EXPERIENTIA

Vol. 36 - Fasc. 7 Pag. 767-890 15.7.1980

GENERALIA

Editorial remarks. The increasing production of CO_2 by industrial processes will, as is well known from changes in infrared absorption, lead to a disturbance in atmospheric heat circulation. Although modern coal-based technology is environmentally conscious, the output of world coal production could be as much as 7 billion tonnes by the year 2000 (from the 'World coal study' chaired by Prof. Carroll Wilson, Massachusetts Institute of Technology, May 12, 1980)[1] and, together with the expected increase in oil and gas production, will lead to threatening regional climatic changes worldwide.
Two international reports published in 1979 clearly pointed out the CO_2 problems that are discussed in this survey: SCOPE 13 'The global carbon cycle' (Scientific Committee on Problems of the Environment/International Council of Scientific Unions (ICSU))[2] and 'Carbon dioxide and climate' (The National Research Council, Climate Research Board/National Academy of Sciences, Washington)[3]. The following review 'The carbon dioxide problem' is an important topical continuation of these fundamental reports. H.M.

The carbon dioxide problem. An interdisciplinary survey

W. Bach (coordinator), H. Bröhl, U. Fischbach, J. Goudriaan, U. Hampicke, G.H. Kohlmaier, G. Kratz, W. Louwerse, C. Marchetti, F. Niehaus, H. Oeschger, R.M. Rotty, W. Schunck, U. Siegenthaler, H. van Keulen and H.H. van Laar

Contents. 1. Introduction (W. Bach); 2. The C cycle: sources and sinks of atmospheric CO_2 (G.H. Kohlmaier, U. Fischbach, G. Kratz, H. Bröhl, W. Schunck); 3. The effect of the atmosphere-biosphere exchange on the global C cycle (U. Hampicke); 4. Past and future emission of CO_2 (R.M. Rotty); 5. Prediction of future CO_2 concentration in the atmosphere (U. Siegenthaler, H. Oeschger); 6. Physiological aspects of increased CO_2 concentration (H. van Keulen, H.H. van Laar, W. Louwerse, J. Goudriaan); 7. The impact of different energy options on atmospheric CO_2 levels (F. Niehaus); 8. Climatic effects of increasing atmospheric CO_2 levels (W. Bach); 9. Measures of CO_2 control (C. Marchetti); 10. Conclusions (H. Oeschger).

Introduction

by Wilfrid Bach

Center for Applied Climatology and Environmental Studies, University of Münster, D-4400 Münster (Federal Republic of Germany)

The basic problem can be briefly stated as follows: the increasing combustion of fossil fuels and the destruction of forests and organic matter in soil may lead to the release of large amounts of CO_2 to the atmosphere at a rate that is faster than the absorption rate by the natural system. The result is an accumulation of CO_2 and other heat-absorbing gases, which, by changing the heat budget of the earth-atmosphere system, may also change the earth's climate. There is a wide consensus that the increasing CO_2 concentrations in the atmosphere will lead also to an increase in the surface air temperature and to an enhancement of the hydrologic cycle, both varying greatly by season and geographic region. The dilemma is that probably none of these effects caused by man's activities (the signal) will be detectable in the natural climatic trend

1 'World coal study'. Massachusetts Institute of Technology, 12 May, 1980. Ed. C. Wilson. MIT, in press 1980.
2 SCOPE 13 'The global carbon cycle'. Ed. B. Bolin, E.T. Degens, S. Kempe and P. Ketner. J. Wiley, New York 1979.
3 'Carbon dioxide and climate'. Report of an 'ad hoc study group' on CO_2 and climate, Woods Hole, Mass., 23-27 July, 1979. Ed. National Academy of Sciences, Washington, D.C., 1979.

(the noise) before the end of this century, and that by that time, it may be too late for countervailing measures. It is feared that by then the CO_2 accumulation in the atmosphere may be well on its way to producing climatic impacts that are potentially irreversible.

