REFERENCE SHEET: ACTIVE CARBON OR PERMANGANATE-OXIDIZABLE CARBON (POXC)

MATERIALS:

1. Potassium Permanganate ($KMnO_4$)
2. Calcium Chloride ($CaCl_2$)
3. Water: clean water from a faucet, or clean bottled water, is acceptable
4. Graduated cylinder, 25 mL or 30 mL
5. Centrifuge tubes, 50 mL or similar small bottles or tubes, for extracting samples
6. A small, graduated dropper or transfer pipet that has been calibrated to contain 0.5 mL (weigh it empty and then mark the line where it contains 0.50 g water)
7. Hanna colorimeter, model HI-717, 'checker' model for high range phosphate

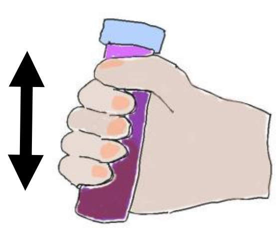
PROCEDURE:

MAKING THE PERMANGANATE + CALCIUM CHLORIDE SOLUTION, PER 100 ML OF SOLUTION:

1. Measure or weigh 100 mL water (equal to 100 g) in a transparent water bottle (an amber colored dark bottle or wrapping with tape or foil after preparation is also good, to protect the solution from light.
2. Add 1.11 g $CaCl_2$ for each 100 mL of water.
3. Mix the solution well until all $CaCl_2$ is dissolved.
4. ***To this same solution of water + $CaCl_2$,*** add 0.237g $KMnO_4$ (potassium permanganate) per 100 mL; or 0.24 g if you have a scale with only 0.01 g precision). Mix well.
5. Making a volume of solution greater than 100 mL will give greater precision in the concentrations, for example, 500 mL of solution with 5.55 g $CaCl_2$ and 1.185 g $KMnO_4$ (multiply 1.11g and 0.237g which correspond to 100 mL by 5) will mean that the weighing errors for permanganate are not as great.

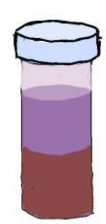
CARRYING OUT THE MEASUREMENT:

1. Mix 2.5 g of soil, sieved to 2 mm or with stones removed, with 20 mL permanganate solution, in a centrifuge tube (50 ml) or similar bottle. In practice, it is easier to pre-weigh soils in tubes and then add 20 mL solution to start the reaction as you begin measuring the time. Be sure to record the weight of the soil, which can vary a bit from exactly 2.5 g.
2. Close the tube well and shake for 2 minutes.



Shake 2 minutes

Figure 1



Let settle 10 minutes

Figure 2

3. Before allowing the solution to settle, swirl the capped tube once, without turning upside down, to wash any remaining soil from the cap and sides of the tube.

4. Let sit for 10 minutes. The clays will settle out because of the calcium chloride, leaving a purple solution without suspended soil.
5. During this time, or prior to the analysis, prepare a tube with 30 mL of tap water to dilute the permanganate solution, and at least one of 30 mL to prepare a dilution of the 100% standard or raw permanganate solution.
6. At the end of the 10 minutes settling time, withdraw 0.5 mL of the overlying soil-free solution with the dropper from the tube with permanganate and soil, as precisely as possible (Fig. 3). Add this to the tube with 30 mL of water to dilute the color for reading with the colorimeter. Rinse the dropper with the water in the tube, drawing and releasing a few times, to ensure that all the color is transferred to the tube with water.

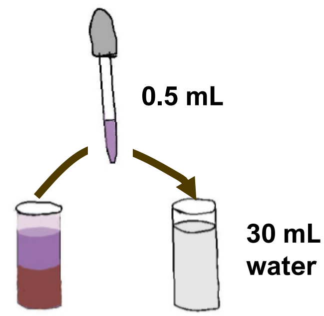


Figure 3. Transfer 0.5 mL of the purple sample solution to 30 mL of clean water. Repeat for raw solution without reacting with soil.

