THE ROYAL SOCIETY OF CHEMISTRY

ENVIRONMENTAL CHEMISTRY GROUP

Newsletter

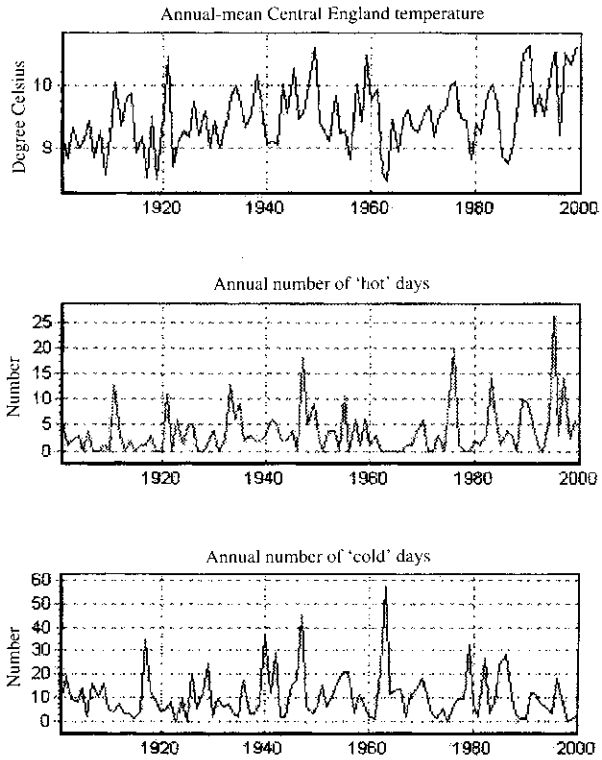
Issue No.12 - July 2000

RS•C ROYAL SOCIETY OF CHEMISTRY

CONTENTS

ECG Newsletter No. 12 - July 2000

The contents page of this ECG Newsletter may be seen on the Internet at http://www.rsc.org/lap/rsccom/dab/scaf003.htm



UK Indicators of Climate Change: Air Temperature Measurements in Central England, 1900-2000

For further details, see the Web site http://www.nbu.ac.uk/iccuk/

Reports from the 2000 ECG Distinguished Guest Lecture and Symposium

***Climate Change and its Impact* – pp. 2-14**

RSC ENVIRONMENTAL CHEMISTRY GROUP OFFICERS

(from March 2000)

Chairman

Dr. Leo Salter
Centre for Science,
Cornwall College, Pool, Redruth
Cornwall TR15 3RD
Tel: 01209 712911
e-mail l.salter@cornwall.ac.uk

Hon. Secretary

Dr. Andrea Stroh
School of the Environment
University of Leeds
Leeds LS2 9JT
Tel: 0113 233 6728
e-mail: andrea@env.leeds.ac.uk

Vice-Chairman

Dr. Peter O'Neill
Dean of the Science Faculty
University of Plymouth,
Drake Circus
Plymouth, Devon PL4 8AA
Tel: 01752 232984,
e-mail p.oneill@plymouth.ac.uk

Hon. Treasurer

Professor Peter Craig
School of Applied Science
Department of Chemistry and Physics
De Montfort University
The Gateway, Leicester LE1 9BH
Tel: 0116 2577102
e-mail pjcraig@dmu.ac.uk

NEWSLETTER EDITOR

Dr. Rupert Purchase
38 Sergison Close, Haywards Heath
West Sussex RH16 1HU
Tel: 01444 455673
e-mail rp@rupertpurchase.prestel.co.uk

Chairman's Report on Recent Activities of the ECG

This issue of the ECG Newsletter features reports from the three speakers at this year's Distinguished Guest Lecture and Symposium on *Climate Change and its Impact* plus an additional contribution from Cornwall College on the effects of climate change on demography and human health. Appropriately for the new century, these four articles describe the increasingly diverse and strong signals that the effect of human activity is having on the world's climate. This adjustment to climate change will present profound challenges for large sections of the world's population.

It is beginning to become apparent that the global commitment to ameliorating the rate of climate change is decidedly weak. Whether this is because the effects of change on the Western Hemisphere are predicted to be tolerable or whether it is because the actions needed are too difficult to implement, it appears that the political will, the economic imperatives, and the concerns for the world's ecosystems are not strong drivers for behavioural change.

So it seems that the future lies in responding and adapting to an environment which will be, if predictions are correct, substantially different a hundred years from now. The articles in this issue offer at least some insight into what that difference may be like.

The Environmental Chemistry Group is continuing to develop symposia and conferences that offer insights and updates of key environmental issues. The 2001 Distinguished Guest Lecturer will be Dr. John Emsley and the theme of his Lecture and the accompanying Symposium will be *"PVC and Persistent Organic Pollutants in the Environment."* Dr. Emsley's fluency in informing a wider audience about chemistry is well known, as perhaps are his views on a breadth of current environmental issues. The need for compromise between consumer demands and ecosystem changes are starkly apparent in the debate between the chemical industry and the "champions" of the environment. And yet it is only by tackling the detail of the environmental risk and by using sustainable "green" chemical manufacturing techniques that acceptable compromise solutions can be found. The DGL and accompanying symposium are aimed at providing a snapshot of the debate and the detail necessary for comprehending its complexity.

This issue of the Newsletter continues the standard of high-quality content developed by Rupert Purchase. Members of the Group are encouraged to contact Rupert and to submit articles, conference reports and similar for dissemination to the Group membership via the Newsletter. Feedback is welcome.

LEO SALTER
June 2000

Global Warming and Climate Change: the Latest Science and the Likely Impacts

Sir JOHN HOUGHTON was this year's RSC Environmental Chemistry Group Distinguished Guest Lecturer. We are grateful to Professor Houghton for making available the following article, which incorporates the text of his lecture presented at the Royal Society on March 1st 2000. This lecture was part of a symposium on *Climate Change and its Impact.*

Introduction

There is strong scientific evidence that the average temperature of the Earth's surface is increasing because of higher concentrations of carbon dioxide and other 'greenhouse' gases in the atmosphere. Greenhouse gases are mainly a result of human activity, for example the burning of fossil fuels, coal, oil and gas. Global warming will lead to substantial changes of climate; many of these changes will affect human communities in deleterious ways.

In terms of the likely global pattern of climate change, this century, in the absence of any mitigating action, the global average temperature is likely to rise by about 2.5 °C (range 1-3.5 °C) and sea level by about 0.6m (range 0.2-1m). The hydrological cycle is likely to be more intense (leading in some places to more frequent and more intense floods and droughts) and the rate of climate change is likely to be substantially greater than the Earth has experienced over at least the last 10,000 years. It will be difficult for many ecosystems and for humans to adapt in particular to this rapid rate of change.

Action has been taken by the world's scientists through the Intergovernmental Panel on Climate Change (IPCC) to assess as thoroughly as possible knowledge regarding the basic science and the impacts including an assessment of the uncertainties. The world's governments have also taken action in setting up the Framework Convention on Climate Change (FCCC) at the Earth Summit in 1992 and at subsequent meetings of the Parties to that Convention especially that at Kyoto in 1997.

In order to mitigate climate change, the FCCC in its Article 2 has set as an Objective the stabilisation of the concentration of greenhouse gases in the atmosphere at a level and on a timescale consistent with the needs both of the environment and of sustainable development. Such stabilisation will eventually demand severe cuts in global emissions, for instance for CO_2, to levels well below today's emissions by the second half of the 21st century. To achieve the required reductions in the

emissions of carbon dioxide, three possibilities are available:

- to sequester carbon dioxide resulting from the burning of fossil fuels rather than releasing it to the atmosphere;
- to become much more efficient in the generation and use of energy;
- and to provide for energy supply from non-fossil fuel sources.

This article will briefly summarise the science and impacts of climate change, and the current and future actions designed to mitigate climate change.

The Science of Climate Change

The Variability of Climate

Variations in day-to-day weather occur all the time; they are very much part of our lives. The climate of a region is its average weather over a period that may be a few months, a season or a few years. Variations in climate are also very familiar to us. We describe summers as wet or dry, winters as mild, cold or stormy, recognising that in many parts of the world the seasons vary a great deal from year to year.

To obtain a perspective on climate change we shall first look at the climate of the last 100,000 years or so, which has been dominated by the last ice age, and then look at climate trends over the last century.

The climate record over many thousands of years can be built up by analysing the composition of the ice and the air trapped in the ice obtained from different depths from cores drilled from the Antarctic or the Greenland ice caps. Figure 1 is a record of the temperature at which the ice was laid down and of the atmospheric carbon dioxide content over the last 160,000 years from an Antarctic ice core. Currently the Earth's climate is in a warm phase that began when the last ice age came to an end about 20,000 years ago; the last warm period was about 120,000 years ago. The main triggers for the ice ages have been the small regular variations in the geometry of the Earth's orbit about the sun that affect the distribution of solar radiation at the Earth's surface. Of particular interest is

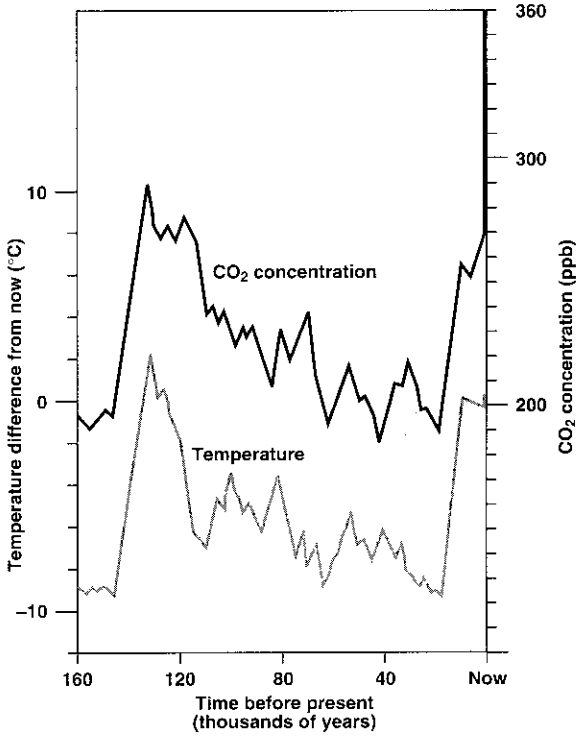


Fig 1. Observations from the Vostok ice core, showing for the last 160,000 years the variation of atmospheric temperature over Antarctica (it is estimated that the variation of global average temperature would be of the order of half that in the polar regions) and the atmospheric carbon dioxide concentration. Note the current value of carbon dioxide concentration of just over 360 ppm.

the strong correlation between the atmospheric temperature and the carbon dioxide content. Part of this undoubtedly arises because the amount of carbon dioxide in the atmosphere is dependent on factors that are strongly related to the average surface temperature. But it is also true that it is not possible to understand the range of temperature variations of the past without allowing for the influence of carbon dioxide on atmospheric temperature through the greenhouse effect. Note also from Figure 1 the very rapid rise in atmospheric carbon dioxide concentration over the past two hundred years or so because of human activities which has taken the concentration of this gas well outside the range of its natural variation during the last million years or more.

Changes in the average air temperature near the Earth's surface from instrumental records for the past 160 years are shown in Figure 2. Over this period this temperature has increased by somewhat more than 0.5 °C although the increase has not been uniform. There are strong indications that the increase since the 1970s is linked with the growth in the atmosphere of greenhouse gases such as carbon dioxide from anthropogenic sources. The 1990s have been particularly warm in terms of this global

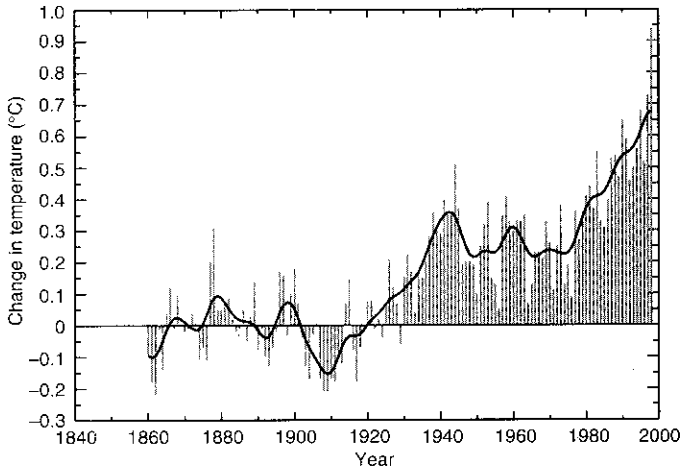


Fig 2. Changes in the global annual mean surface temperature, relative to that at the end of last century, shown by the vertical bars. A smoothed curve has been added. (From Hadley Centre UK.)

average temperature. Not only was 1998 the warmest year on record, the first eight months of 1998 were the warmest of those months on record. Note also the year-to-year variations that are a further illustration of natural climate variability.

The Greenhouse Effect

In 1896 Svante Arrhenius, the Swedish physical chemist, made the first calculation of the average rise in temperature to be expected at the earth's surface if the atmospheric carbon dioxide concentration were to double. His estimate of 5 or 6 °C was not far out, just a little larger than current estimates, which are in the range 1.5 to 4.5 °C.

