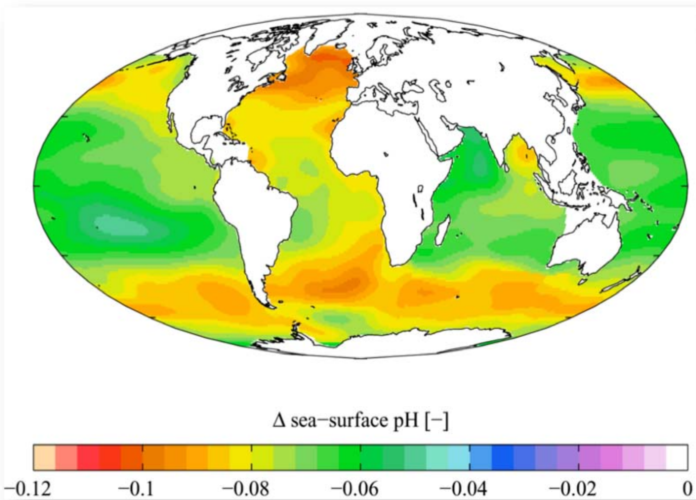
COSEE
CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

Ocean Acidification

Overview

Human activities such as the combustion of fossil fuels and cutting down trees (deforestation) have led to an increased influx of carbon dioxide (CO_2) into the atmosphere. Some of the CO_2 remains in the atmosphere, but much of it is taken up by terrestrial plants and absorbed by the oceans. While people previously thought that the ocean had an unlimited capacity to absorb whatever we put into it, we have since come to understand that this is not the case. Ocean surveys and modeling studies have revealed that our climate is changing with increased CO_2 and the chemistry of the ocean is changing too. The pH of seawater is decreasing (that is it is becoming more acidic) as the ocean absorbs this extra CO_2. . This is called **ocean acidification**.



So why is this a problem in the ocean? When CO_2 reacts with seawater, the pH of the seawater decreases, which then decreases the availability of carbonate ions. Carbonate ions are needed by many ocean organisms in order to form shells. The shells of organisms such as clams, scallops, and mussels among others, and the skeletons of a large number of marine organisms such as corals and marine plankton are made of calcium carbonate. These shelled organisms will be unable or will be limited in their ability to build their skeletons or shells and eventually their carbonate skeletons and shells may start to dissolve. This will impact the survival of these organisms and may ultimately lead to fundamental changes in the ecosystem.

Materials

For the leader:

Whiteboard or chart paper and a marker

6-8 pictures of marine organisms for display

2-4 seashells for display

For each group:

5 small cups

pH test strips or red cabbage juice pH testing solution with an eyedropper

1 graduated cylinder

5 pieces of chalk

1 data sheet

1 marker

Paper towels

Tap water

25mL of lemon/lime juice or distilled vinegar

25mL of baking soda solution (mix 15 teaspoons to 1 quart tap water)

25mL of clear soda or seltzer water

25mL of water from a local source (from a river, pond, ocean, snow, rain etc.)

1 scale or balance kit with paperclips or other measuring weights (optional)

1 tray

This phenomenon, called "ocean acidification," could have impacts on the biology, geology and chemistry of the ocean. In this lesson, students will examine what happens to shelled (calcium carbonate) organisms when exposed to environments of varying pH (acidic, neutral, basic).

Motivating Question: What will happen to organisms in the ocean (corals, marine plankton, and shelled organisms like clams) if the water becomes more acidic as a result of excess CO_2 in the atmosphere?

Engage: Students discuss how gases are dissolved in liquids and brainstorm how changes in CO_2 gas concentration in the atmosphere can impact ocean life	10 minutes
Explore: Students investigate the relationship between pH and the rate chalk dissolves	40 minutes
Make Sense: Each group shares and compare their results	10 minutes
Total:	**60 minutes**

Preparation (30 minutes)

1. Write the motivating question on the board or a large piece of paper:
   What will happen to organisms in the ocean (corals, marine plankton, and shelled organisms like clams) if the water becomes more acidic as a result of excess CO_2 in the atmosphere?
2. Setup a tray of materials for each group of 3-5 children, including 5 paper cups, 5 pH test strips or red cabbage juice (25 ml/cup) with an eyedropper, a graduated cylinder, 5 pieces of chalk, a data sheet, a marker, and paper towels.
3. Each group needs 25mL of each of 5 sample solutions to run their experiment. Sample solutions include tap water, lemon lime juice vinegar, baking soda solution, seltzer or clear soda (make sure cap remains on tight until needed) and water from a local source such as a nearby river, pond, stream, collected rain or melted snow. You can provide a cup of each solution to each group or, if you wish, you can setup a community

Preparation Tip

If you are using cabbage juice instead of pH paper, prepare the solution as follows: (*from Cabbages and Chemistry, Lawrence Hall of Science*).

