Urban Agriculture and Soil Contamination: An Introduction to Urban Gardening

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Introduction

This practice guide is written as a primer for those interested in urban gardening—individual gardeners as well as community groups—and speaks directly to the issue of soil contamination. Several important aspects of soil contamination are addressed, including the dangers of gardening in contaminated soil, potential sources of contamination, acceptable levels of contamination, how to test soil for contamination and evaluate the results, and costs of soil testing, as well as various options for addressing these issues. Also included are appendices identifying urban agriculture best practices and additional electronic and print resources for urban gardeners.

Dangers of Soil Contamination: The Need for Soil Testing

Soil contamination can be problematic on several levels. Risks from soil contamination include plants absorbing contaminants through the soil; groundwater becoming contaminated as it interacts with and flows beneath the soil; and bioaccumulation, occurring when livestock or humans ingest contaminants from vegetation growing in compromised soil (Rosen, 2002).

While each of these issues is important, the primary concern for most urban gardeners relating to soil contamination is human health. Significant health risks resulting from exposure to a wide range of soil contaminants have been observed and documented. Some examples of these contaminants include heavy metals, pesticides, and polychlorinated biphenyls (PCB's), which are a general class of organic compounds and persistent environmental pollutants.

When investigating the risks associated with soil contamination, as well as identifying appropriate remediation strategies, it is critical to determine the level, or concentration, to which contaminants are present in soil. The particular level of any given contaminant is usually expressed in mass per unit mass of soil (e.g. mg/kg), ppm (parts per million), or ppb (parts per billion) (Heinegg et al., 2000). The contamination level can be identified through soil testing. Soil testing should be the first step in ensuring the health and safety of the people involved in any urban gardening venture.

Sources of Soil Contamination

There are many different sources of soil contamination. Soil properties vary from place to place and are influenced by many factors. Most potentially harmful substances, however, end up in soils as a result of human activities. Soil properties are affected by past and current land uses, as well as proximity to pollution sources. Some substances, such as pesticides and fertilizers, are intentionally added to soils while other substances, such as commercial and industrial chemicals, cause contamination through accidental spills or leaks. Contaminants can also be spread through the air and are deposited as dust or by precipitation (Shaylor et al., 2009b).

In many cases, soil contamination is the result of past land uses. For example, gas stations and mechanics' garages use different fuels and lubricants on-site. These contaminants generally enter the soil inadvertently as a result of poor storage practices or spillage onto the ground. Other sources of contamination may be more indirect. Examples of these sources of contamination include rain runoff from roofs, roads, and other structures that may introduce heavy metals such as lead or mercury into the soil. Contaminants can also be introduced from adjacent properties through the movement of groundwater and soil water. Depending on the specific hydrological features of the surrounding area, contaminants can ultimately end up in soil designated for gardening (Shaylor et al., 2009b).

While the levels of possible contaminants depends on the specific conditions of a property, soil contamination may be more likely if the property is or has been the site for the production or use of: lead paint, high traffic, fertilizers or pesticides, industrial or commercial activity, treated lumber, petroleum spills, automobile or machine repair, junk vehicles, furniture refinishing, fires, landfills, or garbage dumps. Information regarding the toxicological profiles of specific contaminants is available through the Agency for Toxic Substances and Disease Registry (ATSDR) (http://www.atsdr.cdc.gov/). Table 1 provides a list of some general sources and locations of contamination along with the specific contaminants typically associated with those sources.

Table 1: ***Common Sources of Contamination***

General Source	Specific Contaminant
Paint (‹ 1978)	Lead
High Traffic Areas	lead, zinc, PAHs
Treated Lumber	arsenic, chromium, copper
Burning Wastes	PAHs, dioxins
Manure	coppers, zinc
Coal Ash	molybdenum, sulfur
Sewage Sludge	cadmium, copper, zinc, lead, PBTs
Petroleum Spills	PAHs, benzene, toluene, xylene
Commercial/Industrial Site Use	PAHs, petroleum products, solvents, lead, other heavy metals
Pesticides	lead, arsenic, mercury (historical use), chlordane and other chlorinated pesticides

Source: Heinegg et al., 2000

Acceptable Levels of Contamination

Certain chemical elements exist naturally in soils as components of minerals, yet may be toxic at high concentrations. Ideally, garden soils should not have contaminant levels exceeding those that are naturally occurring in the soil. In urban settings in particular it is likely that soil contaminants will exceed natural levels. This raises the question – how much contamination is acceptable?

