SHORT FEATURE

Turning Ocean Waters Acidic
Threatening Marine Life

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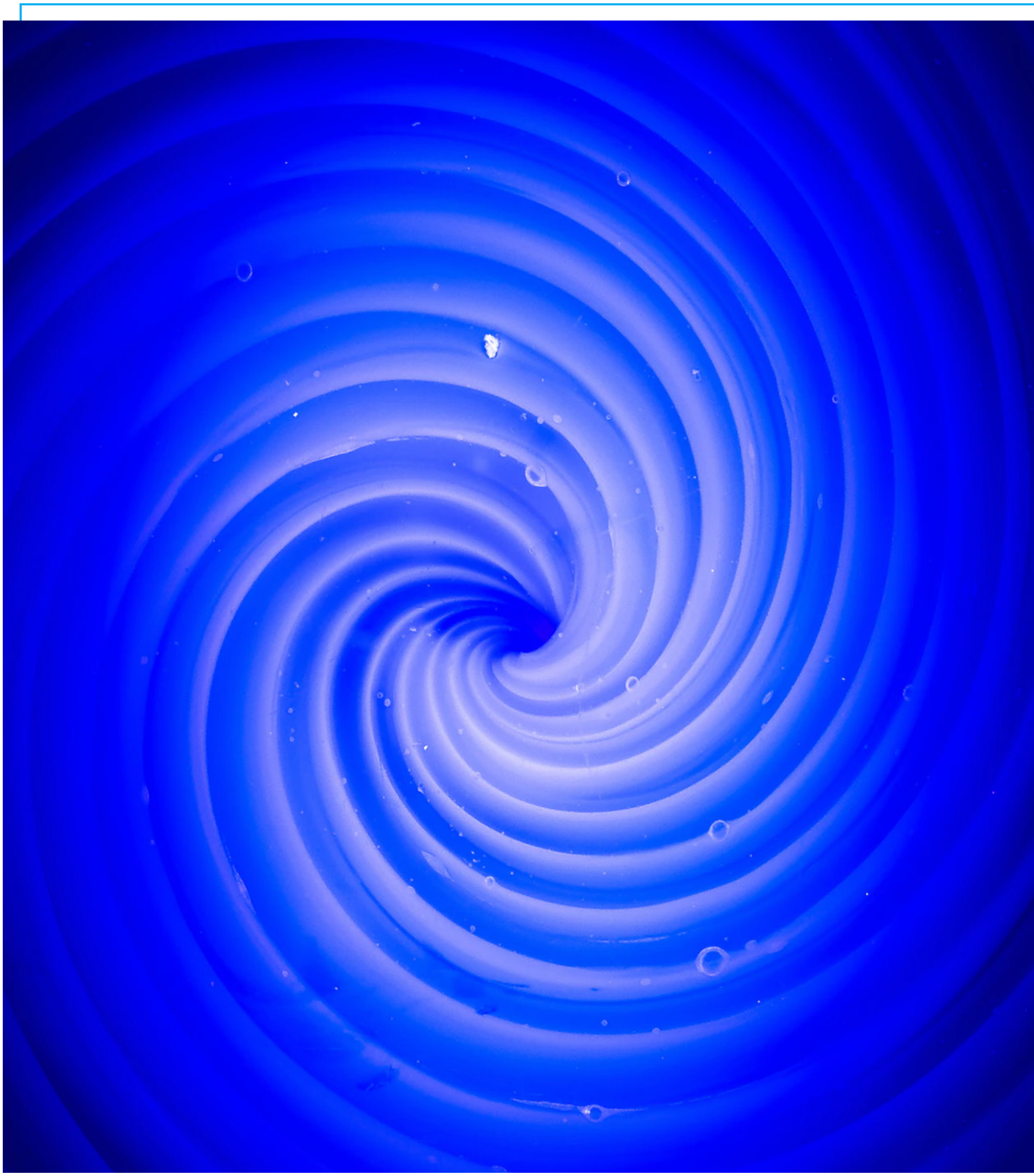


SEAWATER is salty, and as such one would expect it to be alkaline. Yet, our oceans are becoming more and more acidic. In fact, they are currently 26% more acidic than they were before the world became industrialized, with the rate of acidification increasing faster than we have ever witnessed before.