1. Chop the cabbage into small pieces until you have about 2 cups of chopped cabbage.
2. Place the cabbage in a large beaker or other glass container and add boiling water to cover the cabbage.
3. Allow at least ten minutes for the color to leach out of the cabbage. (Alternatively, you can place about 2 cups of cabbage in a blender, cover it with boiling water, and blend it.)
4. Filter out the plant material to obtain a red-purple-bluish colored liquid. This liquid is at about pH 7. (The exact color you get depends on the pH of the water.)

station where participants can retrieve samples as needed.

4. Print out pictures of marine organisms. You can use the ones included below or collect your own. You will need about 6-8 pictures for the whole group. Images should include ocean waves, coral reefs, phytoplankton (coccolithophores), shell organisms such as clams and mussels, pictures of water (i.e. ponds, rivers) and pictures of fossilized animals (limestone formations – including coccolithophores, crinoids, etc.). Fossilized shells provide evidence that mid western states were covered by the ocean millions of years ago and is particularly interesting and relevant for mid-west students.

Engage (10 minutes)

1. Distribute 3-4 copies of the pictures of marine organisms you printed per small group.
2. Ask the students to look carefully at the pictures and then share their ideas with their small group using the following prompts:
   Q. How would you describe the organism in your picture?
   Q. What do all these creatures have in common?
3. After a minute or two, ask the groups to summarize their observations about marine organisms and share with the larger group. Be accepting of all responses from the students.
4. Depending on what the students already know, share some or all of the following information:

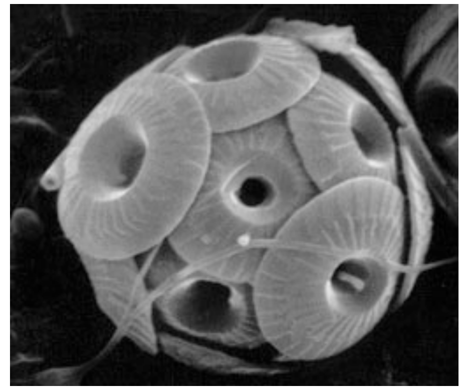
   The organisms pictured in our picture gallery (corals, clams, tube worms) all have one important thing in common – they have hard shells made of calcium carbonate – the same material we will be using in the exploration part of this activity to explore the effects of climate change on the ocean.

5. Hold up the shells for the students to see and if you have time, pass them around the room. Emphasize

Preparation Tip

Make the baking soda solution by mixing 15 teaspoons of baking soda with 1 quart of tap water.

What is a Coccolithophore?



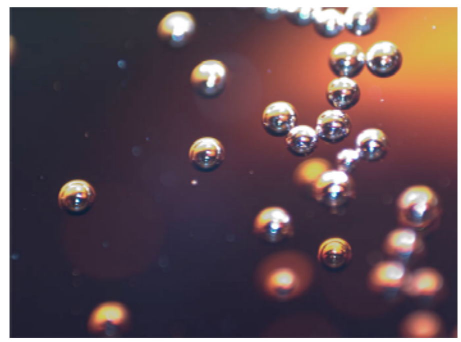
One organism the students may not recognize is the coccolithophore. These single celled plant-like organisms are extremely abundant and live in the upper sun lit layers of the ocean. Coccolithophore surround themselves with microscopic plates made of limestone (calcite) called coccoliths. These hubcaps shaped plates are only three one-thousandths of a millimeter in diameter (see gallery picture). When these creatures die, they sink to the bottom of the ocean and form large chalk deposits. A notable chalk deposit is the British White Cliffs of Dover and in the United States a large deposit runs from Austin, Texas, southwestward into Mexico. Other large deposits in the United States are the Niobrara formation in the central Great Plains, and the Selma Chalk in the Black Belt of Alabama and Mississippi. These limestone deposits are mined and pulverized to make chalk for use in the classroom again that all of the shells are made of calcium carbonate and that a marine organism made each one of them.

6. Explain to the students that we will be taking a closer look at the ocean and how a changing climate and changing ocean chemistry might affect life in the ocean. Lead a brainstorm with the students and ask them to complete the following sentence:
   Q. When I think of a changing ocean as a result of climate change, I think of… (one word responses).