There is no single standard that defines acceptable levels of contaminants in soils. In 1996, the U.S. Environmental Protection Agency (EPA) established Soil Screening Levels (SSLs) to facilitate the evaluation and cleanup of contaminated properties intended for residential land use in the future or Superfund sites. These values were designed to direct resources for site evaluation and cleanup to those areas most in need. SSLs are risk-based values developed for specific land use scenarios using assumptions about how soil contaminants may affect people or the environment. SSLs serve as a general guide; however, it is important to remember that these values were developed for certain programs to be used under specific conditions and may not be relevant for assessing all properties. It should also be noted there are different standards for different potential land use types (i.e. industrial, residential, or agricultural use). Of these three, the agricultural standard is the strictest, as it is important to have relatively minimal levels of contaminants present in soils that will be used to grow food. More information, including a Quick Reference Fact Sheet, User Guide, and tables of all SSL values, is available at: http://www.epa.gov/superfund/health/conmedia/soil/index.htm.

Soil Testing: Collection Strategies and Sampling Procedures

There is no best, one-size-fits-all, strategy for collecting soil samples. To determine the most appropriate and helpful strategy, it is important to consider how people might be exposed to contaminants at a certain site as well as what type of information the gardener hopes to learn from testing the soil (Nathan, 2009).

Exposure to Soil Contaminants: Sources and Effects

In general, there are three ways in which people are exposed to contaminants in soil: ingestion (eating and drinking), dermal exposure (skin contact), and inhalation (breathing) (Anigma & Sullivan, 2008; Rosen, 2002; Shaylor et al., 2009b). People may accidentally ingest small amounts of soil during activities such as yard work, gardening, or playing. Ingestion also occurs when people eat garden produce grown in contaminated soil or groundwater. Some contaminants, such as pesticides, can be absorbed through the skin when people come into contact with the soil. In addition, people can inhale airborne soil particles, such as dust, or contaminants that have vaporized from the soil after precipitation.

The possible health effects of exposure to any contaminant depend on the toxicity of the contaminant, the level at which it is present, and how long and how often the exposure occurs. An individual's response to a given level of exposure to a particular contaminant is also affected by gender, general health and lifestyle, age, and inherited family traits (Shaylor et al., 2009b). Information regarding the health effects of particular contaminants is available through the ATSDR (http://www.atsdr.cdc.gov/) and the EPA (http://www.epa.gov).

Determining and Implementing a Strategy

There are several reasons why the contaminant levels in soil would need to be measured, and depending on the future use of the area one treatment strategy may be better than others. Below are examples of what strategies work best for particular uses:

- For specific areas such as a children's play area, collect separate samples of the top 1 to 2 inches of soil. This strategy is also useful when trying to identify a contamination source, such as a chemical spill.

- To measure the average levels of contaminants in surface soil, collect multiple composite samples of the top 1 to 2 inches of soil from across the site. To determine if the concentrations vary throughout the property, collect a separate sample from each area.

- To measure the contaminant levels in garden soil, collect deeper samples (about 6 inches) from multiple locations (between five to 10 spots) and mix them together to create a composite sample. Because the levels of a particular contaminant can vary throughout a site, it is important to collect and test at least three composite samples. To find out if certain areas have higher concentrations than others, reserve a small amount of each separate sample for discrete testing (Heinegg et al, 2000).

General Collection Procedures

1. *Select the collection sites* based on what information you hope to learn from the test results. It is important to consider what information is needed relative to the cost of analysis so that you can get the most information with the resources you have.

2. *Make a map or diagram* to record where the samples are collected and how they were collected (including the depth of soil collected). Labels on each sample should correspond with the diagram for easy reference. This information will be useful for interpreting the test results from the laboratory. Consider adding 3-4 photos of the site to ensure it becomes part of a permanent record.

3. *Collect the* samples from each sampling location. It is important to remove any surface vegetation and use a clean trowel, scoop or spoon to collect the sample to avoid cross-contamination. Use a different trowel, scoop or spoon for each sample or wash your tool with soap and water between samples. For composite samples, it is fine to use the same sampling instrument to take the 5 - 10 samples.

