Reduction:__ Use good gardening practices: Wash hands after gardening and particularly before eating and wash produce with soap and water.*

g *__Tier 2 Exposure Reduction:__ Use good gardening practices (see above); and, reduce exposure pathways:*
*dilute soil concentrations by adding clean soil and organic matter (compost and manure); lower bioavailability of contaminants by adding organic matter and raising pH; reduce dust by covering bare soil with mulch; peel root vegetables before cooking and eating; and, avoid or restrict growing of produce that accumulate contaminants.*

h *__Tier 3 Exposure Reduction:__ Use good gardening practices (see above); and, reduce dust by covering bare soil surrounding garden with ground cover or mulch; and, eliminate exposure pathways__:__ build raised bed gardens (minimum of 40 cm over a geotextile barrier), or use container gardens, and, add clean soil and organic matter annually (compost and manure); OR grow only nut and fruit trees (do not grow other types of produce).*

## Step 1 - Establish a Level of Concern

The initial step of the guidance is to assess the likelihood that the soil quality for a garden may be of concern due to contamination from past activities. The appropriate Level of Concern is identified by conducting a site visit and researching the land use history to determine if various indicators are present[17].

- A site visit is conducted by walking through and inspecting the site thoroughly. The site is walked through and checked for indications of illegal dumping or burning of garbage. The soil is turned over with a shovel in the areas intended for gardening and checked for soil staining (discolouration, usually dark patches) and odours (chemical and gasoline smells).
- A site history is researched by searching the City Archives, available City records[18], and asking local neighbours for information about the past and current use of the site and adjacent properties.

Each indicator is associated with a level of concern. The indicator of greatest concern defines the level of concern for the site as a whole. Table 2.1 lists the various indicators, the appropriate Level of Concern, and the recommended next steps for the garden site.

In the Province of Ontario, brownfields are regulated by Ontario Regulation 153/04 (updated in 2009, O. Reg. 511/09), under Part XV.1 of the Environmental Protection Act. During Step 1 of the guidance, the site should be assessed for whether there are any requirements for the site under O.Reg 153/04. In addition to any provincial requirements, the guide is intended to be used on all lands that the City is considering for gardening and food production.

For sites that have been characterized as Medium Concern, go to Step 2. For all other gardens, go to Step 4.

[17] TPH developed a list of indicators for soil contamination for the City of Toronto based on a literature review of urban soil contaminants, the current limited information on Toronto's soil, and a pilot study on five proposed community and allotment gardens on Toronto parkland.

[18] Toronto Public Health developed the Historical Land Use Inventory; Parks, Forestry and Recreation has information on risk managed parks; Technical Services has information on former landfills.

**Table 2-1: Land Use and other Indicators for Establishing the Level of Concern for Urban Garden**

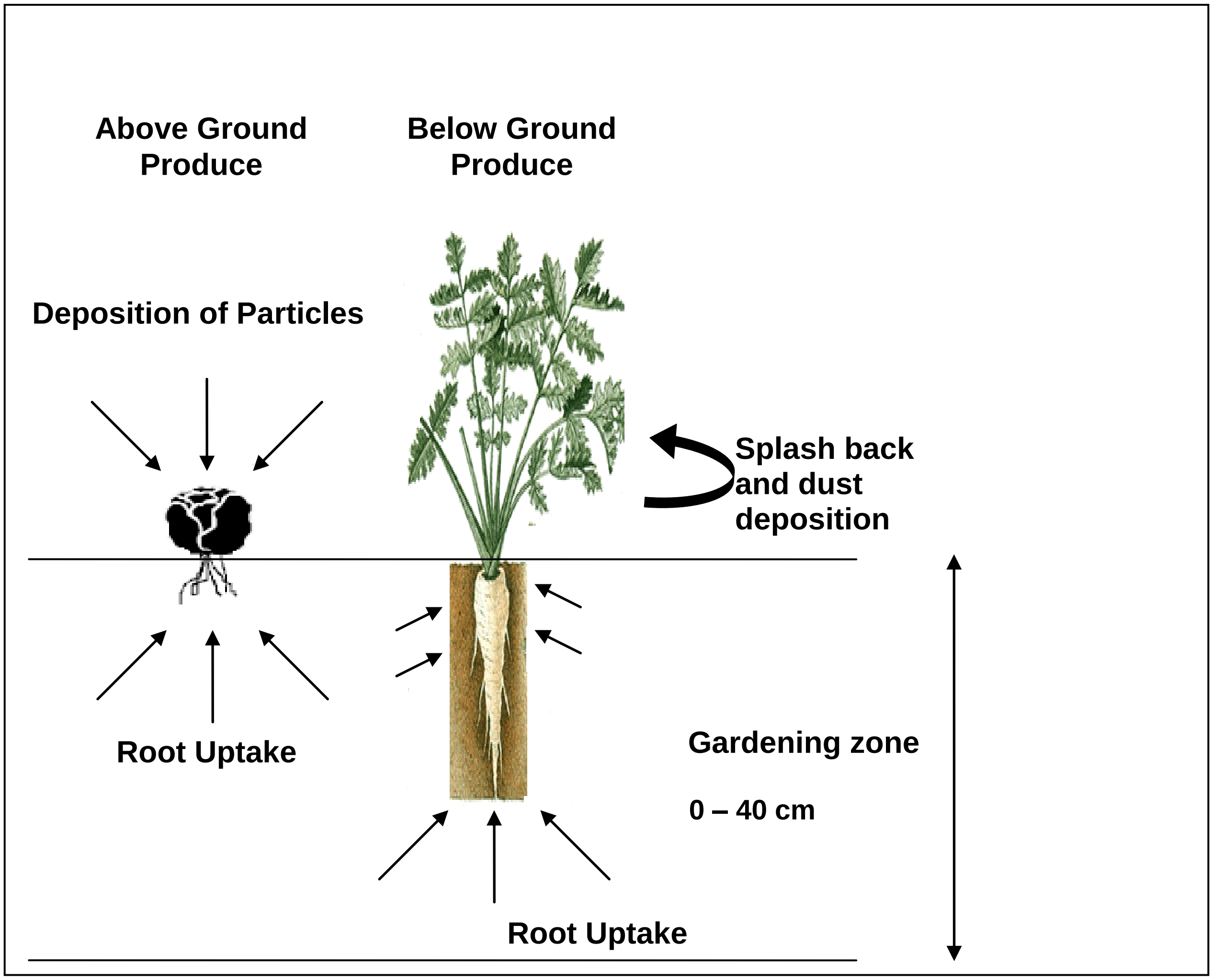
| Level Of Concern | Indicators | Next Step/ Soil Testing |
|---|---|---|
| **Low Concern** | Site is and has always been:<br>• Residential;<br>• Parkland;<br>• Farmland; or,<br>• Child care centre or school.<br><br>And, site is not located within:<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road.<br><br>And, site visit does not reveal:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | Soil testing not required.<br><br>**Go to Step 4 - Tier 1 Exposure Reduction.**<br><br>Use good gardening practices. |
| **Medium Concern** | Site is or has once been:<br>• Risk-managed park;<br>• Orchard;<br>• Hydro corridor;<br>• Infill area; or,<br>• Commercial land uses (excluding gas station, dry cleaner, printing or autobody shop- see High Concern).<br><br>Or, site is located within:<br>• Former landfill;<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road. | If the garden is small (less than 16 $m^2$ or 170 $ft^2$) it is not cost effective to conduct soil sampling, instead adopt exposure reduction strategies to eliminate exposure pathways. **Go to Step 4 (Tier 3 Exposure Reduction).**<br><br>For gardens larger than 16$m^2$ **Go to Step 2.** Sample and analyze the soil; the results of the soil testing will then indicate the appropriate exposure reduction measures to be taken. |
| **High Concern** | Site is or has once been:<br>• Gas station;<br>• Dry cleaner;<br>• Printing shop;<br>• Autobody shop;<br>• Rail line or rail yard; or,<br>• Industrial land uses.<br><br>Or, site visit reveals:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | **Eliminate exposures.**<br><br>**Go to Step 4 -Tier 3 Exposure Reduction** |

# Step 2 - Sample and Test the Soil

If the planned garden on a Medium Concern site is larger than 16 $m^2$ (170 $ft^2$) or 4 by 4 m (13 by 13 ft), TPH recommends that the soil be tested to determine the concentrations of soil contaminants. The cost of a raised bed garden of this size is less than soil sampling, thus it is not cost effective to conduct soil testing for gardens that are smaller than this size. TPH recommends that small gardens in the Medium Concern category go to Step 4.

Figure 2-2 depicts the depth of soil to be sampled is (0 to 40 cm), and the potential movement of soil contaminants into and onto garden produce.

**Figure 2-2: Gardening Zone Depth of Soil and Movement of Contaminants into and onto Urban Garden Produce**




Sampling strategies should reflect how the gardeners use the garden. Community gardeners have unrestricted movement in the whole garden, whereas, allotment gardeners are restricted to a small garden plot within the larger garden area. In order to reflect these differences in the way that people use gardens, TPH recommends different sampling strategies for allotment and community gardens:

- For an allotment garden, nine individual sub-samples are taken in an X or Z pattern for every 10 by 10 metre area. Each sub-sample is combined and mixed into one composite sample. This composite sample is placed in a clean, labelled container.
- For a community garden, nine individual sub-samples are taken in an X or Z pattern for every 15 x 15 metres of land. Each sub-sample is combined and mixed into one composite sample. This composite sample is placed in a clean, labelled container.

The Ontario Brownfields Regulation O. Reg 153/04 provides a list of over 300 potential soil contaminants of concern (COCs)[19]. It is neither economically feasible nor necessary to analyze the urban impacted soils for this entire list of contaminants. TPH developed a streamlined list of COCs for the Medium Concern sites (see Table 2.2). The cost to analyze each composite sample for all the parameters listed in Table E.2 is approximately $250. The number of required composite samples is determined by the size of the garden. For a community garden 1 to 2 sample covers 225 to 450 $m^2$, respectively. The average community garden is 280 $m^2$. Thus, most community gardens will require 2 samples at a cost of approximately $500.

**Table 2.2: Chemicals of concern for Medium Concern garden sites**

| Metals: | Polycyclic Aromatic Hydrocarbons (PAHs): |
|---|---|
| Arsenic (As) | Acenaphthene |
| Cadmium (Cd) | Acenaphthylene |
| Cobalt (Co) | Anthracene |
| Chromium, total (Cr) | Benz(a)anthracene |
| Chromium, VI (Cr VI) | Benzo(a)pyrene |
| Copper (Cu) | Benzo(b)fluoranthene |
| Mercury (Hg) | Benzo(g,h,i)perylene |
| Molybdenum (Mo) | Benzo(k)fluoranthene |
| Nickel (Ni) | Chrysene |
| Lead (Pb) | Dibenz(a,h)anthracene |
| Selenium (Se) | Fluoranthene |
| Zinc (Zn) | Fluorene |
| | Indeno(1,2,3-c,d)pyrene |
| | Phenanthrene |
| | Pyrene |

If the indicators identified during the site visit and site history suggest that the soil might be contaminated by other soil contaminants not on TPH's streamlined list of COCs, then the site should be treated as a site of *High Concern* (Go to Step 4). Guidance on how to find an appropriate laboratory to conduct the soil analysis is being developed in consultation with PF&R staff.

[19] http://www.ene.gov.on.ca/envision/land/decomm/condition.htm

## Step 3 - Interpret the Soil Tests

In Step 3, the Exposure Reduction Tier for the garden is determined by comparing the soil concentration of each COC with the Soil Screening Values (SSVs) (see Table 2.3). A summary of the basis, derivation and comparison of the SSVs to available soil screening values is provided in Appendix D.

**Table 2.3: Urban Gardening Soil Screening Values (mg/kg)**

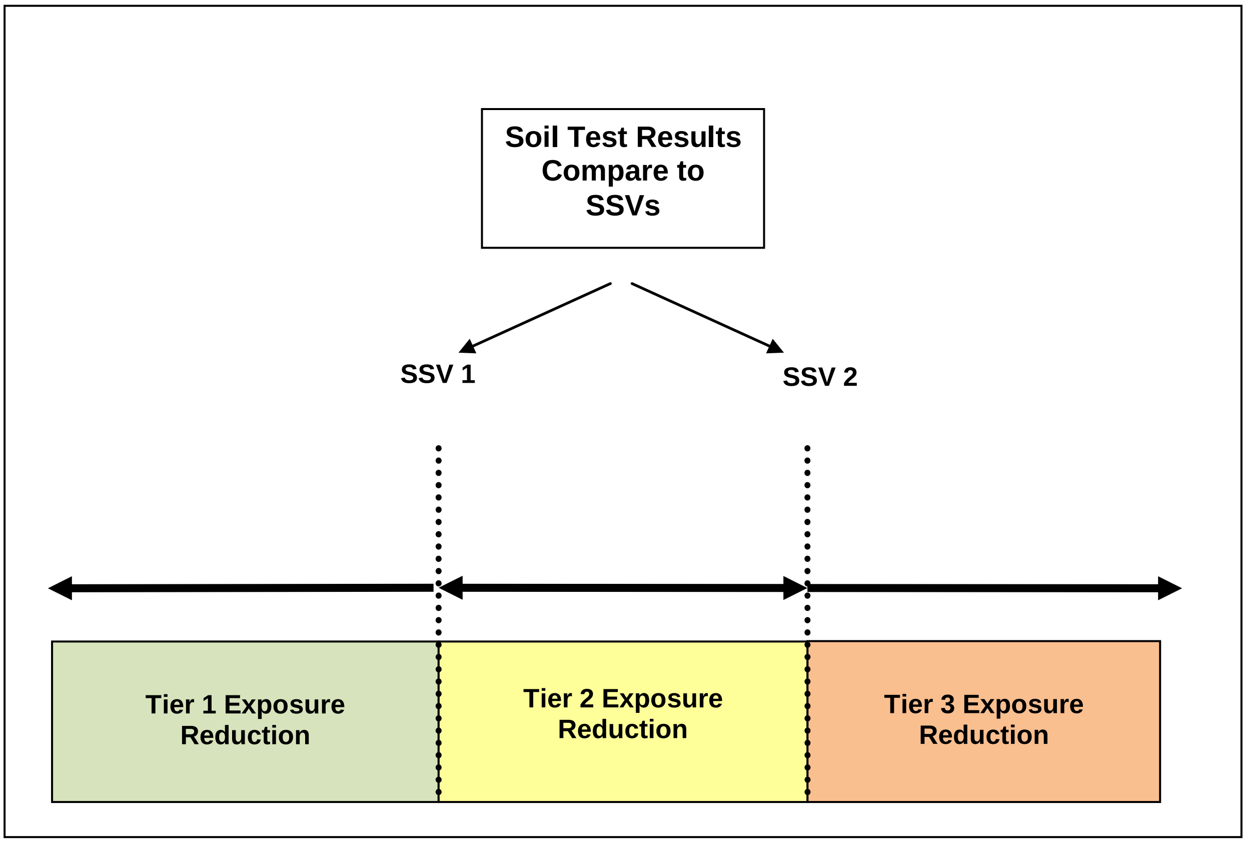
| | Soil Screening Value (SSV) | |
|---|---|---|
| Metals | **SSV 1** | **SSV 2** |
| Arsenic | 11 | 110 |
| Cadmium | 1.0 | 10 |
| Cobalt | 23 | 170 |
| Chromium, total | 390 | 630 |
| Chromium, VI | 5.0 | [b] |
| Copper | 180 | 660 |
| Mercury | 2.7 | [b] |
| Molybdenum | 13 | [b] |
| Nickel | 34 | 340 |
| Lead | 34 | 340 |
| Selenium | 10 | 11 |
| Zinc | 500 | 1800 |
| PAHs | | |
| Acenaphthene | 0.050 | 0.32 |
| Acenaphthylene | 0.093 | 0.47 |
| Anthracene | 0.58 | 0.58 |
| Benz(a)anthracene | 0.23 | 2.3 |
| Benzo(a)pyrene | 2.3 | 3 |
| Benzo(b)fluoranthene | 0.23 | 2.3 |
| Benzo(g,h,i)perylene | 0.10 | 1.0 |
| Benzo(k)fluoranthene | 0.23 | 2.3 |
| Chrysene | 0.099 | 0.99 |
| Dibenz(a,h)anthracene | 0.77 | [b] |
| Fluoranthene | 0.14 | 1.4 |
| Fluorene | 0.39 | [b] |
| Indeno(1,2,3-c,d)pyrene | 0.23 | 2.3 |
| Phenanthrene | 3.1 | [b] |
| Pyrene | 0.11 | 1.1 |

b Only Level 1 SSV was derived for this parameter. The human health component value of this SSV is higher than 10 times urban background – the maximum value allowed in the guidance. Thus, the only SSV for this parameter is based on 10 times urban background.

The SSVs define the three risk levels, and are used to interpret the soil test data as follows (Figure 2-3):

- If the concentrations of *all of the COCs* are below the respective SSV 1, then the site requires Tier 1 Exposure Reduction;
- If the concentration of *any COC* is above the SSV 1 but does not exceed the SSV 2, then the site requires Tier 2 Exposure Reduction; or,
- If the concentration of *any COC* is above the SSV 2, then the site requires Tier 3 Exposure Reduction.

**Figure 2-3: Determining the Risk Level for the garden by comparing the soil concentrations to the SSVs**




## Step 4: Mitigate the Risks

There are many simple and inexpensive actions gardeners can easily take to reduce their exposure to urban soil contaminants depending on the risk level for the site. Table 2-4 summarizes the recommended exposure reduction measures for the gardens that are required for Tier 1, 2 or 3 Exposure Reduction.

**Table 2-4: Recommended Actions to Reduce Gardeners' Exposures to Soil Contaminants**

| Risk Level | Recommended Actions |
|---|---|
| **Tier 1 Exposure Reduction** | **Use good gardening practices:**<br>• Wash hands after gardening and particularly before eating; and<br>• Wash produce with soap and water. |
| **Tier 2 Exposure Reduction** | Use good gardening practices (see above); and,<br>**Reduce exposure pathways:**<br>• Dilute soil concentrations by adding clean soil and organic matter (compost and manure);<br>• Lower bioavailability of contaminants by adding organic matter and raising pH;<br>• Reduce dust by covering bare soil with ground cover or mulch;<br>• Peel root vegetables before eating or cooking; and,<br>• Avoid or restrict growing produce that accumulate contaminants. |
| **Tier 3 Exposure Reduction** | Use good gardening practices (see above); and,<br>• Reduce dust by covering bare soil surrounding the garden with ground cover or mulch; and,<br><br>**Eliminate exposure pathways:**<br>• Build raised bed gardens (minimum of 40 cm over a landscape fabric), or use container gardens, and,<br>• Add clean soil and organic matter annually (compost and manure).<br>OR<br>• Grow only nut and fruit trees (do not grow other types of produce). |

Table 2-5 provides recommendations for avoid or restricting growing produce that accumulate contaminants. The information in Table 2-5 is based on a phytoremediation database developed by Environment Canada in 1999 (summarized in Appendix C). There are many gaps in this research, thus, we use a precautionary approach by recommending the avoidance or restriction to raised bed gardens produce that has been demonstrated to bioaccumulate soil contaminants. Tier 2 Exposure Reduction measures significantly reduce the concentration and bioavailability of soil contaminants over time. Thus, after two years of implementing the Tier 2 Exposure Reduction measures, soil should be considered for retesting and if the soil concentrations meet SSV 1, restrictions on bioaccumulating produce can be lifted.

**Table 2-5: Advice for Bioaccumulating Produce for Gardens in Tier 2 Exposure Reduction Sites**

| Eat Whole Plant[a] | Eat Part of the Plant[b] | Do not Eat the Plant or Grow Plant in Clean Soil[c] |
|---|---|---|
| All garden plants not listed in *Eat Part of the Plant* or *Do Not Eat Plant or Grow Plant in Clean Soil*. | Tomato (Cd, Pb)<br>Corn (Cd, Cu, Pb, Ni, Zn)<br>Barley (Zn)<br>Oat (Cd, Pb, Ni)<br>Rice (Cd, Zn)<br>Rye (Pb)<br>Soybean (Cd, Zn)<br>Sunflower (Pb)<br>Wheat (Cd, Pb) | Alfalfa (Cd, Cr, Cu, Pb, Ni, Zn)<br>Amaranth (Cu, Pb)<br>Brassicas (cabbage, cauliflower, broccoli, brussel sprouts, kale, kohlrabi, mustard greens, rape, turnip) (Cd, Cr, Cu, Pb, Ni, Zn)<br>Beet (As, Pb)<br>Carrot (Cd)<br>Chicory (Cd)<br>Dandelion (Cd, Cu, Pb, Ni, Zn)<br>Endive (Pb, Zn)<br>Garden Pea (Cd, Pb, Ni)<br>Lettuce (Cd)<br>Radish (Cd, Ni)<br>Rice, wild (Cr, Pb)<br>Sorghum (Pb)<br>Sorrel (Pb)<br>Spinach (Cd, Pb) |
| **Recommendation:**<br>Use Good Gardening Practices - Wash produce with soap and water. | **Recommendation:**<br>Restrict consumption of plant to edible portion of the plant.<br><br>Follow Tier 2 Exposure Reduction actions to reduce the concentration and bioavailability of the soil contaminant. | **Recommendation:**<br>Avoid growing these garden plants in site soil.<br><br>OR<br><br>Grow these garden plants in raised beds or containers. |

a There are no studies available. Assume negligible risk of bioaccumulation.
b Available research demonstrates that these plants can bioaccumulate soil contaminants but <u>not</u> in the edible tissue of the plant (for the soil contaminant in brackets).
c Available research demonstrates that there is a risk of bioaccumulation of soil contaminant(s) into the edible tissue of the plant (for the soil contaminant in brackets).

## Existing Gardens

Through regular gardening practices gardeners already do many of the activities outlined in Tier 1 and 2 Exposure Reduction risk levels. For example, gardeners add soil and organic matter to their gardens on an annual basis to improve the yield of their garden. These behaviours, year after year, result in a reduction in both the concentration and bioavailability of soil contaminants. In addition, gardeners turn over their soil at least twice a year, aerating their soils and exposing deeper soil to sunlight (two mechanisms to degrade and reduce organic soil contaminants). These practices over many years significantly reduce the concentration and the bioavailability of soil contaminants.

Existing gardens on lands that are in the Low Concern category should continue to use Tier 1 Exposure Reduction measures. Existing gardens in the Medium Concern category should use

Tier 2 Exposure Reduction measures, with the exception of avoid or restrict growing produce. There is no need to test the soils. Existing gardens in the High Concern category should follow the soil testing indicated for Medium Concern sites.

# 3.0 Pilot Study of the proposed Urban Gardening Soil Assessment Guide

In the fall of 2009, PF&R, in collaboration with TPH and the TEO, assessed the feasibility of the soil sampling and analysis aspects of the proposed soil assessment guide. This was done by applying the proposed guide to five planned community and allotment gardens.

The objectives of this pilot study were to explore the feasibility of the proposed guide, in terms of a) ease of execution for City staff, and b) whether soils from various locations in the City could meet the proposed Soil Screening Values.

PF& R staff followed the soil sampling steps outlined in the draft guide:

**Step 1:** Based on the current and historical land uses, the sites had low to medium concern levels.

**Step 2:** PF&R staff took composite soil samples from each of the five sites (0-40 cm depth). Staff used a shovel to collect individual samples, a bucket to mix the soil, and a large sealable plastic bags to contain the composite samples.

The samples were sent to a laboratory for analysis for the list of chemicals, plus additional chemicals, which included:

- Metals[20];
- PAHs[21];
- Semi-volatile organic compounds (SVOCs)[22]; and,
- Organochlorinated (OC) pesticides and PCBs[23].

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[20] Antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel selenium, silver, thallium, vanadium, zinc, mercury.

[21] Acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorine, indeno(1,2,3-c,d) pyrene, phenanthrene, pyrene.

[22] 2,4,6-tribromophenol, 2-fluorobiphenyl, 2-flurophenol, D14-terphyl, D5-nitorbenzene, D5-phenol, 1-methylnaphthalene, 2,4,5-trichlorophenol, 2,4,6-trichorophenol, 2,4-dichlorophenol, 2, 4-dimethylphenol, 2,4-dinitrophenol, 2,4-dinitrotoluene, 2-chlorophenol, 2-methylnaphthalene, bis(2-chloroethyl)ether, bis(2-chloroisopropyl)ether, bis(2-ethylhexyl)phthalate, p-chloroaniline, pentachlorophenol, phenol.

**Step 3:** The soil analytical results were screened against the SSVs. All five of the gardens met the Level 1 SSVs, thus were characterized as Level 1 Exposure Reduction sites.

Table 3-1 provides a summary of the results of the guide for these sites.

**Table 3-1: Results of the Pilot Study of the soil assessment guide**

| Park | Garden Type | Current Land Use | Period of Original Land Development[24] and Historical Land Use[25] | Level of Concern | Exposure Reduction Tier |
|---|---|---|---|---|---|
| **Daventry** | Proposed expansion Allotment | Hydro corridor | 1961-1979 Residential | **Medium** | **Tier 1** |
| **Thorncliffe Garden** | Proposed expansion of Community | Parkland | 1940-1960 Commercial /industrial | **Medium** | **Tier 1** |
| **Panaroma Park** | New Community | Parkland | 1967-1975 Hospital; commercial | **Medium** | **Tier 1** |
| **Scarlett Mills Park** | New Community | Parkland | 1961-1975 Residential | **Low** | **Tier 1** |
| **Scarlett/Foxwell** | New Community | Hydro corridor | 1901-2003 Residential | **Medium** | **Tier 1** |

[23] 2,4,5,6,-tetrachloro-m-xylene, decachlorobiphenyl, hexachlorobutadiene, aldrin, a-chlorodane, g-chlorodane, o,p-DDD, p,p-DDD, o,p-DDE, p,p-DDE, o,p-DDT, p,p-DDT, dieldrin, endosulfan I, endosulfan II, endrin, heptachlor, , heptachlor epoxide, hexachlorobenzene, lindane, methoxychlor, total PCBs, Aroclors (1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, 1268).

