INVESTIGATION:

Flour vs. Bread: How Soil Aggregate Structure Influences Water Flows

Time: 15-60 minutes, depending on the amount of discussion.

Grade Level: appropriate for any age.

Summary: If I only have time to do one activity with a group, this is my favorite one. Using flour and bread as models of degraded versus healthy soil, this exercise engages people in a hands-on exploration of what happens when water (or wind) hits aggregated vs. un-aggregated particles. The main takeaway is that microorganisms and other living things are responsible for creating the structures and pore spaces of the "soil carbon sponge" that we depend on for the water cycle to function properly on land: giving us clean filtered water, protection against flooding and drought, .and a stable infrastructure for our civilization. (Parts 2 and 3 can be swapped if you like, and there are lots of additional activities at the end that can be added on.)

Setting: Indoor classroom or other indoor space. A sink is a big help!

Materials:

- ✓ White Flour (if you have students with gluten allergies you may want to choose a gluten-free flour), approximately 1 cup for each team.
- ✓ Square loaf of sliced white bread, 2-3 slices for each team.
- ✓ Paper cups (any size--but smaller is better so that people don't overdo it with the water!), 2 for each team. Make sure you can poke holes in them.
- ✓ Water available for each team—in water bottle or second cup.
- ✓ Toothpicks, or unfolded paperclips, to poke holes in cups.
- ✓ Large plastic plates, 2 for each team. (make sure there is room to leave some space around the bread for water to flow without dripping off the edge.)
- ✓ (Optional) paprika, for filtration experiment.
- ✓ Compost bucket for wet bread and flour at end.
- ✓ WORKSHEET: Why Does Water Move Differently into Flour than into Bread?

➧ **Note**: At the end of this activity, you will end up with a lot of wet bread and wet sticky flour. It is helpful to have a compost bucket ready, and a plan for whether you are going to wash off the plastic plates to use them again, or just dispose of them.

Video Examples:
Emaline's Demo of Water infiltration
https://www.youtube.com/watch?v=LLuWvekrnYw

Soil Runoff Dinner Party Demonstration Part 1:
https://www.youtube.com/watch?v=9aC9kynpVxk
and Part 2: https://www.youtube.com/watch?v=6ewiV19yJoQ

Goals:
After this activity, participants will be able to:

- Understand that living organisms create soil structure.
- Describe and visualize how extreme weather events will affect healthy vs. degraded soil.
- Create a mental picture of healthy soil as a living, sponge-like structure, covering the landscape, and that accepts, holds, and filters water, and maintains its structural integrity.
- Understand that healthy soil has two aspects: mineral and biological.

Assessment: Completed worksheet with correct observations and reasonable hypotheses.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:

HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Science and Engineering Practices:

Asking Questions and Defining Problems; Developing and Using Models.

Disciplinary Core Ideas:

LS2.C Ecosystem Dynamics, Functioning, and Resilience

ESS2.A Earth Materials and Systems; **ESS2.C** The Roles of Water in Earth's Surface Processes; **ESS2.E** Biogeology; **ESS3.B** Natural Hazards; **ESS3.C** Human Impacts on Earth Systems.

ETS1.A Defining and Delimiting an Engineering Problem; **ETS1.B** Developing Possible Solutions

Cross-cutting Concepts:

Structure and Function, Stability and Change

Common Core State Standards:

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

SL.9-10.1 and 11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on appropriate grades' topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Activity

Part 1: What happens when you pour water onto flour?

Hands-on

1. Put about 1 cup of flour in a small pile onto a plastic plate for each team.
2. Tell them to imagine that this flour is soil.
3. Explain that the **substrate** (or base material) of soil is simply broken down rocks. This is called the **mineral portion of soil**, referred to as "**sand, silt, and clay."**[1]
4. Hand out a cup with about an inch of water in it, plus a second empty cup, and a toothpick (or unfolded paperclip) to each team.
5. Have someone from each team poke about 10 small holes in the bottom of their empty paper cup, to create a "Rain Cloud."
6. Ask people to watch carefully what happens to the water, while one person holds the "Rain Cloud" over the flour, and another person pours water into it so that it rains down onto the flour.

