Quicksand: a case of liquefaction

Soil Science Society of America

Type of Lesson
Hands-on

Materials Needed
- 3 plastic bottles
- 3 cups
- Support structure (a box works)
- Bottle of water
- Bare soil
- Soil with leaf litter/mulch
- Soil with grass

NGSS Standards
- ESS2.A
- ESS2.C
- ESS3.B
- PS2.A
- PS2.B

Quicksand is an interesting natural phenomenon that happens when soil begins to act more like a liquid than a solid. The "quick" refers to how easily the sand (soil particles) shifts when in this semi-liquid state.

First the Sand …
Though soil may seem solid, it is really a mixture of particles (sand, silt, clay) of different sizes with pores (spaces) between them. As the name implies, most of the particles in quicksand are usually sands (although some silts can be “quick).” While most soils have structure (aggregates that are clumps of soil particles held together by soil “glues”), sands are typically without structure.

So how does a sandcastle stay together? As a kid, you might have discovered that you can’t build a sandcastle with dry sand. Why? Friction and gravity are the only forces at work in dry sand. Sand grains have rough edges and irregular shapes. In dry sands, these shapes help “lock’ the sand grains together so that while gravity tries to pull the sand into a flat layer, the friction of the rough edges causes the sand to form a mound. Then, water adds two more forces to the mix: adhesion – the attraction of water for the sand particles, and cohesion – the attraction of water molecules for other water molecules. In a wet and unsaturated sand, the combination of adhesion and cohesion creates a tension that pulls the particles together, thus keeping a sandcastle together.

Then the “Quick”…
In sandy soil the solid particles might comprise 60 to 65% of the total volume. The other 35 to 40% of total volume comprises the pores, the empty space between the particles. However, the space is not really empty – it is always filled with air and/or water. In dry sand less than 5% of the pore volume would be water and in an almost saturated sand, less than 5% of the pore volume would be air.

Top: mound of dry sand
Middle: wet sand
Bottom: saturated sand
Credit: Clay Robinson, https://cdrdirt.com/sand-castles/

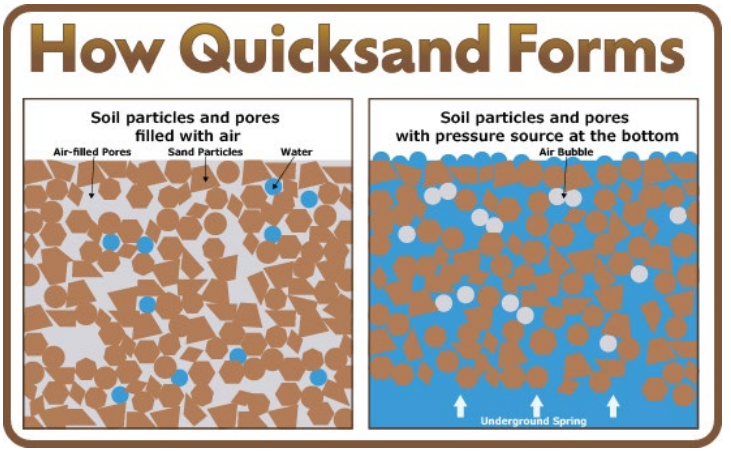
Soil is saturated when its pores are almost completely filled with water, essentially forming a soupy mixture of soil particles and water,

The saturated soil becomes “quick” when it is suddenly agitated**.** When the water trapped in the pores can’t escape, the tension that held the sand particles together becomes a pressure that pushes them apart, creating a **liquefied soil.** There are two ways in which these soils can become agitated enough to create quicksand:

- **Flowing underground water** - The force of an upward water flow opposes the force of gravity, pushing the particles apart, causing the soil particles to become more buoyant. Examples include natural springs and water from lakes and oceans coming from underneath the soil.
- **Earthquakes** - The force and vibration of the shaking ground can increase the pressure of shallow groundwater, which liquefies sand and silt deposits.

The liquified soil loses strength and can cause buildings or other objects on the surface to sink or fall over.

While quicksand can occur in almost any location where water is present, there are certain locations where it's more likely to be found, such as riverbanks, beaches, lake shorelines, marshes and near underground springs.



The next time you're at the beach, notice the difference in the sand as you stand at different parts of the beach. Stand on the driest part of the beach - the sand at the surface may be loose but still holds you up just fine. The friction between the sand particles creates a stable surface. As you move closer to the water, you'll notice the **moist** sand is firmer than the dry sand. In a moist sand, the adhesion and cohesion create a tension that holds the particles together.

However, move right to the shoreline and as the waves come in, you'll feel the "quick". Why? The force of the waves not only pushes water over the surface onto the beach, but also into the pores in the sand under the surface.

After the wave recedes, notice the surface glistens for a few seconds as the water soaks back into the soil. So why aren't all beaches quicksand? The water at the beach is in the sand and on top when the wave comes in. Quicksand occurs when the sand becomes saturated AND there is water pressure/vibration in the sand. We can make shoreline soils act like quicksand by wiggling our feet which pressurizes the water, forcing the air out and pushing the sand and soil particles apart.

