

Harmful Chemicals in Urban Soils: A Step-by-Step Guide to Soil Testing and Risk Reduction for Urban Food Growers

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Growing food in an urban area can present safety concerns because of the potential for harmful chemicals to exist in the soil. This factsheet outlines the steps involved in risk assessment, safer growing practices, and how to test your soil when growing food in an urban area (fig. 1). These practices refer mainly to metals like lead in soil but may also keep you safe from organic chemicals. Sources of soil pollution by metals might include (Wortman and Lovell 2013):

- lead-based paint and leaded gasoline
- nearby industry (refineries, smelters, pesticide manufacturers, municipal waste incinerators, battery recycling plants, mines, chrome plating plants, and tanneries, among others)
- junk piles in yards or illegal dumping refuse

Safer growing practices decrease the risk of chemical exposure and ensure food can be grown safely. The risk that a chemical will harm our bodies depends on how hazardous it is, and how we are exposed. We can be exposed to harmful chemicals in soil by breathing in soil dust, ingesting soil particles, and eating plants that have taken up harmful chemicals. Safer growing practices protect you and your family from harmful chemicals.

Take these preventative measures to stay safe:

1. Determine if it is safe to grow food in your soil using our **guide to risk-based decision making**.
2. Follow **safer growing practices** to decrease your exposure to harmful chemicals if you believe some might be present in your soil.
3. **Test your soil** if you can. It is never too late!



Figure 1. Risk assessment and safer growing practices are the foundation for risk reduction and are always accessible. Soil testing provides important information to support risk assessment but is not always accessible.

Guide to risk-based decision making

Are you wondering if it is safe to grow food in your soil? There is no comprehensive set of guidelines on assessing the risk of exposure to harmful chemicals in urban agriculture (US EPA 2011). You and your soil are unique. You can determine your risk using the decision-making questions in table 1.

If most of your answers to the Site assessment questions fall within the Higher risk category, it is important to avoid growing food directly in your soil. Raised beds are a good alternative to growing plants in higher risk areas. If you are not sure, county cooperative extension staff can help you answer these questions.

Table 1. Site assessment questions for risk-based decision making

Site assessment questions	Lower risk	Higher risk
Are chemicals of concern present above background levels that naturally occur in soils?	fewer chemicals or lower levels of chemicals	more chemicals or higher levels of chemicals
Are there kids in the garden?	no or rarely	yes or frequently
What size is the garden?	small	large
Are there painted buildings older than 1978 on adjacent properties?	no	yes or I do not know
Is the garden within 10–15 feet of a painted building built before 1978?	no	yes or I do not know
Have there ever been industrial processes that might have polluted soil on or near the property?	no	yes or I do not know
How much time do you spend in the garden?	little time	a lot of time
What crops do you grow? (This applies to lead but not arsenic.)	fruiting crops (squash, tomatoes, peppers, fruit trees, etc.)	root vegetables (especially carrots and radishes) and leafy greens
How much garden-produced food do you eat?	food produced in garden is a small amount of all the food eaten	food produced in garden makes up most of the food eaten
Is the soil surface covered?	covered with mulch	uncovered or bare soil
What is the soil texture?	clayey soil	sandy soil
What is the soil pH?*	neutral to alkaline (6.5–8.0)	acidic (< 6.5)
What is the soil organic matter content?	high	low

*If soil contains arsenic, pH should be 5.5–6.5.

← Lower risk factors: more support for gardening in the ground, less important to follow safer growing practices

→ Higher risk factors: more support for raised beds or containers, more important to follow safer growing practices

Safer growing practices

Follow safer growing practices to decrease your risk of exposure to metals in soil.

- If harmful chemical exposure levels might be moderate or high, **do not let children come into contact with the soil**. Protect children from the soil if lead or other chemicals might be present at levels above the soil screening level (table 2) (Laidlaw and Filippelli 2008).
- If chemical levels might be high, or if there might be a wide variety of chemicals in your soil, perhaps because you live near current or former industry, **do NOT grow in your soil**. Use raised beds (at least 1 ft deep, possibly lined with landscaping fabric to prevent mixing with native soil) or containers filled with clean soil.



