

Sinkholes

Chemistry Goes Deep

By Brian Rohrig

On February 28, 2013, Jeff Bush went to bed in his home near Tampa, Fla. Shortly afterward, the earth swallowed him up, as his home sank into a giant sinkhole. He was never seen again.

On July 3, 2013, Pamela Knox, an elementary school principal, was driving her car down a city street in Toledo, Ohio, when the ground opened up, and her car dropped out of sight as she was suddenly engulfed in a giant sinkhole. Fortunately, she escaped without serious injury.

On August 12, 2013, a large portion of a three-story building at the Summer Bay Resort near Disney World in Florida collapsed into a giant 18 meter (59 feet) diameter sinkhole. Fortunately, no one was injured.

Central Florida is the sinkhole capital of the world, and has been dubbed “Sinkhole Alley.” Between 2006 and 2010, insurance companies in this region received an average of 17 claims per day from sinkhole damage! About 20% of land in the United States is susceptible to sinkholes. Pennsylvania, Kentucky, Tennessee, Missouri, Alabama, and Texas are especially prone to sinkholes.

Sinkholes are a worldwide phenomenon. One of the largest natural sinkholes in the world is in Egypt. It measures 80 kilometers (km) (50 miles) long by 120 km (75 miles) wide—larger than the state of Delaware! It is 133 meters



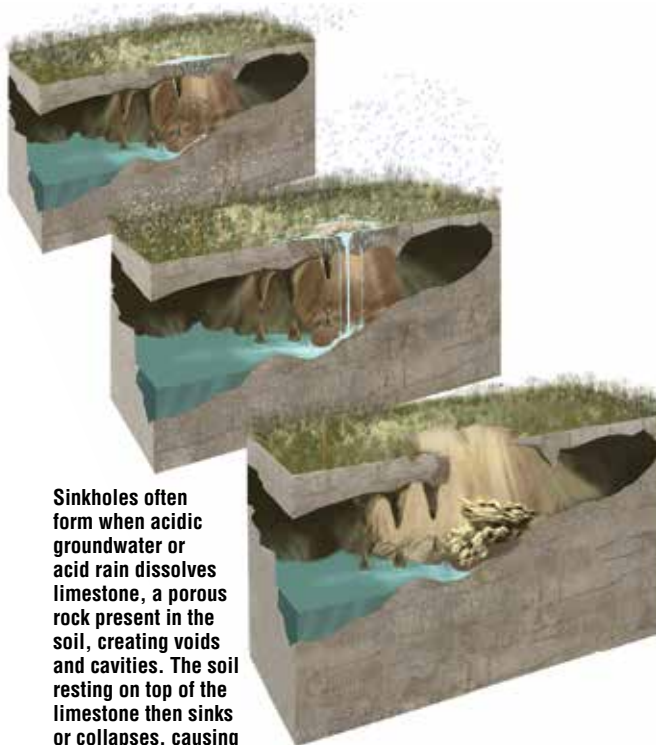
This aerial photo shows workers picking up remnants from a home in Seffner, Fla. A huge sinkhole opened under the bedroom in this home and swallowed the owner, Jeff Bush.

(436 feet) deep, and parts are filled with quicksand. In Chongqing, China, you can find perhaps the world’s deepest sinkhole at a depth of more than seven football fields! Thousands of new sinkholes open up every day. One sinkhole in Texas, known as the Devil’s Sinkhole, plunges 122 meters (400 feet) before opening into a cavern and is home to thousands of bats.

What is a sinkhole?

A sinkhole is a depression in the ground that opens up suddenly. There are various reasons about why sinkholes form. Human activity is a major cause, and it is likely the reason the number of sinkholes is increasing in populated areas. Any time underlying soil is removed, such as through mining or construction, the soil on the surface can collapse. The sinkhole in Toledo was caused by the collapse of the roof of the underlying sewer, perhaps precipitated by a water main break.

Sinkholes can also form due to pressure from above the soil. One morning in June 2004, residents of Wildwood, Mo., woke up to find that a 23-acre lake in their development had simply disappeared. A giant sinkhole opened up under the lake and drained it dry. Ponds and lakes—usually man-made—that disappear suddenly are most likely draining into giant sinkholes. The soil underneath is simply not strong enough to support the immense weight of the water above it. Since water has a density of 1 kilogram per liter (kg/L), a cubic meter of water has a mass of 1,000 kg (2,200 pounds). The builders of the lake had no idea that there was an enormous cavity underneath the lake which it eventually emptied into, similar to pulling the plug in a bathtub.



Sinkholes often form when acidic groundwater or acid rain dissolves limestone, a porous rock present in the soil, creating voids and cavities. The soil resting on top of the limestone then sinks or collapses, causing a sinkhole.

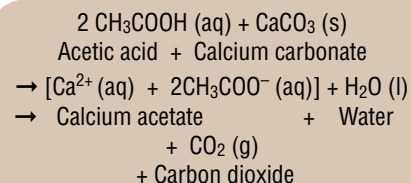
How sinkholes form

Naturally occurring sinkholes are most commonly found in a type of terrain known as karst topography, which consists of bedrock (rock beneath the soil) filled with nooks and crannies. The underlying bedrock in karst landscapes is usually made of limestone.

A great portion of the state of Florida is, in essence, sitting atop one continuous slab of limestone, making it vulnerable to sinkholes. Limestone is composed of calcium carbonate (CaCO_3), which primarily comes from the remnants of corals and other types of marine organisms, whose shells are made of calcium carbonate. Limestone builds up slowly after these animals die and their shells are deposited and accumulate over time. Other substances composed of calcium carbonate include marble, chalk, Tums antacid tablets, and eggshells.

