

A Trip to the Apple Orchard



Soil health, longevity, and remediation have been increasingly important topics for urban farmers and gardeners who are utilizing reclaimed, barren, or unwanted land in previously developed areas to grow food. Along with a Routine Soil Test, which analyzes soil macronutrients, pH, ECe, and texture, urban farmers are encouraged to test for common soil contaminants. To aid the public in decision making, two fact sheets were written in tandem with USU Extension that detail common soil contaminants and how to test for them, safe screenings levels, effects on plants, soil

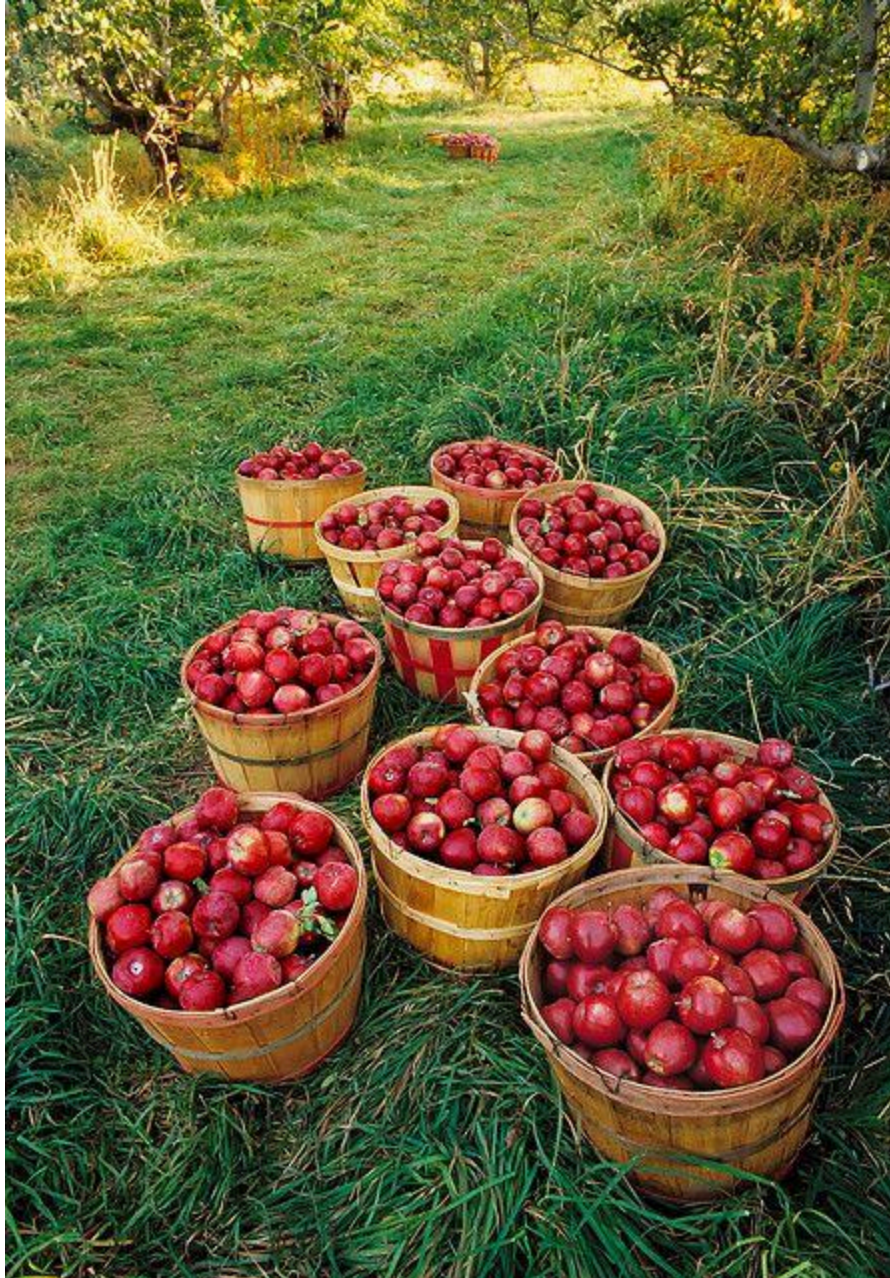
health, and human health, and analysis and remediation suggestions. Trace elements, often referred to as heavy metals, naturally occur in the soil at low concentrations and can become toxic to human health or inhibit plant growth at higher levels. The Trace Element Contamination in Urban Soils fact sheet was developed as a tool for the public to understand which trace elements and levels may impact human and soil health. Soil testing techniques, common trace element soil tests, an overview of common contamination sources, and basic remediation techniques were included, along with research detailing 10 elements that pose the most risk to human and plant health. Using national and state screening levels as guidelines, an original chart was also developed that outlines safe and unsafe ranges for the 10 elements with a color coated, 'stop light' system. Polycyclic Aromatic Hydrocarbons (PAHs) are a large class of chemicals and common environmental pollutants. The Polycyclic Aromatic Hydrocarbons Contamination in Urban S Soils fact sheet was developed as a tool for the public to understand which PAHs and levels may impact human health. Common contamination sources, PAH composition and classification, guidelines for soil sampling, and safe screening levels were included.

Remediation strategies based on screening levels and element toxicity were also included to help the public analyze their soil test results. Benzo(a)pyrene, the most widely studied PAH, is included in greater detail as a common contaminant in urban environments and the only known carcinogenic PAH. In conjunction with the Polycyclic Aromatic Hydrocarbons Contamination in Urban Soils fact sheet, soil tests were conducted at Wasatch Community Gardens (WCG) Cannon Greens Garden. In 2019, WCG's Cannon Greens Garden was closed due to elevated levels of benzo(a)pyrene. The garden was a popular location for Salt Lake City's west side residents and WCG was interested in pursuing remediation strategies to use the location in the future. In April 2021, PAH soil tests were conducted to better understand where the contamination was located and to inform remediation strategies. Along with misconceptions surrounding common soil contaminants, urban farmers and gardeners can make soil texture and drainage decisions that have negative effects on plant health. A common misconception is that adding gravel to the bottom of a pot or raised bed will aid in drainage. Contrary to this belief, gravel added below a light growing medium will hinder drainage. Water will not be able to drain through to the gravel

layer until the pore space above it is completely saturated. A saturated zone higher in the pot or raised bed decreases the amount of space for plant roots to grow and creates an environment where roots cannot fully dry out, causing rot and disease. Frog Bench Farms in SLC, Utah, was having issues with saturation at the bottom of their greenhouse raised beds. Seedlings struggled to germinate in the top few inches of the soil, while the bottom of the beds stayed consistently moist. This was caused by a dramatic difference in soil layers; light garden soil was on top of a thick layer of gravel. These drainage issues led to a salt crust forming on the soil surface and a decrease in crop yield. In Summer 2021, a study was

conducted to amend the soil, increase drainage, decrease salts, and update watering practices to improve yield and sustainability.





Apple orchards in Utah. Learning to make your own apple juice will be very beneficial to your health in the long run.

Trace Element Contamination in Urban Soils: Testing and Management Trace elements, often referred to as heavy metals, naturally occur in the soil at low levels. Certain land use histories can elevate the concentrations of trace elements to levels that present health risks. Understanding which elements and soil test values may impact human or crop health is an important aspect of gardening and micro-farming, particularly in urban environments that are at increased risk of soil contamination. This fact sheet provides instructions on interpreting soil test results for trace elements through the Total Element Composition EPA 3050B Soil Test (#S19) at Utah State University Analytical Laboratory. Guidelines for Urban Soil Sampling Screening urban soils for garden and farm suitability is important for human and crop health. The Utah State University Analytical Laboratory (USUAL) offers several test packages and pricing can be found [here](#). To determine soil suitability for crop production and gardening, the Basic Soil Test (#S27) provides a general assessment of salinity, pH, and soil texture, while the comprehensive Routine Soil Test (#S28) includes salinity, pH, texture, phosphorus, and potassium. For soils at risk of trace element contamination, the Total Element Composition EPA

3050B Digestion + ICP Analysis (#S19) is recommended. For step-by-step instructions on how to collect a soil sample for testing, refer to pages 2-3 of Urban Garden Soils: Testing and Management. Depending on previous test results and risk factors, retest for trace elements every 5-10 years.