Atmospheric Carbon Dioxide (CO_2) continues to rise due to anthropogenic CO_2 emissions which are released when fossil fuels are burned. This CO_2 doesn't just waft away into space, some of it remains in the atmosphere where it acts as a greenhouse gas that traps heat, making the planet warmer; and about 30% of it is absorbed by the oceans, where it changes the chemistry of seawater, making it more acidic. Yet, while this does reduce the amount of carbon dioxide in the atmosphere — which is currently 40% higher than it was before the industrial revolution — it is the primary cause of ocean acidification.

There are two other potential causes of acidification: 1) Acidification of coastal waters due to runoff containing nitrogen and phosphates from land-based sources; 2) Release of carbon stored in frozen methane hydrates found in the ocean sediments, which can potentially be released due to ocean warming — a process that would not be reversible.

Oceans Act as Carbon Sink

The oceans play a key role in the natural carbon cycle, with carbon dioxide moving from the atmosphere into the oceans across the ocean-atmosphere interface. As carbon dioxide is found in higher concentrations in the atmosphere, it is readily absorbed by the oceans, which traditionally act as a carbon sink.

When carbon dioxide dissolves in seawater it enters the carbonate system where it occurs in one of three forms: dissolved carbon dioxide, carbonate ions (CO_3^{2-}) or bicarbonate ions (HCO_3^-). When carbon dioxide is absorbed into the oceans from the atmosphere it can chemically react with seawater to form carbonic acid (H_2CO_3), which slowly releases hydrogen ions (H^+). Some of these hydrogen ions bond with carbonate ions present in seawater to form bicarbonate.

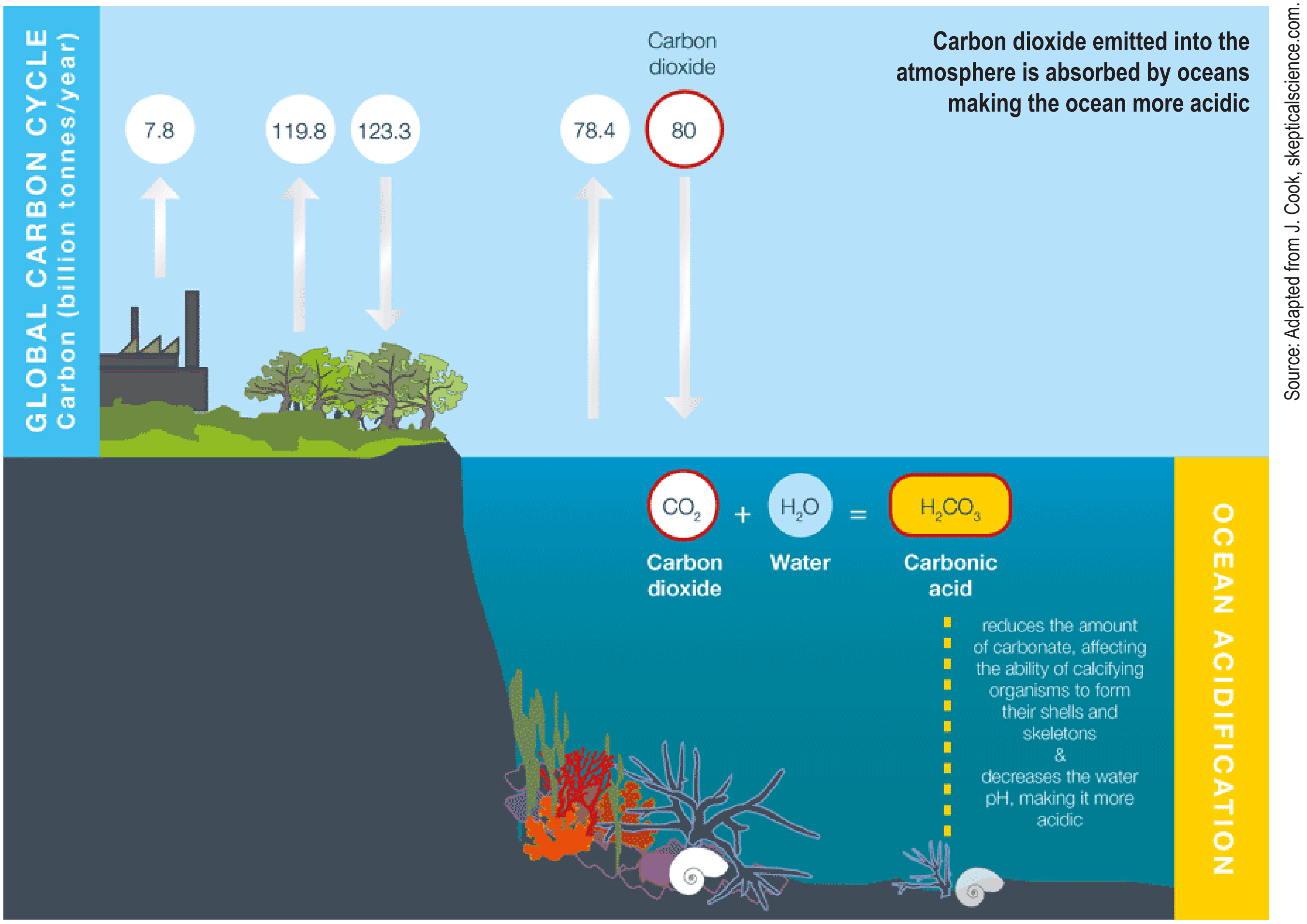
Consequently, as more and more carbon dioxide is absorbed by the oceans, the concentration of carbonate decreases while the concentrations of hydrogen and bicarbonate increase, resulting in a decrease in pH (potential of hydrogen — the scale used to measure the concentration of hydrogen). The more hydrogen ions are present in seawater (or any solution), the more acidic it is, and therefore the lower the pH.

