

Ocean Acidification

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Ocean acidification is defined as the drop in pH that occurs due to the absorption of carbon dioxide by ocean waters, $\text{CO}_2 + \text{H}_2\text{O}$ creates carbonic acid. The change in pH we have already experienced is the biggest change to oceans in the past 20 million years and the change is happening so quickly marine organisms cannot adapt to the change. Read through the background information page 4-5 before developing and adapting the lessons for your class.

Purpose: The purpose of this lesson is to teach about ocean acidification, its causes and impacts on marine life especially zooplankton, an essential part of marine food webs.

Time: There are four different activities included in this document. To do all four you should plan on at least two 45 minute periods. The activities define and explain the process of acidification as well as its impacts on shelled organism.

Grade levels: Pick and choose from the activities and background information and fit it to your classroom needs. This information can be adapted for grades 5-12 to provide an introduction to plankton and its role in ocean food chains. Grades 8-12 can explore plankton and its role in food chains, and learn about the problems ocean acidification is causing. Also included is a pH testing activity and a list of various student friendly energy conservation measures to reduce CO_2 emissions. The last piece is step-by-step outline of the chemistry of acidification that could be used with high school students.

Objectives: Students will:

- 1 know that the tons of CO_2 we have added to the atmosphere is lowering the pH of ocean waters, a process called ocean acidification.
- 2 understand that acidification chemically changes dissolved calcium so that it can no longer be utilized by shelled creatures for shell building.
- 3 understand how acidification can affect shelled creatures in the sea.
- 4 understand that the base of the food chains and webs in the sea are plankton. There are phytoplankton (plants) and zooplankton (animals).
- 5 know that many zooplankton species have delicate calcium carbonate shells as well as a few of the phytoplankton such as the Coccolithophores, that have microscopic plating of calcite. These are found in all oceans of the world, and are very abundant in Antarctic waters.
<http://tinyurl.com/7cplgk3>
- 6 be able to identify sources of CO_2 emissions and understand how we are increasing CO_2 levels in our atmosphere.
- 7 be able to identify ways of conserving energy, and begin to practice conservation measures to reduce CO_2 emissions.

Equipment

Microscopes or a video microscopy set up for the classroom. If unfamiliar with video microscope equipment see here:

<http://tinyurl.com/c6scovv>

Several models of microscope video cameras and monitors are available for purchase on the web and some models can be found on Amazon. A video camera that fits on the eyepiece of the microscope has been used in our labs for years and has proven to be a valuable aid for

classroom instruction. Check out the PupilCAM on this website: <http://tinyurl.com/7nek9ng> or other choices here: <http://tinyurl.com/7c8jcmx> These websites are starting points and do not constitute a recommendation of any one product by the author.

Materials-

Plankton net
Plankton sieve (For a description how to build one see Page 7.)
Litmus - pH paper
Plankton guide for your local area, if available
Carbonated soft drinks
Calcium shells of any type: Oysters, clams, snails or the like
Vinegar or other weak acids from your lab
Images of ocean plankton See the samples on these URLs or search for webs typical of your local area.

<http://uncyclopedia.wikia.com/wiki/File:Zooplankton.jpeg> and
<http://tinyurl.com/6wd27um> or <http://tinyurl.com/coyebyh>

Activity 1. Collecting and viewing plankton

Collect a plankton sample if you are near the ocean, bay, or pond (fresh water plankton). Pull the plankton net through the water for a short time or pour buckets of water through the net. Five minutes towing or several buckets should gather enough for this lab. Pour the contents of your plankton sample through a plankton sieve until only a few drops are left on the netting. (see page 6 for sieve construction instructions). With a pipette or eye-dropper collect the sample and place it on a microscope slide. Slip the slide under the microscope for videomicroscopy or use individual microscope to view the plankton. The monitor screen should be filled with tiny zooplankters darting about on the screen as well as phytoplankton species.

Using a local plankton guide identify as many of the species as you can and also identify those that have shells, ie copepods. Depending on the time of year you may be able to identify barnacle and crab larvae etc.

If you cannot collect live plankton, set up a tank in the classroom and raise brine shrimp.

Project the illustrations of food webs and food chains. Some samples are here, <http://tinyurl.com/6wd27um> or locate images of marine food webs and chains from your local regions if available.

Discuss with students the importance of phytoplankton that are plants. Identify and discuss the tiny microscopic zooplankton, animals. These are the key to supporting life in the sea. Obtain a guide to plankton for your region and become familiar with common species. Copepods are tiny, shelled zooplankters that are abundant in plankton samples in most areas. Copepods are pictured here: <http://tinyurl.com/87s64o3>. Shelled zooplankton includes krill, amphipods, crab and barnacle larvae, among others.