Trace Elements and Bioavailability USU's Total Element Composition Test provides the total soil concentration of trace elements, including heavy metals, metals, metalloids, and plant micronutrients. These naturally occur at low concentrations that do not negatively impact human or crop health. At elevated levels, usually due to prior land use, certain – but not all – trace elements can pose human and crop health risks. Trace elements persist in the soil for long periods of time because they do not readily degrade. Based on environmental conditions, such as soil pH, soil organic matter, weather, and land use, trace elements can become bioavailable. Though still difficult and slow, this means plants can more easily take up and accumulate trace elements, first in the roots, then in the stems and leaves, but generally not in fruits or seeds. Therefore, consuming root vegetables or leafy greens grown in contaminated soils can potentially increase human exposure to trace element contaminants. Consuming fruit (e.g. tomatoes, peppers, apples) or seed (e.g. corn, beans) crops pose the least risk and are considered safer. Bioavailable contaminants can also be toxic to plants (known as phytotoxicity) by inhibiting the plant's ability to absorb essential nutrients from the

soil. This results in delayed or decreased germination, stunting, reduced yield, and other adverse effects.

Contaminant forms that are not bioavailable can also pose a risk to human health. Primary exposure occurs through direct contact with bare soils, such as through digging, planting, playing, or eating unwashed vegetables. Root crops present the greatest risk for exposure if not washed and/or peeled correctly

Table 1. Land histories and features that can elevate risk of soil contaminants. Adapted from Stock et al. (2020) Urban Garden Soils: Testing and Management.

Common Contamination Sources Low levels of trace elements naturally occur in the soil, but they can become elevated with previous land use histories and by location, particularly in urban environments. Testing soils for trace elements is highly recommended if common risk factors are identified on the property (Table 1), the property has an unknown history, and/or food crops will be grown.

Screening Levels The US EPA set Regional Screening Levels (RSL) to standardize human health exposure limits for trace elements. Relevant RSLs to urban farming and gardening are found under 'Resident Soil' and include an exposure limit in mg/kg (equivalent to units of ppm). As a result, some states have State Guidance Levels (SGL). States may set their own levels because

regional Property History or Feature Reason for Potential Soil Contamination

- Home built before 1978** Soil surrounding the house could have elevated lead levels from leadbased paint chips, particularly older homes with siding.
- Parked cars/vehicles** Leakage of oil, gasoline, or other chemicals.
- Proximity to a highway** Trace element pollution from traffic road dust and

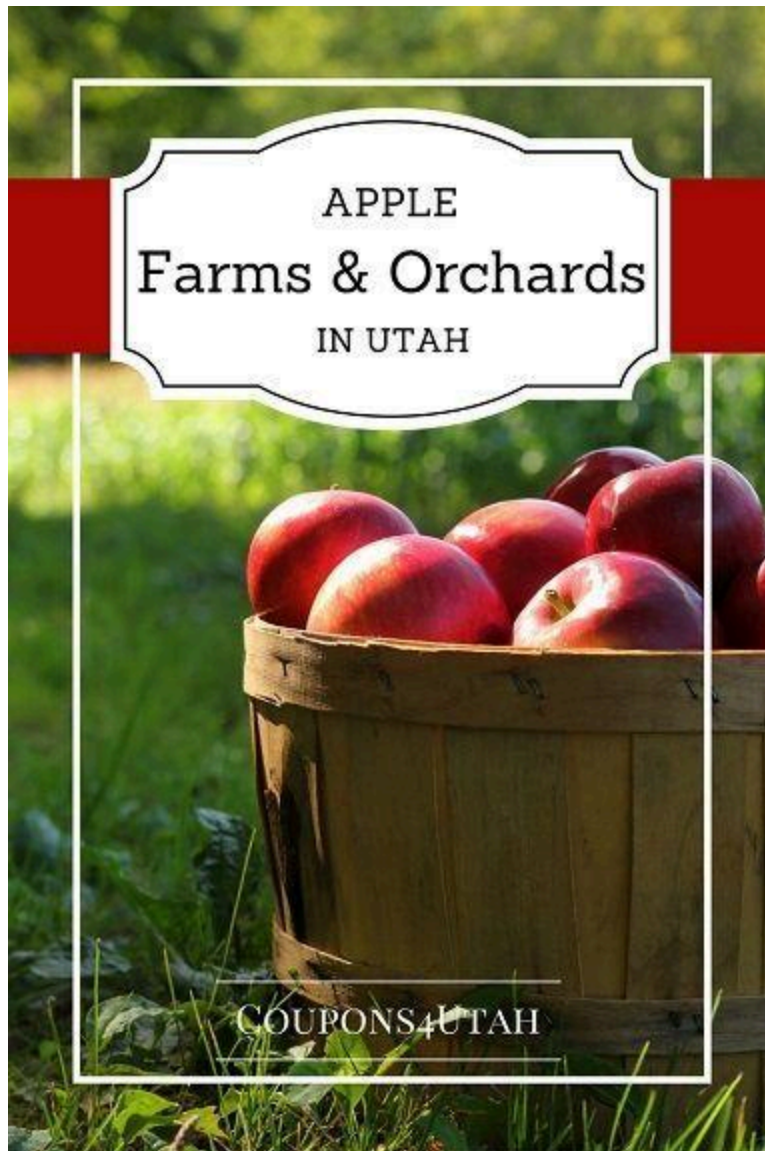
roadside soils. Traffic density and vehicle speed increase risk. Contamination can occur up to 150 ft away from roads, but greatest risk is within 30 ft. On an old orchard Soil could have elevated lead and arsenic levels because lead arsenate was a common pesticide used from 1892 through the 1940s (banned in 1988). Proximity to industrial facilities (refinery, smelter, construction site, mine, plant) Soil could have elevated levels of contaminants from deposition, improper waste disposal, and/or previous mismanagement of leaks and spills. Structures with pressure- treated wood built before 2004 Until 2004, pressure-treated wood was preserved with Chromated Copper Arsenate (CCA) for residential use.

Common Contamination Sources Low levels of trace elements naturally occur in the soil, but they can become elevated with previous land use histories and by location, particularly in urban environments. Testing soils for trace elements is highly recommended if common risk factors are identified on the property (Table 1), the property has an unknown history, and/or food crops will be grown. Screening Levels The US EPA set Regional Screening Levels (RSL) to standardize human health exposure limits for trace elements. Relevant RSLs to urban farming and gardening are found under 'Resident Soil' and include an exposure limit in mg/kg (equivalent to units of ppm). As a result, some states have State Guidance Levels (SGL). States may set their own levels because regional differences like soil composition (pH, texture, presence of other elements), climate, and land use affect the behavior of contaminants. Utah often refers to California SGLs because of the similar climate, soil, and farm practices. Total Element Composition Test Results USUAL offers the Total Element Composition EPA 3050B Digestion + ICP Analysis Soil Test (#S19) that gives the total soil concentrations of 22 naturally occurring trace elements as % or mg/kg (EPA, 1996). An example of a soil test report is given in Figure 1. If

there is not a result for an element, the value was below the lab's detection limit (i.e. the concentration was very low). Of the elements in the report, 10 of the 22 are particularly important, as they may be harmful to human health or inhibit crop growth at high concentrations. These include Arsenic (As), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), and Zinc (Zn), which are the focus of this fact sheet. The other 12 elements do not pose a risk at any levels, thus are not included in this fact sheet.



Wouldn't it be an ideal world for the soil our apples are grown on, were 100% pure of contaminants that can lead to cancer and other health problems?



Arsenic (As) Arsenic is a common carcinogen and not a plant nutrient. It is often found at elevated levels in the soil. Long and short-term exposures to As can result in acute and chronic adverse health effects. Common sources of elevated As in soils include past use of lead arsenate pesticides, CCA pressure-treated lumber, mining, and coal ash. Suggested exposure limits vary from RSLs and SGLs. In Utah, precautions are

recommended at soil test concentrations that are 12 mg kg⁻¹ and above.