Effects of Ocean Acidification

Impact on Marine Life: Dissolved carbon dioxide is assimilated by phytoplankton during the process of photosynthesis, and carbonate ions (calcium carbonate, $CaCO_3$) are synthesized by zooplankton and other marine organisms, such as snails, shellfish and corals to build shells and skeletons. While high concentrations of CO_2 may be beneficial to photosynthesizing

Coral bleaching under water in Japan

(https://www.iucn.org/)



phytoplankton, fleshy algae and seagrasses if sunlight and nutrients are freely available, it can be detrimental to other marine life.

Carbonic acid can reduce the concentration of calcium carbonate needed by zooplankton and other calcium builders to build and maintain their shells and skeletons. This can affect development, growth, and survival of a wide range of species – from tiny zooplankton to mollusks, coral, urchins and to a lesser degree, even crustaceans such as crabs.

Ocean acidity tends to be higher in the Polar Regions, where important prey species are already being negatively affected. For example, in the Southern Ocean the shells of pteropod snails — which play a key role in marine food webs, supporting the abundant and diverse range of marine life living there — are dissolving. Should a vital prey species such as these be wiped out, it can have spin-off effects that would adversely affect productivity and biodiversity.

As corals are calcifying organisms, coral reefs are also threatened by ocean acidification. Should CO_2 emissions continue to rise, it is highly likely that coral reefs will erode faster than they can be rebuilt. Tropical coral reefs face a double-whammy of erosion due to acidification, as well as bleaching due to ocean warming.

Coral reefs provide essential ecosystem services: they provide food and shelter for a wide range of marine species and are important breeding habitat and nursery grounds for commercial fishery species. They also offer coastal protection from storm surges and are an important source of tourism revenue. Their demise would have substantial ecosystem, economic and social implications.

While ocean acidification may also affect fish physiology, behaviour and health, they are likely to be less affected than calcifying organisms. However, they will be impacted by a reduction in habitat or availability of prey, which could ultimately affect their abundance or survival.

Also, the combined effect of ocean acidification and warmer ocean temperatures has a negative impact on many marine species, reducing the rate of development, growth, and survival. As oceans become more acidic, some species become less tolerant to temperature shifts, while other species become more susceptible to ocean acidification as waters become warmer.

Impact on Marine Ecosystems: With some species, such as phytoplankton and seagrass expected to fare better in acidic waters than others, we are likely to see shifts in the species composition of various marine ecosystems. This will lead to changes in food webs, where predators will have to find alternative food sources in order to survive. Those that are unable to adapt are likely to disappear.