With the food web projected on the screen, use a marker to black out several of the shelled zooplankton to indicate their loss from acidification. On the next trophic level black out or cover one or two small fish to indicate they die from lack of food due to the loss of the

zooplankton. At the next level remove one of the big fish to show loss from its reduced food supply. Remind students that it takes many, many zooplankton to support one small fish and many small fish to support one big fish and so forth to the top animals of the web. This illustrates how acidification can affect the whole web of life in the oceans.

Activity 2 Test the effect of acid on shells.

Equipment and materials

Small plastic cups

Vinegar

Shell chips or thin pieces of shells.

Demonstrate the effect of acid on shelled animals such as oyster, mussels, snails, or crabs. Place a shell chip into a cup and cover it with vinegar. Select a thin-shelled specimen or break the shell and use a thin chip for best results. An inch is plenty. Test the shell for strength before placing it in the vinegar. Poke at it with a probe try to break a piece of the shell with your fingers.

Observe the shell immediately after it is placed in the vinegar. The shell should immediately start to release bubbles. The bubbles may look like a faint white cloud as the acid dissolves away the shell. Discuss with students that the chemical reaction is releasing bubbles of CO₂ into the water.

Leave the shell soaking over night and the next day again test for strength, again try to break the shell fragment with your fingers. Poke the shell with a probe to see if the vinegar has dissolved enough calcium carbonate to make it more brittle.

NOTE - Different shells may react differently to the vinegar test. Run a test on the shells you plan to use prior to presenting this activity.

NOTE: If you have only 45 minutes or 1 hour to present the plankton, plus the affects of acid on shells, prepare the containers of shell chips in vinegar the night before. Make up enough to provide a container for every 3-4 students. Explain to students the shell has soaked in acid overnight. Again use the test for strength. Compare the difference between the vinegar soaked and the fresh shell.

Activity 3 Testing acidity of carbonated drinks

Materials

Carbonated soft drinks, club soda, or sparkling water

Small containers such as plastic cups

Litmus paper

Just as carbonated drinks have CO₂ pumped into them which results in their being acidic, the oceans are absorbing CO₂ from the air and the pH is being lowered. This is called acidification. The mixing of the CO₂ in both the drinks and oceans produce carbonic acid.

Use litmus paper to test the acidity of soft drinks or carbonated water. Carbonated water (also known as club soda, soda water, sparkling water, seltzer, or fizzy water) is water into which carbon dioxide gas has been dissolved under pressure, a process that causes the water to become effervescent (bubbly). Carbon dioxide and water form carbonic acid (H₂CO₃),^[2] which gives the water a slightly sour taste with a pH between 3 and 4. If you can test ocean water the pH the results will be higher, at about 8 on the scale. (See *Background Information* that beings at the bottom of this page, for a discussion of pH scale and changes occurring in the ocean)

Discussion: Solutions - What should we do?

Discussion: Acidification is already causing problems and the impacts will become more severe. What can we all do to keep CO₂ out of the air to slow ocean acidification? We know that using cars that burn gasoline adds CO₂ to the air. Much of the electricity used in the US is produced by burning coal and releases huge amounts of CO₂. Jet planes burn jet fuel that contributes to the amounts CO₂ into the air.

What can be done to reduce the amount of CO₂ being released into the air?

Electric cords with boxes continue to draw electricity if left plugged into the wall.

Cell phones are a good example. They are called vampire cords and include, computers, VCRs, televisions, and stereos. The savings is small, but using the switch on the power strip makes it easy to switch them off.

Close doors and windows and turn off lights that are not needed.

Do not waste. Everything is delivered to our stores by trucks

Turn down the heat, or if air conditioning, use in moderation. Walk or ride bikes to school rather than being driven.

Explore the school to spot wasteful practices. Are cans recycled? Are computer cords disconnected or power strips flipped off? How much food waste is there in the school lunch-rooms? Could some of that food be composted?

Check Green Schools <http://tinyurl.com/8xtxs5a> and Cool Schools <http://tinyurl.com/77g6opr> for conservation measures on a school wide basis.

Background information

Ocean acidification is the name given to the decrease in pH in ocean waters caused when CO₂ is absorbed by the water. CO₂ is released into the air when we burn gasoline in our cars or from burning coal to produce electricity. Where the air meets the ocean surface the CO₂ is dissolved into the water and carbonic acid is formed. CO₂- H₂O = H₂CO₃.

