Soils And Urban Agriculture: Guidelines for Safe Gardening Practices

Overview

Across the country, communities are adopting the use of urban agriculture and community gardens for neighborhood revitalization. Sites ranging from former auto-manufacturers, industrial complexes, and whole neighborhoods, down to small individual lots, including commercial and residential areas, are being considered as potential spots for growing food.

Redeveloping any potentially contaminated urban property (often referred to as brownfields), brings up questions about the site’s environmental history and the risks posed by a proposed reuse. At this time there are no definitive standards for soil contaminant levels that are safe for food production. EPA has long-established soil screening levels for contaminated site cleanup, but these threshold-screening levels usually serve as a starting point for further property investigation and do not factor in plant uptake or bioavailability.

How clean is clean for gardening activities?

Clean-up and reuse of any contaminated site is based on risk assessment and exposure scenarios – the levels of contamination present and how a person can be exposed to that contaminant, based on the intended reuse. These criteria for residential, commercial and industrial reuse are based on potential exposure: length of time spent on the site, types of activities performed on the site, and potential contamination pathways such as inhalation, ingestion, or possible skin contact with contamination.

Step-By-Step Guidelines

The following process proposes a series of questions you need to ask and the information you need to gather in order to make decisions while implementing an urban agriculture project. This model may be applied to any urban agriculture project on any brownfield site, and may be of value for other reuses where contact with soil may be higher, such as parks or recreational areas.

The previous use of the property and those surrounding it will be the major deciding factor on how cautious you should be before gardening. The more historical information learned about a site’s previous uses, the more informed decisions can be made during garden development.

We can infer possible types of contamination based on the previous use of the property. For example, residential areas may have unsafe concentrations of lead where the presence of older housing stock or structures indicates lead-based paint was present. Industrial areas may be high in heavy metals such as cadmium, mercury, chromium and arsenic. Heavy metals are elements, the basic building blocks of matter. They cannot be broken down any further by regular natural processes. If left alone, heavy metals present in soils remain indefinitely. Excessive exposure to heavy metals can result in a number of negative health effects, including organ damage, birth defects, and immune system disorders.

Phytoremediation and compost remediation are the bioremediation methods most commonly used to treat heavy metal contamination. Phytoremediation accumulates metals in certain metal-loving plants that are then removed and disposed of elsewhere. Compost binds up metals with organic molecules in the soil, reducing the percentage that is absorbed by plants or human tissue.

Molecular contaminants are made up of molecules: elements bound together in different ways to create substances with varying chemical properties. Some molecular contaminants found in soils are pesticides (dieldrin, chlor dane, glyphosate), fuels (diesel, gasoline), and byproducts of industry (PCBs, dioxin). Polycyclic aromatic hydrocarbons (PAHs), a group of chemicals formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, can be found at former residential properties as well as commercial and industrial properties from fires or

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Why Soil Remediation?

by Jack Kittredge

Backyard farms, community gardens, parklands, rail trails and dozens of other creative repurposings of land are transforming our landscape. Many of these changes involve introducing agricultural activities where they had not existed for many years. In the past decade the number of community gardens in the US increased from 6,000 to 18,000, and the trend is accelerating. But as more of us come to live in cities, or try to bring into production land that has had previous contaminating uses, we need to be more thoughtful about avoiding toxic chemicals, heavy metals, or other man-made problems in our soil.

This issue is an attempt to survey the topic of Soil Remediation and report on groups that are in the trenches (literally, in some cases) dealing with contaminated ground and the current methods -- in some cases physical barriers, in other cases planting in containers, some using plants to accumulate or microbes to detoxify contaminants, others applying humic substances to immobilize them -- for making soil usable again.

Those of us blessed with rural farm locations and healthy soils may not think twice about how fortunate we are to have such gifts. But even pristine environments sometimes suffer spills and dumpings, so increased from 6,000 to 18,000, and the trend is accelerating. But as more of us come to live in cities, or try to bring into production land that has had previous contaminating uses, we need to be more thoughtful about avoiding toxic chemicals, heavy metals, or other man-made problems in our soil.

One of the most valuable methods for treating molecular contaminants. The natural metabolic processes of bacteria and fungi are capable of breaking the molecular bonds of contaminants, making them into benign components which they then use as food. These processes occur naturally over time, but the rate of degradation can be accelerated by adding beneficial organisms to a site and providing the proper habitat and nutrients.

Identify Previous Use -- What is the history of your proposed site?

Maps and Photographs -- One of the most valuable sources of land use information is fire insurance maps made and published by the Sanborn Map Company. These maps are detailed and beautifully illustrated, and at a scale of 50-feet-to-one-inch they show building footprints, gas lines, underground storage tanks, pipelines, prevailing wind direction, railway corridors, and other information for some 12,000 U.S. towns and cities starting in 1867 and continuing to the present. Perhaps the most important features to locate on these maps are the drains, where facilities released effluent that may have contained heavy metals, solvents, and other contaminants from production processes. No other published maps show such detailed urban land use information.

Historic Sanborn maps can be accessed in a number of ways. They are typically found in the archives and special collections of city halls or in public and university libraries. Most Sanborn maps have also been digitized by Environmental Data Resources, and can be searched online through latitudinal and longitudinal coordinates for a fee. See http://www.ednet.com/environmental-services/sanborn-maps.

Changes in land use can also be detected through aerial and historic photographs. The oldest available aerial photography dates back to the 1920s, and those sources are the U.S. Geological Survey’s Urban Dynamic Research Program, state natural resources and transportation departments, and regional, county, and city planning agencies. In addition, there are numerous commercial aerial photography studios that have large archives, but their rates are high compared to government agencies.

New technologies, however, make it easier to access historical images. The “time slider” feature in Google Earth allows one to compare satellite images of a city’s built environment at different points in time. Currently Google Earth has made images available from the mid-1970s to the present, though the time period varies with location.

City Directories -- City directories can also be used to research past uses of a property. They are not telephone directories, but rather indexes that provide a record of changes in property occupancy at specific addresses going as far back as the late 19th century in many cities. Starting with the most recent directory and working backward, it is possible to develop a list of business operations at single address over decades. One could determine, for example, that a vacant lot that looks suitable for a community garden was previously used as a gas station after having been an auto body shop, or a dry cleaners, or some other use that might have led to soil contamination. One can broaden a search to include business operations on nearby properties if there is reason to believe that contamination from these properties may have migrated onto the target site.

City directories are often overlooked in researching the historical uses of a property, but they show the dynamic nature of urban development—that is, and effort is necessary to repair tainted land should make us all more grateful for the miracle of living, active soil that we can so easily take for granted.

Some wise person once observed that the only thing standing between humanity and starvation is a few inches of biologically active topsoil. It is humbling to think that most of what we do as farmers and gardeners is tend forces that we don’t really understand, letting the knowledge bound up in seeds and soil sustain us. We hope that you enjoy this issue and it energizes your appreciation of these mundane miracles.

continued from page B-1

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Sanborn Map of Black Diamond Steel Company, Pittsburgh, PA
the boom and bust cycles of urban history. They can identify how these broad changes played out at specific addresses. City directories can be found in many major public libraries, as well as state archives.

**Environmental Databases** – While no comprehensive list of contaminated properties is available, one can search a number of online environmental databases. For example, the Right-to-Know Network’s website—rtknet.org—provides access to site-specific information on chemical and oil spills, as well as the locations of illegal dumping, through the Emergency Response Notification System database (ERNS).

The RTKNet site also links to CERCLIS (Comprehensive Environmental Response, Compensation, and Liability Information System), an EPA-maintained database that contains information on preliminary assessments, potential and actual hazardous waste sites, site inspections, and cleanup activities at thousands of sites across the country. Similarly, EPA’s Resource Conservation and Recovery Act Information System (RCRIS), contains extensive data on hazardous-waste-handler permits and activities, which can be searched by address and or zip code. A wealth of environmental information can be found online at the state level through the state’s environmental protection agency.

