Cornell Waste Management Institute

Department of Crop & Soil Sciences
http://cwmi.css.cornell.edu

Rice Hall • Ithaca, NY 14853
607-255-1187
E-Mail: cwmi@cornell.edu

by:
Hannah Shayler
Murray McBride
Ellen Harrison

Guide to Soil Testing and Interpreting Results

When is Soil Testing Helpful?

Certain chemical elements occur naturally in soils as components of minerals, yet may be toxic at some concentrations. Other potentially harmful substances may end up in soils through human activities. This could happen if former industrial or agricultural lands are later used for residential properties, and contaminants remain in the soil. Spills, runoff, or aerial deposition of chemicals used for agriculture or industry can also cause soil contamination in residential areas. At times, the amounts of some soil elements and other substances may exceed levels recommended for the health of humans, animals, or plants.

Soil contamination may be more likely if the site has or had any of the following: lead paint, high traffic, use of fertilizers or pesticides, industrial or commercial activity, treated lumber, petroleum spills, automobile or machine repair, junk vehicles, furniture refinishing, fires, landsfills, or garbage dumps. See the Cornell Waste Management Institute's document *Sources and Impacts of Contaminants in Soils* for more information.

Soil testing can help answer questions and address concerns about possible contamination. The sampling strategies outlined here can also guide efforts to test soils for other properties, such as pH, nutrient levels, or organic matter content. When deciding how soil tests can be helpful in a particular situation, consider the cost of analysis, as well as the property's location, size, history, current use, and overall soil quality.

CWMI Resources for Healthy Soils

http://cwmi.css.cornell.edu/soilquality.htm

- **Sources and Impacts of Contaminants in Soils**
- **Guide to Soil Testing and Interpreting Results**
- **Best Practices for Healthy Gardens**
- **More Information about Arsenic and Lead**

Strategies for Collecting Soil Samples

There is no one-size-fits-all strategy for collecting soil samples. Carefully consider what information soil tests can provide. Think about how people (especially children) might be exposed to soil contaminants at a particular site. People are generally exposed to soil contaminants through skin contact, breathing in dust, accidentally eating small amounts of soil, or eating fruits and vegetables with contaminants on or in them. Then, decide on a sampling strategy to best answer questions about that situation. For example,

To measure contaminant levels in particular areas, such as children's play areas, collect separate samples of the top one to two inches of soil. This could help identify a contamination source, such as a chemical spill.

To measure the average levels of contaminants in surface soil, collect several composite (combined) samples of the top one to two inches of soil from across the property. To find out if the concentrations are different in different areas, collect a separate sample from each area.

To measure contaminant levels in garden soil, collect deeper samples (the top six inches) from several locations and mix them together as a composite sample. To find out if some parts of the garden have higher concentrations than others, collect separate samples from the areas of interest.

Remember to:

♦ Collect the top six inches of soil from garden areas, or the top one to two inches from other areas.

♦ Take a composite sample by combining a number of samples from different locations (usually five to ten spots) and mixing them together.

♦ Collect at least three separate composite samples for each area of interest because the levels of a particular contaminant can vary throughout a site.

♦ Consider dividing larger areas (larger than 100 feet by 100 feet) into smaller parts for planning purposes.

Key Steps in Soil Testing Process

- ♦ Identify questions or concerns
- ♦ Consult with local county cooperative extension or other resources
- ♦ Select a laboratory
- ♦ Devise a sampling strategy
- ♦ Collect and submit samples
- ♦ If needed, use results to help make decisions to reduce exposure and improve garden health

General Procedure for Sample Collection

1. *Select the sites.* Based on the questions to be answered with test results, select the specific locations from which to collect samples.

NOTE: Carefully consider what information is needed, and the cost of analysis. Try to get the most information with available resources.

2. *Make a map or diagram.* Record where samples are collected and how they were collected (including the depth of soil collected), and label the samples accordingly. This information will be useful for interpreting the test results from the laboratory.

3. *Collect the samples.* At each sampling location, remove any surface vegetation and use a clean trowel, scoop or spoon to collect the sample to avoid contamination. For individual samples, use a different trowel, scoop or spoon for each sample or wash with soap and water between samples. It is fine to use the same sampling instrument to take the five to ten samples to mix for a composite sample.

4. *Package the samples.* For individual (not composite) samples, put each sample into a different container (double plastic bags, or containers provided or recommended by the laboratory). For composite samples, mix the individual samples in a clean container (such as a clean plastic bag placed inside a bucket) and then transfer the mixed sample to the container that will be sent to the laboratory. Follow the instructions provided by the laboratory regarding how to package and label the soil samples.