4. *Package the samples.* For individual samples, put each sample into a different container (laboratories will often provide or recommend a specific type of container). For composite samples, mix the individual samples in a clean container (such as a clean plastic bag placed inside a bucket) and then transfer the mixed sample to the container that will be sent to the laboratory. To ensure accurate and timely results, it is important to carefully follow the instructions provided by the laboratory regarding how to package and label the soil samples.

5. *Send the sample(s) to the laboratory as instructed.* Again, to ensure accuracy and timeliness, carefully follow the shipping instructions provided by the laboratory. Also take note of the how long it takes to receive the results so samples that need to be analyzed within a certain timeframe will be processed (Shaylor et al., 2009c). Make sure that the sample submission form contains comments regarding potential contaminants so that those who come into contact with it are aware of the risks.

Soil Testing Costs

The cost of testing depends on: (a) the number of samples tested (more samples will be more expensive); (b) whether the samples are analyzed for one contaminant or many (tests for multiple contaminants will be more expensive); and (c) which contaminants are being tested (analyses for some contaminants are more complex and cost more than others). Costs also vary from lab to lab due to the use of different analytical methods and pricing structures.

There are certain steps, however, which can be taken to reduce the cost of testing. In order to narrow the range of contaminants which need to be tested for, a review of previous land uses can be undertaken to determine if there have been any obvious potential sources of contamination (Heinegg et al., 2009).

Determining Land Use History

1. Inquire about the property's previous owners. This information is generally available from local government.

2. With this information, current owners can contact previous land owners and investigate past land uses. There are a variety of resources which can help: city archives, courthouse records, and map libraries (governmental and academic).

As mentioned above, certain types of land use are associated with specific types of contamination. If this is the case, property owners can request that these contaminants be included in their soil tests. Likewise, certain contaminants can be easily excluded from soil testing if the land use history is not associated with those particular contaminants. It is also important to remember that contaminants can come from neighboring or nearby properties. Knowledge of these potential sources of contamination can also help property owners determine which need to be performed. In addition, it is important to remember that contaminants can come from neighboring or nearby properties. Incorporati8ng knowledge of such properties will be critical if a soil and plant monitoring program is established.

Metro Louisville: Local & Regional Soil Testing Laboratories

The information provided below is for soil testing laboratories in Kentucky; however, any local Cooperative Extension Service office should be able to provide information for laboratories in their particular state. In addition, a simple internet search with the key words, "soil testing laboratories" and your state name should yield a variety of alternatives.

University of Kentucky Soil Testing Labs
103 Regulatory Service Building
University of Kentucky
Lexington, KY 40548-0275
Phone: (859) 257-7355

The goal of the Soil Testing Laboratories is to help the citizens of Kentucky maintain productive and economical plant growth operations. It will direct you to your local extension office for a soil collection kit. Once your soil sample is returned to that same local office, it will be sent to the lab and you will be contacted with the results. The Soil Testing laboratories charge between $4 and $20 for various tests and routines and these prices do not include postage and handling. A complete list of the tests offered and corresponding prices is available at the University of Kentucky Division of Regulatory Services website: http://soils.rs.uky.edu/tests/routine.php.

Microbac Laboratories Inc.
3323 Gilmore Industrial Blvd
Louisville, KY 40213-2174
(502) 962-6400
http://www.microbac.com

Microbac is a national commercial testing and analytical laboratory group and offers services in environmental testing, environmental monitoring, and environmental analysis. Its laboratories are equipped to test for contaminants such as mercury and arsenic that are often not included in routine analyses. Microbac charges $20 per sample to test for mercury and $15 per sample to test for arsenic.

Non-Local Soil Testing Laboratories

Soil and Plant Tissue Testing Lab
West Experiment Station
682 North Pleasant Street
University of Massachusetts
Amherst, MA 01003
Phone: (413) 545-2311

Email: soiltest@psis.umass.edu

The goal of the Soil and Plant Tissue Testing Laboratory, located on the campus of the University of Massachusetts at Amherst, is to provide test results and recommendations that lead to the safe and cost-effective use of soils and soil amendments. To test for lead and to measure the levels of major nutrients in soil, the Soil and Plant Tissue Testing Lab charges $9. An online list of their services as well as a brochure and order form is available at the University of Massachusetts Amherst Department of Plant and Soil Sciences website: http://www.umass.edu/plsoils/soiltest.

