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Side Effects of Oceanic Iron Fertilization

OCEANIC IRON FERTILIZATION COULD increase phytoplankton primary productivity in iron-poor oceanic regions, enhancing the carbon flux to the deep sea and drawing excess CO_2 out of the atmosphere. It has been proposed as a way to sequester carbon and thus help to mitigate climate change. S. W. Chisholm and colleagues ("Dis-crediting ocean fertilization," Policy Forum, 12 Oct. 2001, p. 309; and "Response," Letters, 19 Apr., p.467) argue that "manipulations of the oceans at this scale will... alter marine ecosystems dramatically" (19 Apr., p. 468), and therefore "ocean fertilization... should never become eligible for carbon credits" (12 Oct., p. 310) on the global carbon-trading market. Their arguments are based almost exclusively on marine ecology issues. They briefly mention that "the carbon cycle is intimately coupled with those of other elements, some of which play critical roles in climate regulation" (12 Oct., p. 310). The possibility of unintended climatic and atmospheric change, however, is a crucial argument against ocean fertilization that deserves elaboration and public discussion.

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Phytoplankton produce dimethylsulfide (CH_3SCH_3 or DMS), an important precursor for maritime sulfate aerosols and cloud condensation nuclei (CCN), which influence cloud properties and climate (*1–3*). An increase in phytoplankton primary productivity and thus in DMS levels should lead to cooling of the sea surface waters; the strength of this effect and possible feedbacks on the phytoplankton productivity are presently uncertain (*4–6*). Other important chemicals that may also be influenced include volatile organohalogens (*7*, *8*) such as methyl halides (CH_3Cl, CH_3Br, and CH_3I). These photolyze to produce reactive halogens, which are believed to contribute to lower stratospheric O_3 depletion (*9*), as well as to marine boundary layer O_3 destruction (*10*, *11*). Finally, carbonyl sulfide (*12*) (OCS) contributes to the stratospheric aerosol layer (*13*) and thus to heterogeneous O_3 loss. An increase in these gases would enhance stratospheric ozone depletion and lead to intensified ultraviolet levels at Earth's surface, with possible biological health consequences (*14*).

Letters to the Editor

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Ocean fertilization could also directly affect the atmosphere-ocean system radiative budget. The extreme scenario of removing 600 μmol/mol of atmospheric CO_2 over a period of 100 years by fertilizing 30% of the world's oceans would require a sustained increase in photosynthetic energy equivalent to ~1.5 W/m^2 over the fertilized region (*15*). Most of this would be transferred as heat to the ocean's surface waters via respiration (*15*), increasing regional sea surface temperatures. However, as Chisholm *et al.* point out, this scenario for complete removal of anthropogenic CO_2 may not even be realizable unless limitations on the availability of N and P were also overcome.

One could imagine many other possible climate effects, such as ocean circulation changes due to modified surface water temperatures and salinity (via brine content). Nevertheless, K. S. Johnson and D. M. Karl ("Is ocean fertilization credible and creditable?", Letters, 19 Apr., p. 467) have suggested that "[i]t is simply not credible, or creditable, to suggest that we know enough to understand the impacts of ocean fertilization at the present time." Although, indeed, we cannot predict exactly what would happen after a given fertilization scenario, Johnson and Karl do not give sufficient credit to our knowledge about the wide range of side effects with various probabilities. It is hard to believe that the developers of any profit-driven commercial CO_2 draw-down strategy would voluntarily assess and (where possible) avoid environmental side effects. Could such a task be accomplished by an intergovernmental body (e.g., UNEP)? Perhaps, but it seems that the resources necessary for fertilization, logistics, and assessment programs would be better spent on more pressing problems, such as new measures to reduce CO_2 emissions. In any case, Chisholm *et al.* should be lauded for their efforts toward ensuring that basic science, rather than market interests, drives future research on marine ecology and its relationship to the climate.

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15. Photosynthesis is endothermic, requiring 686 kcal/mol ($C_6H_{12}O_6$), or 1.1×10^7 J/kg (CO_2). Because only about 10% of the carbon involved in photosynthesis is removed as fecal pellets and not recycled in the surface waters (*16*), the photosynthetic energy per unit area required is $E = 10 \times 1.1 \times 10^7$ J/kg (CO_2) $\times\, M\,(CO_2)/(A_{ocean} \times \tau)$, where $M\,(CO_2)$ is the mass of atmospheric CO_2 to be removed, A_{ocean} is the oceanic surface area over which the fertilization would take place, and τ is the time period over which the removal should occur.
16. H. de Baar, *Change* **17**, 13 (1993).