Soil Contamination and Mitigation

Contents

Project goal:

To conduct tests to determine the quality of soil (organic matter and nutrient content, possible contamination, etc.) on garden sites before a project begins, and determine the effects of various permaculture-based practices through regular sampling. This project will ensure any food grown at these sites is safe, and that the techniques used to grow that food are regenerative and improve the nutrient content and soil health of the area.

Project site:

Two sites will be selected for repeated sampling in Solano County. These sites should not be utilizing permaculture-based agriculture when sampling begins. This project will take place over several years, with samples being taken on a regular basis (once every 12 months for most tests). More sites may be added as needed.

The two initial sites which present prime opportunities are

- Touro University in Vallejo
    - Site has a long history of "light industrial" use as a hospital. Located near multiple DTSC cleanup sites. Slated to be turned into food forest. Great opportunity to check for contaminates and show the effect of permaculture practices for a food forest on soil health.
- Downtown Community Garden in Rio Vista
    - Site has a well-documented history as a vacant lot for more than 40 years. Slated to be turned into community garden. Would be great opportunity to evaluate inground planting, remediation techniques, check for possible contamination.

Methods:

- The history of both sites will be researched to determine possible contaminants.
- Samples will be collected from multiple areas around the site and tested for a variety of minerals, nutrients, and contaminates.
- The sample locations will be recorded for future reference.
- Test results should be published online.

Limitations and Issues:

This toolkit draws conclusions from a number of important documents, many of which represent years of research into developing safe urban agriculture sites. The following limitations may impact the scope, sites, and overall message of this testing program.

Issue 1: Control samples.

To make scientifically valid claims about the effects of permaculture-based practices on land, a sample must be taken from the land before the project begins. Since each plot of land is so unique, it is impossible to draw conclusions about the effectiveness of a practice if a sample was not taken before the project begins. As such, two new sites will be selected to participate in this soil monitoring project.

Issue 2: Site history.

Solano County was incorporated in 1850, and the county has seen a variety of industries come and go. As such, many possible urban agriculture sites lack a robust history. To determine possible

contaminants, Sustainable Solano should run a standard nutrient panel on site soil samples, as well as a CAM-17 or PPM-13 test to determine the variety of contaminants on site. See Tables 1 and 3 for more information.

Issue 3: Limitations of exposure guidelines.

"[T]he cleanup standards [provided by the EPA] are designed to protect people on the site from ingestion and inhalation of contaminants in the soil, water and air, but **do not address consumption of food grown on the site**" (Brownfields and urban agriculture, Interim Guidelines for Safe Gardening Practices, 2011). Additionally, "Leafy vegetables like lettuce are considered as potential hyperaccumulators of heavy metals ... One of the properties of green leafy vegetable is the accumulation of heavy metals in their tissues without exhibiting any toxicity symptoms" (Khan, 2015). As such, Sustainable Solano should err on the side of caution and should avoid any urban agriculture projects on land where the "maximum contamination level" exceeds recommended OSHA/EPA guidelines. Both to reduce employee exposure to toxic or dangerous materials, as well as to reduce possible community exposure through plants or earthworks. See Table 4 for more information.

Sources to evaluate the history of a site:

Examine these sources to determine past uses for the site. Using this information, determine possible contaminates which should be tested for. **See Table 3 for more information**.

EPA Superfund site list:

https://cumulis.epa.gov/supercpad/cursites/srchsites.cfm

Search for:

- Site status: All sites
- County: Solano
- State: California

Department of Toxic Substances Control:

https://www.envirostor.dtsc.ca.gov/public/search?basic=True

Search for:

- County: Solano

USGS Earth Explorer:

https://earthexplorer.usgs.gov

- Search for: (navigate to area of interest using map)
  - Select, under "Polygon", the button labeled "Use Map"
  - Click "Data Sets"
  - Check "Aerial Photo Single Frame"
  - Click "Results"
- Locate images of the site in question for the last 50 years (if possible),
- Find one photo each from the 1970s, '80s, '90s, and '00s (if possible),
- Download and examine these photos with the help of InfranView.