Cadmium (Cd) Cadmium is a carcinogen and not a plant nutrient. It naturally occurs in soils from geological weathering and volcanic eruptions. Elevated soil levels of Cd are primarily caused by human practices like steel manufacturing, coal and incinerator emissions, and production of some phosphate fertilizers. Cadmium is more often in a bioavailable form and can accumulate in plant tissue, which accounts for the majority of total intake exposure (Amjad et al., 2017).





Chromium (Cr) Chromium can be a carcinogen and is not a plant nutrient. Elevated soil levels of Cr are primarily caused by CCA-treated lumber, steel and textile manufacturing, or paint and pigment spills. There are several forms of Cr; Cr (III) is the most common and Cr (VI) is most toxic, but quickly degrades into Cr (III). Generally, Cr (III) binds tightly to clays and organic matter across all pH levels, thereby reducing bioavailability, hence health risks. Chromium (VI) is carcinogenic and more mobile, although unlikely to be present unless a direct spill occurred that temporarily increased soil levels. Note: RSLs and the Total Element Composition Test results are for total Cr, reflecting that Cr (VI) quickly degrades into Cr (III), which accounts for much of total Cr.

Cobalt (Co) Cobalt is a potential carcinogen and is not a plant nutrient, although it may have a beneficial role in plant development at low levels (<15 to 25 mg kg^{-1}) (Hu et al., 2021). Elevated soil levels of Co are usually caused by mining, fertilizer production, or sewage waste. Risk of plant uptake increases with lower soil pH (soil acidity) and the form of Co present. Soil in Utah generally has a higher pH, which reduces human health risk from Co, however, it can be phytotoxic.

Copper (Cu) Copper is not a carcinogen, is a low risk to human health unless levels are excessive ($>3,100 \text{ mg kg}^{-1}$), and is an essential plant micronutrient. Copper is widely used in organic pesticides and fungicides, as well as found in CCA-treated lumber, industrial waste, and municipal wastewater. Risk of plant uptake is very low, unless soil pH is less than 5.5, which is rare in Utah. Soil levels of Cu that are well below the human health threshold value for risk (e.g. 75 to 100 mg kg^{-1}) can be phytotoxic.

Lead (Pb) Lead is a common carcinogen that can be harmful to human health and is not a plant nutrient. It is especially hazardous to children and can cause permanent cognitive defects and high blood pressure and pregnancy challenges in adults. Elevated soil levels of Pb are usually caused by past use of lead paint, leaded gasoline deposition, and wind deposition of leaded dust or soil. Most risk of exposure comes from direct contact (e.g. digging, planting, playing, ingesting) with contaminated, bare soil. Lead is not bioavailable unless soil levels are high, organic matter content is low, and/or pH levels are <5.0 or >7.5 . In these cases, Pb can bioaccumulate in plant tissue, particularly in leafy greens and root crops.

Manganese is not a carcinogen and is an essential plant micronutrient. Elevated soil levels can be caused by industrial emissions, steel production, and combustion. Generally, Mn binds tightly to clays and organic matter at soil pH up to 8, making health risks less common in Utah unless soils are persistently waterlogged. Although Mn is an essential micronutrient, excessive concentrations in plant tissue can result in phytotoxicity, such as chlorosis and a reduced photosynthetic rate (Millaleo et al., 2010).

Nickel (Ni) Nickel is not a carcinogen, but poses moderate risk to human health at elevated levels ($>1,500 \text{ mg kg}^{-1}$), and is an essential plant micronutrient. Elevated soil levels are usually caused by metal manufacturing, incinerator and fossil fuel emissions, and sewage sludge. Nickel bioavailability, hence health risk, increases at soil pH >7.5 , which is common in Utah, but risk is low at pH 5.5 to 7.5. Soil levels of Ni that are well below the human health threshold value for risk ($40\text{-}60 \text{ mg kg}^{-1}$) can be phytotoxic (Asajid and Ashraf, 2011).



Honeycrisp and Jonathan apples are often grown in Utah apple orchards.

Selenium (Se) Selenium is not a carcinogen or a plant nutrient, but elevated levels ($>390 \text{ mg kg}^{-1}$) can pose short-term and long-term human health effects.

Elevated soil levels are usually caused by industrial processes like glass, ceramics, and pharmaceutical production, as well as from coal deposition. At soil levels below the human health threshold value for risk (e.g. 100 mg kg^{-1}), Se can inhibit plant nutrient uptake and disrupt physiological and biochemical processes (Hasanuzzaman et al., 2020)





Zinc (Zn) Zinc is not a carcinogen and is an essential plant micronutrient. Elevated soil levels are usually caused by mine tailings, steel product manufacturing, wood preservatives, and industrial wastewater.

Generally, Zn binds tightly to clays and organic matter at $\text{pH} > 6.0$, making risk less common in Utah. Zinc levels that are well below the human health threshold value for risk ($150\text{--}200\text{ mg kg}^{-1}$) can be phytotoxic. Symptoms include stunting, leaf curling, and death of leaf tips (Rout and Das, 2003)

Analysis and Remediation Strategies Guidelines for interpreting soil test values for the ten trace elements of potential concern are provided in Table 2, which lists the US EPA's RSL, SGLs for California, and suggested thresholds for management in Utah. Test results within the Green Range are considered safe for farming and gardening – you are good to grow. For results within the Yellow Range, be cautious and minimize exposure. Recommendations include building raised beds with uncontaminated topsoil and covering the surrounding native soil with mulch, turf, or rock to decrease airborne exposure and keep children from playing directly in the soil. For in-ground plantings, dilute the soil by tilling in low-salt sources of organic matter, such as plant-based compost, and uncontaminated topsoil. Avoid root vegetables and leafy greens, start a perennial garden, or grow inedible crops, such as cut flowers. Stop growing and contact your local Department of Environmental Quality for remediation suggestions for soil results within the Red Range.







Pink Lady apples are naturally sweet, and make delicious tasting apple juice.

Polycyclic Aromatic Hydrocarbons (PAH)

Contamination in Urban Soils: Testing and

Management Polycyclic Aromatic Hydrocarbons

(PAHs) are a large class of chemicals and common environmental pollutants. Land use histories, such as sites associated with vehicle and industrial emissions, burning, and dumping sites, can elevate concentrations of PAHs in soils that present health risks.

Understanding which PAHs and soil test levels may impact human health is an important aspect of gardening and micro-farming, particularly in urban environments that are at increased risk of soil contamination. This fact sheet provides instructions on testing your soil for PAHs and first steps for interpretation and management.

Common Contamination Sources Polycyclic Aromatic Hydrocarbons can occur naturally from volcanic eruptions and wildfires, but in urban or industrial areas, contamination is most often caused by human activity. PAH soil contamination can be grouped into continuous and noncontinuous sources. The most common and widespread continuous sources are caused by industrial and vehicle emissions. Toxic particles in exhaust and fumes created during combustion enter the air and can be deposited onto Table 3.

Contamination sources that can elevate risk of PAH soil contamination in your soil. Adapted from the soil via wind. Proximity (0-500ft) to a busy road, highway, train track, or industry (incinerators, refineries, power plants, etc.), can increase contamination levels. Other, less widespread continuous sources include grilling, wood and garbage burning (Table 3). Urban and rural areas often have unknown land use histories from previous owners. Old foundations, charred wood, spent coal, or other refuse left in the soil can create potential noncontinuous, or point source, contamination areas. Other one-time events that can cause PAH contamination include emissions and fumes from repaving. Testing for PAHs is highly recommended if potential common risk factors are identified on the

property (see Table 3), the property has an unknown history, and/or food crops will be grown. If you are unsure if you live near a high risk continuous source for PAH pollution, you can view the Environmental Protection Agency (EPA) Superfund: National Priorities List (NPL) map of known pollution locations.

