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Scientists take a stand against ocean fertilization with urea



With atmospheric emissions of CO₂ growing at an alarming rate, there is no shortage of geo-engineering schemes to limit the effects of climate change. One of the most extravagant proposes installing a giant parasol in orbit to cool the planet! More down to Earth are schemes to inject CO₂ into the ground or ocean or to 'fertilize' the ocean. The ocean is a tempting target because it absorbs about one-third of atmospheric CO₂. In recent decades, several controversial experiments have 'fertilized' parts of the ocean with iron in an attempt to stimulate plankton growth at the surface. Now, attention is turning to doing the same with urea. Plankton absorb carbon through photosynthesis, so accelerating plankton growth would remove massive amounts of carbon from the Earth's atmosphere, the theory goes. When these microscopic plants died, they would conveniently carry the carbon to the ocean floor, storing it there for eons. Many marine biologists and climate scientists shudder at the thought: we simply do not know yet whether fertilizing the ocean might trigger runaway algal blooms which could deprive vast expanses of ocean of oxygen. This uncertainty has not deterred companies from proposing to dump large quantities of urea into the sea.

In what some are calling a *de facto* moratorium, delegates from 191 countries attending the 9th Conference of the Parties to the Convention on Biological Diversity (CBD) adopted a document on 30 May requesting that countries prohibit ocean fertilization until there is an adequate scientific basis. The delegates agreed that the CBD should look to the London Convention for guidance on regulating fertilization. Here, Patricia Glibert from the University of Maryland Center for Environmental Science in the USA takes us behind the scenes of this burning issue.

Why are people turning from iron to urea fertilization?

More than a dozen large-scale iron enrichment experiments have been conducted in the ocean in the past two decades. Most have involved adding iron to the equatorial North Pacific, the subarctic Pacific and the Southern Ocean, known to have ample amounts of nitrogen and phosphorus but limited quantities of iron and thus little phytoplankton.

The iron enrichment experiments have consistently demonstrated that a phytoplankton bloom can be 'manufactured'. However, they have been less successful in demonstrating that the carbon biomass produced (the algae) could be exported to the deep sea for even short periods of time, let alone long enough to have an effect on climate. Meanwhile, the carbon-offset market has been expanding rapidly and attracting new enterprises. If phytoplankton blooms can lock away carbon by sinking it to the seabed, the market for these carbon-offset markets could be huge, particularly if an international quota system for carbon trading is agreed upon.

In regions where it is the lack of nitrogen, rather than the lack of iron, that is limiting plankton growth, nitrogen is being proposed to stimulate new blooms. New 'prime the pump' schemes in recent years thus propose fertilizing the oceans with one form of nitrogen, urea. Urea is the major nitrogen fertilizer used in agricultural applications; it is thus thought that its effect on plant growth can be mimicked in the sea. Proponents of this plan not only suggest that carbon

will be drawn down from the atmosphere; they claim that fish production will be enhanced as well.

Although urea is excreted naturally by many animals as urine, it is produced commercially by getting CO₂ and anhydrous ammonia to react under high pressure and temperature. The molten mixture is then processed into a useable liquid or granular form. For urea enrichment at sea, the idea is to pump urea through a pipe from a urea-generating plant on shore. Urea production is energy-intensive and the energy used is most commonly derived from natural gas. There is thus a touch of irony in the idea of using fossil fuels to create biomass to sequester carbon from the atmosphere that was derived from fossil fuel burning!

Several commercial enterprises hope to benefit from ocean fertilization. One such company is the Ocean Nourishment Corporation based in Australia; it recently proposed to enrich the Sulu Sea off the Philippines, home to the UNESCO World Heritage Tubbataha Reef Marine Park, with 1000 tonnes of urea. They have also targeted the Arabian Gulf recently as another potential site for such an experiment.

Why did scientists feel this plan was unwise?

Urea enrichment inspires many of the same concerns that have been expressed for iron fertilization. If large-scale blooms do occur and, if they settle and decompose, the area could be starved of oxygen (hypoxia). Oxygen 'dead zones'

are not only unlikely to enhance fish production but may also generate other greenhouse gases: both methane (CH₄) and nitrous oxide (N₂O) may be produced by the microbial degradation of organic matter under low oxygen conditions. These gases would counteract any potential benefits of trapping carbon from the atmosphere.

