Québec OCÉAN

OCEAN ACIDIFICATION

Oceans play an essential role in regulating the Earth's climate, driving the hydrological cycle and providing habitat for marine organisms. One of the most major roles oceans play is in the exchange of carbon dioxide (CO_2) with the atmosphere. CO_2 is a natural constituent of the atmosphere and one of the most important greenhouse gases. It contributes to the natural greenhouse effect that keeps the Earth's surface at a comfortable global average temperature of about 15°C. But since the beginning of industrialization in the 1800s, human activities have steadily increased the amount of greenhouse gases, such as CO_2, in the atmosphere as a result of the combustion of fossil fuels and the production of cement.

The effects of increasing atmospheric CO_2

The rapid rise of atmospheric CO_2 levels is one of the main causes of climate warming and has already resulted in a 1°C increase in the global average temperature. About half of all the CO_2 emitted by human activity in the last 200 years was dissolved and stored in the oceans, and the oceans still take up one third of the CO_2 emitted each year. This is a good thing, but the additional uptake of CO_2 by oceans is affecting their chemistry: waters are becoming more acidic (see Box 1). Ocean acidification is thus another consequence of human activity.

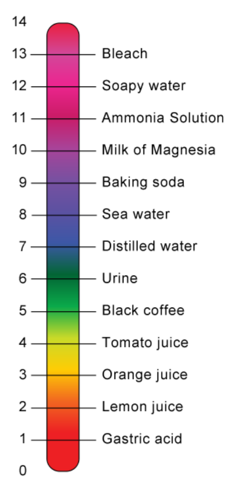
Credit: iStockphoto

Reef-building corals in tropical and sub-tropical seas build their skeletons from mineral calcium carbonate and are vulnerable to acidification.

What is ocean acidification ?

- Carbon dioxide (CO_2) from atmosphere naturally sinks in oceans and reacts with seawater.
- The acid-base balance of seawater is forced towards acid, mainly as a result of too much CO_2 emissions associated with human activity.
- Ocean acidification has increased by 30% since the beginning of the industrial era, and this rate could reach 120% in 2060.
- Ocean acidification reduces the availability of calcium carbonate which is used by marine organisms, such as corals, plankton and mollusks, to build shells and skeletons.

pH: a measure of acidity



Acidity ranges from 0 to 14, as measured by a pH unit. The average ocean pH has remained around 8.2 for 800 000 years and has declined to 8.1 since the beginning of industrialization. This pH difference may seem small, but the pH scale is logarithmic, which means that the 0.1 pH unit represents a 30% increase in the concentration of hydrogen ions (H^+) which control the pH level of seawater (see Box 1). This decrease represents a global average, but the trend is much more pronounced in polar regions. For example, the pH in the Arctic has already declined by 0.12 compared to 0.06 in the tropics.

BOX 1. Ocean carbonate chemistry

As CO_2 dissolves in seawater, it reacts with water molecules (H_2O) to form carbonic acid (H_2CO_3):

$[CO_2] + [H_2O] \Leftrightarrow [H_2CO_3]$

Most carbonic acid dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+):

$[H_2CO_3] \Leftrightarrow [H^+] + [HCO_3^-]$

It is the increase of H^+ that lowers the pH of seawater and makes the ocean more acidic.

Additional H+ causes carbonate ion (CO_3^{2-}) to react with H^+ to form more bicarbonate:

$[H^+] + [CO_3^{2-}] \Leftrightarrow [HCO_3^-]$

Thus, the equilibrium of these three reactions is pushed toward the right and concentrations of H^+, H_2CO_3 and HCO_3^- increase, while the concentration of CO_3^{2-} decreases.

Less carbonate impedes the formation of carbonate minerals by marine organisms (for shells, skeletons).

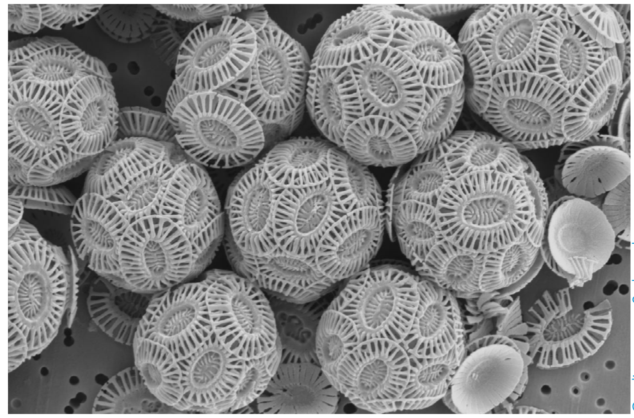
$[Ca_2^+] + [CO_3^{2-}] \Leftrightarrow$ Mineral $CaCO_3$

Credit: Russ HOPCROFT

Pteropods live in polar regions where they are an important component of the food chain. They will be among the first organisms to respond to ocean acidification and their loss or decline would have tremendous consequences for polar marine ecosystems.

Into the future

As more CO_2 enters the atmosphere from human activity, more will be taken up by the oceans. If CO_2 emissions continue at the same current trends, global ocean pH is projected to drop another 0.3 – 0.4 by 2100. This acidification process is happening much faster than has ever been registered in the geological past. So marine species and ecosystems might not have the time to *acclimate* or adapt to these rapid changes in ocean chemistry.



Credit: www.co2.ulg.ac.be

The single-celled coccolithophorids are among the tiniest calcifying organisms living in the ocean. These planktonic cells sit at the front-end of the marine food chain.

Effects of ocean acidification on living organisms

Marine organisms that produce shells or skeletons made from mineral calcium carbonate ($CaCO_3$) will be the most affected by ocean acidification:

- Corals: Reduced calcification, growth and survival of reef-building corals; loss of these unique habitats.
- Shellfish: Reduced growth and survival of sea urchins, seastars, mussels and lobsters.
- Plankton: Reduced calcification of microscopic coccolithophorids, foraminifera and pteropods that form the base of many food chains in surface waters. Degradation of plankton survival will diminish the amount of food available to primary consumers and top predators.

Fish: Less habitat and redistribution. Decrease in hearing, balance and sense of smell.

Undergoing science

Marine organisms will respond differently to rising ocean acidity, depending on their physiology and habitat. Québec-Océan researchers are in the forefront of worldwide science in ocean acidification, and are actively working to understand its effects on key organisms and on the marine environment, especially in cold waters.

Québec OCÉAN Le groupe interinstitutionnel de recherches océanographiques du Québec

Pavillon Alexandre-Vachon
1045, Avenue de la Médecine, local 2078
Université Laval, Québec (Québec) G1V 0A6

T 418.656.5917
F 418.656.2339
www.quebec-ocean.ulaval.ca