Ocean Acidification: Evil Twin of Global Warming?

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Abstract

Ocean Acidification is one of the biggest threats to the marine ecosystem in our generation. This article tries to analyse Ocean Acidification through the prism of current research in the area and tries to explain the phenomenon and its effects in a simpler way. The decrease of 0.1 units in pH scale over two centuries might seem very small but it actually indicates a net increase of 30% acidity in the sea water and if we continue the business-as-usual the pH might reduce by 0.3 to 0.4 units further indicating an increase of over 100% acidity. This will be a situation that has never been experienced by our oceans over hundreds of millions of years and that is the reason; many refer ocean acidification as the 'Evil Twin of Global Warming'. The major possible effects of ocean acidification include a decrease in saturation of seawater with respect to Calcium Carbonate, coral bleaching, reduced metabolism, effects on photosynthesis, reduced health, for marine organisms and the socio-economic impacts on human beings. Thus, it becomes very much essential to adopt the mitigation techniques to overcome this problem. It should not happen that in a time when we are going to other planets in search of life, we lose it in our own oceans where the life originated. This paper also tries to highlights the current researched level, research gap and puts the understanding about the ocean acidification into intense scientific scrutiny.

Keywords: Ocean Acidification; Climate Change; Global Warming; Carbonate Saturation; Pteropods; Sea Water pH

1. Introduction.

Oceans are believed to be the source of life on earth. Ocean or Marine Ecosystem is very rich covering almost two third of the surface of the earth. Oceans play a very important role in the biogeochemical cycle, form a habitat for a countless number of species, and provide a livelihood for millions of people. They generate more than 50% of the earth's oxygen and act as the largest sink of CO_2 (National Research Council, 2010). The chemistry of the ocean leads to the formation of life as we know it billions of the years ago. The change in the same chemistry is now threatening the existence of this vast biodiversity of Oceans. Ocean Acidification (or more precisely the reduction in ocean alkalinity) is not a theory to be debated upon now, it is a reality whose long-term implications are experimented upon. Ocean acidification is a continuous process by which ocean pH has decreased from 8.25 to 8.14 since the beginning of the industrial revolution due to the continuous absorption of Carbon Di-Oxide emitted from various anthropogenic activities (Sponberg A. F., 2007). The dire need for finding the way out is being mired with the scientific uncertainties regarding organism responses and implications of mitigation methods. This article tries to analyse this phenomenon through the prism of current research in the area and tries to explain the phenomenon and its effects in a simpler way.

2. Chemistry of Ocean Acidification

Oceans play a pivotal role in global carbon cycle and earth's climate system. Oceans moderate the amount of Carbon in the atmosphere by absorbing CO_2. As the famous scientist Scott C. Doney points out, the oceans have taken up approximately half of all the fossil carbon that are released into the atmosphere due to the anthropogenic activities since the beginning of the Industrial Revolution (Doney, S. C., 2006). Though this phenomenon may seem very beneficial for mitigation of Global Warming, it also leads to increase in Hydrogen ion concentration [H+] through the hydrolysis of CO_2 in seawater. This process ultimately results in

making the oceans more and more acidic. The decrease of 0.1 units in pH scale over last 200 years might seem very small but it actually indicates a net increase of 30% acidity in the sea water and if we continue the business-as-usual the pH might reduce by 0.3 to 0.4 units further indicating an increase of over 100% acidity (Caldeira K. and Wickett M. E., 2003). This will be a situation that has never been experienced by our oceans over hundreds of millions of years and that is the reason; many refer ocean acidification as the 'Evil Twin of Global Warming'.

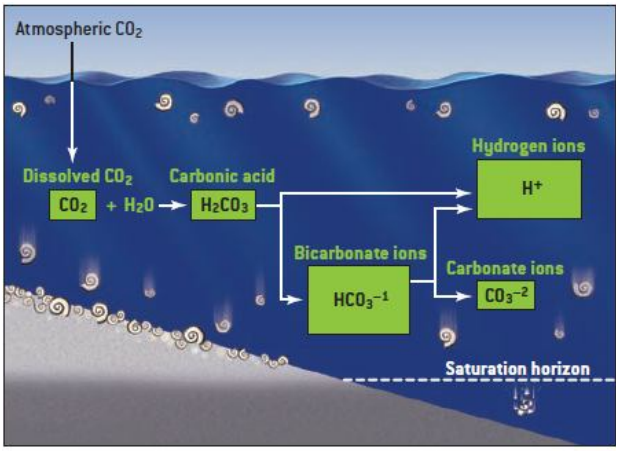


Fig. 1. Chemistry behind Ocean Acidification (Source: Doney, S. C., 2006)

Carbon dioxide (CO_2) absorbed by the oceans combines with seawater to form carbonic acid (H_2CO_3) releasing hydrogen [H^+] ion and leaving both carbonate [CO_3^{2-}] and bicarbonate [HCO_3^{1-}] ions behind [Fig. 1]. The chemistry is not so straight forward sometimes with some part of carbonic acid might remain without dissociating and some CO_2 also will remain free (Congressional Research Service, 2013). The ultimate result of all these reactions is the net increase in the hydrogen ion concentration as shown in equation (1) which results in a more and more acidified seawater.