5. *Send the sample(s) to the laboratory as instructed.* If samples need to be analyzed within a specified time frame, select an appropriate shipping option.

What Laboratories Can Test Soils?

To find a laboratory that tests for the contaminant of concern, contact your local county cooperative extension office (*http://www.csrees.usda.gov/Extension/*), look in the yellow pages or search on the internet. Contact the laboratory before collecting a sample to find out if there are any specific forms or instructions. For samples collected in New York State, a list of laboratories certified by the NYS Department of Health Environmental Laboratory Approval Program (ELAP) is available at: *http://www.wadsworth.org/labcert/elap/comm.html*.

How Much Does it Cost to Test Soil Samples?

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

What Do Soil Test Results Mean?

Laboratory results report the amount of a particular substance measured in a soil sample, and can help people decide if changes in land use, gardening practices, or other behaviors might help reduce exposure to contaminants or improve soil health. Many common soil tests report the total amount of a particular contaminant. For metals, this usually means that the soils are digested in strong acid to bring all or most of the metal into solution for measurement. The resulting metal concentration is reported as "total metal" (for example,"total lead"). Other tests may measure some chemically extractable portion of the contaminant and use this value to estimate the total amount of contaminant in the sample.

Results are often given in soil concentration units as parts per million (ppm) of the contaminant being measured. A value of 1 ppm would mean that for every million "parts" of soil by dry weight, there would be 1 part of the contaminant. These values are the same as results reported in mg/kg (milligrams of contaminant per kilogram of soil) or µg/g (micrograms of contaminant per gram of soil).

There is no single standard that defines acceptable levels of contaminants in soils. Regulations issued by the NYS Department of Environmental Conservation (NYS DEC) and soil screening guidance provided by

the US Environmental Protection Agency (USEPA) may be a helpful place to start. The NYS DEC and USEPA values were developed for use in certain programs under certain conditions. However, these values can provide some guidance for interpreting test results since they are based on assessments of risks to human health or the environment posed by exposure to various soil contaminants through different site uses.

When comparing the different values to each other and to soil test results, it is important to understand the purpose of the numbers. Consider the differences in the intended uses of the values and why they were developed, and focus on the value that is most appropriate for a particular situation. The information below will help answer questions such as:

♦ Are the different values based on assessments of risks to human health, or other concerns such as protecting groundwater or ecological health?

♦ Did the risk assessments consider all of the likely exposure pathways for a particular contaminant that would result from a certain type of site use?

♦ How did the risk assessments account for background levels of contaminants that may be present in uncontaminated soils due to natural soil processes?

NYS DEC Soil Cleanup Objectives

With guidance from the NYS Department of Health, the NYS DEC has established Soil Cleanup Objectives (SCOs) under their Environmental Remediation Programs as part of regulations (6 NYCRR Part 375) intended to streamline the cleanup of contaminated Brownfield and Superfund sites. Remember, these regulations were developed specifically to determine if sites under these programs need further study. However, the science behind the SCOs can be used to help interpret the results of soil tests on properties that may not necessarily be Brownfield or Superfund sites.

The SCOs specify concentrations that soil contaminants should not exceed in order for a site to be used for a particular purpose. These values are based on risk assessments that make different assumptions in order to protect human health, groundwater, or ecological resources, and account for factors such as rural soil background levels. There are different SCOs for specific contaminants and for particular land uses, such as residential, commercial, or industrial use. This is because the values were calculated using different assumptions about exposure and how the intended use of the site will affect public health or the environment. A Technical Support Document with more information can be found at: *http://www.dec.ny.gov/chemical/34189.html*.

USEPA Soil Screening Levels

The USEPA has established Soil Screening Levels (SSLs) to streamline the evaluation and cleanup of Superfund sites intended for residential land use in the future. These guidance values aim to focus resources for site evaluation and cleanup where they are most needed. When SSLs are exceeded, it does not mean that cleanup is required, but rather that further study is necessary. If soil contaminant concentrations are less than the SSLs, no further action is required under the Superfund program. However, sites must still comply with any standards or screening levels under state or local programs.

Like the SCOs, the SSLs are risk-based values developed for specific land use scenarios using assumptions about how soil contaminants may affect people or the environment. The USEPA did not consider background levels of contaminants in soils when it developed the SSLs, so some of the values are below what is typically found in soils in some regions. More information, including a Quick Reference Fact Sheet and tables of all SSL values (see Appendix A), is available at: *http://www.epa.gov/superfund/health/conmedia/soil/index.htm*.