**Historical documents** as well as environmental databases are key components of a site investigation. But in many cases, there may be limitations or gaps in the historical and regulatory record. One way to address these limitations is to find out about the property from persons who live nearby. Neighbors are likely to have a wealth of knowledge about a potentially contaminated site, particularly if the property was used for unregulated activities, such as midnight dumping, illegal auto repairs, etc. In addition, one can interview local planners, town historians, previous site owners, and others who have some connection with the property.

Perhaps the most critical step in the process is to walk through and inspect the site thoroughly. One often finds conditions not reflected in official records and photographs. The site can be checked for indications of illegal dumping or the burning of garbage. The presence of building rubble, old foundations, back-filled areas, and spots where subsidence has occurred all indicate areas potentially requiring further assessment. The property can also be checked for soil staining and chemical and gasoline smells.

**Determine Whether Previous Use is High or Low Risk to Site Soil and Water**

Once you feel you have an understanding of the previous uses of the site, determine whether that use is high or low risk for agriculture reuses, the likely crops or garden design, and sample the site accordingly. As a rule of thumb, recreational or residential previous uses are typically lower risk while commercial and industrial uses can be considered higher risk.

**Perform Sampling**

Low risk previous uses like residential areas, green space, traffic corridors and parking areas generally have a narrow band of likely contamination that allows for a basic sampling strategy. High risk uses, like manufacturing or rail yards, open up the possibility of many types of contamination over a wide area of the site, and require a more rigorous sampling strategy.

Not all types of contamination will have the same effect on you as a gardener or on your crops. Research on soil metal chemistry and plant uptake has found that most metals are so insoluble or so strongly attached (i.e. adsorbed) to the actual soil particles or plant roots, that they do not reach the edible portions of most plants at levels which would compromise human health when eaten.
Most tests for soil contaminants use extraction methods (i.e., the sample is digested in acid and then diluted prior to analysis) yielding a total contaminant concentration. The amount of that contaminant that is bioavailable or bioaccessible (i.e., the ability of ingested contaminants to be absorbed by the body) to plants or people will be less than the resulting total contaminant level – actually a fraction of the total value. Often in the case of lead in urban soils, a small fraction of the total lead concentration is found to be bioavailable, likely due to the historic application of fertilizers, manures and composts, which change the characteristics of soil and can cause inactivation of lead in soils over time. Because determining bioavailability is costly and because regulating a total concentration is the most protective of human health, test result interpretation frequently focuses on total concentrations.

Manage Risks

Perform Clean-Up

If results indicate that the existing soil is not safe for gardening activities and you are planning to plant in-ground, remediation may be necessary. Techniques most applicable for agriculture projects include physical (excavation, installing geotextiles, soil washing or soil vapor extraction) or biological (microbial, phytoremediation, or application of soil amendments).

Many non-remedial options exist for sites with low levels of contamination, or sites with contamination exposure risks which can be controlled by planting above ground, including installing raised beds, gardening in containers, green walls or rooftop growing, and aquaponics.

Each remediation technique has unique benefits and drawbacks. Digging away the contaminated soil and disposing it in a landfill is the most effective technique for removing contaminants but can discard valuable topsoil. This is also the most expensive method, and replacing the contaminated soil with clean, non-industrial fill (that has been sampled for contaminants or has been certified as safe) can be cost-prohibitive to a non-profit gardener or community group. In-situ or on site remediation techniques or biological strategies may take multiple growing seasons or multiple applications, costly monitoring, and maintenance. Even remediation by amending with compost may be more involved than it sounds since composting needs to have preceded growing to create sufficiently healthy soil.

Construct physical controls

• Build your garden away from existing roads and rail, or build a hedge or fence to reduce windblown contamination from mobile sources and busy streets.

• Cover existing soil and walkways with mulch, landscape fabric, stones, or bricks.

• Use mulch in your garden beds to reduce dust and soil splash back, reduce weed establishment, regulate soil temperature and moisture, and add organic matter.

• Use soil amendments to maintain neutral pH, add organic matter and improve soil structure.

• Add topsoil or clean fill to ensure the soil is safe for handling by children or gardeners of all ages and for food production. Your state or local environmental pro- gram, extension service, or nursery may be able to direct you to providers of ‘certified safe’ soils, or to recommended safe sources for gardening soil.

Begin Farming

Whether it is a long-term or an interim use, simply greening a once-blighted or vacant property and improving the soil structure has real effects on the economic and social value of land and community health. It can also reduce the runoff of urban soil, silt and contaminants into stormwater systems by allowing greater infiltration of rain into soils improved with added compost and soil amendments. The ability to grow food or horticultural crops such as flowers or trees on this newly greened area will produce multiple beneficial effects to those who may farm it. Healthy eating, increased physical activity, reduction of blight, improved air quality and improved quality of life are all nearly immediate health benefits from urban agriculture.
Assessing Urban Impacted Soil for Urban Gardening

from a Guide Prepared by Toronto Public Health

Introduction

Urban gardening is gaining momentum in North America. Urban gardening can provide broad health, environmental, social and economic benefits.

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. Despite 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.

This 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.

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.

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 (discoloration, usually dark patches) and odors (chemical and gasoline smells).

A site history is researched by searching available city records and asking local neighbors 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. The table to the upper right lists the various indicators, the appropriate Level of Concern, and the recommended next steps for the garden site.

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

Step 2 - Sample and Test the Soil

If the planned garden on a Medium Concern site is larger than 13 by 13 ft, the soil should 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. We recommend that small gardens in the Medium Concern category go to Step 4. For larger gardens, the depth of soil to be sampled is 0 to 40 cm.

We developed the above streamlined list of contaminants of concern (COCs) for the Medium Concern sites. The cost to analyze each composite sample for all the parameters listed is approximately $250. The number of required composite samples is determined by the size of the garden. For a community garden 1 to 2 samples covers 225 to 450 m², respectively. The average community garden is 280 m². Thus, most community gardens will require 2 samples at a cost of approximately $500.

If the indicators identified during the site visit and site history suggest that the soil might be contaminated by other soil contaminants not on our streamlined list of COCs, then the garden site should be treated as a site of High Concern (Go to Step 4).

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) on page B-8. The SSVs define the three risk levels, and are used to interpret the soil test data as follows:

- 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.

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. The illustration on page B-8 summarizes the recommended exposure reduction measures for the gardens that are required for Tier 1, 2 or 3 Exposure Reduction.
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Determining the Risk Level for the garden by comparing the soil concentrations to the SSVs

<table>
<thead>
<tr>
<th>Metals</th>
<th>SSV 1</th>
<th>SSV 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>11</td>
<td>110</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.0</td>
<td>10</td>
</tr>
<tr>
<td>Cobalt</td>
<td>23</td>
<td>170</td>
</tr>
<tr>
<td>Chromium, total</td>
<td>390</td>
<td>630</td>
</tr>
<tr>
<td>Chromium, VI</td>
<td>5.0</td>
<td>k</td>
</tr>
<tr>
<td>Copper</td>
<td>180</td>
<td>660</td>
</tr>
<tr>
<td>Mercury</td>
<td>2.7</td>
<td>k</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>13</td>
<td>k</td>
</tr>
<tr>
<td>Nickel</td>
<td>34</td>
<td>340</td>
</tr>
<tr>
<td>Lead</td>
<td>34</td>
<td>340</td>
</tr>
<tr>
<td>Selenium</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Zinc</td>
<td>680</td>
<td>1980</td>
</tr>
</tbody>
</table>

