



# climate teacher

## OCEAN ACIDIFICATION

After reading the *EHP* news article **In Hot Water: Global Warming Takes a Toll on Coral Reefs**, students conduct experiments that simulate ocean acidification resulting from excess atmospheric carbon dioxide and discuss potential human implications of increases in ocean temperatures and acidification due to climate change.

*(Adapted from EHP Lesson **The Buffer Zone: Acid-base Chemistry in the World's Oceans** for grades 5-8)*

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## Overview

Grade Level: 5-8

Subjects Addressed: General Science, Chemistry, Environmental Science

Class Time: Part 1: 1 class period, Part 2: 2-3 class periods

Summarize or have students read **In Hot Water:**

**Global Warming Takes a Toll on Coral Reefs**

<http://ehponline.org/article/info:doi/10.1289/ehp.116-a292>

## OBJECTIVE

By the end of Part 1: Students should be able to **explain** how climate change can impact the pH of oceans and **define** and **measure** pH, acids, and bases.

Part 2: Students should be able to **explain** how a change in pH impacts coral reefs, **define** coral bleaching, and **measure** loss of coral mass.

## VOCABULARY WORDS

Part 1: Acid, Acidic, Base, Basic, pH, Neutral, Alkaline, Carbon dioxide (CO<sub>2</sub>)

Part 2: Coral bleaching, Climate change, Degradation, Ocean Acidification

## NOTES AND HELPFUL HINTS

- » In Part 1, suggested pH strips: colorpHast pH-indicator strips from Carolina Biological. If you use other pH strips, do a test-run of the activity to make sure the pH strips are accurate.
- » In Part 1: with younger students (Grade 5), eliminate pH test strips, and just gauge pH based on color change.
- » Each part of this lesson can be used as a stand-alone lesson. You do not need to complete Part 1 in order to use Part 2.
- » Part 2 can also be completed as a teacher demonstration.
- » In Part 2, attempt to provide students with shells that are similar in shape, size, and composition.
- » In Part 2, extend the lesson by allowing students to attempt to dissolve the coral pieces in various liquids.

## Aligning with Standards

### NATIONAL SCIENCE EDUCATION STANDARDS

#### Specific Content Standards

##### *Unifying Concepts and Processes Standards*

- » Systems, order, and organization
- » Evidence, models, and explanation
- » Changes, constancy, and measurement

##### *Science As Inquiry Standards*

- » Abilities necessary to do scientific inquiry
- » Understandings about scientific inquiry

##### *Physical Science Standards*

- » Properties and changes of properties in matter

##### *Life Science Standards*

- » Populations and ecosystems

##### *Earth and Space Science Standards*

- » Structure of the earth system

##### *Science in Personal and Social Perspectives Standards*

- » Personal health
- » Populations, resources, and environments

##### *History and Nature of Science Standards*

- » Nature of science

## SKILLS USED OR DEVELOPED

- » Classification
- » Communication (note-taking, oral, written – including summarization)
- » Comprehension (listening, reading)
- » Critical thinking and response
- » Experimentation (conducting, data analysis, design)
- » Manipulation
- » Observation

# OCEAN ACIDIFICATION

## Background Information

The oceans and human health are connected together: each affects the health and well-being of the other. Seventy percent of the Earth is covered by oceans, and they provide valuable biological and physical processes for the planet. Sixty percent of the human population live on or near the coast, meaning that a decline in the health of the oceans would affect human health. Similarly, human activities affect the health of the oceans. Oceans provide great health benefits for humans, including food resources, recreation, and resources for treating diseases. The degradation of coasts, changes in climate, and increased pollution can pose human health risks.

## Algal Blooms

As human population increases, so does human waste, including trash and toxic pollutants. Some of these pollutants eventually make their way to the oceans, altering marine food chains and affecting the health of the oceans. When marine food chains are altered, such as a pollutant accumulating through the food chain (bioaccumulation), human health is impacted. Humans tend to eat high on the food chain, ingesting higher amounts of the pollutant as its concentration builds through each level.