- If chemical levels might be moderate and you're growing in the ground:
 - **Do not work with dry soil.** Only work with moist (but not wet) soil to avoid producing dust (especially when tilling).
 - **Mix soil** by tilling one to two times and add compost (6 lb by ft² or 2 in deep) to the top foot of the soil to dilute the chemicals (Attanayake et al. 2014). Do not grow in 100 percent compost.
 - **Do not track soil inside.** Leave shoes outside. Wear gloves and wash your hands with soap and water after working with the soil.
 - **Do not leave the soil bare.** Use mulch beds and paths. Keep the surface of the soil covered to prevent particles from splashing or dust from blowing onto the plants.
 - **Plant hedgerows.** Grow tall shrubs, vines, or flowers along the street to block vehicle exhaust.

Table 2. California residential soil screening levels and background levels of common metals and inorganic compounds in soils of the western United States

Chemical	California residential soil screening level (mg/kg*)	Western U.S. background level† (mg/kg)
Lead	80	17
Arsenic	0.11	11‡
Cadmium	71	uncommon
Chromium (VI)§	0.3	41
Nickel	820	15
Zinc	23,000¶	55

*The lower of either cancer or noncancer based risk, from the California Department of Toxic Substance Control (Cal DTSC), Human Health Risk Assessment (HHRA) Note Number 3, and DTSC-modified Screening Levels (DTSC-SLs) (table 1). All soil screening level reports are found at the DTSC Human and Ecological Risk Office. The Human Health Risk Assessment Note Number 3, and DTSC-modified Screening Levels can be found at: dtsc.ca.gov/human-health-risk-hero/.

†Elemental concentrations in soils and other surficial materials in the conterminous United States, U.S. Geological Survey Professional Paper 1270, except arsenic (Shacklette and Boerngen 1984).

‡Occasionally, like with arsenic, SSLs are lower than the natural background level (Duvergé 2011).

§Must test for chromium (VI); chromium (III) is nontoxic and common in California soils.

¶US EPA Residential Soil Screening Level; not available in HHRA Note Number 3.

- **Wash produce and your hands before eating.** Wash produce with commercial vegetable wash, vinegar (2.5 tbsp of vinegar in 1 gallon of water), or tap water (Egendorf et al. 2022).
- Plant the right crop in the right place:
 - **Do not plant root vegetables and leafy greens in soil where chemical levels, especially lead, might be high** (McBride et al. 2014). Lead levels are likely to be very high within 3 feet (1 m) from painted, older buildings, and could still be high up to 10 to 15 feet (3 to 4.5 m) from such buildings (Hansen and Jelinski 2016; Schwarz et al. 2012).
 - Plant **root vegetables, onions, and leafy greens** where lead levels in soil are likely to be lower (farthest from buildings and in a raised bed).
 - Plant **fruiting crops** (tomatoes, corn, beans, squash, fruit trees) in soil where lead is close to or exceeds screening levels (for example, close to buildings). Always ensure that this produce is washed before consuming.
- Only grow ornamentals, not food, adjacent to buildings (within 3 ft).

These practices refer mainly to lead in soil but may also keep you safe from other metals and organic chemicals.

Test your soil for metals and organic chemicals

Before you test your soil for metals and organic chemicals, you should find out what chemicals to test for based on site history. Different chemicals have different testing fees, so a little preparation can save you money. You might only need to test for a few chemicals (see page 6 for a list of common chemicals in urban soils). You will need to collect soil samples carefully to increase confidence in the test results. Finally, use the results-interpretation tools (page 8) and guide to risk-based decision making (table 1) to understand the risk of exposure to chemicals in your soil based on your results. The following are steps for testing your soil for contaminants:

1. Research your land's history to decide what chemicals to test for:
 - Testing for chemicals in soil runs from tens to hundreds of dollars per sample, so this detective work can save you money (see a list of common chemicals found in urban soils on page 6). You might only need to test for a few possible soil contaminants.
 - Find out what your land was used for and what was located nearby before you decide to grow there. One way to do this is to ask neighbors and longtime residents.
 - If you are testing soil in a residential neighborhood with houses older than 1978, or soil in

an area with high vehicular traffic, test for lead. Federal regulations banned use of lead paint in residential structures constructed after 1978, and lead-based gasoline was phased out beginning in the 1970s.

