

Uptake of Carbon Dioxide from Water by Plants

Aim

The following experiments demonstrate the role of plants in mitigating the acidification caused when CO_2 is dissolved in water.

Introduction

Oceans are effective sinks for anthropogenic CO_2 emissions. Two mechanisms are responsible for this feature: the “physical carbon pump”, where CO_2 taken up from the atmosphere by the ocean is transported to the deeper layers through “vertical deep mixing”; and the “biological carbon pump”, where CO_2 taken up by plants is converted to organic matter, a portion of which is transported to the deep as a result of decay.

The role of marine plants in reducing CO_2 in the atmosphere is currently the subject of extensive research. Unquestionable though, is the role of phytoplankton in this process. Phytoplankton are microscopic algae which live in the ocean and are the basis of the marine food chain. These live mostly in the surface and near the surface layer of the water column, because, like terrestrial plants, they need sunlight for photosynthesis.

One of the requirements for photosynthesis is CO_2 . Phytoplankton can fix CO_2 from the air overlying the sea surface or they obtain CO_2 that is dissolved in the water. Phytoplankton are not limited by CO_2 , because the concentration of carbon far exceeds the concentration of other nutrients needed for growth and they are capable of taking up other sources of carbon in the ocean like HCO_3^- .

Carbon dioxide dissolves in water making it acidic. The experiments shown here make use of the increase in pH as an indication of dissolved CO_2 uptake by the plants. We will use two kinds of plants: the freshwater aquarium plant, *Cabomba* and the marine microalgae, *Dunaliella tertiolecta*. Other aquatic plants can be used for these experiments. The aim of the following experiments is to show how plants help in reducing the dissolved CO_2 in the water, thus also aiding in pH regulation.

Part 1. Experiment with *Cabomba*

Preparation time:	10 minutes
Activity time:	10 minutes (set-up), 1-24 hours for observation
Type of activity:	Hands-on experiment
This activity had been tested on students aged:	10-12 yrs., grades 5-7
Application:	Biology, Chemistry, After-school activity
Time for data analysis and discussion:	20 minutes
Prior knowledge required:	Principles of photosynthesis, acid-base reactions
Cost:	Indicator (12€/250 ml)
Degree of difficulty:	Easy

Materials

- 50-ml bottles or flasks with caps (any material)
- drinking straw
- Pipette or medicine dropper
- Universal indicator (McCrumb)
- Distilled water
- Scissors
- Aluminium foil or black paper
- Table lamp (optional)
- Several stems of *Cabomba*



Fig 1a. Materials



Fig 1b. *Cabomba*

Procedure

1. Fill the bottles half-full with distilled water. Put several drops of indicator solution into the bottles with the pipette until the water in the bottles has attained the same shade of green. Be sure to add the same amount of indicator in both bottles, about 10 drops.



Fig 2. Fill the bottles with distilled water and add 10 drops of Mc Crumb indicator solution

2. Using the drinking straw, blow air into the bottles until the colour changes from green to yellow (basic to acidic) and no further colour change can be obtained.

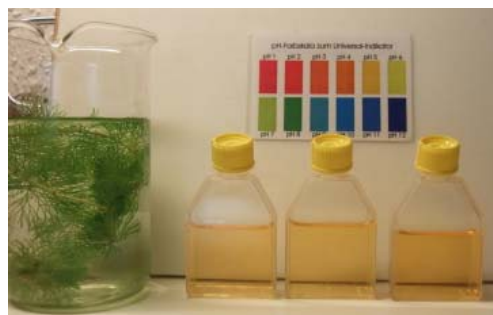


Fig 3. CO₂ is blown into the bottles turning the water yellow (acidic).

- Cut several fronds of *Cabomba* with the scissors. Make sure that you don't injure the plant tissues.



Fig 4. *Cabomba* fronds

- Place the same number of fronds (about 10) in two of the bottles. Put on the caps of the bottles. The bottle without plants will serve as a control.

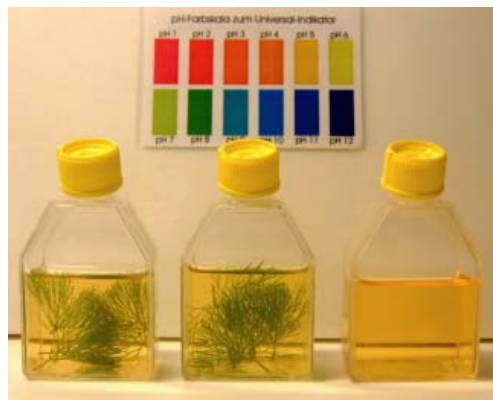


Fig 5. The same number of fronds are placed in two of the bottles

- Cover one of the bottles containing plants with aluminium foil or black paper. Place all the bottles on the windowsill or expose them to light using the table lamp. Depending on the intensity of light, results can be obtained after 1 or several hours.