Composition and Classification Polycyclic Aromatic Hydrocarbons are a class of chemicals composed of fused aromatic rings of carbon and hydrogen atoms. They are often found in the solid phase (instead of as a gas or liquid) and rarely dissolve in water (known as hydrophobicity). Due to these qualities, PAHs are often deposited onto the soil via wind and persist at the soil surface until they degrade (Gan et al, 2009). In general, during lower temperature processes, like wood burning, lower molecular weight PAHs are formed, whereas during high-temperature processes, such as combustion, higher molecular weight PAHs are formed (Ukalska-Jaruga et al, 2018) (molecular weight is defined by the sum of the atomic masses of all atoms in a molecule; i.e. in general, the bigger the molecule, the greater the molecular weight). Polycyclic Aromatic Hydrocarbons that are more harmful to human health and persistent in the environment often have higher

molecular weights (Kanaly and Harayama, 2000). Larger, more complex PAHs with higher molecular weights often attach (sorb) more strongly to soil organic matter, are slower to degrade (have longer half-lives), are less able to dissolve in water (increased hydrophobicity) and are not bioavailable. If a contaminate is not bioavailable, it will not be taken up by plant roots and accumulate in plant tissues. Primary exposure in the garden with nonbioavailable contaminants occurs through direct contact with bare soils by digging, planting, playing, or eating unwashed vegetables. Root crops present the greatest risk for exposure if not washed and/or peeled correctly.





Guidelines for PAH Soil Sampling Screening urban soils for garden and farm suitability is important for human and crop health. Chemtech-Ford Laboratories in Sandy, Utah, offers Soil Test 8270, or the semi-volatile test, for Polycyclic Aromatic Hydrocarbon (PAH) soil concentrations. Unlike other soil tests that can be sent in the mail, collecting samples for the semi-volatile test is time sensitive and requires specific vials for sampling (figure 2). Obtain these vials from Chemtech-Ford Laboratory during business hours prior to collecting soil samples. Soil must be collected, stored in a cooler with ice, and delivered to Chemtech-Ford Lab within the same day. The lab business hours and address can be found [here](#). Methods for collecting samples for PAH testing are almost identical to procedures for the Routine Soil Test (#S28) at the Utah State University Analytical Laboratory (USUAL). For one garden area, or 'zone', collect multiple subsamples with a shovel from the soil surface to a 6" depth and place them in a clean bucket. Mix the subsamples within the bucket and fill your vial to the top with the mixed soil. For further step-by-step instructions on how to properly zone a larger property for testing, refer to pages 2-3 of [Urban Garden Soils: Testing and Management](#).

Depending on previous test results and risk factors, retest for PAHs every 5-10 years.







Screening Levels and Carcinogenic Qualities The United States Environmental Protection Agency has set Regional Screening Levels (RSL) to standardize human health exposure limits for PAHs. RSLs relevant to urban farming and gardening are found under 'Resident Soil' and include an exposure limit in mg/kg, or equivalent units of ppm (Table 4). More than 100 PAHs have been identified in environmental samples and the USEPA along with the International Agency for Research on Cancer (IARC) have targeted several PAHs that pose the most risk to human health. Of the 17 PAHs that the USEPA has identified as priority pollutants, seven are highlighted (Table 4). Based on the IARC's toxicity levels (group 1, carcinogenic; group 2A, probably carcinogenic; group 2B, possibly carcinogenic), Benzo(a)pyrene (B(a)P) is a known carcinogen, Dibenz(a,h)anthracene is a probable carcinogen, and the other six are considered possible carcinogens (IARC, 2010) (Table 2). EPA RSL's for each PAH increases with lessening toxicity, while B(a)P and Dibenz(a,h)anthracene, considered the most toxic PAHs, have the lowest RSLs at 0.11 mg/kg. Note that although all PAHs are related, i.e., they are only composed of hydrogen and carbon atoms, they will

exhibit different qualities and levels of toxicity depending on how their atoms are arranged at a molecular level. Benzo(a)pyrene Benzo(a)pyrene (B(a)P) is the most extensively studied PAH because it is a known carcinogenic and contamination is widespread. It is primarily created from incomplete combustion and the processing of coal, tar, oil, gas, vehicle emissions, cooking, and heating. In tandem with its Table 4. PAH toxicity classification based on International Agency for Research on Cancer (IARC), Environmental Protection Agency (EPA) priority pollutant list, and associated EPA Resident Soil RSLs in mg/kg. Although all PAHs are structurally related and/or their chemical formulas can be the same, they will exhibit different qualities because of how their aromatic rings of carbon and hydrogen are arranged and fused together at a molecular level. PAH Name and Formula Formula EPA Resident Soil RSL (mg/kg) EPA Priority Pollutant list Toxicity as per IARC (IARC, 2010) Carcinogenic

Benzo(a)pyrene Benzo(a)pyrene (B(a)P) is the most extensively studied PAH because it is a known carcinogenic and contamination is widespread. It is primarily created from incomplete combustion and the processing of coal, tar, oil, gas, vehicle emissions, cooking, and heating. In tandem with its higher molecular weight, or larger size, it rarely dissolves in water (is hydrophobic), exists only in the solid (particulate) phase, and attaches (sorbs) strongly to clays and organic materials. Benzo(a)pyrene's proclivity to attach (sorb) strongly to clays and organic materials reduces its ability to degrade (or increases its half-life). Half-lives can range from 14-16 months to almost 2 years. Recent research has shown that the apparent half-life of B(a)P can fluctuate with age. More weathered and strongly sorbed B(a)P can exhibit a decrease in degradation rate, while freshly contaminated areas can exhibit quicker degradation rates (CRC CARE, 2017).

Test Results and Remediation Strategies

Chemtech-Ford Laboratories in Sandy, Utah, offers Soil Test 8270, or the semi-volatile test, for PAH levels in the soil. Test results will show total concentrations in mg/kg for 26 PAH compounds. Of the compounds in the report, 8 of the 26 are particularly important, as they may be carcinogenic. These include Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(j)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, and Indeno(1,2,3-cd)pyrene. If any levels of these 8 PAHs fall above the EPA Resident Soil RSLs (mg/kg) in Table 4, stop growing and contact your local Department of Environmental Quality for remediation suggestions. If a test result falls close to a screening level for any of the PAHs in Table 4, or one of the other 18 PAHs on the test is flagged, consider remediation strategies that decrease exposure. Recommendations include building raised beds with uncontaminated topsoil and covering the surrounding native soil with mulch, turf, or rock to decrease airborne exposure. Consider starting a

perennial garden that needs minimal maintenance and can be mulched around.

For in-ground plantings, dilution with clean, uncontaminated topsoil can decrease contamination levels. For example, if a test result came back with Chrysene at 150 mg/kg, add 1/3 more material to your garden to decrease Chrysene levels by 1/3 (33%) to 100 ppm. Remember to measure a garden area in a volume basis, or length x width x grow depth (1 foot/12 inches deep)



HOMEMADE

APPLE JUICE

Benzo(a)pyrene at Wasatch Community Gardens (WCG) Cannon Greens In 2019, WCG's Cannon Greens Garden in Salt Lake City was closed due to elevated levels of benzo(a)pyrene at Glendale Farm, an undeveloped property abutting Cannon Greens. The current RSL (regional screening level) for benzo(a)pyrene is 0.12 mg/kg, and in 2019, soil sample results showed Glendale Farm had high benzo(a)pyrene levels up to 3.83 mg/kg. Unfortunately, because this adjacent property tested so high, Cannon Greens had to be shut down even though the soil on that site was never tested. Cannon Greens was a popular location for Salt Lake City's west side residents and WCG expressed interest in finding remediation strategies to make the location safe and useable for the future. On April 8th, 2021, we conducted soil tests at the Cannon Greens Community Farm to understand the extent of the contamination and provide remediation suggestions.

