Gardening in urban areas is increasingly popular in North Carolina. Growing food locally (which requires less energy for packaging, transit, and storage), connecting to nature at your doorstep, engaging children in agriculture, and controlling the amount and types of pesticides and fertilizers applied to your food are among the many wonderful reasons to garden in the city. But urban gardening poses potential risks. Before planting, city gardeners must evaluate how a prospective site was previously used, to identify potential safety hazards—including chemical contaminants—in the soil.

This publication alerts prospective gardeners to some of the most common contaminants in urban soils, such as lead and other toxic metals, solvents, pesticides, and total petroleum hydrocarbons. Readers will learn how to minimize potential risks to gardeners and to those who consume garden produce. The document includes information regarding site characterization, common contaminants, soil testing, interpretation of results, and strategies for reducing exposure risks. To ensure quality site assessment and analyses, it may be necessary to engage trained professionals. Links to certified professional soil scientists, environmental consultants, and laboratories are provided.

Exposure routes to soil contaminants from urban gardens

Gardeners, garden visitors, neighbors, and animals (including pets, wildlife, and aquatic organisms) can each be exposed to soil contaminants in a variety of ways including:

- Eating soil (including soil adhering to fruits and vegetables)
- Breathing volatiles and dusts
- Absorbing contaminants through skin
- Eating fruits and vegetables that have absorbed contaminants
Specific exposure routes to contaminants in soils vary based on the particular contaminant, site characteristics, and management practices.

**Site characteristics that indicate potential soil contamination**

Take a careful look at the history of land use before selecting a site to garden. Evaluate not only the actual plot to be developed but the surrounding lots as well. Start with city records available online or at city hall. They will help you identify the property class, zoning information, and current and previous owners. Long-time neighbors can be valuable sources of information. If the history is questionable, check with local and state agencies to see if an environmental evaluation has been conducted or if the property is listed in the N.C. Department of Environment and Natural Resources Division of Waste Management Brownfields Program Map Viewer (http://portal.ncdenr.org/web/wm/bf/map).

Sites of special concern include those currently or formerly associated with land uses as described below and in Table 1.

- Manufacturing and industrial sites, abandoned railroad lots, dry cleaners, and gas stations may have risks associated with chemical storage, leakage, and discharge into the environment.
- Landfills, junkyards, and waste disposal sites may have inorganic and organic contaminants that have leached into soils.
- Highway corridors, parking lots, or heavily trafficked areas are commonly associated with high lead levels from vehicle emissions.
- Household sites may have substantial lead deposits from older paints and plumbing fixtures.
- Former farmland may have built-up concentrations of inorganic and organic contaminants from fertilizers and pesticides due to excessive application or spills in storage and mixing areas. Otherwise, cropland acreage is generally immediately suitable for gardening applications.

**Testing the soil**

Documenting the actual site contaminant levels requires appropriate soil sampling, laboratory analysis, and data interpretation. It may be difficult to adequately

---

**Table 1. Potential Issues Associated with Different Previous Land Uses**

<table>
<thead>
<tr>
<th>Type of Site</th>
<th>Lead</th>
<th>Other Inorganic Pollutants</th>
<th>Organic Pollutants</th>
<th>Compacted Soil</th>
<th>No Topsoil</th>
<th>Glass, Misc. Litter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near coal-fired plant</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway corridor</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House demolition</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Industrial site</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Parking lot</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Farmland</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage lot</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Vacant urban lot</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1 Different metals are likely to result from specific activities or sources, i.e. paint, galvanized metal, pesticides, wood preservatives, etc. Inorganic pollutants like nitrates and trace elements are naturally found in the environment, but in urban areas they may be concentrated to unsafe levels. Examples include arsenic, barium, cadmium, chromium, lead, mercury, and zinc.

2 Organic pollutants, including petroleum hydrocarbons, pesticides, solvents, and pharmaceuticals are likely to result from specific activities or sources, i.e. fuel storage, cleaning fluids, etc.

3 Crop fields generally have few limitations, but storage, loading, and mixing areas may have problems similar to non-agricultural industrial sites and storage or parking lots. Some older fields and orchards may have been treated with arsenic pesticides.

4 Check how long the lot has been vacant, what its prior uses were, and what has been stored there (for example, road salts).