PAHs

<table>
<thead>
<tr>
<th>Compounds</th>
<th>SSV 1</th>
<th>SSV 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acenaphthene</td>
<td>0.050</td>
<td>0.32</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>0.090</td>
<td>0.47</td>
</tr>
<tr>
<td>Anthracene</td>
<td>0.84</td>
<td>0.58</td>
</tr>
<tr>
<td>Benz(a)anthracene</td>
<td>0.23</td>
<td>2.3</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.23</td>
<td>k</td>
</tr>
<tr>
<td>Benzo(b)fluoranthene</td>
<td>0.23</td>
<td>2.3</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.14</td>
<td>1.4</td>
</tr>
<tr>
<td>Benzo(k)fluoranthene</td>
<td>0.23</td>
<td>2.3</td>
</tr>
<tr>
<td>Chrysene</td>
<td>0.099</td>
<td>0.99</td>
</tr>
<tr>
<td>Dibenzo(a)anthracene</td>
<td>0.77</td>
<td>k</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>0.14</td>
<td>1.4</td>
</tr>
<tr>
<td>Fluorene</td>
<td>0.39</td>
<td>k</td>
</tr>
<tr>
<td>Indeno[1,2,3-c,d]pyrene</td>
<td>0.23</td>
<td>2.3</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>Pyrene</td>
<td>0.11</td>
<td>k</td>
</tr>
</tbody>
</table>

* Any level 1 SSV was derived for this parameter. The forensic health intervenible value of the SSV is greater than 10 times urban background, the maximum value allowed in the guideline. Thus, the only SSV for this parameter is based on 10 times urban background.

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

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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 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.

**Recommended Actions to Reduce Gardeners’ Exposures to Soil Contaminants**

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

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Guide for Soil Testing in Urban Gardens

from a Guide prepared by Toronto Public Health

We recommend testing the soil if the planned garden is on a Medium Concern site AND if the garden is larger than 13 X 13 ft. Testing the soil consists of taking a soil sample, having it analyzed, and interpreting the results. It is not cost-effective to conduct soil testing for small gardens. This is based on estimates of the cost of soil testing versus building a raised bed garden.

Soil Sampling
Collect a representative soil sample of the site. A composite soil sample is made up of two or more combined sub-samples to represent an area of the garden. Use the following checklist to walk you through taking a soil sample.

Materials needed

- Work Boots
- Work Gloves
- Measuring Tape
- Trowel
- Shovel
- 2 Clean Plastic Buckets (9L each)
- Reusable Bags (3.7L)
- Cooler & Ice Packs
- Notebook & Pencils
- Large Black Permanent Marker
- Taper, Pylons or Ropes, Stringing to mark boundary of proposed garden area

Create a diagram and plan where you are going to take your soil samples:

- Make note of the name and address of the property
- Draw a line around your garden using pylons, tape or rope. The soil sample should be taken from the area that the gardeners use. A typical community garden will need only one or two soil samples. We recommend that a composite soil sample is taken every 10 x 10 to 15 x 15 m area (approximately 50 x 50 ft). Starting at one corner of the composite soil sampling area, walk diagonally to the far corner and repeat, making an “X” pattern. Mark the location of a sub-sample approximately every 2.5 m (8 ft) using a pylon or some other marker. This is where you will take your sub-samples of soil that will make a sample. For gardens larger than half an acre, call 311 for help
- Note the location of the sub-samples on your diagram

Sample the soil

- Strip off turf or other vegetation from the sub-sample spot
- Take shovel and dig into soil down to 40 cm (16 in) Place sub-sample soil into Bucket 1
- Break up and mix the sub-sample soil in Bucket 1
- Remove stones and visible debris
- Note the presence and type(s) of debris, smells, and staining in your field notes
- Transfer a trowel full of the mixed soil from Bucket 1 to Bucket 2
- Refill the hole with the remainder of the soil in Bucket 1, and replace the turf
- Repeat until nine sub-samples have been collected separately in Bucket 1 and transferred to Bucket 2

Create composite soil sample

- Mix the combined sub-samples in Bucket 2 to

Real Time Map Tool
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The laboratory will tell you how much soil you need. Typically, each composite soil sample is approximately 2 cups (2 small trowels of soil). Each laboratory is different and prices change over time. You should expect to pay between $150 to $300 for each composite soil sample.

**Soil Analysis**

**Purpose:** Select a laboratory for the soil analysis and tell the lab staff what analyses you would like them to do.

Toronto Public Health has identified a list of the most likely contaminants present in Medium Concern sites. Use the following checklist to walk you through getting your samples analyzed.

**Soil Analysis Checklist**

1. Select a laboratory able to do the analysis
   - Find qualified labs in your area through:
     - Yellow Pages (heading: Laboratories – Analytical & Testing)
     - Internet search
   - Contact the Laboratory
     - Get in contact with your chosen lab several days before you take the samples to:
       - Confirm price and turnaround time
       - Obtain a chain of custody form. The chain of custody form provides information on you (the client), the samples, and the analyses that you want
       - Tell the lab when you expect to deliver the samples
       - Obtain instructions for handling the samples and delivering them to the lab
   - Fill out a Chain of Custody Form
     - Fill out the chain of custody form and keep the required copies with the samples
     - Every lab’s form differs, but you will have to indicate that you want the soil tested for pH values, metals and PAHs. Write out the full name of each metal and PAH you want tested for
   - Deliver Samples to the Lab
     - Deliver or ship samples to lab within one day of sampling. Some laboratories will pick up the soil sample
     - Keep samples refrigerated or in a cooler between the time you take them and the time you deliver or send them to the lab
Three young women turned their love of gardening into a thriving farm business. After college Fay Strongin, and sisters Laura Brown-Lavoie and Tess Brown-Lavoie, did not seek desk jobs but instead decided to start farming on an abandoned lot just minutes from busy downtown Providence, in Rhode Island.

The future farmers searched every side street in ever-increasing circles, seeking an open lot. They researched lot ownerships at city hall and reached out to landowners. “It took a lot of detective work and repeated efforts to connect with the owner of the abandoned lot on Harrison Street that became Sidewalk Ends Farm,” Tess said. The three sought a written multiyear lease, but faced communication challenges with the landowner. The farm team eventually secured verbal permission from the lot owner to farm the land for a year.

Harrison Street neighbors said there had been a rundown house at number 47 until it was torn down in the 1970s. Invasive vines and brush had completely taken over the lot. As the team began clearing away the brush, they found building debris, concrete and rubble in the cellar hole. Like many abandoned lots, this one had become the neighborhood’s dumping ground. The farmers found bottles and broken glass near every fence line.

Ever the optimist, Laura was confident the neighbors would stop dumping trash over the fence once they saw the land producing food.

City Farming Concerns

Suspecting the Harrison Street lot soils might contain toxins, heavy metals or lead, the farmers conducted thorough soil tests before beginning site preparations in September 2011. The front of their chosen lot had building debris from the original house – including lead paint chips. To mitigate risks, Tess said the team shoveled and carried all the “OK” topsoil from the back of the property to cap or cover the tainted soil at the front. Soil test results after moving the soil were in the acceptable range for growing food and raising animals.
As an added protection, the farm team installed thick layers of bedding over a liner before setting up a brightly colored chicken pen near the front fence for everyone to see. When refreshed, the used bedding helps feed the active compost pile. The chickens enjoy eating excess farm vegetables.

A series of raised beds were constructed from gleaned lumber and wood scraps, used pallets and other recycled materials. These beds were filled with 8” – 10” of fresh soil and rich compost before plantings. The farmers collect food scraps from their CSA customers and their own compost from a variety of local inputs. Since then, the farmers have produced and used their own compost from a variety of local inputs.