Evaluating Soil Test Results

Laboratory results report the amount of a particular substance measured in a soil sample and can help people decide if changes in land use, gardening practices, or other behaviors might help reduce exposure to contaminants or improve soil health. The most common soil tests report the total amount of a particular contaminant (Shaylor et al., 2009c). For example, the test for most metals involves the use of strong acids to digest the soils and bring all or most of the metal into solution for measurement. The resulting metal concentration is reported as "total metal" (for example, "total lead").

Other tests measure a chemically extractable portion of the contaminant and also estimate the total amount of contaminant in the sample. Results are often given in soil concentration units as parts per million (ppm) of the contaminant being measured. A value of 1 ppm would mean that for every million "parts" of soil (by dry weight) there would be 1 part of the contaminant. These values can also be expressed as mg/kg (milligrams of contaminant per kilogram of soil) or µg/g (micrograms of contaminant per gram of soil) (Shaylor et al., 2009c).

There is no clear standard of what is considered "safe." In general, if test results show that all or some areas of a property have contaminant levels higher than agency guidelines or levels recommended by other reliable sources, it is prudent to reduce the exposure to both children and adults.

Remediation Options

Once a gardener has established that there are levels of contaminants that exceed the acceptable levels for agricultural use, there is a range of options available to deal with the contamination. There are various techniques to reduce the level of contamination in the soil. Some of these practices, known as soil remediation, are more practical than others.

When choosing the most effective and appropriate remediation technique for an urban agriculture project, it is important to consider the following five factors:

1. Accessibility**:** Is this technique readily available to non-expert individuals and groups? Is it commercially available, or still in the development phase?

2. Cost: Relatively inexpensive techniques are desirable, as the gardens generally don't generate revenue to pay back the costs of remediating. Except in large scale remediation efforts, or when combined with other economically productive land uses, it is important to remember that the costs of consulting and soil testing are separate from this cost. Urban gardeners should take into account the total of all these expenditures when considering affordability.

3. Timeframe: Some techniques are implemented and completed over the course of a few days, while others may take years to be effective. This can be an important factor, depending on the desired implementation of the garden.

4. Effectiveness for urban agriculture: This refers to the ability of the technique to bring the soil up to agricultural standards. Some techniques can do this in every situation, some depend on the nature and extent of contamination, and some are not effective at this time.

5. Environmental effects: Remediation techniques will vary in how environmentally sound they are. Some have toxic by-products, others involve placing materials in the soil that are not biodegradable, and still others have no adverse environmental effects. Often, contaminated soil must be disposed of at a landfill (Heinegg et al., 2000).

Using these factors as a framework, urban gardeners can examine the various remediation techniques that are available. These techniques can be categorized as *physical* or *biological*.

Physical Soil Remediation Techniques

These techniques generally involve the use of technology for remediation purposes. They include excavation, capping with geotextiles, soil washing, and soil vapor extraction. The descriptions of these techniques provided here are by no means comprehensive, but seek to highlight the main advantages and drawbacks of each.

Excavation*:* Excavation refers to physically removing contaminated soil, normally for disposal at a landfill. Excavation is accomplished with heavy machinery, at a relatively high cost. However, it can take place quickly. New soil is needed after the excavation, at extra cost.

Geotextiles*:* Geotextiles are a synthetic blanket-like material. They can be used after the excavation process to provide a protective barrier, impermeable to any remaining contaminants which may otherwise migrate into the new soil after excavation. Geotextiles are relatively low-cost themselves, but must be combined with excavation. One concern with geotextiles is that the fabric can tear, allowing contaminants to pass through into the new soil.

Soil Washing*:* Soil washing is a technique which involves the physical removal of the contaminated soil, followed by treatment at a plant on or offsite. After the contamination is removed through the treatment process, the soil is put back into the ground. This technique is generally high-cost, and the disposal of the removed contaminants must be addressed after the process is complete.

Soil Vapor*:* Soil vapor extraction involves the installation of wells and pipes in the soil, through which soil contaminants are extracted. This is the most costly procedure of the physical remediation techniques listed here, but is effective at removing the contaminants.