[24] For the address or intersection and immediate vicinity. For some sites the land use could not be determined because the address did not exist. Therefore, the land use was interpolated from the immediate vicinity of the site. Source: Toronto Archives.

[25] Historical land uses were researched at the Toronto Archives by TPH staff in February 2010. The following sources of information were searched by address and/or intersection:

1. 1961 Toronto City Directory (includes all amalgamated cities not considered in the City of Toronto);
2. 1981-82 Metropolitan Toronto City Directory (included York County, Cities of Toronto, North York, Boroughs of East York, Etobicoke, Scarborough); and,
3. 2000 Toronto-Scarborough Criss Cross Directory (also Toronto Central; East York; North York; Central West York).

### Lessons Learned

Through this pilot project, TPH determined that the draft urban gardening soil assessment guide met the feasibility objectives: City staff could easily follow the guide, and the SSVs were achievable for the urban gardens. We also learned that SVOCs volatilize into the air when the soil is disturbed. Thus, SVOCs required specialized equipment and expertise to sample. We also confirmed what the literature review had indicated – that OC pesticides and PCBs residues are not of concern as soil contaminants when the site history indicates there is no potential source.

# 4.0 Discussion

The site screening, soil sampling and risk mitigation portions of TPH’s soil assessment guide draw on the existing soil assessment guidance and the soil quality guidelines from other jurisdictions. The result is a decision support tool that includes detailed site screening advice, soil sampling guidance and a flexible risk mitigation approach developed specifically for urban gardening.

*Worst-case* scenarios are often used to assess the potential for an event, activity, or exposure to cause harm. Worse-case scenarios assume the maximum level of exposure and toxicology for all aspects of the risk assessment. The advantage of this approach is the high level of confidence that the risks are not underestimated. Another advantage of this approach is that decisions can be made despite an incomplete dataset and a high level of uncertainty about exposures and toxicity.

The disadvantage of a worst-case scenario is that it grossly over-estimates risks, and in some circumstances suggests the need for more extensive and expensive measures than is really necessary to protect health.

Typically worst-case scenarios are used in multi-stage processes where additional sampling, analysis and research are used to further characterize any risks predicted at earlier stage(s). However, urban gardeners often do not have the resources to gather and interpret extensive datasets. Thus, assessments for urban gardens that are based on worst-case scenarios will typically not proceed to more detailed assessment, and risk management decisions will be made based on the assessment of the worst-case scenario. The result may be unnecessary restrictions that are unnecessarily costly, and could deter beneficial and healthy behaviours.

We incorporated consideration of the benefits of urban gardening into a risk assessment approach by developing a *reasonable* worst-case scenario. Significant professional judgement is used when applying precaution to address uncertainties.

We therefore opted to use more realistic values for parameters used in the guide (e.g., depth of soil sample) and the derivation of the Soil Screening Values to develop a reasonable worst-case urban gardening scenario. This reduces the need for further study. We have summarized the parameters along with an analysis of the impact of each parameter on the risk characterization (see Table 4-1).

**Table 4-1: Addressing Uncertainty, Assumptions and the Effect on the Risk Characterization**

| Parameter in the Guide and Derivation of the SSVs | Rationale | Impact on Risk Characterization |
|---|---|---|
| Composite soil samples used to establish soil concentrations | Soil is highly heterogeneous, and will be thoroughly mixed during garden creation and maintenance; composite sample mimics gardeners behaviour (Standard practice) | Best estimate |
| Minimum list of contaminants of concern (metals and PAHs) for medium concern sites. Additional COCs may be selected in consultation with environmental professionals, based on site history and site visit or the site can be risk managed (Level 3 Exposure Reduction). | Typical contaminants in urban soils, based on literature review and Toronto specific data | Best estimate |
| Soil sampling at depth of 0-40 cm | Various ranges of sampling depths are described in the literature. 0-40 cm includes the tillage depth and the rooting zones of most crops, and accounts for the entire horizon of exposure. | Best estimate |
| SSVs derived by TPH used to interpret soil concentrations | SSV is more health protective than the MOE soil standards as the SSVs account for increased exposure due to produce consumption. SSV eliminates irrelevant considerations (i.e. exposure via indoor dust and ground water consumption). | Best estimate |
| Multi-media exposures accounted for -- exposures to soil from the urban garden are assumed to be 10% of total daily exposure from all media | In the derivation of the SSVs, water, air, food, and consumer products were each assumed to account for 20% of total exposure (standard practice[a]). It was assumed that urban gardening would partially replace other soil contact activities, and half of the portion for soil (i.e., 20/2 = 10%) was allocated to the specific soil-contact activity of urban gardening. | Variable and unknown. Site-, receptor- and chemical-specific. More precautionary than general practice in risk assessment. Assumed to be an overestimate for most chemicals. |
| Consumption of garden produce in addition to supermarket foods (Toddler and adult eating produce from garden + 100% of diet from super market (i.e., full 20% of total intake allocated to supermarket foods)) | Exposure via consumption of garden produce was not quantitatively estimated, but was assumed to be four times exposure via soil ingestion.[b] | Variable and unknown. Site-, receptor- and chemical-specific. More precautionary than general practice in risk assessment. Assumed to be an overestimate for most chemicals. Appendix D for an evaluation of the health protection of this assumption using Toronto-specific data. |

| Parameter in the Guide and Derivation of the SSVs | Rationale | Impact on Risk Characterization |
|---|---|---|
| De minimis cancer risk level: 1/million | TPH policy | Health protective |
| Ingestion, dermal and inhalation exposure pathways considered (The lowest or most protective value of the combined ingestion/dermal and inhalation exposure pathways is used to derive the screening value. They are not cumulative.) | Standard practice in risk assessment. | Variable and unknown. |
| Relative absorption factors (Estimate of bioavailability) | 50 – 100% for oral[a]<br>10 – 100% for dermal[a]<br>100 % for inhalation[a] | Variable and unknown. Site-, receptor- and chemical-specific. More precautionary than general practice in risk assessment. Assumed to be an overestimate for most chemicals. |
| Soil ingestion rate for toddler | 100 mg/day[a] | Best estimate of soil-only ingestion. Does not account for pica behaviour in a child (child intentionally eats soil). |
| Soil ingestion rate for adult | 100 mg/day[a] | Likely an over estimate. Assumes that gardeners have the same high level of soil contact as outdoor and subsurface workers. |
| Toddler body weight | 16.5 (36 lbs)[a, c] | Central tendency |
| Female adult body weight | Non – cancer<br>63.1 kg (140 lbs)[a]<br><br>Cancer<br>56.8 kg (125 lbs) (composite receptor body weight)[a] | Central tendency |
| Generation of respirable dust while gardening | 100 μg/m$^3$ PM dust; 60% deposited[a] | Best estimate. Assumes that gardeners have the same high level of soil contact as MOE's estimate for subsurface workers. |
| Toddler inhalation rate | 1.1 m$^3$/h<br>(Standard risk assessment practice) | Central tendency. The selected value is intended for shorter exposure durations than it is used for here. However, the alternatives are either hyper-conservative or not conservative at all. |
| Toddler exposure frequency | 5 h/d, 2 d/w, 6 m/y (= 260 h/y)<br>(Standard assumptions in risk assessment methodology with input | Over estimate of risk. |

| Parameter in the Guide and Derivation of the SSVs | Rationale | Impact on Risk Characterization |
|---|---|---|
| | from Toronto gardeners) | |
| Adult female exposure frequency | 5 h/d, 5 d/w, 6 m/y (= 545 h/y) (Standard assumptions in risk assessment methodology with input from Toronto gardeners) | Over estimate of risk. Assumes a female adult is exposed 6 months a year, every year for 75.5 years. |
| Assumption that gardener is exposed for a lifetime | 75.5 years (Standard risk assessment practice.) | Over estimate of risk |
| Adult female inhalation rate | 1.5 $m^3/h$ [a] | Over estimate of risk |
| Dermal exposure skin exposed | 1958, 4438 and 4130 $cm^2$ for toddler, adult female and composite, respectively. (Based on data for summer and spring/fall.) [a] | Large over estimate of risk |
| **Interpretation of assumptions used to address uncertainty and total affect on the level of conservatism of the risk characterization = URBAN GARDENING REASONABLE WORST CASE SCENARIO** | | |

a Source: MOE, 2009
b Source: NY DEC and NY DOH, 2006
c Source: HC, 2004

In the planning phases of this initiative, we developed key aims for this initiative. The aims of the guide were to:

1. **Provide a decision support tool that encourages safe urban food production while minimizing unnecessary soil assessment and risk mitigation**

We developed guidance on how to determine a Level of Concern, and developing a short list of COCs to provide an appropriate scope for urban gardening soil assessments. The approach is designed to be health-protective while not over-estimating risks. Use of the decision-support tool can provide confidence that food production on the site will not result in increased exposures to soil contaminants, and at the same time minimizing unnecessary soil assessment and risk mitigation.

2. **Provide a decision support tool that addresses the questions, concerns and needs of communities as they relate to soil contaminants and urban gardening**

We created a decision support tool that relates specifically to COCs in urban impacts soils, and specifically to urban gardening (including consumption of urban produce). We ensured that our literature review included key areas of concern of our stakeholders, for example, contaminant uptake into garden produce and the impacts of air pollution from vehicle exhaust.

3. **Develop a tool that is easily understood and relatively inexpensive to use**

We developed a tool that provides a comprehensive reference for all concerns about gardening in urban impacted soils. By establishing Level of Concern, we developed a method that identifies only those sites for which soil sampling is necessary. For High Concern sites, we think that resources available are best directed to risk mitigation, rather than to soil sampling and analysis. Moreover, we developed a tool that is specific to urban gardening. This is an advantage over using the existing soil sampling and soil standards because additional sampling and analysis are not required to achieve confidence in the risk estimate.

4. **Develop a tool that is transparent and flexible, so that risk management decisions can be tailored to the specific risks at the site and the needs of the urban gardeners**

We developed SSVs specific to urban gardening, eliminating all other considerations that generic soil standards include. We also provided information on the level of uncertainty in the assumptions of the guide, and the resulting impacts the risk characterization. We also provide a list of produce that bioaccumulate specific COCs. This gives guidance to gardeners on suitable crops they can grow without prohibiting gardening activities.

# 5. Next Steps

The development of the Urban Gardening Soil Assessment Guide is a step forward in the efforts to increase food production in the City of Toronto. We have identified a number of key next steps.

1. **Develop Outreach and Educational Materials**

- Consult with PF& R staff to develop procedures and materials that meet their needs;
- Consult with urban gardeners in Toronto to ensure guidance and materials meet their needs and integrate local knowledge;
- Develop clear language guidance materials (including a check list for the site visit and site history steps, sampling the soil, sending samples to a laboratory, etc.) that meets the needs of diverse audiences; and,
- Promote the guide at workshops, through LiveGreen and Food Animators, and conduct train-the-trainer sessions.

2. **Evaluate the Urban Gardening Soil Assessment Guide**

    - Evaluate the guide, and assess the need for additional or revised resources and tools to meet the needs of at-risk groups (i.e., newcomers, low income, racialized communities).

3. **Update Guide and Supporting Information on Regular Basis**

    - Regularly update the guide by integrating current science, experience, needs and concerns of Toronto gardeners and City staff to ensure guide reflects evolving knowledge and needs of urban gardeners.

# References


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# Appendix A – Summary of the Process to Develop The Urban Gardening Soil Assessment Guide

## The Overall Process

Toronto Public Health followed the model developed by the National Collaborating Centre for Tools and Method for evidence-informed decision-making in public health[26]. Table A-1 summarizes the types, examples, and sources of evidence that were used to develop the Urban Gardening Soil Assessment Guide.

**Table A-1: Types, examples, and sources of evidence used to inform the development of the urban gardening soil assessment guide**

| Types of Evidence | Examples relevant to Urban Gardening | Source of Evidence |
|---|---|---|
| Research | • Scientific literature from a variety of disciplines on:<br>- Urban soil contaminants,<br>- Uptake into produce<br>- Assessments of risk and benefits of urban gardening<br>- Methods of soil sampling and analysis | • Literature reviews of primary and secondary sources<br>• International jurisdiction scan for guidance of soil sampling, testing, analysis and interpretation for urban gardening<br>• Peer Review by experts in soil science, agriculture, public health, risk assessment and risk mitigation |
| Local community health knowledge and perspectives | • Local data on soil contaminants and risks<br>• Health and food security needs of at risk populations in Toronto<br>• Gardening behaviour of local gardeners | • Scan of City of Toronto data on soil contaminants<br>• Toronto Public Health Food Strategy consultation process (2009-2010)<br>• Dialogue with local urban gardeners |
| Local community preferences | • Needs and interest of community members<br>• Support or opposition of urban gardening or soil testing<br>• Risk perceptions and risk tolerance of gardening community | • Continuing dialogue with local urban gardeners |
| Local public health resources | • Human resources<br>• Costs<br>• Willingness to pay for soil sampling and risk mitigation | • Consultation with City of Toronto divisional staff, management, and City Legal<br>• Costs of soil sampling and testing and various risk mitigation measures |

[26] Available at: *www.ccnmo.ca*

We conducted a series of literature reviews, contacted experts[27] and accessed the expertise and resources of City personnel. The following sections provide a brief summary of the literature review strategy and stakeholder consultations conducted to date.

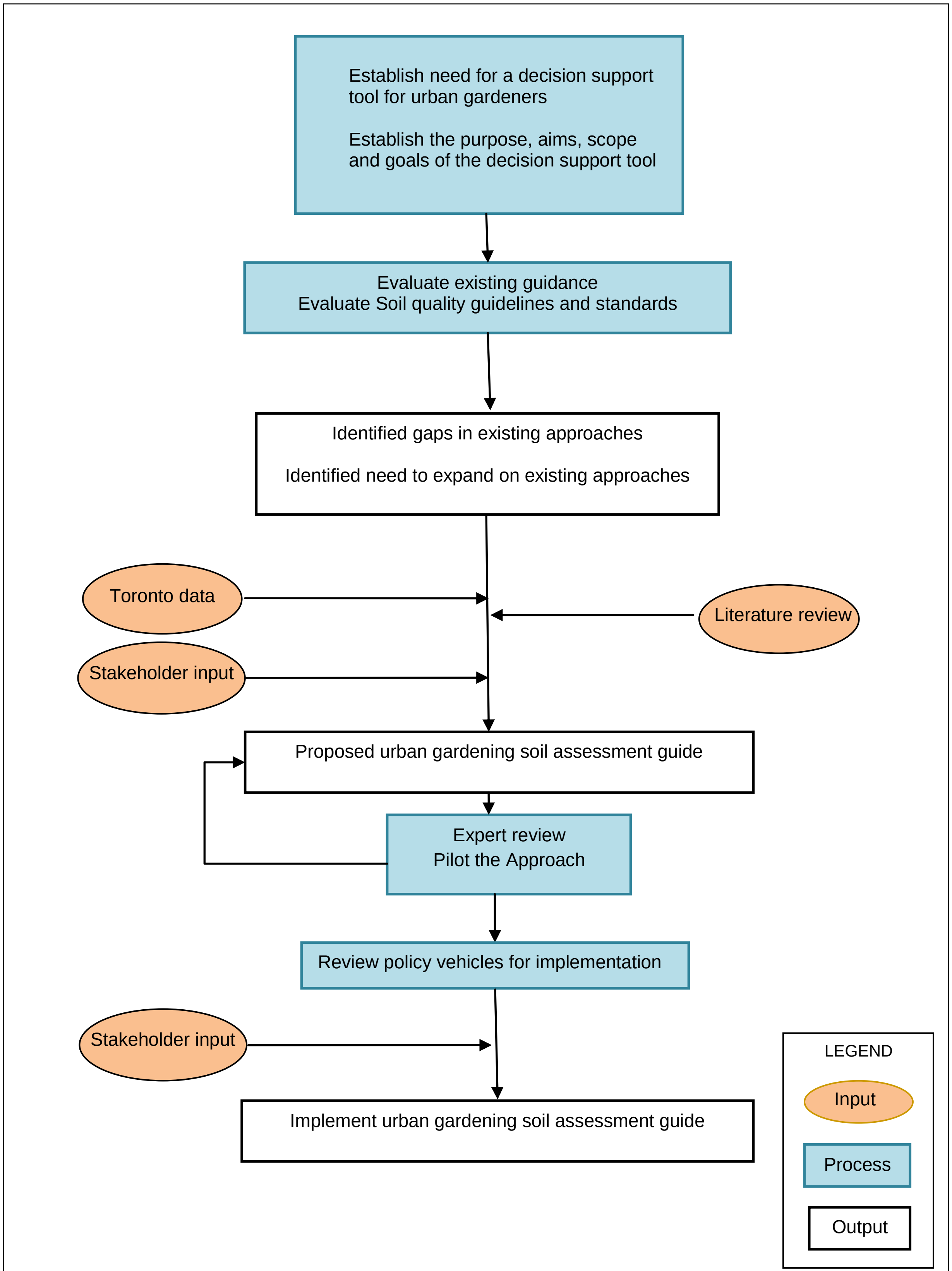
Appendix B describes our review of existing soil screening guidance for urban agriculture, their basis and our evaluation of their suitability for use in Toronto.

Appendix C provides the evidence we identified to shape each Step of the Urban Gardening Soil Assessment Guide.

Appendix D provides the details of our search for existing soil screening standards or guidelines; and, ultimately, our derivation of Toronto Public Health's Soil Screening Values (SSVs) based on the Ontario Ministry of the Environment's formulae for calculating Site Condition Standards, and a method from New York State for qualitatively accounting for the vegetable consumption exposure pathway.

[27] Knowledge leaders, gardeners, academics, other levels of government, City of Toronto staff

**Figure A-2: Process used by Toronto Public Health to develop the Urban Gardening Soil Assessment Guide**



## Stakeholder Consultation

In the winter of 2009, colleagues from local public health units, the Ontario Ministry of Agriculture, Food and Rural Affairs, Ontario Ministry of the Environment, Agriculture and Agri-Food Canada, Health Canada were contacted via email and asked whether they had guidance that could be used to assess soils for use in urban gardening. Colleagues were also asked whether the assumptions that underlie the available standards are appropriate for urban gardening. Colleagues agreed that there were no standards or guidance available for the assessment of urban garden soils and produce consumption and that the development of guidance would be helpful.

An urban gardening workshop was held at the University of Toronto in April 2010. We presented our preliminary approach to stakeholders, and received feedback on the approach. That feedback was incorporated into subsequent drafts of the Urban Gardening Soil Assessment Guide.

The guide was internally reviewed by City staff and peer reviewed by experts in soil science, agriculture, policy development, public health, toxicology, risk assessment and risk management. The valuable comments and insights from our reviewers were integrated into the guide. Documentation of the reviewers' comments and our responses is available upon request.

Ministry of the Environment staff were consulted on intersection between the Urban Gardening Soil Assessment Guide and the Ontario Brownfields Regulation 0.Reg 154/04.

A small group of urban gardening and food security community leaders were consulted on the general approach of the guide in March of 2011. Their feedback was integrated into the approach.

## Literature Search Strategy

The literature was searched for relevant information on urban gardening. We endeavoured to answer the following questions:

1. What are the sources and potential contaminants of concern in Toronto soils to consider in developing an Urban Gardening Soil Assessment Guide?

2. Are there existing protocols or guidance on assessing urban soils for urban gardening in other jurisdictions to adopt or adapt for use in Toronto?

3. What are the factors to consider when assessing uptake into produce?

A comprehensive, systematic review of the literature was outside of the scope of this initiative. Instead of conducting reviews on each of these subject areas, we conducted a literature review on urban gardening/agriculture and used this literature base to identify the key information sources. Abstracts were reviewed for relevance and relevant articles were retrieved.

Two strategies were used: first, a search of the electronically available information was used to find secondary sources and grey literature from government, public health, and non-governmental organizations. Second, a review of the scientific literature was conducted. Scientific journals on environmental sciences, engineering, public health, agriculture, earth sciences were accessed.

The following search terms were used for both search strategies: “urban", "garden", "horticulture", "farming", "community garden", "risk", agriculture”, "health", "metal", "soil", "contaminant".

# Appendix B – Review and Evaluation of Existing Urban Gardening Soil Assessment Guidance

Toronto Public Health (TPH) saw a need for a soil assessment decision support tool to provide guidance and support to community gardeners producing food on potentially contaminated land. Given the health benefits that are associated with urban gardening, any urban gardening soil assessment guide for Toronto must consider these benefits along with the risks of exposure to soil contamination.

TPH consulted with stakeholders and searched the literature for existing soil assessment protocols for urban gardening. We define a soil assessment protocol as guidance on soil sampling, analysis, and interpretation, all specifically targeted for urban gardening. We also searched for evaluations of the protocols' effectiveness that would inform our evaluation of the protocols and enable us to better judge which protocol to adopt or adapt for use in Toronto. The results of these literature searches are summarized below.

# Canadian Protocols

Our literature search identified several partial protocols from Canadian agencies (e.g., Niagara Region (2005); McGill University [Heinegg et al., 2002]; Ecology Action Centre). These protocols recommend soil testing when soil contamination is suspected at potential garden sites, but do not provide instructions on how to sample or how to interpret the soil concentrations.[28] A complete protocol was identified from the City of Montreal. It is discussed in detail below.

The partial protocols we identified also frequently point out aspects of the site history that are cause for a higher level of concern, and further investigation. For example, the Niagara Region Public Health Department (2005) suggests soil sampling for gardens located in the yards of older homes, on former industrial or commercial lands, or within 30 m of major roadways.

## Community Garden Protocol from the City of Montreal

In 2005, the City of Montreal developed a soil sampling, analysis and interpretation protocol for all new community and allotment gardens on public lands (Beausoleil, M. pers comm., 2010; Beausoleil and Price, 2008a, b).[29] The protocol specifies that one composite sample of the

[28] We also found several sets of soil quality guidelines and standards, with accompanying protocols for the evaluation of brownfields. (brownfields are vacant, underutilized lands that are often contaminated by old industrial activity or dumping of hazardous waste.) Financial and technical resources are not available for the urban gardening community to apply these protocols. Moreover, the level of complexity of these protocols is unnecessary to assess soils for use in urban gardening.

[29] The Montreal protocol does not apply to gardens on private land (Beausoleil, M. pers comm., 2011). Home owners planning new gardens are advised not to test their soil, and to mitigate the potential health risks. The reason provided was that the size of the garden makes the risk mitigation cost effective. Residents with existing gardens are

surface soil be taken for every 30 allotment plots. Surface soil is sampled with an auger to the full depth of the topsoil (up to 40 cm). In addition, one sample of the deeper soil is taken for every 400 to 1,600 $m^2$. Deeper soil is sampled with a backhoe at depths of up to 3 metres. The soil samples are tested for metals, polycyclic aromatic hydrocarbons (PAHs), and petroleum hydrocarbons.

Interpretation of the soil test results is provided by Agence de la Santé et des Services Sociaux de Montréal. The soil samples are compared to background levels of contaminants in the soil for Quebec; provincial soil quality standards for residential, commercial and industrial land use; and finally, the Quebec hazardous waste regulations for soils. Agence de la Santé et des Services Sociaux de Montréal tested produce taken from gardens that had exceeded the provincial soil quality standards for residential land use. None of the produce sampled were found to have levels of contaminants above levels in supermarket produce (Beausoleil, M. pers comm. 2010).

If the soil samples exceed any of the guidelines, Agence de la Santé et des Services Sociaux de Montréal provides advice to the City of Montreal on appropriate risk mitigation measures. Their advice takes both the risks and benefits of urban gardening into account, and can include: remediation with clean soil, restrictions on growing vegetables and other edible produce, and raised bed or container gardening. To date, Agence de la Santé et des Services Sociaux de Montréal has not recommended that any gardens be closed. To date, four gardens have been remediated with clean soil and raised bed gardens have been installed in three other gardens (Beausoleil, M. pers comm. 2010). The protocol is expensive for the City of Montreal to implement, with soil sampling and analysis costing approximately $10,000 per garden (Beausoleil, M. pers comm., 2010).

# International Protocols

## United States (US)

### US Environmental Protection Agency

In the US, the EPA (2009) supports redevelopment of brownfields as community gardens. They suggest that communities conduct environmental site assessments[30] of potential garden sites located on brownfields, and that communities remediate their sites, as needed, to ensure that food production is safe.

Environmental site assessment can be far more complex than a simple site screening, and particularly when combined with remediation, it can require significant expertise and financial

advised that the risk of consuming home grown produce is most likely low, and to continue gardening while implementing mitigation measures. Specifically, the recommended mitigation for new residential gardens is to remove 1 foot of topsoil, apply a geotextile barrier and replace the topsoil that was removed with new soil. For existing residential gardens, the recommended mitigation is to add soil and compost to the plot, and/or consider raised bed gardening.

[30] The US EPA suggests that communities do a Phase I (review of historical uses of the site, interviews with neighbours, and visual inspection) and Phase II (additional site review, sampling and analysis of soil samples) assessments of the prospective site.

investment, which may not be available to community groups. This represents a significant barrier to the creation of new community gardens on Brownfield sites in the US.