$$CO_{2\,(aq)} + H_2O \leftrightarrow H_2CO_3 \;\; HCO_3^{"} + H^+ \;\; CO_3^{2"} + 2\,H^+ \quad \ldots (1)$$

3. Effects of Ocean Acidification

The primary and most widely discussed ill effect of ocean acidification is the simultaneous drop in the Carbonate ion [CO_3^{2-}] concentration with the rise of aqueous CO_2 concentration [$CO_{2(aq)}$] which will eventually result in making it much more difficult for the marine calcifying organisms to form biogenic calcium carbonate [$CaCO_3$] shells. (Orr et. al., 2005) Formation of Calcium Carbonate shell by these organisms happen at the surface of the oceans where there is a supersaturation state for the [$CaCO_3$]. This supersaturation stage occurs at different heights across the globe. Below this saturation horizon the [$CaCO_3$] shells start dissolving and eventually disappear since the water is in the less saturated or unsaturated condition for these minerals.

Whenever there is an excess hydrogen ion present in the system the equilibrium shifts towards the left since Carbonate ion [CO_3^{2-}] has more affinity towards hydrogen [H^+] ion than the Calcium ion [Ca^{2+}] resulting in making the water unsaturated. Thus, Ocean acidification causes a dramatic upward shift of the saturation horizon resulting in a continuous decrease in the habitable zone of the calcifying organisms. The most vulnerable organisms to these changes are phytoplankton such as coccolithophorids, planktonic organisms such as foraminifera and pteropods that are considered to be at the bottom of the food chain which most of fishes and mammals depend on (Ries J. B., Cohen A. L., and McCorkle D. C., 2009). As projected by some studies, by the year 2050, the surface waters of Southern Oceans will experience undersaturation with respect to aragonite, a metastable form of calcium carbonate [$CaCO_3$] and even more worrying prospect is that this under-saturation could be seen throughout the Southern Ocean and in the subarctic Pacific Ocean, before the end of this century (Orr J. C., et. al., 2005).

Another adverse effect of ocean acidification is its role in coral bleaching (Participants of the Ocean Acidification Workshop & the Nature Conservancy, 2009). Corals are marine invertebrates which live in colonies and secrete Calcium Carbonate skeleton that accumulates over time to form the coral reefs. The beautiful colours of these reefs, that cradle almost a quarter of oceans biodiversity, are usually imparted by the symbiotic algae and protozoans like Zooxanthellae (The Royal Society, 2005). Under

various environmental stresses, these symbiotic organisms are expelled revealing the white calcium carbonate skeleton underneath. This phenomenon is referred as the 'Coral Bleaching'. One of the environmental stresses that trigger this is ocean acidification and along with global temperature rise acidification is one of the biggest threats to the survival of corals in future. All in all, calcification may not be the only physiological process that suffers severely from ocean acidification. In response to acidification, many species display physiological trade-offs including amplified metabolism, reduced fitness and health, and changes in behavioural responses associated with calcification upregulation, which poses a great threat to their survival (Findlay H. S. et. al., 2011).

Ocean acidification (OA) also weakens the capacity of marine and coastal ecosystems to provide economic services to humans such as tourism, extraction of red coral for jewellery production, and fisheries (capture and aquaculture). Additionally, there is an expected disruption of the carbon sequestration service of the oceans, which will indirectly affect climate stability. (Rodrigues L. C., Bergh J. C. J. M. V. and Ghermandi A., 2012)

In spite of all these adverse effects the increased CO_2, there might just be an advantage also. There are some phytoplanktons whose growth is limited by the low availability of dissolved carbon dioxide (Doney, S. C., 2006). These organisms might be benefitted from increases availability of dissolved CO_2 though this fertilization effect is yet to be proven scientifically.

4. Conclusion

The phenomenon of Ocean Acidification was unimaginable just a century ago since the very concept of pH did not exist then. Now, the great biodiversity of the ocean is at great danger will face extinction within one more century if not acted responsibly. The scientific uncertainty regarding the potential impacts has long been used as an excuse for delaying the actions. Recent studies listed in the article are clearly indicating the huge threat being faced by the marine organisms and the uncertainties have been washed off. The precautionary principle should be applied in this regard and the acidification problem should be mitigated. There are numerous mitigation options available such as the reduction in CO_2 emissions, iron fertilization, carbon sequestration etc. Most of these options are though considered to be expensive and the ultimate implications of these methods are also debatable. But since the mitigation option for Ocean Acidification will also help in the reduction of global warming, it seems beneficial either way to adapt these technologies with all prior precautions. It is essential to maintain the vast biodiversity present in the oceans and the livelihood of millions of people dependent on these changing oceans. It should not happen that in a time when we are going to other planets in search of life, we lose it in our own oceans where the life originated.

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