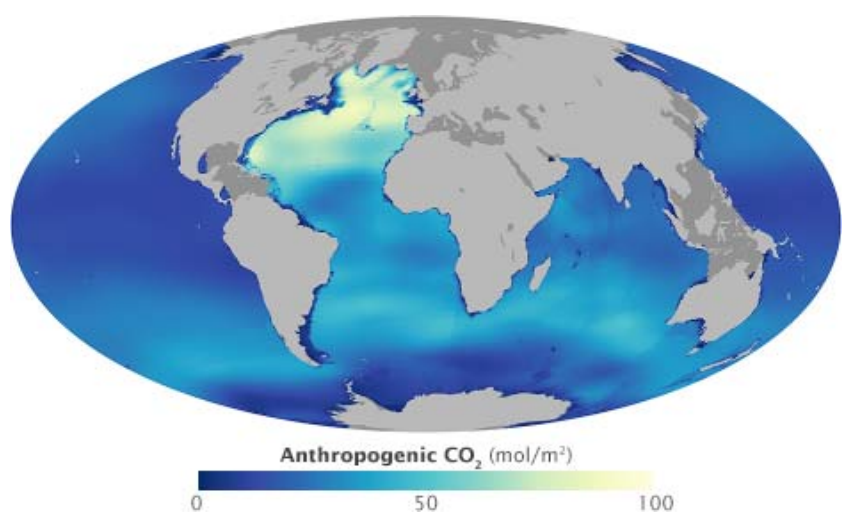
Important Note

Although the students may not have a lot of information to share about a changing ocean as a result of climate change at this point, this is a good way to access their prior knowledge and help them connect with what they do know about it.

7. Gather the students together around a table. Place a liter bottle of seltzer/soda on the table. Ask the children:
   Q. What will happen when we open the bottle of soda? Can water contain a gas?
   Engage the students in a short discussion. After a few minutes of discussion, open the bottle and have the students carefully observe what happens.
   Q. What do you think makes the soda fizz? What causes the bubbles? Is that a gas? What kind of gas?



8. Tell the students that the gas bubbles in the bottle are actually made of carbon dioxide (CO_2) gas. The gas was put into the liquid to make it really bubbly. When the cap is taken off, you can hear the 'whoosh' and see the bubbles start to escape from the liquid. CO_2 is also a very important part of our atmosphere. We breathe out CO_2 and plants use CO_2 as part of the process of photosynthesis. There is also CO_2 in ocean water – not as much as in the seltzer water of course. So how does the CO_2 get into the ocean? The ocean actually absorbs CO_2 from the atmosphere – in fact the ocean absorbs about 50% of all



the CO_2 added to the atmosphere. Tell the students that the global climate is also influenced by the amount of CO_2 in the atmosphere. The more CO_2 in the atmosphere the more the climate warms.

9. In this next part of the experiment, we will be exploring how changing ocean water chemistry (such as changes in the amount of CO_2) can impact the organisms living in the ocean. Tell the students that they will now be scientists – charged with making observations and measuring water quality. This investigation will help us assess how well the water can support living things that make calcium carbonate shells and skeletons.

10. Point to the motivating question and ask:
Q. What will happen to organisms in the ocean (corals, marine plankton, and shelled organisms like clams) if the water becomes more acidic as a result of excess CO_2 in the atmosphere?
Ask students to share their ideas about the question with a partner and then with the table group. Finally, ask volunteers to share the ideas their table group discussed with the entire group. Tell them that we will now explore this question with some experiments.

Explore (40 minutes)

1. First let's explore pH. Share some or all of the following information with the students depending on their age and experience:
    - ✓ pH is a measurement of how acidic or how basic (alkaline) a solution is.
    - ✓ When substances dissolve in water they produce charged molecules called ions.
    - ✓ Acidic solutions contains extra hydrogen ions (H^+) and basic solutions contains extra hydroxyl (OH^-) ions.

Science Tip

About half the carbon dioxide emitted into the air from burning fossil fuels dissolves in the ocean. This map shows the total amount of human-made carbon dioxide in ocean water from the surface to the sea floor. Blue areas have low amounts, while yellow regions are rich in anthropogenic carbon dioxide. High amounts occur where currents carry the carbon-dioxide-rich surface water into the ocean depths. (From NASA's Earth Observatory)

- ✓ pH is measured on a scale of 0 to 14 with 1-6 representing the acidic side of the scale and 8-14 representing the basic side of the scale.