Many American universities provide guidance on soil assessment for urban agriculture. Information available from the University of Minnesota and from the Cornell Waste Management Institute provide examples of the range of detail and completeness to be found in soil assessment protocols from American universities.

## University of Minnesota

The University of Minnesota provides a complete protocol for one element only: lead (Rosen, 2002). The protocol provides recommendations for gardeners who are concerned about lead levels in their gardens and wish to test the soil. Rosen (2002) recommends that between 6 and 12 subsamples should be taken from the top 3 to 4 inches of garden soil, and combined to make one composite sample. Samples may be analysed for lead content by any testing laboratory. According to Rosen (2002), soils with lead content up to 100 ppm can be used for gardening where there is a possibility that children will be exposed to bare soil. Where there is no possibility that children will be exposed to bare soil, lead levels up to 300 ppm are acceptable for gardening. The protocol also includes advice on:

- Washing, trimming and peeling produce to remove lead from surfaces;
- Precautions for garden soils to minimize uptake of lead into produce, including include maintaining soil pH above 6.5, adding organic matter and locating gardens away from busy streets and old buildings; and,
- Remediation of lead-contaminated soils, including immobilizing the lead in soils by raising the pH, adding organic matter and covering the soil with sod, diluting or covering contaminated soil with clean soil, or removing the contaminated soil.

## Cornell University

The Cornell Waste Management Institute of Cornell University provides guidance on soil contamination, soil testing and best practices for healthy gardens related to soil contamination in a series of fact sheets (Shayler et al., 2009a, b, c). For garden soil, Cornell recommends that the top six inches be sampled from five to ten locations within a garden area up to 100 square feet in size and composited into one sample for analysis (Shayler, et al., 2009a).

The guidance from Cornell states that there is no single standard that defines acceptable levels of contaminants in soils (Shayler et al., 2009a). They cite New York State's Soil Cleanup Objectives and the US EPA's Soil Screening Levels. However, Shayler et al. (2009a) note that both sets of values are intended for land uses other than urban gardening, and that exceedance of any of the values is intended to trigger further investigation. Urban gardeners do not have the resources to embark on investigations that require extensive follow up and additional soil sampling.

The guidance from Cornell also includes advice on best practices to manage soil contamination in vegetable gardens (Shayler et al., 2009b). The recommended best practices include: amending the existing soil with clean materials, increasing the soil pH to near neutral, mulching walkways, avoiding growing food crops adjacent to buildings, growing food crops in raised beds filled with clean soil, and growing food plants that are less likely to be contaminated. However, Shayler et al. (2009b) also recommend that gardeners first consider whether the best practices can sufficiently reduce exposure to soil contamination. Growing ornamental rather than food plants is recommended as a last resort.

## United Kingdom (UK)

As part of the Contaminated Land Exposure Assessment (CLEA) project, the Environment Agency in the UK is developing tools to provide a government supported methodology to estimate the risks from contaminants in soil (EA, 2009). Although not the sole intent of the program, CLEA provides a partial soil assessment protocol for urban agriculture. The soil guideline values (SGVs), calculated using the CLEA model, provide a means of interpreting soil contaminant levels in urban gardens. The CLEA project documentation provides little guidance on sampling, and none on risk management.

The SGVs are estimates of the level of soil contamination below which the human health risks for a given land use are considered minimal. The allotment land use scenario that is used in the CLEA model is based on common urban agriculture practices in the UK. The SGVs are trigger values, in that an exceedance of the applicable SGV indicates that further investigation is required to make a more precise evaluation of risk. The CLEA model uses biotransfer factors to estimate contaminant uptake into produce.

# Discussion

We assessed each of the existing protocols against the goals, objectives and principles established for our decision support tool for urban gardening. We concluded that none of the approaches from other jurisdictions would meet all of the objectives. However, elements of several could be adapted to create an urban gardening soil assessment protocol suitable for Toronto. Specifically, we adapted:

- The methods for Brownfields risk assessment developed by the Ontario Ministry of the Environment, and New York State Departments of Health and Environmental Conservation (MOE, 2009; NY DEC and NY DOH, 2006; US EPA, 2009);

- The garden soil sampling protocols recommended by the University of Minnesota, and Cornell University (Rosen, 2002; Shayler et al., 2009a, b, c);

- The exposure reduction measures recommended by the University of Minnesota, and Cornell University (Rosen, 2002; Shayler et al., 2009a, b, c); and,

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# Appendix C – Summary of Evidence of to Support the Urban Gardening Soil Assessment Guide

Appendix C provides a summary of the evidence that supports the approaches and assumptions made in the development of the Urban Gardening Soil Assessment Guide. The Appendix is organized into the four steps of the Guide. Further information for Step 3 (Interpretation) is provided in Appendix D.

## Step 1: Establish a Level of Concern

Toronto Public Health (TPH) recommends that urban gardeners establish a Level of Concern for potential garden sites by identifying risk factors through a site visit and site history evaluation. These two processes are the basic elements of an environmental site assessment (ESA), and are included in Ontario environmental regulations (e.g., the Records of Site Condition Regulation (O.Reg. 153/04) made under the Environmental Protection Act, which incorporates the Phase I ESA Standard (CAN/CSA Z768-01) and Phase II ESA Standard (CAN/CSA Z769-00) of the Canadian Standards Association).

The risk factors and associated levels of concern recommended by TPH are provided in Table C.1. These risk factors were identified through literature review and consulting with experts.

**Table C.1: Land Use and other Indicators for Establishing the Level of Concern for Urban Garden**

| Level Of Concern | Indicators | Next Step/ Soil Testing |
|---|---|---|
| **Low Concern** | Site is and has always been:<br>• Residential;<br>• Parkland;<br>• Farmland; or,<br>• Child care centre or school.<br><br>And, site is not located within:<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road.<br><br>And, site visit does not reveal:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | Soil testing not required.<br><br>**Go to Step 4 - Tier 1 Exposure Reduction.**<br><br>Use good gardening practices. |
| **Medium Concern** | Site is or has once been:<br>• Risk-managed park;<br>• Orchard;<br>• Hydro corridor;<br>• Infill area; or,<br>• Commercial land uses (excluding gas station, dry cleaner, printing or autobody shop- see High Concern).<br><br>Or, site is located within:<br>• Former landfill;<br>• Former lead reduction zone; or,<br>• 30 metres of a rail line or major arterial road. | If the garden is small (less than 16 $m^2$ or 170 $ft^2$) it is not cost effective to conduct soil sampling, instead adopt exposure reduction strategies to eliminate exposure pathways. **Go to Step 4 (Tier 3 Exposure Reduction).**<br><br>For gardens larger than 16$m^2$ **Go to Step 2.** Sample and analyze the soil; the results of the soil testing will then indicate the appropriate exposure reduction measures to be taken. |
| **High Concern** | Site is or has once been:<br>• Gas station;<br>• Dry cleaner;<br>• Printing shop;<br>• Autobody shop;<br>• Rail line or rail yard; or,<br>• Industrial land uses.<br><br>Or, site visit reveals:<br>• Indications of dumping or burning;<br>• Smells in the soil; or,<br>• Staining of the soil. | **Eliminate exposures.**<br><br>**Go to Step 4 -Tier 3 Exposure Reduction** |

## Risk Factors – Site Visit

To assess the need for exploratory sampling, a site visit is recommended as part of the Phase I Environmental Site Assessment Standard (CAN/CSA Z678-01), and is required when Ontario's Records of Site Condition Regulation (O.Reg. 153/04) is triggered. Soil contamination can be observed via:

- visual inspection (i.e. identification of soil discolouration, spill and stain areas, dead or dying plants;

- odours (i.e. smelling of the earth); and

- presence of material and equipment, such as

    - abandoned aboveground or underground tanks or pipes,
    - buried debris or trash,
    - contaminated material or asbestos-containing materials (e.g., drywall joint compound, mechanical insulation, roofing materials, floor and ceiling tiles, and fire doors),
    - lead-containing material (paint chips, plumbing solder and old pipes)
    - PCBs containing material (old electrical equipment such as transformers, fluorescent lamp ballasts, and capacitors),
    - storage use and handling of hazardous material on the site, solid waste handling, hazardous waste, and
    - high-tension transmission lines and electrical substations.

## Stains and Odours

As part of the site assessment, soils are checked for stains and odours. Soil stains and odours can indicate that illegal dumping of oils, liquid toxic wastes, or burning of garbage has taken place on the site. Illegal dumping can introduce contaminants like oils, solvents, PCBs, pesticides, and lead. The burning of garbage can introduce dioxins/furans and polycyclic aromatic hydrocarbons (PAHs).

## Proximity to Major Roadways

Transportation-related soil contaminants are primarily metals and polycyclic aromatic hydrocarbons (PAHs). These contaminants are emitted from tailpipes, roadwear, tirewear, and brakewear from cars and trucks. While lead was phased out of petroleum in the 1970s, and banned in the early 1990s, lead is still present in urban soils because of years of atmospheric deposition and accumulation (Mielke et al., 2010).

Many studies demonstrate that the majority of contaminants associated with transportation are subject to rapid deposition, and that soil contaminant levels decrease with distance from roadways (Crépineau et al., 2003; Legret and Pagotto, 2006; Nabulo et al., 2006; Swaileh et al., 2004; Trombulak and Frissell, 2000). The review by Trombulak and Frissell (2000) found that most studies indicate that soil contamination declines within 20 metres of the roadway. More recently, Legret and Pagotto (2006), Nabulo et al. (2006) and Swaileh et al. (2004) demonstrated that soil contaminant concentrations return to background levels at 5 to 30 metres away from the roadway. These data have led many agencies to recommend that gardens be planted at least 30 metres away from major transportation corridors (e.g., Niagara Region, 2005).

**Table C.2: Summary of primary data on the effect of distance on levels of soil contamination adjacent to major roadways**

| Contaminants | Site Description | Distance | Level | Reference |
|---|---|---|---|---|
| PAHs | France, highway | <10 m | Rapid decrease | Crépineau et al., 2003 |
| PAHs | France, highway | 10-50 m | Slow decrease | Crépineau et al., 2003 |
| Various | Various | ≤20 m | Reduced | Trombulak and Frissell, 2000 |
| Heavy metals | West Bank, main road | ≥20 m | Background | Swaileh et al., 2004 |
| Heavy metals | France, major rural highway | <25 m | Background | Legret and Pagotto, 2006 |
| Pb | Uganda, major highway | ≥30 m | Background | Nabulo et al., 2006 |

The weight of evidence indicates that a setback from major roadways of 30 metres is adequate to protect urban gardens from deposition and accumulation of major traffic emissions. For the purposes of this guide, major roadways are those roads described as major arterial roads by the City of Toronto: roadways with traffic frequency of greater than 20,000 vehicles per day and speed limits of 50 to 60 km/h; roads with traffic lights only (no stop signs); and frequent city bus traffic( www.toronto.ca/transportation/road_class/index.htm).

## Risk Factors in Site History

Obtaining information on land use, the practices/industry that occurred on-site, and the chemicals used, is invaluable to help determine which contaminants can be expected on a site. Toronto Public Health prepared a "Historic Land Use Inventory" which is available in database and report form, which allows users to look up addresses in the old City of Toronto that are known to have past and present land uses with potential environmental concerns (i.e., historical industrial area, lead reduction zone, historical coal gasification and related tar processing site, historical waste disposal site, gas station site, lakefill and former ravine)[31]. In addition, the Ontario Ministry of the Environment prepared a "Site Inventory Study" of former waste disposal sites in Toronto.[32]

[31] Toronto Public Health's "Historic Land Use Inventory" was originally prepared as an internal resource. Options to make this Inventory more readily available to the public, including placing a copy in the City Archives, are being explored.

[32] It is not clear whether copies of the Ontario Ministry of the Environment's "Site Inventory Study" are available outside of Toronto Public Health. Options to make this Study more readily available to the public, including placing a copy in the City Archives, are being explored.

Various activities (including industrial activity, old orchards, older homes, major roadways, old landfills, waste water and municipal sludge applications, and ravine in-filling) can leave a legacy of contamination in soil (Papritz and Reichard, 2009; US Department of Agriculture, 2004; Kaufman and Bailkey, 2000). Studies have identified industrial activity, age of housing, ravine in-filling, and risk-managed parks as risk factors for soil contamination for the City of Toronto (Boettcher et al. 1995; De Sousa, 2003; Yuan, 1991; EPO, 1995).

## Industrial Activity

The City of Toronto was home to many different kinds of industrial, manufacturing and construction businesses (Campbell, 1996; De Sousa, 2003). Currently, there are over 300 facilities in the City of Toronto that are large enough to report to the National Pollution Release Inventory, and small and medium sized businesses will begin to report to Toronto Public Health's ChemTRAC program in 2011. Some historical and current facilities may have left a legacy of soil contamination. For example, automotive repair and refinishing shops leave behind metals and metal dust, solvents, paint and paint sludge, scrap metals, and waste oil. A study conducted in 1998, estimated there are 865 acres of brownfield lands in the City of Toronto, including 109 acres in the old City of Toronto (Hemson Consulting, 1998). Benazon (1995) estimates that up to 25% of the land area in major urban centres in North America is potentially contaminated because of previous industrial activities.

## Age of Housing

Paint chips and house dust contaminated with leaded paint can contaminate soil. Bailey (1994) found that paint chips and dust from old lead-based paints produced before the 1950s are one of the major sources of lead soil contamination. Clark et al. (2008) found that 40 to 80 percent of the lead found in surface soil originated from lead-based paint used in and on the outside surfaces of homes. Clark et al. (2008) found that dust from lead-based paint was a source of lead to the urban gardens, even recontaminating the gardens after remediation and construction of raised beds. Dust blowing in from areas that were not remediated was found as the mechanism for recontamination of the garden soils (Clark et al., 2008).

Regulations began to limit the concentration of lead in paint in the 1960s, and finally banned lead-containing interior and exterior residential paints in the early 1990s. Paint used before the 1950s can have as much as 50 percent lead. In Toronto, it is estimated that about 22% of the homes were built before 1946, with a higher percentage in the former cities of Toronto (46%), East York (31%) and York (34%), and a lower percentage in the former cities of Etobicoke (5%), and Scarborough (4.5%) (Campbell, 1996). Renovations, demolitions and wear and tear on these older houses can contaminate soil. Use of lead-based paint on the exterior of homes can contaminate the soil, particularly in the drip zone of the house.

## Ravine and Waterfront In-filling

In the City of Toronto, many old rivers and streams were in-filled as the City was developed (De Sousa, 2003). In Toronto, the ravines and lake were in-filled with unknown materials and soils, and they are suspected of being contaminated with metals. The infill material included soil from other locations in the City, construction debris, materials dredged from waterways, coal ash, and municipal solid waste. Some parks in the City of Toronto are built on in-filled ravine areas and the City's waterfront in made of infill materials. Areas of the City that are in-filled are summarized in the Historical Land Use Inventory report.

## Orchards

Lead arsenate pesticides were used in orchards up to the 1950s. Soil sampled from old fruit orchards in Ontario have elevated levels of lead and arsenic (Frank et al., 1976; Elfving et al., 1994).

## Risk-Managed Parks

The City of Toronto has a number of risk-managed parks. Some of these parks were conveyed to the City prior to 2004 and thus, were subject to Level II Site Specific Risk Assessments. Sites conveyed to the City since 2004 have followed the MOE's process for a Record of Site Condition (RSC) and have Certificates of Property Use (CPU) registered on title. The CPU lists the required administrative, maintenance and operational controls for the park in question. These records are available through Parks, Forestry and Recreation.

## Background Ontario Brownfields Regulation

In the Province of Ontario, brownfields are regulated by Ontario Regulation 153/04 (updated in 2009, O. Reg. 511/09), under Part XV.1 of the Environmental Protection Act ("EPA"). In general, the regulation is triggered when a property owner wants to change the use of their property from a "less sensitive" property use to a "more sensitive" property use. In these circumstances a "record of site condition" (RSC) is required. For example, if a property owner wishes to redevelop a former industrial building into residential properties, the owner must file an RSC.

An RSC is a document that summarizes the environmental conditions of the property. RSCs are prepared by experts in contaminated sites, otherwise known as Qualified Persons. These experts are typically engineers and geoscientists.

Before an RSC can be filed, the Qualified Person must conduct the necessary environmental site assessments and, if necessary, complete appropriate remediation to ensure that all soil contaminants meet the soil quality standards (as well as groundwater and sediment) applicable to the proposed property use (as specified in the Ministry of the Environment's *Soil, Ground Water and Sediment Standards*). Alternatively, a property owner may also develop property-specific standards by preparing a risk assessment.

Sites may require risk management in order to ensure the safety of the intended property use. In these circumstances, a Certificate of Property Use (CPU) is issued for the site by the province. The CPU outlines the required risk management measures and any property use restrictions for that site (which could include restrictions related to gardens) and is a legally binding document.

RSCs and associated CPUs are filed in the brownfields environmental site registry and are available to the public through the Ministry's website.

"More sensitive" property uses are residential, parkland, agricultural, and institutional uses (examples include hospitals, day cares, schools, and residential condominiums).

“Less sensitive” property uses are industrial, commercial, and community uses (examples include churches and other places of worship, libraries, indoor recreation centres, and other community centres).

It is important to note that the “property use” designation under O. Reg. 153/04 is not necessarily related to the land use zoning or the dominate use of the land. The definition relates to the current property use for the particular parcel of land that is being developed. If the parcel is already considered a “more sensitive” property use, then an RSC is not required. Some sites are more complicated under the regulation because they are complex sites comprised of many parcels of land that have different property uses (e.g., office buildings and laboratories on parcels of land as part of a university campus. These parcels of land would be defined as commercial property uses, whereas a university residence building would be defined as a residential property use).

We explore the specifics of the regulation and how it applies to gardening and food production in the City of Toronto in the section below.

## O.Reg 153/04 and the Urban Gardening Soil Assessment Guide

The following property uses are already defined as “more sensitive” property uses, thus, there is no change in property use when building community and allotment gardens and agricultural space on them:

- parkland;
- residential (including community housing) properties; and,
- institutional (schools and daycares) properties.

Under O. Reg. 153/04, universities and colleges are typically complex sites with various property uses across the site. The applicability of O. Reg. 153/04 depends on the property use for the particular parcel of land for the community garden. If the parcel of land in the university or college is already being used as parkland or outdoor leisure space, then a RSC is not required.

The following property uses are defined as “less sensitive”:

- industrial;
- commercial; and,
- community property uses (churches and community centres).

The current interpretation of O. Reg. 153/04 indicates that an RSC is required to build a community garden if the current property use is industrial or commercial. The obligation to conduct an RSC for a community garden on places of worship and community centres is less clear. As per the considerations of the institutional property use mentioned above, if the parcel of land intended for a garden is already being used as parkland or outdoor leisure space, then a RSC is not required. Table C.3 summarizes the requirement and recommendation for submitting an RSC and the use of the guide for different property uses.

The Urban Gardening Soil Assessment Guide is intended to be used on all lands that the City is considering for gardening and food production regardless of the requirement to conduct an RSC.

Whereas the provincial requirements are triggered by broad property use changes and were developed to address historic contamination at the time of redevelopment, the Guide applies specifically to urban gardens.  As such, it is an extra recommendation over and above the general Provincial requirements for brownfield redevelopment.

The guide cannot be used to circumvent the City's requirements under Part XV.1 of the Environmental Protection Act. All risk measures and property use restrictions documented in the Certificate of Property Use for risk-managed parks or other properties must be strictly adhered to by the City of Toronto.

**Table C.3: Property use and requirements and recommendations to follow the Record of Site Condition and the Urban Gardening Soil Assessment Guide**

| Property use | Requirement to Submit an RSC | Recommendation to Follow Urban Gardening Soil Assessment Guide |
|---|---|---|
| Parkland | No | Yes |
| Day care | No | Yes |
| School | No | Yes |
| Community housing | No | Yes |
| Farmland | No | Yes |
| Hospital | No | Yes |
| University/college campus | Depending on property use of parcel of land intended for garden | Yes |
| Community centre | Depending on property use of parcel of land intended for garden | Yes |
| Residential condo | No | Yes |
| Commercial space | Yes | Yes |
| Industrial | Yes | Yes |

# Step 2: Test the Soil

Gardeners are potentially exposed to soil contaminants through direct exposure to soil and through consumption of produce. Soil testing to determine the concentrations of soil contaminants is an important next step in guide. Given the costs involved, the guide recommends soil testing only for larger *Medium Concern* sites. For *Low Concern sites,* small gardens on *Medium Concern sites* or *High Concern* sites, adoption of measures to eliminate potential exposures without further risk characterization is recommended.

## Sampling Depth

Typical, non-gardening activities result in contact with only the top five centimetres of soil (MOE, 2001). Gardeners are exposed to deeper soils through planting and harvesting produce, weeding, and bi-annual turning over of the land. We assumed that the gardening zone extends 40 centimetres below the soil surface, and that this provides a reasonable estimate of the maximum depth of a gardener's exposure to soil. The following section summarizes the various recommendations by experts and agencies for soil sampling depths.

Typically in risk assessments, it is assumed that people are directly exposed[33] to the first 2 (US EPA, 2006) to 5 centimetres of soil (MOE, 2001). However, gardeners may dig down below the 0 to 5 centimetre level. In addition, people with vegetable gardens are also exposed to soil contaminants by ingestion of garden produce that has accumulated soil contamination. The US EPA advises that under circumstances where gardening is expected, that soil deeper than 2 centimetres should be sampled for contaminants (US EPA, 1996). The US EPA (2006) and Washington State University (Peryea, 1999) advise that a 20 centimetre tillage depth should be assumed for the purposes of risk assessment. Similarly, the recommended soil depth to be sampled on tilled soils is 20 centimetres (US EPA, 2005). Shayler et al. (2009a) recommends that urban gardens be sampled down to a depth of 6 inches (~15 centimetres). Clark et al. (2006; 2008) considers the 0 to 10 cm horizon to be surface soil, and 30 to 40 cm to be the rooting depth. Nova Scotia Department of Agriculture suggests that homeowners sample the soil in their agricultural fields at depths up to 15 cm for most crops, and a depth up to 5 to 8 cm for sod crops. For garden sampling, they recommend taking soil samples up to 12 to 15 cm depth (Nova Scotia Agriculture, 2009). The Prince Edward Island Department of Agriculture recommends a soil sampling depth up to 15 to 20 cm (PEI, 2005).

The City of Montreal soil sampling protocol specifies that one composite sample of the surface soil to be taken for every 30 allotment plots. Surface soil is sampled with an auger to the full depth of the topsoil (up to 40 cm). In addition, one sample of the deeper soil is taken for every 400 to 1,600 $m^2$. Deeper soil is sampled with a backhoe at depths of up to 3 metres. The soil samples are tested for metals, polycyclic aromatic hydrocarbons (PAHs), and petroleum hydrocarbons (Beausoleil and Price, 2008a, b).

## Compositing Soil Samples

Soil samples are often taken during a site assessment of a brownfield to determine if the soil is contaminated. The method to take soil samples is to take soil cores down to a depth of 1.5 metres. Discs of various depths are then taken from the core to represent "surface soil". Core samples are taken from various locations from the site, typically from areas suspected of contamination.

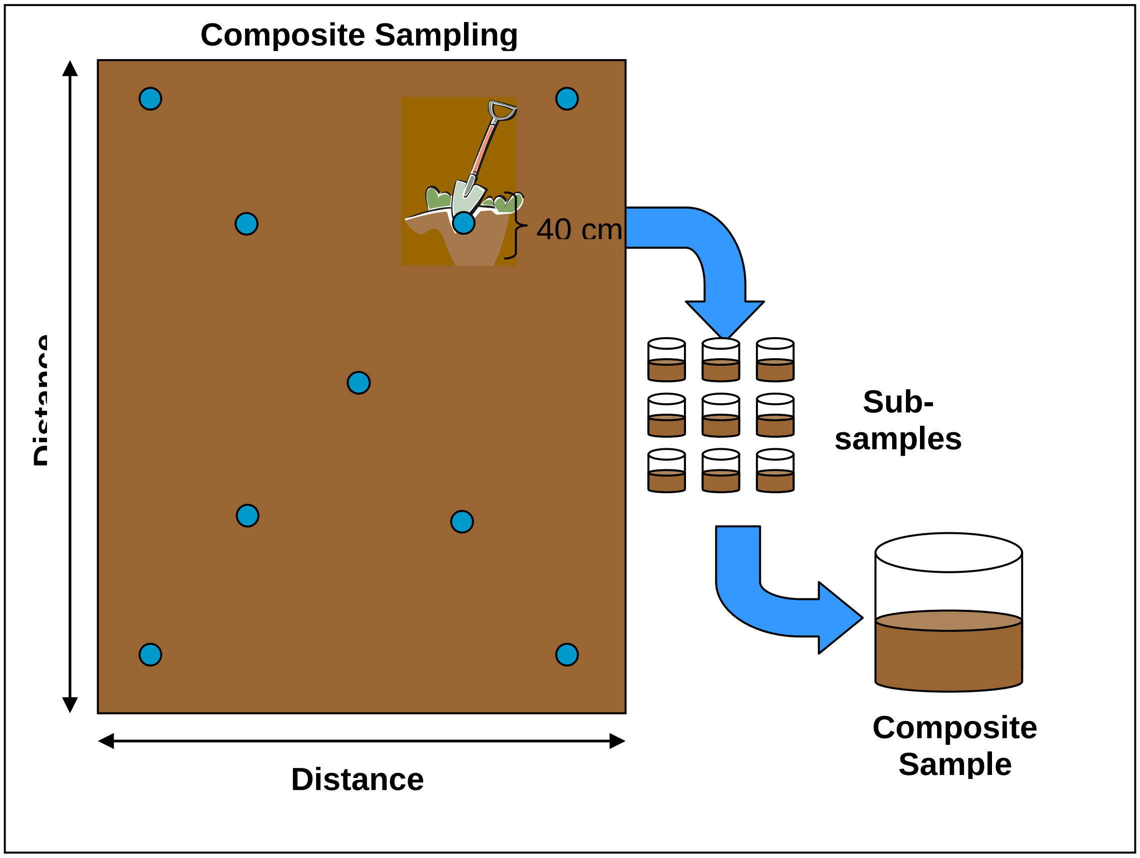
Unlike water and air, soil is a highly heterogeneous medium, with a high degree of variability in soil parameters. Gardeners move around their gardens, weeding, digging and planting, and mixing the soil by turning it over and adding organic matter. Gardening results in thorough mixing of the soil. Thus, a composite sample is more reflective of a gardener’s exposure to contaminants. Composite samples are recommended for soil sampling of gardens due to the high degree of small scale variability in most soils (Clark et al., 2008). Various agencies recommend taking a composite sample in a W or X pattern from gardens ranging in size from 65 to 150 square feet (Clark et al., 2008; Shayler et al., 2009a; Beausoleil and Price, 2008a, b). Various researchers also took composite samples when investigating soil contamination issues in urban gardens (Rosen, 2002; Douay et al, 2008; Finster et al., 2004).