In addition to bioaccumulation of toxins in the food chain, ocean health is also impacted by the increase in algal blooms (algal bloom is a rapid increase or accumulation in the population of algae in an aquatic system). Harmful algal blooms (e.g., red tides) caused by toxic algae have become increasingly common. As with pollutants, these toxins accumulate through the food chain, and may have severe impacts on human health.

## Ocean pH

pH is the measure of the acidity or basicity of solution, with values ranging from 0 to 14. A solution with a pH of 0-6 are acidic, with acidity increasing as the value decreases. A solution with a pH of 7 is neutral, and a solution with a pH of 8-14 are basic, with basicity increasing as the value increases. On the pH scale, the values that are farthest from seven (neutral) are increasing in their acid or



basic strength. pH is measured on a log scale, meaning that as the pH value decreases (or increases), the strength is magnified by a factor of 10. For example, a substance with a pH value of 5 is a 10 times stronger acid than a substance with a pH value of 6. The oceans have a slightly basic pH, with values depending on location. The average pH of the ocean is 8.179.

## MATERIALS (per group)

### Part 1

- » 4 test tubes
- » 1 test tube rack
- » 4 clear sample cups
- » pH indicator strips
- » 1 dropper container of pH indicator
- » 250 mL of distilled water
- » 250 mL of seawater (made with aquarium salt)
- » 250 mL of carbonated water
- » 250 mL of tap water
- » 4 straws
- » Marker
- » Student Worksheet
- » 4 500 mL beakers

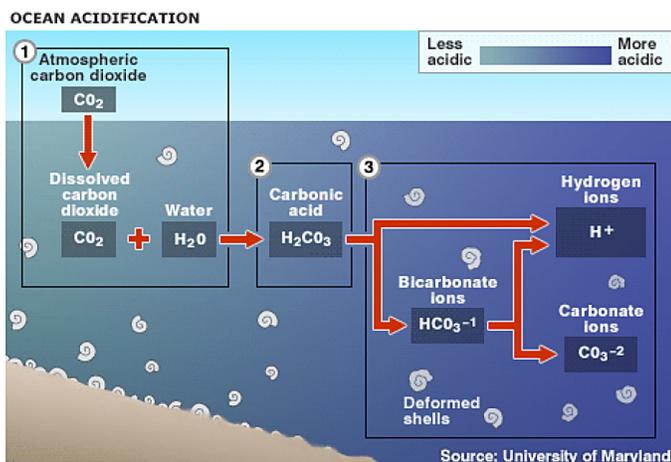
### Part 2

- » 250 mL of white vinegar solution
- » 250 mL of water
- » Forceps
- » Gloves
- » Scale
- » pH indicator strips
- » 2 small, thin seashells
- » 2 500 mL beakers
- » Student worksheet

## Ocean Acidification

Ocean acidification is the general term for the decrease in ocean pH from the uptake of carbon dioxide, a greenhouse gas. Ocean acidification is primarily caused by increased CO<sub>2</sub> concentrations in the atmosphere, primarily due to anthropogenic (human) activities. Since 1751, there has been an estimated decrease in ocean pH to 8.104 in 1994. At the current rate of releasing carbon dioxide into the atmosphere, ocean pH is predicted to drop to 7.824.

The increase in CO<sub>2</sub> concentration in the oceans affects the seawater carbonate system and causes a decrease in pH and availability of carbonate ions. Increased dissolved carbon dioxide in the oceans leads to an increase in bicarbonate ions, which are formed at the expense of carbonate ions. ( $\text{CO}_2 + \text{CO}_3^{2-} + \text{H}_2\text{O} = 2\text{HCO}_3^-$ ). Carbonate ions are needed for the formation and maintenance of shellfish and corals. As pH decreases (becoming more acidic), carbonate ions decrease, thus decreasing the amount available for shell-forming organisms. The figure below shows the process of ocean acidification.