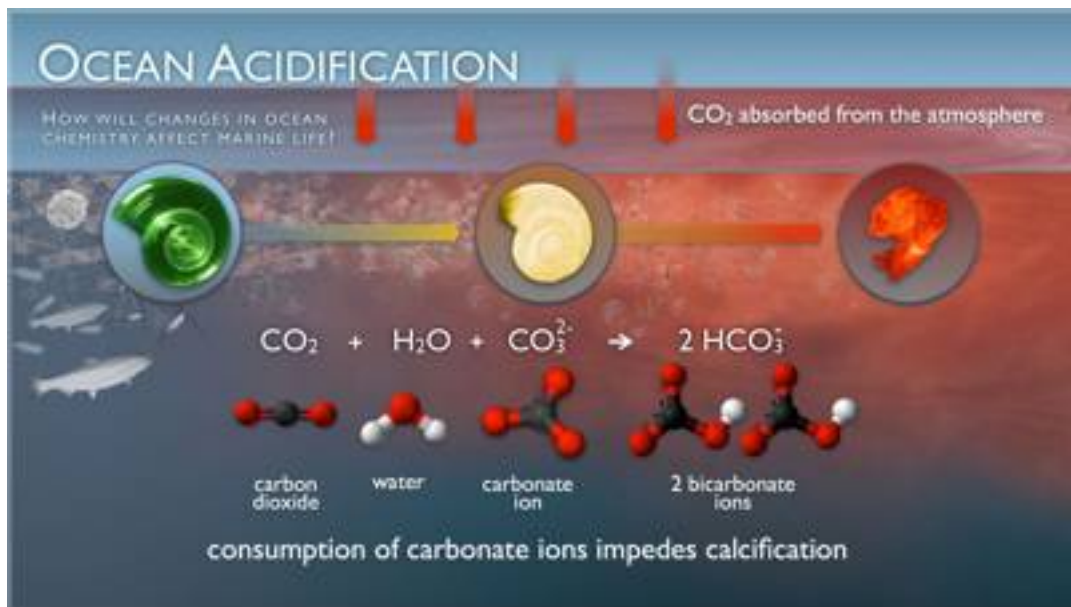


Illustration- Pacific Marine environmental Laboratories.

<http://www.pmel.noaa.gov/co2/story/Ocean+Acidification>

The pH scale is a numerical scale with 7 being neutral. Above 7 is basic and below 7 is acidic. The pH scale is used to rank acids and bases with the numbers 0-14. The numbers 1-6 are assigned to acids, with 0 being the strongest acid. The numbers 8-14 are assigned to bases, with 14 being the strongest base. The number 7 represents pH level that is neutral, neither an acid nor a base.



pH scale see: <http://www.greatscience.com/think/projects.php?id=21>

Ocean acidification is a drop in pH on that scale. Scientists report there has been a decrease of pH in all ocean waters from 8.25 to 8.14 since the onset of the Industrial Revolution. That change represents an increase of 30% in the hydrogen ion concentration. This is the biggest change to ocean pH in the last 20 million years. Like the magnitude scale of earthquakes, one unit on the pH scale reflects a change of a factor of 10. The 0.1 pH change means there are now 30 percent more hydrogen ions in the water. Scientists also warn that unless we quickly reduce our CO₂ emissions the acidification will continue and we will experience an increase of .3 – .4 points on the pH scale. That would mean a 90-120%, other sources predict an increase of up to 140% increase. Without action to reduce CO₂ scientists warn that we can create an acid spike more intense than the earth has seen in the past 8,000,000 years. The change we are currently experiencing is happening too quickly and too intensely for ocean animals to adapt. Source: Real Climate <http://tinyurl.com/y44sg3>

Although ocean pH has not dropped into the acidic side of the pH scale, the change has been enough to disrupt shell formation in sea creatures as the carbonic acid chemically changes calcium carbonate to the point that shelled organisms can no longer utilize it. This is a threat to tiny, fragile-shelled zooplankters, as well as the microscopic larvae of shelled creatures including clams, mussels, crabs and oysters. The second problem is the acid may become

eventually become strong enough it will dissolve the shells of adult animals and become a threat to corals, as well as a many other economically important animals.