Observing

› Ask: *What do you see happening?*

Let the participants notice and describe as many things as they can, prompt if necessary:

› *Is the water soaking in?*

› *Where is the water going?*

› *Is the water that is running off clear?* (No, it has particles in it.)

› *What effect is the water having on the flour?* (Erosion is happening—creating gullies in the flour—and it is also sealing off the surface)

Small group processing

Use worksheets, and/or discuss in small groups

1. When rain water runs off the land, where does the water go?
2. If soil erodes, and the particles get washed away, where do the particles end up?

---

1 The size and shape of the mineral particles classifies them as "sand" "silt" or "clay." Most soils will have some combination of **sand, silt, and clay**, and the relative portion of each of them will define the basic **soil texture**. This will be addressed in another activity, and there is no need to go into it here unless someone asks.)

3. Why do you think the "soil" moved with the flow of water?
4. What would need to be different in order for the particles to stay in place?

Group discussion of same questions

Part 2: What is the Difference Between Flour and Bread?

Hands On

Give each team a plate with two or three slices of bread piled up in a stack.

Engaging Question

› *What do you add to flour to turn it into bread?* (Participants will often say "add water" and others will say "add yeast.")

› *What is yeast?*

Brief Lecture: *healthy soil is alive!*

Explain to participants that there are only three ingredients necessary to make bread: flour, water, and yeast. Yeast is a microorganism, a tiny living thing that does work. To turn flour into bread, you need biology—living things— to do that work.

A very similar thing happens with soil. Microorganisms and other living things turn mineral particles into a structured soil—with pore spaces.

How do they do that? All living things exude carbon-rich "snots, slimes, and glues." These are called **exudates**. We exude them when we are alive and also after we die. Usually those exudates are sticky. In healthy soil with lots of life in it, the exudates from roots, fungi, bacteria, earthworms, and other living things help bind the particles of sand, silt and clay together into **aggregates**, leaving **pore spaces** in between. This process is called **soil aggregate formation**. Thread-like root hairs and fungal hyphae help tie those smaller aggregates together into a porous spongy structure that holds and filters water and maintains its structure. We call that the **"soil carbon sponge."**

In actual soils, the particles are not made of flour, they are made of tiny pieces of rocks. The (non-living) **mineral portion of soils** comes from the breakdown of rocks over time. The largest particles are **sand**, medium-sized particles are called *silt*, and the smallest particles are called **clay**. It can take 1,000 years or more to form a single inch of sand, silt, or clay. Most soils have a mixture of these three in different ratios.

Without contact with life, however, these particles cannot become soil. They are just particles of sand, silt and clay. (Some people call this dirt, rather than soil.) In order for those to become soil, they need to be in contact with living organisms, root hairs, **fungal hyphae**, and the exudates and remnants of living organisms ("the living, the dead, and the very dead.") Over time, the relationship between lifeless minerals and living organims creates living soil, or a soil carbon sponge. This soil carbon sponge is a living ecosystem, with many processes going on all at once, similar to the living tissue of animals.

We will talk more about the details later, but let's see what happens when water hits bread: flour that has been transformed by microorganisms into an aggregated porous structure. The bread is a lot like the structure of the soil carbon sponge.

Part 3: What Happens When You Pour Water onto Bread?

Hands-on

1. Put a stack of several slices of bread (with crusts cut off) onto the second plastic plate for each team. Ask them to imagine this is healthy, living soil.
2. Using the same cups, ask people to watch carefully what happens to the water, while one person holds the "rain cloud" over the bread, and the other person pours water into it so that water rains down onto the bread.

Observing

› *What do you see happening?*

Let participants notice and say what they observe. Prompt if necessary.

› *Is the water soaking in?*

› *Is it running off?*

› *Are the flour particles that are in the bread moving with the water or staying in place?*

› *If the bread were soil, would the rain reach the roots of the plants?*

› *If there were contaminants in the water, or on the surface of the bread, how well do you think they would be filtered out before they reached the bottom or got out to the edge of the plate?*

GROUP SHOUT OUT

Ask this series of questions and let people call out the answers as a group. (The answer to all of them, except the last one, should be "THE BREAD!!")