- Look at [Sanborn fire insurance maps](#) to see historical buildings in the area or on the property. This is especially important if you are testing soil in a vacant residential neighborhood lot because an older house might have burned down, depositing metals, especially lead, and other chemicals in the soil.
 - In addition to lead paint and gasoline, consider if there are other sources of pollution like illegally dumped trash, industrial plants, refineries, and municipal garbage incinerators.
 - If you are not able to find information about the likely contaminants in your soil, then talk to your local UC Cooperative Extension staff about what to test for or grow your crops in raised beds or containers.
2. Identify the area or areas you will sample:
- Choose the area you expect will be safest to grow food in (like the middle of your yard). Take soil samples from this area as shown in figure 3.
 - Other higher risk areas may also be sampled using the methods provided to determine their suitability for growing food.
 - Never mix soils from higher and lower risk areas.
 - Draw and label maps to remember your sample areas and to later be able to precisely identify their locations.
3. Gather the tools you will need (fig. 2):
- ruler
 - one to three clean buckets
 - shovel or trowel

- one to three quart-sized, labeled plastic bags
- spoon
- gloves (clean)
- materials to draw a map

4. Collect your samples following the “How to collect your soil” instructions in figure 5. Remember, you do not know what the metal or chemical content of your soil is. Follow these safety guidelines as if your soil contains harmful chemicals:
- Children must not touch soil during sampling.
 - Only work with moist soil to avoid breathing in soil dust. Thoroughly wet soil 1 to 2 days before sampling.
 - While collecting your samples, do not touch the soil with your bare hands. Wear gloves. When you are done, wash your hands and wrists with soap.
 - Clean your shoes when you are done and do not track the soil into your home, car, or anywhere else that should be kept clean from possible contaminants.

Getting the most out of your soil samples

You can get the most out of your soil samples by identifying what soil is and is not contaminated. Chemicals in soil usually are not distributed evenly. For example, if a lead paint chip falls on soil, the soil where the chip landed will have a very high amount of lead, but the soil just an inch away could have a very low amount of lead. This means the way you collect your sample has an impact on how accurate your results are. Public health guidelines are based on the average concentration of a chemical in an area, so the best sample will represent both the high and low concentration levels. For very good results, many experts recommend collecting fifteen to thirty subsamples, regardless of how big your area is, and combining them into one composite sample to get the most accurate representation of what is in your soil (State of Hawai'i Department of Health 2016). Your composite sample is the collective mix of your subsamples. The number of subsamples you need for good quality results is proportional to the variability in expected chemical concentrations in the soil. For example, if your house was built in 1920 and has lead paint chipping off it, that could mean there is high variability in lead concentrations and that you need more subsamples for good quality data.



Figure 2. Tools used to collect soil samples for testing.