**Note:** Sites are highly variable and need to be evaluated on an individual basis. A thorough site analysis is required to determine appropriate soil sampling positions, depths, methods, and analytical needs.
Minimizing Risks of Soil Contaminants in Urban Gardens

**Special Concerns for Children**

Children are a target audience for many community gardens, but they are also more vulnerable to contaminants for several reasons:

- They love playing in the dirt.
- When they put fingers, sticks, or even soil in their mouths, they directly consume more soil contaminants.
- Being closer to the ground means they inhale more dust and volatile compounds in the soil.
- Their bodies are rapidly growing and developing, so they have lower tolerances for many contaminants.

Tables 1 and 2 will help you select the appropriate laboratory analyses by identifying which contaminants may be present in the soil and thus which tests are needed.

- If there are no contaminant issues and soil sampling is for routine liming and soil fertility assessment only, North Carolina soil samples can be submitted to the NCDA&CS Agronomic Division laboratory for analysis and recommendations. This routine analysis includes copper and zinc, as they are also plant nutrients. The lab is capable of analyzing for other heavy metals but provides this service only to state-regulated sites.
- If inorganic contaminants are suspected, a typical analysis may also determine the levels of lead, zinc, mercury, cadmium, arsenic, barium, chromium, and selenium.
- If organic contaminants are suspected, analyses could determine levels of total petroleum hydrocarbons (TPH)—particularly polycyclic aromatic hydrocarbons (PAH)—solvents such as trichloroethylene and perchloroethylene (TCE, PCE/PERC), pesticides (e.g. atrazine, carbaryl), dioxin, and bisphenol A(BPA).

Select and contact a soils lab ahead of time to identify fees and get specific directions on how samples should be collected and submitted. See the link to North Carolina Soils Labs at the end of this publication. For general directions on how to collect a soil sample, see A Gardener’s Guide to Soil Testing, http://www.cals.ncsu.edu/agcomm/publications/Ag-614.pdf.

**Interpreting the results of the soil test**

Some contaminants occur naturally in the soil, while others are introduced by humans. The trace elements most frequently found at unsafe levels in urban soils are lead, arsenic, cadmium,
keeping risk in perspective

It is important to identify and minimize potential risks from soil contaminants, but it is also useful to keep the level of risk in perspective. Smoking 1.4 cigarettes or eating 100 grilled steaks presents the same health risk as a lifetime of exposure to PAHs in soils at the recommended clean-up level (Folstad et al., 2011). Moreover, high concentrations of arsenic and other metals can be found in natural, non-polluted soils, often even above remediation goal levels.

Table 3a. Median Soil Concentrations, Thresholds for Concern, and Management Recommendations for Selected Trace Elements in Urban Soils

<table>
<thead>
<tr>
<th>Trace Elements</th>
<th>Median and Range of Soil Concentrations (mg/kg)</th>
<th>Remediation Goal (mg/kg)</th>
<th>Common Sources</th>
<th>Management Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (As)</td>
<td>7.2; &lt;0.1–97</td>
<td>4.4</td>
<td>Lumber treated prior to 2003; pesticides; manure; coal ash</td>
<td>High concentrations, above remediation goals, found naturally</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>580; 10–5,000</td>
<td>3000</td>
<td>Paint, brick, glass, tile production; medical diagnostics</td>
<td>Less plant uptake at high pH (&gt;6.5)</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.35; 0.01–2</td>
<td>14</td>
<td>Biosolids; phosphate fertilizers; coal burning</td>
<td>Less plant uptake at high pH (&gt;6.5)</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>54; 1–2000</td>
<td>24000 (Cr[III]); 0.29 (Cr[IV])</td>
<td>Wood preservatives; consumer products</td>
<td></td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>19; &lt;10–700</td>
<td>0.0012–400³</td>
<td>Formerly used in gasoline, paint, and plumbing fixtures; gasoline emissions; paint chips; used batteries; biosolids; coal ash</td>
<td>Less plant uptake at high pH (&gt;6.5)</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.09; &lt;0.01–4.6</td>
<td>0.98–4.7³</td>
<td>Paint; fungicides; coal-fired power plant emissions; used batteries</td>
<td></td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>0.39; &lt;0.1–4.3</td>
<td>7.8</td>
<td>Coal ash</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>60; &lt;5–2900</td>
<td>4.6–4600³</td>
<td>Biosolids; manure</td>
<td>Less plant uptake at high pH (&gt;6.5)</td>
</tr>
</tbody>
</table>

Note: Only select contaminant elements are included. Selection of contaminants for testing should be determined based on site history. It is likely that all contaminants listed in Tables 3a and 3b need not be analyzed, but it is also possible that additional contaminants not included here should be investigated.