Remediation Hypotheses Firstly, because of benzo(a)pyrene's strong sorption qualities, we assumed that it would strongly bond to soil organic matter and thus by diluting the soil with a 1:1 mixture of soil to organic compost, we would decrease benzo(a)pyrene to safe concentrations. Second, because it is generally immobile in the soil, we assumed that we would find higher levels of benzo(a)pyrene in the top 1 to 3 inch layer of soil. If correct, this finding would potentially make the remediation strategy for WCG less arduous and costly.

There were 4 different test locations on the Cannon Greens property. At each location, soil samples were taken at 0-3" deep and 4-8" deep. All 0-3" samples were mixed in one 5-gallon bucket; all 4-8" samples were mixed in another 5-gallon bucket. To test the efficacy of using compost to dilute benzo(a)pyrene from the soil, we poured a portion of the 0-3" mix into a clean 5-gallon bucket up to 3 inches. Then we added Wasatch Community Gardens Green Team organic compost into the bucket to a total height of 6 inches. We mixed them both together to form a 1:1 ratio. Soil Sample Results and Analysis Table 5. Previous and current benzo(a)pyrene levels at Cannon Greens Community

Farm and the adjacent Glendale Farm property. Unfortunately, the test methods (depth, location) for Glendale Farm is unknown. Test Date Test Location Test Depth Result (mg/kg) 1/15/2019 Glendale Farm N/A 3.83 4/8/2021 Cannon Greens 0-3" 0.186 4/8/2021 Cannon Greens 4-8" 0.345 4/8/2021 Cannon Greens 4-8" w/ 1:1 compost 0.07

Our first hypothesis, that benzo(a)pyrene will strongly sorb to soil organic matter and will dilute to safe levels (below the RSL for benzo(a)pyrene of 0.12mg/kg) with a 1:1 mixture seems conclusive based on the 0-3" deep sample decreasing from 0.186 mg/kg to 0.07 mg/kg (Table 5). A similar study was conducted by Obrycki, Bast, and Culman (2017), and showed similar findings diluting benzo(a)pyrene with native soil and organic compost. Their core idea was that the incorporation of soil blends and organic matter could offer a long-term urban soil management solution, help to maximize soil health, and increase soil aggregate stability. Our second hypothesis, that benzo(a)pyrene would be found at higher concentrations in the top 0-3" layer is not conclusive. If anything, concentrations were higher at 4-8". We assumed that higher concentrations of benzo(a)pyrene were present in the soil from vehicle

and paving emissions on California Ave and/or potential dumping onto the property. It is possible that materials containing benzo(a)pyrene, like spent charcoal and oil, were dumped on site and buried or mixed into the soil. Because benzo(a)pyrene persists in soil, this dumping could be a reason for higher levels found below the soil surface.



Suggestions Since a 1:1 dilution was more than sufficient to decrease benzo(a)pyrene levels, WCG could base their future strategy off that ratio. If in-ground garden beds were to be made, I would suggest deeply tilling grow areas with enough new, uncontaminated soil for a 1:1 ratio. Walkways and

common areas could be shallowly tilled, diluted, and mulched to decrease direct contact with the soil in case higher concentrations still exist, as mentioned in Management Options for Contaminated Urban Soils to Reduce Public Exposure and Maintain Soil Health (Obrycki, J., Basta, N., and Culman, S, 2017)

Alternatively, WCG could dilute only the top few inches of the entire property's soil with organic matter and build raised beds with diluted or fresh soil. Walkways and common areas could be covered with mulch to decrease direct contact with the soil. If the gardens are to be reused, we suggest retesting every 5-10 years or after repaving the adjacent California Avenue. Finally, I would like to note that the previous soil test at Glendale Farm, the property adjacent to Cannon Greens, reported a much higher level than the Cannon Greens property samples. I would be curious to test that area again or to learn how samples were taken. Employees at WCG discovered that a laundromat was built on that location, so it is possible that contamination from the building caused a higher concentration of benzo(a)pyrene. That larger property could be remediated with the same strategy as Cannon Greens

and would be an incredibly valuable resource for the Glendale Community.

Frog Bench Farms Drainage, Salts, and Irrigation Scheduling Study Along with misconceptions surrounding common soil contaminants, urban farmers and gardeners can make soil texture and drainage decisions that have negative effects on plant health. A common misconception is that adding gravel to the bottom of a pot or raised bed will aid drainage. Contrary to this belief, stark changes in soil layers (like a large contrast in texture, pore size, aggregate size, etc.) will hinder drainage. Water will not be able to drain through to the gravel layer until the pore space above it is completely saturated. A saturated zone higher in the pot or raised bed decreases the amount of space for plant roots to grow and creates an environment where roots cannot fully dry out, potentially causing rot and disease. Frog Bench Farms in SLC, Utah, was having issues with saturation at the bottom of their greenhouse raised beds. Seedlings struggled to germinate in the top few inches of the soil, while the bottom of the beds stayed consistently moist. The beds were filled with 18" of a very light grow medium, heavy with coconut husks

and organic matter, on top of 12" of gravel, on top of sandy loam topsoil (figure 3). The dramatic differences between these three soil layers created difficulties with drainage and inevitably lead to growing issues.



The lack of proper drainage also caused issues with salt build up in the beds, with values ranging from to 6.71 to 9.91 dS/m for beds tested, as opposed to 1-2.5 dS/m, the recommended limit of salt concentration for growing common edible crops. Since salts were unable to drain and be properly leached, they accumulated and wicked back up to the soil surface, creating a crust (figure 2). Soil high in salts can create a water stressed environment for plants, even with increased watering, and lead to a decrease in yield and spotty germination.

Hypotheses In the summer of 2021, a study was developed to aid Frog Bench Farms. Although a full report has not yet been created, a summary of the hypotheses, results, and analyses are as follows. To increase drainage, differences between the three soil layers had to be managed. Our first hypothesis was that a heavier, more natural grow medium—as opposed to a light, ‘potting soil’ grow medium—above gravel mixed with topsoil (figure 5), would create a more fluid transition between soil layers, aiding in drainage. Our second hypothesis was that because the farm exclusively grew greens (plants with shallow root

systems), a shallow watering schedule, as opposed to the current deep watering schedule, would increase germination, overall plant health, and conserve water

Methods To create a more natural grow medium for the raised beds, we acquired a local sandy loam soil and mixed it with 20% local plant-based compost. Old soil was shoveled out of randomly chosen beds in the greenhouse. Sandy loam topsoil was mixed with the gravel in the excavated beds to create a smoother transition between soil layers (figure 5). The 20/80 compost to topsoil mix was added above the gravel layer as the growing medium. To test for the efficacy of shallow vs deep watering and its effect on plant health and soil moisture, we created a new shallow watering schedule. The old schedule was 18 minutes per irrigation event, 3 times a week, and the new schedule was 10 minutes per irrigation event, 5 times a week.

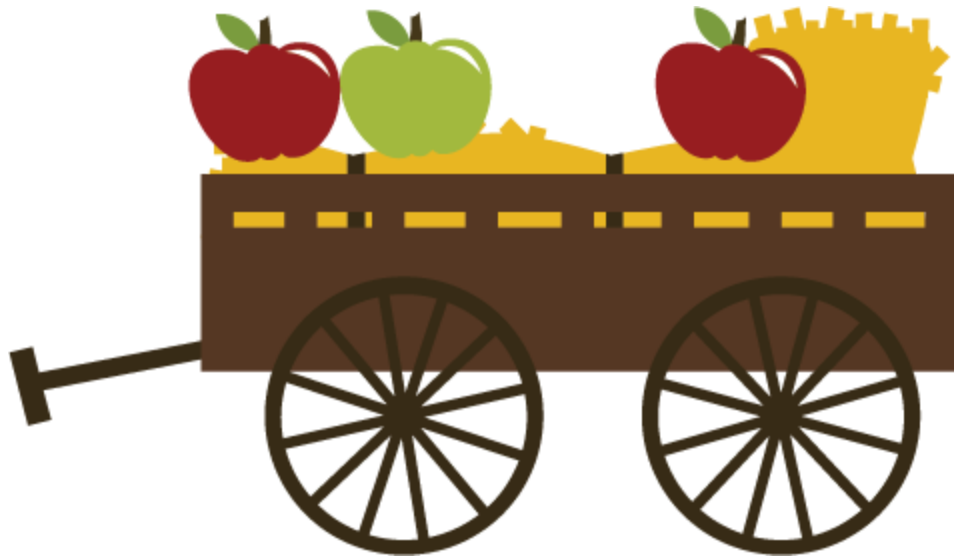




Sensors to measure soil moisture and ECe were added in four of the greenhouse beds at 3", 6", and 12" deep. Bed 1 had old soil and new irrigation; bed 2 had new soil and old irrigation; bed 3 had old soil and old irrigation; bed 4 had new soil and new irrigation. All beds were leached for salts with adequate amounts of water about 2 weeks after installing the sensors and were left to dry for about 2 weeks prior to turning on the irrigation. Sensor Results In Charts 1, 2, and 3 below, the leaching event happened at about 410 hours and the irrigation schedules resumed at about 825 hours. At 3" depth, the new soil and new (shallow) irrigation held the most moisture for germination, whereas the old soil and old (deeper) irrigation held the least moisture. The new (shallow) irrigation schedule did help to increase moisture levels in the old soils as opposed to the old irrigation.