Scientists report that the Pacific will be more severely affected by acidification than the Atlantic. But that does NOT mean that organisms in the Atlantic are safe from damage. The reason for the difference is the west coast experiences upwelling, a process that brings nutrients to the surface. Upwelling areas are some of the most productive regions in the oceans. Pacific Northwest coastal upwelling brings “old” bottom water to the surface. This water is already depleted of dissolved calcium compounds, aragonite and calcite. These are the compounds that shelled creatures, from plankton to clams, need to build their shells. The source of the old water is from downwelling areas off Vancouver Island, Canada. Downwelling delivers water to depths on the ocean shelf where it is transported down the coastline to areas along northern California to Oregon and Washington coasts. It takes 40 years for the water to travel that distance and during that time the calcium carbonate has been depleted. When strong, steady NW winds blow during the spring and summer months, the surface waters are moved and are deflected off shore by the Coriolis effect. This water is replaced by deep-water upwelling to the surface near the coastlines. The upwelling brings the old, calcium carbonate depleted Canadian waters to the surface where it mixes with surface water that, now too, is depleted of useable calcium for shell building. Plankton as well as spring spawners such as oysters and razor clams, need calcium carbonate for their larvae to build shells and flourish. Without enough calcium carbonate, the creatures cannot build their shells and will die.

Oyster hatcheries in the Washington and Oregon have recently experienced near total losses of their spring spawn of oyster larvae, in 2009 and 2010. Researchers linked the problem to the lack of enough dissolved calcium carbonate to build their shells. They concluded that the cause was the drop in pH of ocean waters. With acidification the calcium carbonate is chemically changed into a form that cannot be absorbed by the creatures for shell building that resulted in the losses. The problem in the hatcheries gives us an indication of what is very likely happening in near shore waters to zooplankton and to the larvae of various shelled creatures found in the affected areas. Source NOAA Fisheries Researcher

How acidification was discovered – an example of how science is conducted.

Ocean acidification offers educators an opportunity to teach students how science is conducted. The drop in pH was discovered on a NOAA research cruise in the Pacific. NOAA did not immediately announce to the world that ocean acidification was occurring but rather sent out a notice to the research vessels around the globe, including Russian, Australian, and European vessels. All vessels were requested to test the pH of the area of their cruise. At the end of the next year the results from all vessels found the pH drop of .1 in all oceans and ocean regions of the planet. Only after that confirmation was the announcement released. The same holds true for all scientific research. Before research reports are published in journals they must go through peer review. Scientists in related fields review the report to check procedures and analysis of data. Only those that pass this review are approved for publication. This quality control has served us well and ensured that the most accurate information is presented.

How to build and use a plankton sieve.

Materials .

PCV pipe about 4-5 inches –in diameter and the pipe at least ¼ inch thick. (you need the thickness to cement the netting in place..

PCV pipe cement.

Plankton netting from an old net, , or order a yard of netting from a supply house, Wildco Nitex netting if you can afford it. <http://tinyurl.com/6r8jmq4> about a six inch diameter piece is needed. Try nylon stockings or other fabric but the results will not likely be as effective.

Instructions

Cut the pipe into 4 - 5 inch high rings. Spread a thin layer of the pipe cement on the bottom lip of your cut pipe. Lay the plankton netting, nitex cloth, over the cut edge with the glue. Stretch the cloth so it makes good contact with the lip. Let dry. Trim off any excess the netting. *Use rubber gloves or be careful not to get the PCV pipe glue on your fingers.*

To concentrate the plankton taken from a brief tow from the shore or dock, pour the contents form the plankton net through the sieve. The “catch” will be concentrated into just a few drops. Collect with eye dropper or pipette and place on a slide for viewing under a microscope.

Chemical reactions of carbonic acid with calcium compounds in seawater

When CO₂ reacts with seawater it creates carbonic acid, lowering the pH of the of the ocean water. At the same time, the reduction in pH also reduces the availability of carbonate ions, which play an important role in shell formation in a number of marine organisms.

The chemical process of acidification is listed below.

CO₂ dissolves in water to form carbonic acid. In the oceans, carbonic acid releases hydrogen ions (H⁺), reducing pH, and bicarbonate ions (HCO₃⁻).

(1)

CO₂ + H₂O => H⁺ + HCO₃⁻ The additional hydrogen ions released by carbonic acid bind to carbonate ions (CO₃²⁻), forming additional HCO₃⁻

(2)

H⁺ + CO₃²⁻ => HCO₃⁻ This reduces the concentration of CO₃²⁻, making it harder for marine creatures to take up CO₃²⁻ to form the calcium carbonate needed to build their exoskeletons.

(3)

Ca²⁺ + CO₃²⁻ => CaCO₃

The two main forms of calcium carbonate used by marine creatures are calcite and aragonite. Decreasing the amount of carbonate ions in the water makes conditions more difficult to build shells for both calcite users (phytoplankton, foraminifera and coccolithophore algae), and aragonite users (corals, shellfish, pteropods and heteropods).