Solano County Parcel Viewer:
https://www.solanocounty.com/depts/rm/planning/zoning_maps.asp

Solano County GIS Parcel Viewer:
https://solanocountygis.com/portal/apps/webappviewer/index.html?id=b2a40316824143fc9f361d5d81c51a7a

1. Use the Address Search tool, or zoom into the area of concern.
2. Click on the parcel in question
3. Scroll to "Property Characteristics" and click on "More Info"
4. Under "Property Information", look under "Class" to determine the zoning for the parcel in question.

Using the techniques above, determine the past uses for the land in questions. **Based upon these past uses, and Table 3, select the appropriate tests from one of the labs listed in the resource section. For cost information see Table 1.**

Sampling Technique:

1. Create a map of the site to be sampled.
    a. Utilize a "rolling ruler" to create an on-site grid using twine and stakes.
    b. Create a grid over the whole site at regular intervals (e.g., every 5 - 20') using twine.
    c. Designate sample points where gridlines cross.
        i. Plant flags if needed and remove the twine. Photograph as you go.
    d. Utilize an immovable, stationary landmark to ensure your grid in repeatable.
        i. (e.g., "the grid point A-1 is 12' north of the yellow fire hydrant, 3' to the left water meter hatch, and is 12' 4" from storm drain")
    e. Divide the grid up by location "uses" (e.g., growing area, flood zone, unused area, etc.).
        i. Sample by area: i.e., growing areas, ornamental areas, and flooded areas should be separate from one another.
            1. To save funds on more expensive tests, divide the garden space into "food producing" land and "other" land.
        ii. Areas that differ in soil texture, color, plant growth, or treatment should be sampled separately (if they will be treated differently)
        iii. Unless of specific interest, **avoid** unused land, corners of lots, and areas that are poorly drained and/or have had fertilizers or amendments dumped on them.
        iv. Stay at least 50 feet back from ag operations, roads, lanes, or fence lines when sampling.
        v. **For S-103 tests:** You should have 15 – 20 sample points **per "use" area** on site.
            NOTE: these samples will be mixed into a single, larger sample (Combined sample weight for S-103 is 2.2 lbs. or 1000g).
        vi. **For CAM-17 and PPM-13 tests**: take fewer, smaller samples over a larger area.
            Note: these samples will be mixed into a single, larger sample (Combined sample weight for CAM-17, PPM-13 is 8 oz or 225 g)
    f. Create a prefix for each use-area (e.g., GROW-, FLOOD-, ELEV-)
        i. Number these samples from West to East from smallest to largest number.

ii. Label each row North to South with a letter, starting with A in the northernmost row.
iii. Each sample should now have an ID, (e.g. GROW-2C, FLOOD-1A).

g. Use what3words.com to determine the approximate sample area.
h. Calculate the estimated volume per sample for each "use" area.

2. Begin sampling the various locations by use.
    a. For S-103 tests, samples should reach a depth of **at least 6 inches**.
    b. Record the depth of each sample.
        i. If using the probe, the sample depth is 12"
    c. Banded areas: Avoid areas where commercial fertilizer has been applied.
    d. Drip systems: Do not sample directly below drip-system emitters.
3. Take each sample and transfer it to the zip-lock bag (if instructed to). Track the weight of the bag as you go.
    a. From A&L Western Agricultural Laboratory's website:
    "If samples are very wet, they should be air-dried to a workable condition before packaging. (Nematode samples are an exception. They should be kept cool and moist). ***Include a completed soil sample information sheet or cover letter with instructions within the same package.*** *Processing will be delayed if sent separately.*
    Also, include payment if you do not have an established account.
    Samples should be shipped by a carrier such as UPS or FedEx*, or by first-class mail.* ***Ensure that samples are not packaged loosely, as they are likely to shift around and burst open during shipping****.*
    Caution: Do not submit organic amendments or soilless nursery media as "soils". They require different testing
    (the total weight of each zone's sample should be 1000g)."
4. Send the sample to the lab. Be sure to follow all instructions given by the lab in terms of shipment and storage.

