and 7 per cent of the residual but only about 4×10^{-9} of the total local gravity field. Despite this seemingly impossible accuracy, under Antarctic conditions to boot, C. L. Hager (University of California, Los Angeles) and R. V. O'Connell (United States Coast and Geodetic Survey) have managed to obtain some beautiful records of gravity tides with typical peak to peak amplitudes of 50 μgals and periods of fourteen days.

Antarctica also possesses a natural advantage for geomagnetic measurements (J. V. Hastings, ESSA). The ice thickness, about two miles at the South Pole Station, effectively removes the magnetographs from sources of crustal magnetic anomalies and structural geological materials with varying induction properties. The three orthogonal components of the Earth's magnetic field have now been recorded at the Byrd and South Pole Stations for more than eleven years, which puts these two stations among the Coast and Geodetic Survey's fourteen most reliable sources of geomagnetic observations. The data gathered are thus of the quality necessary for accurate determination of secular variation; and this will be reflected in better polar coverage for the 1970 issue of the five-year World Magnetic Charts.

Palaeomagnetism, on the other hand, suffers badly in Antarctica because of limited accessibility to samples. Nevertheless, L. Sharon (Washington University) and his colleagues have, during the past few years, managed to build up an impressive collection of samples from exposed regions. Measurements show that virtual geomagnetic poles from East Antarctica are displaced significantly from those in the West, which seems to suggest that East and West Antarctica are unrelated geologically or structurally. This fits in with Schopf's analysis of sea floor spreading (*Science*, **164**, 63; 1969) which indicates that the reconstruction of Gondwanaland "would be simplified if West Antarctica is not regarded as part of the ancient Antarctic crustal unit", and also with Hamilton's tectonic analysis (*Tectonophys.*, **4**, 555; 1967) which leads to a similar conclusion.

Commonsense on Environmental Pollution

THE most level-headed analysis so far of the problems of the environment seems to have been produced by a committee of the American Chemical Society under Dr F. A. Long of Cornell University (*Cleaning Our Environment. The Chemical Basis for Action.* American Chemical Society, \$2·75). The lasting value of the report will no doubt lie in the detailed recommendations which it contains for future research programmes aimed at removing some of the uncertainties which at present abound in the assessment of environmental hazards. The committee begins, however, by drawing attention to the way in which environmental problems must necessarily involve both governments and people, to the international character of a great many problems of pollution (such as the spread of long-lived pesticides) and to the need that governments should be concerned not merely with legislation but with support of research.

The committee says that in the long run, "the cost of pollution and its control will be borne by the citizen", both in taxes and in prices. But people have already elected to pay for certain important controls of sources of pollution—automobile engines, for example. "A parallel value judgment" is involved in the current discussion of the control of water quality, but, the report says, comparatively little has so far been done to deal with solid rubbish. On some occasions, there may be direct money saving in methods of control, but on other occasions the benefits are less tangible.

The scientific problems that the committee has identified for solution by others include the effect of low doses of pollutants on living things, the fact that understanding of the effects of pollutants on ecology is in an "even more primitive condition", and that the analytical methods available for the monitoring and control of these phenomena "are not as good as they ought to be". The committee's recommendations on air pollution should be a powerful stimulant to research and development. The committee points to the areas in which ignorance and even frank disagreement are rife and says that what little is known of the problems of air pollution "has been worked out in the teeth of formidable scientific odds"—chiefly the small concentrations of atmospheric contaminants which must be investigated. The committee points out, however, that the United States is at present producing atmospheric pollutants at the rate of 142 million tons a year (in 1965)—72 million tons of carbon monoxide, 26 million tons of sulphur oxides, 19 million tons of hydrocarbons, 13 million tons of nitrogen oxides and 12 million tons of solid particles. Automobiles are the worst offenders, and are responsible for 86 million tons of pollutants a year, most of it as carbon monoxide.

Whether there has been a secular increase of the amounts of the various contaminants is an open question, chiefly because of the uncertainties of monitoring. Measured sulphur dioxide concentrations in various cities of the United States in the first half of the sixties show a fluctuating pattern, with concentrations ranging from 0·21 (in Denver, Colorado) to 0·13 (in Chicago, Illinois). The committee was, however, impressed with the way in which the removal of sulphur compounds from the atmosphere by means of rain increased the acidity of rainfall over Europe in the early sixties until, by 1966, rainfall over central Sweden had a *p*H of 4·5 and until the *p*H of Lake Vanern in Sweden fell from 7·3 at the beginning of 1965 to about 6·8 two and a half years later. The committee says, however, that the long term importance of sulphur pollution in the air "is essentially unknown" although the possibility that sulphur compounds as particles might have geophysical consequences cannot be ruled out.

