ENVIRONMENT

Ocean Iron Fertilization—Moving Forward in a Sea of Uncertainty

It is premature to sell carbon offsets from ocean iron fertilization unless research provides the scientific foundation to evaluate risks and benefits.

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The consequences of global climate change are profound, and the scientific community has an obligation to assess the ramifications of policy options for reducing greenhouse gas emissions and enhancing CO_2 sinks in reservoirs other than the atmosphere (*1*, *2*).

Ocean iron fertilization (OIF), one of several ocean methods proposed for mitigating rising atmospheric CO_2, involves stimulating net phytoplankton growth by releasing iron to certain parts of the surface ocean. The international oceanographic community has studied OIF, including 12 major field programs with small-scale, purposeful releases of iron since 1993 (*3*, *4*). Although these experiments greatly improved our understanding of the role of iron in regulating ocean ecosystems and carbon dynamics, they were not designed to characterize OIF as a carbon mitigation strategy. The efficacy by which OIF sequesters atmospheric CO_2 to the deep sea remains poorly constrained, and we do not understand the intended and unintended biogeochemical and ecological impacts. Environmental perturbations from OIF are nonlocal and are spread over a large area by ocean circulation, which makes long-term verification and assessment very difficult. Modeling studies have addressed sequestration more directly and have suggested that OIF in areas of persistent high nutrients (so-called high-nutrient, low-chlorophyll areas) would be unlikely to sequester more than several hundred million tons of carbon per year. Thus, OIF could make only a partial contribution to mitigation of global CO_2 increases.

Despite these uncertainties in the science, private organizations are making plans to conduct larger-scale iron releases to generate carbon offsets. We are convinced that, as yet, there is no scientific basis for issuing such carbon credits for OIF. Adequate scientific information to enable a decision regarding whether credits should be issued could emerge from reducing uncertainties; this will only come through targeted research programs with the following specific attributes:

- Field studies on larger spatial and longer time scales, because ecological impacts and CO_2 mitigation are scale-dependent.
- Consideration of OIF in high- and low-nutrient regions to understand a wider range of processes that are affected by iron, such as nitrogen fixation and elemental stoichiometry.
- Detailed measurements in the subsurface ocean to verify the fate of fixed carbon, including remineralization length scales of carbon, iron, and associated elements.
- Broad assessment of ecological impacts from bacteria and biogeochemistry to fish, seabirds, and marine mammals.
- Characterization of changes to oxygen distributions, biophysical climate feedbacks, and cycling of non-CO_2 greenhouse gases, such as methane, nitrous oxide, and dimethylsulfide.
- Long-term monitoring and use of models to assess downstream effects beyond the study area and observation period.
- Improved modeling studies of the results and consequences of OIF, including higher spatial resolution, better ecosystem parameterization, inclusion of other greenhouse gases, and improved iron biogeochemistry.
- Analysis of the costs, benefits, and impacts of OIF relative to other climate and carbon mitigation schemes and to the impacts of global change if we take no action.

The organization of such experiments is as critical as the scientific design. The scope of the problem will require individual sponsors and partnerships of national science agencies, philanthropies, and commercial entities. Academic scientists need to be involved but must maintain independence. This can be accomplished by regulating experiments in a uniform manner under such international agreements as the London Convention, widely distributing science plans and results via open meetings and peer-reviewed journals, and requiring clear and explicit statements of conflicts of interest.

This group feels it is premature to sell carbon offsets from the first generation of commercial-scale OIF experiments unless there is better demonstration that OIF effectively removes CO_2, retains that carbon in the ocean for a quantifiable amount of time, and has acceptable and predictable environmental impacts. As with any human manipulation of the environment, OIF carries potential risks, as well as potential benefits; moving forward on OIF should only be done if society is willing to acknowledge explicitly that it will result in alteration of ocean ecosystems and that some of the consequences may be unforeseen. We are currently facing decisions on climate regulations, such as the post-Kyoto framework discussed in Bali, carbon cap-and-trade bills in the U.S. Congress, and consideration of OIF by the parties to the London Convention, and we feel that ocean biogeochemical research will help inform these important policy decisions.

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