In general, these physical remediation techniques are all available for the purposes of urban agriculture, are relatively fast to implement, and are effective at remediating soil to agricultural standards. However, they can be very costly, and have other environmental drawbacks such as disposal of contaminants/contaminated soil and air pollution from machinery. Excavation, with or without geotextiles, is generally considered the most useful physical remediation technique for small-scale urban agriculture (Heinegg et al., 2000). The main benefits of these techniques are relative low cost and fast and effective remediation of contamination. Using the five factors discussed above, Table 2 illustrates these conclusions and uses a scale of 1 – 3 where 1 is unconditionally effective, 2 is conditionally effective, and 3 is ineffective.

Table 2: ***Summary of Physical Remediation Techniques***

	Excavation	*Geotextiles*	*Soil Washing*	*Soil Vapor Extraction*
Access	Yes	yes	yes	yes
Cost	Low	low	moderate	high
Timeframe	short ‹ 1 season	short ‹ 1 season	short ‹ 1 season	short ‹ 1 season
Effectiveness for UA	1	2	1	1
Environmental Effects	energy use air pollution disposal	energy use air pollution disposal	energy use air pollution disposal	energy use air pollution disposal

Source: Heinegg et al., 2000

Biological Soil Remediation Techniques

Unlike physical remediation techniques, biological techniques are generally performed directly on-site. These techniques include microbial remediation, phytoremediation, fungal remediation, and composting techniques. Again, the following descriptions are not comprehensive, but are designed to highlight the main benefits and drawbacks of each technique, and facilitate a comparison for a range of techniques.

Microbial Remediation*:* Microbial remediation refers to the use of microbes in degrading contaminants into a less toxic form. This technique can be very effective in the treatment of hydrocarbons, polycyclic aromatic hydrocarbons (PAH's), pesticides, and PCB's. Cost is generally relatively low, and timeframe is short. However, there is the possibility of increased toxicity of certain metals. It is important to be aware of the potential increased toxicity of certain metals when considering the health risks of consuming edible plants.

Phytoremediation*:* Phytoremediation is the process of using plants to extract contaminants or to degrade them in the soil. As with microbial remediation, the cost is low. However, the timeframe can be longer than several years. Effectiveness in bringing soil up to agricultural standard varies, as one species of plant is generally used on one type of contaminant, potentially leaving a range of contaminants behind. As well, the contaminated plants used for extraction must be disposed of properly.

Fungal Remediation*:* Fungal remediation refers to the use of certain species of fungus to degrade contaminants. This technique is still in the development phase and is not commercially available as of now.

Compost Remediation*:* Compost remediation involves the addition of compost to the soil. This is cheap, and quick to do. However, it is not a true remediation technique, as the contaminants generally remain intact in the soil. The addition of compost can, however, be used to create a raised bed, in which the plant roots may not reach the contaminated soil.

In general, bioremediation techniques are conditionally effective in bringing soil up to agricultural standards. Because the original soil remains intact, there may still be some contaminants that are unaffected by the technique used, resulting in a certain degree of uncertainty about the treatment of the contamination. Phytoremediation can take long periods of time to take effect, and the plants used must be disposed of after the project. Prior to their disposal, however, it is good practice to analyze the plants for toxins to determine the technique's effectiveness. Despite their extended time frame, these techniques are generally inexpensive, easy to implement, and environmental effects are low. In general, microbial remediation is thought to be the bioremediation technique most useful to urban agriculture (Heinegg et al., 2000). The main benefits of this technique are relatively low cost and a short timeframe. Using the same five factors and effectiveness scale as Table 2, these conclusions are illustrated in Table 3.

Table 3: ***Summary of Bioremediation Techniques***

	Microbial	*Phyto-*	*Fungal*	*Compost*
Access	Yes	yes	no	yes
Cost	Low	low	n/a	low
Timeframe	short ‹ 1 year	2-5+ years	n/a	short ‹ 1 season
Effectiveness for UA	2	2	3	2-3
Environmental Effects	potential metal toxicity	disposal of toxic plants	potential metal toxicity	none

Source: Heinegg et al., 2000

Non-remediation Options

In addition to the remediation techniques mentioned, there are some other options for dealing with the issue of soil contamination. These alternatives involve growing the produce in a separate container or bed above the contaminated soil (Heinegg et al., 2009). Raised beds or other containers can be used in an effort to prevent plant roots from reaching the contaminated soil. When using raised beds, it is important to include a layer of landscape fabric to prevent the plant roots from entering the contaminated soil below the bed. Similarly, emergent technologies such as aquaponics are another way to avoid growing directly in the soil. Alternately, if the site turns out to be heavily contaminated, gardeners may consider trying to find another piece of land for the garden.

