# Earth System Science Topics in the News: How Teachers Can Use These Contexts To Teach Chemistry and Inquiry

***by Ann Benbow and Cheryl Mosier***

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## Introduction

The earth sciences provide many natural links to chemistry topics and are an excellent way of introducing chemistry to students early in their high school careers. Using an earth system science approach, students can investigate the chemical aspects of the *hydrosphere* (composition, water cycle, water quality, role as a solvent), the *atmosphere* (composition, air quality, acid rain), *geosphere* (soil chemistry, composition of volcanic eruptions, composition of rocks and minerals, chemical weathering), and the *biosphere* (biochemistry, carbon cycle, effects of pollutants on the biosphere).

This chapter describes ways in which teachers can use earth science topics that are of great interest to students and are frequently in the news to serve as contexts for chemical investigations. The topics in this chapter include "earth as a connected set of systems," "earth change over time," "natural hazards," and "water and the earth system." Suggestions for activities provide opportunities for students to not only progress toward proficiency in the science as inquiry standards, but also to make connections between the chemistry-related physical science standards and the earth and space science standards (see Table 1).

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**Table 1. National Science Education Standards for physical science and earth and space sciences**

| Content Standard B: Physical Science | Content Standard D: Earth and Space Science |
|---|---|
| • Structure of atoms<br>• Structure and properties of matter<br>• Chemical reactions<br>• Motions and forces<br>• Conservation of energy and increase in disorder<br>• Interactions of energy and matter | • Energy in the earth system<br>• Geochemical cycles<br>• Origin and evolution of the earth system<br>• Origin and evolution of the universe |



## Earth as a Connected Set of Systems

Until recently, the earth sciences tended to be studied and taught as independent subjects. Now there is a strong movement toward studying the Earth as a set of *interconnected systems*: the **hydrosphere** (water), **geosphere** (solid part of the planet), **atmosphere** (air), and **biosphere** (all life on the Earth). One of the ways in which these Earth systems are studied today is through remote sensing. This involves the use of satellite technology to gather data on cloud cover, aerosol movement, ozone concentrations, gravity variations on the planet, water temperature, chlorophyll production, storm tracking, and much more. Using data from remote sensing satellites is an engaging and unusual context for introducing such chemistry topics as the formation of various types of aerosols and their potential effects on the environment, ozone formation around the planet, and the role of ozone in the atmosphere.

## Suggested Activities

Teachers can introduce students to a number of chemistry concepts using online satellite data. The Aura satellite, for example, monitors ozone concentrations. Students studying the formation and effects of ozone on the planet can access these data and build their own animations showing changes in global ozone concentrations over set periods of time. They can then hypothesize about factors contributing to the changes in these levels. Students interested in biochemistry can explore the role of chlorophyll in the carbon cycle by using data collected by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) instrument on the SeaStar satellite. The data from both Aura and SeaWIFS are on NASA's Earth Observatory Web site (see Recommended Web Sites at the end of this chapter).

Additional questions that students could investigate include:

- In which directions do aerosols move around the globe?
- What types of aerosols end up in the atmosphere and how are they formed? What are their chemical compositions?
- How does ozone form and how are satellites able to measure its concentration?
- Why is it important to keep track of ozone concentrations?

## Earth Change Over Time

Scientists use a variety of evidence to track how the Earth has changed over its 4.5 billion year life span. Fossil evidence collected by paleontologists is extremely important in putting together the picture of how life forms developed, were related, spread, altered, and became extinct. Paleoclimatologists, on the other hand, are interested in how Earth's climate has changed over time. One of the data sets they collect is the relative levels of oxygen isotopes in ice cores (related to *structure of atoms*). These levels are used to determine when ice covered different parts of the earth and when those ice sheets receded. Using the ice core evidence as a context, students can be introduced to the concept of isotopes and how they are used in many ways as "trackers" in scientific research. This same context could be used to introduce students to the properties of gases.

## Suggested Activities

Students could degas samples of carbonated beverages through heating. They could capture the released gas and test it by passing it through a solution of bromthymol blue (the carbonic acid formed by the carbon dioxide in water will turn the solution yellow). Students can also graph the changes in carbon dioxide, methane, or oxygen isotopes over time using data taken from ice cores in Antarctica. The National Oceanographic and Atmospheric Administration Web site http://www.ncdc.noaa.gov/paleo/icecore/antarctica/antarctica.html contains data from a variety of locations in Antarctica.

