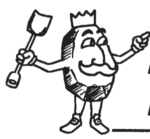
Exploring the Process of Sedimentation

Developed by Bruce Golden, Western Pennsylvania Coalition for Abandoned Mine Reclamation



About This Activity...

Prep Time Required:
1 hour

Grade Level:
High school

Subjects:
Chemistry, Earth Science, Environmental Science

Duration of Activity:
45 minutes

Pennsylvania Standards Addressed:
3.5.7-10.AB
4.1.7.A
4.1.10.B
4.3.10.B
4.8.10.ABC

Setting:
Classroom

Vocabulary:
Density
Sedimentation
Viscosity

Prerequisites:
Knowledge of the formation of abandoned mine drainage and its environmental impacts; general science concepts such as density and viscosity; ability to algebraically rearrange an equation.

Summary:
Using sand, students will learn through experimentation what sedimentation is and the importance of Stokes Law, and finally how the two of these apply to abandoned mine drainage in Pennsylvania.

Materials:
- Packets of sand (coarse, medium and fine)
- Water
- Mineral oil
- Ruler
- 6 test tubes
- Watch or stopwatch capable of measuring seconds

Objectives:
Upon completion of the lesson, 10th grade students will be able to:

- write an explanation of the process of sedimentation, to include:
- Understand the importance of Stokes Law in describing the relationship of particle size to settling time
- List at least 3 real world examples of sedimentation
- Explain how sedimentation is both a problem and a remedy for abandoned mine drainage.

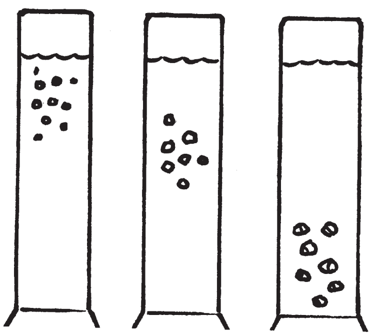
Background
Abandoned mine drainage (AMD) often has high levels of pollutants called heavy metals. Iron and aluminum are the most common. Iron is often visible in AMD polluted streams as orange water. The orange color can also be seen on the stream's banks and rocks. At low water periods, it may look like the stream bottom has been painted orange. The iron in AMD is actually in the form of rust-like compounds called iron oxides and iron hydroxides. There are several different kinds of these oxides, but to keep things simple, we'll refer to them as iron oxide. Iron oxide is an orange solid present as very fine particles. In a stream polluted with AMD, the churning action of the moving water keeps much of the iron oxide suspended in the water for some distance, while some of it settles by gravity to the stream bottom. Over time, more and more iron oxide accumulates to form a harmful, slippery sediment that smothers aquatic insects and disrupts the food web.

This lesson explores a process called **sedimentation**. Sedimentation is the process that describes the settling of solid particles by gravity to the bottom of a liquid. A particle will sink to the bottom of a liquid if it is denser than the liquid. Sedimentation of iron oxide particles causes the orange coating on stream bottoms. Similarly, the accumulation at the bottom of a bottle of orange juice or salad dressing is caused by sedimentation. We shake the bottle to suspend the particles in the liquid, but as soon as the shaking stops, the particles immediately start to settle.

To understand this better, we will look at the process of sedimentation in more detail. Stokes Law describes the rate (velocity) at which a particle will settle to the bottom of a liquid. Here is a synopsis of what Stokes Law says:

- The rate is dependent on the size of a particle. Larger particles settle faster than smaller particles
- The rate is dependent on the **viscosity** (thickness) of the liquid. A particle will fall faster in water than in pancake syrup (an inverse relationship of rate to viscosity).
- The rate is dependent on the difference in densities of the particle and the liquid. In water, a particle of a given size made of lead will fall faster than one made of plastic.

A Visual Concept of Stokes Law



Stokes Law is mathematically expressed as:

$V = 2r^2g(d_p - d_l)/m$

Where

- g=acceleration of gravity
- d_p=**density** of particle
- d_l=density of liquid
- m= viscosity of liquid
- v=velocity
- r=radius of particle (assume it is spherical)

Another common way of expressing Stokes Law mathematically is

$V = Kr^2$, where $K = 2g(d_p - d_l)/ m$

Using Sedimentation as a means to remove pollutants

Sedimentation can also be exploited to remove pollutants.

Iron Oxide

What we want to do is keep the iron oxide from getting into the stream in the first place. A solution is to construct a treatment system that first captures the polluted mine water at the point where it emerges, then directs the water into a pond where the water will be calm enough to allow settling of the iron oxide particles. The iron oxide will be collected on the bottom of the pond, and clean water from the pond will be released into the stream.

Ponds constructed for this purpose are called settling ponds or sedimentation ponds. They work well for removing fairly high concentrations of iron oxide, but they usually allow some of the iron oxide to pass on through. Sometimes a second settling pond is constructed to capture more of what was missed by the first.