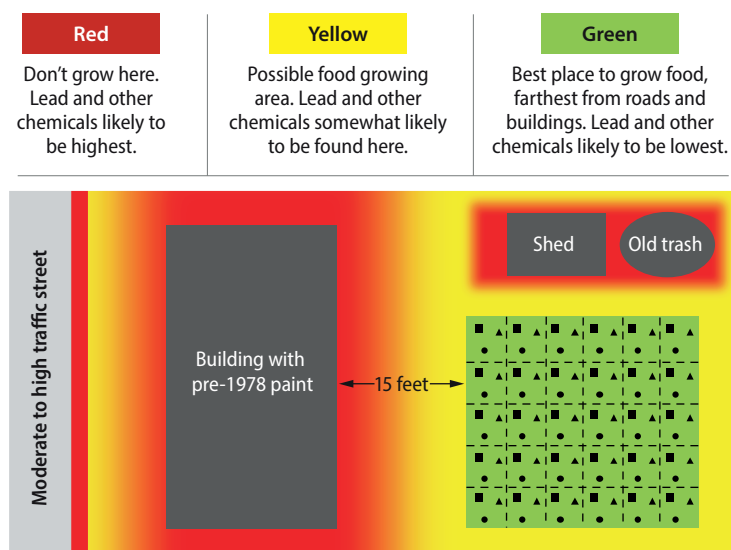


Figure 3. Choose a food plot location farthest from roads and buildings (green area). Divide the area to be sampled into approximately thirty equally sized sections. Red areas are the most likely to contain harmful chemicals. If you also want to sample red area soil, sample this soil separately from the food area sample—don't mix the green and red areas' soil together. Yellow areas are somewhat likely to contain harmful chemicals, but less so than red areas. The circle, square, and triangle symbols represent the option to take up to three replicate samples. These replicates can be collected from separate holes that are equally spaced—as shown here—or from three sides of the same hole—as demonstrated in figure 3.

To get even more accurate results, you can repeat the process one or two times. Each replicate subsample collection is labeled as the *circle*, *square*, and *triangle* samples (see figs. 3 and 4). Replicates give you information on how much variability there is in the amount of chemicals in your soil. If the replicates are similar, the chemicals in your soil are evenly distributed. If they are different, the difference between the replicate samples tells you how much variation there is in chemical levels in the soil. For example, if two samples are similar and one is different, the different one might represent an outlier (a fluke or a hotspot, for example, one chip of lead paint in an area where there are not a lot of lead paint chips), whereas if all three samples are different, that could indicate more variability (fig. 4).

Replicates are optional. While replicates help identify chemical variation in the soil, it is most important to collect at least one good composite sample. If you do decide to collect replicates, one option is to dig one hole and take a small sample of soil from two to three sides of the hole. This will give

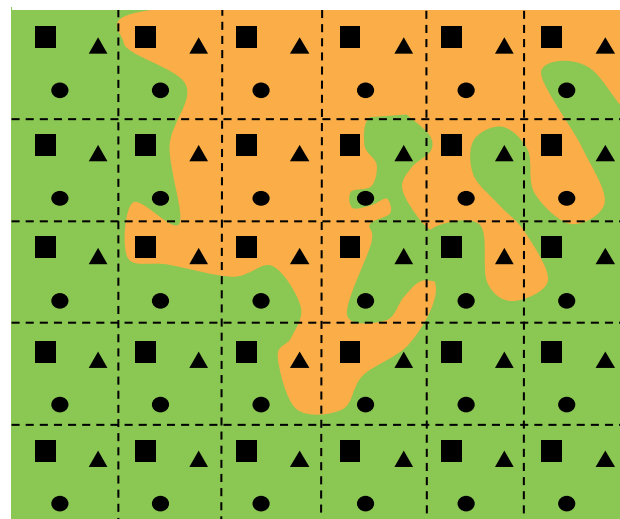


Figure 4. Replicate samples are helpful when chemicals are not evenly distributed in soils. Here, the green area represents lower chemical concentrations, and the orange area represents higher concentrations. The circle sample only contains six subsamples from the orange area. The triangle sample contains eleven subsamples from the orange area. The square sample contains thirteen subsamples from the orange area. If only one sample was collected and it happened to be the circle sample, the results would be too low and would not represent the actual exposure to chemicals when working in this soil.

you information about variation from paint chips. A better but more time-consuming way to collect replicates is to dig two to three separate holes and take a small amount of soil from each hole. This will give you information about variation from paint chips and larger sources of chemicals like burn piles, sheds, spills, and the like.