Understanding Results:

It is important to remember that "the dose makes the poison", and there is no singular "acceptable" level of contamination. From Cornell Waste Management: "*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 the"* (Hannah Shayler, 2009). Length of exposure and method of exposure to a contaminant is an important part of understanding it's possible effects on people. This makes it difficult to determine when soil is "bad" or dangerous. There are three fairly well accepted standards for what is often referred to as the "maximum contamination level". **See Table 4 for more information.** It is also important to understand "the bioavailability of heavy metals in plant varies for different [parts of the plant]" (Khan, 2015), so the types of vegetable being grown in contaminated soil is also important.

- There is the US EPA Soil Screening Levels: samples which test above the US EPA SSL warrant "further study". US EPA SSL listed in the table below are the lower end of the range. US EPA SSL MCLs do not account for "background" levels of contaminants.

- The New York State Department of Environmental Conservation's (NYS DEC) Soil Cleanup Objectives (SCO) uses a collection of samples taken around the state of NY to determine what concentration of various heavy metals is considered safe.
- The California Human Health Screening Levels (CA HHSL), were replaced in October of 2015, "CHHSLs are no longer generally recommended for use in a human health risk evaluation, because they are not routinely reviewed and revised as new scientific information becomes available". Examine the CA HHSL website for the most recent data on pollutants of concern based upon results from your PPM-13 or CAM-17 test.
- Use the DTSC's HERO (Human and Ecological Risk Office) guidance. Check the HERO site to learn more about the specific contaminate and get the most up-to-date information about what is considered safe exposure. For a complete list of contaminates go to the main page, view "Human Health Risk Assessment Note 10 – Toxicity Criteria".

Soil Remediation Techniques:

In areas where lead or other heavy metal (HM) concentration is low to medium, plants can still be grown with a bit of ingenuity. Heavy metals (and most contaminants) spread via touch, inhalation, or ingestion. By reducing exposure to these contaminants, we can minimize their effects on people.

Container Gardening:

The most common method to avoid bioaccumulation of HM is by using a raised garden bed. Raised beds allow you to bring in better quality soil, but require you to 1) purchase soil, 2) purchase materials to create garden beds, 3) build the garden beds. Beds can be made from redwood, lumber, bricks or cement. Raised beds allow you to grow on nearly any surface, while reducing the risk of lead exposure.

Working with existing soil:

There are a variety of issues with raised beds, so some urban farmers may opt to work with existing soil. Begin by heavily mixing the soil and adding organic matter. Since contamination is often located in the upper most levels of soil, contaminants can be "diluted" when soil is mixed and organic matter is introduced. This organic matter decreases run off, increases infiltration, and provides heavy metals with organic matter to bind to (as opposed to plant roots). Adding amendments and compost may help you to dilute the concentration of heavy metals in your soil to a safer level. You may wish to add biochar or activated charcoal, which can help bind to heavy metals and petroleum products respectively. But be warned – both products will raise the soil pH. Maintaining pH between 6.5 and 7 (neutral) can also help reduce the amount of heavy metals your plants are able to metabolize. Conduct research on the effectiveness and drawbacks of either product before using it in your garden (Surls, 2016).

Soil testing schedule

Comprehensive soil tests should be taken before any work is done on the site (aside from simple trash cleanup). Begin with a S-103 test and a PPM-13[1] test. Schedule any additional[2] tests based on site history, **see Table 2 for more information.** If a supplementary test returns a "not detected" result, there

[1] A more comprehensive and expensive CAM-17 test can be run instead of PPM-13. **See Table 2 for more info**
[2] DDT, PCBs, or TPH variants

is no need to test for that pollutant going forward (unless you believe the original sample was corrupted).