Planning well, the farmers planted herbs and flowers in portable, repurposed containers like milk crates, burlap coffee sacks gleaned from a nearby café keep weeds down between rows of salad greens at the back of the lot. Some deep-rooted crops accumulate minerals from well below the soil surface and can offer excellent nutrition. If grown in tainted soils, however, they can accumulate toxins. To minimize risks, Sidewalk Ends Farm grows shallow-rooted, short-season crops like salad greens and annual herbs.

Compost & Organic Matter

The first fall the three farmers splurged on truck loads of high quality compost from Smithfield Peat (<www.smithfieldpeat.com>. Additional material was gathered and added all winter long (leaves, coffee grounds, etc.) and blended with a broad fork in the spring before the seeds and transplants went in. Since then, the farmers have produced and used their own compost from a variety of local inputs. Farmers collect food scraps from their CSA customers, local restaurants and coffee shops.

Taking advantage of urban closeness, these farmers encourage their neighbors to add to the farm’s active compost pile. Fun, informative signs help remind families how to compost. Fay said: “Composting helped us connect with our neighbors even more than growing food.” The neighbors now have an excuse to visit the farm regularly. Their random evening visits help to reduce their trash hauling needs and to see their kitchen scraps recycled into next year’s salads.

“The farm neighbors get composting. We have a network of fertility,” said Tess when she described a recent bike trip where a driver pulled over and tossed her banana peel into Tess’s bike cart of food waste.

Fay is very enthusiastic about her farm-made compost. She said, “Compost is the key to our soil fertility because the only time this land is fallow is when it is frozen!”

Old carpet squares and flattened cardboard boxes marked paths at first. Now shredded leaves and burlap coffee sacks cleaned from a nearby café keep weeds down between rows of salad greens at the back of the lot. The farmers repeat their soil tests annually and are happy to report the organic matter keeps rising. Sidewalk Ends Farm’s lead and heavy metals levels continue dropping towards undetectable levels.

Organics & Carbon Footprint

The Cranston Armory Farmers Market at the corner of Parade and Hudson Streets is just two blocks away from Sidewalk Ends Farm. CSA members pick up their shares at the farm. The farmers use bikes with trailers to deliver produce or collect food waste. Adding organic matter increases carbon in the soil. Biking and selling locally has decreased food transportation miles and further lowering carbon dioxide emissions while increasing local food security.

Water Challenges

When the house at 47 Harrison Street was demolished in the 1970s, city water pipes were disconnected. Hooking up city water without a building proved too challenging, so the Sidewalk Ends Farm crew developed a creative solution with their neighbors. Hoses connected to neighboring buildings provide irrigation and wash water in return for a weekly CSA share (spring – fall) and a weekly loaf of fresh bread (winter months).

Urban Setting

goals & results

To keep this farm viable, every inch of growing space needs to deliver two to three crops per year. The back lot uses bio-intensive planting patterns of tight, staggered rows to increase outputs in small spaces. As soon as a crop is harvested, any crop residue is quickly moved to the active compost pile. That same day, 1” to 2” of finished compost is spread and forked into the bed to provide organic matter and fertility. New seeds or transplants are then installed. Soils do not sit bare and exposed to wind or erosion.

Since 2011 Sidewalk Ends Farm has supplied greens and produce to a 20-member CSA and restaurants through the Little City Growers Co-Op <www.farmfresh.org/food/member.php?fn=272>. Their CSA shares are comparable to half shares from other farms; this fits the needs of city dwellers with their small kitchens, refrigerators and families. Sidewalk Ends Farm covered or capped their urban farms; this fits the needs of city dwellers with their CSA shares. Their produce to a 20-member CSA and restaurants through the Little City Growers Co-Op <www.farmfresh.org/food/member.php?fn=272>. Their CSA shares are comparable to half shares from other farms; this fits the needs of city dwellers with their small kitchens, refrigerators and families.

Phytoremediation

Sidewalk Ends Farm covered or capped their urban soils with fertile compost and clean soils. By selecting shallow-rooted crops, they grow safe, healthy foods for themselves and their CSA customers. By placing a liner under their chicken pen, they protect the chickens from scratching too deep.

Larger farms may not have the financial resources to move or replace soils on a big scale. Another soil treatment option is to use accumulator plants for phytoremediation. Growing specific plants on treated land can help cleanse soils for future agricultural use. Various plants and microorganisms can degrade, tie up or even remove toxins from the soil.

Some plants can accumulate heavy metals like arsenic (sunflower and Chinese brake fern), cadmium (willow), common salt (sugar beet and barley) and radioactive elements (sunflowers). Other transgenic plants and microorganisms target mercury, selenium, petroleum and PCBs.

High levels of soil organic matter help tie up many heavy metals, making them unavailable to plants, preventing leaching and reducing toxic dust.

Toxic dust becomes airborne when soils are disturbed during removal and hauling. Bare infertile soil remains. Ozone treatment significantly reduces costs and the carbon footprint of hauling contaminated soils to hazardous waste facilities. In situ treatment significantly reduces exposure risks to neighboring children. Phytoremediation and urban agriculture can also prevent toxins from blowing or leaching onto surrounding properties or into ground water aquifers.

Plant Selection

According to “The Use of Plants for the Removal of Toxic Metals from Contaminated Soil” by Mitch Lasat, root exudates and symbiotic microorganisms help plant roots tolerate and absorb metals. Soil toxicity levels will affect typical plant biomass. High biomass crops create higher disposal costs. Lasat recommended site managers select plants with root system depths that match the depth of soil contamination.

Lasat reported that some species of maize tolerate and absorb high levels of Cadmium (Cd) but cannot tolerate high levels of Zinc (Zn). Maize and Indian mustard (Brassica juncea) show some promise for extracting Lead (Pb) from soils when synthesized chelates are applied after normal biomass levels are reached. According to Lasat, moderate Lead accumulators include Asian dayflower (Commelina communis), common ragweed (Ambrosia artemisiifolia), nodding thistle (Carduus nutans) and hemp dogbane (Apocynum cannabinum).

Lasat suggested acidic soils allow greater metals uptake. Cadmium is required as soluble lead can quickly leach below root zones. After plants remove sufficient metals, lime can be applied in preparation for new plantings. Early lime applications could tie up remaining metals and prevent further phytoremediation. Lasat reported that phosphorus could increase biomass but inhibit metals uptake, particularly lead.

Phytoremediation crops should be rotated and planted with modest spacing for highest effectiveness, according to Lasat. If plants are grown directly in known toxic soils, the plants should not be eaten. After the plants have absorbed or tied up toxins, the plant biomass should be removed to a hazardous waste facility.

Lasat recommended additional research be conducted on spacing, soil fertility amendments and metals recovery processes and opportunities.

To learn more about Sidewalk Ends Farm, see their Facebook page <www.facebook.com/pages/Sidewalk-Ends-Farm/213101742058011> or Side- walk-Ends-Farm/213101742058011 website. To arrange a visit to Sidewalk Ends Farm at 47 Harrison St, Providence, RI, email <laura.brown.lavoie@gmail.com> or call 617-817-6598.

The workshop was followed by a Young Farmer Nights potluck supper and storytelling around a fire.

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Lead in Urban Soils

by Jack Kittredge, incorporating information from The Food Project (Boston) and Worcester Roots

Lead is a widespread problem in America’s urban areas. Years of driving with leaded gasoline, using lead paint on our houses, and running our water through pipes joined with lead solder have seriously contaminated our soils.

Background concentrations of lead in agricultural soils average 10 parts per million. In urban soils, however, lead levels typically are much higher. The Centers for Disease Control estimate that some 21 million pre-1940s homes contain lead paint. When lead paint on our houses, and running our water through pipes joined with lead solder have seriously contaminated our soils.