The Earth absorbs radiation from the Sun, mainly at the surface. A balancing amount of energy is then radiated to space at longer, infrared, wavelengths. Some of the gases in the atmosphere, particularly water vapour, carbon dioxide and methane, and clouds, absorb some of the infrared radiation emitted by the surface and themselves emit radiation from higher altitudes at colder temperatures. The Earth's surface is thereby kept about 30 °C warmer than it would otherwise be. This is known as the 'greenhouse effect' because the glass in a greenhouse possesses similar optical properties to the atmosphere.

Increases in the concentration of the 'greenhouse gases' will tend to lead to further warming of the surface and the lower atmosphere; this is the 'enhanced greenhouse effect'. Its approximate magnitude can be simply estimated from radiation energy balance calculations, but for detailed information about it, sophisticated computer models have to be used which take into account the influences of the atmospheric and oceanic circulations.

In the late 1960s scientists began to realise that the rate of increase of the amount of atmospheric carbon dioxide, due to the increasing rate of burning of fossil fuels, was such that significant global warming would occur. Associated with the warming would be substantial changes in the earth's climate. By the late 1980s, wide concern was being expressed about the likely impact of climate change and it became a subject firmly on the political agenda.

The Intergovernmental Panel on Climate Change (IPCC)

The IPCC was formed in 1988 jointly by two United Nations bodies, the World Meteorological Organisation and the United Nations Environment Programme, to provide assessments of future climate change and its likely impact. Its first report published in 1990 provided the scientific basis for the Framework Convention on Climate Change (FCCC) agreed at the Earth Summit held at Rio de Janeiro in June 1992 and signed by about 160 nations. To assist in the Convention process, a new comprehensive report was produced by the IPCC at the end of 1995 and a further report is being prepared for 2001.

The IPCC has not only assessed the basic science of climate change but also its likely impacts on human activities and the options for adaptation to those impacts. It has also addressed how climate change can be mitigated through the reduction of emissions of greenhouse gases into the atmosphere, for instance by changes in the generation and use of energy, by the sequestration of carbon dioxide or by reducing the emissions of methane from a variety of sources. The IPCC has also supported the work of the FCCC through its assessments of studies of the likely economic costs of the damage due to climate change and its assessments of adaptation and mitigation, and of studies of the social and political implications of action or of inaction. The material in this article is substantially based on the Second Assessment Report of the IPCC published in 1996.

Greenhouse Gases

The main greenhouse gases resulting from human activity are carbon dioxide and methane. Their atmospheric concentrations have risen by about 30% and 145% respectively since pre-industrial times largely because of fossil fuel use, land-use changes (e.g. deforestation) and agriculture. Carbon dioxide is responsible for about two-thirds of the enhanced greenhouse effect arising from the increases in greenhouse gases. If no action is taken to mitigate emissions from carbon dioxide, the level of emissions and the atmospheric concentration of CO_2 will continue to rise throughout this century. Its concentration could reach 560 ppm or double its pre-industrial concentration before the year 2100. Other greenhouse gases of importance are nitrous oxide, the chlorofluorocarbons (CFCs) and ozone. Emissions of chlorofluorocarbons into the atmosphere have led to some destruction of the ozone layer, most dramatically illustrated by the discovery of the 'ozone hole' over Antarctica in 1985. Because ozone is also a greenhouse gas, this ozone destruction has partially compensated for the greenhouse effect of the chlorofluorocarbons.

An important consideration is the time taken for the anthropogenic emissions of greenhouse gases to be removed from the atmosphere. For methane, the removal process is governed by chemical reactions; the lifetime of methane in the atmosphere is about 10 years. On the time scales we are considering, carbon dioxide emitted into the atmosphere is not destroyed but redistributed among the carbon reservoirs, in the biosphere and in the ocean. The carbon reservoirs exchange carbon between themselves on a wide range of timescales that vary from less than a year to decades (for exchange with the top layers of the ocean and the land biosphere), or to millennia (for the deep ocean or long-lived soil pools). The large range of turnover times means that the time taken for a perturbation in the atmospheric carbon dioxide concentration to relax back to an equilibrium state cannot be described by a single time constant. Although a lifetime of about a hundred years is often quoted for atmospheric carbon dioxide so as to provide some guide, use of a single lifetime can be misleading.

Other Factors Influencing Climate Change

In recent years there has been more recognition and quantification of the role of anthropogenic aerosols (microscopic particles in the atmosphere) in climate change. Of particular importance are those originating from the sulphur containing gases emitted from power stations – the effluents that also give rise to the acid rain problem. These aerosols reflect sunlight and so tend to cool the earth's surface. However, they are very short lived (a few days), so that they are concentrated near industrial regions. Locally their cooling effect can be comparable in magnitude to the warming effect of the increase of greenhouse gases.

However, it is important to realise that their effect on the climate is not confined to the regions where they are concentrated so that their impact on climate change is not a simple offset to that of the greenhouse gases. Their effect in the future will be limited by the increasing recognition of the requirement to avoid the deleterious effects of acid rain.

"Has Anthropogenic Climate Change Actually Been Observed?"

Can the observed warming in recent years be attributed to the increase in greenhouse gases? The 1990 IPCC Assessment concluded that there was insufficient evidence to argue that the anthropogenic climate 'signal' had emerged from the 'noise' of climate variability. However, including the effects of aerosols in climate models has substantially improved the agreement between models and observations (Figure 3). Also during the last few years, knowledge of natural climate variability has improved so that more realistic statistical studies have been possible. Recent studies have therefore been more positive and the 1995 IPCC Assessment includes the sentence – agreed after a long and lively debate – "The balance of evidence suggests a discernible human influence on climate."

Modelling Climate Change

To project anthropogenic climate change into the future, estimates of future emissions of greenhouse gases are first required. These will depend on the assumptions made about such factors as the likely growth of the world economy, the availability of fossil fuels and the degree of pressure for environmental change. For carbon dioxide, the higher scenarios assume large economic growth coupled with little pressure for reduction in emissions for environmental reasons. Under these scenarios emissions of carbon dioxide into the atmosphere due to human activities, currently about 7 billion tonnes of carbon per year rise to up to 20 billion tonnes by the year 2100. A much lower but achievable emission scenario is shown in Figure 4. It assumes strong environmental pressure for change, and leads by 2100 to stabilisation of the carbon dioxide concentration at about 450 ppmv, about 60% above its pre-industrial level.

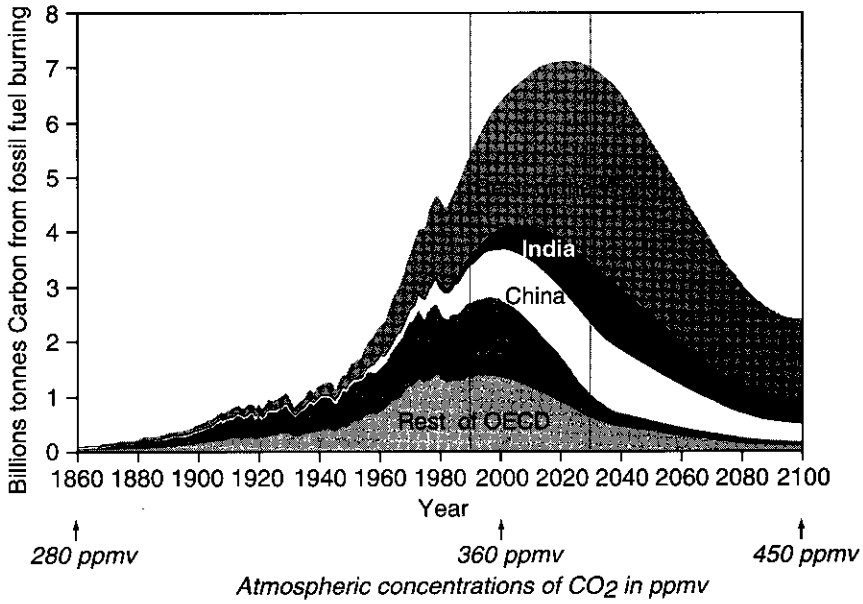


Fig 4. The 'Contraction and Convergence proposal of the Globals Commons Institute'. Global carbon emissions from fossil fuel use 1860-1990 showing share amongst groups of countries; then as projected for a scenario leading to eventual stabilisation of atmospheric carbon dioxide concentration at 450ppm. By 2030 it is assumed that the sharing of emissions has converged to be on the basis of equal per capita emissions rights. (From World Energy Council Report 'Global Energy Perspectives' CUP 1998.)

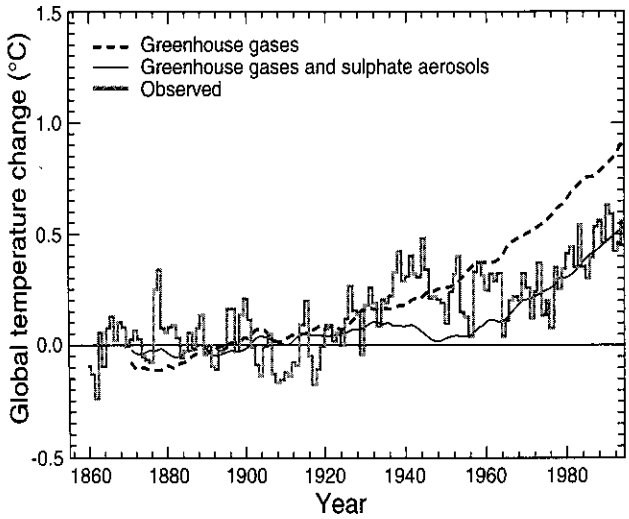


Fig 3. Global annual mean warming from 1860 to 1990 as simulated by the UK Hadley Centre climate model allowing for increases in greenhouse gases only (dashed curve) and greenhouse gases and aerosols (solid curve) compared with observations over the same period. (From IPCC Report 1995: Technical Summary.)

Other greenhouse gases will also increase in concentration. For instance, methane (the anthropogenic sources of which are mainly due to cattle, rice cultivation, the oil and gas industry and landfill) may double in concentration by 2100. Because of other environmental problems (e.g. that of 'acid rain') aerosol concentrations from anthropogenic sources are not likely to grow substantially, they might even on average reduce from their present level.

From the projections of the concentrations of carbon dioxide and other greenhouse gases, estimates may be made from climate models of the associated increases in global mean surface air temperature. For the business-as-usual scenario the increase, from pre-industrial times to 2100 is about 3 °C (range from about 1.5 °C to 4 °C). For the environmentally driven scenario, the increase by 2100 is 1.5 °C (range 1 °C to 2 °C).

The greatest uncertainties in the projection of climate change this century arise from our lack of knowledge of: (1) the future profiles of emissions of greenhouse gases, (2) some of the feedbacks in the climate system especially those arising from changes in cloudiness, (3) changes in the ocean circulation and (4) changes in the biosphere. Because of these factors,

projections of climate change on the regional scale possess greater uncertainty than those of global averages. Increased understanding regarding these will come from combining more accurate observations possessing better coverage with careful model simulations.

The Impacts of Climate Change

Expressing climate change in terms of the increase in global average temperature is not very meaningful for most of us. What about its impacts on our lives? In some locations, the impacts may be positive. For instance, for some crops, increased carbon dioxide aids growth and at high northern latitudes the growing season will be longer. However, because humans and ecosystems have adapted closely to the current climate, most of the impacts will be deleterious. The most important impacts are likely to be on sea level, changes in rainfall and on temperature extremes.

Sea Level Rise

The expected rise in sea level of about 0.5 m (range from 0.2 m to 1 m) by the year 2100 arises mostly from the expansion of water in the oceans because of the increased temperature and from the melting of glaciers; the contribution from changes in the ice sheets in the Arctic and Antarctic is expected to be small. As more of the ocean warms, sea level will continue to rise for many centuries, even if the greenhouse gas concentrations are stabilised. Adaptation, at a cost, to a rise of a metre or less will be possible in many coastal regions. However, adaptation will be extremely difficult, if not impossible, in some particularly vulnerable areas such as the delta regions of large rivers in Bangladesh, Egypt and Southern China and the many low lying islands in the Indian and Pacific oceans.

A major impact of global warming is likely to be on water supplies. Warming of the Earth's surface means greater evaporation and, on average, a higher water vapour content in the atmosphere that in turn leads to a more vigorous hydrological cycle. That means an increased tendency to heavy rainfall, leading to an increasing possibility of floods in some places. It also means, perhaps surprisingly, because of the interaction of the more vigorous hydrological cycle with the atmospheric circulation, an increased tendency to less rainfall and hence periods of drought in other places. Many parts of the world are likely to see substantial changes in rainfall patterns and the availability of soil moisture. Those likely to be most seriously affected are those with periods of particularly heavy rainfall (e.g. the regions of the Asian summer monsoon) and those with marginal rainfall.

Impacts on Food and Health

Studies of global food supplies in a globally warmed world tend to suggest that the global quantity of available food supply might not be affected by very much – some regions might be able to grow more while others grow less. However, the distribution of food production will change, not least because of changed water availability. The regions likely to be adversely affected are those in developing countries in the sub-tropics where there are rapidly growing populations. In areas where agricultural production becomes inadequate to meet local needs there could be large numbers of environmental refugees.

Other important impacts of the likely climate change are on human health (increased heat stress and more widespread vector-borne diseases such as malaria) and on the health of some ecosystems (e.g. forests), which will not be able to adapt rapidly enough to match the rate of climate change.