[33] Direct exposure to contaminants in soil occurs by skin contact with soil, ingestion of soil through hand-to-mouth activity, and through the inhalation of dust and subsequent ingestion of dust particles.

The Nova Scotia Department of Agriculture suggests that farmers take composite soil samples, each comprised of 20 sub-samples from fields of 10 hectares or less. For garden sampling, they recommend taking sub-samples from 6 to 10 areas in your garden, and combining them into one composite sample (Nova Scotia Agriculture, 2009). In PEI, the Agricultural department recommends taking sub-samples from 10 to 20 different places in the field and homogenizing them into one composite sample for analysis (PEI, 2005).
The Protocol recommends taking one composite sample comprised of at least nine sub-samples in an X pattern for every 15 by 15 metres of community garden, or 10 by 10 metres of allotment garden (Figure C.1).

In the event that the site history suggests that sampling for volatile or semi-volatile organic soil contaminants (VOCs and SVOCs) (e.g., benzene, toluene, ethylbenzene, xylene) is needed, a professional should be consulted as these compounds volatilize and must be sampled using specific procedures.[34]

**Figure C.1: "X" Pattern of sub-samples for composite sampling of a proposed garden site**




## Sampling Equipment and Procedures

[34] Samples for VOCs should be taken at least 10 cm below the soil surface using a stainless steel spatula or knife, and placed on glass jars tightly sealed maintained at < 10°C. The analysis of these samples should be completed as soon as possible after sample collection. Discrete samples (not composites) should be taken when there is a visible soil stain (Clark et al. 2006).

The following section was researched by consulting with laboratory and site assessment consultants. There are several different devices that can be used for soil sampling. For example, shovels, trowels and tulip bulb planters are inexpensive devices that can be used to sample surface soils.

To avoid contamination of samples, it is recommended that samplers use protective gloves (e.g., latex), and sampling equipment must be cleaned between potential garden sites and air dried. The soil collected for the samples can be placed in plastic bags or glass jars.

When sampling is being conducted, is important to take field notes to help interpret the analytical results. These notes should include: sampling locations, vegetative cover at the sample site, sample depths, observed soil horizon and horizon depths and any soil staining or unusual odours observed.

## Contaminants of Concern for Soil Testing

Based on the literature and the information available for Toronto, the guide includes a streamlined list of contaminants of concern (COCs) for urban gardening. Table C.4 lists the COCs and the rationale for their inclusion.

**Table C.4: Minimum list of COCs and Rationale for Inclusion**

| Class | Chemical | Rationale for Inclusion |
|---|---|---|
| Metals | Arsenic (As)<br>Cadmium (Cd)<br>Cobalt (Co)<br>Chromium, total (Cr)<br>Chromium, VI (Cr VI)<br>Copper (Cu)<br>Mercury (Hg)<br>Molybdenum (Mo)<br>Nickel (Ni)<br>Lead (Pb)<br>Selenium (Se)<br>Zinc (Zn) | • Literature review indicates that listed metals are common urban contaminants<br>• Data on Toronto soils indicates possible presence of metals at elevated levels in Toronto soils<br>• Some metals can accumulate in the edible tissues of garden produce<br>• Common industrial pollutants<br>• Literature identified metals in soils as posing a potential risk to urban gardeners<br>• Inexpensive laboratory analysis<br>• No expertise or special equipment necessary for soil sampling |
| Polycyclic aromatic hydrocarbons (PAHs) | Acenaphthene<br>Acenaphthylene<br>Anthracene<br>Benz(a)anthracene<br>Benzo(a)pyrene<br>Benzo(b)fluoranthene<br>Benzo(g,h,i)perylene<br>Benzo(k)fluoranthene<br>Chrysene<br>Dibenz(a,h)anthracene<br>Fluoranthene<br>Fluorene<br>Indeno(1,2,3-c,d)<br>Pyrene<br>Phenanthrene<br>Pyrene | • Literature review indicates that PAHs are common urban soil contaminants<br>• The PAHs listed are persistent in soil<br>• PAHs are primarily related to incomplete combustion of organic material (petroleum, garbage, leaves)<br>• Inexpensive laboratory analysis<br>• No expertise or special equipment necessary for soil sampling |

Gardeners may also wish to have soil samples analyzed for general soil chemistry (chloride, conductivity, pH, sodium adsorption ratio (SAR)) at the same time as the soil contaminant analyses for the following reasons:

- Soil chemistry parameters analyses aids in the interpretation of risk (soil chemistry influences exposure and toxicity of soil contaminants);
- Excessive salt in urban soils can be the result from runoff of salts from roads and sidewalks. While not considered of concern for human health, high concentrations of salts in soils can prevent or delay germination of seeds and can kill established plants or retard their growth. Soil salt concentrations between 0.5 to 1.0 mS/cm will cause damage to most plants;
- Knowing soil parameters will guide the preparation of the garden; and
- General soil chemistry analyses are very inexpensive.

Other soil contaminants were considered for inclusion in the lists of standard COCs but were not included in the lists of standard COCs (See Table C.5).

**Table C.5: Contaminants Excluded from List of Standard COCs for Sites of *Medium Concern* and the Rationale for Exclusion**

| Chemical | Rationale for Exclusion |
|---|---|
| Asbestos | • Asbestos is associated with construction debris. Sites with debris are considered High Concern. Debris on site should be assumed to contain asbestos and removed using appropriate precautions.<br>• Does not accumulate into produce<br>• Interpretation of analysis of soil poses significant challenges for analysis and interpretation<br>• Expensive soil analysis |
| Benzene, toluene, ethylbenzene and xylenes (BTEX) | • Common contaminants in soil of gas stations. Gardening is restricted on sites of existing gas stations. Gardens on old gas stations are Tier 3 exposure reduction – elimination of exposure pathways.<br>• Do not persist in surface soil<br>• Soil turned over and mixed during the process of creating a garden will release residual BTEX from surface soil<br>• Soil sampling must be conducted by professionals |
| Petroleum hydrocarbons | • Common contaminants in soil of gas stations. Gardening is restricted on sites of existing gas stations. Gardens on old gas stations are Level 3 exposure reduction – elimination of exposure pathways.<br>• Do not persist in surface soil<br>• Can occur at sites with industrial sources and illegal dumping.<br>• Expensive analysis, and soil sampling must be conducted by a professional as some of these compounds volatilize and must be sampled using specific procedures |

| Chemical | Rationale for Exclusion |
|---|---|
| Polychlorinated biphenyls (PCBs) | • Not expected in urban soils, unless site history indicates that PCBs were used or stored on site. The guide recommends these sites for Tier 3 Exposure Reduction.<br>• Expensive laboratory analysis. |
| Pesticides | • City of Toronto former Pesticide by-law prohibited the cosmetic use of pesticides since 2006 (superseded by province-wide ban in 2010)<br>• Modern pesticides degrade rapidly or strongly bind to soil<br>• Toronto soil data did not find pesticide residues at elevated levels.<br>• Expensive laboratory analysis. |
| Dioxins | • Ministry of the Environment data collected in the late 1980s demonstrated that dioxins are ubiquitous in urban and rural soils at trace levels<br>• Urban soils have higher levels than rural soils<br>• Urban soils collected in the 1980s in areas known to be impacted by a local source of dioxins were found at levels below the health based standards (Birmingham, 1990)<br>• Very expensive laboratory analysis $900 per soil sample |

Soil contaminants can degrade (organic contaminants only), migrate, become buried under organic matter, and/or become unavailable for uptake by binding to organic matter of time. Thus, historical and current land uses are a clue to the potential for soil contamination, but do not necessarily mean there will be present day soil contamination. The physical and chemical characteristics of soils are complex and heterogeneous. Soil contamination is highly heterogeneous and site specific. The presence and degree of soil contamination depends on the:

1) type of release (to air, water, land; point of impingement or diffuse release; etc.);

2) timing and magnitude of release (mass and concentration; current or historical);

3) nature of the chemical (i.e., form, persistence, bioavailability, volatility); and,

4) soil characteristics (impacts the bioavailability of the contaminant).

There are very few data sources available on soil contaminant levels for the City of Toronto. Two reports (Perrota, 1999; De Sousa, 2003) explore soil contaminant issues in the City and identify the following as potential contaminants in Toronto soils: heavy metals (e.g., Pb, Cd, Cr), PCBs, polycyclic aromatic hydrocarbons (PAHs), benzene, ethyl benzene, toluene, xylene, styrene, rubble, asbestos, gasoline, coal tar, oil, lubricants, and hydrocarbons.  Various site specific soil analyses have been conducted in the City of Toronto to support development activities, hazard assessments, and brownfield remediation. It is beyond the scope of this report to provide a summary of those studies.

Metals (e.g., lead (Pb), cadmium (Cd), copper (Cu), arsenic (As), chromium (Cr)) are the contaminants most often cited as elevated in urban soils compared to rural soils (Pilgrim and

Schroeder, 1997; Aelion et al., 2009). Papritz and Richard (2009) and Clark et al. (2008) note that lead is the most likely contaminant of concern in urban gardens.

In the early 1990s, the Ministry of the Environment (MOE) conducted soil sampling across the province with the goal of establishing provincial background levels of soil contaminants (MOE, 1994). The MOE tested soils away from any known source of contamination, in order to provide an estimate of the range of typical soil concentrations in urban, old urban, urban parkland, rural, rural parkland locations. The MOE noted that concentrations of most chemicals tested were higher in urban soils than in rural soils.

The province defined background concentrations as "the upper limit of normal" [35]. A summary of these values is provided Table C.7. For the purposes of this report, we assumed that the upper limit of normal in old urban parkland is a reasonable approximation of uncontaminated or "background" soil concentrations for the City of Toronto.

The MOE's province-wide soil sampling found trace concentrations of volatile organic compounds in both urban and rural soils. This is most likely because VOCs readily volatilize when soil is disturbed (US EPA, 2005). VOCs do not persist in the environment and they do not bioaccumulate. Based on the physical/ chemical properties of VOCs and within the context of gardening, it is assumed that once the soil has been tilled, most VOCs already present in the soil will readily volatilize into the atmosphere.

The City of Toronto and the Province of Ontario banned the cosmetic-use of pesticides in 2004 and 2009, respectively. Organochlorine pesticides have been banned in Canada since the 1970s. However some pesticides are so persistent that they can be detected in soil years many years after their application. Less persistent pesticides are not expected to be found due to evaporation and degradation in soil. The City of Toronto tested urban soils for pesticides in 1999 and also in 2009 (Perrota, 1999; PF&R soil analysis, unpublished). The vast majority of soils tested had no traces of pesticides. In a few samples, trace amounts of organochlorine pesticides were detected (Perrota, 1999; PF&R soil analysis, unpublished).

The Province of Ontario is conducting a province wide assessment of the use of 2,4-D and 2,4.5-T. The use of these pesticides may have resulted in residues of dioxins in urban soils, in particular hydro corridors. The results of this review will be considered and any required changes will be made to the guide to reflect the findings.

[35] The upper limit of normal is defined as the 98$^{th}$ percentile of all the samples taken in the province for that land use category. Samples were deliberately located away from known point sources of contaminants (e.g., industrial activities, buildings, and roads). Therefore, 98% of soil samples in that land use category in the Province of Ontario are expected to be at that level or below.

**Table C-7: Summary of background concentrations of contaminants in urban and rural parkland soils in Ontario**

| Contaminant | Background[a] Soil Concentrations | |
|---|---|---|
| | Urban Parkland | Rural Parkland |
| Arsenic (As) | 18 | 11 |
| Cadmium (Cd) | 1.2 | 0.7 |
| Cobalt (Co) | 17 | 16 |
| Chromium (Cr, total) | 63 | 58 |
| Chromium VI (Cr, VI) | 0.5 | 0.5 |
| Copper (Cu) | 66 | 46 |
| Mercury (Hg) | 0.27 | 0.13 |
| Molybdenum (Mo) | 1.3 | 0.984 |
| Nickel (Ni) | 50 | 34 |
| Lead (Pb) | 120 | 34 |
| Selenium (Se) | 1.1 | 0.91 |
| Zinc (Zn) | 180 | 160 |
| Polychlorinated Biphenyls (PCBs) | 0.032 | 0.015 |
| Polycyclic aromatic hydrocarbons (PAHs)[g] | -- | -- |
| Acenaphthene | 0.032 | 0.006 |
| Acenaphthylene | 0.047 | 0.093 |
| Anthracene | 0.058 | 0.006 |
| Benz(a)anthracene | 0.36 | 0.049 |
| Benzo(a)pyrene | 0.3 | 0.039 |
| Benzo(b)fluoranthene | 0.3 | 0.15 |
| Benzo(g,h,i)perylene | 0.28 | 0.081 |
| Benzo(k)fluoranthene | 0.26 | 0.006 |
| Chrysene | 0.94 | 0.099 |
| Dibenz(a,h)anthracene | 0.077 | 0.052 |
| Fluoranthene | 0.56 | 0.14 |
| Fluorene | 0.039 | 0.0094 |
| Indeno(1,2,3-c,d) pyrene | 0.23 | 0.054 |
| Phenanthrene | 0.31 | 0.092 |
| Pyrene | 0.49 | 0.11 |
| F1 Petroleum Hydrocarbons | 10 | - |
| F2 Petroleum Hydrocarbons | 10 | - |
| F3 Petroleum Hydrocarbons | 50 | - |
| F4 Petroleum Hydrocarbons | 50 | - |

## Step 3: Interpret the Soil Test Results

The most complex step in the Urban Gardening Soil Assessment Guide is the interpretation of soil contaminant concentrations. Many soil contaminants are naturally occurring or are ubiquitous in the environment; thus, their presence alone does not indicate a health risk. Health risk occurs when the frequency, duration and magnitude of exposure exceeds a level that is associated with health effects. In the guide, soil concentrations are interpreted by comparing the measured concentrations of soil contaminants with levels of contaminants in soil that are deemed health protective. Health protective levels in soil are derived by many agencies and organizations, however, these values were not found to be appropriate for use with urban gardening in Toronto. The primary reason why these values were found to be not appropriate is because they do not include consumption of garden produce as an exposure pathway. Thus, we derived Urban Gardening Soil Screening Values (SSVs). Appendix D provides a detailed summary of our review of existing soil standards/guidelines and the derivation of the Urban Gardening SSVs.

## The Importance of Uptake into Produce

Contaminants in soil can be taken up into the various edible tissues of plants as well as adhere to the surface of plants.[36] This has been identified as an issue of concern for urban gardening (Hough et al., 2004). As people eat much larger qualities of produce than their estimated accidental consumption of soil, a small degree of contaminant uptake into produce from soil may constitute a significant exposure pathway from urban produce (Hristov et al., 2005). Some metals, are essential to plant health, and are found naturally in low concentrations in most plants (i.e., micronutrients: Cu, Zn, Mn, and Fe) (Fytianos et al., 2001). Other metals (such as lead) play no essential role in plant biology. Both types of metals can accumulate in plants, although micronutrients appear to be better regulated by the plant (Fytianos et al., 2001).

Very little is known about plant uptake of other soil contaminants like PAHs and synthetic organic compounds (Hristov et al., 2005). PAHs can be taken up into plant tissues from contaminated soil; however, it is not considered an important exposure pathway (Environment Canada and Health Canada, 1994).

The MOE recently conducted a study on plant uptake of metals grown in an allotment garden (MOE, 2007). They tested the levels of uptake in produce harvested from allotment gardens in an old industrial area of Toronto. The MOE compared the results to a control plot that had very low levels of metals in the soil, comparable to background levels in rural areas. In general, they found that the produce in the control plot had lower levels of metals than the produce grown in the allotment gardens. However, they found that the ratio between the soil and the produce was higher in the control plot. In other words, the produce grown in the control plot had a higher levels of uptake than the allotment gardens. The reasons for this were not controlled for in this study, and therefore, cannot be explored. However, the authors note that it is mostly likely due to the presence of coarser (sandier) textured soil in the control plot which in turn affects the bioavailability of the metals.

Research also indicates that the level of contaminants found in plants growing in contaminated soil is usually considerably less than the level found in the soil (Spittler & Feder, 1979; MOE, 2007). Research has demonstrated a “soil-plant barrier”, whereby many soil characteristics affect the uptake of metals into plant tissues (US EPA, 2007). Reactions and processes that take place at the soil-plant barrier are influenced by the following factors: (1) the soil matrix has chemical properties and surfaces that bind contaminants (e.g., iron, aluminum, and manganese oxyhydroxides and organic matter); (2) uptake and translocation of most metals to shoots from roots is limited by adsorption or precipitation of metals in soils or in roots; and (3) the phytotoxicity of some contaminants limits their uptake and translocation.

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[36] EPA note that if the edible portion of the above ground produce is protected by an inedible skin or husk, then it is protected from wet and dry deposition of particles and vapour transfer (e.g., peas, corn, melons) (US EPA, 2005).

## Contaminant Accumulation in Specific Plant Tissues

Contaminant movement from soil into plants is specific to the contaminant, the soil and the plant. Different contaminants accumulate at varying levels according to the part of the plant. For example, root systems accumulate higher levels of cadmium while leaves accumulate higher levels of lead than other parts of the plant (Voutsa, et al. 1999). It is difficult to make generalities about contaminant uptake into plants, but it is generally accepted that the below-ground parts of the plant contain more contaminants than parts of the plant located above ground (Spittler, 1979).

The root system is anticipated to have the highest levels of contaminants, while the fruits, flowers and nuts have the lowest levels (Spittler, 1979). Some plants may not accumulate contaminants at all. Specifically, lead does not accumulate in the fruiting part of vegetables and fruit crops, but does accumulate in the leaves of vegetables like lettuce, and on the surface of root crops (MOE, 2007; Okornokwo et al., 2005). In general, fruits and legumes (e.g., tomato and beans) accumulate the lowest levels of lead, followed by root crops (e.g., beets and carrots) with the highest levels in leaf vegetables (e.g., lettuce) (MOE, 2007).

Once PAHs are taken up into plant tissues, from either the atmosphere or contaminated soil, they tend not to transfer into other tissues, and are found in higher concentrations in outer tissues (e.g., peels) versus internal structures (Environment Canada and Health Canada, 1994).

In 1999, the Environmental Biotechnology Division of Environment Canada created the PhytoRem Phytoremediation Database of plant species with the potential to accumulate or tolerate toxic metals. The data records also show which tissues of specific plant species are known to accumulate specific elements. Table C.8 was created using the PhytoRem database – it indicates that roots and shoots are the plant tissues that most commonly accumulate toxic elements.

**Table C.8: Summary of food plants identified in the Phytorem Database (Environment Canada, 1999/2003) as accumulating[a] (+) or hyperaccumulating[a] (++) arsenic (As), cadmium (Cd), chromium, (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn) in the root (R), shoot (S), leaf (L) or whole plant (WP).**

| Accumulator | Tissue[b] | Element | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | As | Cd | Cr | Cu | Pb | Hg | Ni | Zn |
| Alfalfa (*Medicago sativa* L.) | S | | ++ | ++ | ++ | ++ | | ++ | + |
| Amaranth (*Amaranthus hybridus* L.) | R, S | ++ | | | + | ++ | | | |
| Barley (*Hordeum vulgare* L.) | S | | | | | | | | + |
| Brassicas[c] (e.g., cabbage, cauliflower, broccoli, Brussels sprouts, kale, kohlrabi, mustard greens, rape, Turnip; *Brassica spp.*) | R, S, L | | ++ | + | ++ | ++ | | ++ | ++ |
| Beet, wild (Amaranthus hybridus L.) | R, S | ++ | | | | ++ | | | |
| Carrot (*Daucus carota* L. var. sativa DC) | R | | ++ | | | | | | |
| Chicory (*Cichorium intybus* L. var. foliosum Hegi) | R, S | | ++ | | | | | | |
| Corn (*Zea mays* L.) | R, S | | ++ | | ++ | ++ | | ++ | + |
| Dandelion (*Taraxacum officinale* Weber) | R, S | | ++ | | | | | | |
| Endive (*Cichorium endiviae* L.) | R | | | | | ++ | | | ++ |
| Lettuce (*Lactuca sativa* L.) | R, L | | ++ | | | | | | |
| Oat, wild (*Avena fatua* L.) | S | | | | | + | | | |
| Oat (*Avena sativa* L.) | R, S, L | | ++ | | | + | | + | |
| Pea, garden (*Pisum sativum* L.) | R, S | | ++ | | | ++ | | | |
| Radish (*Raphanus sativus* L.) | R, L | | ++ | | | | | | + |
| Rice (*Oryza sativa* L.) | S | | + | | | | | | + |

| Accumulator | Tissue[b] | Element | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | As | Cd | Cr | Cu | Pb | Hg | Ni | Zn |
| Rice, wild (*Hygrorrhiza aristata* Nees) | WP | | | + | | ++ | | | |
| Rye (*Secale cereale* L.) | R | | | | | ++ | | | |
| Sorghum (*Sorghum bicolour* L. Moench) | R, S | | | | | ++ | | | |
| Sorrel, garden (*Rumex acetosa* L.) | L | | | | | + | | | |
| Soybean (*Glycine max* Merr.) | S | | + | | | | | | + |
| Spinach (*Spinacia oleracea* L.) | R, L | | ++ | | | ++ | | | |
| Sunflower (*Helianthus annuus* L.) | R, S | | | | | ++ | | | |
| Tomato (*Lycopersicon esculentum* Mill.) | R | | ++ | | | ++ | | | |
| Wheat (*Triticum aestivum* L.) | R, L | | + | | | ++ | | | |

a. Accumulators and hyperaccumulators are defined in the Phytorem database according to elemental concentrations in plant tissues. Generally, minimal levels were used, most commonly 100-200 µg/g (dry weight) of accumulated metal in a plant, as the cut-off point for entering a record into the database. Some species, however, were included as accumulators if the elements were elevated to at least 5 to 10 times the normal background levels commonly found in plants

b Note that where specific plant tissues are indicated, this does not necessarily mean that the element does not accumulate in other tissues. It is not clear whether the elements accumulate into the fruits and seeds of the plants (which are commonly consumed for many of species listed). However, it is generally understood that fruits and seeds are the last tissues to be contaminated by toxic elements.

c The PhytoRem database separately identifies many individual brassica species as hyperaccumulators of numerous elements. Given the close relationship among these plants, and that the greens may be consumed in all cases, we considered it to be the most health protective option to identify the entire genus as accumulators and hyperaccumulators.

Several factors impact the absorption of metals into plants. The bioavailability[37] of soil contaminants is highly variable (Clark et al. 2006). Many factors affect the bioavailability of metals in the soil: the pH[38] of the soil; organic matter content; presence of $CaCO_3$, phosphorous[39] and iron[40]; clay content; pore size; redox potential; the form of metal; and the presence of other contaminants (Clark et al., 2006; US EPA, 2007). The most important factor is pH (US EPA, 2007). Soil pH is often termed the master soil variable because it controls virtually all aspects of contaminant and biological processes in soil. Increasing the pH of soil results in a decrease in the bioavailable fraction of metal soil contaminants (US EPA, 2007). When soils are more acidic the metals are taken into the plants far more readily, but at neutral and basic pH the metals are less readily taken up, with the exception of molybdenum and selenium (US EPA, 2007).

Certain other soil characteristics also influence the rate of metal uptake into plants. Some soils appear to bind or neutralize metals making them far less available for plants, other soils are far less absorbent and allow for larger proportions of contaminants to reach plant tissue. For example, metals are less bioavailable in finer textured soils (MOE, 2007). Deficiencies of certain metals in plants may increase the uptake of other metals that would otherwise not be taken up. The solubility of the metal species in question also determines its rate of uptake into the plant. The more insoluble the chemical form of the metal, the harder it is for it to cross the plant-soil barrier. In other words, the more insoluble the metal the less likely it is to be incorporated into edible parts of the plant. The uptake of contaminants into roots is inversely rated to the water solubility of the contaminant (US EPA, 2005).

As metals age in soils, they decrease in bioavailability. The aging process is partially reversible if environmental parameters change (e.g., if pH decreases), although a portion of the metal ions will be securely trapped in the soil matrix and not available to be resolubilized. Evidence of aging processes is provided by studies (US EPA, 2007). After 1 year, aging reactions are almost complete (US EPA, 2007).