In Syracuse, New York soil sampling conducted by university researchers found high levels of lead and arsenic in five out of six community gardens in low-income and minority neighborhoods where residents grew much of their own fresh vegetables during the summer months. The gardens were located on plots where abandoned homes had been razed. Lead paint from the demolished houses contaminated the soil, and lead-rich exhaust from passing traffic built up in the soil over decades.

Where to Look for Lead

Visual assessments of painted structures help to identify areas around the property that are high risk for causing lead poisoning, but they cannot be used to confirm lead contamination of soil. You can look for deteriorated paint on all painted building components, especially any exterior walls, windows, or trim damaged from a roof or plumbing leak. Also look on surfaces that experience friction or impact from the dripline. This includes bare soil, or thin grass that are greater than 6 square feet. The special risk areas for soil are dripline – within 2 feet of the house, play areas, gardens (in native soil) and uncovered walkways. If the house/structure was built before 1978, and you see deteriorated paint or there is bare soil or thin grass in special risk areas, you should test your soil for lead. Testing is especially important if there are children under the age of six living in the house and if there is or will be a garden in native soil.

Soil Testing

Suggested Sampling Materials:

- Gloves
- 1 quart Ziploc-style bags (one per composite sample, usually 1-4 per yard)
- Permanent marker (to mark bag)
- Record Sheet, Map Sheet (see samples Appendix B and C)
- Auger, shovel, trowel or similar tool
- Rag or paper towels
- HEPA filter
- 1-quart Ziploc-style bags (one per composite sample set, not individual samples).
- Label bag with sample name/number, address of site, name of organization and date.

Sampling Procedure:

Step 1 – Identify Potential Risk Areas

With input from resident and/or owner, identify areas that are most likely to be a risk based on the following high risk factors:

a. High use, especially by children (play areas, gardens, walkways)

b. Bare soil

c. Proximity to house (especially the “drip zone”) within 3 feet of the house, aka “drip line”) (see "drip line")

d. Visible chipping paint or known former structures

Choose the areas to be tested and mark them on a Map (optional), drawn in the context of the property, streets, and compass heading (mark North on the map). Give each area a sample name/number (ex. #1 = Drip line).

Step 2 – Collect Composite Samples

Within each possible risk area chosen, collect 6-8 samples (easily spread out in the area) in this way:

a. Make a hole with auger, shovel, trowel or similar tool. The hole should be thin and approximately 6 inches deep. Take some soil from each depth of the hole either by scraping the tool along the side of the hole, or poking out a column of soil from the core if using a bulb tool or something similar. Mark each hole with an “X” on the Map Sheet. Wear gloves and, if windy, respirator to prevent inhaling dust.

b. Put all 6-8 soil samples in one bag, avoiding insects and large pieces of debris such as sticks, stones, bark, etc. Total soil should be approximately one cup. Wipe off sampling tool between composite sample sets (not individual samples).

c. Label bag with sample name/number, address of site, name of organization and date.

Step 3 – Document Area

Complete the map and record sheet, making sure sample names/numbers match up and marking important structures, notes and other relevant details such as type of siding, use of spaces, etc.

Post-Sampling Procedure:

Each lab requires different sample preparation and labeling. For labs that require dry samples, rinse them by placing soil in sun on a piece of dark flexible material or newspaper in an area with little or no wind. Return to bag when dry, being careful not to mix up the samples. Debris can be removed at this stage as well. Send samples, with a list of samples, to soil testing lab. You may want to retain a “copy” of each sample in case of a lab or mail error.

Where can you send your soil samples?

One recommended lab for quick turn-around and inexpensive testing, useful if just the lead concentration is needed is Environmental Health Services Lab: http://www.leadlab.com/

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Interpreting the Soil Test

Look for the “total concentration” or “total estimated lead” or similar number on the lab report. Results are measured in μg/g or mcg/g or most commonly: Parts Per Million: PPM.

0-400 PPM Recommended options:
The EPA deems these levels safe for gardening and play. At levels of 200 and above, some groups advise using compost amendment and/or phytoremediation.

400-2000 PPM Recommended options:
--Build raised beds or containers gardens for immediate gardening
--Phytoremediation
--Compost amendment (in addition to diluting toxic concentrations, studies have shown high phosphorus compost amendment reduces bioavailability of lead)
--Cover with 6 inches of clean soil, then stabilize or create a barrier using the following: perennial plants, wood chips, landscaping fabric, crushed stone, patio, stepping stones, etc.

2000+ PPM Recommended options:
Immediate Steps:
• Get children who have come in contact with infected area tested (blood lead level tests done at most doctor’s offices and health clinics).
• Block off or cover area.
• Long-term Solutions:
  • Some groups recommend permanent coverings (see above) for this level.
  • Build raised beds or container gardens for immediate gardening
  • Some groups recommend excavation or burying on site with proper safety precautions. This can be very costly, especially for disposal, and safety precautions are extensive.

Remediation

Phytoremediation

• As densely as possible, plant hyper-accumulators, such as scented geraniums (others include mustard greens, Indian mustard, sunflowers, collards or spinach), to accumulate lead into the roots, stems and leaves of the plant. After the growing season, safely dispose of the plants (if you put into the municipal waste stream, ensure that your area has good lead protections on incubators, landfills, etc.) Note: this technique is very slow, and depending on the lead concentrations and soil conditions remediation can take several growing seasons. It is advisable to combine these phytoextraction techniques with other lead-safe landscaping techniques in most cases.

• Stabilize the soil by planting plants that grow soil-retaining root systems such as shrubs or ground-covers to reduce foot-traffic access and dust creation. This process is called “biostabilization.”

Advantages of Phytoremediation:
• Inexpensive
• Does not disrupt ecosystems
• Low-tech, accessible
• Metals can be reclaimed

Disadvantages of Phytoremediation:
• Remediation is confined to depth of roots
• Leaching into groundwater is not prevented
• Time consuming (studies suggest 300 ppm can be removed in 7 to 10 years)

Compost and Soil Amendments

• Add 6-12 inches compost to your garden to dilute and bind up the lead.
• You can reduce the amount of lead that is available to be absorbed into people’s bodies by adding phosphorus to the soil (in the form of rock phosphorus) forming pyrophosphate crystals.
• Some states and towns have free or inexpensive municipal composting programs.

Other Landscaping Techniques

Capping with clean soil: Add 6-12 inches of clean screened loam on top of contaminated areas, then stabilize the new soil. Stabilization techniques include bio-stabilization (lawns, perennial garden beds, bushes, spreading ground covers such as pachysandra) or installing a hardcape (patios, walkways, crushed stone/peastone beds with sturdy edging).

Drainage: All our suggested hardscaping techniques are waterproof (as opposed to paving, for example) but most require drainage to be taken into account, especially when capping with clean soil is used, as to not have the capped soil wash away. Lawns that are the low-points of the yard often require a buried drainage pipe (also called French Drain) which is installed by digging a trench with at least a 1% slope, lining it with landscaping fabric, installing a drain pipe (ideally a 4 inch rigid plastic perforated drain pipe, flexible corrugated pipe can be used but is harder to clean out), then surrounded by crushed stone, and covering with landscaping fabric to divert water from undesired areas (like towards foundations or low lawns).

Edging: usually the most challenging aspect of hardscaping work, especially in the case of lead-safe landscaping where disturbance of native soil must be minimized. Some digging to set edging (blocks, plastic edging, rot-resistant lumber) is often unavoidable, but the more you can use existing edges or build up clean soil to retain hardscaping base or material the better. For all projects that include digging, remember to call dig safe (dial 811), use respirators (3M HEPA filter), coveralls, boot coverings, and other dust prevention such as tarps and wetting soil before displacement.