## Coral Bleaching

Research has shown that the implications of ocean acidification can be devastating for ocean and coastal ecosystems, and in turn, for human health. Many marine organisms, including coral and mollusks, whose structures are based on calcium carbonate, are sensitive to changes in pH. Acidic substances can wear away at the calcium carbonate and cause damage to the marine life. Impact on these organisms can have lasting impacts on the food chain. Any impact on the marine food chain has the potential to negatively impact human health, especially in populations that are dependent on a marine food supply.

Corals are highly sensitive to environmental changes. The corals that form the structure of the great reef ecosystems of tropical seas depend on a symbiotic relationship with photosynthesizing unicellular algae called zooxanthellae that live within their tissues. Zooxanthellae give coral its particular coloration. Under stress, corals may expel their zooxanthellae, which leads to a lighter or completely white appearance, hence the term "bleached." Scientists have predicted that over 50% of the coral reefs in the world may be destroyed by the year 2030. Coral will also die if the water temperature changes by more than a degree or two beyond its normal range, if the salinity of the water drops, or the pH becomes too acidic.

Higher rates of bleaching are being linked to climate change, but bleaching may occur from other stress factors, such as solar irradiance (photosynthetic active radiation and ultraviolet band light), changes in water chemistry, and silt runoff. Some of these factors are anthropogenic, while others occur naturally. Once bleaching begins, corals tend to continue to bleach even if the stressor is removed. If the coral colony survives, it often requires weeks to months for the remaining symbiotic population to reach a normal density.

## Human Health Impacts

Ocean acidification impacts seafood safety – the primary place with potential for impact on human health. Furthermore, the oceans provide many biological and chemical services that are negatively influenced by changes in pH and temperature. Some of these services, such as medicines from marine life, are needed to ensure human health. When the oceans are disrupted, so is human health.

## Prepping the Lesson (Part 1)

### Making Red Cabbage Indicator<sup>1</sup>

1. Chop one head red/purple cabbage and put in pot with enough water to cover the cabbage.
2. Bring the water to a boil, then turn off the heat and allow the cabbage and water to sit for approximately 10 minutes until the water is dark purple.
3. Fill a clean storage bottle about 10% with isopropyl alcohol and fill it the rest of the way with cabbage extract.
4. Use a strainer to filter out cabbage pieces. (Note: the cabbage color can stain. Avoid spilling).
5. Cap the bottle and shake to mix.

- Cool the solution and label the bottle. One head of cabbage provides approximately one liter of solution.
- Fill dropper bottles as needed for the class (one per group).

### Making Artificial Seawater<sup>2</sup>

- Mix aquarium salt with water according to directions on the aquarium salt package to make artificial seawater.
- Make enough so that each group has 250 mL of artificial seawater.

\*Note: If the water in your area is very hard, use distilled water instead of tap water.

<sup>1</sup> Cooley, S. and OCB Ocean Acidification Subcommittee (2009). OCB Ocean Acidification lab/outreach kit. Ocean Carbon and Biogeochemistry Program.

<sup>2</sup> Cooley (2009)

### Implementing the Lesson (Part 1)

- Assign students the reading (**In Hot Water: Global Warming Takes a Toll on Coral Reefs**) as a homework assignment, or complete together as a class. Encourage students to highlight or take notes on how coral reefs are impacted.
- Review what students have learned from the reading.
- Instruct students that they will be conducting an experiment on the pH of seawater and hand out copies of the student instruction pages.
- Review the procedures with students and assign into groups.
- Supervise student experiments as necessary.

### Assessing the Lesson (Part 1)

#### Table 1: Changes in pH

There will likely be some variety in the data tables based on student interpretation of the pH colors. Ensure that students have completed their data table and that the data are reasonable (e.g., each liquid should become more acidic with bubbling).

#### Discussion Questions:

- Which sample had the highest pH before bubbling? The lowest before bubbling?**

Check that student answers match the pH values on their data charts.

- Did the measuring with pH paper give you approximately the same results as measuring pH with the color change?**

The pH paper should give about the same results as the color change. pH paper provides a more exact value than the color change. Verify that students used both the pH paper and color changes correctly by looking at their data tables.

