Ocean Acidification – The Next Phase in Reducing CO_2 Emissions

By Jasmijn Appels, Wageningen University and Research Centre

Introduction

The problem of ocean acidification, also called "the other CO_2 problem"[1], is seen as one of the largest threats to marine ecosystems and organisms.[2] Oceans have the natural ability to absorb carbon dioxide (CO_2). When CO_2 dissolves in the ocean, it forms carbonic acid, which leads to a reduction in seawater pH and thus more acidic conditions in the oceans. Since preindustrial times, there has been a 30 per cent increase in ocean acidity.[3,4,5] This natural buffering is being used as a means to mitigate anthropogenic climate change, but the speed and magnitude of the ocean acidification process adversely affects marine ecosystems and species.[6]

The consequences of ocean acidification are far-reaching and multi-dimensional, affecting the marine environment directly and indirectly.[7] Ecosystems' functioning will be hampered due to ocean acidification, especially those who form shells and plates.[6] Subsequently, other organisms that feed on them will face changes in the availability and composition of nutrients as a result of the increased acidity.

Furthermore it is expected that ocean acidification will affect various economic sectors such as fisheries, aquaculture and tourism,[8] and consequently food security.[9] Among the most affected are communities living in areas highly dependent on fisheries, mostly coastal communities in developing countries. 26 out of the 30 countries that are the most dependent on fish as a protein source are developing countries.[10]

Ocean acidification facts & figures

- Over the past 50 years, the oceans have absorbed between 24% and 33% of the CO_2 emissions.[11]
- There has been a 0.1 pH unit reduction since pre-industrial times, and an additional decrease of 0.4 pH is expected for the upcoming 100 years.
- Especially organisms that form shells and plates, such as plankton, corals and coralline algae will be among the most affected.

Source: authors' compilation.

Scientific Debate

Researchers already have been making efforts to find measures to adapt to and mitigate ocean acidification. There are several options to take action against ocean acidification, ranging from solar radiation management to improving ecosystem resilience. The options of 'reducing CO_2 emissions' and 'removing atmospheric CO_2' have the greatest potential. However, political and social feasibility of reducing CO_2 emissions raises concerns and therefore, depending on the viewpoint, feasibility can be considered relatively high or low.[12]

This is mainly because of the difficult positioning of ocean acidification in scientific and political debates. Ocean acidification is linked to the climate change agenda as well as to the marine pollution agenda.[13] In both regimes ocean acidification is partly regulated, but the problem in its entirety is addressed by neither. This phenomenon is called the 'international twilight zone' in which ocean acidification is placed.[14]

It can be illustrated by looking at the positioning of ocean acidification within the climate change debates.

Ocean acidification is frequently linked to climate change in policy frameworks, since the climate system is defined to include the oceans.[14] What is important to stress out is that ocean acidification is not an effect of climate change, it rather shares the same cause as climate change: an increase of atmospheric CO_2.

Consequently, actions to mitigate adverse effects of climate change do not necessarily contribute to mitigation of ocean acidification.[15] Current agreements do not prioritize reductions in CO_2 emissions, but work with overall reduction of greenhouse gas emissions. Ocean acidification can only be tackled by a reduction in CO_2 emissions, and this has not been incorporated in current agreements. Therefore current agreements may not necessarily lead to a reduction in ocean acidification.

The geophysical processes of ocean acidification are generally well known.[16] Ocean pH has decreased 0.1 units since pre-industrial times. Modelling shows that, with CO_2 emissions increasing at current trends, the ocean average pH will decrease a further 0.4 pH units by the end of the century and, by 2300, the pH at the ocean surface may decrease 0.7 units.[17] Although the ocean pH has varied in the past, those variations are thought to have occurred over millions of years. On the contrary, the future pH reductions from CO_2 emissions would be happening at an unprecedented speed and marine species may not have time to adapt to these sudden changes in the ocean.

Presently, surface waters are saturated with respect to aragonite and calcite. This saturation is essential for calcifying organisms to produce their skeletons and shells as well as to keep these structures intact. But oceans become less saturated as their pH decreases. If the oceans reach under-saturation, existing shells and skeletons will start to dissolve and the oceans will turn corrosive for these organisms, presumably with a ripple effect up the food chain and associated ecosystems.[16] As the ocean absorption of CO_2 is not evenly distributed spatially, some oceans are expected to reach this tipping point earlier than others. Projections suggest that large parts of the Southern Ocean and the Arctic Ocean may be affected as early as 2030-2060.[18, 19] Coral reefs are in danger to be affected by as early as 2050.[20]

J. Rockström et al. define a possible planetary boundary for the saturation threshold.[21] However, the article also expresses the uncertainty of this planetary boundary, because the responses of organisms other than calcifying organisms as well as of the overall ecosystems are still unclear.

Indeed, although the magnitude of ocean acidification can be predicted with a high level of confidence, the impacts of acidification on marine organisms are less known. The impacts will likely differ per organism. As there is hardly any knowledge on the threatening level of acidification for each marine organism, it is difficult to define a "safe" level of atmospheric CO_2 to protect the oceans. For calcifying marine ecosystems such as continental shelves and coral reefs, scientists cautioned against levels of atmospheric CO_2 above 450-500 ppm.