To understand how limestone bedrock contributes to sinkholes, consider what

happens when you place an egg in a glass of vinegar, which contains 5% acetic acid (CH_3COOH). You will notice that little bubbles of carbon dioxide gas form almost immediately and, within a day or two, the eggshell will have completely disappeared, leaving you with the egg's translucent membrane to protect the egg. The eggshell, which is composed of calcium carbonate, does not normally dissolve in water, but in the presence of acetic acid, calcium carbonate and acetic acid react with each other, causing the eggshell to dissolve according to the following chemical reaction:



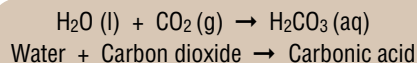
Any substance made of calcium carbonate will react with an acid. Limestone, being made of calcium carbonate, will react with an acid and will be slowly worn away. But are there acids underground?

To answer this question, consider what happens to rainfall (which eventually becomes groundwater) as it passes through the atmosphere. While falling through the air, the rain comes into contact with carbon dioxide. Although carbon dioxide comprises

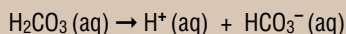


A sinkhole opened in Duluth, Minn., on June 20, 2011. Steady torrential downpours caused residents to evacuate their homes and this car to fall into the sinkhole.

only about 0.04% of the atmosphere, that is enough to make rainfall acidic, lowering its pH to about 5.6. So, by the time rainfall reaches the ground, it has turned into acid. The reaction is as follows:



Carbonic acid then dissociates to give a hydrogen ion (H^+) and a bicarbonate ion (HCO_3^-):




A large sinkhole appeared suddenly in a street of Shenzhen, China. A security guard fell into it and died.

The ability of carbonic acid to dissociate by producing hydrogen ions is what makes this molecule an acid.

Over time, acidic rainwater seeps into the ground and comes into contact with limestone bedrock. Water makes its way into cracks or pockets in the rock, reacting with the

Soft Drinks and Carbonic Acid

If you read the first ingredient on the label of any type of carbonated soft drink, it will most likely read “carbonated water,” which is mostly water and a small amount of carbonic acid (H_2CO_3). Soft drinks are carbonated by adding carbon dioxide gas to water, which reacts to form carbonic acid, contributing to their sour taste. Carbonic acid is a weak acid, so it is harmless when consumed as part of a soft drink.



limestone and eventually making holes and fissures in the rock. Sinkholes occur when acidic rainwater has eaten away so much of the underlying limestone bedrock beneath the soil that the ground collapses.

The more it rains, the greater the amount of carbonic acid leaching into the soil below. Humid areas have the most rainfall. High humidity in the air leads to cloud formation, which eventually produces rainfall. So it is no surprise that Florida leads the United States in the number of sinkholes because it has both limestone bedrock and high humidity.

The acidity of rainwater is not the only reason water in the ground is acidic. Decaying organic materials and root respiration also produce carbon dioxide, which dissolves in soil water to form carbonic acid.

Warning signs

You should not be afraid of falling into a sinkhole on your way to school tomorrow or be concerned about a sinkhole swallowing up your school, because there are ways to detect a potential sinkhole. Look for dying

vegetation, sudden appearance of standing water, muddy well water, cracks in the ground, and fence posts or signs that appear to be slumped over. If you live in a house, look for a crumbling foundation or doors and windows that do not close properly.

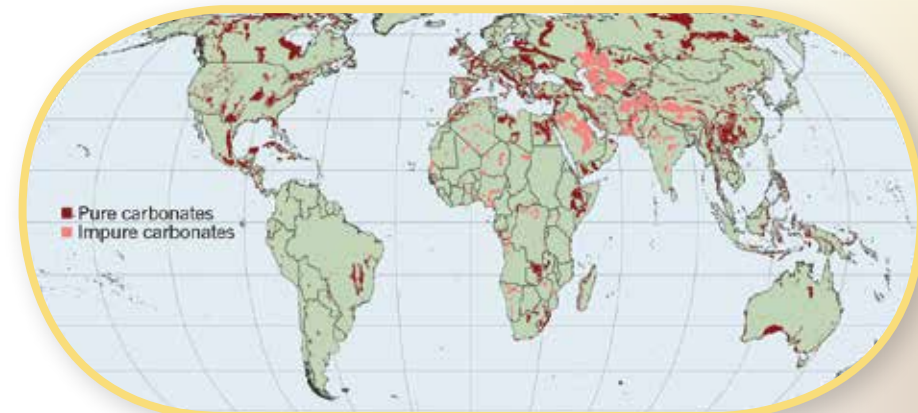
If a sinkhole is suspected, ground-penetrating radar can be used to confirm your suspicion. This method uses electromagnetic radiation in the microwave portion of the spectrum to look underground. This is the same type of radar used by stealth bombers and by the U.S. military to locate roadside bombs in Iraq and Afghanistan. If a large underground void is detected, then further investigation is warranted. It is always a good idea to have your property inspected for sinkholes by a trained professional, especially if you live in a sinkhole-prone area.

The concept of a sinkhole makes one wonder about the expression “solid ground.” Just beneath our feet is an active world of physical and chemical processes. Sinkholes are a scary—and sometimes tragic—reminder that our planet is dynamic and ever-changing. Fortunately, our technology has advanced to the point where we can detect sinkholes, and, hopefully, it can be used to prevent more tragedies from occurring. *CM*

SELECTED REFERENCES

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This map shows the areas where carbonate rocks can be found throughout the world. These areas are more susceptible to erosion by running water and thus to the formation of sinkholes.