Appendix A: Urban Agriculture Best Practices

The following appendix summarizes some helpful guidelines for healthy urban gardening from the Cornell Waste Management Institute (Shaylor et al., 2009a).

General Gardening & Land Use

- Incorporate or top dress the garden area with clean materials such as uncontaminated soil, compost, manure, or peat moss.

- Adjust soil pH to near neutral. Most metals are more bioavailable in more acid soils and can harm plants or animals when pH is too low. Most plants will thrive at pH 7; however, some may require an adjusted level ranging from pH 6.2 – 6.7.

- Mulch walkways and other areas to reduce dust and soil splashback onto crops, or maintain healthy grass or other ground cover.

- Don't grow edible produce directly adjacent to buildings, where lead levels are likely highest.

- Build raised beds with clean soil to grow food crops in more contaminated areas. Regardless of its source, even soil in raised beds should be tested to determine toxicity and nutrient levels. Once this is done, a layer of landscape fabric will prevent plant roots from entering the contaminated soil below the bed.

- For raised beds and other garden projects, don't use certain types of treated lumber that may have chemicals that will further contaminate the soil. In the past, some commercially-available treated lumber contained copper, chromium, and arsenic.

- In more contaminated areas, first consider whether the practices outlined here can sufficiently reduce the amount of contaminants in contact with crops. This can be verified by testing the soil or plant tissue.

- If it is not possible to protect crops from contamination, consider growing crops that are less likely to be contaminated.

- Because of the many benefits of eating fresh fruits and vegetables, growing ornamental plants instead of food crops should only be considered as a last resort.

Food Preparation Practices

- Wash produce well to remove soil particles. A 1percent vinegar solution (1 part vinegar to 100 parts water) can be used.

- Peel root crops.

- Discard outer leaves of leafy vegetables since soil may cling to them.

General Practices

- Wash hands and other exposed skin areas that come into contact with soil, especially before eating or preparing food, soil sampling, and mixing composting sampling.

- Use gloves when handling soil, and change gloves when wet or soiled.

- Watch children carefully to prevent them from eating soil.

- Frequently wash toys and pacifiers.

- Cover contaminated soil with clean soil, mulch or other materials, or keep these areas well vegetated.

- Limit access to more contaminated areas; do not locate storage units (especially containers for toys) in these areas. Consider restricting access to these areas, i.e. fences or lattice.

- Keep soil outdoors:
    - Take off shoes.
    - Use doormats.
    - Clean floors often with a damp mop. Vacuum cleaners put dust in the air, unless they are equipped with a high efficiency particulate air filter.
    - Wash boots and tools outside.

- Clean or replace filters on heating and cooling systems.

- Reduce exposure from pets that go outside:
    - Wash pets.
    - Wash hands after handling pets.
    - Limit pets' access to more contaminated areas.

- Seal pressure-treated wood (and re-seal as needed).

How Do Plants Get Contaminated?

There are three main ways that heavy metals, such as lead, could contaminate garden crops. This information is important to help select the best crops for particular situations.

(1) *Deposition from the air:* In the recent past, this was a major source of lead contamination in urban areas until leaded gasoline was phased out completely in the 1980s. Some lead deposition still occurs due to windblown dust from contaminated soils and streets. Other airborne contaminants can also end up on plants. This is a particular problem for leafy crops, which have a high surface area in contact with airborne particles. In particular, some ester (and amine) herbicides can spontaneously volatize and travel great distances unbeknownst to the individual or group who initially applied it.

(2) *Uptake into plant roots*: In most situations, unless soil is acidic (low pH) or very low in organic matter, not much lead is transferred from contaminated soils to garden crops through plant roots. However, roots are likely to have a higher concentration of lead than leaves and stems, and fruits or seeds are

likely to be lowest in lead of all plant parts. Cadmium and some other heavy metals of concern are more readily taken up from contaminated soils into roots and plant tops.

(3) *Direct contamination by garden soil*: Root and tuber crops are more likely to be contaminated than other types of crops because they are in direct contact with soil. Leafy vegetables (lettuce, spinach, collard greens) are also easily contaminated by soil splash and dust. Washing leafy crops can remove up to 80 percent of lead contamination, and much of the lead can be removed from vegetables such as carrots and potatoes by peeling. However, in situations where lead contamination is moderate to severe, growing these types of crops directly in the contaminated soil is not recommended.