Rain gardens: also a great design element that address drainage and flooding issues, More info on Rain Gardens here: http://www.raingardennetwork.com/build.htm

Raised Beds and Containers: See below on how to make raised garden beds. Container gardens are also a good immediate option for gardeners wanting to safely grow within one season. Get creative with your containers! Recycled bathtub bins, mini swimming pools make great container garden receptacles, as long as they have a way to drain excess water.

Construction Guide for Raised Beds

Want to grow this season and worried about your soil being contaminated or not good enough quality? You can make a raised garden bed for about $100 and fill it with fresh compost!

Materials Needed:
Wood: 4x4s in 30 lengths or longer (our most common combinations: for 10x14x1 bed that is approximately 1ft deep, we use six 10ft and three 8ft cut in half ~ 4x6 timbers). Make sure to get naturally rot-resistant (black locust is great, cedar works) or alternatively pressure treated wood (ideally sodium silicate), especially avoiding those that contain Arsenic (most often in the form of Chromated Copper Arsenate – CCA) as you don’t want to be putting toxins near your food crops! Some use 2x6 inch boards, but we’ve found that, though less expensive, they have half the life span.

• Spikes: These are 6inch long nails. 30 spikes needed for each one foot deep bed. You can also use 6 inch screws such as “timberlocks” with a strong power drill or using pre-drilled holes in the timbers.

Compost: (soil made from composted organic matter such as yard waste) Make your own from food/yard waste, purchase, or look for free or inexpensive municipal composting programs.

Landscaping Fabric: To create a barrier under the bed so that water can go through but the plant’s roots can’t. One small roll will be plenty, most hardware stores carry this.

Tools: Four-to-six pound sledge hammer for spikes, shovels for soil, scissors or utility knife to cut the landscaping fabric, gloves, eye protection and a circular saw if you need to cut the timbers to length.

Step-by-step Instructions:
• Find a flat place that gets lots of sun. Gather materials (see above). Cut lumber and landscaping fabric to desired lengths.
• Pin the landscaping fabric on the ground with fabric staples, then place the first level of boards in the shape and location desired. Notice how each piece of wood is touching the end of only one other piece (i.e. you do not want the end pieces touching the ends of both side pieces, etc.)
• Hammer the spikes into the ends of the wood horizontally – connecting them to the other pieces in the rectangle – and four spikes into the ground to hold the fabric bed in place. For hills, it is recommended to use re-bar that go through pre-drilled holes in wood and are pounded into the ground at least 1 foot deep.
• Lay the second layer remembering to rotate the wood so that no connection is directly above the one below it (see image above).
• Hammer the second layer vertically down into the first layer with spikes every 2-3 feet. Some horizontal spikes into the ends of the timbers are useful to keep tight corners.
• Repeat with a third layer, remember to rotate the lay-out again.
• Fill the bed with soil.
• Plant your organic vegetables!

Excavation

You can excavate very small gardens with extremely high levels of lead by replacing the top three feet of contaminated soil with compost and clean soil. Due to the high costs and intense labor of the excavation process, the opportunity to use this technique is very limited.
Phytoremediation: Using Plants to Clean Up Soils

by Jack Kittredge based on an article in Agricultural Research magazine

Phytoremediation is the use of green plants to remove pollutants from the environment or render them harmless. Current engineering-based technologies used to clean up soils -- like the removal of contaminated topsoil for storage in landfills -- are very costly and dramatically disturb the landscape. But the “green” technology of using plants to take up heavy metals and radioisotopes can, in certain situations, provide a more economical approach and one that is less disruptive as well.

Certain plant species -- known as metal hyperaccumulators -- have the ability to extract elements from the soil and concentrate them in the easily harvested plant stems, shoots, and leaves. These plant tissues can be collected, reduced in volume, and stored for later use. In addition, of course, while acting as vacuum cleaners these unique plants must also be able to tolerate and survive high levels of heavy metals in soils -- like zinc, cadmium, and nickel.

We are at the early stages of identifying and learning about the transport and tolerance mechanisms of these plants. One, for instance, Thlaspi caerulescens, or alpine pennycress, is a small, weedy member of the broccoli and cabbage family and thrives on soils having high levels of zinc, nickel, cobalt and cadmium. Researchers have been studying the underlying mechanisms that enable this species to accumulate excessive amounts of heavy metals.

It apparently possesses genes that regulate the amount of metals taken up from the soil by its roots and deposited at other locations within the plant. These genes govern processes that can increase the solubility of metals in the soil surrounding the roots as well as the transport proteins that move metals into root cells. From there, the metals enter the plant’s vascular system for further transport to other parts of the plant and are ultimately deposited in leaf cells.

Thlaspi accumulates these metals in its shoots at astounding high levels. Where a typical plant may accumulate about 100 parts per million (ppm) zinc and 1 ppm cadmium, and would be poisoned with as little as 1,000 ppm of zinc or 20 to 50 ppm of cadmium, Thlaspi can accumulate up to 30,000 ppm zinc and 1,500 ppm cadmium in its shoots, while exhibiting few or no toxicity symptoms.

Whereas in normal plants zinc transporter genes, for instance, appear to be regulated by the zinc levels in the plant, in Thiaspi some sort of mutation has enabled these genes to stay maximally active at all times, independent of zinc levels until they are raised to very high concentrations.

Fortunately, zinc, nickel, cobalt and cadmium are metals that can be economically extracted from the shoots of Thiaspi, providing a viable process for removing these metals as soil contaminants. The crop would be grown as hay, and the plants cut and baled after they’d taken in enough minerals. Then they’d be burned and the ash sold as ore. Ashes of alpine pennycress grown on a high-zinc soil in Pennsylvania yielded 30 to 40 percent zinc -- which is as high as high-grade ore.

Phytoremediation and Radioactivity

Phytoremediation has also shown promise as a means of dealing with radioactive elements. For soil contaminated with uranium, studies have found that adding the organic acid citrate to soils greatly increases both the solubility of uranium and its bioavailability for plant uptake and translocation. Citrate does this by binding to insoluble uranium in the soil. With the citrate treatment, shoots of test plants increased their uranium concentration to

Plants Which Can Clean Up Various Contaminants
The Natural Farmer Spring, 2014

over 2,000 ppm – 100 times higher than the control plants.

The radioactive element cesium-137, with a half-life of 32.2 years, was released during the cold war by aboveground nuclear testing. Large land areas are now polluted with radionuclides and the costs of cleaning up these nuclear energy sites in the United States with engineering technology has been estimated at over $300 billion.

Fortunately, phytoremediation is an attractive alternative to these approaches. Studies showed that the primary limitation to removing cesium from soils with plants was its bioavailability. The form of the element made it unavailable to the plants for uptake. But now it appears that the ammonium ion is effective in dissolving cesium-137 in soils. This treatment increases the availability of cesium-137 for root uptake and significantly stimulates radioactive cesium accumulation in plant shoots.

And one plant species, a pigweed called Amaranthus retroflexus, has been found to be highly effective in removing radioactive cesium from soil. Researchers were able to remove 3 percent of the total amount in just one 3-month growing season. With plantings of two or three crops annually, the plant could clean up a contaminated site in less than 15 years.

Aluminum Tolerance in Acid Soils

Aluminum is the third most abundant element in the Earth’s crust and is not a major component of it in soils. At neutral or alkaline pH values, aluminum is not a problem for plants. In acid soils, however, a form of aluminum – Al³⁺ – is solubilized into a soil solution that is quite toxic to plant roots. Well over half the world’s 8 billion acres of arable land suffer from some degree of aluminum toxicity, including 6 million acres in the US.

Studies have found that, in aluminum toxicity, the root tip is the key site of injury, leading to inhibited root growth, a stunted root system, and reduced yields or crop failures from decreased uptake of water and nutrients. In some plants, however, aluminum triggers the release of protective organic acids whose functions include further enhancing the tolerance of existing aluminum-tolerant genes conferring aluminum tolerance. It should then be possible to improve the tolerance of relatively aluminum-sensitive crop species, such as barley, or to further enhance the tolerance of existing aluminum-tolerant germplasm.

