Does Soil Breathe: A Respiration Activity!

Soil Science Society of America

NGSS:
HS-LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

HS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience

HS-ESS2.E: Biogeology

MS-ESS3.C: Human Impacts on Earth Systems

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When mentioned, most people think about what they can see: earthworms, ants, centipedes, millipedes, pill bugs, termites, grubworms, and other insects which spend part of their life in soil. But that is only a miniscule fraction of the diversity of soil life. Microorganisms – microbes – are microscopic organisms that cannot be seen with the human eye. In soils with no limiting factors, there are more microbes in a handful of soil than there are people on the planet. Even these organisms come in a variety of sizes, including bacteria, actinomycetes, algae, fungi, protozoa, and amoebae, among many others.

Five things are necessary for all living organisms to survive and grow:

- water,
- energy (electron donor),
- electron acceptor (oxygen for aerobic organisms),
- carbon source,
- essential elements (nutrients), and
- growth factors (organic compounds they cannot make, like some amino acids)

In photosynthesis, plants obtain water from the soil, carbon from carbon dioxide in the atmosphere and energy from light to form carbohydrates, organic molecules which are the basic building blocks of all other compounds organisms need. Humans obtain their energy and carbon from food as it is digested. Microbes get energy and carbon during decomposition of their "food" - the organic materials in the soil, including dead plant and animal parts, plant exudates (organic compounds that leak from plant roots) and organic matter (partially decomposed products).

Respiration is essentially photosynthesis in reverse:

- Photosynthesis: water + carbon dioxide + energy from light (electrons) => carbohydrate
- Respiration: carbohydrate => released electron (energy) + carbon dioxide + water

In microbial respiration – digestion and decomposition – about 25% of the carbon is used for growth and reproduction and about 75% is released into the soil as carbon dioxide.

A lack of, or imbalance among, any of those five necessities will affect the amount of biological activity in soil. Further, other soil properties and conditions such as soil texture, temperature and pH affect the availability of the essential elements and the number and type of organisms present.

- Too little water decreases respiration and there is essentially no biological activity in dry soils. Most microbes can enter an inactive mode and exist until favorable conditions return. This is very common among microbes in arid and semiarid regions.
- Too much water generally slows activity as it decreases the oxygen availability and favors anaerobic organisms that use other electron acceptors, such as nitrogen.
- Biological activity increases with temperature from about 5 to 35 °C, then decreases, and little activity occurs below 5°C and above 45°C.
- Simple carbohydrates, such as sugars, are easier to decompose than starches, such as flour.
- Fine-textured soils generally support more organisms than coarse-textured soils.
- Darker soils generally have more organic matter (humus) – food – and have more organism activity than light-colored soils.
- Salt in large amounts decreases microorganism activity.

Extremophiles are microbes that can survive under extreme conditions such as very high or low temperatures, high salinity, very acid or very alkaline soils.

Observing respiration

Though we cannot see respiration, we can observe the result. This simple activity can be used to demonstrate the relative amount of microorganism activity in the soil. Water and a food source are added to the soil, and a balloon is placed on the bottle to collect the carbon dioxide released as the organisms decompose the food source. Different soils, temperatures, amounts and types of food sources (ease of decomposition) can be used to observe their effects on organism activity – the amount and rate of decomposition. More decomposition releases more carbon dioxide, resulting in a larger balloon.

Materials:

- Clear 0.3- to 0.5-L bottles, such as water bottles (larger bottles = more soil = more organisms = more potential activity)
- Small balloons (≤ 15 cm, 6-in)
- Energy source – sugar or others
- Soils of different types: texture, color, from different depths or different management – lawn, garden, prairie, forest, desert, farmed – cultivated or uncultivated, cropping systems – types of crops, etc.

Method:

- Fill each bottle with the same amount of soil, a little more than ¾ full.
- Add soil a bit at a time and gently tap the bottle on the table or a hard service between each addition.
- Apply treatments, then place the balloon over the mouth of the bottle.

Possible treatments:

- Nothing added
- Water only
- Mix 15 ml (1 Tbsp) sugar in 100 ml water until dissolved. Slowly add water until soil is moist but air pockets are still visible in pores along sides of the bottle. Often this requires adding water, waiting for it to infiltrate and wet the soil, then adding more water. Depending upon the size of the bottle and initial water content, more than 100 ml may be required. This may result in different amounts of sugar in the soil, adding another variable.
- Double the amount of sugar.
- Add 15 ml flour to the soil before adding to the bottle, then add water without sugar.
- Dissolve 15 ml salt in 100 ml water and add as described above.
- Use your imagination: leaves, grass clippings, tea or coffee grounds, compost, etc.

Procedure:

- To begin, pick one of the above treatments, including a control, for example:
  - Sugar water added to two different soils
- For a more complicated experiment, use one soil with a treatment and controls, for example:
  - Nothing added, water only, sugar only and sugar water to the same soil.
- Set the bottles aside in a warm place 20 to 30 °C.
  - To observe temperature effects, place one of the bottles in the refrigerator.

- Wait and observe.
    - Make observations every 2 to 3 days for the first two weeks, then weekly thereafter.

Some balloons may fill within a few days, others may take weeks or not fill at all. The size of the balloon indicates the amount of biological activity – respiration. Some balloons may expand then decrease in size due to osmosis as carbon dioxide crosses through the balloon to achieve an equilibrium with carbon dioxide in the atmosphere. Unless sterilized, all soils contain some microbes. But if a soil begins with very few organisms, it takes time (maybe hundreds or thousands of generations) for the population to increase sufficiently to produce enough carbon dioxide to begin filling the balloon.

Observations:

- Record: date, diameter, and height of balloon.
- Journal: At each observation time, consider these questions:
    - Do all treatments have the same result?
    - Do soils make a difference?
    - Can you see any changes in the soil color or pores?
    - Does the soil appear to get wetter?
    - Do you see bubbles rising to the soil surface?
    - Can you think of other questions?
- Graph the data for each balloon with time as the X-axis.

Example data sheet:

Air in balloon (Y/N) – pay careful attention to the appearance of the balloon when first put on the bottle.

Balloon inflated (partially, erect)

Erect balloon (height above mouth of bottle, diameter): record dimensions in mm

Day	Soil 1, water, no sugar				Soil 1, water + sugar			
	Air? Y/N	Inflated?	Erect		Air? Y/N	Inflated?	Erect	
			height	diameter			height	diameter
0								
2								
5								
7								
10								
14								
21								
28								

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