The Framework Convention on Climate Change (FCCC)

The Establishment of the FCCC

The Framework Convention on Climate Change (FCCC) signed by over 160 countries at the United Nations Conference on Environment and Development (the Earth Summit) held in Rio de Janeiro in June 1992, came into force on 21 March 1994. The Convention sets the context in which international action regarding the issue of climate change can be pursued. It recognises the reality of global warming and also recognises the uncertainties associated with current predictions of climate change The Convention agreed that action to mitigate the effects of climate change needs to be taken and pointed out that developed countries should take the lead in this action. In its consideration of an appropriate response to the possibility of climate change, the FCCC applies the Precautionary Principle.

The FCCC mentions one specific *aim* and one longer-term *objective*. The specific *aim* is that the developed countries should take action to return their greenhouse gas emissions, in particular those of carbon dioxide, to their 1990 levels by the year 2000. The longer-term *objective* stated in Article 2 states:

"The ultimate objective of this Convention....is to achieve...stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

In this statement of its *objective*, the FCCC places action concerning climate change clearly in the context of sustainable development. The balance that this implies between environmental protection on the one hand and economic development on the other must be based on the best possible scientific, economic and technical analyses of all the factors involved. The IPCC is the international body through which the information is assessed and provided to the FCCC.

What does the requirement for the stabilisation of the atmospheric concentrations of greenhouse gases, expressed in the *objective* of the FCCC, imply? For methane it is easy to estimate what this would mean. For instance, to stabilise methane at today's concentration would require a reduction in anthropogenic emissions by about 8%. For carbon dioxide the situation is more complex. It is already clear from impact studies (most of which have been made for carbon dioxide concentrations of about 550 ppmv – double its pre-industrial value) that politicians and decision makers are likely to be looking at stabilisation levels below 550 ppmv. To achieve stabilisation at such levels, emissions should not rise much during the first half of the 21st century and

should decrease substantially below today's levels during the second half of the century.

The Kyoto Protocol

The first conference of Parties to the FCCC was held in Berlin in April 1995; it was agreed that a plan of action should be prepared for agreement by the Parties in 1997. That plan was agreed by the Parties in the **Kyoto Protocol** of December 1997. Under that Protocol, which has yet to be ratified by many countries, developed countries agreed by 2010 to reduce their emissions of greenhouse gases (all significant greenhouse gases being included in the calculation) by amounts which generally varied from 5 to 8% below their 1990 level.

The Kyoto Protocol is a first step in a long political process that will continue and gather momentum over the next decades.

The agreement at Kyoto is strongly rooted in the context of accurate and honest science and balanced technology (as was the Framework Convention on Climate Change (FCCC) itself, as signed at the Earth Summit in Rio in 1992) – the belief that the science of climate change as expounded by the Intergovernmental Panel on Climate Change (IPCC) is basically sound and that adequate and appropriate technology is available to enable the necessary reductions in the emissions of greenhouse gases to occur.

The Mitigation of Climate Change

Actions to Mitigate Climate Change

Mitigation of the effects of global warming can be achieved by the following actions:

- increase the sinks which remove carbon dioxide from the atmosphere:
  - by reducing deforestation
  - by increasing aforestation
  - by sequestering carbon dioxide
- reduce the emissions of both carbon dioxide and methane from anthropogenic sources.

Forestry

Over the past century the destruction of forests has contributed significantly to the increase of the concentration of carbon dioxide in the atmosphere. Recent decades have seen loss of tropical forests, averaged over the globe, of about 1% per annum. Halting this deforestation (which would be good for other reasons) and encouraging aforestation could make a significant contribution to the sequestering of carbon from the atmosphere.

Methane reduction

Methane is an important greenhouse gas; its increase since pre-industrial times has contributed about 20% of the enhanced greenhouse effect to date. A reduction of anthropogenic emissions by around 10% would lead to stabilisation of the atmospheric methane concentration. Reductions in methane emissions can be achieved by giving attention to leaks from pipelines, by reducing the amount of waste going to landfill sites and by collecting the gas they emit, by reducing deforestation and by reducing the methane arising from agricultural sources.

Sequestration of carbon dioxide

A number of possibilities exist for sequestering carbon dioxide from fossil fuel emissions. The most promising is to pump it down into porous rocks, for instance into spent or partially spent gas or oil wells where it can be used to increase the gas or oil yield. Such sequestration is already occurring. For instance, a company in Norway where there is a carbon tax has found it economic to sequester unwanted CO_2 in a gas well rather than pay the tax that would be required if it were released to the atmosphere.

Energy generation and use

Two approaches are possible to reduce emissions of carbon dioxide in the energy industry: to become much more efficient in the generation and use of energy; and to provide for energy supply from non-fossil fuel sources.

In most energy uses, energy is employed inefficiently; only a few per cent of primary energy is turned into effective use, the rest is wasted. There is enormous potential to increase the efficiency of energy use in buildings, in industry, in domestic appliances and in transport. Some of the possibilities are:

- Improved design of buildings (around 35% of energy is used in buildings) through higher building standards (e.g. in insulation) together with the integration, through changes in engineering practice, of different areas of design and construction so as to minimise energy use;
- Improved electrical appliances (e.g. low energy light bulbs or refrigerators with better insulation) again designed to minimise energy use;
- The development and marketing of more efficient vehicles, for instance hybrid vehicles (which combine small petrol or diesel engines with electric propulsion) and vehicles employing fuel cells.

The rapid development and growth of renewable energy sources (i.e. those not dependent on fossil fuels) is key to future sustainable energy provision. A number of such sources are poised for growth. In appropriate locations wind energy can be supplied at a price which is becoming competitive with fossil fuel sources. Power stations, which employ waste materials or renewable biomass as sources of fuel, are being developed. Solar energy especially through the use of photovoltaic cells as a source of electricity (with hydrogen produced electrolytically as a storage medium) is likely to become one of the major sources of world energy in due course. There are also possibilities for the development of wave and tidal energy sources.

Contraction and Convergence

The technical and political problems inherent in achieving large reductions in carbon dioxide emissions are illustrated by a proposal made by the Global Commons Institute called 'Contraction and Convergence' (Figure 4). The Figure first shows the profile of global emissions that would be necessary to stabilise the atmospheric carbon dioxide concentration at 450ppmv. That is the 'Contraction' part of the proposal. The other part of the proposal addresses how the reductions are to be shared out between countries. It suggests that the simplest and fairest way to do this is to share carbon dioxide emissions equally

per capita and to converge (hence 'Convergence') to a situation of equal shares by, say, 2030. The diagram shows how, on this basis, emissions would be shared between countries. The further part of the proposal is that, having allocated profiles of emissions this century between countries, trading of those allocations would be allowed. If carried out responsibly this trading could act so as to transfer economic and technical resources to developing countries enabling their programmes of industrialisation to be carried forward in ways that have minimum impact on the environment. Although there are clearly many practical difficulties in its realisation, this 'Contraction and Convergence' proposal is one way in which the necessary reductions in carbon dioxide emissions could be achieved with consequent implications for climate stabilisation.

The Achievement of Change and the Likely Cost

Figure 4 demonstrates by way of an example the enormous technical and political problems involved in any solution to the problem of achieving the necessary reduction in the use of fossil fuels. But can the world's energy industry contemplate the changes required? In a detailed study by the World Energy Council (WEC) of energy generation and use this century, an 'ecologically driven' scenario is described associated with which there would be a profile of carbon dioxide emissions similar to the 450 ppmv stabilisation curve shown in Figure 4. The WEC show how this can be achieved – particularly by strong drives to increase energy efficiency and to develop the use of energy sources with much lower carbon dioxide emissions of the kind we have mentioned above. Under this scenario by 2020, 'new' renewable energy sources make up 12 % of total energy provision. Further, by 2020 developing countries, as they industrialise, are projected to roughly double their energy use and their carbon dioxide emissions, while developed countries are projected to reduce their energy use by about 10% and their carbon dioxide emissions by about 30%. Estimates of the annual cost of realising such a scenario suggest figures of 1% or less of Global World Product (GWP) which is considerably less than most of the estimates which economists have made of the damage likely to result from climate change impacts.

However, with the availability of cheap energy being seen as the engine for industrial and economic growth, reductions in carbon dioxide emissions are not going to come easily. A large challenge to economists and to governments is to devise appropriate economic instruments and incentives to bring about the large increases in efficiency and the switch to non-fossil fuel energy sources that are necessary.

To achieve adequate mitigation of climate change will require commitment from all sections of the community. The challenge therefore is to scientists to improve the base of knowledge regarding climate change and its impacts, to governments to commit themselves to action adequately to address the problems of climate change and its mitigation and to industry to develop and market the technologies required to reduce anthropogenic greenhouse gas emissions. The transfer of technology from developed to developing countries will also be important; the FCCC has emphasised the benefits that will accrue to industries in both the developed and developing worlds. Commitment is also required from all of us as individuals to take seriously the challenge of environmental stewardship. Further, the matter is an urgent one. As the WEC points out 'the real challenge is to communicate the reality that the switch to alternative forms of supply will take many decades, and thus the realisation of the need and the commencement of the appropriate action must be *now*' (their italics).

Bibliography

Further detailed information about global warming can be found in the IPCC 1995 Reports *Climate Change 1995* published in 3 volumes: *The Science of Climate Change; Impacts, Adaptations and Mitigation of Climate Change: Scientific -Technical Analyses*; and *Economic and Social Dimensions of Climate Change*, Cambridge University Press, 1996.

John Houghton, *Global Warming: The Complete Briefing*, 2nd edition, Cambridge University Press, 1997 provides a comprehensive account of the science, impacts and mitigation of climate change.

A challenging assessment of the potential for increases in energy efficiency can be found in E. von Weizsacker, A. B. Lovins and L. H. Lovins, *Factor Four; Doubling Wealth, Halving Resource Use*, Earthscan Publications, 1997.

Detailed projections for the global energy industry are given in *Global Energy Perspectives*, ed. N. Nakicenovic, A. Grubler and A. MacDonald, Cambridge University Press, 1998.

JOHN HOUGHTON
Hadley Centre, Meteorological Office
Bracknell RG12 2SY, UK

Some Web sites on Climate Change

IPCC Web site: http://www.ipcc.ch/

UN Framework Convention on Climate Change: http://www.unfccc.de/

Worldwide Fund for Nature Climate Change Campaign:
http://www.panda.org/climate

The US Global Change Research Information Office:
http://www.gcrio.org/gwcc/toc.html

Global Change Master Directory:
http://gcmd.gsfc.nasa.gov/pointers/glob_warm.html

Sir John Houghton

Sir John Houghton, CBE, FRS is co-chairman of the Science Assessment Working Group of the Intergovernmental Panel on Climate Change and a member of the British Government's Panel on Sustainable Development. He was Professor of Atmospheric Physics at the University of Oxford form 1976-1983, Chief Executive of the Meteorological Office from 1983 to his retirement in 1991 and Chairman of the Royal Commission on Environmental Pollution from 1992-1998. He has received Gold medals from the Royal Meteorological Society and the Royal Astronomical Society and the prestigious International Meteorological Organisation Prize. Sir John is the author of a number of books including two textbooks, *The Physics of Atmospheres* (Cambridge University Press, 2nd edition, 1986) and *Global Warming: The Complete Briefing*, Lion Publishing, 1994; 2nd edition, Cambridge University Press, 1997.

The Implications of Global Climate Change for Human Health

In the first of two presentations from the symposium on *Climate Change and its Impact,* which accompanied Sir John Houghton's 2000 Distinguished Guest Lecture, Professor TONY McMICHAEL from the London School of Hygiene and Tropical Medicine spoke on *The Implications of Global Climate Change for Human Health.* We are grateful to Professor McMichael for providing the following article based on his talk in March.

Introduction

Human societies since hunter-gatherer times, but particularly as agriculturalists, have degraded local ecosystems and modified regional climates. Today, the aggregate human impact has attained an unprecedented global scale, reflecting rapid increases in population size and in energy-intensive, high-throughput consumerism. We are therefore now encountering unfamiliar human-induced changes in the composition of the lower and middle atmospheres and worldwide depletion of soil fertility, aquifers, ocean fisheries, and biodiversity in general. Although we can readily recognise that such changes would affect economic activities, societal infrastructure and managed ecosystems, we have been less attuned to the idea that these changes are eroding our own life-support system. The topic of global climate change, in particular, is changing that situation: it is leading scientists to model the risks to human population health.

Climate change is likely to have direct impacts on injury and disease via changes in the frequency of extreme weather events. For example, tropical cyclones may increase as sea-surface waters warm; floods may increase as the hydrological cycle intensifies; and heatwaves may increase in mid-continental locations. A change in the frequency and intensity of heatwaves and cold spells would affect seasonal patterns of morbidity and mortality. The production of various air pollutants and of allergenic spores and pollens would also be affected by warmer and wetter conditions.

Of equally great, perhaps greater consequence, climate change is expected to affect patterns of human health via various indirect pathways: in particular, it may alter the geography and seasonality of infectious diseases (especially vector-borne diseases such as malaria and dengue which are very sensitive to changes in climatic conditions), the yield of food-producing systems on land and at sea, the availability of freshwater, and, by contributing to biodiversity loss, may destabilise and weaken the ecosystem "services" upon which human society depends. There is yet another category of impact on health – the diverse (physical, mental, microbiological and nutritional) health consequences of socio-economic disruption and demographic displacement, such as would follow sea-level rise and inundation of small-island and low-lying coastal populations.

This topic will become a major theme in public health research, social policy development, and political advocacy early in this twenty-first century. Consideration of global climatic-environmental hazards to human population health should be central to the large and complex debate on why and how we must strive, now, for a "sustainability transition."