The curriculum *Earth System Science in the Community: EarthComm* (AGI, 2001) includes an activity in the *Earth System Evolution* unit that is very similar to the above online activity. In the chapter on climate change, the activity entitled *How Do Carbon Dioxide Concentrations in the Atmosphere Affect Global Climate?* has students work through a graphing activity ($CO_2$ vs. temperature) and interpret a graph ($CH_4$, $CO_2$, and temperature variations), looking for correlations among the three variables. The activity section ends with students creating their own experiments that demonstrate the greenhouse effect in the atmosphere. Students then read a short section called "Digging Deeper" that discusses $CO_2$ and global climate, greenhouse gases, and the carbon cycle.

Additional questions that students could investigate include

- How do chemists identify different gases?
- How do gases get trapped in liquids? How is it possible to get gases out of liquids?
- How are the isotopes of oxygen different from one another? How can these be used in paleoclimatological research?
- How are isotopes of various elements used as "trackers" in scientific research?

## Natural Hazards

Natural hazards are of great interest to secondary school students. Hurricanes, earthquakes, tornadoes, tsunamis, volcanic eruptions, landslides, blizzards, dust storms, sink holes, and floods happen all over the world, every day. The hazards that link most readily to introducing chemistry concepts are volcanic eruptions, floods, and tsunamis. Any hazard that disrupts the water supply can work as a method for introducing solubility, units of concentration, drinking water purification processes, and wastewater treatment. Volcanoes are an interesting context in which to explore the chemical composition of matter erupting from volcanoes and its effects on the environment.

The eruption of a volcano puts particles into the atmosphere that can result in acid rain (related to *chemical reactions*). In fact, isotopes of sulfur from volcanic eruptions are being used to study climate change. A team of American and French scientists recently reported that they were able to study the effect of major volcanic eruptions on climate change by measuring the sulfur isotopic "fingerprint" of several relatively modern major volcanic

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eruptions. Those that shot particles into the stratosphere (where the particles were able to reflect enough sunlight to lower the Earth's temperature) had different concentrations of sulfur isotopes than volcanoes with weaker eruptions (related to *structure and properties of matter*).

Understanding the chemical structure of magma offers students an opportunity to understand how viscosity has an impact on lava flows. The viscosity of lava controls the shape of a volcano and determines whether the volcano will erupt explosively like Mt. St. Helens, or ooze like Kilauea. Lava viscosity is determined mostly by the silica content within the lava, along with the temperature of the magma. Knowing the type of lava that may come out of a volcano helps geoscientists determine where and when people should be evacuated.

## Suggested Activities

Students could investigate the pH of simulated volcanic products. Students could also create and test the pH level of their own acid lake using carbon dioxide bubbled through water. They could then use their acid lakes to investigate the rate of chemical weathering on small samples of limestone, marble, and other common rocks.

*EarthComm, Earth System Science in the Community* has an investigation on viscosity in the "Earth's Dynamic Geosphere" unit. During the investigation "Volcanic Hazards: Flows," students model the viscosity of lava using liquid soap. Students first investigate how much area is covered using increasing volumes of soap, and then create their own investigation, changing the slope of the land, viscosity of the soap, or using channels. Most students compare temperature effects on the soap, which models the change in viscosity based on temperature of the lava. Some also choose to add something to the soap to thicken it, modeling the effect that more silica has on lava. Students then complete a graph that shows the travel times of lahars (volcanic mudflows) from Mt. St. Helens and read about lava, pyroclastic flows, and lahars.

Sample questions students could investigate include

- How does acid rain form from volcanic products and how acidic is this rain?
- How does acid rain affect limestone and marble?
- How can gases released from volcanoes have an impact on groundwater?
- How does the viscosity of a liquid affect how fast a liquid flows?