All of the schemes for ocean enrichment and fertilization share concerns over verification. Quantifying the flux of carbon to the deep sea – or the potential enhancement of fisheries from increased algal production – is not easy. Much of the carbon is recycled before it sinks through microbial food webs; some may be transported via ocean currents, with the effects felt far from the initial site of fertilization. Satellite imagery, proposed by the Ocean Nourishment Corporation, is not sufficient, as it may only verify that a near-surface bloom has occurred, not its composition, nor its rate of sinking.

One risk that may be greater under urea enrichment than under iron enrichment is the potential for an increase of toxin-producing microalgae called dinoflagellates. In many coastal regions of the world where urea dominates the agricultural use of nitrogen fertilizer and where such nutrient runoff enriches the nearshore waters, the frequency and duration of toxin-producing dinoflagellates have increased.

In the Philippines, the site of the recent proposal for urea fertilization, known toxic dinoflagellates include *Pyrodinium bahamense* and *Gymnodinium catenatum*, both of which cause paralytic shellfish poisoning, as well as *Cochlodinium sp.* which causes fish kills. Numerous deaths have been recorded in the Philippines from people eating shellfish containing paralytic shellfish toxins. There is thus a real concern that seafood contamination could increase. Moreover, there is some evidence that, for at least some species, the toxin content of dinoflagellates increases under urea enrichment. Many dinoflagellates also produce resting stages during their life cycle when the cells are capable of blooming again if conditions are right, leading to the potential for new blooms even after the initial urea enrichment has come to an end.

Laboratory studies show that cyanobacteria, or blue-green algae, are likely to respond to urea enrichment, as they have high rates of urea uptake relative to many other groups of phytoplankton. Interestingly, many species from this group do not have a tendency to sink. One of these, *Trichodesmium*, can form extensive surface scums visible from space, but that nonetheless do not sequester carbon to the deep sea!

How did the scientific community stop the experiment in the Philippines?

In the specific case of the plan to fertilize the Philippines with urea, a group of 57 scientists from 18 countries⁹ combined their expertise on urea metabolism, algal physiology, harmful algal blooms, eutrophication, hypoxia and local regional oceanography, as well as the economics of carbon cap-and-trade programmes, in a scientific paper expressing their concerns published in June¹⁰. The scientific reasons outlined in the paper – the same as those I summarized earlier – were also presented by local scientists to the Philippine officials.

The World Wildlife Fund for Nature and other bodies also raised concerns. These were heard and the Philippine government subsequently declined permission for the Ocean Nourishment Corporation to proceed with its plan.

Is the scientific community unified on this question?

There is a great deal of unity regarding concern about ocean fertilization. Concerns over iron enrichment experiments have been expressed for many years, in scientific journals and by individuals to their governments. Moreover, several scientific bodies have urged caution in ocean enrichment experiments and called for independent verification of the outcome of such experiments. Among them are the Scientific Committee on Ocean Research (SCOR) and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), an independent international advisory body of the United Nations, as well as two international programmes, the Surface Ocean Lower Atmosphere Study (SOLAS) and the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB), which is supported by the UNESCO-IOC and SCOR.

Several conventions have followed suit. The London Convention, under the auspices of the International Maritime Organization, is examining the scientific and regulatory aspects of large-scale open-ocean fertilization experiments through a scientific working group. This May, the UNESCO-IOC was invited to participate in discussions within this working group; the group issued a consensus statement based on a series of scientific and technical questions posed by the London Convention Scientific Group, underscoring the same concerns. Later the same month, the Convention on Biological Diversity held that, given the uncertainties as to the outcome of ocean fertilization, large-scale efforts to fertilize the oceans were simply not justified.

Although there is much that we still do not understand about how the oceans may respond to large-scale enrichments with urea, iron or other elements, the environmental impact may be considerable, especially in areas where marine biodiversity is high and marine life is important for the local economy. There are major concerns over urea fertilization and the potential for development of harmful algae and hypoxia. Promises of enhanced fish production or the selling of carbon credits based on expected long-term sequestration are premature at best.

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On the growing impact of harmful algal blooms on fisheries and human health, see *The red tide*, in *A World of Science*, July 2006

9. from Australia, P.R. China, Denmark, France, Germany, Indonesia, Ireland, Japan, Rep of Korea, Kuwait, Malaysia, Oman, Philippines, Sweden, South Africa, UK, USA and Vietnam

10. Glibert, P.M et al. (2008) Ocean urea fertilization for carbon credits poses high ecological risks. *Marine Pollution Bulletin* 56 : 1043–1236

11. GEOHAB programme: h.enevoldsen@unesco.org