Global climate change is a qualitatively distinct – and very significant – addition to the spectrum of environmental health hazards encountered by humankind. Historically, our environmental health concerns have been focused on toxicological or microbiological risks to health from local exposure factors. However, in the twenty-first century the scale of environmental health hazards is increasing. As the burgeoning human impact on the environment has begun to alter global biophysical systems (such as the climate system), so a range of larger-scale environmental hazards to human health has emerged. This includes the health risks posed by climate change, stratospheric ozone depletion, loss of biodiversity, stresses on terrestrial and ocean food-producing systems, changes in hydrological systems and the supplies of freshwater, and the global dissemination of persistent organic pollutants (1). This ecological perspective recognises that the foundations of long-term good health in populations reside in the continued stability and functioning of the biosphere's ecological and physical systems – often referred to as "life-support systems."

Potential Health Impacts of Climate Change

Global climate change would affect human health via paths of varying complexity, scale and directness. The timing of the various impacts would also differ. There would be both positive and negative effects, although expert scientific reviews assess that the latter would clearly predominate.

The more direct impacts include those due to changes in exposure to weather extremes (heatwaves, winter cold), those due to increases in other extreme weather events (floods, cyclones, storm-surges, droughts), and those due to increased production of certain air pollutants and aeroallergens (spores and moulds). Decreases in winter mortality due to milder winters may compensate for increases in summer mortality due to the increased frequency of heatwaves. In countries with a high level of excess winter mortality, such as the UK, the beneficial impact may outweigh the detrimental (2,3). The extent of change in the frequency of extreme weather events due to climate change remains uncertain.

Climate change would affect infectious disease transmission and regional food productivity (especially cereal grains) by essentially indirect mechanisms. In the longer term, it is probable that these indirect impacts would have greater magnitude than the more direct impacts (4,5,6).

For vector-borne infections, the distribution and abundance of vector

organisms and intermediate hosts are affected by various physical factors (temperature, precipitation, humidity, surface water and wind) and biotic factors (vegetation, host species, predators, competitors, parasites and human interventions). Various integrated modelling studies have forecast that an increase in ambient temperature would cause, worldwide, net increases in the geographic distribution of particular vector organisms – such as malarial mosquitoes – although some localised decreases may also occur. Further, temperature-related changes in the life-cycle dynamics of both the vector species and the pathogenic organisms (flukes, protozoa, bacteria and viruses) would increase the potential transmission of many vector-borne diseases such as malaria (mosquito), dengue fever (mosquito) and leishmaniasis (sand-fly) (7,8). Schistosomiasis (water-snail), however, may undergo a net decrease in response to climate change (8).

Considerable effort has recently gone into developing mathematical models for making such projections (5,6,8). The models in current use have well-recognised limitations – but they have provided an important start. For example, from multiple modelling runs by computer it seems likely that malaria will significantly extend its geographic range of potential transmission, and its seasonality, during the twenty-first century as average temperatures rise by several degrees centigrade (9).

Climate change would effect the transmission of water-borne infectious diseases via several mechanisms (5), including intensification of the rainfall cycle, leading either to flooding that causes contamination of water supplies or drought that depletes safe drinking water supplies. Bacterial water-borne illnesses such as cholera and parasitic diseases such as cryptosporidiosis may thus be affected.

Modelling studies, allowing for future trends in trade and economic development, have been used to estimate the impacts of climate change upon cereal grain yields (which account for two-thirds of world food energy). Globally, a slight downturn appears likely, but this would be greater in already food-insecure regions in South Asia, parts of Africa and Central America. Such downturns would increase the number of malnourished people in the world at large by at least several percent.

Global warming may alter the atmospheric heat budget so as to increase the cooling of the stratosphere (10). If such stratospheric cooling continues, the risk of ozone depletion could continue to increase even after chlorine and bromine loading starts to decline (11). If so, the potential health consequences already documented for ozone depletion (an increase in skin cancer incidence in fair-skinned populations, in the incidence of eye lesions such as cataracts, and, perhaps, in suppression of immune activity) would become an issue for climate change.

The Relative Timing of Health Impacts

The first detectable changes may well be alterations in the geographic range (latitude and altitude) and seasonality of certain vector-borne infectious diseases. Summer-time food-borne infections (e.g. salmonellosis) may show longer-lasting annual peaks. There has been some debate over whether recent increases of malaria and dengue in highland regions around the world may be due to climate factors or other factors (12,13). There are several other categories of likely early impact. Hot weather would amplify the production of noxious photochemical smog in urban areas, and warmer summers would increase the incidence of food poisoning. By contrast, the public health consequences of the disturbance of natural and managed food-producing ecosystems, of rising sea-levels and of population displacement for reasons of physical hazard, land loss, economic disruption and civil strife may not become evident for several decades.

The time of first detectability of health impacts of climate change will depend particularly upon: (i) the sensitivity of response (i.e. how steep is the rate of increase), and (ii) whether there is a threshold that results in a "step function". Further, detectability will be influenced by the availability of high-quality data and by the background variability in the health-related index in question.

Health Impact Assessment: Methods and Difficulties

There are three different logical strategies for assessing the health impacts of global environmental change (14,15):

- By direct inference or extrapolation from existing (past or present) analogue situations that are believed to approximate aspects of future climate change. The analogue situations, which arise from (apparently) naturally occurring situations, may entail either temporal or geographic variation in climatic conditions.

- By seeking evidence, in response to incipient anthropogenic climate change, of changes in indicators of health risk or health status that are especially climate-sensitive. (While related to the preceding item, this study stratagem depends on the existence of identifiable global environmental change – or its local manifestation.)

- By using existing knowledge and theory to conduct mathematical modelling (or other types of assessment) of likely future health outcomes. The three main types of mathematical models are empirical-statistical models (based on statistical equations derived from directly relevant sets of observations), process-based models (in which theoretically formulated relationships are represented by the accepted equations representing key processes), and integrated assessment modelling (which extends the other two approaches by the inclusion of a much fuller range of interacting and modulating influences, including social, economic, behavioural and technical influences).

Because of the largely anticipatory nature of this environmental health hazard, we must carry out risk assessment in relation to *future* environmental scenarios – i.e. scenario-based health risk assessment. Further, the inherent complexity and dynamical properties of the climate system and climate-sensitive ecological systems means that, under conditions of climate change, we should expect interactions, feedbacks, threshold

phenomena and surprises. The assessment of scenario-based health risks with mathematical models entails three key challenges relating to validity, uncertainty and contextual realism (8,14):

- The adequate and valid representation of the central set of environmental and biological relationships, and of the interacting ecological and social processes that influence the impact of those upon health, is difficult. A balance must be attained between complexity and simplicity (transparency).

- The complex configuration of causal and modifying factors results in substantial uncertainties in the model's output projections. In the first instance, there is the uncertainty attached to the input scenarios of climate change (and of associated social, demographic and economic trends). Subsequently, there are three main types of uncertainties in the modelling process: (i) "normal" statistical variation (reflecting the stochastic processes of the real world); (ii) uncertainty about the correct or appropriate values of key parameters in the model; and (iii) incomplete knowledge about the structural relationships represented in the model.

- Climate change is not the sole global environmental change that is impinging upon human health. Various large-scale environmental changes can affect human population health simultaneously, and often interactively (1). An obvious example is in the realm of agricultural crop yields, where climatic conditions, ultraviolet radiation levels (reflecting stratospheric ozone depletion), soil fertility, freshwater availability, and the ecological balance between pests and their predators all affect yields. Similar configurations of environmental stresses influence patterns of vector-borne infectious diseases.

Population Vulnerability, and Adaptation

Human populations, as with individuals, vary in their vulnerability – or susceptibility – to certain health outcomes. A population's vulnerability is a function of the extent to which a health outcome is sensitive to climate change and of the capacity of the population to adapt to new climate conditions (16). The vulnerability of a population depends on factors such as population density, level of economic development, food availability, local environmental conditions, pre-existing health status, and the quality and availability of public health care.

Adaptation refers to actions taken to lessen the impact of the (anticipated) climate change. There is a hierarchy of control strategies that can help to protect population health. These strategies are categorised as: (i) administrative or legislative; (ii) engineering, or (iii) personal (behavioural) (17). Legislative or regulatory action can be taken by government, requiring compliance by all, or by designated classes of, persons. Alternatively, an adaptive action may be encouraged on a voluntary basis, via advocacy, education or economic incentives. The former type of action would normally be taken at a supra-national, national or community level; the latter would range from supranational to individual levels. Adaptation strategies will be either reactive, in response to climate impacts, or anticipatory, in order to reduce vulnerability. Adaptation can be undertaken at the international/ national level, the community level and the individual level – that is, at the macro-, meso-, and micro-levels.

The reduction of socio-economic vulnerability remains a priority. The poor are likely to be at greatest health risk because of their lack of access to material and information resources. The long-term reduction in health inequalities will require income redistribution, full employment, and better housing and improved public health infrastructure. Services which have a direct impact on health, such as primary care, disease control, sanitation and disaster preparedness and relief, must also be improved. The vulnerability of the poor may jeopardise the well-being of more advantaged members of the same population. Examples of "spillover" effects include spread of infectious diseases from primary foci in poor populations, and the opportunity cost of public services committed to dealing with problems related to disadvantage.

The environmental management of health-supporting ecosystems (e.g. freshwater resources, agricultural areas) should be improved. A good example is the control of water-borne infections. In many areas increased density of rainfall is likely to lead to more frequent occurrence of significant human infections such as giardiasis and cryptosporidiosis (7). Traditional public health interventions that focus entirely on personal hygiene and food safety have limited effectiveness. A broader approach would consider the interactions between climate, vegetation, agricultural practices and human activity – and would result in recommendations for the type, time and place of "up-stream" public health interventions such as changes in management of water catchment areas.

The maintenance of national public health infrastructure is crucial. The 1990s have witnessed the resurgence of several major diseases once thought to have been controlled, such as tuberculosis, diphtheria, and sexually transmitted diseases. Deteriorating public health infrastructure (especially the vaccination programme), as well as socio-economic instability and population movement, were the major causes. Malaria is increasing again in many parts of the world. Environmental control programmes are weaker, and less enforced, than they were several decades ago (18). For example, in Madagascar, vector control programmes in the 1950s eradicated the vector Anopheles funestus in the central highland plateau and almost totally eradicated malaria. Since then, however, there has been a progressive increase in malaria because of the collapse of the insecticide spraying programme. Similar setbacks have occurred in Ethiopia and in the highlands of Zambia.

Elementary adaptation to climate change can be facilitated by improved monitoring and surveillance systems. Basic indices of population health status (e.g. life expectancy) are available for most countries. However, disease (morbidity) surveillance varies widely depending on locality and on the specific disease. To monitor disease incidence/ prevalence – which may often provide a sensitive index of impact – low-cost data from primary care facilities could be collected in sentinel populations.

These top-down approaches must be widely supplemented by bottom-up approaches to adaptation at the community and individual levels. These would include local environmental management, urban design, public education, neighbourhood alert and assistance schemes, and individual behavioural changes. When implementing adaptation technologies, care must be taken to prevent adverse secondary impacts, that is, new health hazards created by the application of technologies (19). For example, conventional air-conditioning systems can increase the urban heat-island effect, and might even exacerbate climate change itself. Water development projects can have significant effects on the local transmission of parasitic diseases including malaria, lymphatic filariasis and schistosomiasis (20).

Conclusion

Public health scientists anticipate that global climate change will have a range of impacts, mostly adverse, upon human health. While some impacts would result from direct changes in the physical conditions of living, many of the impacts would reflect more complex changes in the biophysical and ecological systems that determine the prospects for population health. The advent of global climate change thus foreshadows the need for us to think about "environmental health problems" not only within the framework of environment-as-hazard, but also within the framework of environment-as-habitat.

Adaptations to the health hazard posed by global climate change can be both proactive and reactive, and can occur at the macro-, meso-, and micro- scales; that is, at the population, community and individual levels. Because climate change represents a one-off global experiment, there will be only limited opportunity to carry out preliminary evaluation of adaptation options. The case for prudence, both in relation to mitigating climate change and adapting to its impacts, is therefore strong.