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[37] ***Bioaccessibility*** refers to the amount of *environmentally available metal* that actually interacts with the plant and is potentially available for absorption (or adsorption to the plant surface). *Environmentally available metal* is the total amount of metal that not sequestered in an environmental matrix (i.e., bound to organic material).

***Bioavailability*** of metals is the extent to which bioaccessible metals absorb onto, or into, and across biological membranes of organisms.

***Bioaccumulation*** of metals is the net accumulation of a metal in the tissue of interest or the whole organism that results from *all environmental exposure media*, including air, water, solid phases (i.e., soil, sediment), and diet, and that represents a net mass balance between uptake and elimination of the metal.

[38] Higher pH soils have decreased metal mobility and bioavailability since fewer H+ ions are available to compete with cations for binding sites; thus cations remain bound to soil decreasing bioavailability.

[39] Facilitates binding and precipitation out of solution.

[40] Creates anionic surface binding sites for cations (e.g., Pb).

## Estimating Uptake into Produce

The process of characterizing the amount of soil contaminant in urban produce involves predicting the amount of chemical transferred from the soil to the edible portion of the produce and then estimating the amount of produce consumed by people. This process is highly complex, highly variable, and different for each soil characteristic, plant, and contaminant, and as such, it is rarely attempted (Hristov et al., 2005). The reviews conducted by US EPA, CalEPA and the New York Departments of Environmental Conservation and Health found that there is a high degree of uncertainty in quantitatively predicting exposure via the vegetable consumption pathway (Hristov, *et al*., 2005; NYDEC and NYDOH, 2006; US EPA, 1996b). The models that predict contaminant uptake into produce are highly uncertain for the following reasons (Hristov et al., 2005; MDEP, 2006):

- The mechanism of soil to plant transfer are not well known and are highly site, contaminant and plant tissue specific (as described in the preceding sections);
- There are limited empirically derived ratios of soil-to-plant transfer factors (these transfer factors will be site, contaminant and plant tissue specific);
- The amount of produce consumed by people varies greatly;
- The amount of urban produce consumed by people is unknown;
- Experiments often analyse the whole plant, not the edible portion, whereas the literature demonstrates that plant tissue accumulates different levels of contaminants. This can result in an overestimation of the risk if the contaminants are not preferentially translocated to edible tissues.
- Experiments are typically conducted with the most bioavailable form of the contaminant. This results in an overestimate of risk.
- Data are only available for a small number of contaminants.
- Data are only available for a small number of produce types.
- pH, organic carbon content, and other soil characteristics have a dramatic impact on contaminant uptake into plants
- Primarily the studies are based on experiments using sewage sludge, or potted plants in green houses. The soil chemistry of these studies and the bioavailability of the soil contaminant are not transferable to urban gardening scenario.

The use of biotransfer factors can result in risk characterizations that are highly restrictive for urban gardening. This is demonstrated in the work conducted by Hough et al. (2004) where they found that >99% of highly exposed individuals in an urban area in the UK had an unacceptable risk (Hazard Index > 1) from exposure to soil and home grown produce. Based on the review of the literature, it appears that the use of biotransfer is commonly used in risk assessments. Due to the highly uncertain nature of these factors, they tend to signal a need for additional research. Generally, follow up studies find that most contaminants in produce do not exceed the levels of supermarket produce (MOE, 2007; Beausoleil, 2010 pers.comm). Thus, the use of biotransfer factors is not explored further.

For similar reasons the US EPA and CalEPA have chosen to not consider the vegetable consumption exposure pathway for any soil contaminants, with the exception of lead, for which more is known (Hristov et al., 2005). The Ontario Ministry of the Environment and the Canadian Council of Ministers of the Environment do not provide guidance to assess this exposure pathway, nor do they incorporate this pathway into the derivation of their soil quality standards (with the exception of CCME guideline values for cadmium).

Recently, New York State developed a method to qualitatively evaluate exposure via produce consumption without using biotransfer factors. This method was used to account for uptake into produce in deriving the Soil Screening Values. It is described in Appendix D.

## Step 4: Develop Risk Mitigation Plan for Site

It is standard practice in risk management to either reduce or eliminate exposure pathways, as needed. The decision to reduce or eliminate exposure pathways is based on the level of risk and the risk management goals. The Protocol recommends three different levels of exposure reduction. For Tier 1 Exposure Reduction, the recommended mitigation is to use specific good gardening practices. For Tier 2 Exposure Reduction, gardeners should use good gardening practices, and also implement other measures to reduce exposure pathways. For Tier 3 Exposure Reduction, gardeners should completely eliminate certain exposure pathways. The specific practices for each risk level are described in Table C.9.

**Table C.9: Garden Risk Level with Recommended Risk Mitigation Measures**

| Risk Level | Recommended Actions |
|---|---|
| **Tier 1 Exposure Reduction** | **Use good gardening practices:**<br>• Wash hands after gardening and particularly before eating; and<br>• Wash produce with soap and water. |
| **Tier 2 Exposure Reduction** | Use good gardening practices (see above); and,<br>**Reduce exposure pathways:**<br>• Dilute soil concentrations by adding clean soil and organic matter (compost and manure);<br>• Lower bioavailability of contaminants by adding organic matter and raising pH;<br>• Reduce dust by covering bare soil with ground cover or mulch;<br>• Peel root vegetables before eating or cooking; and,<br>• Avoid or restrict growing produce that accumulate contaminants. |
| **Tier 3 Exposure Reduction** | Use good gardening practices (see above); and,<br>• Reduce dust by covering bare soil surrounding the garden with ground cover or mulch; and,<br><br>**Eliminate exposure pathways:**<br>• Build raised bed gardens (minimum of 40 cm over a landscape fabric), or use container gardens, and,<br>• Add clean soil and organic matter annually (compost and manure).<br>OR<br>• Grow only nut and fruit trees (do not grow other types of produce). |

## Tier 1 Exposure Reduction

Toronto Public Health recommends that for even the low risk sites, that gardeners take action to reduce their direct exposure to urban garden soils. The actions noted in Table C.9 are congruent with typical gardening practices. These actions are recommended in recognition that soil contaminants are common in urban soils and taking easy, no cost actions to reduce exposures to urban soil is prudent. For example, the US EPA's (2008) Child-Specific Exposure Factors Handbook notes the dermal loading on gardener's hands is 0.20 the $mg/cm^2$, which amounts to between 86 and 166 mg of soil (depending on the size of the gardener's hands) (US EPA, 2008). Some toddlers may deliberately eat soil, and all toddlers frequently put their hands and other objects in their mouths, along with any clinging dirt. Washing of hands and produce will remove the clinging soil and deposited particulates (Rosen, 2002). These measures are also good practices for other reasons, such as reducing the transmission of bacteria and viruses that can be present in the faeces of urban animals (domestic and wild).

## Tier 2 Exposure Reduction

At the medium risk level, it is appropriate to reduce exposure via one or more exposure pathways. The recommended risk management for medium risk garden sites includes the good gardening practices discussed above, plus a combination of measures to reduce incidental soil ingestion, reduce uptake of soil contaminants into edible portions of produce and reduce inhalation of soil particles.

- Diluting contaminated soil with clean amendments will reduce uptake of the soil contaminants into garden produce (Rosen, 2002; Shayler et al., 2009b). It is common gardening practice to till a 1 to 2 inch layer of manure or compost into the garden once or twice annually. The addition of 2 to 4 inches (5 to 10 cm) of clean organic material to a 40 cm deep garden bed represents a 12 to 25% increase in the volume of soil, and 12 to 25% dilution of contamination in the original soil (assuming that the densities of the original soil and amendments are approximately equal).

- Reducing the bioavailability of the contaminants in the soil will reduce uptake of the soil contaminants into garden produce (Rosen, 2002; Shayler et al., 2009b). The bioavailability of soil contaminants is influenced by the pH and organic matter content of the soil (Clark et al., 2006; US EPA, 2007). Uptake of most metals is less pronounced in alkaline or neutral than in acidic soils (US EPA, 2007). Similarly, the uptake of some metals is reduced in soils with high organic matter content because metal cations bind to organic acid functional groups (US EPA, 2007).

- Inhalation of soil dust particulates can be an important exposure pathway that can be greatly reduced by covering bare soil surfaces to control dust (Rosen, 2002; Shayler et al., 2009b). One study found that covering 20% of the soil surface with mulch material reduced soil losses due to wind erosion by 57%, and that 50% cover reduced soil losses by 95% (Fryrear, 1985), which may be equated with a significant reduction in dust production. (Reducing dust also prevents circulation of existing contamination (Clark et al., 2008).)

- Certain plant species (e.g., spinach and brassicas vs. tree fruits) and certain parts of the plant (e.g., roots vs. fruits) are known to take up and accumulate more soil contamination (Environment Canada's PhytoRem database, 1999; Spittler, 1979). Avoidance of these high-accumulating species and tissues is therefore an effective method of reducing exposure via the produce consumption pathway (Shayler et al., 2009b).

- Peeling of root vegetables serves two purposes. First, it removes the soil that is adhered to the skin of the produce. Second, peeling removes some of the most contaminated tissue of the plant. For most soil contaminants, the root tends to be the most contaminated part of a plant (Spittler, 1979). Many organizations recommend peeling root vegetables to minimize expsosure to soil contaminants (Rosen, 2002).

We recognize that the risk mitigation measures listed above are unlikely to achieve their full risk reduction potential in practice. In particular, dilution of contaminated soil will almost never achieve the theoretical risk reduction of 12 to 25% because readily available soil amendments are not entirely contaminant free. However, we predict that the above combination of exposure reduction measures will likely reduce exposures to soil contaminants by about an order of magnitude.

## Tier 3 Exposure Reduction

At the high risk level, it is appropriate to adopt a risk mitigation plant that will eliminate exposure pathways. This is a standard risk management practice.

Raised bed and container gardening (Shayler et al., 2009b) ensures that the contaminated soil is not used for gardening, and that all gardening-related exposures to the original, contaminated soil are eliminated. Covering bare soil in the rest of the garden area will reduce dust production (as discussed above for medium risk sites), and help to prevent contamination of imported soil.

Fruiting and nutting trees may be grown directly in contaminated soil, and are a good option for high risk gardens where raised beds or containers are not feasible. Several natural barriers prevent uptake of soil contaminants into fruits and nuts (US EPA, 2007): the soil-root, root-shoot and shoot-fruit barriers mean that fruits and nuts are expected to have the lowest contaminant levels of all plant tissues (Spittler, 1979; Turner, 2009).

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# Appendix D – Development of Soil Screening of Soil Screening Values (SSVs) for Urban Gardening

For the Urban Gardening Soil Assessment Guide, we needed two sets of concentrations of contaminants in soil to trigger three different tiers of risk management. The purpose of these soil screening values (SSVs 1 and 2) is to ensure that users can garden in urban settings without being exposed to unsafe levels of soil contaminants through contact with garden soil and consumption of garden produce. The SSVs were also designed to consider that urban gardeners may be exposed to many of the same contaminants through other aspects of their lives, such as breathing polluted air and eating grocery store foods.

Many soil quality standards and guidelines are available that set maximum safe concentrations of contaminants in soil for residential, agricultural and other land uses. Criteria were used to define the essential characteristics of an SSV for urban gardening (Table D-1).

**Table D-1: Evaluation criteria used for evaluating the suitability of soil quality standards from other jurisdictions for Toronto**

Soil screening values must:

- Be protective of human health;
- Consider the potentially greater exposures and increased susceptibility of children (in utero to adolescence);
- Be based on an exposure scenario that is
  - appropriate for Toronto[a], and
  - based on a reasonable worst-case[b];
- Consider other sources of exposure to the soil contaminant; and,
- Consider all the exposure pathways associated with urban gardening in Toronto (incidental soil ingestion, inhalation of soil particles, dermal exposure to soil, and ingestion of produce grown in the soil) and exclude irrelevant pathways.

a. Both site and human characteristics should be appropriate for Toronto. Important site characteristics that should be appropriate for Toronto include soil and ambient temperatures, soil type, absorption factors, etc. Appropriate human characteristics for Toronto include 6 months per year of gardening activity, and warmer clothing covering more parts of the body during spring and fall.
b. Discussed in detail in Section 4.

When we evaluated the existing values, we found that:

- None of the soil quality standards or guidelines from various jurisdictions met all of our criteria; and,
- The methods of two of the jurisdictions could be adapted to create SSVs for urban gardening that met all of our criteria.

The process used to review the existing soil quality standards and guidelines is shown graphically in figure D-1.

Using our criteria as a guide, we calculated SSVs for urban gardening following the soil-quality-standard derivation protocols from the Ontario Ministry of the Environment, and with the addition of a technique from the New York State Department of Environmental Conservation to account for the consumption of garden produce. The result of our calculations is two sets of SSVs for 37 soil contaminants. The process used to develop the SSVs for urban gardening in Toronto is shown graphically in Figure D-2, and described in detail in the sections that follow.

**Figure D-1: Process used to review existing soil quality standards and guidelines**

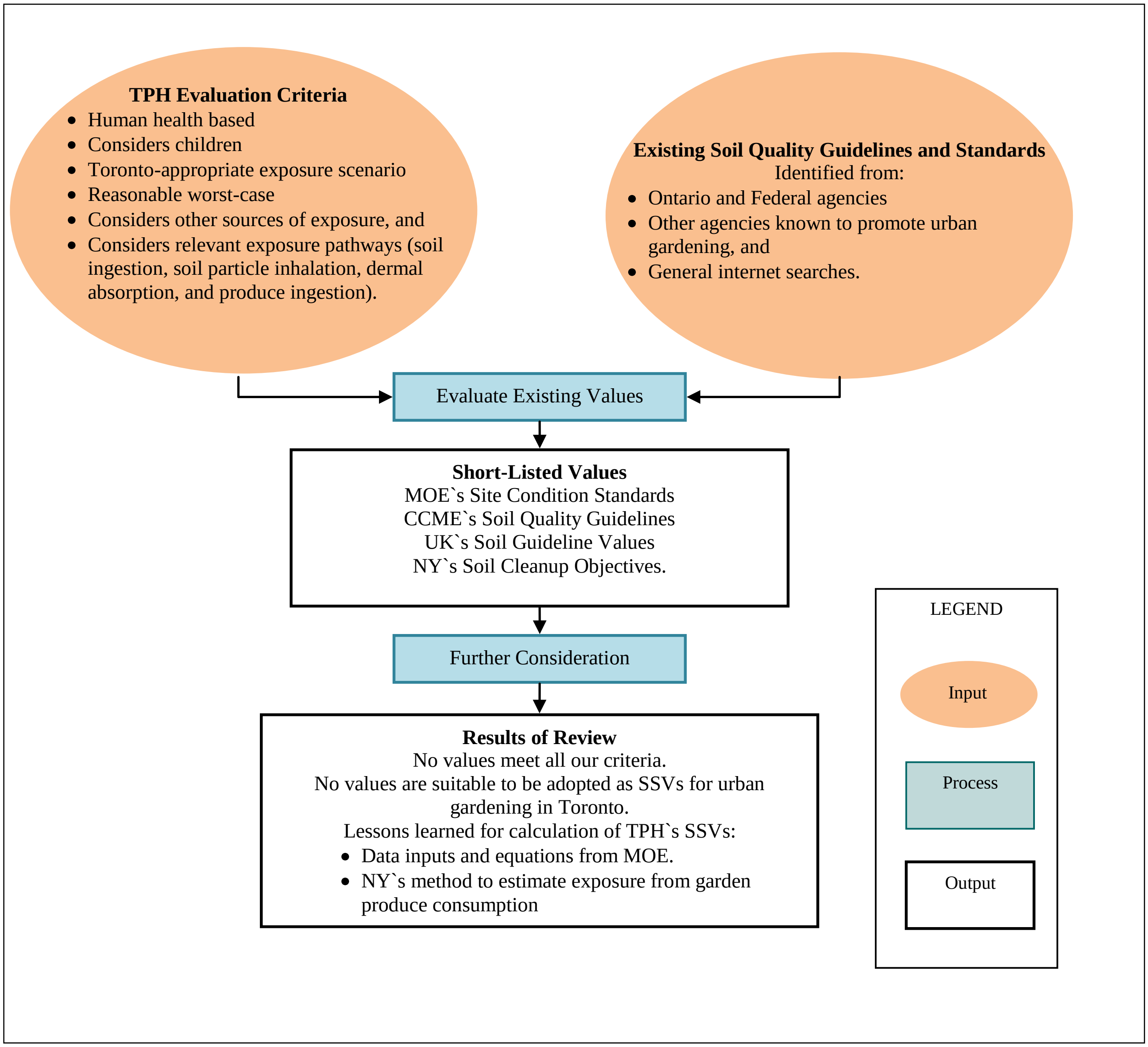
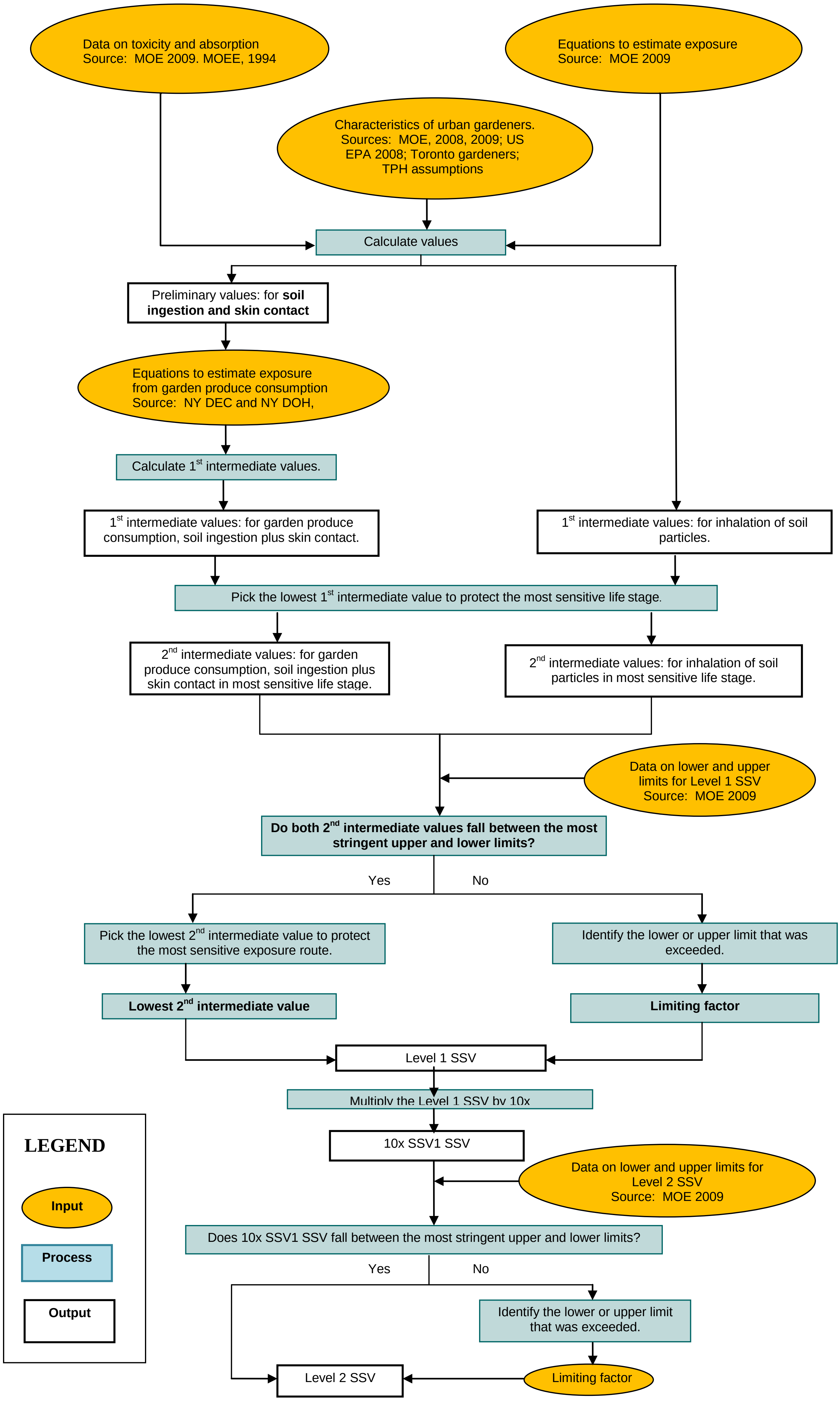


**Figure D-2: Process used to calculate a new soil screening value (SSV) for urban gardening in Toronto**
***(Click on link to view/print on legal \\Vs-131-hlh\hlhdata\HLH\HLH\HP&EP\Urban Gardening\Draft Reports\UG_Master Technical Report_Figure D-2.docx***



# EVALUATION OF EXISTING SOIL QUALITY STANDARDS AND GUIDELINES

## Criteria Defining Suitable Soil Screening Values (SSVs) for Urban Gardening

A set of criteria were developed to define the essential characteristics of an SSV for urban gardening (Table D-1). The original intent was to use these criteria to help select, from among the existing soil quality standards and guidelines published by other jurisdictions, values that could be adopted or adapted as SSVs for urban agriculture. Ultimately, when we evaluated the existing soil quality standards and guidelines against our criteria, we did not identify any that could be adopted or adapted as SSVs for urban agriculture. Therefore, we derived our own set of values using our criteria to shape them.

One criterion turned out to be a key issue during the process of developing SSVs for urban gardening: that the SSVs must consider all the exposure pathways associated with urban gardening, and must exclude irrelevant pathways. The exposure pathways associated with urban gardening in Toronto are:

- incidental soil ingestion,
- inhalation of soil particles,
- dermal exposure to soil, and
- ingestion of produce grown in the soil.

Another exposure pathway that may be relevant to urban gardening in locations other than the City of Toronto is ingestion of meat or milk produced on the site. This pathway is not relevant to Toronto because animal production is not permitted in the City, and was therefore excluded from consideration when deriving SSVs.

Estimating exposure due to ingestion of produce grown in the soil was particularly problematic due to the large uncertainties around both the uptake of soil contaminants into produce, and produce consumption (see Appendix C).

## Review of Existing Soil Quality Standards and Guidelines

First, we considered values from Ontario and Federal agencies: Agriculture and Agrifoods Canada (AAFC), the Canadian Council of Ministers of the Environment (CCME), the Ontario Ministry of the Environment (MOE), and the Ontario Ministry of Food and Rural Affairs (OMAFRA). We also considered values from international agencies, especially agencies in jurisdictions known to promote urban gardening (e.g., California and the UK). The full lists of jurisdictions investigated, and soil quality standards and guidelines reviewed are provided in Tables D-2 and D-3.

**Table D-2: Summary of the results of the Ontario and Canada jurisdictional review to identify values for adoption**

| Agency | Values | Summary |
|---|---|---|
| CANADA | | |
| Agriculture and Agri-Food Canada (AAFC) | na | AAFC does not have any soil quality standards for the protection of human health that address chemical contaminants. |
| Canadian Council of Ministers of the Environment (CCME) | Soil Quality Guidelines | CCME's current protocol requires all direct and indirect exposure pathways to be considered, but indirect pathways are often not quantitatively accounted for. |
| ONTARIO | | |
| Ministry of the Environment (MOE) | Site Condition Standards (SCSs) | Health-based values developed by the MOE to account for dermal and soil ingestion exposures of a toddler and adult, respectively (S1 and S2 component values). Indirect exposure pathways are not considered. |
| Ministry of the Environment (MOE) | Non-Agricultural Source Material (NASM) Metal Standards | The standards for metal content in NASM (e.g., sewage biosolids) for land application were established to protect plants and to prevent metal accumulation in soil. In Ontario, sewage biosolids are typically not applied to land used for fruits, vegetables or pasture because the mandatory waiting periods between application and harvest/pasturing make the use of sewage biosolids impractical. |
| Ministry of Agriculture, Food and Rural Affairs (OMAFRA) | na | OMAFRA does not have any soil quality standards for the protection of human health that address chemical contaminants. |

**Table D-3: Summary of the results of the jurisdictional review to identify values for adaptation**

| Agency | Values | Summary |
|---|---|---|
| BRITISH COLUMBIA | | |
| BC Environment | Soil Quality Standards (SQSs) | BC Environment publishes SQS-human health that incorporate the ingestion pathway, but exclude inhalation and dermal exposures (BC Environment, 1996) |
| UNITED STATES | | |
| US EPA | Preliminary Remediation Goals (PRGs), Risk-Based Concentrations (RBCs) and Soil Screening Levels (SSLs) | Region 3 RBCs, Region 9 PRGs<br>Pathway-specific generic SSLs are provided for the soil ingestion, inhalation and drinking water pathways. Guidance is provided to derive site-specific SSLs where needed. This guidance fully addresses soil ingestion, inhalation and drinking water exposures; but is only able to address dermal, plant consumption and indoor air exposures in a limited fashion. Site-specific methods are not suitable for screening large numbers of sites across Toronto. |

| Agency | Values | Summary |
|---|---|---|
| CALIFORNIA | | |
| Office of Environmental Health Hazard Assessment (OEHHA) / Environmental Protection Agency (CalEPA) | Screening numbers | OEHHA's human-exposure-based screening numbers for contaminated soil are intended as a reference for local government, community groups, etc. to determine the degree of effort required to clean up a contaminated site. Soil ingestion, inhalation and dermal exposure were considered for the residential scenario. Exposure via consumption of vegetables grown in contaminated soil was not considered in the derivation of the screening numbers. |
| NEW YORK | | |
| NY Department of Environmental Conservation | Soil Cleanup Objectives (SCOs) | Both direct and indirect exposure pathways are accounted for, although the produce ingestion pathway is evaluated qualitatively. |
| NETHERLANDS | | |
| Environment Agency (RIVM) | Soil Intervention Values | Intervention Values are generic soil quality standards used to classify historically contaminated soils as seriously contaminated in the framework of the Dutch Soil Protection Act. They are based on a residential exposure scenario with the following pathways: ingestion, inhalation and dermal uptake of soil; inhalation of vapours; drinking water; and consumption of homegrown crops. |
| UNITED KINGDOM | | |
| Environment Agency | Soil Guideline Values | SGVs are scientifically based generic assessment criteria that can be used to screen for human health risks arising from long-term and on-site exposure to chemical contamination in soil. SGVs are derived for residential, allotment and commercial land uses. The SGVs for the allotment land use quantitatively account for exposures via direct soil ingestion, consumption of homegrown produce, consumption of soil adhering to homegrown produce, skin contact with soil and outdoor inhalation of dust and vapours. SGVs are available for a limited suite of parameters. |
| GERMANY | | |
| Environment Agency (UBA) | Trigger Values | Germany has established trigger values for direct intake of 14 pollutants in the soils of residential areas, as well as trigger values for 6 pollutants with regard to plant quality for human consumption in agricultural and vegetable garden soils. The exact exposure scenarios used to derive the trigger values are not clear and many of the contaminants of concern for Toronto are not addressed. |
| INTERNATIONAL | | |
| World Health Organization (WHO) | na | WHO does not have any soil quality standards for the protection of human health that address chemical contaminants. |
| Food and Agricultural Organization of the United Nations (UN FAO) | na | FAO does not have any soil quality standards for the protection of human health that address chemical contaminants. |

We concluded that none of the existing soil quality standards and guidelines that we reviewed met all of our criteria and were not suitable for adoption in Toronto. However, we learned from four sets of values in particular, and they are discussed below.

