DMS: The molecule that can make or break climate change

Earth's atmosphere was created an astounding 5 billion years ago, providing the opportunity for the first primitive life on Earth to form. After the beginning of life the Earth's atmosphere continued to evolve parallel to its organisms, allowing the formation of far more complex life-forms. To this day the atmosphere is maintained by a complex network of natural processes: from the formation of ozone that protects us from UV rays, to the plants that provide the oxygen we breathe. This delicate balance provides the optimum conditions to continue to perpetuate life. It is only in modern times that this vital equilibrium has shifted.

Since the industrial revolution our atmosphere has altered dramatically, experiencing a 45% increase[i] in the amount of carbon dioxide. This world's oceans have provided us with a temporary salvation by absorbing over 30% of the CO_2 released, acting as a carbon sink. However, with over 29 billion tonnes produced every year[ii] we may have pushed the oceans to their limit. There is only a finite amount of CO_2 that can be taken up and once exceeded the ocean pH has the potential to reach dangerously low levels.

CO_2 dissolves in the oceans to form carbonic acid. Some of this is utilised by organisms to build their shells, and when they die it is converted to sedimentary rock containing calcium carbonate. Marine photosynthetic organisms can also directly take up CO_2 and convert it into food. As more CO_2 is absorbed the concentration of the carbonic acid rises. Less CO_2 can be absorbed, and the oceanic pH can plummet.

The pH of the ocean has decreased from 8.2 to 8.1[iii], meaning that the acidity has increased by over 30%. This has already caused unprecedented destruction to the fragile marine ecological systems[iv]. In 2005 half of the Carribean coral reefs were lost due to bleaching. Even minute changes in the ocean environment such as temperature, light availability or pH, can cause the coral to expel the resident algae in their tissues that provide them with their food source, leaving the corals decolourised. Once bleaching has occurred it is extremely difficult for corals to recover and this can have a domino effect on the rest of the ecosystem. The affect on organisms is well recognised and researched but is viewed as more of a side-affect of global warming. New research, however, has revealed news of greater concern: that ocean acidification could even exacerbate the already dire effects of global warming.

One of the organisms threatened by ocean acidification is a group of microorganisms known as phytoplankton. These marine photosynthetic organisms reside just below the ocean's surface and are prey for the larger zooplankton. When consumed, phytoplankton release a molecule known as dimethylsulfoniopropionate (DMPS). Scientists are unsure exactly why pytoplankton produce this molecule, with speculations on its function ranging from salt regulation inside the cell to a deterrent to predators. Bacteria known as plegibacterales convert DPMS to a source of energy with a side product of dimethylsulphide (DMS)[v]. DMS is an extremely simple molecule consisting of a sulphur molecule bonded to two methyl groups. It has the chemical formula $S(CH_3)_2$.

DMS is the source of over 40% of the atmospheric sulphur. Once released from the ocean it is rapidly converted into a range of other sulfur-based compounds all of which contribute to cloud formation[vi]. Clouds are formed when water vapour in the atmosphere condenses to liquid water over 2km above the Earth's surface. Sulfur-based molecules act as a surface to which water vapour molecules can adhere to, thus enabling them to condense. Clouds are vitally important in regulating a climate as they reflect UV radiation away from the Earth. Icebergs act in a similar manner. This is especially useful over the ocean, as the darker ocean tends to absorb more radiation than land.

Research published in Nature has also predicted that the disruption of cloud formation through the reduction in DMS could lead to a global temperature increase of 0.23 to 0.48° C[vii]. The limit for global temperature increase was agreed at 1.5 ° C at the Paris Climate Change Summit, after being reduced from the originally agreed value of 2° C. The driving factor in the debate between setting the limit at 1.5° C instead of 2° C was that after a 1.5° C global temperature increase, the effects of global warming would be much more severe in the more poverty prone and vulnerable communities worldwide. This disproportionately affects the countries that have fewer resources to deal with the impacts. These effects would include a higher incidence of extreme weather, droughts and floods as well as food shortages. If ocean acidification continues to increase at the projected rate, the phytoplankton population, which is responsible for DMS production, will continue to decline and the resultant global temperature increase will reach a third of the limit.

Unfortunately, studies have shown that an increase in ocean acidity results in a lower production of DMS from phytoplankton[viii]. Increasing temperature and higher CO_2 levels, both of which are also predicted to increase in the following years, will also decrease DMS production[ixx]. One solution this would be a process called carbon capture whereby carbon dioxide is artificially removed from the air and stored, sometimes underground, so that it cannot be re-released into the atmosphere. Carbon capture uses a variety of chemicals to trap the carbon dioxide molecules. This technology is still in its infancy and requires much more research and investment. A study has also shown that increasing DMS production has a much greater effect on reducing atmospheric temperature than the removal of carbon dioxide, so this may be the area for future development.

Additional research is investigating the possibility of artificially stimulating the growth of phytoplankton throughout the ocean. Knows as fertilizing, this technique involves introducing iron into seawater. Iron is an essential mineral for photosynthesis, but is not abundant in the ocean and is often the limiting factor to phytoplankton growth. The higher the global population of phytoplankton, the higher the global production of DMS. The fact that the phytoplankton will also consume CO_2 when they photosynthesise is a welcome side affect. To increase the effectiveness of this process a greater understanding of the biological pathways that generate DMS needs to be achieved. This could enable the genetic alteration of phytoplankton to increase the production of DMS.

At the time when scientists were starting to accept that human activity was causing global warming, a chemist named James Lovelock presented the Gaia Hypothesis. He theorized that the Earth's living organisms interact with their non-living surroundings to maintain the ideal conditions for life. Using this logic, DMS production could be seen as phytoplankton's defence against the warming and rising CO_2 levels that reduce their growth. There is no doubt that we need to start using natural processes to our advantage, and increasing DMS production provides us with an opportunity we cannot afford to ignore. DMS holds the potential to stop us reaching our global temperature limit and prevent worldwide destruction. When just one molecule can provide the tipping point for climate change, there is no time to waste.

---

[i] World Meteorological Organization https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocms/s3fs-public/ckeditor/files/GHG_Bulletin_13_EN_final_1_1.pdf?LGJNmHpwKkEG2Qw4mEQjdm6bWxgWAJHa

[ii] C. Le Quéré et al**.** *Earth Syst. Sci. Data*, 6, 235-263, (2014)

[iii] Pacific Marine Environmental Laboratory https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F

[iv] A.C. Whitmann, H.O. Pörtner *Nature Climate Change* 3, 995–1001 (2013)

[v] Woods Hole Oceanographic Institution https://www.whoi.edu/oceanus/feature/dms--the-climate-gas-youve-never-heard-of

[vi] New Scientist https://www.newscientist.com/article/dn6953-coral-reefs-create-clouds-to-control-the-climate

[vii] Six, K. D., Kloster, S., Ilyina, T., Archer, S. D., Zhang, K. & Maier-Reimer, E. *Nature Climate Change* (2013).

[ix] H.E Arnold, P. Kerrison, M. Steinke, *Glob Chang Biol*. Apr;19(4):1007-16. doi: 10.1111/gcb.12105. (2013)

[x] Maureen D. Keller *Biological Oceanography*, 6:5-6, 375-382 (1989)