Researchers looking for better aluminum tolerance are studying Arabidopsis thaliana, or thale cress, a diminutive, weedy member of the mustard family, is tolerant to aluminum.

Amaranthus retroflexus is highly effective in removing radioactive cesium from soil. From the root tip into adjacent soil. When released, these acids form a complex with the toxic aluminum, preventing the metal’s entry into the root. Wheat and corn, for instance, tolerate aluminum by excluding the metal from the root tip.

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Bioremediation of Contaminated Soil

excerpts from a paper by Dana L. Donlon and J. W. Bauder

Bioremediation is defined as the use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments of quality from soil and water. Bioremediation is a natural process which relies on bacteria, fungi, and plants to alter contaminants as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or at least making them less toxic. This paper summarizes the general processes of bioremediation within the soil environment, focusing on biodegradation of petroleum hydrocarbons. The effect of soil conditions on rate of biodegradation of hydrocarbons is addressed. Further, limitations and potential of both ex situ and in situ bioremediation as viable alternatives to conventional remediation are explained and addressed.

Many substances known to have toxic properties have been introduced into the environment through human activity. These substances range in degree of toxicity and danger to human health. Many of these substances either immediately or ultimately come in contact with and are sequestered by soil. The emerging science and technology of bioremediation offers a method to detoxify contaminants. Bioremediation has been demonstrated and is being used as an effective means of mitigating:

- hydrocarbons
- halogenated organic solvents
- halogenated organic compounds
- non-chlorinated pesticides and herbicides
- nitrogen compounds
- metals (lead, mercury, chromium)
- radionuclides

Bioremediation technology exploits various naturally occurring mitigation processes: natural attenuation, biostimulation, and bioaugmentation.

- Bioremediation which occurs without human intervention other than monitoring is often called natural attenuation. This natural attenuation relies on natural conditions and behavior of soil microorganisms that are indigenous to soil.
- Biostimulation also utilizes indigenous microbial populations to remediate contaminated soils. Biostimulation consists of adding nutrients and other substances to soil to catalyze natural attenuation processes.
- Bioaugmentation involves introduction of exogenous microorganisms (sourced from outside the soil environment) capable of detoxifying a particular contaminant, sometimes employing genetically altered microorganisms. During bioremediation, microbes utilize chemical contaminants in the soil as an energy source and, through oxidation-reduction reactions, metabolize the target contaminant into useable energy for microbes. By-products (metabolites) released back into the environment are typically in a less toxic form than the parent contaminants. For example, petroleum hydrocarbons can be degraded by microorganisms in the presence of oxygen through aerobic respiration. The hydrocarbon loses electrons and is oxidized while oxygen gains electrons and is reduced. The result is formation of carbon dioxide and...
To organic farmers everywhere for treating their animals and earth with care and treating us with some of the finest organic ingredients around, thanks.

Donegan Family Dairy, VT. One of the Organic Valley family farms that supply milk for our yogurt.
Three primary ingredients for bioremediation are:
1) presence of a contaminant,
2) an electron acceptor, and
3) presence of microorganisms that are capable of degrading the specific contaminant.

Generally, a contaminant is more easily and quickly degraded if it is a naturally occurring compound in the environment, or chemically similar to a naturally occurring compound. Microorganisms capable of its biodegradation are more likely to have evolved. Petroleum hydrocarbons are naturally occurring chemicals; therefore microorganisms which are capable of attenuating or degrading hydrocarbons exist in the environment. Development of bioremediation technologies of synthetic chemicals such as DDT is dependent on outcomes of research that searches for natural or genetically improved strains of microorganisms to degrade such contaminants into less toxic forms.

Microorganisms have limits of tolerance for particular environmental conditions, as well as optimal conditions for pinnacle performance. Factors that affect success and rate of microbial biodegradation are nutrient availability, moisture content, pH, and temperature of the soil matrix. Inorganic nutrients including, but not limited to, nitrogen, and phosphorus are necessary for microbial activity and cell growth. It has been shown that “treating petroleum-contaminated soil with nitrogen can increase cell growth rate, decrease the microbial lag phase, help to maintain microbial populations at high activity levels, and increase the amount of hydrocarbons degraded.” However, it has also been shown that excessive amounts of nitrogen in soil cause microbial inhibition. Walworth et al. (2005) suggest maintaining nitrogen levels below 1800 mg nitrogen/kg H2O for optimal biodegradation of petroleum hydrocarbons. Addition of phosphorus has benefits similar to that of nitrogen, but also results in similar limitations when applied in excess.

All soil microorganisms require moisture for cell growth and function. Availability of water affects diffusion of water and soluble nutrients into and out of microorganisms. However, excessive moisture content, such as in saturated soil, is undesirable because it reduces the amount of available oxygen for aerobic respiration. Anaerobic respiration, which produces less energy for microorganisms than aerobic respiration and slows the rate of biodegradation, becomes the predominant process. Soil moisture content “between 45 and 85 percent of the water-holding capacity (field capacity) of the soil or about 12 percent to 30 percent by weight” is optimal for petroleum hydrocarbon degradation.

Soil pH is important because most microbial species can survive only within a certain pH range. Furthermore, soil pH can affect availability of nutrients. Biodegradation of petroleum hydrocarbons is optimal at a pH of 7 (neutral); the acceptable range is pH 6 – 8.

Temperature influences rate of biodegradation by controlling rate of enzymatic reactions within microorganisms. Generally, speed of enzymatic reactions in the cell approximately doubles for each 10˚C rise in temperature. There is an upper limit to the temperature that microorganisms can withstand. Most bacteria found in soil, including many bacteria that degrade petroleum hydrocarbons, are mesophiles which have an optimum temperature ranging from 25˚C to 45˚C. Thermophilic bacteria (those which survive and thrive at relatively high temperatures) which are normally found in hot springs and compost heaps exist indigenously in cool soil environ-ments and can be activated to degrade hydrocarbons with an increase in temperature to 60˚C. This finding “suggested an intrinsic potential for natural attenuation of soil through thermally enhanced bioremediation techniques”.

Contaminants can adsorb to soil particles, rendering some contaminants unavailable to microorganisms for biodegradation. Thus, in some circumstances, bioavailability of contaminants depends not only on the nature of the contaminant but also on soil type. Hydrophobic contaminants, like petroleum hydrocarbons, have low solubility in water and tend to adsorb strongly in soil with high organic matter content. In such cases, surfactants are utilized as part of the bioremediation process to increase solubility and mobility of these contaminants. Additional research findings of the existence of thermophilic bacteria in cool soils all year round have since confirmed the hypothesis that high temperatures enhance the rate of biodegradation by increasing the bioavailability of contaminants. It is suggested that contaminants adsorbed to soil particles are mobi-lized and their solubility increased by high tempera-tures.

Soil type is an important consideration when determining the best suited bioremediation approach to a particular situation. In situ bioremediation refers to treatment of soil in place. In situ biostimulation treatments usually involve bioventing, in which oxygen and/or nutrients are pumped through injection wells into the soil. It is imperative that oxygen and nutrients are distributed evenly throughout the contaminated soil. Soil texture directly affects the utility of bioventing, in as much as permeability of soil to air and water is a function of soil texture. Fine-textured soils like clays have low permeability, which prevents bio-vented oxygen and nutrients from dispersing throughout the soil. It is also difficult to control moisture content in fine textured soils because their smaller pores and high surface area allow them to retain water. Fine textured soils are slow to drain from water-saturated soil conditions, thus preventing oxygen from reaching root microorganisms throughout the contaminated area. Biventing is well-suited for well-drained, medium, and coarse-textured soils.