References

1. Watson, R.T. *et al.* 1998. Protecting Our Planet, Securing Our Future. Linkages Among Environmental Issues and Human Needs. UNEP, NASA, World Bank.
2. Langford, I.H. and Bentham, G. 1995. The potential effects of climate change on winter mortality in England and Wales. *International Journal of Biometeorology* **38**: 141–147.
3. Rooney, C., *et al.* 1998. Excess mortality in England and Wales during the 1995 heatwave. *Journal of Epidemiology and Community Health,* **52**: 482-486.
4. McMichael, A.J. *et al.* 1996. Climate Change 1995: Scientific–Technical Analyses of Impacts, Adaptations, and Mitigation of Climate Change, edited by Watson, R.T., Zinyowera, M.C. and Moss, R.H. (New York, Cambridge University Press), 561-584.
5. McMichael, A.J. *et al.* eds. (1996) Climate Change and Human Health. (WHO/EHG/96.7) Geneva, World Health Organization.
6. Epstein, P.R. 1999. Climate and health. *Science* **285**: 347-348.
7. Patz JA, Epstein PR, Burke TA, Balbus JM 1996 Global climate change and emerging infectious diseases. *Journal of the American Medical Association* **275:** 217-223.
8. Martens, W.J.M. 1998. Health and Climate Change: Modelling the Impacts of Global Warming and Ozone Depletion. (London, Earthscan).
9. Martens, W.J.M. *et al.* 1999. Climate change and future populations at risk of malaria. *Global Environmental Change,* in press.
10. Houghton, J.T. *et al.* 1996. Climate Change 1995. The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. (New York, Cambridge University Press).
11. Shindell, D.T., Rind, D. and Lonergan, P. 1998. Increased polar stratospheric ozone losses and delayed eventual recovery owing to increasing greenhouse gas concentrations. *Nature* **392**: 589–592.
12. Epstein, P. R., *et al.* 1997. Biological and physical signs of climate change: focus on mosquito–borne diseases. *Bulletin of the American Meteorology Society* 78: 409–417.
13. Reiter, P. 1998. Global warming and vector-borne disease in temperate regions and at high altitude [letter]. *Lancet* 351, 839–840.
14. McMichael, A.J. 1997. Integrated assessment of potential health impact of global environmental change, prospects and limitations. *Environmental Modeling and Assessment:* 2, 129–137
15. McMichael, A.J. and Kovats, R.S. 1999. Global environmental change and health: Approaches to the assessment of risk. *Ecosystem Health,* in press.
16. Parry M.L. and Carter T. 1998. Climate Impact and Adaptation Assessment. (London, EarthScan).
17. Patz, J.A. 1996. Adapting to Climate Change: An International Perspective, edited by Smith, J.B. *et al..* (New York, Springer), 440–464.
18. Lindsay, S. and Martens, W.J.M. 1998. Malaria in the African Highlands: past, present and future. *Bulletin of the World Health Organization* **78**, in press.
19. Klein, R.J.T. and Tol, R.S.J. 1997. Adaptation to Climate Change: Options and Technologies. An Overview Paper. Technical Paper commissioned by UNFCCC Secretariat, Bonn, Germany.
20. Hunter, J.M. *et al.* 1993: Parasitic Diseases in Water Resource Development: The Need for Intersectoral Negotiation. (Geneva, World Health Organization).

A.J. McMICHAEL

Professor of Epidemiology,
Department of Epidemiology and Population Health,
London School of Hygiene and Tropical Medicine,
Keppel Street, London WC1E 7HT UK

Professor Tony McMichael

Tony McMichael, a medical graduate from Adelaide, South Australia, is currently Professor of Epidemiology at the London School of Hygiene and Tropical Medicine, UK. His research interests, over 25 years, have encompassed the causes of occupational diseases, diet and cancer, and environmental epidemiology (including environmental/dietary causes of cancer, effects of environmental lead (Pb) upon childhood intellectual development, aetiology of cataracts, and methods of

quantitative environmental health-risk assessment). He has been an advisor to WHO, the World Meteorological Organisation and the World Bank (Environment Division). In 1990-92 he chaired the Scientific Council of the International Agency for Research on Cancer (WHO).

He has major interest in the assessment of population health risks from global environmental change (see also his: "Planetary Overload: Global Environmental Change and the Health of the Human Species." Cambridge University Press, 1993). During 1994-98 he convened the Intergovernmental Panel on Climate Change (Second Assessment Report) review of potential health impacts of climate change. He will be doing likewise for the IPCC Third Assessment Report (1999-2001). He has written extensively on the methodology and recent findings in environmental health research.

Impacts of Climate Change on Terrestrial Ecosystems: the Importance of Long-term Observations and the UK Environmental Change Network

In the second presentation from the symposium, which accompanied this year's EGC Distinguished Guest Lecture, Dr. TERRY PARR, from NERC Centre for Ecology and Hydrology spoke on the effect that climate change will have on terrestrial ecosystems.

Dr. Parr reviewed the data that are available for assessing climate change impacts on ecosystems at local, UK, European and Global scales.

There is an increasing array of predictions concerning the likely impacts of climate change on global ecosystems over the next 100 years. But how do we know what is really happening? Current knowledge is based on a combination of theory, experiment, modelling and observation, but all too often the weakest part of this quartet is the absence of reliable long-term data on which to test and develop our ideas. Given the complex non-linearities in the response of populations, communities and ecosystems to even simple drivers of change such as temperature and rainfall, this could lead to serious mistakes being made in the ways in which we are planning to mitigate or adapt to global climate change. It is certainly obvious that well managed long-term observations should be an essential part of the global change science strategy.

Simple observations of change such as those provided by the UK Phenology Network (http://www.nmw.ac.uk/ite/phenology/) and in the Department of the Environment, Transport and the Region's report on Climate Change Indicators for the UK (http://www.nbu.ac.uk/iccuk/) show how changes in climate may be beginning to impact on the UK's flora and fauna. (Phenology is the recording and study of periodic natural events). These results complement short term experimental and modelling work completed in, for instance, the NERC TIGER Programme (Terrestrial Initiative in Global Environmental Research) http://www.nwl.ac.uk/tiger/index.html. However, fully integrated long-term programmes are required to disentangle the complex interactions between the main drivers of change and changes in ecosystems.

The UK Environmental Change Network (ECN)

ECN is the UK's long-term integrated monitoring network designed to aid in the detection, interpretation and forecasting of environmental changes resulting from natural and human causes. It is a multi-agency initiative, which currently consists of a network of 54 terrestrial and freshwater sites making regular measurements on the main drivers of change (e.g. climate, atmospheric chemistry, land use) and ecosystem responses (e.g. soil, flora, fauna and water quality). ECN has been collecting data since 1993 and is already producing data and information relevant to users in education, research and policy. It covers issues such as ecosystem change, environmental indicators, and the impacts of climate change, biodiversity loss, atmospheric pollution, soil degradation and water quality.

ECN has a central database and rigorous quality control procedures, including a standard set of measurement protocols. Part of the philosophy of ECN is that it must make its data readily available to a wide spectrum of users for research in relation to environmental change. Raw data are available under licence and over the past two years this facility has resulted in a rapid rise in the use of ECN's data for a wide range of purposes.

Summary data and information products are also available (no licence necessary) through the ECN Web site (http://www.nmw.ac.uk/ecn/). Figure 1 shows an example of the kind of time series data that are already available from this source. In this case, data on dissolved organic carbon (DOC), have been selected by the user (it could be you!) from a range of surface water chemistry variables. One hypothesis is that DOC in upland surface waters may begin to increase as global change affects the hydrology of the ecosystems, which feed them - ECN data can be used to test and explore such ideas.

The Global Terrestrial Observing System

Initiatives to monitor global change impacts at continental and global scales are only slowly developing and require co-ordination and funding on a scale that is difficult to achieve through existing mechanisms. For instance, the Global Terrestrial Observing System (GTOS - http://www.fao.org/gtos/) was launched in 1996 as a "partnership of partnerships" to co-ordinate observing activities in terrestrial systems. The GTOS Mission is "*to provide policy makers, resource*

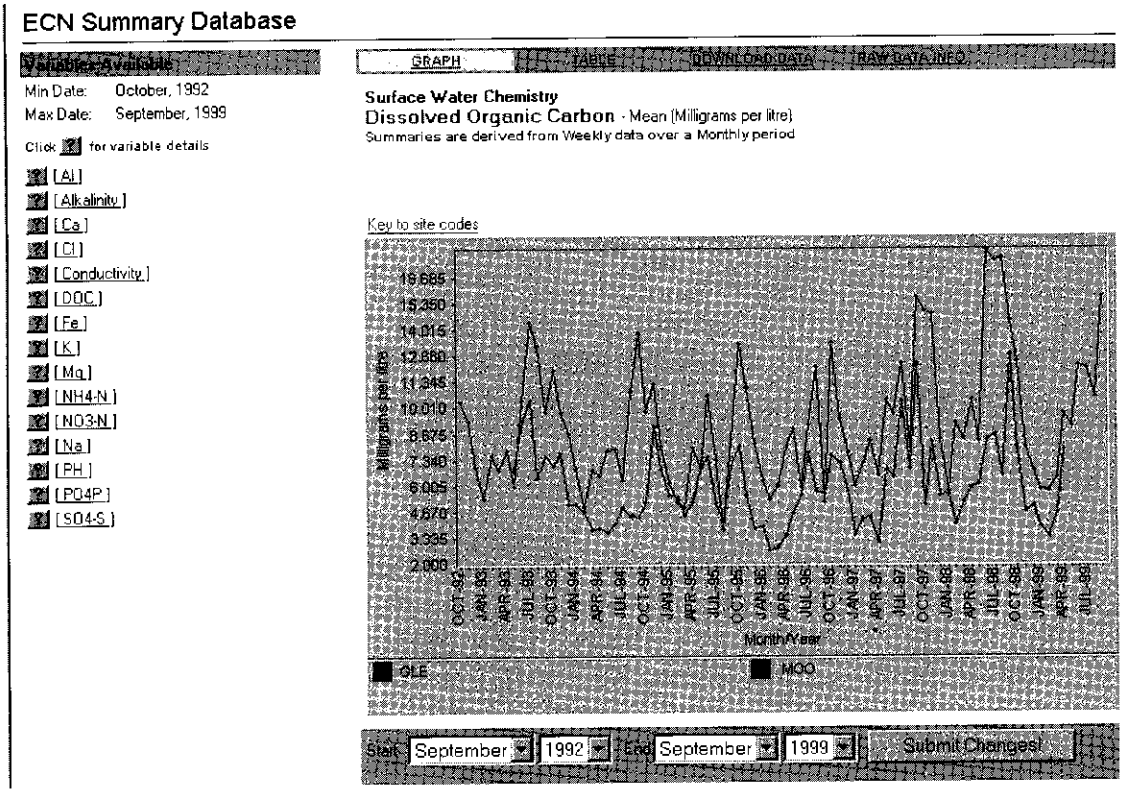


Figure 1. Example of the data available through ECN's interactive summary database on the WWW (http://www.nmw.ac.uk/ecn): a graph of dissolved organic carbon at two of ECN's upland sites Moor House (MOO) and the MLURI site at Glensaugh (GLE) from 1992-1998.

managers and researchers with access to the data they need to detect, quantify, locate, understand and warn of changes (especially reductions) in the capacity of terrestrial ecosystems to support sustainable development." GTOS is currently implementing demonstration projects (e.g. on global mapping of Net Primary Productivity) to help provide a "proof of concept" but it is still some way from becoming an operational global network.

In summary, the implications of climate change on ecosystems are currently poorly validated and only some of the observation systems are now in place to collect long-term large-scale data required to understand and provide early warning of changes.

Further Reading:

Sykes, J.M. & Lane, A.M.J. (1996) *The United Kingdom Environmental Change Network: Protocols for Standard Measurements at Terrestrial Sites.* Stationery Office, London.

Sykes, J.M., Lane, A.M.J. & George, D.G. (1999) *The United Kingdom Environmental Change Network: Protocols for Standard Measurements at Freshwater Sites.* Institute of Terrestrial Ecology, Huntingdon.

DR TERRY PARR
UK Environmental Change Network
Central Coordination Unit
Centre for Ecology and Hydrology
CEH Merlewood
Grange over Sands
Cumbria
LA11 6JU
Tel: 015395 32264
Fax: 015395 34705.
Email: twp@ceh.ac.uk
Website: www.nmw.ac.uk/ecn

Dr Terry Parr

After completing a D.Phil at the University of York in 1978, Terry Parr worked as a plant ecologist at the Institute of Terrestrial Ecology (ITE) where he undertook research on woodland change, wetland dynamics, vegetation management and modelling. From 1990 to 1993 he was seconded to the Department of the Environment's Directorate of Rural Affairs where, amongst other things, he provided scientific advice to policy sections and managed a wide range of research projects including 'Countryside Survey 1990', the first major survey of the British Countryside. On returning to ITE in 1993, he joined the Environmental Information Centre and worked on the development of Geographical Information Systems and environmental indicators for the investigation of the impacts of land use and climate change.

Since 1995 he has been the Co-ordinator of the UK Environmental Change Network, which is a long-term multidisciplinary integrated monitoring network. He is currently co-ordinating an EC project on integrated monitoring requirements in Europe and, through ECN, has direct links with initiatives such as the Global Terrestrial Observing System, the International Long-term Ecological Research Network and the European Biosphere Reserves Network. The detection, interpretation and forecasting of climate change impacts on terrestrial systems is one of the key issues in the monitoring and research programmes associated with all these initiatives.

The Effects of Climate Change on Demography and Health

In a contribution, which complements the preceding three articles from this year's ECG Distinguished Guest Lecture and accompanying Symposium on *Climate Change and its Impact,* LEO SALTER and FLEUR FISHER explore further the implications of climate change on human health, and in particular how the South West of England might be affected.

Introduction

The health impacts of climate change are generally expected to be adverse. However, the detail of such impacts would depend greatly not only on the vulnerability of populations[1] and their abilities to adapt, but also on which of the various possible warming rates as predicted by the UK Climate Impacts Programme (UKCIP)[2] - Low, Medium-Low, Medium-High and High - actually occurred. Given the relative uncertainty of the current predictions concerning warming rates, a degree of caution must be exercised before translating the potential health impacts of climate change into real expectations.

The natures of the demographic variations initiated by climate change are even more difficult to predict than the health effects. Movements of populations will be related to sea-level rise,[3] changes in agricultural productivity[4] and – of particular relevance to the South West of England – changes in the tourism potential for a region. These demographic changes will in themselves carry health risks.[4] However, the nature of human responses to threats such as sea-level rise has much more to do with perceptions of risk rather than actual risk and (as with health) policy developments based on predictions about the demographic implications of climate change must be aimed at the crucial interface which separates caution and pragmatism.