If your Year Zero test results indicate that none of the heavy metals tested for are present, simply run an S-103 test once per year on the site.

If you Year Zero test results indicate there are heavy metals present in your soil, consider appropriate remediation action based upon the levels reported. Take precautionary measures as recommended by CA law.

Proposed TUC Testing Schedule		
Year	**Tests to run**	**Cost of test(s)**
Year 0	S-103 (3 sample locations) PPM-13	$48 x 3 = $144 $118 **Total $262**
Year 1	S-103	$48 x 3 = **Total $144**
Year 2	S-103, PPM-13[3]	$48 x 3 = $144 $118 **Total $262**
Year 3	S-103	$48 x 3 = **Total $144**
Year 4	S-103, PPM-13[4]	$48 x 3 = $144 $118 **Total $262**
Total		**5-year total $1,074**

Proposed Rio Vista Testing Schedule		
Year	**Tests to run**	**Cost of test(s)**
Year 0	S-103 PPM-13	$48 $118 **Total $166**
Year 1	S-103	$48 **Total $48**
Year 2	S-103, PPM-13[5]	$48 $118 **Total $166**
Year 3	S-103	$48 **Total $48**
Year 4	S-103, PPM-13[6]	$48 $118 **Total $166**

[3] if detected in year 0
[4] if detected in year 2
[5] if detected in year 0
[6] if detected in year 2

Total		5-year total $594

Distributing test results:

Test results should be distributed in a variety of ways. Once test results have been received, an experienced team member who is able to understand the results should produce a short narrative (less than 350 words) explaining the results and their meaning. This narrative should be combined with the test results into a PDF.

This PDF, along with an edited version of the narrative, should be posted as a "What's Growing" blog post. This blog post can be linked on the Sustainable Solano website under the Solano Gardens → Community Gardens section.

That same PDF containing the results and the narrative should printed and laminated. This laminated copy should be given to the garden for their own use (preferably left in a public space for viewing).

A QR code should be created, linking to the blog post and the PDF. This QR code should be posted in public view at the garden site, laminated if possible.

Sustainable Solano should post the test result information on its social media. How this information is presented depends upon the test results. No-detection results can be shared as is, results which warrant remediation should be presented with sufficient context to explain the meaning of the results and the reason for remediation.

Tables

Table 1: Tests and prices by company

Company	Test	Price per sample
A & L Western Agricultural Laboratory	S-103	$48
California Laboratory Services	CAM-17	$175
California Laboratory Services	PPM-13	$115
California Laboratory Services	TPH (Gas, BTEX, MTBE)	$75

as of January 4, 2024

Table 2: Testing parameters

Test	Symbol/unit	Location/test	Site type	Frequency[7]
Antimony	Sb, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
Arsenic	As, ppm	CLS; CAM-17	Always	1 per 12 - 24 months
Barium	Ba, ppm	CLS; CAM-17	By history	1 per 12 - 24 months
Beryllium	Be, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
Boron	B, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months

[7] Frequency of testing is based upon how quickly different contaminants or nutrients can be added or removed. I.e., Lead removal vs DDT degradation

