USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

SOIL SCREENING PROCEDURE USING pXRF

PURPOSE

The purpose of this procedure is to provide steps, and a comprehensive method, to conduct soil screening data collection of heavy metals or other targeted elements using a portable X-Ray Fluorescence (pXRF) device in urban areas. This method covers steps before and during on-site visits. The goal is to provide technical assistance and may be used for conservation planning development.

PROJECT DEVELOPMENT

Before visiting the site, a clearly defined objective for the project must be set. You should be able to answer the following questions:

- What will be analyzed?
- For what purpose?
- What elements are going to be surveyed?
- What is the practice being designed or in place that needs review?

The National Conservation Evaluation and Monitoring Activity (CEMA) Site Assessment and Soil Testing for Contaminants Activity (207) is available for adoption by NRCS States if Basic Site Assessment, Phase I Environmental Site Assessment, and/or Phase II Environmental Site Assessment is needed to meet conservation planning objectives.

SITE HISTORY AND LOCATION

Once project goals have been identified, a site history review should be conducted consisting of a documentation or literature search on changes in previous land use and land management. This information could provide insights into previous land uses, past or on-going disturbance including excavation or filling, or other activities that could create a resource concern. In addition to the local site history, it is important to know the history of the surrounding areas that might contribute past or on-going impacts to the study site. Nearby industry or major highways have the potential to generate particles that could be transported by wind for example. In addition, prevailing winds could also transport soil particles such as fine to very fine sands, silt, and clay. Silt and clay particles move the furthest distances and tend to carry contaminants with them.

- Sources of information include but are not limited to
  - Historical aerial photos
  - Historical topographic maps
  - Historical soil and geology maps
  - Geology maps with fill areas identified
  - Historical property records
  - Engineering plans
  - Wind history maps
  - How to understand the diagrams (About WindHistory.com)
  - Wind history map (Wind history map)
  - Flood maps
  - Interview with landowner or lease holder

INITIAL ON-SITE EVALUATION

The initial on-site evaluation consists of a walk around the site to observe the surface soil condition, possible resources concerns, and evidence of past and present site management. Recording observations provides information including the presence and amount of anthropogenic soil material, human artifacts, water discharge from adjacent properties, areas with evidence of ponding and/or flooding, and presence of non-native or invasive plants as well as others.

In addition to recording the observed information, a brief soil description of the dominant soil condition should be conducted if soil survey information is not available or if the available information is too general not providing sufficient information of the type of soil. The minimum soil description should record soil color, redoximorphic features, soil texture, percent, and source of the coarse material (rock fragment and human artifacts), soil structure, and depth to seasonal high-water table to a minimum depth of 1 meter or to a root restrictive limiting layer whichever is shallower.

Soil pH should be taken into consideration and measured as part of the brief soil description activities described above. Soil chemistry dictates the fate and transport of different elements in the soil.

Additionally, soil moisture and organic matter are two soil properties with the potential to influence the accuracy of the results. Soil moisture, even though, generally is not a limiting factor (Li and others, 2022), XRF readings decreased about 15 to 20 percent in samples analyzed with 30 percent moisture (Nakano, 2022) and in saturated samples significantly underestimate the results (Sahraoui and Hachicha, 2017). Likewise, organic matter has the potential to underestimate the concentration on some heavy metals because equipment soil models are developed using organic-free soil material (Ravansari and Lemke, 2018, and Shand and Wendler, 2014).

While the steps in this section do not constitute a Phase I Environmental Site Assessment, an awareness of ASTM E1527-13 methodology is beneficial for staff conducting pXRF soil screening.

SITE LAYOUT

Site screening layouts can vary depending on the present use, obstructions such as existing structures, and/or customer land use plans. The process starts by listing the different land uses such as cropping in the natural ground or raised beds. Then develop a data collection plan for each of the land uses with enough data points to avoid any unpredictability in data interpretations. For example, if you have two land uses with two different soil types, you will want to collect points in both soil types for both land uses. As opposed to composite sampling methods typically used for soil nutrient analysis in rural agricultural fields, mixing of samples from different spatial locations is not typically used for soil screening in urban areas. The primary reason for this is the need to identify potential hot spots of certain elements.

- Reconnaissance method
  - Zigzag: you walk in a zig zag pattern through the site and perform soil screenings
  - Random: you randomly walk around the site to perform soil screenings

The zigzag and random methods are implemented to get a general idea of the soil condition, to plan a detailed screening plan, or for very small study areas.

Figure 1. Data collection is following a non-linear patter or zigzag for general information.

Figure 2. Random data collection provides generalized information as a starting point for more systematic data collection.

- Sample size

  Sample size could differ by the sampling method, size of the study area, consistency of the soil material and the confidence level of the data collected. It is reasonable follow similar data collection rules used for map unit requirement in soil survey. Where typically, a soil survey will use a minimum of 30 recorded points for each map unit to document the composition for map units that are less than 2,000 acres (NSSH,

Section 627.8). However, the sample size must take into consideration consistency in data collected and must be adjusted or increased as data variability increases.