It has also been shown that shallow ponds that have aquatic plants such as cattails can also serve to remove iron oxide particles from the water, primarily by filtration in their roots. These ponds are called aerobic wetlands. Aerobic wetlands work best if the iron oxide concentrations are relatively low to begin with, and they do a good job of removing most of the iron oxide. A common strategy is to follow a settling pond with an aerobic wetland.

Sewage/solid waste treatment systems

Municipal solid waste treatment systems employ sedimentation to separate solid material from water as a step in purifying waste water.

Other Situations where Sedimentation is Important

Soil Erosion and Sedimentation

Runoff of rainwater over land may cause erosion of soils, as may fast running water along stream banks. This action suspends and transports soil particles to streams and rivers. Sedimentation of this material within other parts of the stream may lead to a variety of problems.

Sedimentation as a geological process

Over eons, sedimentation and accumulation of various materials has led to the formation of geological rock strata. For example, limestone is made out of the accumulation of calcium remains of aquatic organisms.

Procedure:

Warm-up:

Having bottles of Italian salad dressing and orange juice, ask class why they need to be shaken prior to use. Ask what happens if they're allowed to set for a period of time. Ask what other products might also require mixing. Ask students to speculate on why particles accumulate on the bottom of the bottles.

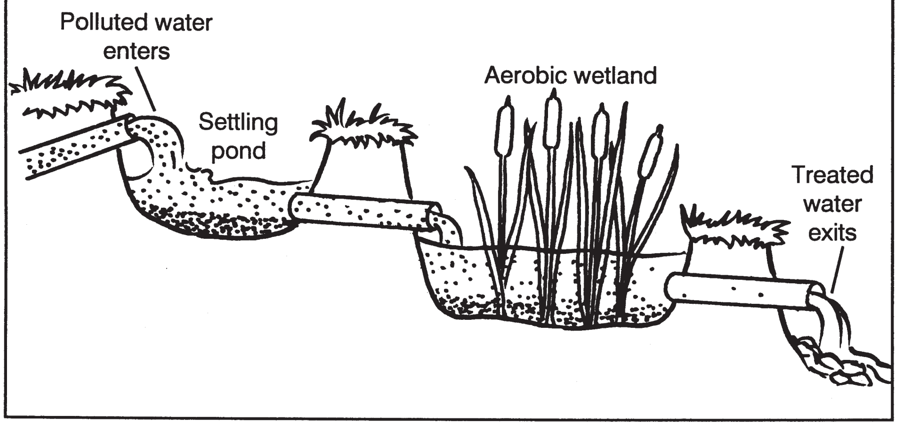
Activity:

This experiment will demonstrate Stokes Law using sand. Three grades of sand (coarse, medium and fine) will be used representing 3 particle sizes.

- Place a small amount of coarse sand in a clean test tube. The sand should be 2 to 4 mm deep.
- Fill the test tube about three quarters full with water.
- While holding the test tube upright in your hand, cover the top of the test tube tightly with your thumb and shake vigorously to thoroughly mix the sand with the water. Immediately following shaking, observe the behavior of the particles as they settle to the bottom of the liquid. In particular, measure the number of seconds it takes for the particles to settle to the bottom. You can use a watch, or simply count "one thousand one, one thousand two,… etc.
- Measure the height (in cm) of the water in the test tube using a ruler. Record both time and height of the water column. Determine the velocity of the particles (cm/sec). **Velocity= distance traveled/time required to travel that distance**
- Calculate the approximate particle size using Stokes Law Equation and the following information:
  - Density of water = 1 g/cm^3
  - Density of sand = 2.1 g/cm^3
  - Viscosity of water = 0.01 g/ cm sec
  - Viscosity of mineral oil = 0.3 g/ cm sec
  - Acceleration of gravity = 980 cm/sec^2
- Repeat the experiment for medium and fine sand samples

  Mineral oil has a much higher viscosity than water (it is thick and resistant to flow). Particles fall slower through a thick liquid.
- Instead of using water, repeat the experiment using mineral oil for coarse, medium and fine sand.

How the Wetland System Works



Teacher notes:

Students should observe that the larger sizes of sand settle quicker than the smaller particles, qualitatively verifying Stokes Law. The settling action is fairly quick in water, from a second to several seconds, making accurate time measurements difficult. With mineral oil, which is much more viscous than water, the effect of particle size on the velocity will be much more pronounced than with water and easier to measure.

The choices of sand in water and sand in mineral oil were made to enable experimentation to be done in a normal class period. The particle sizes of iron oxides are very much smaller than those used in these experiments and consequently the settling times are measured in hours instead of seconds.

Wrap-up/Conclusion:

Sedimentation is a very important physical process occurring in numerous settings. For abandoned mine drainage, sedimentation of heavy metals onto stream bottoms degrades the streams by altering the habitat of aquatic insects and disrupting the food web. As a means of treating heavy metal pollution from abandoned mine drainage, sedimentation is a process that is purposely employed to remove the metals from the polluted water.

Assessment:

Written explanation of the process of sedimentation, to include:

- The importance of Stokes Law in describing the relationship of particle size to settling time.
- Citation of at least 3 real world examples of sedimentation
- An explanation of how sedimentation is both a problem and a remedy for abandoned mine drainage.