Salt and Vinegar: A taste of climate change and ocean acidification

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To date the focus of climate change impacts has been increased temperature and sea level rise. What is less well known, is that the increased carbon dioxide (CO_2) levels in the atmosphere brought about by human activities are also having a significant effect on the pH and chemistry of the oceans. Globally the world's oceans are experiencing a decline in pH - that is, they are becoming more acidic. Such chemical changes pose a serious threat, particularly to marine organisms that secrete skeletal structures and support oceanic productivity and biodiversity.

pH

Carbon dioxide mixed with water produces carbonic acid (H_2CO_3) which is making the alkaline oceans more acidic. pH is the measure of acidity or alkalinity of a solution based on the activity of hydrogen ions (H^+). In general, fresh water is neutral at a pH of about 7.0, with solutions less than 7.0 considered acidic - such as vinegar (pH 2.9) or battery acid (pH 0.5). Alkaline (or basic) solutions have a pH higher than 7.0 - such as blood (pH 7.34 - 7.45) or household ammonia (pH 11.5). pH is measured on a negative logarithmic scale. For example, a shift in pH from 1 to 2 represents a decrease in total concentration of ten times less H^+ concentration, and a shift from 1 to 3 represents a one-hundred-fold decrease in H^+ concentration. So quite small changes in pH of the ocean equate to large changes in chemistry.

Oceans and CO_2

Much of the carbon dioxide produced by human activity does not stay in the atmosphere - it is naturally absorbed and stored in the oceans or on land in plants and animals. The oceans actually help to regulate atmospheric CO_2 concentrations through air-sea exchange. In the past 200 years the oceans have absorbed about half of the CO^2 produced by fossil fuel burning and cement production[1]. The oceans naturally maintain a high abundance of bicarbonate (HCO_3^-), and they do that by using carbonate (CO_3^{2-}) to buffer excess CO_2 gas as it enters the ocean[2]. This is known as the '*carbonate buffer*', and it is thought that this is the mechanism for stabilising pH in the oceans. The pH of seawater is generally considered to be pH 8.1 (give or take 0.3) and it has been stable at this level for millions of years[1,2]. Scientists used to believe that the *carbonate buffer* was very resilient and pH would not change, however it is now recognised that the system cannot cope with the current excess carbon dioxide entering the oceans.

A pH reduction of about 0.1 unit in surface waters has already occurred due to anthropogenic carbon dioxide input[1,2]. This equates to about a 30% increase in the concentration of hydrogen ions (H+) in the past 200 years. If current trends in CO_2 emissions continue, scientists predict that the average pH of the world's oceans could fall by 0.5 units (equivalent to a three fold increase in the concentration of hydrogen ions) by 2100[2]. In geological time scales, the rate of pH change we are now witnessing is greater than that seen for the last 20 million years and the corresponding predicted decrease in pH has not been experienced for at least the past 420,000 years or more[1]. Ocean acidification is essentially irreversible in human lifetime terms - it would take tens of thousands of years for ocean chemistry to return to pre-industrial (200 years ago) conditions[1].

Impacts on Marine Life - in Brief

The implications of ocean acidification to marine life are likely to be complex and have been poorly studied to date. However the extent and rate of change to ocean chemistry will inevitably profoundly affect marine organisms and ecosystems[1]. There is convincing evidence to suggest that acidification will affect the process of calcification, by which animals such as tropical corals and mollusks make shells and plates from calcium carbonate ($CaCO^3$). Under a more acidic ocean, carbonate ions are becoming scarcer, leading to an inhibition of calcium carbonate formation. Another compounding factor is that calcium carbonate is more likely to dissolve in colder and deeper waters. This has important ramifications for planktonic organisms such as cocolithophores and pteropods that fuel much of the oceans food webs (particularly in polar regions), and for cold water deep-sea corals. pH changes will also affect the availability of nutrients and metals available to phytoplankton - thus affecting photosynthesis and primary productivity. Larger organisms such as fish and squid have high oxygen demands. Research has shown that a decrease of pH by 0.25 units will cause a reduction in their oxygen-carrying capacity of 50 percent - thus affecting growth and survival[2]. Such change may have important flow-on effects to fisheries.

The Future?

Life will continue in the oceans whatever the conditions. However, given the combined effects of declining pH and other environmental pressures, such as pollution or extraction, major changes are likely to occur in species composition and ecosystem structure. At present, it seems that tropical coral reefs, Southern Ocean food webs, and deep-water coral reef ecosystems may be most at risk from acidification[1]. A future ocean dominated by jellyfish and slime - an untasty thought!

References

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[An abridged version of this article was published in: Newton, G (2007) Salt and Vinegar – A Taste of Climate Change and Ocean Acidification. *Waves* (Publication of the Marine and Coastal Community Network) 13(1): 7.]