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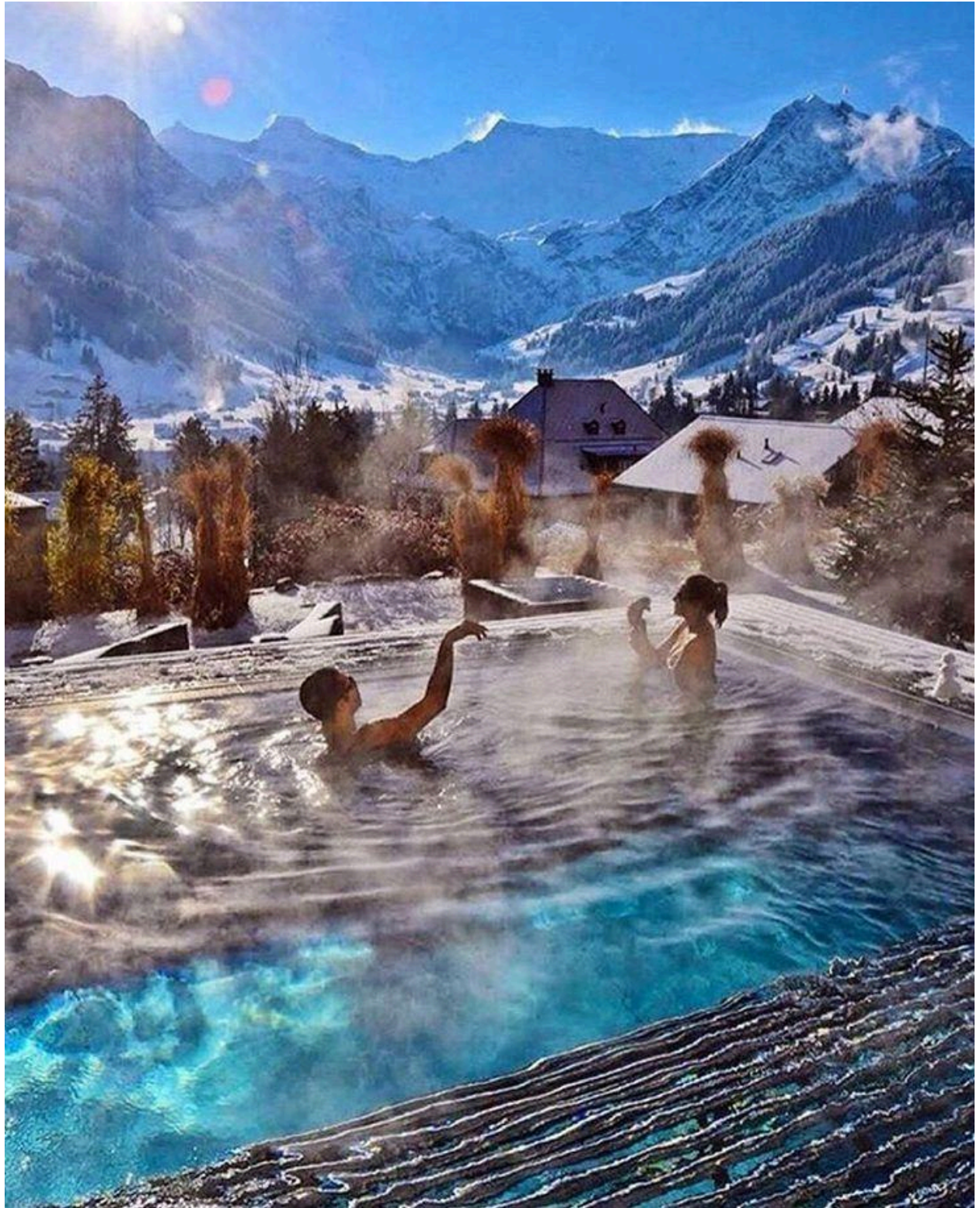
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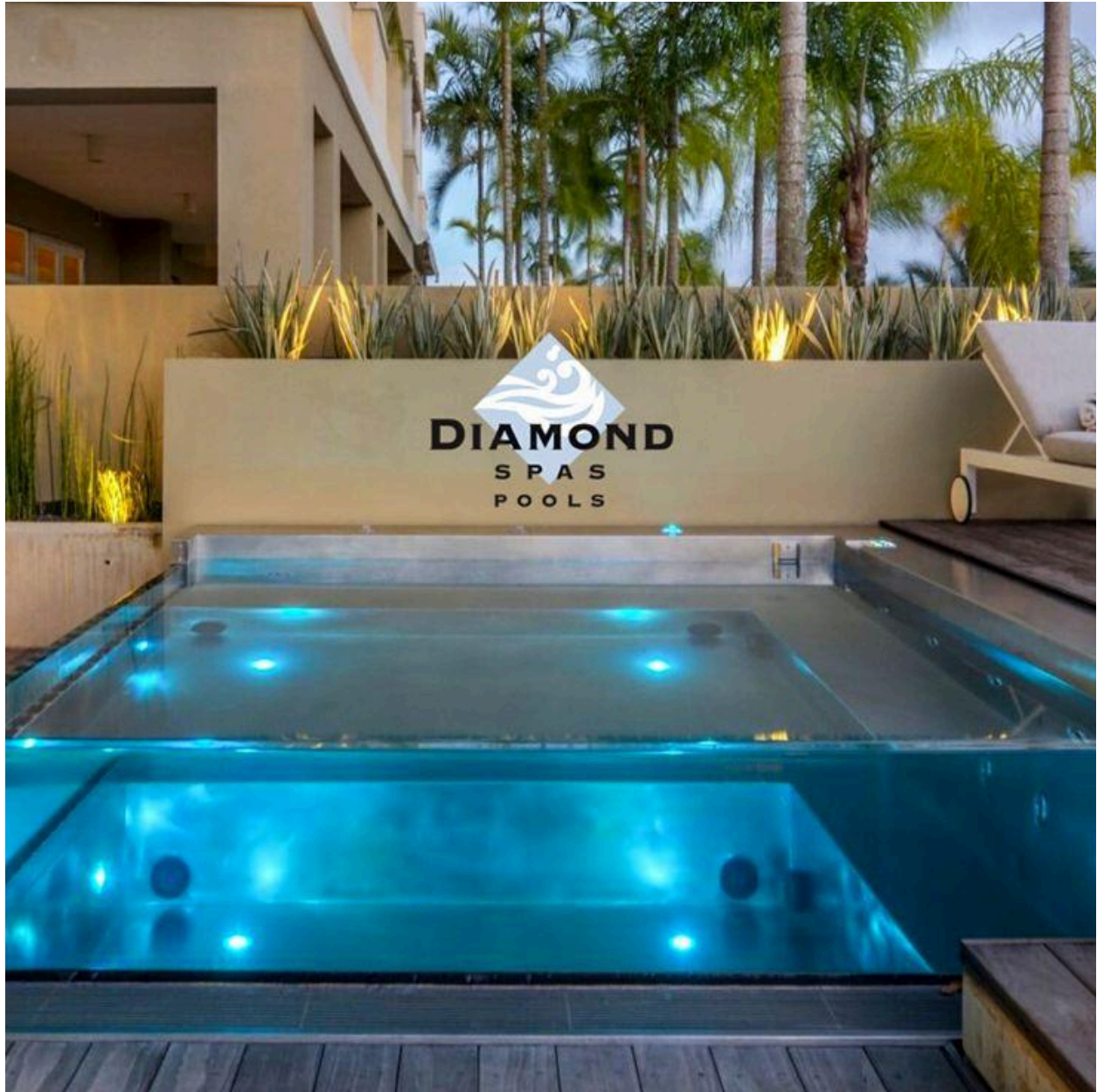
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Located at the northern-most point of world-famous Napa Valley wine country, Dr. Wilkinson's Back Yard Resort & Mineral Springs is a Calistoga, California landmark. A pioneering wellness destination, the historic resort features a mod, mid-century setting with lush, mature landscaping and a welcoming, attentive staff.

