Oceanography

with Professor Katja Fennel, Dr Dariia Atamanchuk and Professor Ruth Musgrave

Talking *points*

Knowledge & Comprehension

1. What role does the ocean play in mitigating climate change?
2. What is ocean alkalinity enhancement (OAE), and how does it mimic the process of rock weathering?
3. Why is it preferable that carbon in the ocean is in the form of bicarbonate, rather than carbon dioxide (CO_2)?
4. How did the Halifax Harbour trial allow scientists to explore the feasibility and implications of OAE?

Application

5. How would you design a study to investigate the effects of OAE on marine ecosystems?
6. Imagine you are a policymaker tasked with developing regulations for OAE as it continues to be studied and rolled out as a climate change mitigation approach. What factors would you consider as you develop these regulations? How would you address environmental, technological and economic concerns in your policies?
7. How do you think Katja (an ocean modeller) and Ruth (a physical oceanographer specialising in ocean mixing) collaborate to build computational simulations of CO_2 absorption? What expertise will each bring to the task?
8. How could ocean technology, such as robotic boats equipped with sensors, be applied to help understand and solve other ocean-related challenges?

Analysis

9. Why is it important that carbon dioxide removal (CDR) is not viewed as an alternative to reducing CO_2 emissions? And why is it essential that we explore CDR techniques alongside efforts to reduce CO_2 emissions?

Evaluation

10. To what extent do you agree that large-scale OAE should be carried out to mitigate the impacts of climate change? What do you feel are the greatest potential benefits and risks of this approach? Consider feasibility, ethics, and environmental, technological and economic factors.
11. How have Katja, Dariia and Ruth's personal experiences influenced their educational and career pathways?
12. Which aspect of oceanography would you most like a career in, and why?

Activities

CO_2 acidification experiments

One consequence of increasing the amount of CO_2 dissolved in the ocean is ocean acidification, caused by the increase in carbonic acid. A key advantage of OAE is that it is a CDR technique that does not exacerbate ocean acidification because the additional carbon is stored as bicarbonate.

In this simple experiment, you can observe how adding CO_2 to water increases its acidity.

- Create a pH indicator by tearing up two leaves of red cabbage and adding them to a zip-lock bag with 1 cup of water. Remove as much air as possible from the bag and seal it. Squish the leaves with your hands until the water turns dark blue.
- Place 1 tablespoon of your blue indicator solution into a cup with a bit of water. Blow into the water through a straw. What happens?

Your breath contains CO_2, and when you breathe into the water some of the CO_2 is dissolved. This forms carbonic acid, which causes the indicator to change from blue to purple.

You can extend this experiment to observe how increasing the concentration of CO_2 in the air will increase the concentration of CO_2 in water.

- Place 1 tablespoon of your cabbage indicator solution into a small, clear cup.
- Place 1 tablespoon of vinegar into a medium-sized, clear cup.
- Add 1 teaspoon of bicarbonate of soda (baking soda) to the vinegar in the medium cup, then quickly place the small cup containing the indictor into the medium cup.

- Place a tall, clear cup upside down over the medium cup to prevent gas from escaping
- Gently swirl the entire set of cups. What happens?

When vinegar and bicarbonate of soda are mixed, they react to produce bubbles of CO_2. By trapping this gas in the cups, the concentration of CO_2 in the air within the cups increases. Gas exchange occurs at the surface of the water containing indicator, as CO_2 from the air is absorbed into the water. This CO_2 then reacts with the water to form carbonic acid, causing the indicator to change from blue to purple. The vinegar and bicarbonate of soda reaction will produce much more CO_2 than your exhaled breath, so it will produce more carbonic acid and cause a greater colour change in the indicator.

Alternative CDR methods

Adding brucite to seawater is only one way to remove CO_2 from the atmosphere. Explore other CDR methods and create a poster or presentation to explain the advantages and challenges of different options.

- Begin by researching different methods of CDR, such as blue carbon sequestration, the use of biochar, electrochemical methods, and direct air carbon capture and storage.
- Make notes of the advantages and challenges associated with each method, considering factors such as effectiveness, scalability, environmental impact and cost.
- Design a visually engaging poster or presentation that introduces each method and its potential benefits and drawbacks. Your poster or presentation should be eye-catching, informative, and include images and diagrams as well as text to explain different CDR techniques.
- Present your poster or presentation to your class and encourage your classmates to ask questions once you have finished.

Once everyone has presented their findings, discuss the different CDR methods people investigated.

- What are the similarities and differences between different CDR methods?
- What are the similarities and differences between the advantages and challenges of different CDR methods?
- Which CDR method do you believe has the greatest potential for widespread implementation, and why?
- Reflecting on the advantages and challenges of each CDR method, which factors do you think are most important to consider when selecting a method for real-world application?

More *resources*

- Learn more about the Ocean Alk-Align Project at Dalhousie University: **www.alkalign.ocean.dal.ca**
- Learn more about different ocean-based CDR methods: **www.oceanvisions.org/ocean-based-carbon-dioxide-removal**
- Read about the current global state of CDR: **www.stateofcdr.org**
- OceanNETs is exploring different ocean-based negative emission technologies: **www.oceannets.eu**
- Read the US National Oceanic and Atmospheric Administration's report about CDR research: **sciencecouncil.noaa.gov/wp-content/uploads/2023/06/mCDR-glossy-final.pdf**