This article will discuss the likely consequences of climate change on demography and health with a special focus on health impacts - mainly because the health consequences of climate change, rather than the demographic consequences, have attracted most interest and research.

The article will also try to discuss the predicted changes in health and demography in the context of the SW region of the UK, and *inter alia* make some attempt at evaluating the economic effects of such changes for the regional economy. Finally an attempt will be made to contextualise the effects of climate change on demography and health in terms of the various other (different but linked) threats, which anthropogenic influences have initiated.

Health and Climate Change

Climate change is expected to affect the following aspects of human health:

- winter and summertime mortality
- the incidence of food poisoning and other gastrointestinal infections
- the occurrence of vector borne diseases
- air pollution related morbidity and mortality
- the consequences of deteriorating water quality.

Each of these aspects will be discussed in turn.

Winter and Summertime Mortality

Opinions have differed as to whether global warming would have an adverse effect on heat related mortality (i.e. mortality related to thermal stress). Simplistically the argument revolves around whether decreased mortality in winter (due to milder winters) will balance any increased mortality in summer (due to hotter summers). In the UK at least it seems that the reduction in mortality due to milder winters may well dominate and it has been estimated that in England and Wales for a 2.5°C increase in mean monthly winter temperatures (UKCIP Medium-High scenario) 9000 fewer winter deaths would occur annually by 2050.[5] Hence,

"The data on seasonal mortality clearly suggest that the direct effect of moderate global warming on mortality, at least when temperature has stabilised and temporary disruptions have passed, would be beneficial."[6]

However, opinions do differ and although the figure of 9000 fewer winter deaths was calculated using statistical models which took account of influenza epidemics, chronic bronchitis, pneumonia and other circulatory and respiratory conditions, work published in the USA[7] suggests that on balance climate change induced summer increases in mortality will prevail,

"There have been suggestions that climate warming might decrease winter weather-related mortality and even offset predicted summer increases. This seems unlikely. Most weather-related mortality is not due to hypothermia or to heart attacks brought on by shovelling snow, but to infectious diseases, such as influenza, which are dependent upon human proximity exacerbated by inclement weather. It is unlikely that a few degrees rise in winter temperatures would encourage outdoor activities to such an extent that people would largely avoid droplet-transmitted viruses."[7]

But on balance given that a '*few degrees rise in winter temperatures*' could have a profound effect on human behaviour during the already mild winters experienced in the South West,

" . . . .*climate change in England and Wales could significantly reduce the burden of excess winter deaths.*" [5]

The results of a meta-analysis of research[8] on the potential effects on mortality of climate-induced thermal stress also suggest that,

" . . . . *climate change in areas with temperate, particularly cold temperate climates, could result in a reduction of disease burden due to less excess winter cardiovascular mortality, especially in elderly people.*" [8]

However, it is worth remembering that the consequences of climate change for

UK weather are likely to include more variability in summer temperatures (especially over southern England) and less variability in winter temperatures, less reliable rainfall, greater possibility of flooding (heavier rainfall) and more severe (though less frequent) gales.[2]

"*Relatively little is known, however, about the capacity of human populations to adapt physiologically and culturally to such changes over decades.*" [9]

It is also worth remembering that in countries such as the United Kingdom, which have high rates of excess winter mortality, a greater contribution is likely to come from improvements in socio-economic conditions for example reducing fuel poverty than from climatic change.[10]

A new approach is required to assess the effect of climate change on the world distribution of diseases,

"*Most current surveillance systems for infection have been designed to detect particular causes (for example foodborne disease) and individual risk factors (for example overseas travel or immune deficiency).*" ... "*The epidemiological challenge is to take a more holistic approach to the causes of infection, examining the possible influence of climate both on the environmental sources of pathogens and on human behaviour.*"[11]

The Incidence of Food Poisoning and Other Gastrointestinal Infections

Food poisoning is a major health problem in the UK during summer and it is a problem that has been increasing rapidly over the last decade.[12] At present in England and Wales, 300 deaths and 35000 hospital admissions are attributed to infectious gastrointestinal diseases each year.[13] Research suggests that correlations exist between food poisoning incidence and high temperatures in the prior month (indicating that animal husbandry and slaughterhouse procedures may be at fault) as well as between incidence and high temperatures in the current month (suggesting that food preparation routines are important).[12] Statistical models have been developed from which it is estimated that,

" . . . .*annually there might be an additional 179 000 cases of food poisoning by the year 2050 as a result of climate change.*" [12]

This will be due in part to the increased frequency of heatwaves. It has been estimated that heatwaves like that experienced in the summer of 1976, currently occurring about every 310 years could happen as often as every 5 or 6 years by 2050.[14]

Heatwaves have been associated with an increase in mortality from all causes,[15] for example the 1995 London heatwave was linked to a 16% increase in mortality above the seasonal average.[16]

It seems unlikely that novel problems will arise and hence, given appropriate investment, current methods for minimising and controlling increased incidence of food poisoning will suffice. But some form of planned response is necessary, especially when climate change impacts on water quality are considered,

"*The predicted impact on food-borne disease of the changes associated with global warming suggest the challenge for the future to be more one of scale than of novel problems. Current trends leave no room for complacency, however, and food-borne disease surveillance remains important.*" [17]

The Occurrence of Vector Borne Diseases

One of the first signs of the effects of climate change on human health may be a change in the distribution of important vector species.[18]

It seems self-evident that global warming will bring an increased threat of tropical diseases to the UK - though the ability to control the impact of such a threat will depend very much on the resources made available to counteract it. The global status of vector borne diseases and the

Table 1.[19] *Distribution of Vector-Borne Diseases*

Disease	Vector	Population at Risk (millions)	Number of New Cases Per Year (millions)	Present Distribution	Likelihood of Altered Distribution with Climate Change
Malaria	Mosquito	2400	300-500	Tropics/subtropics	+++
Schistosomiasis	Water Snail	600	200	Tropics/subtropics	++
Lymphatic filariasis	Mosquito	1094	117	Tropics/subtropics	+
African trypanosomiasis	Tsetse Fly	55	0.25-0.3	Tropical Africa	+
Leishmaniasis	Phlebotomine sandfly	350	0.5	Asia/Americas/ Africa/ Southern Europe	+
Onchocerciasis	Blackfly	123	17.5	Africa/Latin America	++
American trypanosomiasis	Triatomine bug	100	18-20	Central-South America	+
Dengue	Mosquito	2500	50	Tropics/subtropics	++
Yellow fever	Mosquito	450	A few thousand	Tropical South America and Africa	++
Dracunculiasis	Copepod	100	0.1	South Asia/Middle Africa East/Central-West	?

potential for their altered distribution with climate change are shown in Table 1 (taken from Reference 19).

Insects are especially sensitive to changes in temperature, humidity and wind and hence it would be expected that maturation, extrinsic parasite incubation, biting behaviour and abundance will be affected by climate change. Paleological records support such linkage.[20]

In Western Europe, rising temperatures increase the risk of malaria by providing a suitable environment for the proliferation of mosquitoes arriving at airports. Six cases of malaria were reported close to or inside the airport in Paris during the hot summer of 1994.[21]

The extent to which such effects of global climate change will impinge on the UK are as yet unclear. Cases of Lyme disease and Leishmaniasis may increase,

"*Natural vectors already exist for a number of diseases present in neighbouring continental Europe, including arbovirus and hantavirus disease, the viral encephalitis fevers and tick borne rickettsioses. Lyme disease is already established in the UK where it is most frequently transmitted by the native tick (Ixodes ricinus).*" [17]

" . . . . *Leishmaniasis is endemic in the south of France . . . . It is a disease of dogs and man, and the parasite is transmitted by Phlebotomus sandflies or midges. These are currently absent from mainland Britain but have been recorded in the Channel Islands. It is likely that even a small degree of warming could permit their establishment here and freer movements of animals in Europe, including dogs, could result in the disease following the vector.*" [17]

Mild winters have and will lead to enormously increased rat populations and increased populations of their fleas. Plague carried by the common brown rat and its predominant flea may lead to the establishment in Britain of campestral endemic plague foci such as persisted in Suffolk for some years.[17] (Suffolk was the site of one of the last substantial outbreaks of plague in Britain in 1906-1918).[22]

There is also potential for health 'surprises' from climate change-induced increases in mutational frequencies amongst pathogens and their vectors with consequent increase in their virulence[4]. The re-emergence of diphtheria has been associated with this effect,

"*Low immunisation rates, large movements of population, possible 'changes' within the organism, reduced potency of some vaccine preparations and decreasing immunity within the population have all contributed to the rise in incidence of diphtheria.*" [23]

It is estimated that by 2050 an increase in UV-B radiation of up to 20-25% (depending on latitude) will occur[24]. This is caused primarily by depletion of stratospheric ozone and would occur anyway without climate change. Such increases will have effects on melanoma and non-melanoma skin cancer and cataract formation and, additionally, UV-B initiated suppression of the human T-lymphocyte-mediated immune system may also affect responses to herpes simplex, tuberculosis and leprosy[24]. If climate change leads to a more outdoor lifestyle in the South West then the associated increased exposure to the predicted high levels of UV-B will also lead to increases in these effects.

Air Pollution-Related Morbidity and Mortality

The impact of climate change on air pollution is difficult to assess – wind speed, temperature, wind direction and precipitation are all important for determining air pollution.

"*Some regions may experience more frequent and prolonged periods of atmospheric stagnation caused by low wind speeds and thermal inversions while other regions may experience fewer such periods.*" [24]

The higher the air temperature the greater the rate of reaction between chemicals in the air and so reactions producing secondary chemical pollutants such as ozone will become faster and the concentrations of secondary air pollutants will increase. But whether there is a synergistic health effect between hot days and high air pollution days is unclear,

"*High pollution concentration is associated with marginally higher daily mortality only when the weather is benign.*" [7]

If there are altered concentrations of aero-allergens (such as spores and moulds) and secondary air pollutants (such as ozone), then there will be effects on respiratory health.[9]

Current knowledge of the specific links between air pollution and health is limited and the topic is being actively researched. However, the UK Government's National Air Quality Strategy is recognition that such links are real. Specific research into the effects of climate change on air quality is necessary and new guidelines for acceptable levels of primary and secondary air pollutants may be needed as a response to the increased reaction rates implicit in the projected climate change scenarios.

These guidelines will need to be incorporated into transport policies, which obviously play a large part in determining the extent and distribution of air pollution in Europe,

"*The current burden of transport policies on health is higher than it should be given the present knowledge of interventions and the availability of current technologies, many of which are simply not used.*"[25]

The Consequences of Deteriorating Water Quality

Decreased availability of potable water supplies has been a feature of the UK for several years. Such diminishing supplies become increasingly susceptible to contamination and increasingly likely to pose a public health risk.

"*The presence of cryptosporidial oocysts in potable water already pose a problem in this respect and the value of bacterial indicators as a guide to the extent of recent sewage pollution may be diminished if water temperature increases.*" [17]

In coastal marine ecosystems changes in temperature will change the incidence and abundance of toxic algae,

"Algae transport Vibrio cholera and other human enteric pathogens, and harmful species emit biotoxins that effect finfish, shellfish, marine mammals, sea birds and humans." [20]

Hence as well as the need to develop techniques for monitoring viral contamination of water there is also a need for methods by which cyanobacterial toxins can be quickly identified and quantified.

The proliferation of these algal species will also be encouraged by the demographic changes global warming will bring about. This will be of particular relevance to the South West because the increase in tourism potential for the region will place an extra burden on the often low summer water supplies and on the sewerage infrastructure,

"Although having large numbers of people living together in close proximity simplifies the collection of waste water, disposal of large amounts of solid and liquid waste generated can compromise the quality of the body of water that receives the waste. Conventional mechanical (primary) and biological (secondary) treatment processes do not remove plant nutrients (nitrogen and phosphorus) that often cause excessive growth of algae in fresh and coastal waters." [26]

If the temperature increase were significantly great, the increase in eutrophication could outweigh the reduction that has been accomplished by the use of phosphate-free detergents and chemical wastewater treatment programmes in Europe.

Demography and Climate Change

Globally the effects of climate change on demography seem likely to be stark,

"An ultimate outcome of global climate change is the expected development of a new class of displaced persons ('environmental refugees'). Thus, the abandonment of low-lying coastal areas due to rising seawaters will especially affect developing nations and will lead to overcrowding of urban centres and further increase in water and air pollution already associated with such population centres. Moreover, global warming is itself expected to increase such pollution." [3]

Such movements of populations will be exacerbated by the depletion of resources in regions where extreme climate change occurs and where high birth rates, regional food scarcity and poor agricultural resources already exist. Not only will the final destinations of such 'environmental refugees' experience the indirect health effects associated with migration,

"Migrants carry the diseases of their place of origin to their destinations and, once there, they may be susceptible to diseases that they have not previously experience," [4]

but they will also have to cope with disruption to the local economy and possibly with inadequate infrastructure to support the enlarged population.

Thus it is important to develop detailed models predicting the likely demographical consequences of global warming to allow Government and Local Authorities to be adequately prepared.

The Effects of the Climate Change on Health and Demography in the SW Region

First and foremost it must be recognised that any predictions, which focus on climate change impacts on the SW region, will be fraught with uncertainties. Although the UKCIP model is representative of the current state of knowledge there remains plenty of potential for surprises when it comes to the understanding of how global climate operates! Major research efforts are needed e.g.