² NC Department of Environment and Natural Resources Inactive Hazardous Sites Branch Soil Remediation Goals (SRG) Table: http://portal.ncdenr.org/c/document_library/get_file?uuid=5539ecfb-739f-4345-9459-b514508135f1&groupId=38361.
³ Soil remediation goal dependent on species or form of contaminant.
Strategies for reducing exposure risks

If your analysis reports levels lower than those in Tables 3a and 3b, gardening at that site presents minimal risks. If your soil’s levels exceed those in the chart, you should either choose a different site or take precautions to protect gardeners, neighbors, and those who consume produce from the garden. If you decide to garden on the site, use some of the strategies in Table 4 to minimize physical contact with contaminated soil and plant uptake of contaminants. These strategies will help prevent toxins from being absorbed through the skin, breathed in as dust, or consumed.
Table 4. Strategies for Reducing Risk of Exposure to Soil Contaminants

<table>
<thead>
<tr>
<th>Personal Hygiene</th>
<th>Soil Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wear gloves and wash your hands well after working in the garden.</td>
<td>• Apply lime based on soil-test recommendations to avoid excess acidity. Some contaminants move more readily into the plant when the pH is low.</td>
</tr>
<tr>
<td>• Remove shoes outside to avoid tracking soil into the house.</td>
<td>• Organic matter often binds and renders some contaminants unavailable for plant uptake. Amending soils with good-quality compost may help lower the risk of some contaminants and improve overall soil fertility and physical properties.</td>
</tr>
<tr>
<td>• Prevent children from ingesting soil.</td>
<td>• If necessary, soil may be decontaminated by physical (excavation, washing, vapor extraction) or biochemical (microbial degradation, phytoremediation) techniques. Consult a professional to determine the optimal remediation strategy appropriate to your site.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Safety</th>
<th>Garden Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Remove outer leaves of leafy crops, and wash all produce with a mild detergent to remove dirt and dust.</td>
<td>• If the contamination is limited to part of the garden, consider modifying the layout to avoid areas with excessive contaminants. Plant those areas with perennial ornamentals to minimize soil disturbance.</td>
</tr>
</tbody>
</table>
| • Peel root crops.       | • When possible, locate gardens away from buildings and heavily traveled roads. |}

Food Safety
- Remove outer leaves of leafy crops, and wash all produce with a mild detergent to remove dirt and dust.
- Peel root crops.
- Conduct plant tissue testing to assess the level of contaminants actually in the produce.

Garden Design
- If the contamination is limited to part of the garden, consider modifying the layout to avoid areas with excessive contaminants. Plant those areas with perennial ornamentals to minimize soil disturbance.
- When possible, locate gardens away from buildings and heavily traveled roads.
- Install raised beds with imported healthy soil. Be sure to allow drainage, but seal off the bottom of the bed so that roots do not penetrate contaminated soil.

Plant Selection
- The edible parts of root crops (carrot, potato, beet, onion) are in direct contact with the soil, so avoid planting these in riskier sites. Peeling reduces some risk.
- Shoot and leaf crops (celery, lettuce, broccoli, cabbage) represent an intermediate level of risk.
- Fruit-bearing crops (tomato, cucumber, bean, pea) will have lower contaminant concentrations.

Soil Management
- Apply lime based on soil-test recommendations to avoid excess acidity. Some contaminants move more readily into the plant when the pH is low.
- Organic matter often binds and renders some contaminants unavailable for plant uptake. Amending soils with good-quality compost may help lower the risk of some contaminants and improve overall soil fertility and physical properties.
- If necessary, soil may be decontaminated by physical (excavation, washing, vapor extraction) or biochemical (microbial degradation, phytoremediation) techniques. Consult a professional to determine the optimal remediation strategy appropriate to your site.

Sources for certified soils professional consulting, sampling, and analyses

Inclusion here does not imply endorsement of any specific service or suggest that alternatives not mentioned are unsuitable.

- Active Licensed Soil Scientists in North Carolina, with designation of area of state providing consultation: http://www.ncblss.org/director.html

Additional information

Your local Cooperative Extension Service center is a valuable source of information on lawn and garden care (http://www.ces.ncsu.edu/).


North Carolina Department of Agriculture and Consumer Services, Agronomic Division, Soil Testing Laboratory: http://www.ncagr.gov/agronomi/sthome.htm


See p. 67 diagram for exposure pathways.

References