- *If you lived in a place where it rained a lot every year, and there was a lot of flooding, which kind of landscape would you rather have around your house, the flour or the bread?*
- *Let's say you lived in area where it only rained a few inches every year, and you were trying to grow food, which kind of land would you want to be farming on, the flour or the bread?*
- *What if you got your water from a well? Which would fill the well better?*
- *What if you lived somewhere very hot and dry, would the bread or flour hold water better without it evaporating?*
- (I pick up a plate of flour that isn't completely wet, and hold it up, ready to blow on it…) *What if you lived somewhere VERY windy—like the prairie was during the dust storms—what kind of land would you want around you, the flour or the bread?*
- *What if you lived somewhere prone to earthquakes, and you were trying to build roads and bridges and railroad tracks? Would you rather be building them on the flour or the bread?"* (I usually shake the two plates here)
- *What if you were a fish in a lake, and people were using chemicals that were poisonous to you on the farms that surrounded the lake, would those chemicals be more likely to be filtered out through the flour or the bread?*
- *If the water or soil became polluted with something hazardous, which landscape would be more likely to clean the water before it reached a well, stream or lake?*

Small group processing

Use worksheets and/or discuss in small groups:

1. Why do you think the water entered the "soil" more easily this time?
2. Why do you think the "soil" stayed put this time?
3. What is different with the structure of the particles?
4. If you compare the bread and the flour, which one reminds you more of living tissue (such as that found in an animal or plant)? In what ways is (the bread) similar?

Group Discussion

- *Is there any situation where you think the flour would be better?* (The only ones I can think of are some species adapted to living in relatively pure sand in a geological desert or coastal area, such as clams, turtles, etc.)
- *When water runs off the land, where does it go? What kinds of problems does runoff create?*

› *If soil erodes, and the particles get washed away, where do the particles end up? What kinds of problems does erosion create?*

› *What do you think you would need to do in order to create living soil out of degraded soil that has reverted back to mineral particles?* (We will cover this in the Soil Health Principles section.)

OPTIONAL ACTIVITIES

1. **Wind blowing onto bread vs. flour**
   For younger students, before pouring water, have students blow on the flour and bread, (or take plates with flour vs. bread outside on a windy day.) This can be useful when discussing the dust bowl.

2. **Creating a landscape with bread vs. flour**
   Using a water play table, or a large, shallow plastic box, create a landscape with bread as the soil, leaving some space for "rivers" and "lakes." Rain onto the landscape and see what happens. Repeat using flour or very fine sand and see what happens. Do the rivers and lakes stay in place? What happens when there is a flood?

3. **Which one works better as a filter?**
   If the water or soil became polluted with something hazardous, which system (flour or bread) would be more likely to clean the water before it reached a well, stream or lake? Put paprika or other particulate matter into the water, repeat experiment.

4. **Raining onto hardened flour**
   Mix flour and water, and leave out to dry in sun. Repeat activity to show how water moves onto hardened desertified predominantly clay soils, in places like Africa.

5. **Raining onto compacted soil**
   How do you think driving heavy machinery over healthy soil would impact it? Squish the bread with your hand, and use a 5x magnifying loupe (available online from The Private Eye) to observe what happened to the pore spaces. Pour water over it again. What happens to the water? Does it run off? Do the particles of bread move?

Part 4 (optional): "Raining" on Real Landscapes

Hands on

Save the cups, and go outside with a gallon of water and "rain" water on various soil surfaces, such as loose soil at the edge of a parking lot, grassy areas, flower beds, school gardens, etc. Try digging up some grass as well, and rain underneath it.

Observations

› *What do you notice?*

On worksheet, have participants mark down which places were more like flour, and which were more like bread.

Part 5: Moving Forward

Circle Questions

Ask all participants to take turns answering the following questions (or if time is short ask them to write answers on a sticky note, and put them on the board as they leave):

› *What did you learn and how do you feel about it?*

› *What new questions do you have, based on what you learned today?*

Keep track of the new questions, and use some of them to begin the next activity.