"Improvements in mathematical models for predicting the impact of climate change on health, including models which enable local and regional impact assessments to be made." [12]

However, in the absence of specific research data, reflection on the information presented above suggests that within the South West the major impacts of climate change will be associated with public health.

There will be a need for increased investment in the Public Health Service (and associated laboratories) and in the role of Environmental Health Officers. Increased temperatures will produce more rapid spread of infection, new viral and bacterial strains will enter the water systems of the region and water resources will be under great stress (especially during the summer months). Hence the monitoring of water quality (freshwater and seawater) will need to be increased in frequency and in type. These are actions which need to be addressed by the Environment Agency, Local Authorities, the water companies and the Public Health Service. Technologies already exist to deal with these threats provided the investment is made in early identification and the necessary contingency plans. Linked to these 'water-related' problems are those associated with the provision of food. Greatly increased inspection of abattoirs may be required with (possibly) legislation for new standards to meet the threat implicit in increased temperatures. A similar response is needed for food preparation.

Increased awareness of the potential for tropical disease is necessary. The creation of regional facilities for rapid diagnosis of (currently) exotic diseases should be examined. Speed of response is of utmost importance.

Air quality monitoring (including UV intensity) and links with hospital admissions/referrals should be researched so that advice can be offered to the population in terms of behaviour.

Of all of the responses to climate change the need for continuing and clear education is probably the most important. Hygiene, awareness of sunlight intensity, knowledge of the early symptoms of disease, an understanding of dehydration, the preservation of a limited water supply - these are all issues of public education to be tackled on an ongoing basis for the foreseeable future.

Demographic changes will need to be closely monitored and, unpalatable as it may be, action needs to be considered in relation to the sustainability of uncontrolled population growth in the region - irrespective of whether that growth is permanent (immigration into the region) or temporary (tourism).

Table 2[27] indicates the nature of the general responses that could be adopted to minimise the health effects of climate change. Most (if not all) are relevant to the South West.

Eco-epidemiology

It has been increasingly recognised that global change has to be treated holistically. Climate change is just one strand of several interlinked phenomena most of which are related to man's activities.

" . . . .*even without climate change and ozone depletion the complexity of influences of various factors upon health defies a ready quantitative analysis of net effects. For example, there appears to be a widespread increase in the tempo of new and emerging infectious diseases which probably reflects a combination of demographic and environmental (climatic) changes in addition to increases in drug and pesticide resistance. rates of disease and deaths from cigarette smoking are likely to increase in many countries, and rates of chronic non-infectious disease, especially heart disease, diabetes and certain cancers in rapidly developing countries are increasing. This complex balance sheet makes it difficult to estimate the net impact of climate change and ozone depletion on human population health.*" [28]

Table 2. [27] *Matrix of Possible Adaptation Strategies for Specific Health Impacts of Climate Change*

Adaptation Measures	Heat-Related Mortality	Extreme Weather Events	Vector-borne Diseases	Water-borne Diseases
Public education	Publicise precautions to take during heat waves		Educate public to encourage elimination of artificial breeding sites	Educate public on sources of infection
Surveillance and monitoring	Establish new weather watch/warning systems that focus on health-related adverse conditions such as oppressive air masses	Maintain disaster preparedness programs including tools for local public health facilities to conduct rapid health needs assessments	Institute surveillance for both disease incidence and vector populations or other intermediate hosts	Create early warning systems based on algal blooms to predict cholera
Ecosystem intervention	Plant trees within cities to reduce the urban heat-island effects	Adopt land-use planning to minimise erosion, flash-flooding, precarious placements; restore wetlands	Release sterilised male insects to reduce reproductive capacity of vector populations	
Infrastructure development		Site intakes for water facilities far enough upstream to tolerate saline intrusion from storm surges	Anticipate effects of irrigation projects on vector breeding sites	Construct water treatment facilities, waste facilities, waste treatment measures
Technological and engineering	Design buildings to be more heat resistant	Strengthen sea-walls; require contractors to follow hurricane standards in coastal areas	Promote the use of pyrethroid impregnated mosquito bed-nets; install window screens in areas endemic to insect-borne disease	Distribute low-technology water filtration systems
Medical interventions	Schedule work to avoid peak daytime temperatures for outdoor labourers		Sensitise health-care givers in geographically vulnerable regions	

For instance, changes in agriculture associated with climate change become difficult to predict in a period when agriculture is undergoing other changes in practice – as well as new strains of crops and new agrochemical treatments the uncertain effects of climate change have to be taken into account,

"Temperature, precipitation, solar radiation and carbon dioxide are important for crop production - but variations in crop yield because of climate change are poorly understood e.g. the effects of climate on weeds, insects and plant diseases are not well known"[28]

The complexity of these (and other) linked issues has been recognised,

"The potential health impacts of climate change are wide-ranging, from the direct impacts at familiar local scales, through indirect effects occurring at the regional or ecosystem level, to long-term effects on the sustainability of global systems. Environmental health researchers have an important contribution to make in each of these areas. Whilst conventional methods can be applied to the study of local effects, the study of regional and global effects will usually require the application of new scientific approaches.

In the field of public health, eco-epidemiology is emerging as a response to this need. Eco-epidemiology entails a shift from analysis of direct (toxicological) to indirect (ecological) mechanisms; and from the conventional, bottom-up reductionist approach to a top-down holistic approach. At the global scale, interactions and feedbacks between systems are critical determinants of long-term outcomes."[19]

The causes of (and solutions to) climate change lie in changes in life-style,

"The underlying pressure causing climate change – the unsustainable pattern of consumption in the world's rich countries – also has other, more immediate consequences. Changes in technology, social organisation and lifestyles that have accompanied the changes in consumption are associated with chronic heart disease, diabetes, respiratory disorders and osteoporosis. Unfit, obese populations with a high prevalence of coronary heart disease are a product of the same unsustainable consumption as drives climate change . . . . The recognition that unsustainable development underlies both climate changes and much ill health is helpful in that policies aimed at reducing the impact of climate change will help prevent illness."[29]

Without incorporating actions that are designed to minimise the impacts of climate change into strategies that are designed to reduce the processes, which cause it, politicians and businesses will deservedly earn themselves the incredulity and wrath of their children.

References

1. Kovats, S. and Haines, A. "The Potential Health Impacts of Climate Change: An Overview," *Medicine and War*, **11**, 168-178, (1995).

2. Hulme, M. and Jenkins, G., "Climate Change Scenarios for the United Kingdom," Summary Report, ISBN 0 902 170 15 5, UK Climate Impacts Programme Technical Report No. 1, September, (1998).

3. Rosenkranz, H.S., "Health Effects Associated With Global Climate Changes; A Role for Environmental Mutagens?," *Environmental and Molecular Mutagenesis*, 27, 81-83, (1996).

4. Last, J.M., "Global Change: Ozone Depletion, Greenhouse Warming and Public Health," *Annual Review of Public Health*, **14**, 115-136, (1993).

5. Langford, I.H. and Bentham, G., "The potential effects of climate change on winter mortality in England and Wales," *International Journal of Biometeorology*, **38**, 141-147, (1995).

6. Keatinge, W.R., "Global warming and health," *British Medical Journal*, **302**, 965-966, (1991).

7. Kalkstein, L.S., "Health and climate change: Direct impacts in cities," *The Lancet*, **342**, 1397-1399, (1993).

8. Martens, W.J.M., "Climate Change, Thermal Stress and Mortality Changes," *Social Science and Medicine*, **46**, 331-344, (1998).

9. McMichael, A.J. and Haines, A., "Global climate change: the potential effects on health," *British Medical Journal*, **315**, 805-809, (1997).

10. Curwen, M., "Excess Winter Mortality: A British Phenomenon?," *Health Trends*, **22**, 169-175, (1991).

11. Kovats, R.S., Haines, A., Stanwell-Smith, R., Martens, P., Menne, B., Bertollini, R., "Climate Change and Human Health in Europe" *British Medical Journal*, **318**, 1682-5, (June 1999).

12. Bentham, G. and Langford, I.H., "Climate change and the incidence of food poisoning in England and Wales," *International Journal of Biometeorology*, **39**, 81-86, (1995).

13. Wheeler, J.G., Sethi, D., Cowden, J.M., Wall, P.G., Rodrigues, L.C., Tompkin, D.S., et al. "Studies of infectious disease in England: rates in the community, presenting in general practice, and reported to national surveillance." *British Medical Journal*, **318**, 1046-50, (1999).

14. Hulme, M., "The 1996 CCIRG Scenario of changing climate and sea level for the UK.," Technical Note No 7, Norwich Climatic Research Unit, (1996).

15. McMichael, A.J., Haines, A., Slooff, R., Kovats, S., (eds.) "Climate change and human health," Geneva: World Health Organisation, (1996).

16. Rooney, C., McMichael, A.J., Kovats, R.S., Coleman, M. "Excess Mortality in England and Wales and in Greater London, during the 1995 Heatwave," *J. Epidemiol Community Health*, **52**, 482- (1998).

17. Rowland, M.G.M., "Climate Change and Human Health: Possible Communicable Disease Consequences in the United Kingdom," *Medicine and War*, **11**, 188-194, (1995).

18. Centres for Disease Control and Prevention, "Outbreak of Acute

Febrile Illness and Pulmonary Hemorrhage – Nicaragua 1995". *MMWR* **44**, 841-43, (1995).

19. Hales, S., Weinstein, P. and Woodward, A., "Public Health Impacts of Global Climate Change," *Reviews* on *Environmental Health*, **12**, 191-199, (1997).

20. Epstein, P.R., "Framework for an Integrated Assessment of Health, Climate Change and Ecosystem Vulnerability," *Annals of the New York Academy of Science*, **740**, 423-435, (1994).

21. Guillet, P., Germain, M.C., Giacomini, T., Chandre, F., Akogbeto, M., Faye, O., et al. "Origin and Prevention of Airport Malaria in France," *Tropical Medicine Institute of Health*, **3**, 700-5 (1998).

22. Van Zwanenberg, D., "The last epidemic of plague in England? Suffolk 1906-1918," *Medical History*, 14, 63-74, (1970).

23. Wilkinson, M. and Grover, M.J., "Climate change and the threat from infection," *Trends in Microbiology*, **4**, 340-41, (1996).

24. Breslin, K., "Global Climate Change: Beyond Sunburn," *Environmental Health Perspectives*, **102**, 440-443, (1994).

25. Dora, C., "A different route to health: implications of transport policies," *British Medical Journal*, **318**, 1686-89, (1999).

26. Lack, T., "Water and Health in Europe: an overview," *British Medical Journal*, **318**, 1678-82, (1999).

27. Balbus, J.M., "Human health," Chapter 10 p.10-1 to p. 10-31, *Handbook on Methods for Climate Change Impacts Assessment and Adaptation Strategies*, UNEP, (1997).

28. Martens, W.J.M., "Health impacts of Climate Change and Ozone Depletion: An Ecoepidemiologic Modeling Approach," *Environmental Health Perspectives*, **106**, Supplement 1, 241-251, (1998).

29. Read, C. and Stott, R., "Climate change - thinking widely, working locally, acting personally - health workers have a crucial role," *British Medical Journal*, **315**, 758-759, (1997).

LEO SALTER,
Cornwall College, Cornwall, TR15 3RD, UK.
FLEUR FISHER,
Exeter College, Oxford, OX1 3DP

Fleur Fisher, a former student at Cornwall College, wrote this review during a sabbatical at Cornwall College.

New National Climate Change Research Centre

A new multi-million pound research centre located at the University of East Anglia (UEA) will help the UK tackle the global problems raised by the consequences of climate change.

Three UK Research Councils – the Natural Environment, the Economic and Social, and the Engineering and Physical Sciences – have awarded a £10 million contract for the new national climate change research centre to a consortium of nine higher education and research institutions, led by UEA.

The new Centre will:

- undertake inter-disciplinary research into the consequences of climate change for society and the environment, and into possible policy responses;
- explore the new technologies, lifestyles, economic and regulatory measures that may allow climate change to be managed;
- establish a national and international focal point for the open and constructive exchange of ideas for climate change solutions.

To be known as **The Tyndall Centre for Climate Change Research**, the Centre will be based at the University of East Anglia in Norwich, with regional offices at UMIST and the University of Southampton. The full list of participating institutions includes the University of Cambridge, Cranfield University, the University of Sussex, the University of Leeds, the Rutherford Appleton Laboratory and the Centre for Ecology and Hydrology. The Centre will become operational by October 2000 and the Centre's Executive Director will be Dr. Mike Hulme of UEA.

Local *In situ* Aqueous Hydrogen Peroxide Generation

In the environmentally friendly arena of 'green chemistry', hydrogen peroxide (H_2O_2) has become an important commodity, and new ways to produce H_2O_2 are clearly valuable. Dr. TIPPU SHERIFF describes work at the University of Hertfordshire on a novel system for generating H_2O_2 in aqueous solution.

Introduction

Take about three grams of a simple inorganic amine in water and add a tiny green crystal. When air is bubbled through, under ambient conditions, a dilute solution of hydrogen peroxide is produced, which can serve as a mild disinfectant! Is this science fiction or one of those magical potions of the early twentieth century that has managed to linger on into the start of this new century?

Well it is neither, but perhaps this reaction has the potential to provide a method for the generation of local, *in situ*, aqueous supplies of hydrogen peroxide without

the need for a large plant (or on-site storage facility).