Fortunately, there are several natural barriers that limit heavy metal transfer into crops.

- *Soil-Root Barrier*: Some toxic metals (such as lead) have low solubility in most soils, and do not readily enter the plant through roots.
- *Root-Shoot Barrier*: Most toxic metals bind relatively strongly in roots, and movement to other plant parts is limited.
- *Shoot-Fruit Barrier*: Most toxic metals are largely excluded from entering the reproductive parts (fruits, seeds) of the crop, remaining instead in the vegetative parts.

Which Garden Crops Are Suitable to Grow in Contaminated Soils?

Some garden crops can take advantage of these natural barriers. However, the physical contamination of crops by soil dust, splash or aerial deposition can often bypass the natural barriers of protection. Practices to reduce the physical contamination of garden food crops and to reduce human exposure therefore become important.

In addition to what is known about contamination pathways, the results of past research also provide some information about the potential for heavy metal transfer into garden crops. All of this information allows for recommendations for garden crops that are most and least suitable for growing directly in contaminated soils. These resources will be updated and expanded in the future as new information and research findings become available.

Most Suitable

- Vegetable Fruits and Seeds: tomatoes, eggplant, peppers, okra (seed pods only), squash (summer and winter), corn, cucumber, melons, peas and beans (shelled), onions (bulb only)

- Tree Fruits: apples, pears

*Least Suitable**

- Green Leafy Vegetables: lettuce, spinach, Swiss chard, beet leaves, cabbage, kale, collards

- Other Vegetables: broccoli, cauliflower, green beans, snow peas

- Root Crops: carrots, potatoes, turnips

*Given the many health benefits of consuming fresh fruits and vegetables, every attempt should be made to use the steps outlined on the previous pages to create healthy garden conditions to grow a variety of desirable crops. However, eating fruits and vegetables grown in contaminated soils may have both benefits and risks.

In particular, the vegetables on the *Least Suitable* list should preferably be grown in areas where contamination is not a concern or where clean soil materials and composts have been used to create soils with low levels of contamination. Because compost can contain contains toxins and pathogens, it is essential to know the source of both the clean soil *and* the composting materials. Note that constructing raised beds with clean materials will help create healthy gardens in many situations, but may not eliminate airborne contaminants or soil dust and splashback from other areas.

Appendix B: Additional Resources

Agency for Toxic Substances and Disease Registry, Department of Health and Human Services, Atlanta. Provides information to prevent harmful exposures and diseases related to toxic substances. Accessible at: *http://www.atsdr.cdc.gov/*

California Office of Environmental Health Hazard Assessment. A database with toxicity information on many chemicals. Accessible at: *http://www.oehha.ca.gov/risk/ChemicalDB/index.asp*

Cleanup Levels for hazardous waste sites. Links to many federal, state and international websites that address soil clean up levels. Accessible at: *http://cleanuplevels.com/*

Cornell Waste Management Institute. Provides resources intended to help people who are interested in soil testing, interpreting test results, and best practices for healthy soils. Accessible at: http://cwmi.css.cornell.edu/soilquality.htm

National Pesticide Information Center. Provides information about pesticides and related topics. Accessible at: *http://npic.orst.edu/*

New York State Department of Environmental Conservation. Brownfield and Superfund Regulation, 6 NYCRR Part 375 - Environmental Remediation Programs. Accessible at: *http://www.dec.ny.gov/chemical/34189.html*

Penn State University. Agronomy Fact Sheets: Environmental Soil Issues. Information about lead in residential soils, garden use of treated lumber, and other issues. Accessible at: *http://cropsoil.psu.edu/extension/esi.cfm*

US Environmental Protection Agency. Office of Solid Waste and Emergency Response. Soil Screening Guidance:
Quick Reference Fact Sheet, EPA/540/F-95/041. Accessible at: *http://www.epa.gov/superfund/health/conmedia/soil/pdfs/fact_sht.pdf*

Technical Background Document, EPA/540/R95/128. Accessible at: *http://www.epa.gov/oerrpage/superfund/health/conmedia/soil/introtbd.htm*

US Environmental Protection Agency. Integrated Risk Information System (IRIS). Searchable database with information on the toxicity of numerous chemicals. Accessible at: *http://cfpub.epa.gov/ncea/iris/index.cfm*

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