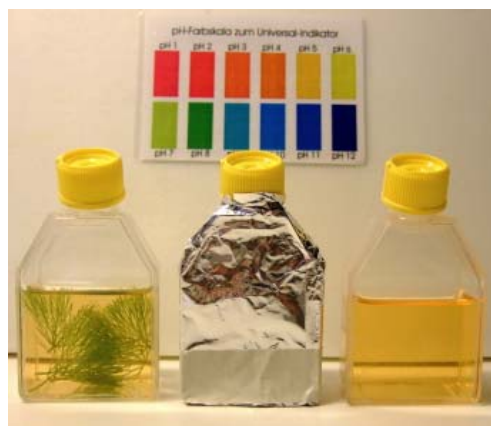


Fig 6. One bottle containing plants is wrapped in aluminium foil
The bottle with no plants acts as control

6. Observe if there is any change in the colour of the water in the control or in the bottle with plants which is not wrapped in foil. As soon as this happens, remove the aluminium foil or black paper from the covered bottle and compare the colour of the water in the different bottles. Put the bottles in front of a white background to see the colours more distinctly or remove the plants from inside the bottles.



Fig 7. Remove the aluminium wrap from the bottle and place the bottles in front of a white background

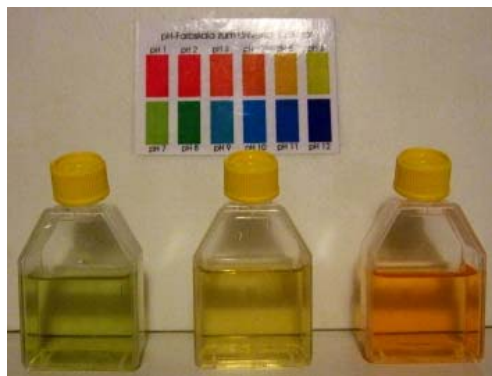


Fig 8. Compare the colour change in the three bottles

Results

1. Is there any difference in the colour of the water in the three bottles?
2. What do you think caused these differences?

Notes

1. The water in the bottle with *Cabomba* exposed to light will obtain a greenish shade (it can be greener depending on the intensity of light and duration of exposure to light) from the original yellow colour (acidic to basic), whereas the water in the darkened bottle with *Cabomba* will remain yellow.

The water in the control will also remain yellow, although it is possible that it will turn even darker (more acidic). Introducing CO_2 into the bottles caused the original low pH in the bottles. The plants in the bottle exposed to light are able to photosynthesize and in this process they take up CO_2 from the water, resulting to an increased pH (green colour). In the absence of light, the plants in the covered bottle cannot photosynthesize, so they do not take up CO_2 , resulting in the water remaining acidic.

2. In the control, the water may turn darker yellow to orange (become more acidic). One probable explanation for this is that there may have been a high concentration of CO₂ inside the bottle, thus more carbon dioxide dissolved in the water.
3. Tap water can also be used in this experiment.

Part 2. Experiment with the Phytoplankton, *Dunaliella tertiolecta*

Preparation time:	10 Minutes
Duration of activity:	20 minutes
Target age group:	12-15 years old / Grades 5-9
Application:	Chemistry and Biology lessons / After school activity
Time for data analysis and discussion:	15 minutes
Previous knowledge required:	Photosynthesis, Phytoplankton
Cost:	all materials and equipment should be available in the school: Phytoplankton culture can be obtained from the pet shop or a partner research institute

Materials

- Young Phytoplankton culture in a flask
- Flask containing the same volume of seawater as the culture
- pH-Meter
- Table lamp or sunlight
- Drinking straw
- Cotton wad stopper wrapped in plastic foil



Fig 1. Materials

Procedure

1. Cover the flasks with the cotton wad and stick the pH-Meter probe and the drinking straw through it, making sure that they are immersed in the water. Record the initial **pH** of the water and write this in the table.



Fig 2. Set-up

2. Blow air through the drinking straw to introduce CO₂ into the flasks until no further decrease of the pH can be observed. Write down the resulting pH in the Table.
3. Expose the flasks to light (table lamp or sunlight) and measure the pH for a further 10 minutes at one-minute intervals.

Change in pH of seawater in the presence and absence of phytoplankton after adding excess carbon dioxide

Time (Min)	pH	
	Seawater with phytoplankton	Seawater without phytoplankton
Sample		
Initial (0 mn)		
pH after adding CO ₂ (0 mn)		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Results

1. Is there a difference in how the acidity of the water in the two flasks changes? Is there any change at all? What could be the reason for this difference?
2. What is the role of phytoplankton in the carbon cycle in the ocean? Phytoplankton are very small, how can they be effective in reducing the carbon dioxide in the atmosphere?

Notes:

1. The pH of the water in both bottles decreased after blowing in CO₂ inside. The CO₂ caused the water to become acidic. After several minutes, however, the pH of the water in the bottle with the phytoplankton should continually increase, whereas in the bottle without phytoplankton the pH should not change at all.

This demonstrates that the phytoplankton took up dissolved CO₂ from the water resulting in an increase in pH. (Be sure to use young phytoplankton cultures as younger cells show more active photosynthesis).

2. Phytoplankton is responsible for the major part of primary productivity in the oceans. Some research indicate that phytoplankton take up enough CO₂ to balance the escape of CO₂ from equatorial waters. These microalgae serve as food for zooplankton, which in turn are consumed by fish and other larger organisms. When plankton die, most of the organic matter and nutrients they contain are recycled back by remineralisation, but a small fraction of this sinks to the deeper layers of the ocean where the carbon they contain is stored for longer periods of time.

Considering that 90% of the world's photosynthesis is carried out by phytoplankton in the ocean, these organisms do indeed play a major role in removing CO₂ from the atmosphere.

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