Furthermore, there is a myriad of other stressors that amplify the impacts of ocean acidification, for example, warming ocean temperatures, changes in ocean salinity, ocean stratification, reduced oxygen concentrations, pollution, overexploitation, extreme events and increasing UV-B irradiance due to ozone depletion. Atmospheric CO_2 is also responsible for some of these stressors, which in combination can result in a reduction in nutrient availability that can negatively affect productivity or can affect ocean biogeochemistry.

Impact on Society: With severe implications to marine food webs, ocean acidification ultimately poses a severe threat to ecosystem health and diversity and to both subsistence and commercial fisheries, as well as coral reef tourism. The demise of these income-generating sectors could have substantial social and economic ramifications.

Not only is food security at risk, but employment and people's livelihoods are also at stake. As coral reefs provide coastal zones with protection against rough seas, the loss of these important ecosystems could put coastal communities at risk from storm surges and coastal erosion, negatively impacting local agriculture and threatening the safety of these communities.

Rising acidification could ultimately reduce the amount of atmospheric CO_2 the oceans are able to absorb, causing atmospheric CO_2 to rise further still. Considering that the oceans currently absorb 24 million tons of CO_2 from the atmosphere every day and the rate of acidification is 10 times faster than it's ever been over the last 55 million years, it's clearly an issue that needs to be urgently addressed. But how?

Solutions

A number of mitigating solutions have been proposed to reduce ocean acidification.

Reducing CO_2 Emissions: As anthropogenic CO_2 emissions are the primary cause of ocean acidification, the most realistic and feasible mitigation solution is to reduce the amount of CO_2 in the atmosphere by reducing CO_2 emissions. To achieve this, we ultimately need to reduce the amount of fossil fuels that are burned to produce power.

This would involve action on the part of both the private sector and the industry, as well as individual action. From installing energy efficient gadgets to burning less fossil fuels and opting increasingly for renewable energy sources are some of the options that are being discussed widely in various forums. Green commuting, public transport, group transport, shared-ride schemes, carpooling, bicycling or walking, and even telecommuting can all help reduce the number of vehicles on the road, and thus the amount of CO_2 emitted from those vehicles.

Removing CO_2 from the Atmosphere: While removing CO_2 from the atmosphere using geoengineering methods seems a tad far-fetched and is likely to be expensive, it can easily be accomplished naturally by implementing appropriate land-use practices that promote the absorption of atmospheric CO_2 by plants and soil — for example, tree planting initiatives, reforestation, and wetland restoration programs.

Reducing Coastal Pollution: Reducing nutrient pollution of coastal zones could be an important mitigation measure in areas where pollution from terrestrial sources is a key driver of acidification. This is particularly relevant in areas where calcifying marine organisms contribute significantly to the local economy, for example, coral reef tourism or shellfish aquaculture.

Improving Ecosystem Resilience: While building ecosystem resilience in itself will not reduce ocean acidification, mechanisms such as marine protected areas can serve as tools to help ecosystems become more resilient to the impacts of ocean acidification and other stressors.

Using Additives: The addition of alkaline mineral rocks to the ocean to act as a buffering agent to reduce acidity, as has been used in freshwater lakes, would only be economically feasible and effective in coastal areas on a small scale. Scaling this up for the entire ocean would simply not be effective; nor would it be economically viable. This option could potentially have negative environmental impacts that are still unknown.

Adapting Human Activities: Human activities that depend on the oceans, such as commercial aquaculture and fisheries, may need to adapt to changes in ocean acidity as our knowledge and understanding improve through research. This may lead to affected industries evolving in line with changes and impacts if they wish to survive. For example, hatchery managers can farm species that have a higher tolerance of acidification, they can relocate their operation, or they can limit pumping of water into tanks/ponds when pH levels are not too low.

Reducing Atmospheric Warming: Reducing other greenhouse gases and using geoengineering methods, such as solar irradiation, that target atmospheric warming rather than atmospheric CO_2 are not likely to be beneficial in the short-term. However, they may play a role over larger time scales by preventing carbon stored in methane hydrates from being released into the oceans due to melting hydrates.

While some of the above solutions are indeed creative, the only truly feasible and effective way to reduce atmospheric CO_2 and ultimately ocean acidification is to reduce the amount of CO_2 emitted into the atmosphere in the first place. The most effective way to do this would be to replace dirty fossil fuels with cleaner sources of energy. The technology is available, we just need the political will to push ahead with this.

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