So why is it different when you stand in water up to your knees? The weight of the water pushing down on the sand had already pushed most of the air out and holds the sand in place.

Liquefaction - (Quicksand experiment)

Main Concept:
Quicksand is just sandy soil that has water under pressure within it. ***It is a suspension, basically, the solid sand particles are suspended in water and seem to float.***

Educational Goals:
To illustrate the concept of liquefaction.

Educational Objectives:
To relate liquefaction to real life events. To illustrate that soil contains air and water. To demonstrate that soil is dynamic and can change due to physical conditions.

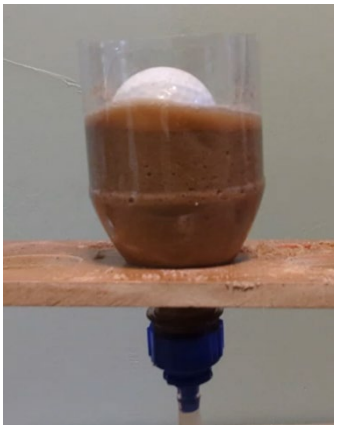
Materials and Preparation:
2 0.5 to 1-L soft drink bottles
2 bottle cap adapters (bottle to 1/8-in connector, available from Blumat)
50 cm 1/8" flexible tubing (plastic, vinyl, etc)
Cotton ball or cheesecloth to create a filter to keep the sand in the bottle
Sand 1 to 2 L (or quarts), 2 kg (4.4 lb is more than enough)
1 quarter, marble or golf ball
Craft knife

Preparation:
(view this video, courtesy of Dr. Dirt, for building the set-up:
https://www.youtube.com/watch?v=ZTT9K9OLfPU)

1. Draw a line around one of the bottles about 12 to 13 cm from the top. Use the ***craft knife to make the cut around the bottle. (This can be dangerous, so you may need to ask an adult for help.)***
2. Put the filter in one of the bottle cap adapters and secure it to the bottle - this is the bottom.

3. Connect one end of the flexible tubing to the bottle cap connector.
4. Add sand to the bottle to within ***3*** cm of the top (the cut end).
5. Fill the other bottle with water and secure the other bottle cap connector to the bottle, then connect the hose.
6. ***You will also need some sort of stand to hold the bottle or a student could assist. Hold it below the bottle containing the sand.***

Explain that soil is made up of a combination of sand, silt, clay, and organic matter. Show that you have a bottle of sand. Ask if the soil is a solid, liquid, or gas. (Confirm that it's a solid with spaces between the solid particles which contain gas.)



- Squeeze the water bottle (apply pressure) to push water up into the sand,
- Observe the pores in the sand fill as the water enters.
- Release the pressure to allow water to flow back into the water bottle.
- Observe that some of the larger pores will empty (fill with air) as the water flows back into the water bottle.

- Put a quarter ***(or marble or golf ball) on top*** of the sand. Ask students to try and press down on the quarter. Note that it will not go very far.

- Then ask a student to press in the center of the quarter as you squeeze the bottom water reservoir bottle. Try to moisten the soil so the water just reaches the top of the sand so liquefaction occurs and the quarter sinks fast, but release before the quarter has sunk more than ***a couple centimeters or so***. Ask why did that happen?

Explain that you forced water up under the sand and that it liquefied the soil.

- Illustrate it by doing it again and allow the water level to rise above the surface of the sand. Show how easy it is to push your finger into the sand at this point.

Ask, "Is the soil now a solid, liquid, or gas?"

- *Answer: **That's a trick question. It acts like a liquid because the sand particles are suspended in the water.** We liquefied the soil by forcing the air out of the sand, adding water and keeping the water in a small area of soil.*

- Next allow the water to flow back down into the bottom bottle and for the sand firm up. Take the quarter back out and place it on the top of the sand and again show how firm the sand is by having someone push on the quarter.

Ask students how the water could flow into the soil. (Answer: Water filled the pores and spaces between the sand grains where there was air.)

Ask students where they might find liquefied soil - in other words quicksand? (Best answers: Anywhere there is a lot of water.

1. Beach. Beaches have lots of water and if it is forced into a puddle below the soil surface, then it might become quicksand. Why isn't all sand at the beach quicksand? There's lots of air in sandy beaches, even below the water. Stomp your feet on sand that's under water you will see lots of air bubbles.
2. Rain forest: Rain forests have lots of water, which we know is needed for quicksand. The leaves and twigs and other organic matter in a rich rain forest may cover puddles of water that are below the soil surface and make it very hard to see and recognize the quicksand.
3. By rivers and marshes.

How to Escape Quicksand

If you ever find yourself in a pit of quicksand, don't worry-- it's not going to swallow you whole, and it's not as hard to escape from as you might think.
With quicksand, don't panic! The more you struggle, the faster you will sink. If you just relax, your body will float because your body is less dense than the quicksand.

While quicksand remains the hackneyed convention of bad adventure movies, there's very little to be afraid of in real life. As long as you keep a cool head in the situation, the worst result will be a shoe full of wet sand.