Food for thought on ocean acidification

- Reducing CO_2 emissions is not the only way to take actions against ocean acidification, but cannot be compared to the other actions in relation to scale. Therefore a reduction in CO_2 emissions is much more effective
- Mitigation of climate change does not necessarily equate to mitigation of ocean acidification.
- It is vital that ocean acidification will be better incorporated in the climate change debate. This can easily be done by focusing more on CO_2 emission reduction
- There is a lot of uncertainty about which marine organisms are affected for each level of ocean pH. For continental shelves and coral reefs, scientists cautioned against levels of atmospheric CO_2 above 450-500 ppm.

Source: authors' compilation.

Issues for further consideration

The following issues were suggested by the team of young researchers for consideration by policy makers:

- There is a need for extended research on the effects of ocean acidification focusing on interdisciplinary issues of ecological and socio-economic impacts
- There should be put a larger emphasis on the reduction of CO_2 emissions by policy makers and within the current climate change debate
- There is a need for more knowledge on the impacts of acidification on marine organisms and their ecosystems.

Notes

[1] Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean acidification: the other CO_2 problem. Marine Science, 1, 169-192.

[2] Gattuso, J. P., & Hansson, L. (2011). Ocean acidification: background and history. In: Ocean acidification, Oxford, edited by: Gattuso, J.-P. and Hansson, L., Oxford University Press, Oxford, 1-20.

[3] Feely, R. A., Alin, S. R., Newton, J., Sabine, C. L., Warner, M., Devol, A., Krembs, C. & Maloy, C. (2010). The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuarine, Coastal and Shelf Science, 88(4), 442-449.

[4] Ocean Acidification Reference User Group (2010). Ocean Acidification: Questions Answered. In: Laffoley,D. d'A., and Baxter, J.M. (eds). European Project on Ocean Acidification (EPOCA). 24 pp.

[5] Dupont, S., & Pörtner, H. (2013). Marine science: get ready for ocean acidification. Nature, 498(7455), 429-429.

[6] Abbasi, T., & Abbasi, S. A. (2011). Ocean acidification: The newest threat to the global environment. Critical Reviews in Environmental Science and Technology, 41(18), 1601-1663.

[7] Royal Society (2005). Ocean acidification due to increasing atmospheric carbon dioxide. London: The Royal Society, 57 pp.

[8] Billé, R., Kelly, R., Biastoch, A., Harrould-Kolieb, E., Herr, D., Joos, F., Kroeker, K., Laffoley, D., Oschlies, A. & Gattuso, J. P. (2013). Taking action against ocean acidification: a review of management and policy options. Environmental management, 52(4), 761-779.

[9] Gattuso, J. P., Mach, K. J., & Morgan, G. (2013). Ocean acidification and its impacts: an expert survey. Climatic Change, 1-14.

[10] Turley, C. (2008). Ocean acidification: Communication, Dissemination and Outreach. Paper presented at ESF Strategic Workshop on Ocean Acidification. Meloneras, Cran Canaries, 28-31 January, 2008. Plymouth: Plymouth Marine Laboratory.

[11] Le Quéré, C., Raupach, M. R., Canadell, J. G., & Marland, G. (2009). Trends in the sources and sinks of carbon dioxide. Nature Geoscience, 2(12), 831-836.

[12] Billé, R., Kelly, R., Biastoch, A., Harrould-Kolieb, E., Herr, D., Joos, F., Kroeker, K., Laffoley, D., Oschlies, A. & Gattuso, J. P. (2013). Taking action against ocean acidification: a review of management and policy options. Environmental management, 52(4), 761-779.

[13] Baird, R., Simons, M., & Stephens, T. (2009). Ocean acidification: A litmus test for international law. Carbon & Climate L. Rev., 459.

[14] Kim, R. E. (2012). Is a New Multilateral Environmental Agreement on Ocean Acidification Necessary?. Review of European Community & International Environmental Law, 21(3), 243-258.

[15] Harrould-Kolieb, E. R., & Herr, D. (2012). Ocean acidification and climate change: synergies and challenges of addressing both under the UNFCCC. Climate Policy, 12(3), 378-389.

[16] Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2), 32-65.

[17] Caldeira, K., & Wickett, M.E. (2003). Anthropogenic carbon and ocean pH. Nature, 425 (6956), 365-365.

[18] McNeil, B.I. & Matear, R.J. (2008). Southern Ocean acidification: A tipping point at 450-ppm atmospheric CO2. PNAS, 105(48), 18860-18864.

[19] Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, & Yool, A. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature, 437(29), 681-686.

[20] Hoegh-Guldberg, O., P. J. Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira, N. Knowlton, C. M. Eakin, R. Iglesias-Prieto, N. Muthiga, R. H. Bradbury, A. Dubi, & Hatziolos, M. E. (2007). Coral reefs under rapid climate change and ocean acidification. Science, 318 (5857), 1737–1742.

[21] Supra note 16.