Amenities include three geothermal mineral spring pools for soaking and enjoying the warm California days, a luxury spa with an extensive list of services and signature mud baths that feature the volcanic ash unique to the region.

The resort was founded in 1952 by the late John "Doc" and Edy Wilkinson. As a chiropractor, Doc was

interested in alternative health and wellness benefits of relaxation from the days of his early childhood in California's San Joaquin Valley. On a visit to Calistoga, he was instantly smitten with the area and envisioned how the healing potential of the mineral springs and volcanic mud treatments could benefit health seekers. In fact, many years after its founding, the resort's mud treatments continue to be among the most popular spa services.

Additionally, Dr. Wilkinson's offers guests spacious, pet-friendly accommodations in a 50-room lodge, as well as in bungalows. Rooms feature comfy beds for a good night's rest, charming vintage décor and clean-lined, mid-century architecture.

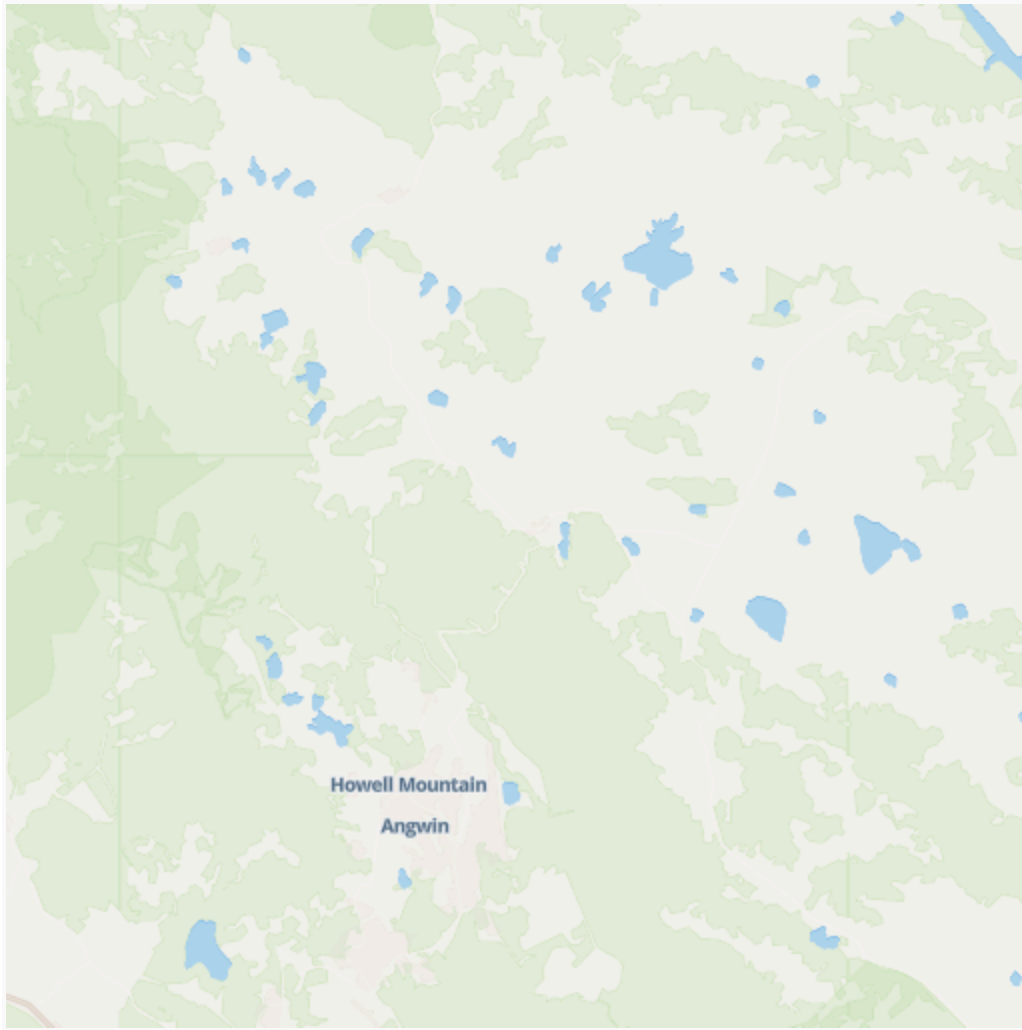
Welcome to Dr. Wilkinson's Back Yard Resort & Mineral Springs—Calistoga's Landmark Natural Mineral Springs Resort.

For additional insight read [Volcanic Ash Mud Baths a Mainstay at Dr. Wilkinson's Back Yard Resort & Mineral Springs.](#)