## Ontario's Site Condition Standards

The Ontario Ministry of the Environment's (MOE's) Site Condition Standards (SCSs) are soil, sediment and water quality screening values for the protection of human and ecological health (MOE, 2009). A number of SCSs for soil have been developed for different land uses. The land uses of most interest for urban gardening are Residential/Parkland/Institutional (R/P/I) and Agricultural.

To derive SCS values for the R/P/I and Agricultural land uses that are protective of both human and ecological health, MOE calculated intermediate, or component, values for different people, animals, plants and exposure scenarios, and selected the lowest value from among the applicable components.

The three human health-based component values that are relevant to urban gardening are termed S1, S2 and S3, and reflect some of the exposures of a toddler/adult, a long-term outdoor worker and a sub-surface worker, respectively. All three components consider direct exposures to soil for nine months of the year. Only the S3 Component Value considers soil particle inhalation, and none of the components considers ingestion of produce; therefore, all three could underestimate exposure to contaminated soil in an urban gardening scenario. This is to be expected because neither the component values nor the final SCSs are specific to urban gardening. Their use in a soil assessment protocol for urban gardening would result in a great deal of uncertainty as to the level of health risk for urban gardeners, and the need for risk mitigation. These standards also overpredict the direct soil contact exposure pathway by assuming a nine-month exposure duration.

Table D-4: Summary of evaluation of existing soil quality standards and guidelines; values of particular interest are in bold text

| | | Evaluation Criteria | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Agency** | **Values** | **Human Health** | **Children** | **Toronto Appropriate[a]** | **Reasonable Worst-Case** | **Other Sources** | **Exposure Pathways** | **Notes** |
| AAFC | none | | | | | | | |
| CCME | **Soil Quality Guidelines** | ✓ | ✓ | ✓ | ✓ | ✓ | × | Desirable due to jurisdictional applicability, but includes irrelevant exposure pathways and does not account for produce ingestion for relevant parameters. |
| MOE | **Site Condition Standards** | ✓ | ✓ | ✓ | ✓ | ✓ | × | Desirable due to jurisdictional applicability, but includes irrelevant exposure pathways and does not account for produce ingestion. |
| OMAFRA | none | | | | | | | |
| BC Environment | Soil Quality Standards | ✓ | ✓ | ✓ | | ✓ | × | Includes irrelevant exposure pathways and does not account for produce ingestion. |
| US EPA | Soil Screening Levels | ✓ | ✓ | × | × | ✓ | × | US EPA's generic SSLs were calculated using a set of default values that are conservative and likely to be protective for the majority of site conditions across the US. |
| US EPA Region 3 | Risk Based Criteria | ✓ | ✓ | ✓ | | ✓ | × | Includes irrelevant exposure pathways and does not account for produce ingestion. |
| US EPA Region 9 | Preliminary Remediation Goals | ✓ | ✓ | ✓ | | ✓ | × | Includes irrelevant exposure pathways and does not account for produce ingestion. |

**Table D-4: Summary of evaluation of existing soil quality standards and guidelines; values of particular interest are in bold text**

| | | Evaluation Criteria | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Agency** | **Values** | **Human Health** | **Children** | **Toronto Appropriate**[a] | **Reasonable Worst-Case** | **Other Sources** | **Exposure Pathways** | **Notes** |
| OEHHA / CalEPA | Screening numbers | ✓ | ✓ | ✓ | | ✓ | × | Includes irrelevant exposure pathways and does not account for produce ingestion. |
| UK EA | **Soil Guideline Values** | ✓ | ✓ | × | ✓ | ✓ | ✓ | Accounts for relevant exposure pathways, but derived using a multi-media model and data inputs that are specific to the UK |
| NY DEC | **Soil Cleanup Objectives** | ✓ | ✓ | ✓ | × | ✓ | × | Clean-down-to objectives that are overly conservative for our purpose, and consider irrelevant exposure pathways, but do account for produce ingestion |
| RIVM | Soil Intervention Levels | ✓ | ✓ | × | × | × | × | Includes irrelevant exposure pathways and does not account for produce ingestion. |
| Germany | Trigger Values | ✓ | ✓ | × | × | ✓ | × | Scenario, pathways and risk-benefit trade-offs not appropriate |
| WHO | none | | | | | | | |
| UN FAO | none | | | | | | | |

Notes: ✓ Criterion met
× Criterion not met
■ Criterion not evaluated
For the full text of the evaluation criteria, see Table D-1.

a Both site and human characteristics should be appropriate for Toronto. Important site characteristics that should be appropriate for Toronto include soil and ambient temperatures, soil type, absorption factors, etc. Appropriate human characteristics for Toronto include 6 months per year of gardening activity, and warmer clothing covering more parts of the body during spring and fall.

## Canadian Environmental Quality Guidelines

The Canadian Council of Ministers of the Environment's (CCME's) Soil Quality Guidelines (SQGs) for the protection of environmental and human health are non-regulatory values for use at contaminated sites. Similar to the approach taken by the MOE, CCME derives individual component values for different people and exposure pathways, and selects the lowest applicable value as the SQG.

According to their current SQG derivation protocol, CCME considers the following soil exposure pathways for the residential/parkland land use: ingestion, dermal contact, inhalation, groundwater, indoor air and backyard produce (CCME, 2006). The SQG derivation protocol for agricultural land use is similar, except that produce, meat and milk ingestion is also included. Although ingestion of vegetable produce is relevant to urban gardening in Toronto, meat and milk consumption are not, because animal production is not permitted in the City. Exposures are assumed to occur year round.

Except for the consideration of the indoor air pathway, which is not relevant to urban gardening, the CCME's residential/parkland scenario seemed perfectly suited to be adapted by Toronto for urban gardening due to the apparent inclusion of produce ingestion. However, closer examination showed that the produce ingestion, dermal contact and soil particle inhalation exposure pathways were not included in the derivations for most of the contaminants of interest to Toronto. In fact, produce ingestion was only considered for cadmium, dermal contact was considered for six contaminants and soil particle inhalation was not considered for any of our contaminants of interest. The CCME values lack specificity to urban gardening, and their use in a soil assessment protocol for urban gardening would result in a great deal of uncertainty as to the level of health risk for urban gardeners, and the need for risk mitigation.

## UK's Soil Guideline Values

The revised Soil Guideline Values (SGVs) recently published by the UK Environment Agency are trigger values based on human health risk (EA, 2009). SGVs have been developed for residential, allotment garden and commercial/industrial land uses. To derive the SGVs, the Environment Agency used an exposure model that considers exposures to all environmental media to estimate the soil concentration of a contaminant that will result in a total human exposure (i.e., exposure via all relevant pathways) that poses only minimal risk.[41]

The Environment Agency notes that SGVs cannot be used for a site evaluation if they are not representative of the site. It is unknown whether the SGVs would be representative of garden sites in Toronto, because they were derived for the UK. One key parameter that would not be appropriate to Toronto is the assumption of year-round urban gardening.

[41] Their use of a multi-media model means that the UK Environment Agency does not provide separate component values for each exposure pathway.

A high degree of uncertainty is associated with the Environment Agency's evaluation of the vegetable consumption pathway. The Environment Agency applied assumptions and UK-specific data to estimate exposure via this pathway. The difficulties with the vegetable consumption pathway lie in estimating both the uptake of soil contaminants into vegetables and vegetable intake by residents. Other agencies recently determined that it was not possible to estimate exposure via the vegetable consumption pathway with a reasonable degree of accuracy (Hristov, *et al*., 2005; NYDEC and NYDOH, 2006; US EPA, 1996b). It is not clear how uncertain the vegetable consumption component of the SGVs is.

We determined that, given the assumptions, UK-specific data and remaining uncertainty inherent in the derivation of the SGVs, that neither the SGVs nor the exposure model used to calculate them is appropriate for use in Toronto. Their use in a soil assessment protocol for urban gardening would result in a great deal of uncertainty as to the level of health risk for urban gardeners in Toronto, and the need for risk mitigation. Furthermore, it is our understanding that the UK SGVs were derived using a very conservative approach meaning that they might unnecessarily restrict the use of certain sites in Toronto for urban agriculture.

## New York State's Soil Cleanup Objectives

New York State's Soil Cleanup Objectives (SCOs) were developed as remedial action objectives for soil based on a site's current or future land use (NYDEC and NYDOH, 2006). Similarly to CCME and MOE, New York derives individual component values for different exposure pathways. SCOs are available for several land uses, including a residential land use scenario that is relevant to urban gardening. This scenario considers the exposures of both a young child and an adult (NYDEC and NYDOH, 2006). The following soil exposure pathways were considered: ingestion, dermal contact, inhalation, indoor dust and backyard produce.

Although the vegetable consumption pathway was considered by NYDEC, it was not evaluated quantitatively. To qualitatively account for the vegetable consumption pathway, NYDEC made an across-the-board proportional reduction in the SCO component for the incidental soil ingestion pathway. (Note that this reduction does not consider any of the factors or variables associated with the vegetable consumption exposure pathway, except to incorporate enough conservatism that the impact of these factors is likely not underestimated.) The proportional reduction attributes 20% of ingestion exposure to the quantified soil ingestion pathway, and 80% to the un-quantified vegetable consumption pathway. The effect is to increase estimated exposure via the ingestion pathway by a factor of five.

The SCOs themselves (and their components) are not specific to urban gardening, and their use in a soil assessment protocol for urban gardening would introduce a great deal of uncertainty as to the level of health risk for urban gardeners, and the need for risk mitigation. However, New York State's decision to allocate 80% of ingestion exposure to vegetable consumption is a conservative, policy-based decision. It follows a precedent by the US EPA where analogous adjustments were made in the context of drinking water standards setting. To avoid over-regulating a quantified exposure based on the allowance for a dominant contribution from an additional unquantified source, US EPA has traditionally set an 80% ceiling for this allowance. This method of qualitatively accounting for the vegetable consumption pathway could easily be transferred to the Toronto context.

## Development of TPH's Soil Screening Values

Elements of the approaches from both the Ministry of the Environment and New York State provided very useful information as we developed our approach. We concluded that the simplest and most health-protective approach to producing SSVs that are suitable for the range of soil and site conditions in Toronto's urban gardens is to adapt the methods used by the MOE for the derivation of their SCSs (MOE, 2009), with the addition of New York State's proportional reduction strategy to account for the vegetable consumption pathway (NYDEC and NYDOH, 2006). The key advantage of this approach is that the methods and many of the input values have been validated for Ontario. With respect to the vegetable consumption pathway, it is important to note that the uncertainty associated with the qualitative evaluation of this pathway is unknown and likely significant. We used a reasonable worst case scenario; thus, the SSVs tend to overestimate exposure and "err on the side of caution."

We combined various input data describing gardeners, gardening behaviour and the soil contaminants in a series of equations to calculate first several preliminary values, then several intermediate values. The intermediate values were compared to various lower and upper limits, and finally the SSVs for urban gardening in Toronto were selected. The input data are described below, followed by the calculations.

## Input Data: Overview

The following exposure scenario and key assumptions were used in the calculations:

**Table D-5: Exposure scenario and key assumptions used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto**

| Non-Cancer Risk | Cancer Risk |
|---|---|
| • Toddler | • Lifetime composite (an average across all lifestages) |
| • Time in the garden: 3.5 hours per day, 2 days per week, 6 months per year, or:<br>o 52 gardening days per year (used to estimate ingestion and dermal exposure)<br>o 182 gardening hours per year (used to estimate inhalation exposure)[a] | • Time in the garden: 5 hours per day, 5 days per week, 6 months per year, or:<br>o 130 gardening days per year (used to estimate ingestion and dermal exposure)<br>o 545 gardening hours per year (used to estimate inhalation exposure) |
| • Direct exposure to contaminants in garden soil:<br>o ingestion of soil (100 mg/d)<br>o dermal exposure to soil (exposed skin only)<br>o inhalation of outdoor soil particles (inhalation rate of 1.1 $m^3$/h) | • Direct exposure to contaminants in garden soil:<br>o ingestion of soil (100 mg/d)<br>o dermal exposure to soil (exposed skin only)<br>o inhalation of outdoor soil particles (inhalation rate of 1.5 $m^3$/h) |
| • Exposure to contaminants via consumption of produce grown in garden soil (qualitatively estimated) | • Exposure to contaminants via consumption of produce grown in garden soil (qualitatively estimated) |

a Our standard exposure scenario amortizes a 6-month exposure period over a year. For the two parameters that pose a developmental hazard via the inhalation route, arsenic and ethylbenzene, a different, more conservative exposure assumption was used as a surrogate method to accounting for developmental effects. We assumed that inhalation exposures to these parameters occur daily (i.e., 1277.5 gardening hours per year).

## Input Data: General

To calculate the soil screening values (SSVs) we used a number of pieces of data to characterize the exposure scenario and gardeners. The majority of the data are from the MOE, although in some cases we used US EPA sources, or made assumptions that are appropriate for urban agriculture.

**Table D-6: Input Values Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto**

| | Value | Units | Source | Comments |
|---|---|---|---|---|
| **Soil Source Allocation Factor** | 10 % | unitless | Assumed | In standards development, 20% of the total daily intake of a contaminant is typically allocated to soil (MOE, 2009). We have allocated half of the total amount for all soil exposures to soil from the urban garden. |
| **Cancer Risk Level** | 1.00E-06 | unitless | MOE, 2009 | all receptors |
| **Exposure Frequency** | | | | |
| female toddler | 52 | d/y | Assumed | 2 d/w, 26 w/y; used for majority of parameters |
| | 365 | d/y | Assumed | Daily exposure assumed where developmental effects were of concern |
| female adult | 130 | d/y | Assumed | 5 d/w, 26 w/y; used for majority of parameters |
| | 365 | d/y | Assumed | Daily exposure assumed where developmental effects were of concern |
| female composite | 109 | d/y | Calculated | Weighted average based on assumed exposure frequencies of 52 and 130 d/y for toddler-teen and adult, respectively |
| **Exposure Length** | | | | |
| female toddler | 3.5 | h/d | Assumed | Assumption is consistent with the application of the EMF prudent avoidance policy. |
| female adult | 5 | h/d | Assumed | |
| female composite | 5 | h/d | Assumed | |
| **Exposure Duration** | | | | |
| female toddler | 4.5 | y | MOE, 2009 | |
| female adult | 56 | y | MOE, 2009 | |
| female composite | 75.5 | y | Calculated | This is the sum of exposure durations from MOE (2009) for age classes from toddler-teen through adulthood (19.5 + 56) |
| **Averaging Period** | | | | |
| female toddler | 4.5 | y | MOE, 2009 | |
| female adult | 56 | y | MOE, 2009 | |
| female composite | 76 | y | MOE, 2009 | |
| **Body Weight** | | | | |
| female toddler | 16.5 | kg | MOE, 2009 | |
| female adult | 63.1 | kg | MOE, 2009 | |
| female composite | 56.8 | kg | Calculated | Weighted average based on data for individual age classes from MOE (2009). |
| assumed in inhalation TRV derivation | 70.0 | kg | MOE, 2008 | |
| **Soil Ingestion Rate** | | | | |
| female toddler | 100 | mg/d | see comments | MOE (2009) uses conservative mean soil ingestion rates. This value is a conservative estimate of the mean soil-only ingestion rate based on the soil-only and indoor dust ingestion rates provided by US EPA (2008). |
| female adult | 100 | mg/d | MOE, 2009 | This is MOE's soil ingestion rate for outdoor fixed/subsurface workers. This value was selected instead of the adult resident value (50 mg/d) to reflect the similar levels of contact with soil among outdoor work and gardening. |

**Table D-6: Input Values Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto**

| | Value | Units | Source | Comments |
|---|---|---|---|---|
| female composite | 100 | mg/d | Calculated | Weighted average based on data for individual age classes from MOE (2009). |
| **Soil Adherence Factor** | | | | |
| female toddler | 0.2 | $mg/cm^2/d$ | MOE, 2009 | This is MOE's recommended value for toddlers, based on the 95th percentile weighted AF for children playing at a child care centre, and the 50th percentile for children playing in wet soil. |
| female adult | 0.2 | $mg/cm^2/d$ | MOE, 2008 | This is MOE's and US EPA's recommended value for outdoor workers. It is based on the 50th percentile weighted AF for utility workers. It is considered a conservative estimate for that population. We judged it appropriate for gardeners, because of the common digging element. An alternative value is the recommendation for adult residents (0.07 $mg/cm^2/d$), which is based on the 50th percentile weighted AF for gardeners. It is considered a conservative estimate for the general population of adult residents since they will often engage in less contact-intensive activities. It is somewhat less conservative for gardeners. |
| female composite | 0.2 | $mg/cm^2/d$ | Calculated | Calculated weighted average based on data for individual age classes and subsurface workers from MOE (2009). |
| **Skin Surface Area Exposed** | | | | |
| female toddler | 1958 | $cm^2$ | Calculated | Weighted average over the 6-month gardening season, based on data for summer and spring/fall from MOE (2009). Assumed that head, hands, forearms, lower legs and feet are exposed for 3 summer months; head, hands and forearms for 3 spring/fall months. |
| female adult | 4438 | $cm^2$ | Calculated | Weighted average over the 6-month gardening season, based on data for summer and spring/fall from MOE (2009). Assumed that head, hands, forearms and lower legs are exposed for 3 summer months; head, hands and forearms for 3 spring/fall months. |
| female composite | 4130 | $cm^2$ | Calculated | Weighted average based on data for individual age classes from MOE (2009) |
| **Inhalation Rate** | | | | |
| female toddler | 1.1 | $m^3/h$ | US EPA, 2008 | This is the mean value for toddlers of both genders engaged in moderate intensity activity. (It was calculated as a weighted average of values for several age classes.) It is intended for exposure durations of less than 30 d, and not for scenarios of the duration considered here. An alternative would be to assume a breathing rate of 1.5 $m^3/h$, which is hyperconservative for a toddler's small body size. Another alternative is to use a general number for female toddlers irrespective of activity level, which would tend to underpredict inhalation exposure (the 24-hour arithmetic mean recommended by Richardson (1997) for Canadian female toddlers (0.37 $m^3/h$) is approximately one third of the selected value). |

**Table D-6: Input Values Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto**

| | Value | Units | Source | Comments |
|---|---|---|---|---|
| female adult | 1.5 | $m^3/h$ | MOE, 2009 | This is MOE's inhalation rate for subsurface workers, which seems to be a reasonable approximation of both the activity level and soil disturbance that will be associated with urban gardening. It is a mean value for moderate activities. |
| female composite | 1.5 | $m^3/h$ | Assumed | Inhalation rates for all age classes recommended for use in chronic exposure assessments were not readily available; therefore, a breathing rate of 1.5 $m^3/h$ was conservatively assumed for the female composite. |
| assumed in inhalation TRV derivation | 0.8 | $m^3/h$ | MOE, 2009 | |
| **PM10 Concentration** | 100 | µg/m3 | MOE, 2009 | This is the central tendency concentration of respirable soil particles in the air around subsurface workers, which was judged to be a reasonable approximation of the concentrations near gardeners. |
| **Fraction of PM10 Deposited** | 0.6 | unitless | MOE, 2009 | This is the deposition fraction for subsurface workers. It was assumed that this value is relevant to gardeners of all ages. |

## Input Data: Chemical Specific

We used additional input values to characterize the toxicity and absorption of each of the soil contaminants.

## Toxicological Reference Values

We used toxicological reference values (TRVs) for each soil contaminant to calculate exposure levels for each contaminant which are not expected to result in unacceptable health risk. TRVs are chemical specific, based on particular health effects, and are differentiated by route of exposure. The TRVs that we used to derive the SSVs are provided in Table D-7. For most TRVs designed to be protective of non-cancer health effects, one-fifth of the value is allocated to each major exposure route. This is standard practice, and the approach followed by the Ontario Ministry of the Environment.[42]

For TRVs designed to be protective of cancer risk, a *de minimis* cancer risk level of 1-in-1 million was allocated to each main exposure route. Again, this is consistent with Toronto Public Health policy and the Ontario Ministry of the Environment's practice.

[42] For the purpose of deriving the SSVs, one-tenth of the value of each non-cancer TRV was allocated to exposures associated with urban gardening. This means that one-tenth of each TRV remains for other soil exposures, and four-fifths of each TRV remain for all other sources of exposure to the parameter, including ambient air, drinking water, consumer products and grocery store foods.

**Table D-7: Toxicological Input Data Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto (MOE, 2009, except where noted)**

| | Direct Contact TRVs | | Inhalation TRVs | |
|---|---|---|---|---|
| | **Tolerable Daily Intake (mg/kg/d)** | **Cancer Slope Factor $(mg/kg/d)^{-1}$** | **Tolerable Concentration $(mg/m^3)$** | **Unit Risk $(mg/m^3)^{-1}$** |
| Arsenic | 3.0E-04 | 1.5E+00 | 3.0E-05[a] | 1.5E+00 |
| Cadmium | 3.0E-05 | none | 5.0E-06 | 9.8E+00 |
| Cobalt | 1.0E-03 | none | 5.0E-04 | none |
| Chromium, total | 1.5E+00 | none | 6.0E-02 | none |
| Chromium, VI | 8.3E-03 | none | 1.0E-04 | 4.0E+01 |
| Copper | 3.0E-02 | none | none | none |
| Mercury | 3.0E-04 | none | 9.0E-05 | none |
| Molybdenum | 5.0E-03 | none | 1.2E-02 | none |
| Nickel | 2.0E-02 | none | 6.0E-05 | 2.4E-01 |
| Lead[b] | 1.85E-03 | none | none | none |
| Selenium | 5.0E-03 | none | none | none |
| Zinc | 3.0E-01 | none | none | none |
| PCBs | 2.0E-05 | 2.0E+00[c] | 5.0E-04 | 1.0E-01 |
| PAH | none | none | none | none |
| Acenaphthene | 6.0E-02 | 7.3E-03 | none | 1.1E-03 |
| Acenaphthylene | 6.0E-02 | 7.3E-02 | none | 1.1E-02 |
| Anthracene | 3.0E-01 | none | none | none |
| Benz(a)anthracene | none | 7.3E-01 | none | 1.1E-01 |
| Benzo(a)pyrene | none | 7.3E+00 | none | 1.1E+00 |
| Benzo(b)fluoranthene | none | 7.3E-01 | none | 1.1E-01 |
| Benzo(g,h,i)perylene | none | 7.3E-02 | none | 1.1E-02 |
| Benzo(k)fluoranthene | none | 7.3E-01 | none | 1.1E-01 |
| Chrysene | none | 7.3E-02 | none | 1.1E-02 |
| Dibenz(a,h)anthracene | none | 7.3E+00 | none | 1.1E+00 |
| Fluoranthene | 4.0E-01 | 7.3E-02 | none | 1.1E-02 |
| Fluorene | 4.0E-02 | none | none | none |
| Indeno(1,2,3-c,d)pyrene | none | 7.3E-01 | none | 1.1E-01 |
| Phenanthrene | none | none | none | none |
| Pyrene | 3.0E-02 | 7.3E-03 | none | none |
| Benzene | 4.0E-03 | 8.5E-02 | 3.0E-02 | 2.2E-03 |
| Toluene | 8.0E-02 | none | 5.0E+00 | none |
| Ethyl benzene | 1.0E-01 | none | 1.0E+00[a] | none |
| Xylene | 2.0E-01 | none | 7.0E-01 | none |
| Styrene | 1.2E-01 | none | 2.6E-01 | none |
| Petroleum hydrocarbons, F1[d] | 4.0E-02 | none | 2.0E-01 | none |
| Petroleum hydrocarbons, F2[d] | 4.0E-02 | none | 2.0E-01 | none |
| Petroleum hydrocarbons, F3[d] | 3.0E-02 | none | none | none |
| Petroleum hydrocarbons, F4[d] | 3.0E-02 | none | none | none |
| Oils & lubricants | none | none | none | None |

a Note that the inhalation tolerable concentrations for arsenic and ethyl benzene are based on developmental effects.

b The source for the Pb Tolerable Daily Intake (TDI) is MOEE, 1993. It is recognized by TPH that this TDI is no longer supported by the literature. This value will be replaced, and an updated SSV for lead will be calculated when Health Canada updates their TDI to reflect current understanding of the health effects of lead at low exposures.

c The Cancer Slope Factor for PCBs was obtained from the 2008 draft Rationale document.

d MOE (2009) breaks each of the petroleum hydrocarbon fractions down into two to four parts and provides specific TRVs for each. The most conservative TRV was selected to represent the toxicity of the fraction. In all cases, this was the TRV for the aromatic portion of the fraction.