In situ bioremediation causes minimal disturbance to the environment at the contamination site. In addition, it incurs less cost than conventional soil remediation or removal and replacement treatment because there is no transport of contaminated mate-rials for off-site treatment. However, in situ biore-

mediation has some limitations:
1) it is not suitable for all soils,
2) complete degradation is difficult to achieve, and
3) natural conditions (i.e. temperature) are hard to control.

Ex situ bioremediation, in which contaminated soil is excavated and treated elsewhere, is an alternative. Ex situ bioremediation approaches include use of bioreactors, landfarming, and biopiles.

• In the use of a bioreactor, contaminated soil is mixed with water and nutrients and the mixture is agitated by a mechanical bioreactor to stimulate ac-tion of microorganisms. This method is better suited to clay soils than other methods and is generally a more expensive treatment option.

• Landfarming involves spreading contaminated soil over a collection system and stimulating microbial activity by providing good aeration and by monitor-ing nutrient availability.

• Biopiles are mounds of contaminated soils that are kept aerated by pumping air into piles of soil through an injection system.

In each of these methods, conditions need to be monitored and adjusted regularly for optimal biodegradation. Use of landfarming and biopiles also present the issue of monitoring and containing volatilization of contaminants. Like in situ meth-ods, ex situ bioremediation are generally more cost than conventional techniques and apply natural methods. However, they can require a large amount of land and, similar to in situ bioremedia-
tion techniques, ex situ bioremediation is difficult to achieve, and evaporation of volatile components is a concern.

If the challenges of bioremediation, particularly of in situ techniques, can be overcome, bioremediation has potential to provide a low cost, non-intrusive, natural method to render toxic substances in soil less harmful or harmless over time. Cur-rently, research is being conducted to improve and overcome limitations that hinder bioremediation of petroleum hydrocarbons. On a broader scope, much research has been conducted to enhance understanding of the essence of microbial behavior as microbes interact with various toxic contaminants.

To a Chicken Found In The Farm Freezer
I just want to thank you for your years of service. You may very well have laid some of the eggs that I have broken for morning omelettes these past years, bright orange yolks swimming in a clear viscous, sometimes flocked with red. Perhaps it was your eggs that began to have those irregular textures on the brown shells, rough as oysters. You may have become too old to lay, but when I found you rigid in the farm freezer, wrapped in a plastic bag, I could see that you were still ready to serve, skinny but game. I am so glad you are not one of those fat chickens I could buy at the wretched meat market, bred for their heavy breasts, fed on grain containing the DNA of god knows what, chickens who never laid a damn thing. You may not be meaty but you can still make a good soup, having transmuted through your stringy flesh worms and petri dishes, wriggles, Litchi scraps and grain pecked in the hayden, grain fertilized by your very own poop. The soup you are making for me has been simmering all day, filling the house the smell of thanksgiving, and I know that the marrow released from your bones will warm my own on this snowy winter night in a land where there are still old-fashioned farmers who love their chickens.

-- Deborah Polikoff

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Spring, 2014 The Natural Farmer
Humic substances, a mixture of complex organic compounds that are usually separated into three fractions: humic acids, fulvic acids and humans, are generally seen as important components of soil and natural water. They are formed during humification of organic matter by soil microorganisms. Humification is the chemical-microbiological process of transforming debris from living organisms into a general class of refractory organic compounds.

Humic substances account for 50 to 80% of the organic carbon of soil, natural water, and bottom sediments. They are typically derived on an industrial scale from natural deposits like peat and coal. Their peculiar feature is polyfunctionality, which enables them to interact in a variety of ways with both metal ions and organic chemicals. As a result, numerous studies have shown, humics are capable of altering both the chemical and the physical speciation of ecotoxicants and in turn affecting their bioavailability and toxicity. Hence humic substances hold great promise functioning as amendments to mitigate the adverse impacts of ecotoxicants and as active agents in remediation.

It has been found that humic substances can enhance biotic and abiotic degradation of phenols, polyaromatic hydrocarbons (PAH) and pesticides in the aquatic environment. They are generally recognized to be responsible for the binding of major parts of the available metal ions in water and soil.

High adsorption capacity, high ion exchange capacity and environmental compatibility makes humic substances an attractive material for environmental remediation. The results of biochemical studies indicate that humates can detoxify organic and inorganic inhibitors of biological processes. Humates also enhance biodegradation of toxic organic substances (phenols, formaldehyde, mineral oil) thus making their treatment more efficient. The results of chemical studies demonstrate that humates can be successfully used for immobilization of heavy metals (copper, iron, manganese). Thus humates can potentially be used as a filling material for barrier walls to prevent transport and bioavailability of heavy metals in soil.

The ability of humic substances to act as chelating agents for metal ions is well-documented. The particular effect that humic substances have on chelatable metals in hazardous wastes depend upon the US Patent application 13/366,814, published in August of 2013, is for a process using humates to remove trichloroethene (TCE) and other chlorinated solvents from polluted aquifers. Traditional treatment methods utilize reagents that deplete oxygen and stimulate anaerobic degradation. While this is effective in removing TCE, it also converts the aquifer into a putrid reaction system and results in significant reduction in water quality. Microbiologically mediated chlorinated solvent degradation occurs naturally in aerobic groundwater systems, but at slow rates that allow the contamination to spread over large distances. Thus there is a need for a way to speed up the process of microbial activity. This occurs when significant amounts of natural organic matter in the form of humates are introduced to the aquifer. They stimulate the growth of the microbes, which is monitored using enzyme activity probes. More humates are added as necessary to maintain microbe activity.
following factors:
· the nature of the humic substances, particularly on their fulvic and humic acid content
· the chemistry of soil or water environment with respect to acidity-alkalinity and oxidation-reduction
· the presence of competing species (e.g. cyanide that compete with humic ligands for metal ions)

There are very few reports on practical applications of humic substances in environmental remediation. Most of them utilized humates to remove metals from water or immobilize heavy metals in soil. Pilot scale applications of humates for removal of petroleum products from groundwater have also been reported.

Recent studies have been initiated on the application of humates in environmental remediation. The studies included biochemical and chemical tests with various heavy metals and organic pollutants. The initial results of the studies indicate that humates can detoxify organic and inorganic inhibitors of biological processes and enhance biodegradation of toxic organic substances (phenols, formaldehyde) as well as detoxify and immobilize phenols, ammonia and heavy metals (copper, chromium, iron, lead, manganese, nickel and zinc). The removal of phenol, formaldehyde and phosphorus by humates was found substantially higher in biological treatment as compared to chemical treatment. The removal of heavy metals was also higher in biological system but the difference was not as dramatic as for organic pollutants.

The complexity of even simple molecules like this humic acid illustrate the diversity of ways it can attract and bind with metallic ions or complex carbohydrates and petrochemicals.

Humates are found in various geological deposits and wetlands, and sold primarily for agricultural purposes.

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Both the rising demand for GMO-free foods and the high cost of GMO seed are fueling a resurgence in conventional agriculture. Although the vast majority of US corn and soy are still engineered, typical premiums such as $1 per bushel extra for non-GMO corn and $2 per bushel for non-GMO soy are attracting farmers. According to one farm consultant, in 2013 a farmer gained an average of $81 per acre for raising non-GMO corn. For a typical thousand acre Iowa farm that is an extra $81,000. Although the large seed companies still push GMO seed, a number of smaller non-GMO ones have emerged to supply the market. Scott Odle, president of Spectrum Seed Solutions had doubled sales every year for the last four and predicts in 5 years non-GMO corn may be as much as 20% of the market. James Frantzen, award-winning Iowa organic farmer, (continued on page A-3)