Why are the Numbers Different?

The values from NYS DEC and USEPA were derived at different times, by different agencies, for different purposes using different methods. For example, different assumptions may be made about factors such as:

♦ The amount of soil a person ingests;

♦ The amount of contaminant ingested from other sources, such as water and food;

♦ Whether children or adults are exposed;

♦ The length of exposure;

♦ The acceptable level of risk of disease;

♦ Uncertainty or missing information.

Background levels (naturally occuring concentrations of contaminants in soils) are also handled differently. For the NYS SCOs, if the risk-based value was lower than rural background values, the background value was used as the SCO. Otherwise, many sites might exceed the SCO based on existing background levels alone.

Other values, like the USEPA SSLs, do not account for background levels. Therefore, the concentrations of some contaminants may exceed the SSLs even in uncontaminated soils. However, knowing that background soil concentrations exceed guidance levels may still be useful information to help appropriately manage risks.

Guidance for Interpreting Test Results

Soil testing can provide information to help guide efforts to improve the quality of gardens and protect public health. There is no clear line of what is considered "safe". Generally speaking, if test results show that all or some areas of a property have contaminant levels higher than agency guidelines or levels recommended by other sources, it is wise to reduce the exposure of both children and adults. Children are especially vulnerable to harmful health effects, so it is particularly important to address any concerns about soil contaminants in areas where children play or where fruits or vegetables are grown for food.

The practices outlined in *Soil Contaminants and Best Practices for Healthy Gardens* will help improve soil quality and limit people's contact with soil contaminants. Given the many benefits of consuming fresh fruits and vegetables, it is important to use these practices whenever possible to create healthy gardens for growing healthy foods.

Some SCO and SSL values are described here and included in Table 1 to help with the interpretation of soil test results from yards, gardens, or other residential and community spaces.

♦ Like all of the SCO values adopted into regulation, the **NYS DEC Unrestricted Use SCOs** account for exposure to soil contaminants through soil ingestion, inhalation, and skin contact. These SCOs also account for exposure to soil contaminants through the consumption of home-grown vegetables and home-produced animal products, including meat, milk, and eggs, as well as the protection of groundwater and ecological resources.

Of the SCO values for different land uses, the Unrestricted Use SCOs are the lowest soil contaminant concentrations. These values were developed to be the most conservatively protective of human health, ecological resources, and groundwater for all land uses, and account for rural soil background concentrations. Similarly, if the calculated value was lower than the detection limit for a particular chemical (as specified by NYS DEC protocol), the detection limit was instead used as the final value for the Unrestricted Use SCO.

♦ The **NYS DEC Residential Land Use SCOs** were developed to help with the clean-up of sites to be used for residential purposes (usually single family housing), but not for raising livestock or producing animal products for human consumption. These values account for exposure to soil contaminants by ingesting soil, breathing in soil particles and vapors, skin contact, and eating home-grown vegetables, but NOT the consumption of animal products produced on site.

♦ The **NYS DEC Restricted Residential Land Use SCOs** are intended primarily for the cleanup of sites to be used for multi-family residential housing. This category DOES NOT account for exposures through the consumption of home-grown vegetable products or home-produced animal products. These activities are meant to be excluded from these sites. Under the SCO regulations, community vegetable gardens may be considered under this category with NYS DEC approval.

♦ The **USEPA SSLs for Residential Scenarios** are federal screening levels at which the USEPA recommends further study to determine whether cleanup is needed at a particular site. The exposure pathways addressed by the SSLs include direct ingestion of ground water and soil, inhalation of volatiles and dust; plant uptake, absorption through the skin, and exposure from volatiles in basements are addressed to a limited extent. SSLs are presented separately for different exposure pathways, rather than combined as in the SCOs. The generic SSL values shown here are intended to be conservative and protective for most site conditions in the United States for the purposes of the specific program for which they were developed. Note that many of the SSL values are considerably higher than the corresponding NYS DEC SCOs, as well as typical soil background concentrations. The assumptions used in the risk assessments may not be sufficiently protective for many situations.

Table 1. Values to guide the interpretation of soil test results for some common soil contaminants of concern to human, plant, and animal health.

A. New York State Soil Background Concentrations. Included here are average background concentrations (with minimum and maximum values in parentheses) measured in mineral soils of central and western New York (see Al-Wardy 2002). These values are intended to help with the interpretation of soil test results by providing some information about the levels of certain chemical elements typically found in uncontaminated soils.