- Your breath contains carbon dioxide. After bubbling the samples with your breath, describe what happened in the samples compared to your controls.**

Students should write that the colors of the experimental samples changed while the colors of the controls stayed constant.

- Which sample had the highest pH after bubbling? Which had the lowest pH after bubbling?**

Check that student answers match with the pH values on their data charts.

- What happened to the pH of the seawater after bubbling?**

The pH of the seawater became more acidic after bubbling. Be sure that students understand that a drop in pH indicates that the sample has become more acidic.

- CO<sub>2</sub> is released during the burning of fossil fuels. As humans use more fossil fuels, more CO<sub>2</sub> is released into the atmosphere. Oceans naturally absorb CO<sub>2</sub>. What do you think will happen to the pH of oceans if CO<sub>2</sub> continues to be released into the atmosphere?**

As more CO<sub>2</sub> is released into the atmosphere, more will be absorbed into the oceans, which will lower the pH, causing the oceans to become more acidic.

## Prepping the Lesson (Part 2)

1. Make up a solution of equal parts vinegar to water. Be sure to make enough so that each group has at least 250 mL. (Optional: if your students are more advanced, allow them to make up their own solutions of vinegar to water).

## Implementing the Lesson (Part 2)

1. If not done with Part 1, assign students the reading **In Hot Water: Global Warming Takes a Toll on Coral Reefs** as a homework assignment, or complete together as a class. Encourage students to highlight or take notes on how coral reefs are impacted.
2. Discuss the article with the class as needed.
3. Instruct students that they will be observing what happens to the calcium carbonate shells of marine organisms when ocean pH is changed.
4. Supervise student experiments as necessary.

## Assessing the Lesson (Part 2)

### Observations:

Student answers will vary. Students should note that the shell in vinegar has begun to show signs of degradation (discoloration, pieces missing, appears smaller, etc).

### Data Table

Ensure that the table is complete with units. There will likely be some variety based on the weight of the initial shells used and the pH of the experimental container.

### Calculating Percent Mass Lost

Check to see if students showed their work. Correct mathematical errors, if applicable.

### Discussion Questions:

1. **What happened to the shell placed in vinegar-water?**  
Student answers will vary based on his/her observations. Acceptable answers include that the shell placed in vinegar-water became discolored, chipped, smaller, etc.
2. **What would you expect to happen if the pH of the vinegar-water was lower?**  
Students should infer that if the pH of the vinegar-water was lower, the pH would be more acidic, thus degrading the shell even faster, or causing increased damage to the shell.

### 3. What happens to coral reefs if ocean pH changes?

Coral reefs are made up of calcium carbonate, which degrades in acidic pH. Coral reefs begin to “bleach” if ocean pH changes, and can die. When ocean pH changes, this causes stress on the corals, which expel zooxanthellae, their symbiotic algae, causing an initial loss of color and eventual die-off.

### 4. How do coral reefs benefit humans? How would a loss of coral reefs impact humans?

Coral reefs provide habitat for important food sources (e.g., fish), protect shorelines from storms and erosions, and are a source of medicines. A loss of coral reefs can impact the food chain, compromise the safety of seafood, and affect the health of humans who eat the contaminated seafood.

### 5. List two ways in which excessive CO<sub>2</sub> can lead to the ocean's decline.

- » CO<sub>2</sub> can increase ocean temperature as a result of an overall increase in the Earth's temperature.
- » CO<sub>2</sub> can lower the pH of the ocean, causing it to become more acidic.

### 6. What are some ways to reduce coral degradation and death?

- » Reduce the input of CO<sub>2</sub> into the atmosphere
- » Reduce ocean dumping of waste, which may change ocean pH
- » Reduce runoff and non-source pollution
- » Treat coral diseases
- » Prevent overfishing

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Hines, Stefanie. (2008). The buffer zone: Acid-base chemistry in the world's oceans. Environmental Health Perspectives Science Education Program. <http://www.ehponline.org/education>

**RESOURCES:**

Environmental Health Perspectives, News by Topic page, (<http://www.ehponline.org/article/browsenews.action>). Choose Climate Change/Global Warming, Marine Science

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