## Relative Absorption Factors

The relative absorption factors used here describe the ratio of the fraction of the contaminant in soil that is absorbed into the human body, to the fraction absorbed in the toxicological study used as the basis of the TRV. Relative absorption factors are chemical, exposure medium and exposure route specific.

**Table D-8: Relative Absorption Factors Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto (MOE, 2009, except where noted)**

| | Relative Absorption Factors | | |
|---|---|---|---|
| | **Oral** | **Dermal**[a] | **Inhalation**[b] |
| Arsenic | 0.5 | 0.03 | 1 |
| Cadmium | 1 | 0.01 | 1 |
| Cobalt | 1 | 0.01 | 1 |
| Chromium, total | 1 | 0.1 | 1 |
| Chromium, VI | 1 | 0.1 | 1 |
| Copper | 1 | 0.06 | 1 |
| Mercury | 0.5 | 0.1 | 1 |
| Molybdenum | 1 | 0.01 | 1 |
| Nickel | 1 | 0.2 | 1 |
| Lead[d] | 1[c] | 1[c] | 1 |
| Selenium | 1[c] | 0.01[c] | 1 |
| Zinc | 1[c] | 0.1[c] | 1 |
| PCBs | 1[c] | 0.14[c] | 1 |
| PAH | 1 | 0.13 | 1 |
| Acenaphthene | 1 | 0.13 | 1 |
| Acenaphthylene | 1 | 0.13 | 1 |
| Anthracene | 1 | 0.13 | 1 |
| Benz(a)anthracene | 1 | 0.13 | 1 |
| Benzo(a)pyrene | 1 | 0.13 | 1 |
| Benzo(b)fluoranthene | 1 | 0.13 | 1 |
| Benzo(g,h,i)perylene | 1 | 0.13 | 1 |

**Table D-8: Relative Absorption Factors Used by Toronto Public Health to calculate soil screening values (SSVs) for urban gardening in Toronto (MOE, 2009, except where noted)**

| | Relative Absorption Factors | | |
|---|---|---|---|
| | **Oral** | **Dermal**[a] | **Inhalation**[b] |
| Benzo(k)fluoranthene | 1 | 0.13 | 1 |
| Chrysene | 1 | 0.13 | 1 |
| Dibenz(a,h)anthracene | 1 | 0.13 | 1 |
| Fluoranthene | 1 | 0.13 | 1 |
| Fluorene | 1 | 0.13 | 1 |
| Indeno(1,2,3-c,d)pyrene | 1 | 0.13 | 1 |
| Phenanthrene | 1[c] | 0.13[c] | 1 |
| Pyrene | 1[c] | 0.13[c] | 1 |
| Benzene | 1 | 0.03 | 1 |
| Toluene | 1[c] | 0.03[c] | 1 |
| Ethyl benzene | 1 | 0.03 | 1 |
| Xylene | 1[c] | 0.03[c] | 1 |
| Styrene | 1[c] | 0.03[c] | 1 |
| Petroleum hydrocarbons, F1 | 1[d] | 0.2[d] | 1 |
| Petroleum hydrocarbons, F2 | 1[d] | 0.2[d] | 1 |
| Petroleum hydrocarbons, F3 | 1[d] | 0.2[d] | 1 |
| Petroleum hydrocarbons, F4 | 1[d] | 0.2[d] | 1 |
| Oils & lubricants | none | none | 1 |

a MOE assumed an $RAF_{derm}$ of 0.01 for inorganic parameters with insufficient quantitative data.
b Note, MOE assumed an $RAF_{inh}$ of 1 for all parameters.
c RAF was not provided in Table 2.24of MOE (2009). GI and dermal absorption factors from Apx B were used to fill in this table. (RAFs from Table 2.24 match the absorption factors from Apx B in all cases, so I'm reasonably confident that they are relative absorption factors.)
d RAF was not available in MOE (2009) and was taken from the Modified Generic Risk Assessment Model provided by MOE (19/Oct/2009)

## Calculation of Preliminary and First Intermediate Values

We combined the input data described above in a series of equations to first calculate several preliminary values, then several intermediate values, and finally the SSVs for urban gardening in Toronto. We calculated up to three preliminary values for each soil contaminant:

- Soil ingestion and skin contact preliminary values for:
    - Non-cancer effects in the toddler receptor,
    - Non-cancer effects in the adult female receptor, and
    - Cancer effects in the lifetime average female receptor (if applicable).

We then calculated up to six intermediate values for each soil contaminant:

- Inhalation intermediate values (if applicable) for:
    - Non-cancer effects in the toddler receptor,
    - Non-cancer effects in the adult female receptor, and
    - Cancer effects in the lifetime average female receptor (if applicable).

- Garden produce consumption plus soil ingestion and skin contact intermediate values for:
    - Non-cancer effects in the toddler receptor,
    - Non-cancer effects in the adult female receptor, and
    - Cancer effects in the lifetime average female receptor (if applicable).

### Soil Ingestion and Skin Contact Preliminary Values

We calculated the soil ingestion and skin contact preliminary values using the following equations:

$$Value_{ingest+dermal,non\text{-}cancer} = \frac{SAF*TDI*C}{(IngC*RAF_{oral}) + (DermC*RAF_{derm})}$$

$$Value_{ing+dermal,cancer} = \frac{CRL*C}{CSF*[(IngC*RAF_{oral})+(DermC*RAF_{dermal})]}$$

Where:

| | | |
|---|---|---|
| SAF | = | source allocation factor, 0.2 |
| CRL | = | cancer risk level, $10^{-6}$ |
| TDI | = | tolerable daily intake, chemical specific |
| CSF | = | cancer slope factor, chemical specific |

| | | |
|---|---|---|
| C | = | unit conversion factor, $10^6$ mg/kg |
| RAF | = | relative absorption factor, chemical specific |
| IngC | = | ingestion contact with soil (see equation below) |
| DermC | = | dermal contact with soil (see equation below) |

$$IngC = \frac{SIR * EF * ED}{BW * AP * C}$$

$$DermC = \frac{SSA * SA * EF * ED}{BW * AP * C}$$

Where:

| | | |
|---|---|---|
| SIR | = | soil ingestion rate, receptor specific |
| SSA | = | skin surface area exposed, receptor specific |
| SA | = | soil adherence factor, receptor specific |
| EF | = | exposure frequency, receptor specific |
| ED | = | exposure duration, receptor specific |
| BW | = | body weight, receptor specific |
| AP | = | averaging period, receptor specific |
| C | = | unit conversion factor, 365 d/y |

## Inhalation Intermediate Values

We calculated the inhalation intermediate values using the following equations:

$$Value_{inh,\,non-cancer} = \frac{SAF * TC}{InhC * RAF_{inh}}$$

$$Value_{inh,\,cancer} = \frac{CRL}{InhC * RAF_{inh} * UR}$$

Where:

SAF = source allocation factor, 0.2

CRL = cancer risk level, $10^{-6}$

TC = tolerable concentration, chemical specific

UR = unit risk, chemical specific

InhC = inhalation contact with soil, see equation below

RAF = relative absorption factor, chemical specific

$$InhC = \frac{[PM_{10}]*FPM*IR_R*EF*ED*BW_A}{BW_R*AP*C*IR_A}$$

Where:

$[PM_{10}]$ = concentration of fine particulate matter in air, 100 μg/$m^3$

FPM = fraction of particulate matter that is deposited in the lung, 0.6

EF = exposure frequency, receptor specific

ED = exposure duration, receptor specific

$IR_R$ = inhalation rate, receptor specific

$IR_A$ = inhalation rate assumed in the derivation of TRVs[43], 20 $m^3$/d

$BW_R$ = body weight, receptor specific

$BW_A$ = body weight assumed in the derivation of TRVs[43], 70 kg

AP = averaging period, receptor specific

C = unit correction factor, unitless, $3.65 \times 10^{11}$

## Garden Produce Consumption, Soil Ingestion and Dermal Intermediate Values

We calculated the intermediate values for produce consumption plus soil ingestion plus dermal exposure (“produce plus direct contact”) using the qualitative method of accounting for garden produce consumption from New York State. This method uses the same equations as for the soil ingestion and dermal preliminary values, with the exception that ingestion contact with soil is

[43] MOE provides inhalation TRVs in the form of ambient air concentrations (i.e., mg/$m^3$ or $[mg/m^3]^{-1}$). An assumed body weight and inhalation rate were incorporated into these values during their derivation. In order to consider different values more appropriate to our receptors and to urban gardening, the initial assumed values were "backed out" of the TRVs. This is why two body weights and two inhalation rates are needed to calculate each inhalation intermediate value.

recalculated according to the equation below to qualitatively account for vegetable consumption in addition to soil ingestion.

$$IngC = \frac{1}{1-PR} * \left( \frac{SIR * EF * ED}{BW * AP * C} \right)$$

Where:

SIR = soil ingestion rate, receptor specific

EF = exposure frequency, receptor specific

ED = exposure duration, receptor specific

BW = body weight, receptor specific

AP = averaging period, receptor specific

C = unit conversion factor, 365 d/y

PR = proportional reduction, 0.8

The method of accounting for garden produce consumption from New York State attributes 80% of ingestion exposure to the garden produce consumption pathway. This means that the estimate of soil ingestion exposure calculated above was adjusted upward to estimate an aggregate exposure that attributes 20% to the quantified soil ingestion pathway and allows an additional 80% for the unestimated vegetable consumption pathway. Whether the 80% allocation factor is health-protective or not is discussed in the Uncertainty section below.

## Selection of Second Intermediate Values

For each major exposure route (that is inhalation, and garden produce consumption plus soil ingestion plus skin contact), we selected the lowest of the first intermediate values as the second intermediate value. For example, the first intermediate values for inhalation of nickel are:

- 73 mg/kg for non-cancer effects in a toddler,
- 56 mg/kg for non-cancer effects in an adult, and
- 1 mg/kg for cancer effects in a lifetime composite.

The lowest of these values is 1 mg/kg, so it was selected as the second intermediate value for inhalation of nickel. This means that at soil concentrations of 1 mg/kg, or less, urban gardeners in Toronto of all ages are not predicted to experience an increased incidence of any type of adverse health effect (cancer or non-cancer) from inhalation of nickel in garden soil.

## Selection of Soil Screening Values (SSVs)

The primary basis of the SSVs is human health; however, other factors enter into the feasibility and suitability of the second intermediate values as SSVs. We considered these factors by using them as lower and upper limits on the SSVs.
Lower limits:

- Urban background soil concentrations: concentrations less than urban background are difficult to achieve (applies to all SSV 2).

- Rural background soil concentrations: concentrations less than rural background are near impossible to achieve on a large scale (applies to SSVs).

- Analytical method detection limit (MDL): concentrations in soil below the detection limit cannot be reliably measured (applies to all SSV 1).

Upper limits:

- Ecotoxicity: concentrations above the ecotoxicity component value are predicted to have negative effects on the health of plants or soil organisms; a garden in this soil is unlikely to thrive without risk mitigation (applies to all SSV1).

- 10 x urban background: concentrations greater than 10 x the urban background concentration indicate soil contamination; even if none of the COCs are present at concentrations above health-based limits, it is probable that other contaminants are present at levels of concern (applies to SSV 1 and 2).

We selected the lower of second intermediate values as the starting point for the selection of the SSV 1 (Table D-9). We then compared the starting point to the applicable lower limits and upper limits, with one of three possible outcomes:

- If the starting point was less than either lower limit, then the higher of the two lower limits was selected as the SSV 1;

- If the starting point was greater than either upper limit, then the lower of the two upper limits was selected as the SSV 1; or

- If the starting point was between the lower and upper limits, then the starting point was selected as the SSV 1.

Our starting point for the selection of the SSV 2 was 10 times the SSV 1 (Table D-9). We then compared the starting point to the applicable lower limit and upper limit, with one of three possible outcomes:

- If the starting point was less than the lower limit, then the lower limit was selected as the SSV 2;

- If the starting point was greater than the upper limit, then the upper limit was selected as the SSV 2; or

- If the starting point was between the lower limit and upper limit, then the starting point was selected as the SSV 1.

**Table D-9: Bases of Soil Screening Values (SSVs)**

| | SSV 1 | SSV 2 |
|---|---|---|
| **Starting Point** | Starting point for SSV 1 is the lower of:<br>- Health-based value for exposures via soil ingestion, dermal contact plus vegetable consumption; and,<br>- Health-based value for exposures via inhalation. | Starting point for SSV 2 is:<br>- 10 x SSV 1. |
| **Upper Limit(s)** | SSV 1 cannot be higher than either:<br>- Soil ecosystem value; or,<br>- 10 x urban background. | SSV 2 cannot be higher than:<br>- 10 x urban background. |
| **Lower Limit(s)** | SSV 1 cannot be lower than either:<br>- MDL; or,<br>- Rural background. | SSV 2 cannot be lower than:<br>- Urban background. |

Notes: SSV 1– Soil Screening Value 1; SSV 2 – Soil Screening Value 2; MDL – method detection limit.

The SSVs are shown in Table D-10 below. The SSVs are also shown in Table D-11, along with the 2nd intermediate values, lower and upper limits, and soil quality standards from the MOE.

**Table D-10: Summary of the Soil Screening Values (SSVs) for urban gardening in Toronto, with the basis for each SSV (mg/kg)**

| | SSV 1 | | SSV 2 | |
|---|---|---|---|---|
| | Value | Basis[a] | Value | Basis[a] |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 |
| Cadmium | 1.0 | MDL | 10 | 10xSSV1 |
| Cobalt | 23 | Health | 170 | 10xBkgd |
| Chromium, total | 390 | Ecotox | 630 | 10xBkgd |
| Chromium, VI | 5.0 | 10xBkgd | [d] | -- |
| Copper | 180 | Ecotox | 660 | 10xBkgd |
| Mercury | 2.7 | 10xBkgd | [d] | -- |
| Molybdenum | 13 | 10xBkgd | [d] | -- |
| Nickel | 34 | RBkgd | 340 | 10xSSV1 |
| Lead | 34 | RBkgd | 340 | 10xSSV1 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd |
| Zinc | 500 | Ecotox | 1800 | 10xBkgd |
| PCBs | 0.32 | 10xBkgd | [d] | -- |
| PAHs | -- | -- | -- | -- |
| Acenaphthene | 0.050 | MDL | 0.32 | 10xBkgd |
| Acenaphthylene | 0.093 | RBkgd | 0.47 | 10xBkgd |
| Anthracene | 0.58 | 10xBkgd | 0.58 | 10xBkgd |
| Benz(a)anthracene | 0.23 | Health | 2.3 | 10xSSV1 |
| Benzo(a)pyrene | 2.3 | Health | 3 | 10xBkgd |
| Benzo(b)fluoranthene | 0.23 | Health | 2.3 | 10xSSV1 |
| Benzo(g,h,i)perylene | 0.10 | MDL | 1.0 | 10xSSV1 |
| Benzo(k)fluoranthene | 0.23 | Health | 2.3 | 10xSSV1 |
| Chrysene | 0.099 | RBkgd | 0.99 | 10xSSV1 |
| Dibenz(a,h)anthracene | 0.77 | 10xBkgd | [d] | -- |
| Fluoranthene | 0.14 | RBkgd | 1.4 | 10xSSV1 |
| Fluorene | 0.39 | 10xBkgd | [d] | -- |

| | SSV 1 | | SSV 2 | |
|---|---|---|---|---|
| | **Value** | **Basis[a]** | **Value** | **Basis[a]** |
| Indeno(1,2,3-c,d) pyrene | 0.23 | Health | 2.3 | 10xSSV1 |
| Phenanthrene | 3.1 | 10xBkgd | [d] | -- |
| Pyrene | 0.11 | RBkgd | 1.1 | 10xSSV1 |
| Benzene | 0.00047 | 10xBkgd | [d] | -- |
| Toluene | 0.0092 | 10xBkgd | [d] | -- |
| Ethyl benzene | 0.004 | 10xBkgd | [d] | -- |
| Xylenes | 0.008 | 10xBkgd | [d] | -- |
| Styrene | 0.00003 | 10xBkgd | [d] | -- |
| F1Petroleum Hydrocarbons | 100 | 10xBkgd | [d] | -- |
| F2Petroleum Hydrocarbons | 100 | 10xBkgd | [d] | -- |
| F3Petroleum Hydrocarbons | 500 | 10xBkgd | [d] | -- |
| F4Petroleum Hydrocarbons | 500 | 10xBkgd | [d] | -- |

a Ecotox – ecosystem health-based value protective of plants and soil organisms
Health – human health-based value
MDL – analytical method detection limit
RBkgd –rural background concentration of the parameter
UBkgd –urban background concentration of the parameter
10xBkgd –10 times the urban background concentration of the parameter
10xSSV1 –10 times the SSV 1

b The urban background values for the metals and metalloids (except for Cr VI) are the Old Urban Parks OTR98 (97.5th percentile of the Ontario Typical Range data set for urban parkland locations in Ontario) provided in the main text of the Rationale Document (MOE, 2009, Sec 8). The values presented for Cr VI and the organic chemicals (except for the petroleum hydrocarbons) are the Urban OTR98 provided in Appendx B of the Rationale Document (MOE, 2009, Apx B). For the petroleum hydrocarbons, the values presented are the Ontario Soil Background values provided in the Soil Component Tables (MOE, 2009, Apx A). (No one source in the Rationale Document provides urban background values for our complete list of soil contaminants. The Old Urban Parks Parks OTR98 values (MOE, 2009, Sec 8) were used first because they specifically relate to what is achievable in parkland, followed by the Urban OTR98 values (MOE, 2009, Apx B). The Ontario Soil Background values (MOE, 2009, Apx A) do not distinguish between urban and rural soils, and, therefore, were used only when values were not available from either of the other sources.)

c For some parameters, MOE provides values for both coarse and fine soil textures. The values for coarse soil are more conservative. Since the soil texture on urban gardening sites is not known, the most conservative option was selected.

d A SSV 2 could not be developed for this parameter. Health-based values for this parameter are higher than 10 times the urban background concentration. Even when the health-based values are not exceeded, concentrations higher than 10 times the urban background concentration are an indicator of soil contamination. Therefore, Tier 2 Exposure Reduction (exposure reduction) is recommended where concentrations are higher than 10 times urban background.

**Table D-11: Soil Screening Values (SSVs) for the Toronto Urban Gardening Soil Assessment Guide, with basis, intermediate values, lower and upper limits, and Soil quality standards from the Ontario Ministry of the Environment (mg/kg)**

| | Toronto Urban Gardening Soil Assessment Guide | | | | | | | | | | | MOE Brownfields Site Condition Stds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil Screening Values | | | | 2nd Intermediate Values | | Lower Limits | | | Upper Limits | | | |
| | SSV1 | Basis[a] | SSV 2 | Basis[a] | Produce + Direct Contact | Inhalation | MDL | Rural Bkgd[b] | Urban Bkgd[b] | 10xBkgd | Ecotox | Table 3 R/P/I[c] | Table 2 Agri[c] |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.0 | 2.6 | 1 | 11 | 18 | 180 | 25 | 18 | 11 |
| Cadmium | 1.0 | MDL | 10 | 10xSSV1 | 0.69 | 2.3 | 1 | 0.7 | 1.2 | 12 | 12 | 1.2 | 1 |
| Cobalt | 23 | Direct + Veg | 170 | 10xBkgd | 23 | 234 | 2 | 16 | 17 | 170 | 50 | 22 | 22 |
| Chromium, total | 390 | Ecotox | 630 | 10xBkgd | 32222 | 28121 | 5 | 58 | 63 | 630 | 390 | 160 | 160 |
| Chromium, VI | 5.0 | 10xBkgd | [d] | -- | 178 | 47 | 0.2 | 0.5 | 0.5 | 5 | 10 | 8 | 8 |
| Copper | 180 | Ecotox | 660 | 10xBkgd | 664 | -- | 5 | 46 | 66 | 660 | 180 | 140 | 140 |
| Mercury | 2.7 | 10xBkgd | [d] | -- | 12 | 42 | 0.1 | 0.13 | 0.27 | 2.7 | 15 | 0.27 | 0.13 |
| Molybdenum | 13 | 10xBkgd | [d] | -- | 115 | 5624 | 2 | 0.984 | 1.3 | 13 | 40 | 6.9 | 6.9 |
| Nickel | 34 | RBkgd | 340 | 10xSSV1 | 401 | 1.2 | 5 | 34 | 50 | 500 | 130 | 100 | 100 |
| Lead | 34 | RBkgd | 340 | 10xSSV1 | 24 | -- | 10 | 34 | 120 | 1200 | 310 | 120 | 45 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 115 | -- | 1 | 0.91 | 1.1 | 11 | 10 | 2.4 | 2.4 |
| Zinc | 500 | Ecotox | 180 0 | 10xBkgd | 6444 | -- | 30 | 160 | 180 | 1800 | 500 | 340 | 340 |
| PCBs | 0.32 | 10xBkgd | [d] | -- | 0.42 | 0.51 | 0.2 | 0.015 | 0.032 | 0.32 | 33 | 0.35 | 0.28 |
| PAHs | -- | -- | -- | -- | | | -- | -- | -- | | -- | -- | -- |
| Acenaphthene | 0.050 | MDL | 0.32 | 10xBkgd | 0.0023 | 0.0056 | 0.05 | 0.006 | 0.032 | 0.32 | -- | 7.9 | 7.9 |

| | Toronto Urban Gardening Soil Assessment Guide | | | | | | | | | | | MOE Brownfields Site Condition Stds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil Screening Values | | | | 2nd Intermediate Values | | Lower Limits | | | Upper Limits | | | |
| | SSV1 | Basis[a] | SSV 2 | Basis[a] | Produce + Direct Contact | Inhalation | MDL | Rural Bkgd[b] | Urban Bkgd[b] | 10xBkgd | Ecotox | Table 3 R/P/I[c] | Table 2 Agri[c] |
| Acenaphthylene | 0.093 | RBkgd | 0.47 | 10xBkgd | 0.023 | 0.056 | 0.05 | 0.093 | 0.047 | 0.47 | -- | 0.15 | 0.15 |
| Anthracene | 0.58 | 10xBkgd | 0.58 | 10xBkgd | 6307 | -- | 0.05 | 0.006 | 0.058 | 0.58 | 3.1 | 0.67 | 0.67 |
| Benz(a)anthracene | 0.23 | Direct + Veg | 2.3 | 10xSSV1 | 0.23 | 0.56 | 0.05 | 0.049 | 0.36 | 3.6 | 0.63 | 0.50 | 0.5 |
| Benzo(a)pyrene | 2.3 | Direct + Veg | 3 | 10xBkgd | 2.3 | 5.6 | 0.05 | 0.039 | 0.3 | 3 | 25 | 0.30 | 0.078 |
| Benzo(b)fluoranthene | 0.23 | Direct + Veg | 2.3 | 10xSSV1 | 0.23 | 0.56 | 0.05 | 0.15 | 0.3 | 3 | -- | 0.78 | 0.78 |
| Benzo(g,h,i)perylene | 0.10 | MDL | 1.0 | 10xSSV1 | 0.023 | 0.056 | 0.1 | 0.081 | 0.28 | 2.8 | 8.3 | 6.6 | 6.6 |
| Benzo(k)fluoranthene | 0.23 | Direct + Veg | 2.3 | 10xSSV1 | 0.23 | 0.56 | 0.05 | 0.006 | 0.26 | 2.6 | 9.5 | 0.78 | 0.78 |
| Chrysene | 0.099 | RBkgd | 0.99 | 10xSSV1 | 0.023 | 0.056 | 0.05 | 0.099 | 0.94 | 9.4 | 8.8 | 7.0 | 7 |
| Dibenz(a,h)anthracene | 0.77 | 10xBkgd | [d] | -- | 2.3 | 5.6 | 0.1 | 0.052 | 0.077 | 0.77 | -- | 0.10 | 0.1 |
| Fluoranthene | 0.14 | RBkgd | 1.4 | 10xSSV1 | 0.023 | 0.056 | 0.05 | 0.14 | 0.56 | 5.6 | 63 | 0.69 | 0.69 |
| Fluorene | 0.39 | 10xBkgd | [d] | -- | 841 | -- | 0.05 | 0.0094 | 0.039 | 0.39 | -- | 62 | 62 |
| Indeno(1,2,3-c,d) pyrene | 0.23 | Direct + Veg | 2.3 | 10xSSV1 | 0.23 | 0.56 | 0.1 | 0.054 | 0.23 | 2.3 | 0.48 | 0.38 | 0.38 |
| Phenanthrene | 3.1 | 10xBkgd | [d] | -- | -- | -- | 0.05 | 0.092 | 0.31 | 3.1 | 7.8 | 6.2 | 6.2 |
| Pyrene | 0.11 | RBkgd | 1.1 | 10xSSV1 | 0.0023 | -- | 0.05 | 0.11 | 0.49 | 4.9 | -- | 78 | 78 |
| Benzene | 0.00047 | 10xBkgd | [d] | -- | 0.031 | 0.011 | 0.02 | 0.000065 | 0.000047 | 0.00047 | 60 | 0.21 | 0.06 |
| Toluene | 0.0092 | 10xBkgd | [d] | -- | 1811 | 2343457 | 0.02 | 0.0013 | 0.00092 | 0.0092 | 220 | 2.3 | 6.2 |

| | Toronto Urban Gardening Soil Assessment Guide | | | | | | | | | | | MOE Brownfields Site Condition Stds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil Screening Values | | | | 2nd Intermediate Values | | Lower Limits | | | Upper Limits | | | |
| | SSV1 | Basis[a] | SSV 2 | Basis[a] | Produce + Direct Contact | Inhalation | MDL | Rural Bkgd[b] | Urban Bkgd[b] | 10xBkgd | Ecotox | Table 3 R/P/I[c] | Table 2 Agri[c] |
| Ethyl benzene | 0.004 | 10xBkgd | d | -- | 2263 | 87147 | 0.02 | 0.0005 | 0.0004 | 0.004 | 120 | 2.0 | 1.1 |
| Xylenes | 0.008 | 10xBkgd | d | -- | 4526 | 328084 | 0.02 | 0.00092 | 0.0008 | 0.008 | 55 | 3.1 | 3.1 |
| Styrene | 0.00003 | 10xBkgd | d | -- | 2716 | 121860 | 0.05 | 0.0000062 | 0.000003 | 0.00003 | 22 | 0.70 | 1.8 |
| F1Petroleum Hydrocarbons | 100 | 10xBkgd | d | -- | 801 | 93738 | 10 | 10 | 10 | 100 | 210 | 55 | 55 |
| F2Petroleum Hydrocarbons | 100 | 10xBkgd | d | -- | 801 | 93738 | 10 | 10 | 10 | 100 | 150 | 98 | 98 |
| F3Petroleum Hydrocarbons | 500 | 10xBkgd | d | -- | 601 | -- | 50 | 50 | 50 | 500 | 1300 | 300 | 300 |
| F4Petroleum Hydrocarbons | 500 | 10xBkgd | d | -- | 601 | -- | 50 | 50 | 50 | 500 | 5600 | 2800 | 2800 |

a Direct+Veg – health-based value protective of the direct contact and vegetable consumption exposure pathways
Ecotox – ecosystem health-based value protective of plants and soil organisms
MDL – analytical method detection limit
RBkgd –rural background concentration of the parameter
UBkgd –urban background concentration of the parameter
10xBkgd –10 times the urban background concentration of the parameter
10xSSV1 –10 times the SSV 1

b The urban background values for the metals and metalloids (except for Cr VI) are the Old Urban Parks OTR98 (97.5th percentile of the Ontario Typical Range data set for urban parkland locations in Ontario) provided in the main text of the Rationale Document (MOE, 2009, Sec 8). The values presented for Cr VI and the organic chemicals (except for the petroleum hydrocarbons) are the Urban OTR98 provided in Appendx B of the Rationale Document (MOE, 2009, Apx B). For the petroleum hydrocarbons, the values presented are the Ontario Soil Background values provided in the Soil Component Tables (MOE, 2009, Apx A). (No one source in the Rationale Document provides urban background values for our complete list of soil contaminants. The Old Urban Parks Parks OTR98 values (MOE, 2009, Sec 8) were used first because they specifically relate to what is achievable in parkland, followed by the Urban OTR98 values (MOE, 2009, Apx B). The Ontario Soil Background values (MOE, 2009, Apx A) do not distinguish between urban and rural soils, and, therefore, were used only when values were not available from either of the other sources.)