How to collect your soil samples

Follow these steps when collecting your soil samples:

1. Now that you have divided your space into separate areas (see figs. 3 and 4), work within one area to collect samples.
2. Plan the composite sample by dividing your area into sections. For best results, create up to fifteen to thirty sections (Hawai'i Department of Health 2016) in a 3 by 5 or 5 by 6 grid, depending on the shape of your space. The more sections, the better your results, but the more time-consuming sampling will be. For many residential yards, up to fifteen sections will be sufficient, while a vacant lot or former industrial site would require thirty to get good results. All sections should be about

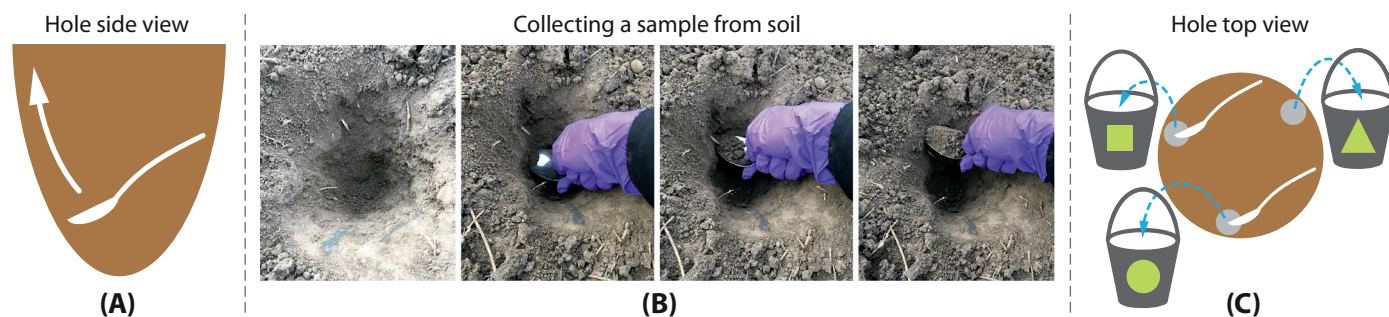


Figure 5. Collect up to three replicate subsamples of soil from a hole using a spoon. To fill the spoon with soil, drag the spoon along the side of hole from the bottom to the top (A). Make sure to get soil from the bottom, middle, and top of the hole in the spoon (B). Place the spoonful of soil into a labeled bucket (C). Optional: Remove two more spoonfuls of soil.

the same size. The size of the sections, or the total area covered, does not matter. Record the grid on your map.

3. To collect a composite sample, remove a small amount of soil from each of the sections. Figure 5 outlines the following steps for removing subsamples from each of the sections:
 - In each section, dig a hole 6 inches deep.
 - Use a spoon to scrape the side of the hole from the bottom to the top. This should give you about one spoonful of soil. Put the spoonful of soil in the square bucket.
 - Optional: Repeat from a different side of the hole and put the soil in the triangle bucket, then from a third side of the hole and put it in the circle bucket. Alternatively, you can dig three separate holes, which gives you better results but takes longer.
 - Repeat this process for every section. Clean the spoon if mud builds up on it, but otherwise you do not need to clean the spoon between sections.
4. When you are done collecting from each section, and each of your one to three buckets has thirty spoonfuls of soil in it, mix the soil in each bucket very well.
5. Scoop 1 cup of soil from each bucket and place the soil in a separate plastic bag to send to the lab. Each plastic bag should only have soil from one bucket, so if you have three buckets, you will send three bags of soil to the lab. Remove rocks and air-dry the soil by opening the bags before shipping.

Lab testing

To find a lab, check with your local agricultural extension or Master Gardener group.

- Test fees run from tens to hundreds of dollars per sample, depending on what you are testing for. The lab can help advise you on what to test for based on site history.
- Some labs test for lead along with routine nutrients, but others require a separate test for lead (and other metals).
- Make sure the lab provides you with a total concentration of lead (after acid digestion of the soil sample) and not just an extractable (for example, Modified Morgan extractable) concentration. Soil screening levels are based on total concentrations of metals, not extractable concentrations.
- Follow lab shipping instructions.
- See the final section of this handout for how to interpret your results.

What chemicals are likely to be in my soil?