- Transect method
  - Linear transect
  - Modified linear transect

The linear transect or modified linear transect are systematic methods to be implemented for a detail screening plan that could be used to identify potential "hot spots" of targeted elements being evaluated. This information can be used to generate spatial distribution maps that are representative of the soil condition in the study area. The linear transect is a typical linear screening plan that consist of sample collection in a linear direction at an established interval. The modified linear transect is like the linear transect method with the difference that when a significance differences in measured element concentrations are identified between consecutive points, an additional sampling point is added mid distance before and after points with the purpose of finding a potential boundary.

Figure 3. Linear transect is a systematic data collection with a defined spacing between points and transects.

Figure 4. Modified linear transect is a detailed systematic data collection with the ability of capturing anomalies along the transects

A grid layout using linear or modified linear transect must consist of a minimum of three transects equally spaced. This will provide a better distribution of sampling points and generate a more comprehensive representation of the soil condition when spatial analysis is utilized with the collected data.

SOIL SCREENING

The soil screening must take into consideration possible lateral and horizontal movement of the targeted elements, the cropping system, and the crops. Two intervals are recommended according to the type of crop and the depth of the crop root systems. A typical approach would be to screen soils at such as 0 to 8 inches and a second screening from 8 to 18 inches in depth. Typically, most leafy vegetable root systems concentrate within 18 inches, fruit vegetables could root deeper (between 24 to 36 inches), and screening depths may need to be adjusted accordingly.

For crops that are grown in-ground and in raised bed where roots extend beyond the bed material into the soils underlying the bed, soil screening must be conducted in both growing media. This serves two

purposes, first to compare the condition of the on-site soil material spatial distribution and the material used in the raised bed, and second, to determinate if there is any upward movement of the targeted elements in the raised bed growing material. In areas without raised beds, the soil screening is conducted at two depths to provide information about potential lateral distribution. This information can be used to develop conclusions about how the targeted elements were deposited in the study area.

At the end of the soil screening meet with customer and soil conservationist to discuss the data collection report and if necessary, assist with strategy for soil sample collection and analyzing by a certify soil lab or possibly recommendation of the CEMA 207.

SAFETY

The portable X-Ray Fluorescence Analyzer is a secure instrument when used following best testing techniques and safety procedures (Olympus, 2015). In the USDA the Office of Homeland Security (OHS) – Radiation Safety Division (RSD) is the governing unit issuing permits (valid for 5 years) for the use and possession of radioactive materials or x-ray producing equipment. The Permit enables the Radiation Safety Division to keep track of radioactive material and x-ray equipment, including acquisition, transfer, and disposal activities. Permit request must be submitted to the Radiation Safety Division through the database, USDA employees who want to use radioactive material or x-ray producing equipment must have or request access to the Radiation Safety Division database (OHS-RSD).

DISCLAIMER

The data collected and reported as part of this procedure is not designed for use as a primary regulatory tool in permitting or citing decisions but may be used as a reference source. If landowner shares this information with a third party (e.g., organizations, agencies, units of government), they assume the responsibility for its appropriate application. Federal, State, or local regulatory bodies are not to reassign to the Natural Resources Conservation Service any authority for the decisions they make. The Natural Resources Conservation Service will not perform any evaluations of these data for purposes related solely to State or local regulatory programs.

REFERENCE

C.A. Shand and R. Wendler. Portable X-ray fluorescence analysis of mineral and organic soils and the influence of organic matter. Journal of Geochemical Exploration 2014, Volume 143, Pages 31-42. https://doi.org/10.1016/j.gexplo.2014.03.005

K. Nakano, S. Tobari, S. Shimizu, T. Ito, A. Itoh. *Effect of soil moisture and its correction method for quantitative analysis of hazardous metals in polluted soil for the on-site XRF analysis*. X-Ray Spectrom 2022, 51(1), 101. https://doi.org/10.1002/xrs.3263

Li, S.; Shen, J.; Bishop, T.F.A.; Viscarra Rossel, R.A. *Assessment of the Effect of Soil Sample Preparation, Water Content and Excitation Time on Proximal X-ray Fluorescence Sensing*. Sensors 2022, 22, 4572. https://doi.org/10.3390/s22124572

Office of Homeland Security (OHS), Radiation Safety Division (RSD). Radiation Safety Division Permits. https://www.dm.usda.gov/ohsec/rsd/permits.htm (accessed November 22, 2022).

Olympus Scientific Solutions Americas. *DELTA Family Handheld XRF Analyzer*. 2015. 48 Woerd Avenue, Waltham, MA 02453.

R. Ravansari and L.D. Lemke. *Portable X-ray fluorescence trace metal measurement in organic rich soils: pXRF response as a function of organic matter fraction*. Geoderma 2018, Volume 319, Pages 175-184. https://doi.org/10.1016/j.geoderma.2018.01.011

Sahraoui H, Hachicha M. *Effect of soil moisture on trace elements concentrations using portable x-ray fluorescence spectrometer*. J. Fundam. Appl. Sci., 2017, 9(1), 468-484. http://dx.doi.org/10.4314/jfas.v9i1.26

U.S. Department of Agriculture, Natural Resources Conservation Service. *National soil survey handbook, title 430-VI*. https://directives.sc.egov.usda.gov (accessed November 22, 2022).