The committee considers that what scanty evidence there is shows that the concentration of airborne particles is increasing, and that there could in the long run be geophysical consequences. The long term effects of carbon monoxide in the atmosphere are

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harder to discern—although local damage may be caused by high concentrations of the gas in traffic-laden city streets, the general concentration of carbon monoxide seems to be about 0·1 part per million, from which it apparently follows that the residence time of this contaminant in the atmosphere is about three years. Certainly there has been no increase in the past fifteen years and it is something of a puzzle to know whether the gas is disappearing by conversion to carbon dioxide or by some other process. In much the same spirit, the committee is at a loss to know what is happening to the concentration of nitrogen oxide, partly because observations are scanty and because little is known of the worldwide nitrogen cycle. Similarly, the pollution of the atmosphere by hydrocarbons, now celebrated by the classical explanation of photochemical smog in Los Angeles, is not sufficiently well described for the committee to know whether the background concentration of about 1·5 parts per million is increasing—one difficulty is that nothing is known of the processes by which hydrocarbons are removed from the troposphere.

On the effect of carbon dioxide on the atmosphere, the committee takes the view that the greenhouse effect could "affect climate markedly" although carbon dioxide is not the only factor which could have such an influence but merely the one that has been most fully considered. The rate of emission of carbon dioxide will have multiplied by eighteen in the century ending in the year 2000. The committee says that the rate of production of carbon dioxide has been greater than the rate at which the natural cycle of carbon dioxide can adjust, and it suggests that the fluctuations of temperature, which increased between 1880 and 1940 by 0·4 degrees centigrade and then decreased by 0·2 degrees centigrade by 1967, could be accounted for by the increasing concentration of carbon dioxide in the atmosphere and then by increasing turbidity brought on by sunspot activity. The committee says, however, that this explanation is only one of many and that more research is necessary.

This analysis of the problems of air pollution prompts the committee to ask for a systematic programme of measurement of relatively long-lived substances in the atmosphere as well as of the turbidity of the atmosphere, a thorough study of the effect of carbon dioxide on climate in which satellite measurements would play an essential part, a study of chemical reactions in the atmosphere using field studies and laboratory work in an attempt to describe what happens in urban and other atmospheres, the rate of removal of specific contaminants from the air and the study of diffusion within urban environments. The committee has been understandably moved by the work begun in California on the control of automobile exhausts but now asks for better instrumentation, more stringent standards of acceptability, particularly including nitrogen oxides (at present not covered by federal regulations), a study of the effect of lead contaminants of the atmosphere, more support for steam and electric engines and more vigorous means of inspection of road vehicles. The committee also considers that there is room for better methods of control for industrial chimneys and commends a number of promising lines of development leading to new cleansing processes for industrial smoke stacks—it suggests, for example, that some attention should be given to a process now in the laboratory for removing sulphur dioxide from exhaust gases by scrubbing in molten carbonate.

Understandably, the committee is less sanguine about the biological problems occasioned by air pollution. It suggests, however, that the difficulties of measuring the erosion of human performance can be avoided by the development of suitable techniques from experimental physiology. The committee points out, however, that studies of this kind are also complicated by fundamental ignorance of simple chemistry—the belief that casualties from the London smog of 1952 were caused by the rapid oxidation of sulphur dioxide to sulphur trioxide has not yet been confirmed.

The committee is also unhappy about the understanding so far available of the effects of atmospheric pollution on vegetation, and raises the nightmare that a contaminant which destroyed "any of at least half a dozen types of bacteria involved in the nitrogen cycle could bring life on Earth to an end". The committee's strong suit is in its recommendations on the monitoring of atmospheric pollution and it has a great many specific suggestions for the development of simpler and cheaper instruments, particularly for use at the sources of air pollution.

On water pollution, the committee says that one of the most urgent needs is a better knowledge of the materials with which large bodies of water are at present being polluted—one of the difficulties in forming a realistic view of the degree of marine and water pollution is the variability of the quality of river water. The committee has an interesting point to make about the need for better mathematical descriptions of natural water systems in which pollution may be a problem. It has made a thorough study of the problems of municipal waste water treatment and asks that there should be a search for radically new solutions to the treatment of sewage based on microbiological techniques, on the use of synthetic polyelectrolytes for improving flocculation in sewage plants and more systematic studies of the composition of storm water. The ultimate in sewage treatment is the conversion of polluted water to a form that can be used directly, the prototype for which is the plant now producing 75,000 gallons a day of potable water at Lebanon, Ohio. The committee estimates that the total cost of such water might be just over $1 per thousand gallons—substantially that of water obtained by efficient distillation plants. There is more scope for using partially purified waste water, which the committee advocates enthusiastically.

The committee has drawn attention to some of the ambiguities in the interpretation of the eutrophic lakes, ranging from Lake Erie in the United States to Lake Zurich in Switzerland. It is commonly argued that the availability of nitrogen and phosphorus will determine the rate of growth of algae, but it seems that algal blooms occur in eutrophic lakes at concentrations that seem to vary remarkably from one set of circumstances to another. This variability is one of the reasons why the committee cannot warmly endorse the notion that eutrophication could be controlled by limiting the use of phosphate detergents and of phosphates and nitrates in agriculture.

On pesticides, the American Chemical Society's committee follows a level-headed line—it wants more vigilance, more understanding, more education of those who use pesticides and a better understanding both of the contamination of the environment and of the long term effects of pesticide accumulation on people and on animals.

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