2. Distribute the trays of equipment and a data sheet to each group.
3. Ask each group to label the five cups as follows: "Control," "Solution 1," "Solution 2," "Solution 3," and "Solution 4." Then, have participants use a graduated cylinder to measure out 25mL of each solution and pour it into the respective labeled cup. Display the table below on a white board to remind students of the samples we will be testing.

Control	25mL of tap water
Solution 1	25mL distilled vinegar
Solution 2	25mL of baking soda solution
Solution 3	25mL of carbonated beverage
Solution 4	25mL of water collected from your local source

4. Have students make predictions about what they think will happen when they place the chalk into each of the solutions. Then have them place each of their 5 chalk pieces into its respective solution, one at a time, and record any initial observations they notice as they placed the chalk into the solution.
5. Let the chalk sit for 10- minutes and record any observations throughout this time.
6. While waiting and observing the chalk, have participants dip a piece of pH paper into the five solution samples starting with the tap water control and record their findings on the data sheet.
7. Have students use a new piece of pH paper to take a measurement for each of the 5 solutions. If you are using the cabbage juice preparation add 1 dropper full of cabbage juice to each sample starting with the tap water. Compare the color change on the paper to the color scale provided by the pH paper manufacturer or

Instructor's Note

Have the participants keep the bottle containing the carbonated beverage closed until they are ready to add it. This will prevent additional carbon dioxide from escaping.

Science Tip

Tap water is usually neutral – although it can be slightly acidic or basic. With the cabbage juice solution, a mild color change to blue/light purple is considered neutral. Discuss the color changes and explain that red cabbage juice and the pH paper are acid/base indicators. In other words, the paper (or cabbage juice indicator) will change color in the presence of an acid or base. If using pH paper, use the scale provided to assess color change. If using the red cabbage juice indicator, use the color changes below (also found on the data sheet) to assess pH.

Red Cabbage pH Indicator Colors

pH	Color
2	Red
4	Purple
6	Violet
8	Blue
10	Blue-Green
12	Greenish Yellow

the scale provided here for the cabbage juice. Record the results on the datasheet.

Optional Activity Extension: The students can try and measure the amount of chalk that dissolves in each of the solutions. If you want to try this, they should then weigh each piece on the scale individually and record this weight on their data sheet BEFORE placing it into one of the cups (based on time and age of children). If you are weighing the chalk you can either provide one scale or balance to each group or you can use a communal scale. A communal scale will make the experiment longer as groups will need to wait for their turn. Another option is to have only one or two groups weigh the chalk and share their findings. If a scale or balance is not available, you can assemble a makeshift balance kit for each group by taping 2 small cups to the ends of a ruler and placing this balance on a small pivot point (like a small wooden wedge or round pencil). Paperclips can be used as measuring weights. After the time is up, remove the chalk from each cup and blot it dry with a paper towel. Weigh each piece again and record the weight on the data sheet. Determine the change in weight by subtracting the original weight of the chalk from the final weight of the chalk. This is a measure of how much chalk was dissolved by the solution.

Make Sense (10 minutes)

1. Have the children continue to work in groups of 3-5. In the Explore part of the experiment, students should have noticed that each solution had a different pH (using either cabbage juice or pH paper). They may also have noticed that each solution produced varying degrees of fizz when chalk was added (for example the vinegar should have produced the most "fizz" when chalk was added). Tell your students that we are now going to analyze, and confer with each other to make some sense of our results.

2. Ask each group to sort their samples/solutions based on <u>similar color change and chalk fizziness</u>. As the students are sorting, circulate around the room and encourage them to discuss their results. Ask some of the following questions:
   Q: Which solutions were similar? Which ones were different?

   Next have each group sort the solutions based on <u>numerical pH values</u>.
   Q: Which ones were similar? Which ones were different?

3. Have the students come together as a class group and share and explain how they sorted the solutions with the class. As they share with the larger group ask some of the following questions:
   Q. Did you group the solutions in the same way based on pH as you did with color and fizziness?

Q. Can we come to a consensus about how to group the solutions?

4. Now bring the students back to the original question: **Q. What will happen to organisms in the ocean (corals, marine plankton, and shelled organisms like clams) if the water becomes more acidic as a result of excess CO_2 in the atmosphere?** (hint: what happened to the chalk?)

   Ask a few volunteers to share their ideas with the entire class.