c For some parameters, MOE provides values for both coarse and fine soil textures. The values for coarse soil are more conservative. Since the soil texture on urban gardening sites is not known, the most conservative option was selected.

d A SSV 2 could not be developed for this parameter. Health-based values for this parameter are higher than 10 times the urban background concentration. Even when the health-based values are not exceeded, concentrations higher than 10 times the urban background concentration are an indicator of soil contamination. Therefore, Tier 2 Exposure Reduction (exposure reduction) is recommended where concentrations are higher than 10 times urban background.

# UNCERTAINTY

## Qualitative Assessment of Vegetable Consumption Pathway

Our calculation of the intermediate values for garden produce consumption, soil ingestion plus dermal exposure attributes 80% of ingestion exposure to the garden produce consumption pathway. This is consistent with how New York State derives their Soil Cleanup Objectives.

The alternative method of estimating exposure via vegetable consumption is to calculate uptake of soil contaminants into the edible portions of plants, and predict consumption of the contaminated vegetable. This process has significant and problematic data needs, including uptake factors (see Appendix C) and vegetable consumption patterns. Reasonably accurate estimates may be possible on a site specific basis (i.e., for a given soil, soil contaminant, vegetable and individual), but not across an entire jurisdiction where soil types, contaminants, gardening practices and diets vary significantly. The uncertainty in each stage of the estimate is multiplicative, meaning that the safety factors needed to account for the uncertainty around the final result may be very large (possibly several orders of magnitude). OEHHA, CalEPA, NYDEC, NYDOH and US EPA recently concluded that it was not possible to quantitatively estimate exposure via the vegetable consumption pathway with the degree of accuracy needed for standards setting (Hristov *et al*., 2005; NYDEC and NYDOH, 2006; US EPA, 1996b).

The qualitative, allocation factor method from New York State is not free from uncertainty, but it does provide a reasonable upper limit to the uncertainty that would otherwise be accounted for through the application of numerous safety factors. This method caps the contribution of the vegetable consumption pathway to total exposure at 80% of ingestion exposure. It is common practice in standards setting to assume that exposure from an unquantified pathway is no more than 80% of exposure via quantified pathways because it is not reasonable to suppose that it could be any larger.

We tested the impact on the risk characterization of using New York State's 80% allocation factor to account for the garden produce consumption factor in the calculation of SSVs for Toronto.

We used data collected by the Ontario Ministry of the Environment on lead concentrations in soil and vegetable samples from a control site with no known soil contamination, and from several plots within an allotment garden in a historically industrial area with suspected elevated levels of soil contaminants[44]. The reported soil concentrations and the arithmetic average concentration in vegetables are summarized in Table D-11.

[44] The City of Toronto and the Ministry of the Environment have been working closely with this group of gardeners for years to minimize their exposure to soil contaminants.

**Table D-11: Summary of lead concentrations in garden soil and vegetables grown in that soil**

| Garden Site | Measured Lead Concentrations[a] (mg/kg dry wt) | |
|---|---|---|
| | Soil | Vegetable |
| Control | 22 | 0.83 |
| Plot A | 103 | 0.18 |
| Plot B | 80 | 0.46 |
| Plot C | 125 | 0.24 |
| Plot D | 97 | 0.28 |
| Plot E | 194 | 1.07 |
| Plot F | 185 | 0.96 |
| Plot G | 199 | 0.91 |
| Plot H | 130 | 1.70 |
| Plot I | 445 | 2.78 |
| Plot J | 244 | 1.16 |

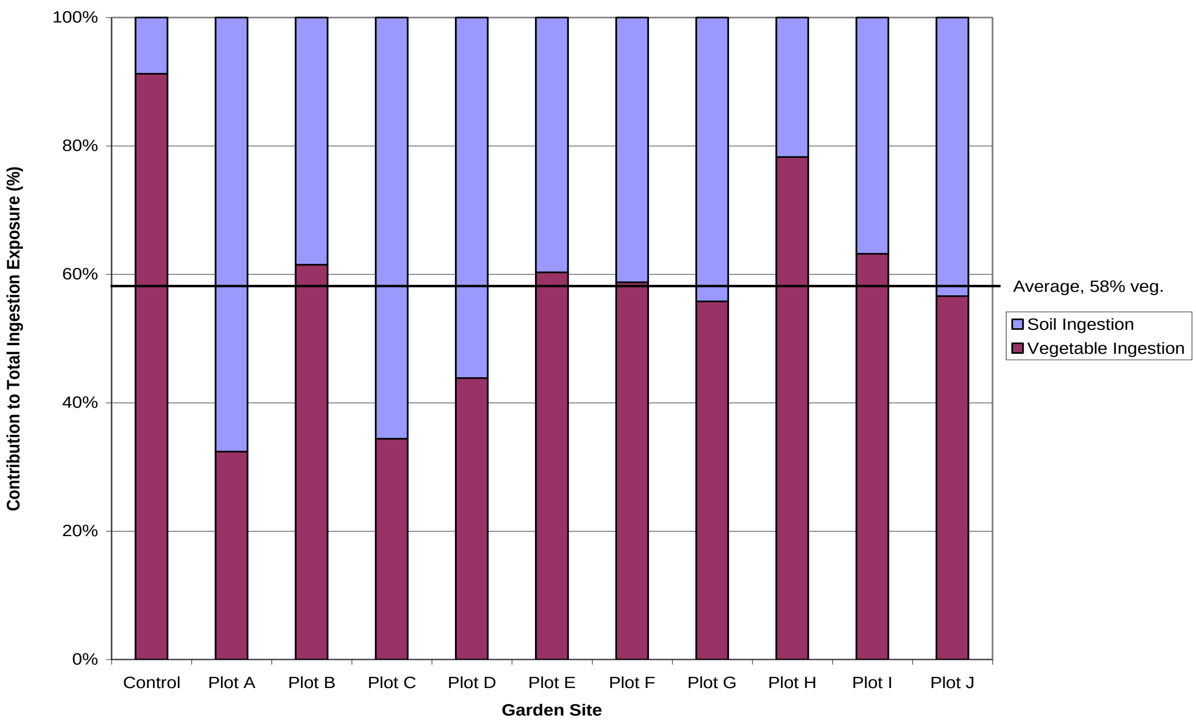
a The reported data represent concentrations in a variety of vegetable types. Lead uptake into different vegetables can differ significantly. This validation process did not attempt to account for differences in uptake. Where more than one type of vegetable was sampled from each plot, the average concentration among vegetable types is reported here.

Using the lead concentration data in Table D-11, and assuming standard intake calculations (MOE, 2009), ingestion exposures were estimated for a hypothetical female toddler whose parents are urban gardeners. It was assumed that the toddler visits the site 2 days per week, 6 months of the year, and that one quarter of the toddler's yearly fruit and vegetable intake is sourced from the site (i.e., about 30 kg of produce). These assumptions are assumed to overestimate exposure.

The resulting proportions of total estimated ingestion exposure attributable to each of soil and vegetable ingestion are shown in Figure D-3. On average, a little over half of the modelled ingestion exposure for these sites came from the vegetable ingestion pathway (range: 32-91%, mean: 58%). Based on our limited case study, use of the 80% allocation factor is likely to overestimate total ingestion exposure in most cases.

At one of eleven sites, the vegetable ingestion pathway accounted for 91% of total ingestion exposure. The soil at this site was sandy and not used as a garden in previous years. The authors of the study (MOE, 2009) hypothesized that the relatively higher concentration of lead in the vegetables from this site was due to the higher bioavailablity of lead in the sandy soil. The lead in the soils at the other sites seemed to be less bioavailable, most likely due to the higher organic matter in the garden soils added over years of active gardening at these sites. Given that the soil of active gardens rapidly develops a high organic content that would tend to bind lead contamination and make it less bioavailable, we consider the 80% allocation factor adequate.

**Figure D-3: Estimated contributions of vegetable and soil ingestion to total ingestion exposure to soil lead contamination of a female toddler, using concentration data from garden sites in Toronto**




## Sensitivity Analysis

The input parameters used in the derivation of TPH's SSVs were selected based on a combination of the recommendations of authoritative agencies such as MOE or US EPA, and assumptions about the characteristics of Toronto's urban gardeners. The selected values have varying degrees of influence on the final SSVs.

We explored the sensitivity of the SSVs (for arsenic, mercury, selenium and benzo(a)pyrene) to changes in six parameters:

- body weight,
- exposure duration,
- exposure frequency,
- proportional reduction,
- soil ingestion rate (two alternative soil ingestion rates were explored), and
- source allocation factor.

We changed the values of these parameters to alternative values, and recalculated the SSVs. The results of these recalculations are shown in Table D-12.

**Table D-12: Sensitivity analysis (mg/kg)**

| | SSV 1 | | SSV 2 | | 2nd Int. Values | |
|---|---|---|---|---|---|---|
| | SSV 1 | Basis[a] | SSV 2 | Basis[a] | Direct + Veg | Inhalation |
| ORIGINAL | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.0 | 2.6 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 12 | 42 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 115 | -- |
| Benzo(a)pyrene | 2.3 | Health | 3.0 | 10xBkgd | 2.3 | 5.6 |
| BODY WEIGHT, reduced to 50, 13 and 43 kg for the adult, toddler and composite, respectively | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 0.8 | 2.1 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 9.5 | 33 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 91 | -- |
| Benzo(a)pyrene | 1.8 | Direct + Veg | 3.0 | 10xBkgd | 1.8 | 4.4 |
| DURATION, reduced to 30 y | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 2.2 | 2.6 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 12 | 55 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 449 | -- |
| Benzo(a)pyrene | 3.0 | 10xBkgd | [b] | -- | 4.8 | 12 |
| FREQUENCY, reduced to 90 and 26 d/y for the adult and toddler, respectively | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.6 | 5.2 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 23 | 61 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 230 | -- |
| Benzo(a)pyrene | 3.0 | 10xBkgd | [b] | -- | 3.4 | 8.3 |
| PROPORTIONAL REDUCTION, reduced to 20% | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 3.3 | 2.6 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 34 | 42 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 449 | -- |
| Benzo(a)pyrene | 3.0 | 10xBkgd | [b] | -- | 6.0 | 5.6 |

| | SSV 1 | | SSV 2 | | 2nd Int. Values | |
|---|---|---|---|---|---|---|
| | **SSV 1** | **Basis[a]** | **SSV 2** | **Basis[a]** | **Direct + Veg** | **Inhalation** |
| SOIL INGESTION, increased to 200 mg/d for the toddler | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.0 | 2.6 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 6.4 | 42 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 58 | -- |
| Benzo(a)pyrene | 2.3 | Health | 3.0 | 10xBkgd | 2.3 | 5.6 |
| SOIL INGESTION, increased to 1,000 mg/d for a pica toddler | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.0 | 2.6 |
| Mercury | 1.4 | Direct + Veg | 2.7 | 10xBkgd | 1.4 | 42 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 12 | -- |
| Benzo(a)pyrene | 2.3 | Health | 3.0 | 10xBkgd | 2.3 | 5.6 |
| SOURCE ALLOCATION FACTOR, increased to 20% | | | | | | |
| Arsenic | 11 | RBkgd | 110 | 10xSSV1 | 1.0 | 5.2 |
| Mercury | 2.7 | 10xBkgd | [b] | -- | 24 | 84 |
| Selenium | 10 | Ecotox | 11 | 10xBkgd | 230 | -- |
| Benzo(a)pyrene | 2.3 | Health | 3.0 | 10xBkgd | 2.3 | 5.6 |

a Ecotox – ecosystem health-based value protective of plants and soil organisms
Health – human health-based value
MDL – analytical method detection limit
RBkgd –rural background concentration of the parameter
UBkgd –urban background concentration of the parameter
10xBkgd –10 times the urban background concentration of the parameter
10xSSV1 –10 times the SSV 1

b A Level 2 SSV could not be developed for this parameter. Health-based values for this parameter are higher than 10 times the urban background concentration. Even when the health-based values are not exceeded, concentrations higher than 10 times the urban background concentration are an indicator of soil contamination. Therefore, Tier 2 Exposure Reduction (exposure reduction) is recommended where concentrations are higher than 10 times urban background.

In general, the sensitivity analysis shows that the SSV 1 and 2 are relatively insensitive to assumptions regarding body weight, exposure duration, exposure frequency, proportional reduction, soil ingestion rate, and source allocation factor. These results also indicate that the SSVs are sensitive to the lower and upper limits, particularly rural and urban background concentrations, and soil ecotoxicity. The results of the sensitivity analysis for each parameter are discussed below in greater detail:

Body weight – Assumed body weights of gardeners were reduced by 20%. The relationship between body weight and the second intermediate values is linear; all of the

Second Intermediate Values are 20% lower when the assumed body weight is reduced. Despite changes in all of the Second Intermediate Values, all but one of the SSVs remained unchanged because the reduced Second Intermediate Values still fall outside the bounds of the lower and upper limits.

Duration – The assumed exposure duration was reduced from 75.5 years (i.e., a lifetime) to 30 years. The reduction in exposure duration approximately doubles most of the Second Intermediate Values. It has no effect on the two Second Intermediate Values that are based on the toddler receptor (because the toddler life-stage only lasts 4.5 years). Most of the SSVs remained unchanged because the increased Second Intermediate Values still fall outside the bounds of the lower and upper limits.

Frequency – Assumed exposure frequency reduced to 90 and 26 d/y for the adult and toddler, respectively. All of the second intermediate values increased when a lower exposure frequency was assumed. Most of the SSVs remained unchanged because the increased Second Intermediate Values still fall outside the bounds of the lower and upper limits.

Proportional Reduction – The proportional reduction used to qualitatively account for the produce consumption exposure pathway was reduced to 20%. The Second Intermediate Values for the "produce plus direct contact" exposure pathway all increased. Despite changes in all of the Second Intermediate Values, all but one of the SSVs remained unchanged because the reduced Second Intermediate Values still fall outside the bounds of the lower and upper limits.

Soil Ingestion – Assumed two different increased soil ingestion rates for the toddler, 200 and 1,000 mg/d. Two of the Second Intermediate Values for the "produce plus direct contact" exposure pathway decreased with each of increased soil ingestion rates. The other Second Intermediate Values were not affected because they are not based on the ingestion exposures of toddlers. All of the SSVs remained unchanged at the 200 mg/d level because the reduced Second Intermediate Values still fall outside the bounds of the lower and upper limits. The SSVs for two parameters were changed at the 1,000 mg/d level.

Source Allocation Factor – Increased to 20%. The Second Intermediate Values that are based on non-cancer effects increased by a factor of 2. All of the SSVs remained unchanged because the increased Second Intermediate Values still fall outside the bounds of the lower and upper limits.

# Discussion

TPH’s SSVs are a valuable new tool for urban gardeners in Toronto. Many urban gardeners are concerned about the exposures to soil contaminants that they and their families may be receiving through their gardens. Many urban gardeners have had the contaminant levels in their soil analyzed. However, interpretation of these data is complex. Until now, none of the available soil quality standards and guidelines was appropriate for Toronto, accounted for the exposures of urban gardeners in Toronto, while also considering the benefits of urban agriculture.

When we compare our SSVs to some of the other soil quality standards and guidelines that are commonly used in Toronto, we find that for some soil contaminants our values are lower, but for others our values are higher. This does not mean that some values are more health protective than others. Many soil quality standards and guidelines account for factors that are not specific to urban gardening, while our SSVs account for only the factors that are relevant to urban gardening.

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# Appendix E: Case Example of the Potential for Exposure Reduction from the Implementation of the Urban Gardening Soil Assessment Guide

## Background and Context

Toronto Public Health developed a decision support tool to guide the selection and management of urban lands for conversion into community and allotment gardens.

In order to describe the potential health relevance of application of the guide, we developed a case example using lead (Pb). The case example describes the potential reduction in health impacts from exposure to lead in garden soil that may be achieved by using the guide to determine appropriate site specific exposure reduction measures.

Lead was selected for this case study for the following reasons:

- Lead is a multi-organ systemic toxicant with no identified threshold for many adverse health effects, including toxic effects to the central nervous system, cardiovascular system, kidneys, and reproduction organs;

- The US EPA Integrated Exposure Uptake Biokinetic Model for lead in Children (IEUBK) toxicokinetic model for lead is available to quantify incremental changes in children's blood lead concentrations associated with incremental changes in environmental lead concentrations. The model is well validated, published and peer-reviewed, and it has been used by numerous regulatory agencies in the context of setting lead exposure regulations and policies.

## Methodology and Assumptions

The US EPA IEUBK model was used to simulate the incremental change in children's blood lead concentrations associated with the assumed reduction in soil lead concentration achieved by using the guide. Peer reviewed information on the quantitative relationships between blood lead concentrations and the various adverse health effects were then used to quantify the health effects associated with the incremental changed in blood lead concentration.

Modelling scenario: We assumed that a child gardening is exposed to garden soil as well as lead in household dust, drinking water, food and air. We used the central tendency data on media concentrations readily available for Toronto and Canada.

We used the IEUBK model to predict the blood lead concentration of a child exposed to typical levels of lead in their environment plus elevated lead in their garden soils. Table 1 outlines the assumptions for each parameter input into the IEUBK model. (All parameters that are not listed were set to IEUBK default parameters. All exposure media and parameters were kept constant for both scenarios, with the exception of the soil lead concentrations.)

Starting lead concentration: We assumed a starting soil lead concentration of 300 ppm. This concentration of lead in Toronto soils has been measured in areas that are impacted by past industrial activities. This assumes that urban gardening is currently occurring at Toronto sites and that the exposure reduction measures suggested in the guide are not occurring.

Application of the guide: According to the guide, the site is classified as a Tier 2 Exposure Reduction Site (based on soil lead concentration of 300 ppm). Gardeners on Tier 2 Exposure Reduction Sites must follow these measures to reduce their exposures to soil contaminants:

- turn over garden twice per year, add organic matter and compost, dilute soil concentrations by adding clean soil (reduce soil concentrations);
- peel root vegetables, wash hands after gardening and particularly before eating, wash produce with soap and water, avoid bioaccumulating produce (reduce exposure with behaviour changes); and,
- lower bioavailability of contaminants by adding organic matter and liming (reduce bioavailability by increasing binding capacity).

Subsequent lead concentration: We assumed a hypothetical order of magnitude reduction in soil concentration as a surrogate for the combined exposure reduction potential of the measures summarized above for Tier 2 Exposure Reduction sites. Note that the specific quantitative exposure reduction expected to be achieved by Tier 2 Exposure Reduction measures is unknown, and would be costly to validate. However, these measures are, in sum, expected to result in a significant exposure reduction. This hypothetical assumption was made instead of attempting to model the reduction in the exposure pathways. The modelling was considered too complex and the result too uncertain to be helpful for the uses of this case example.

**Table E-1: Parameter Assumptions used in the IEUBK Model**

| Parameter | Central Tendency Estimate (range) | Reference |
|---|---|---|
| Soil and dust ingestion rate | 100 mg/day | US EPA, 2008. Central Tendency soil and indoor dust. Does not account for pica behaviour in a child. |
| Child age | 36 – 48 months old | |
| Air | 0.006 µg/m3<br>(not detected to 0.033 ug/m3) | Fine + Coarse Fraction of Mass and Elemental Concentrations (ug/m3) - Toronto (2003 - 2005) NAPS data Toronto data for two Toronto air monitors. Data provided by Tom Dann, Environment Canada. |
| Drinking water lead concentration | 0.14 µg/L | Ontario Drinking Water Information System. Summarized data for 2006 for water at point of consumption. |
| Soil lead concentration, $T_0$ | 300 µg/g | Hypothetical urban impacted soil |
| Soil lead concentration, $T_1$ | 30 µg/g | Hypothetical order of magnitude reduction in soil concentration with Tier 2 Exposure Reduction Measures |
| Food intake rate | 2.04 µg/day | Food intake rate for the 36-47 month old age class, provided to Toronto Public Health by J. Gilmore, MOE on November 2008 |
| Dust lead concentration | 233 µg/g<br>(50 – 3226 µg/g) | Rasmussen, P.E., K.S. Subramanian, B.J. Jessiman. 2001. A multi-element profile of housedust in relation to exterior dust and soils in the city of Ottawa, Canada. The Science of the Total Environment. 267: 125-140. |

# Results and Discussion

Starting lead concentration: The IEUBK model predicts a geomean blood lead level of approximately 3.8 µg/dL in children exposed to 300 ppm lead in garden soil.

Subsequent lead concentration: The IEUBK model predicts a geomean blood lead level of approximately 2.3 µg/dL in children exposed to 30 ppm lead in garden soil.

An order of magnitude reduction in soil lead levels from 300 to 30 ppm is predicted to result in avoiding an increase in blood lead level of approximately 1.5 µg/dL.

Healey et al. (2010) estimate that a 1 to 4 µg/dL increase in childhood blood lead levels is associated with an average loss of between 2 to 5 IQ points (Healey et al., 2010).

The IEUBK model is intended for use in children and there is no guarantee that application of the exposure reduction techniques would result in similar reductions in the blood lead levels of adult versus child gardeners. However, if we assume that this is the case, over this range of increase in blood lead level in adults, Healey et al (2010) estimate a 3-fold increase in pregnancy induced hypertension and an average increase in systolic blood pressure of 1.4 to 2.4 mmHg. A 2 mmHg increase in systolic blood pressure is associated with a 4% increase in coronary heart disease and 6% increase in stroke (McArdle et al. 2006). Thus, by extension, we assumed that the risk of these health effects may be reduced by following the advice for the Tier 2 Exposure Reduction gardens.

The case example, does not account for uptake into the garden produce. Thus, the results do not account for an important contribution to blood lead, which would also be reduced by the Tier 2 Exposure Reduction measures. This case study is for illustrative purposes and the estimates are deemed to be useful in so far as the case examples provide a relative approximation of possible risk reduction from the application of the Urban Gardening Soil Assessment Guide.

# References

Healey, N., Jones-Otazo, H., Walker, M., and Knafla. A. 2010. *Toxicological Review and Recommended Toxicological Reference Values for Lead Exposure in Canada*. Report prepared for Health Canada, Healthy Environments and Consumer Safety Branch, Environmental Health Bureau, Ottawa, ON.

McArdle, W.D., Katch, F.I., and Katch, V.L. 2006. *Essentials of Exercise Physiology*. Lippencott, Williams & Wilkins. 3rd Edition.

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