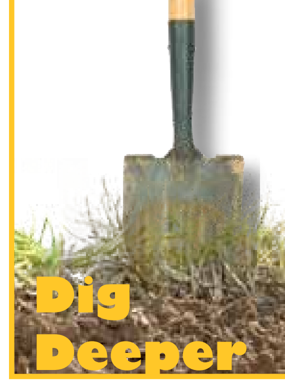
Color Changes in Soil



Instructional Value

Soil chemistry - Soil Morphology
Grade Level: 6+ grade

Type of Lesson

a. Initial demonstration
b. experiment with different materials

Materials Needed

Red, yellow or brown soil
Some moist topsoil or wetland soil
2 or more Pint Mason Jars with lids
Water
Sugar
Additional carbon sources (hay, saw dust, leaves). All should be coarsely ground.
Autoclave or water bath

Time

Teacher prep time – 30-60 minutes
Student class time – 30-60 minutes initially and then observation over days to weeks.

Student Learning Objectives

a. To explain why soils are colored
b. To be able to show that soil color is a coating
c. To explain that water can change the color of the soil
d. To determine how fast color can changes based on several factors

Keywords

soil color, iron oxides, rust, quartz, feldspar, oxidation, reduction, redox, anaerobic, aerobic

Summary

The students will learn that soil color is only skin deep so to speak. The major coloring agent is Fe-oxides or rust. It occurs on the surface of particle just as the color on an M&M is only on the surface. The color can be removed or dissolved off in water. Once removed it is unlikely for the color to return. So the particles that have no coatings help to tell a soil scientist where the soil has been saturated. The rate of the reaction varies due to the type of organic materials present, the type of materials and the amount of Fe-oxide coatings.

Why is this subject/activity important – Soil color is used to identify where the water table is in the soil. This is used for many types of building projects.

Background Information

Soil color can tell us a lot about the soil and the environment. Dark black top soil indicates high organic mater contents as compare to light brown colors. The presence of gray colors in the soil is used to determine the water table depth. This is done when assessing the site for many land uses related both to agriculture and well as urban/suburban development. Often the gray colors are referred to as wetness mottles or redoximorphic features (formed from reduction and oxidation chemical reactions in the soil). Many land use decision are based on these colors and the fact that they do not change season to season. Thus in summer when water tables are deep gray colors indicate how high the water table will rise during the wettest time of the year.

The color change from red (rusty) to gray observe in the soil is due to reduction and oxidation of Fe. This process occurs in soil but in saturated soil this occurs when $Fe3^+$ is reduced to $Fe2^+$ due to a microbial mediated redox reaction.

If air ($O2$) is in the soil the soil is aerobic

- $4e^- + O2 + 4H^+$ à $2H2O$ – rusty or oxidized color persist

If all $O2$ is removed soil becomes anaerobic (saturation occurs)

- Denitrification
  - o $10e^- + 12H^+ + 2NO3$ à $N2 + 6H2O$ – no color change
- Iron (Manganese) Reduction
  - o $2e^- + 6H^+ + Fe2O3$ à $2Fe(II) + 3H2O$ – soil turns gray
- Sulfate Reduction
  - o $8e^- + 10H^+ + SO4$ à $H2S + 4H2O$ – rotten egg odor

You should see little to no changes in the autoclaved sample. This is due to the microbes being killed by the heat. In the other jars bubbles will start to form and over time the soil will turn gray. This may take longer in some soils due to the amount of iron, food, and microbes present in the soil.

Other variables that can be tested are exposure to sunlight (little affect), placing some jars in a refrigerator (slower reaction), or placing jars in a warmer location (faster reaction).

Go outside and dig in the soil. From the colors you observe, can you make a prediction on where the water table is (saturated and reduced – anaerobic conditions)?

Once the gray colors due to $Fe3^+$ reduction and removal have formed it is unlikely that the particles will become coated again. Since this reaction occurs in saturated and reduced or anaerobic conditions the presence of gray colors indicates where the water table is in that soil. This helps soil scientist identify wetland or hydric soils and locate suitable soils for septic systems and related land use. This reaction only occurs if there are sufficient numbers of microbes and a food source (carbon) present to cause anaerobic conditions to occur.

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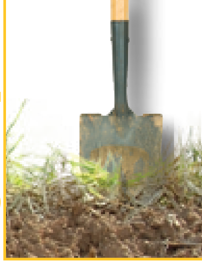

Vocabulary

Fe-oxide – rust
Water table – depth in the soil where the soil is saturated
Saturation (saturated) – water in all pore; water will flow into a hole dug in saturated soil
Anaerobic – no oxygen present
Aerobic – oxygen present
Oxidation – loss of electrons
Reduction – gain of electrons
Redox – combination of reduction and oxidation reactions

Methods/Procedure

1. Fill each jar approximately ½ way with soil.
2. Add a ½ teaspoon top soil
3. Close and shake to mix
4. Remove lid and add at least 2 tablespoons of sugar. You may want to mix but it is not necessary at this point. You could also use different carbon sources – saw dust, corn syrup, grass clippings etc. as well. Each one of these would constitute an additional treatment or experimental variable
5. Fill each jar to within about ¼ to 1/8 inch of top.
6. Put lids on jars.
7. Shake to mix well.
8. Take 1 jar and autoclave it following the instructions for autoclaving liquids. Note: If an autoclave is not available process the jar in a water bath as if canning fruit or vegetables following the USDA methodology for home canning.
9. Allow the jar to cool – make sure lids are tight.
10. Let the jars sit and observe changes over the course of a few weeks.
11. Record observation, particularly color changes and bubbles.

Notes

1. There will be some gas leakage as the reactions occur. Keep all jars in a location where they will not be disturbed. The jars can be placed in a water bath to prevent oxygen from entering if jar seal is compromised.
2. Open the jars very carefully at the end of the experiment as contents could be under pressure.
3. The reactions could occur in as little as 72 hours or could take several weeks.
4. The degree of color change will be variable. Use the control (autoclaved sample) to compare colors.

Questions

1. Discuss why the color changes – it is washed off or dissolved off
2. Discuss if it is likely that the color will change back – it is not likely
3. If you see gray (uncoated) colors in the soil what can that tell you – the soil may get saturated to that depth
4. Will the gray colors in the soil still be gray even when the soil is not saturated – yes, once the color is removed it is not likely to return
5. How does the type of carbon affect the rate of change
6. Why does the change not occur immediately
7. So if you dug a hole and you saw gray colors near the surface would this be a good place to
   i. build a house – No it may be wet
   ii. dig a pond – yes it may be wet

Additional Resources

www.soils4teachers.org