7. Also prepare the same dilution of 0.5 mL + 30 mL of water, but with 0.5 mL of raw permanganate solution directly from the reagent bottle and without having been exposed to soil. Call this the '100% standard'. Only one of these tubes is needed for an entire batch of samples, although preparing two can improve accuracy. It is used to compare the concentration of $KMn0_4$ with and without reacting with soil.
8. Take the reading with the colorimeter. For readings, you will need vials with the sample, the 100% standard, and a blank vial with just water. Pour the samples and 100% standard from the tube where it was diluted into the appropriate vials for the colorimeter (3/4-inch diameter). Make sure all vials are clean and free of dirt or stains on the outside, wiping clean if necessary.
9. For each reading, carry out the procedure shown in figure 4 and 5:
   a. Turn on the colorimeter by pressing the button and wait until 'C1' shows.
   b. Insert the blank vial with clear water and press the button.
   c. Wait for 'C2' to appear.
   d. Take out the blank and insert the sample to read and press the button again.
   e. Wait for the reading and then record it, for example '12.3'
10. Repeat the procedure with the 100% standard, which should have a higher reading than the sample, usually between 19 and 22.

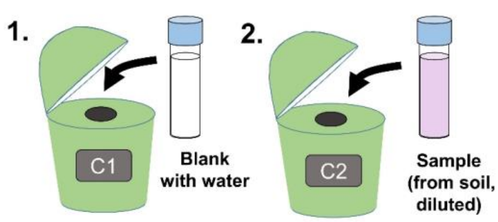


Figure 4. Reading of the sample reacted with the soil sample.

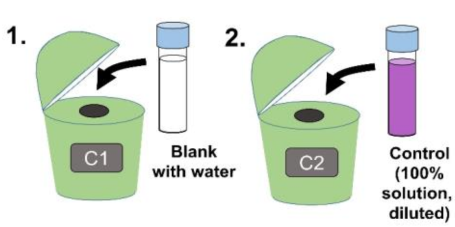


Figure 5. Reading the 100% standard.

11. To convert the readings into the level of active carbon in soil, you can use the online calculator in the tool kit website at https://smallholder-sha.org under the page for this method. You can also use the calculations shown in the manual for the tool kit at the web site. In addition, there are data forms available that will carry out the calculation, through an open data kit (ODK) survey app available at the soil health data platform at https://soils.stats4sd.org. After calculating the value of active carbon, which will generally range from 0 to 1200 mg C/kg soil you can interpret the results using the scoring table at the end of this data sheet.
12. **Note on performing the test on multiple samples:** The timing of the reaction steps in this test is important. For greater precision, it is essential not to vary the shaking (2 min.) and decanting (10 min.) times by more than 10 or 15 seconds. For this reason, to analyze several samples in a row, they should be organized into groups. One strategy is to work in groups of four samples. A single stopwatch is started and a table like the one below can be set up to record the designated timings and record any variations that occur. Sample codes and result values can also be recorded in this table to maintain a hard copy. In this way, about 10 samples per hour can be analyzed, and confusion over timing is avoided.

Sample	Start time (min)	Finish shaking (min)	Finish settling (min)	Colorimeter reading
1	0	2	12	
2	3	5	15	
3	6	8	18	
4	9	11	21	

Figure 6. An example of a table to track the timing of samples precisely, to aid in analyzing multiple samples.

13. Scoring table for active carbon or POXC results:

Active carbon value (ranges, mg C/kg soil)	Score or level	Description
<250	**Very low**	Indicates that the soil probably has not received organic inputs for many years, or that it is partly formed from subsoil due to erosion. These values also occur more frequently in soils in hot climates or with a sandy texture, where residues decompose more quickly.
250-400	**Low**	Indicates a soil that requires more organic inputs or residues to support microbial life, water holding capacity, and to contribute to a strong physical structure (aggregation).
400-600	**Medium**	Soil organic matter is likely supporting biological nutrient cycles, water retention, and other benefits in the soil. These values are also more frequent in soils with a clay texture, which accumulate organic matter more easily. Meanwhile, in a sandy soil these values may represent excellent levels of organic matter.
600-1000	**High**	The soil has high levels of organic matter that may result from remnants of forest or plain or grassland vegetation, or from a special effort to increase organic matter through inputs, incorporation of residues, or fallow practices.
>1000	**Very high**	These very high values are only found in home gardens that receive a lot of manure or compost, soils recently converted from forest or plains vegetation, or in peat soils that can occur in drained marshland and at high elevations. They mean that soil can be highly productive and that added nutrients will remain available. However, these values are not easily found in more extensive systems with cereals or tubers where the level of available inputs is not enough for the cultivated area.