One major source of CO_2 associated with man's activities is the combustion of fossil fuels such as coal, lignite, oil and natural gas. The annual global release of C into the atmosphere from this source was a little under 0.1 Gt in 1860 increasing to about 5 Gt in 1978. Except for brief interruptions by the two world wars and the great depression in the '30s, the worldwide production of fossil C has proceeded up to now at the steady rate of 4.3% per year. Apparently the recession, energy price hikes and conservation measures after the 1973 energy crisis have not resulted in a slowdown of world fossil fuel use.

Another major source of C is possibly deforestation and the oxidation of humus, mainly in the tropics, which may add another 4–5 Gt of C per year to the atmosphere. Inventories of the CO_2 content of the atmosphere indicate that only about 2.5 Gt of C remain airborne, while approximately an equal amount of C is being absorbed by the ocean and by the biosphere (such as through reforestation in temperate latitudes). The whereabouts of the remaining 4–5 Gt, the so-called 'lost carbon', is presently one of the major unresolved questions. One could speculate that either the known sinks are more effective absorbers of C, or that there are other, hitherto unkown, sinks.

Several assessments indicate that the CO_2 content of the atmosphere increased from a pre-industrial value of about 290 ppmv in 1860 to the present level of about 333 ppmv, an increase of about 13%. Regular and accurate measurements made at the Mauna Loa observatory on the Island of Hawaii since 1958 show annual CO_2 increases of about 0.7 ppmv during the 1950s and 1960s increasing to about 1.5 ppmv in more recent years. Similar CO_2 increases have been recorded for such distant places as the South Pole, American Samoa, Point Barrow, Alaska, and Scandinavia indicating that CO_2 is well-mixed throughout the troposphere, and that the CO_2 increase is a worldwide phenomenon.

The increasing CO_2 concentrations in the atmosphere are suspected of being a major contributing factor to global climatic change. A hierarchy of climate models ranging from 1 to 3 dimensions have been used to assess climatic changes due to increasing CO_2. Current state-of-the-art climate modeling indicates that a doubling of CO_2 may result in a 1–3 °C increase in the global mean surface air temperature with large amplifications in polar regions, and cause an enhancement of the hydrologic cycle by about 7%. However, considering the uncertainties in the input data and the present state-of-the-art modeling, these estimates should be considered reliable only within a factor of about two. Thus, it is not possible, at the present time, to predict reliably either the potential regional or seasonal changes in temperature and precipitation due to an increasing atmospheric CO_2 content; and consequently a detailed assessment of the climatic impact on agricultural productivity, water supply and energy resources allocation cannot yet be made.

If, however, a doubling of CO_2 concentration in the atmosphere were to occur in the early or middle part of the next century, as most models have predicted, then a warming greater than at any time in the past 1000 years could be expected. Since this could have a profound impact on both the natural environment and man's life, a brief look at some of the potential effects of a climatic change is appropriate. One likely result could be a shift in climatic zones with a concomitant disruption of agricultural production, especially in marginal climatic areas. Moreover, the melting of the west antarctic ice cap within a period, possibly as short as a few decades to a century, could result in a worldwide sea level rise of some 5–6 m with adverse effects to low-lying coastal areas in northwest Europe and the eastern USA. In a world that is daily becoming more crowded and that is already suffering from frequent food shortages and chronic malnutrition, any additional stress would aggravate the problems and a potential climatic stress should therefore be of serious concern. Additionally, there is much scepticism at present about the potentially beneficial effects for plants of a CO_2 enriched atmosphere.

The CO_2 problem is closely related to the energy issue in that the chosen energy mix will largely determine the resulting impact on the environment. Whatever the adverse effects are or may turn out to be, it would be prudent, as an additional safeguard, to evaluate now all possible measures of controlling the CO_2 impact and to assess their relative effectiveness, so that they would be available, if and when they are required.

It is clear that the CO_2 question is still fraught with many uncertainties. However, it is as well to realise that the uncertainties work both ways: there is no certainty that any of the events will occur in the way they have been described above; equally, there is no certainty that they will not happen that way.

Only concerted research efforts can help reduce the existing uncertainties and supply the knowledge required to solve the problems facing mankind. A better understanding of the processes involved will lead also to a better response from society to natural and anthropogenic climate changes and their implications. The following series of articles has been assembled in an attempt to identify some of the problem areas and to focus the discussion, thereby making a contribution towards that goal.