Cadmium	Cd, ppm	CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Calcium	Ca, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Chromium	Cr, ppm	CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Cobalt	Co, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
Copper	Cu, ppm	A&L Labs; S-103, CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Iron	Fe, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Lead	Pb, ppm	CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Magnesium	Mg, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Manganese	Mn, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Mercury	Hg, ppm	CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Molybdenum	Mo, ppm	CLS; CAM-17	By history	1 per 12 - 24 months
Nickel	Ni, ppm	CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months
Nitrogen, N	N	A&L Labs; S-103	Always	1 per 12 - 24 months
Organic Matter (%)	%	A&L Labs; S-103	Always	1 per 12 - 24 months
Organochlorine Pesticides (DDT)	Ppm/ppb	CLS; EPA 608/8081A	By history	1 per 3 - 5 years
PCB	ppm	CLS; EPA 8082A	By history	1 per 2 – 5 years
Pesticides	Ppm/ppb	CLS; EPA 508	By history	1 per 24 - 36 months
Phosphorus-1	Weak Bray	A&L Labs; S-103	Always	1 per 12 - 24 months
Phosphorus-2	NaHCO3r-P	A&L Labs; S-103	Always	1 per 12 - 24 months
Potassium	K, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Selenium	Se, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
Silver	Ag, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
Sodium	Na, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Sulfur	SO4-S, ppm	A&L Labs; S-103	Always	1 per 12 - 24 months
Titanium	Tl, ppm	CLS; CAM-17, CLS-PPM-13	By history	1 per 12 - 24 months
TPH (Gasoline and BTEX/MTBE)	Ppb	CLS; EPA 8015M/8260B	By history	1 per 24 - 36 months
TPH (Gasoline)	Ppb	CLS; EPA 8015M	By history	1 per 24 - 36 months
Vanadium	V, ppm	CLS; CAM-17	By history	1 per 12 - 24 months
Zinc	Zn, ppm	A&L Labs; S-103, CLS; CAM-17, CLS-PPM-13	Always	1 per 12 - 24 months

Table 3: Types of land use and common contaminates:

Types of land use	Common Contaminates
Parks, ag land, yards	Nitrates, pesticides, herbicides, pathogens from waste, copper arsenate, DDT
Parking lot	Metals, PFAO, PAHs, BTEX
Dry cleaning	PERC solvents
Industrial (general)	Asbestos, lead, PCBs, petrol products, copper arsenate from treated wood
Junkyard	Metals, PCBs, petrol products, copper arsenate from treated wood, creosote
Residential area	Lead, metals, petroleum products, pathogens, copper arsenate, DDT
Stormwater basin/low land	Metal, PFOS, PFAO, pathogens, pesticide and herbicides, petroleum products
Gas station	Metals, PFAO, PAHs, BTEX, petroleum products
Storage (general)	Metals, copper arsenate
Industry (heavy)	Metals, PCBs, solvents,
Electrical power	PCBs, heavy metals, asbestos, copper arsenate
Adopted from ANR Publication 8552, Jan 2016	

Table 4: Various organizations maximum soil contamination levels

	Maximum Contamination Levels (MCL)		
Inorganic Chemical	**CA HHSL**	**NYS DEC SCO**	**US EPA SSL (threshold)**
Arsenic	0.07 ppm	16 ppm	0.4 ppm
Cadmium (and related)	1.7 ppm	2.5 ppm	70 ppm
Chromium III	100,000 ppm	36 ppm	120,000 ppm
Chromium VI	17 ppm	22 ppm	230 ppm
Lead (and related)	80 ppm	400 ppm	400 ppm
Nickel (and related)	1,600 ppm	140 ppm	1,600 ppm
Zinc	23,000 ppm	2,200 ppm	23,000 ppm
	Adopted from ANR Publication 8552, Jan 2016 (Surls, 2016)		

Table 5: Lead risk by concentration:

Lead Levels and Risk			
Risk level	**Concentration (ppm)**	**Planting**	**Gardening**
Low	0 – 100 ppm	No crop restrictions	Wash hands, produce
Medium	100 – 1,200 ppm	Avoid root vegetables. Choose vines, fruit trees. Relocate plants to low lead areas.	Increase soil amendments (e.g., compost) and barriers (e.g., mulch) to minimize inhalation and contact
High*	+ 1,200 ppm	See above. Use raised beds or containers for gardening.	Consider removing top 24” of soil, or adding 24” of soil to site.

		Restrict access to children.
	! - Alternative site selection recommended Adopted from ANR Publication 8552, Jan 2016	

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Prepared by Patrick Murphy, January 4, 2024.