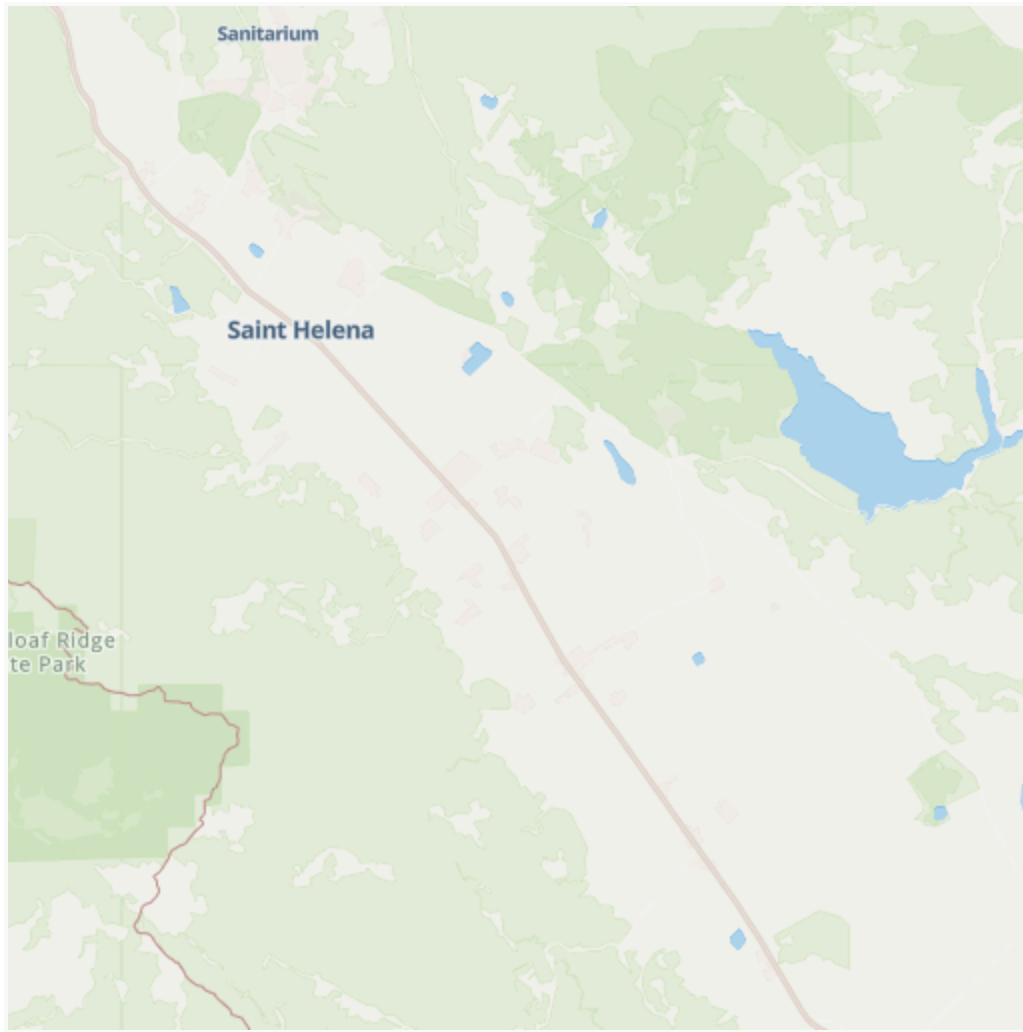












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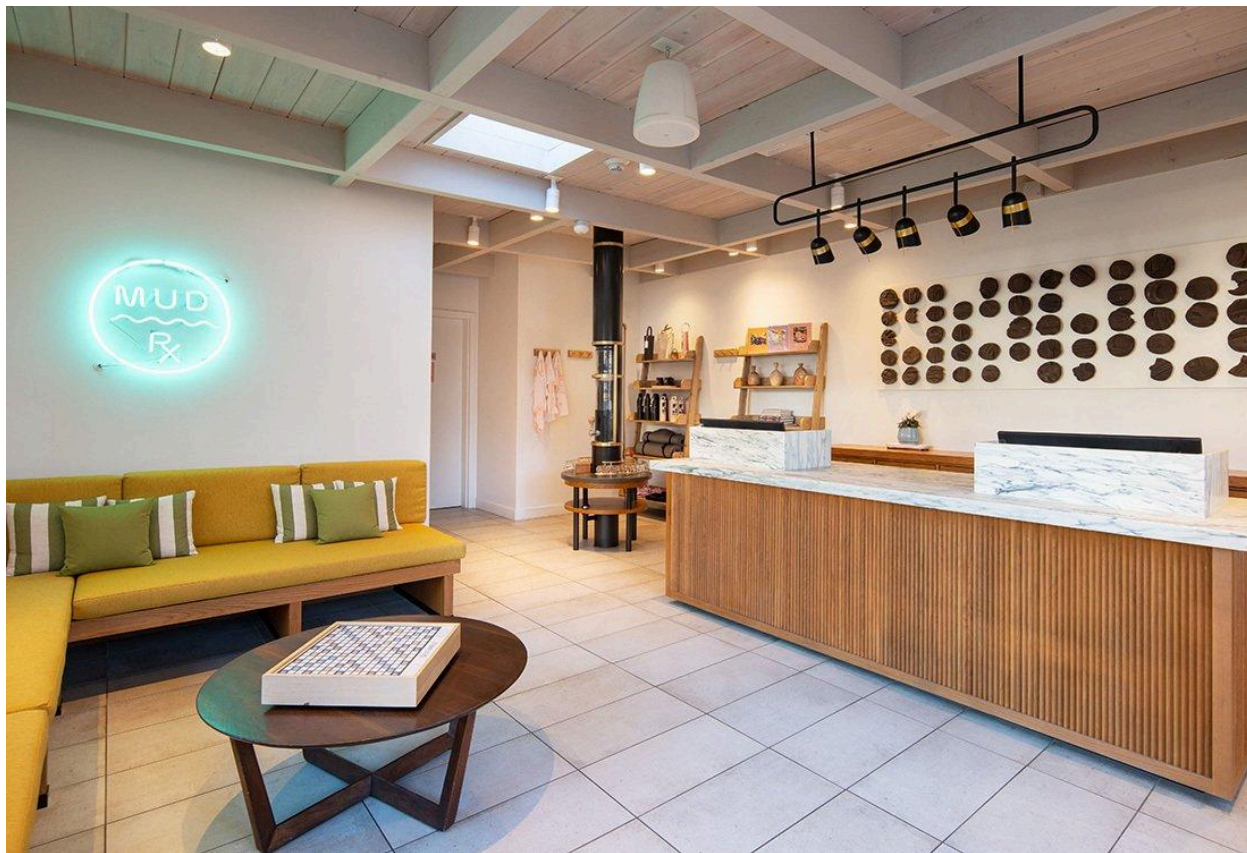
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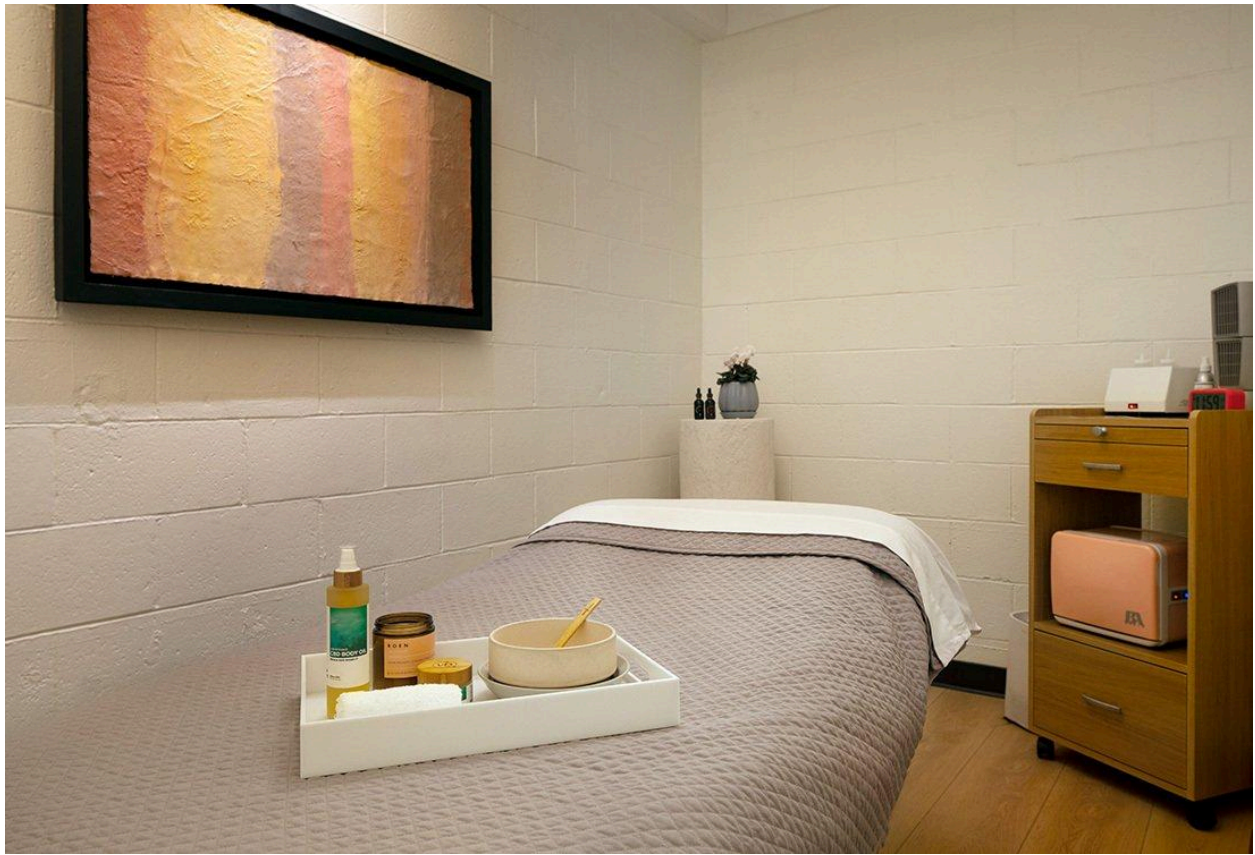


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