5. View the Ocean Gazing slideshow entitled "A plague in air and sea" and then share some or all of the following information with the students:
   - ✓ The ocean absorbs about 50% of all the CO_2 added to the atmosphere.
   - ✓ Some of the CO_2 absorbed by the ocean is used by photosynthetic organisms.
   - ✓ About 50% of the world's photosynthesis occurs in the sunlit layers of the ocean.
   - ✓ Absorbing CO_2 can decrease the ocean's pH, making the ocean more acidic. This can have consequences for many organisms in the ocean. As the ocean becomes acidic, we will likely see that the shells will be thinner and more fragile – like someone with brittle bones (osteoporosis) – and the shells will be easier to break. Coral reefs will be destroyed more easily by storms and shells will be more easily broken and opened by predators. In some places we may see calcifying phytoplankton, like coccolithophores, replaced by other species (those that use other kinds of skeletons).
   - ✓ Phytoplankton are the base of the food chain and if phytoplankton are not as plentiful, the entire food web may be altered. We may see entire ecosystems change. Even the sediments (the "mud") in the ocean may change because portions of it may

Instructor's Note

As the group discusses and comes to consensus, students will likely discover and share that the solutions with lower pH numbers (or those that turned pink or red with cabbage juice) also had a lot of fizziness with the chalk. These acidic solutions were dissolving some of the chalk away. Higher pH numbers turned the cabbage juice green, and the solutions with a pH of 6-7 turned the cabbage juice a bluish/purple color. These solutions were not acidic and didn't cause much fizziness with the chalk.

Instructor's Note

Help the students understand that most aquatic animals and plants have adapted to life in water with a specific pH and may suffer from even a slight change. Ocean acidification is decreasing the ability of most marine organisms to build their shells and skeletal structure. The acidic solutions we experimented with were dissolving some of the chalk away, much like an acidic ocean dissolves shells and skeletons made of calcium carbonate. All calcium carbonate shelled organisms (e.g. clams, oysters) and all corals will find it harder to make their structures as the ocean becomes more acidic.

Online Video

A plague in air and sea can be found on the COSEE NOW website (in both English and Spanish) at http://coseenow.net/blog/ocean-acidification dissolve – we may not see limestone forming anymore.

6. **Final Discussion:** Ask your students the following question:
   Q. What can we do about ocean acidification?

   You may want to discuss with them that combating acidification requires reducing CO_2 emissions (from cars and factories), reducing our carbon footprints and improving the health of the oceans. Creating marine protected areas (or national parks for the ocean) and stopping destructive fishing practices would increase the ability of marine ecosystems to withstand acidification. For example, evidence suggests that coral reefs in protected ocean reserves are less affected by global threats such as ocean acidification. Overall, the same strategies needed to reduce carbon emissions on land can also help slow these changes in the ocean.

Extension Activity: Connecting to your local waterway

Lead a discussion about what the students know about their local ponds or streams. What kinds of organisms live there? What are their predictions about the pH in their local waterway? Why do they think that? For an extension lesson, have students bring in different samples of water to test. Collect information on the:

- pH of sample
- Type of water body (pond, lake, river, stream)
- A picture of the site where they have collected the water

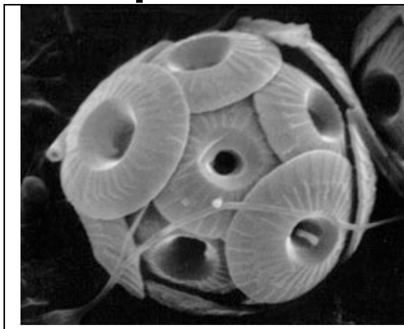
This lesson was developed for COSEE NOW by Janice McDonnell, Catherine Halversen, Lisa Rothenburger, Sage Lichtenwalner, Liz Sikes, and Carrie Ferraro and was adapted from a lesson developed by COSEE–West with additional information provided by the Lawrence Hall of Science.

Ocean Acidification Experiment

Use the following chart to record the results from your experiment.

	Control (tap water)	Solution #1 (lemon juice)	Solution #2 (baking soda)	Solution #3 (clear soda)	Solution #4 (local water)
Color of solution when cabbage juice is added					
Reaction of chalk when added to the solution					
pH of solution					
Optional Activity – Weight the chalk before and after					
Chalk weight at start					
Amount of time in-between measurements: ______ minutes					
Chalk weight at end					
Change in weight					

Example Carbonate Images

 Coccolithophore	 Carbonate Bivalve	 White Cliffs of Dover (carbonate based)
 Oyster Shell	 Coral Reef	 Coral Reef
 Carbonate Sediment Layers	 Carbonate Sediment Layers	