B. New York State Department of Environmental Conservation Soil Cleanup Objectives (SCOs). Unrestricted Use SCOs and Restricted Use SCOs for the Protection Public Health for residential situations are included here for some contaminants of interest. See *http://www.dec.ny.gov/regs/15507.html* for all SCOs included in Subpart 375-6: Remedial Program Soil Cleanup Objectives, including values for other land uses and other contaminants. Additional human health-based SCOs are indicated in parentheses if different from the values included in the regulations. The final health-based SCOs were calculated considering chronic exposure, acute soil ingestion, and irritant contact dermatitis. More complete information about SCO development is available in the Technical Support Document at: *http://www.dec.ny.gov/chemical/34189.html*.

C. US Environmental Protection Agency Generic Soil Screening Levels (SSLs). Values for the ingestion-dermal exposure pathway of the residential use scenario are included here. Note that many of the SSL values are considerably higher than the corresponding NYS DEC SCOs and NYS soil background concentrations. Although the risk assessments used to develop the SSLs accounted for exposures through ingestion of homegrown produce to a limited extent, the assumptions used may not be sufficiently protective for many situations. More information about the development of the USEPA SSLs, as well as values for additional contaminants and commercial/industrial land use scenarios, can be found at *http://www.epa.gov/superfund/health/conmedia/soil/index.htm* (see Appendix A of the Supplemental Guidance).

Contaminant	A. NYS Soil Background[1] (ppm)	B. NYS DEC SCOs (ppm)			C. USEPA SSLs (ppm) *Residential Use, Ingestion-Dermal Exposure*
		Unrestricted Use	Restricted Use for the Protection of Public Health *Residential*	*Restricted-Residential*	
Arsenic	5.0 (1.8-13.3)	13 (0.11)	16 (0.21)	16 (1)	0.4
Cadmium	0.5 (0.3-1.1)	2.5 (0.43)	2.5 (0.86)	4.3	70
Chromium, hexavalent	13.5 (7.7-23.5)[2]	1 (11)	22	110	230
Chromium, trivalent		30 (18)	36	180	120,000
Copper	14.2 (5.7-35.3)	50 (270)	270	270	--
Lead	18.7 (9.8-35.6)	63 (200)	400	400	400[3]
Nickel	17.1 (7.9-36.9)	30 (72)	140	310	1600
Zinc	65.2 (36.3-117)	109 (1100)	2200	10,000 (11,000)	23,000

[1]Al-Wardy, M.M. 2002. Elemental distribution in the surface and subsurface soils of central and western New York. *Doctoral Dissertation*, Cornell University, Ithaca, NY.

[2]Values for total chromium. Hexavalent chromium, or "chromate," is highly toxic to humans. However, total chromium is usually almost entirely in the less toxic form of trivalent chromium.

[3]The USEPA generic SSLs do not include values for lead, dioxins, or PCBs, because separate USEPA documents specify risk-based guidance values for these contaminants in soils. Federal soil standards (Section 403 of the USEPA's Toxic Substances Control Act) defines soil as a hazard in play areas if bare soil contains 400 ppm or more of lead, or if average lead concentrations in bare soil exceed 1200 ppm in other areas of a yard.

Where Can I Get More Information?

Cornell Waste Management Institute Resources for Healthy Soils: ***http://cwmi.css.cornell.edu/soilquality.htm***

♦ Sources and Impacts of Contaminants in Soils ♦ Guide to Soil Testing and Interpreting Results

♦ Soil Contaminants and Best Practices for Healthy Gardens ♦ More Information about Arsenic and Lead

Other Resources

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

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

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

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

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

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

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

US Environmental Protection Agency. US Office of Solid Waste and Emergency Response. Superfund Soil Screening Guidance: Technical Background Document, EPA/540/R95/128. Accessible at: *http://www.epa.gov/oerrpage/superfund/health/conmedia/soil/introtbd.htm*

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

Washington State University Cooperative Extension. Gardening on Lead- and Arsenic-Contaminated Soils. Additional information about arsenic and lead in garden soils. Accessible at: *http://cru.cahe.wsu.edu/CEPublications/eb1884/eb1884.pdf*

Special Thanks to Contributors and Supporters

We greatly appreciate the ongoing insights and feedback provided by the New York State Department of Environmental Conservation and the New York State Department of Health, our colleagues at Cornell University and Cornell University Cooperative Extension-NYC, collaborators in the New York City urban soils group, and the many others whose questions, concerns, and experiences have led to the development of these documents.