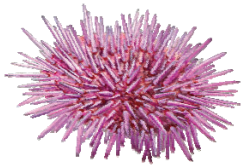
Ocean Acidification

Between 1751 and 1994, surface ocean pH is estimated to have decreased from approximately 8.2 to 8.1. That may not seem like much but it is a nearly 26% increase in acidity!

What is causing the ocean's pH to change?

The ocean is one of the world's largest carbon sinks. Each day it absorbs more than one million metric tons of carbon dioxide (CO_2) every hour! CO_2 is a naturally-occurring gas in our atmosphere that is integral in maintaining a healthy climate. However, additional CO_2 is released into the atmosphere from the burning of coal, oil and other fossil fuels. It is estimated that in the United States, approximately 15 million metric tons of CO_2 are emitted every day due to human activities. When CO_2 dissolves in the ocean, it increases the hydrogen-ion concentration.



A Massive Carbon Sink

The absorption of CO_2 by the ocean is a natural process. Chemically it looks like this:

Carbonate Buffering System: A System Out of Balance

Phase One

As the ocean absorbs carbon dioxide (CO_2) it bonds with water and forms carbonic acid (H_2CO_3).

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_3}$$

Phase Two

Carbonic acid can dissociate into a hydrogen ion (H^+) and a bicarbonate ion (HCO_3^-).

$$\underset{\text{carbonic acid}}{H_2CO_3} \rightleftharpoons \underset{\text{hydrogen ion}}{H^+} + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

Phase Three

The bicarbonate ion can further dissociate into a hydrogen ion (H^+) and a carbonate ion (CO_3^{2-}).

$$\underset{\text{bicarbonate ion}}{HCO_3^-} \rightleftharpoons \underset{\text{hydrogen ion}}{H^+} + \underset{\text{carbonate ion}}{CO_3^{2-}}$$

Seawater is more resistant to changes in pH than fresh water. This is because of a carbonate buffer system. Carbonate ions (CO_3^{2-}) tie up excess hydrogen ions when an acid is added and result in carbonic acid (H_2CO_3). The carbonic acid (H_2CO_3) donates hydrogen (H^+) ions when a base is added. This system regulates the pH of seawater. Depending on the addition of hydrogen ions, the reactions will reduce or increase carbonate ions to remain in equilibrium.

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_3} \rightleftharpoons \underset{\text{hydrogen ion}}{H^+} + \underset{\text{bicarbonate ion}}{HCO_3^-} \rightleftharpoons \underset{\text{hydrogen ion}}{H^+} + \underset{\text{carbonate ion}}{CO_3^{2-}}$$

However, an excessive amount of hydrogen ions released into ocean waters (as with the absorption of excess atmospheric CO_2) causes the ocean to become more acidic and tips the delicate buffering system of the ocean.

The Effects on Marine Organisms

Carbonate ions (CO_3^{2-}) can bond with calcium ions (Ca^{2+}) to form the compound calcium carbonate ($CaCO_3$) which is utilized by marine organisms to build shells and skeletons. However, if there are excess hydrogen (H^+) ions, those ions will usually reunite with the carbonate ions to form more bicarbonate. This makes the carbonate (CO_3^{2-}) ions less available for shell– and skeleton-building animals. If ocean waters become too acidic, calcium carbonate structures may even begin to dissolve!