## Water and the Earth System

Water is a topic constantly in the news. Whether droughts in Ethiopia, floods following a hurricane in Louisiana, or leaking sewers in Rio de Janeiro, water's effect on the planet is profound. Investigations centering on water issues afford rich opportunities for students to explore the chemistry standards through Earth science examples. Students can begin by studying the structure and composition of the water molecule for clues as to why it is such an important substance on the planet (related to *structure and properties of matter*). They can then move on to the properties of water that, in combination with other substances and energy, contribute to weather, erosion, ocean currents, the water table, watersheds, water pollution, climate, and much more (related to *interactions of energy and matter*). Teachers could also create a series of lessons on the role of chemical reactions in monitoring and cleaning water (related to *chemical reactions*).

## Suggested Activities

People who live close to large bodies of saltwater are frustrated with the lack of drinking water available to them. Having students investigate the differences between freshwater and saltwater helps them to understand why ocean water is not usable by humans. This also helps them realize why desalination is so expensive and not an easy option for many communities.

When students compare the properties of fresh- and saltwater through a variety of activities, they gain a better understanding of the chemistry of water and the characteristic properties of both salt-water and freshwater.

One activity involves students calculating the density of freshwater vs. saltwater. Students measure the mass and volume of a sample of each type, calculate their densities, and then compare them. After the density is calculated, students can then predict whether objects of known density will sink or float in each type of water. Predictions can be followed by testing. This can also be done as a demonstration with eggs, which will float in saltwater, but not in freshwater. Next, students can compare the boiling points of both fresh- and saltwater. Students collect and graph temperature data on both types of water to discover that saltwater boils at a higher temperature than freshwater.

Students can simply evaporate both types of water in a shallow pan or clean Petri dish to compare the "stuff" left behind, or they can model the process of distillation. To model distillation, you need a small clear dish (heavy enough to sink in water), a large clear bowl, plastic wrap, some type of small weights, saltwater, and either a sunny location or an overhead projector. A small amount of saltwater is placed into the large bowl, about 5 cm deep, but dependent on the size of the small bowl. The small bowl is placed into the large bowl, carefully keeping the small bowl dry on the inside. The large bowl is covered and sealed with plastic wrap, snugly, but not tightly. The small weights are placed in the middle of the plastic wrap directly over the small bowl, and then the whole setup is carefully moved to a sunny location or placed on a running overhead projector. Over time, the water will evaporate, condense on the inside of the plastic wrap, and then drip into the small bowl. The amount of time this takes will depend on the ambient temperature of the room and the amount of heat supplied by the sunshine or overhead projector.

These activities allow students to investigate the properties of both fresh- and saltwater. They also give them an understanding to support further studies of water purification, desalination, and oceanography.

Sample questions that students could investigate on their own or in small groups can include

- What is the role of water in shaping the Earth?
- Why is water important in the weather machine?
- How does water become polluted?
- How can polluted water be cleaned?
- Why is ocean water salty?
- Why can't living things survive drinking saltwater?
- What is the role of water in photosynthesis? In respiration?
- How does water get into the ground?
- How does desalination work?
- How is flood water able to cause so much damage?

**Recommended Web Sites**

http://www.earthobservatory.nasa.gov This Web site, developed by the Terra satellite team at NASA, contains satellite data, animations, activities, news, and a glossary of Earth system science terms. Students and teachers can create their own animations on this Web site using remote sensing data from a number of the NASA satellites. (accessed March 12, 2008).

http://www.agiweb.org/earthcomm/ The American Geological Institute's Education Department maintains a Web site of state-based resources to teach high school earth science. These resources include activities, maps, geological data, and links to state geological surveys. (accessed March 12, 2008).

### Recommended Readings

American Geological Institute. *Earth System Science in the Community: EarthComm*. It's About Time Publishing: Armonk, NY, 2001: This five-module curriculum is based on the earth science standards of the National Science Education Standards and was funded by the National Science Foundation. It is appropriate for grades 9–12.

American Geological Institute. *Investigating Earth Systems*. It's About Time Publishing: Armonk, NY, 2002: This ten-module inquiry-focused curriculum is based on the earth science standards of the National Science Education Standards and was funded by the National Science Foundation. It is appropriate for students in grades 6–9.

### References

American Geological Institute. *Earth System Science in the Community: EarthComm*. It's About Time: Armonk, NY, 2002.

National Research Council. *National Science Education Standards*. National Academies Press: Washington, DC, 1996.