Common harmful inorganic chemicals in urban soils include lead, arsenic, cadmium, and chromium:

- Lead (Pb) is the most common metal in urban soils, because of the historic use of lead paint and leaded gasoline. Older homes (pre-1978) are most likely to have lead paint. Lead from leaded gasoline is commonly found at high concentrations in the soil on the side of busy roads.
 - Lead exposure has serious negative effects on children's health, including higher rates of attention and behavior problems (Laidlaw and Filippelli 2008; Betts 2012).
 - Eating soil particles (for example, by touching soil then putting hands in mouth) is a common way for children to be exposed to lead. Children can also be exposed to lead inside homes from

paint, soil dust (especially on floors and rugs), and lead water pipes.

- If a building has been painted with lead paint, the soil closer to the building (especially within 3 ft, and up to 10–15 ft away) will probably have the highest levels of lead (Schwarz et al. 2012).
- Arsenic (As) is commonly found in urban soils due to coal burning and pesticide use (Mandal and Suzuki 2002).
- Cadmium (Cd) is commonly found in urban soils due to coal burning, municipal waste incineration, and vehicle emissions (Khan, Khan, Khan, and Alam 2017; Cheng et al. 2013).
- Chromium (Cr) is commonly found in urban soils due to coal burning, chrome plating industries, leather tanning, use of pressure treated wood, and especially in road-side soils effected by debris from the use of vehicle brake pads (Saha, Nandi, and Saha 2011; Choppala, Bolan, and Park 2013).

Common harmful organic chemicals include petroleum byproducts (vehicle exhaust particles, automotive fluids), pesticides and herbicides, and chemical residues from burning trash. Industry, power plants, gas stations, and dry cleaners are major sources of metal and organic chemical pollution in soil. Transformers on utility poles can be a source of polychlorinated biphenyls (PCBs).

How much is too much chemical contamination?

Thresholds or screening levels establish a reference level for harmful chemicals in soil. Screening levels are called *upper bounds*. Below the threshold level, soil is considered safe. Above that level, the soil could be but is not necessarily dangerous, depending on chemical conditions at a particular site and how people interact with the soil. To assess the risk at each site, refer to the guide to risk-based decision making (table 1).

Interpreting the thresholds for “residential soil screening levels” (table 2) is the best option for assessing risk at a residential site. The “background level”—the level of a chemical naturally occurring in a soil—is also helpful for comparison. Unfortunately, thresholds for acceptable chemical levels in urban agricultural soils do not yet exist. It is complicated to determine how people are exposed to chemicals in soil while growing and eating food.

For lead, the California residential soil screening level is 80 milligrams per kilogram (CA DTSC 2020). To apply residential soil screening levels to urban agricultural soils, it is helpful to understand how thresholds are calculated. All threshold calculations are based on assumptions. The residential threshold used for lead in California assumes that a child accidentally ingests 80 milligrams of soil per day, every day of the week. Eighty milligrams of soil can easily be deposited on your hands after working with soil (fig. 6). The residential threshold is designed to keep a child safe under these circumstances. If a child consumes more than 80 milligrams of soil per day, and if the soil contains more than 80 milligrams per kilogram of lead, the child could be exposed to a dangerous amount of lead.

When applying this residential soil screening level to urban agricultural soils, think about how you and those around you, especially children, interact with soil. Compare these interactions to the assumptions built into the residential soil screening level.

For example:

- If children growing food with you spend a lot of time planting and weeding, and you grow and eat root vegetables, the children are probably contacting and ingesting more soil (and possibly lead) than the residential threshold calculations assume. In this case, it is best to apply a lower threshold.
- If you and the people around you rarely contact soil after planting, wash your hands well after contacting soil, do not grow root vegetables or leafy greens in the ground, and there are no children in the garden, your food production activities probably do not result in you contacting and ingesting more soil than is built into the calculations. The residential threshold, or perhaps a higher threshold, could apply to your situation.



Figure 6. This is approximately 80 milligrams of soil using a key for reference.

