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COVER. Heliotropically oriented subtidal columnar stromatolites in Hamelin Pool, Shark Bay, Western Australia. These stromatolites, forming in about 2 meters of water and built by a diatom-dominated microbial community, are inclined toward the north as evidenced by the inclined sunlight rays in the slightly turbid water. See page 1279. [S. M. Awramik, Department of Geological Sciences, University of California, Santa Barbara 93106]

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Greenhouse Role of Trace Gases

Atmospheric scientists are emphasizing the role of trace gases as important factors in a future substantial global increase in temperature. They estimate that, in 1980, trace gases contributed more than half as much to a greenhouse effect as did increased carbon dioxide.

From 1880 to 1980, CO₂ increased from about 275 parts per million (ppm) to 339 ppm. The principal relevant trace gases in 1980 were CH₄, 1.6 ppm; N₂O, 0.3 ppm; CCl₂F₂, 0.00028 ppm; CCl₃F, 0.00018 ppm; and O₃, which increased in the troposphere substantially over earlier values.

The key to effectiveness of the trace gases lies in their infrared absorption characteristics. They are transparent to most of the incoming solar radiation, but effective in absorbing outgoing earth radiation in the wavelength range 8 to 12 micrometers. That is the window through which a substantial fraction of the earth's heat ordinarily escapes. The earth's blackbody radiation is at a maximum in that wavelength region, and water is less effective as an absorber in that part of the spectrum.

Methane (CH₄) is present the most effective greenhouse trace gas. Its concentration has increased about 1 percent per year since 1950. The total content in the atmosphere is about 5000 million tons. Methane is destroyed slowly, mainly in the troposphere, by the reactive OH. Residence time for CH₄ is 5 to 10 years. This implies an annual addition of at least 500 million tons to hold the level constant. Growth of 1 percent per year requires an extra addition on the order of 50 million tons. Principal sources of CH₄ appear to be ruminant animals, organic-rich sediments, and rice paddies. A complicating factor in estimating trends in CH₄ distribution is the competition of CO for OH. Emissions of CO have been increasing, and they destroy OH that otherwise might react with CH₄.

For a long time, nitrous oxide (N₂O) has been present in the atmosphere in substantially its current concentration. It has a residence time greater than 100 years. It is increasing at about 0.2 percent per year, with microbial interactions with fertilizers in soils and combustion of nitrogen-rich fuel likely sources. Destruction by stratospheric photolysis is the only known removal process. The contribution of N₂O to the greenhouse effect is about one-sixth that of CH₄.

The chlorofluorocarbons CCl₂F₂ and CCl₃F (freons) came into major use in the 1960's. Global emissions of them actually declined from the mid-1970's through 1982, but their long residence time, 120 years and 70 years, respectively, leads to a continuing buildup. In 1980, their contributions to a greenhouse effect were, respectively, one-third and one-fifth that of CH₄. Another halocarbon that could become important is C₂H₃Cl₂, which is used as a solvent. It has a residence time of about 10 years, and its concentration has been increasing at the rate of 8 percent per year. Much of the CCl₄ that has been produced is now in the atmosphere—mixing ratio 0.00013 ppm (about 3.6 million tons). Residence time of the chemical is 25 to 50 years. However, it does not absorb in the important region of the spectrum. Two other commercially significant halocarbons, C₂HCl₂ and C₂Cl₄, have short residence times and have thus no consequential greenhouse effects.

Climate modelers have great computational power at their disposal, but the atmospheric system is complex. Thus, estimates of a warming corresponding to the equivalent of a doubling of CO₂ have a range of 1.5° to 4.5°C. In addition, there is uncertainty about the timing of a warming. No one can be sure of the natural lag time in the response of the earth's physical and biological systems. Heat transfer from the oceanic surface waters to deeper waters could determine the rate at which the earth's climate equilibrates to a new energy budget. The other unpredictable is the behavior of humans. Experience tells us that extrapolation from the present is not a good guide to the long-term future. However, humans are increasing the concentrations of greenhouse gases, and ultimately major effects are likely to be manifest.—Philip H. Abelson