

SCOPE 61: Interactions of the major biogeochemical cycles: Global change and human impacts

Jerry M. Mellilo, Christopher B. Field, and B. Moldan, editors. 2003. **Interactions of the major biogeochemical cycles: Global change and human impacts**. SCOPE 61, Island Press, Washington, D.C. xxi + 357 pp. \$75.00 (cloth : alk paper), ISBN: 1-55963-065-5; \$35.00 (paper : alk. paper), ISBN: 1-55963-6066-3.

“Give me a half tanker of iron, and I will give you an ice-age” the oceanographer John Martin proclaimed tongue-in-cheek in the late 1980s. These provocative words summarize succinctly the issues that are at the center of this book, the newest in a series of environmental assessments conducted under the aegis of the Scientific Committee on Problems of the Environment (SCOPE). John Martin’s discovery that dissolved iron is the primary factor limiting the growth of phytoplankton in vast oceanic areas known as High-Nutrient/Low-Chlorophyll (HNLC) solved one of the large paradoxes of biological oceanography and led to a scientific revolution in this research field. Recognizing the tight interaction between the oceanic iron and carbon cycles and their connection with climate, Martin went on to suggest that the lower atmospheric CO₂ concentration during the last ice ages was a consequence of increased iron deposition from the atmosphere. He argued that the higher availability of iron during these times fertilized phytoplankton, which by increasing the export of organic carbon from the surface ocean into the ocean’s interior causes a net oceanic uptake of CO₂ from the atmosphere and therefore lower atmospheric CO₂.

Martin’s bold hypothesis stirred tremendous debate. This debate, however, did not center on his possible explanation of the lower atmospheric CO₂ concentrations during the ice-ages. It rather focused on the potential application of this finding for geo-engineering a solution for the man-made increase in atmospheric CO₂. The idea to sprinkle

a relatively tiny amount of iron into the HNLC regions in order to sequester substantial amounts of the CO₂ emitted into the atmosphere by human actions was too attractive to go unnoticed. Although there is little evidence that oceanic iron fertilization is actually effective in removing CO₂ from the atmosphere (as discussed in chapter 16), this idea has led to several patents and the founding of a number of companies that would like to exploit this possibility commercially. I recommend making this new SCOPE book a mandatory reading for all those who believe that such large-scale manipulations of a complex, interactive biogeochemical system represent a good approach to solve environmental problems. If there is a lesson to be learned from the study of the interactions of the major biogeochemical cycles on Earth, it is that the deliberate management of elemental interactions is extremely difficult and often bound for failure because of unexpected consequences. For example, a successful iron fertilization will accelerate the oceanic nitrogen cycle, which likely enhances the oceanic production and emission of nitrous oxide, another greenhouse gas. By replacing one greenhouse gas in the atmosphere with another one, this would significantly offset the benefit of the fertilization induced atmospheric CO₂ drawdown.

The need for understanding the nature of biogeochemical cycles, their interactions, their human alterations, and their potential for deliberate management transcends the oceanic realm. In fact, human induced changes in elemental cycles stand at the root of most environmental problems of our times. In particular, human activities, such as the burning of fossil fuels, urbanization, land-use change, and agricultural intensification have led to environmental problems as diverse as global climate change, tropospheric air pollution, stratospheric ozone hole, and eutrophication of many aquatic systems.

This book, published as SCOPE 61, represents a highly informative and up-to-date assessment of these human-induced changes of the major biogeochemical cycles. Its particular emphasis is on how the interaction between the various elemental cycles is determining the nature and magnitude of many environmental problems and how this

knowledge can be used to provide possible solutions. SCOPE 61 builds on a successful history of such projects conducted mainly in the 1970 and early 1980s, which culminated in the early 1980s in the first global-scale synthesis of the interactions between all major biogeochemical elements. The resulting book, *SCOPE 21: The major biogeochemical cycles and their interactions*, edited by B. Bolin and R. B. Cook and published in 1983 became an instant classic and has guided biogeochemical research ever since.

The most important result of this assessment was the scientific recognition of the global-scale extent of the human induced changes of elemental cycles and the fact that many of these changes and their environmental consequences are linked to each other. At the ecosystem level, the tight linkage between the different elements is a direct consequence of the processes of life, i.e. the formation, maintenance and respiration of living biomass, which tends to occur in relatively fixed proportions of the elements C, O, H, N, P, S, and a number of trace elements, such as iron. As a consequence, alterations of one elemental cycle often have profound impacts on the working of another elemental cycle. SCOPE 21 was therefore strongly advocating the need to study Earth as an integrated system.

In early October 2002, SCOPE convened a rapid assessment workshop that brought together renowned experts in order to revisit many of the original themes put forward in SCOPE 21, and to discuss and evaluate them in the light of the rich research that has been undertaken since. This book, published as SCOPE 61, is the product of this workshop. It is organized into a series of 13 background chapters that provide brief synopses on a range of specific topics, and a series of 5 crosscutting chapters that provide a synthesis and assessment.

The background chapters are organized into theory, and three themes that follow the classical system boundaries, lithosphere, atmosphere, and hydrosphere. Each background chapter focuses on a few elemental interactions within these systems. Together, these chapters provide a wealth of information and a good overview of the

myriad of possible elemental interactions in the Earth system. The only shortcoming is the relative dearth of information about elemental interactions in the oceans, which is also reflected by an only marginal consideration of these interactions in the synthesis chapters. Many of the background chapters are fascinating to read and since they are short and concise, they are particularly useful for a reader who is interested in having a quick introduction to a particular topic. They are also well referenced, permitting the reader to continue on to original literature if desired. I found the three background chapters on theory particularly insightful, because they prepare the stage for the following background chapters. A particularly fascinating revelation is the true diversity of human interventions, which reach from well-known activities such as land-use change to lesser-appreciated activities such as loss of biodiversity.

The heart of the book is in the five synthesis chapters. In addition to the major themes put forward in SCOPE 21, two new main themes have emerged. First the authors recognized that the deliberate management of elemental cycles has become an important part of the consideration in the political and economical arena and that scientists are increasingly asked to assess and evaluate various management options. Overall, the authors decided to take a carefully measured stance in response to this recognition, highlighting on the one hand the need to focus on the primary agent causing the problem, while pointing out, on the other hand, that deliberate management of elemental interactions has led to successful solutions in a number of cases. The second major new theme that emerges from SCOPE 61 is a reevaluation of the paradigm of fixed stoichiometric ratios in life processes. The research undertaken in the last two decades clearly point toward the need for a modification of this stoichiometric model, but it appears that no new paradigm has emerged yet. An important new observation is that the nature of the human intervention into the workings of elemental cycles primarily consists of the decoupling of previously coupled elemental cycles, and that many of the

environmental consequences can be understood as a response of the Earth system to this decoupling.

Overall, this is a must-have publication for all those who are interested in biogeochemical cycles, their human alterations, and the tools and needs required to abate, adapt, or mitigate the resulting environmental problems. It is a highly valuable resource not only for natural scientists, but also for engineers, economists, social scientists and policymakers.

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