Residential soil screening level calculations do not include ingesting lead or other chemicals that might be in or on vegetables grown in the garden. For example, root vegetables and leafy greens can contain higher amounts of lead than fruiting crops grown in the same soil.

Interpreting your soil sampling results

When you receive your results, use the flowchart in figure 7 to compare them to the chemical soil screening levels in table 2:

- If you took two to three replicate samples, begin at the top of the flowchart in figure 7.
- If your three replicate samples are similar, work with the columns on the left.
- If all three replicate samples are different, work with the columns on the right.
- If two samples are similar and one is different, the different one might represent an outlier. Depending on your situation, you might choose not to include the outlier sample.
- If you only collected one composite sample, skip down to the third row of the flowchart.

- Bring the answer from the fourth row of the flowchart to the guide to risk-based decision making (table 1). Combine this answer with the answers to the questions in table 1 to determine if growing food in your soil is a high or low risk activity overall.

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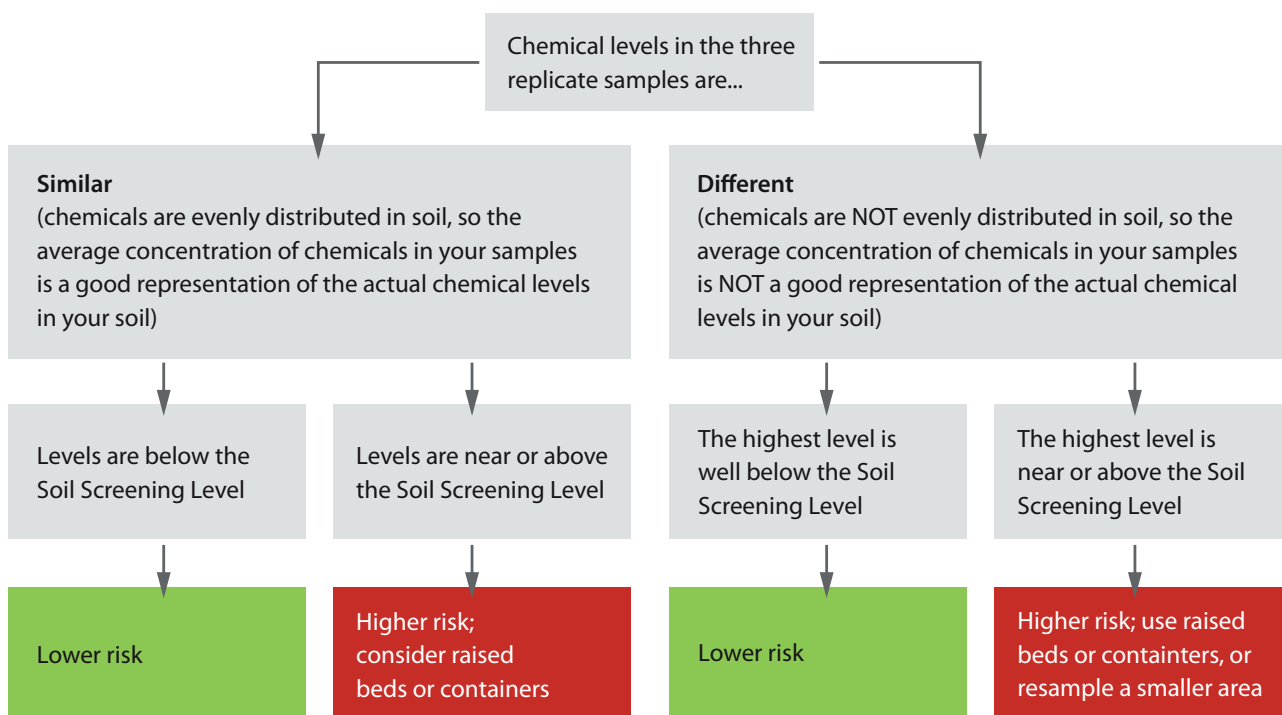


Figure 7. Use this flowchart to compare the results of your soil testing to the chemical soil screening levels in table 2.

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Further reading

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