Hydrogen peroxide (H_2O_2) is viewed as the 'green' oxidising chemical of both the present and the future. Regulatory pressures, influenced by environmental concerns, have combined with the ability of chemists to use this remarkably simple yet versatile inorganic chemical in a safer, more efficient, and innovative manner resulting in a renaissance in its use.

Hydrogen peroxide has several very favourable environmental characteristics:

- It produces a benign (and chlorine-free) by-product – water;
- Being a liquid, hydrogen peroxide is also easier to handle and to store than dioxygen (O_2) or ozone (O_3);
- It is also miscible in water in all proportions but yet can partition into organic solvents;
- The 'active oxygen' content of hydrogen peroxide at 47% is higher than that in ozone (33%) and indeed is second only to oxygen itself.

For all these reasons, the last decade has seen a rebirth in the use of H_2O_2 within the chemical industry, and strategies for its expanded application in organic syntheses. There is an annual growth in hydrogen peroxide consumption, which currently stands at about 2.5 million metric tonnes per year, of about 10%, and this has promoted H_2O_2 to the 17th most important chemical in terms of overall production.

The uses of hydrogen peroxide are varied, e.g. as a hair bleach, in detergents (as a bleaching agent) and in the pulp and paper industries, which has seen one of the largest growths in hydrogen peroxide use as more chemical processes move away from chlorine-based oxidising agents. As well as a growth in the use of H_2O_2 in environmental applications, an area of significant growth is expected in the manufacture of pharmaceutical and fine chemicals. It has been estimated that only 10% of the hydrogen peroxide currently produced is used in the syntheses of organic compounds and this paucity of practical applications contrasts with the clear environmental advantages. Problems of the activation of H_2O_2 to perform selective organic oxidation transformations are being overcome, and this will result in a marked increase in the use of H_2O_2 over the coming decade.

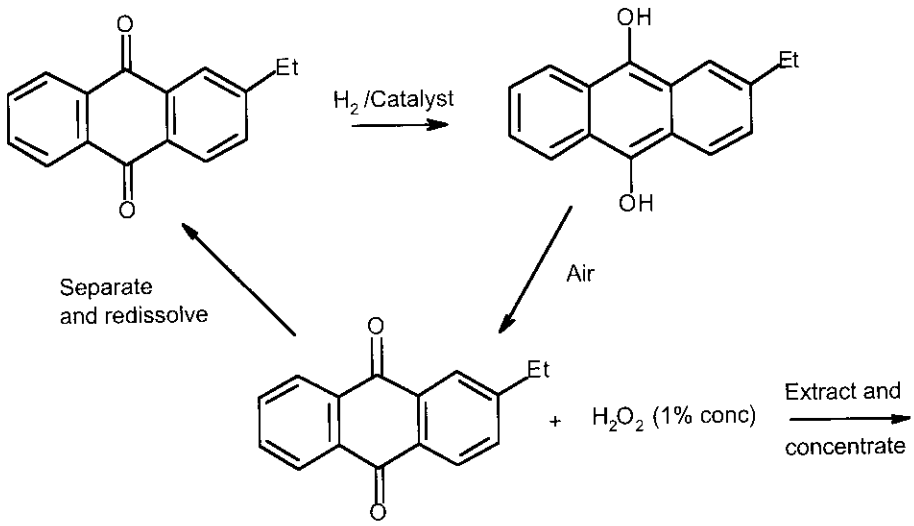


Figure 1. Industrial production of hydrogen peroxide

Hydrogen Peroxide Production

Most of the hydrogen peroxide consumed today is generated by the auto-oxidation (AO) process where an organic solution of an anthraquinone is catalytically reduced using hydrogen to the anthrahydroquinone which is then oxidised in air (or oxygen) to reform the anthraquinone plus hydrogen peroxide, and the cycle is repeated (Figure 1). The hydrogen peroxide is extracted from the organic solvent with water and concentrated to the usual commercial concentration range of 35%-70%. The major disadvantages of this decades old process are that it is only cost effective on a large scale (>20,000 tonnes per annum), capital costs are high, and the reduction catalyst must be periodically regenerated, which is expensive and involves several hazardous steps. It is indeed ironic that >90% of this environmentally desirable commodity is generated by the environmentally undesirable AO process.

A number of major incidents have occurred at plants that operate the AO process. In 1982, the Rheinfelden AO plant operated by Degussa was severely damaged by fire and had to be re-built, and the Oxysynthese plant in France was also badly damaged by fire in 1992.

Thus the AO process in its present form is unsuitable for a small or medium sized enterprise (SME) that wishes to generate local supplies of H_2O_2, and there are added disadvantages in the transport, storage and handling of bulk supplies of hydrogen peroxide on-site.

The direct route to hydrogen peroxide production provides an alternative cleaner route to the AO method, and involves catalytically combining hydrogen and oxygen in water. For example, the DuPont patented process uses a carbon-supported palladium catalyst in 0.1M HCl at pH_2 and pO_2 of 35 and 70 atmospheres respectively. This method produces 15 mol % H_2O_2 in four hours. However, there are disadvantages in this method in the need for pressurized vessels, and the hydrogen peroxide produced is polluted by HCl making recovery of the H_2O_2 uneconomic. The HCl also has a corrosive effect on the catalyst and the reactor. While there have been improvements to the direct method, all these methods have the disadvantage of requiring H_2 and O_2 in pressurized containers, which are conditions not really attractive to SMEs.

Ideally, a small scale user of hydrogen peroxide would like an easy method of generating hydrogen peroxide *in situ*, at the time and place required, cheaply, safely and efficiently. For most uses, it would be advantageous to generate this hydrogen peroxide in an aqueous

environment, which also removes the difficulty and danger of the use of organic solvents, with the minimum of waste and hazardous by-products. According to the Institute of Applied Catalysis (iAc), there are high incentives for developing simple local, *in situ*, modular processes for generating H_2O_2. There are added incentives for developing *in situ* H_2O_2 generating systems that can activate H_2O_2 to perform a range of reactions that are presently considered uneconomic or that require concentrated H_2O_2.

Several *in situ* H_2O_2 generating systems are under development including a specialised reactor design from Princeton Advanced Technologies (PAT) in the USA. PAT have obtained a patent for the design of their reactor which safely combines oxygen and hydrogen by dispersing tiny bubbles in a controlled manner so preventing any reaction taking place in the bubbles themselves. PAT claim that this system offers savings compared to the AO process without the need for an organic solvent.

These developments on the direct production of hydrogen peroxide from H_2 and O_2 are encouraging. However, it is unclear whether SMEs would find the dual storage of H_2 and O_2 on-site any more acceptable than the storage of bulk supplies of H_2O_2.

The UH System for Hydrogen Peroxide Generation

The system being developed at the University of Hertfordshire (UH) satisfies many of requirements of a local system described by iAc and indeed iAc have described this system as the 'most successful' by enzymic-like reactions. As indicated by iAc, the characteristics of this system mimic metal catalysed biological systems such as galactose oxidase, which generate high local concentrations of hydrogen peroxide with great efficiency under ambient conditions:

$$RCH_2OH + O_2 \xrightarrow{Cu(II/I)} RCHO + H_2O_2$$

The UH system also has some remarkable characteristics of natural H_2O_2 generating systems associated with it. These 'magical' properties were alluded to at the start of this article. Thus milligram amounts of a recently characterised dark green manganese catechol (1,2-dihydroxybenzene) complex are able to efficiently catalyse the reduction of dioxygen to hydrogen peroxide using hydroxylamine (or hydrazine) as substrate:

$$O_2 \text{ (or air)} + 2NH_2OH \longrightarrow H_2O_2 + N_2 + 2H_2O$$

This reaction occurs under ambient – room temperature, only slight positive pressures of O_2 (or air) and physiological conditions – pH 8. The by-products (N_2 and H_2O) are also environmentally benign.

Concentrations of H_2O_2 of ~1.5% (w/v) have been generated with remarkable turn-overs (the number of moles of hydrogen peroxide per mole of manganese per hour) of ~10,000 which compare very favourably with the AO process described above.

The system is very sensitive to the nature of the electronic environment around manganese, with substituents on the benzene ring of the catechol having a profound effect on the rate and yields of hydrogen peroxide. Again this is analogous to a natural system.

One of the most interesting features of the UH system is the fact that H_2O_2 and the substrates (either hydroxylamine or hydrazine) can co-exist together because the redox properties of these isoelectronic compounds would suggest that any H_2O_2 generated in this system should be immediately consumed. Indeed, such mixtures were used for rocket propulsion before the switch to using liquid oxygen and hydrogen. These reactions are however catalysed by free metal ions which are not present in this system.

Much of the recent work at the UH has gone into attempting to understand the mechanism of H_2O_2 generation in this system. This has involved kinetic studies in which the concentrations of the reagents, temperature *etc.* have been varied and characterisation of the manganese-catecholate complex that is the active catalyst in this system.

Some success has also been achieved in making the system partially heterogeneous with the manganese adsorbed onto a clay support. Thus milligram quantities of manganese-exchanged clay can be used to generate hydrogen peroxide and then filtered off to produce a virtually pure dilute solution of hydrogen peroxide. The next stage in this development is fix or adsorb the whole complex onto a solid support so that when this is filtered off a pure solution of uncontaminated hydrogen peroxide will be produced.

The UH system in its present form can have applications for the generation of dilute aqueous solutions of hydrogen peroxide where transport and storage of bulk supplies is difficult and in specialised uses e.g. the generation of isotopically-labelled H_2O_2. Commercialisation of this system can occur when cheaper feedstocks have been identified enabling a batch process to be developed. In the use of modified clays there is the possibility of generating active forms of hydrogen peroxide in aqueous solution as visualised by iAc.

Dr. T. S. SHERIFF
Senior Lecturer
Department of Physical Sciences
University of Hertfordshire
Hatfield
HERTS AL10 9AB
United Kingdom

Email: t.s.sheriff@herts.ac.uk

Tel: +44 1707 284576

Environmental Chemistry at the University of Birmingham

Dr. STUART HARRAD, Senior Lecturer in Environmental Chemistry, outlines the teaching and research activities in environmental chemistry conducted by the University of Birmingham's School of Geography and Environmental Sciences.

Introduction

Within the School of Geography and Environmental Sciences, there are seven permanent staff members involved in environmental chemistry teaching and research programmes. All are based within the School's Division of Environmental Health and Risk Management (DEHRM). The Division's expertise covers aspects of atmospheric, water, soil/sediment, and food chemistry, with an additional focus on human exposure and its health impacts. As part of the School of Geography and Environmental Sciences, while maintaining close links with the Department of Public Health and Epidemiology, the Institute of Occupational Health and the Regional Cancer Intelligence Unit, the environmental chemistry grouping plays a pivotal role in the wide range of interdisciplinary research at the University of Birmingham.

Staff

Professor Roy Harrison, Professor of Environmental Health, is internationally renowned for his research in the general area of environmental chemistry and aspects of air pollution related to public health. He heads a substantial research group and is involved in a number of committees advising the UK government, including the Expert Panel on Air Quality Standards (EPAQS) and the Committee on the Medical Effects of Air Pollutants (COMEAP).

Dr. Stuart Harrad, Senior Lecturer in Environmental Chemistry, heads a strong group with research interests in the environmental fate and behaviour of persistent organic pollutants such as PCDD/Fs, PCBs and PAH, with particular reference to human exposure.

Mr. David Mark, Senior Research Fellow, divides his time between DEHRM and the Institute of Occupational Health. He has an international reputation for his work on the definition of health-related aerosol conventions, and the development of suitable sampling instruments for both occupational and ambient environments.

Dr. Robert Kinnersley, Lecturer in Air Pollution, has research interests covering the generation, characterisation, dispersion, fate and sampling of airborne contaminants, with particular interest in their biological impact.

Dr. Andrew Allen, Research Fellow and Laboratory Manager, has expertise in atmospheric chemistry and monitoring techniques. He has particular interests in the behaviour of particles and trace gases in the marine boundary layer.

Dr Jacob Baker, a new Lecturer in Atmospheric Chemistry, is developing a research programme in atmospheric pollution which includes the heterogeneous processing of pollutant gases by condensed phases and the properties of particulates.

Dr. Jamie Lead, is a newly appointed Lecturer in Water Chemistry. His research interests are in the general area of chemical speciation in natural aquatic systems. More specifically he is interested in trace metal speciation, the characterisation of naturally occurring colloidal ligands and the development and use of novel analytical techniques.

Courses

BSc Environmental Science/ BSc Environmental Management

Both these programmes have an appreciable environmental chemistry content. In addition to core modules in Environmental Chemistry, Biogeochemical Cycling, and Environmental Protection, a significant proportion of final year students carry out environmental chemistry-related research projects. The industrial relevance of the course is assured via the active participation of an Advisory panel comprising representatives from:

- Birmingham City Council
- Environment Agency
- ICI plc
- Government Office for the West Midlands
- Severn Trent Water plc.

MSc/PG.Dip in the Science of Occupational Health, Safety and the Environment

In addition to a core curriculum developing the underpinning knowledge common to both Environmental Protection and Occupational Health & Safety, this course offers students the option of developing skills in the science and practice of monitoring and managing air, land, and water quality and their implications for human health. Candidates for the MSc degree study research methodology and conduct a major research project in the 2nd year.

MSc in Environmental Health

This programme offers students the opportunity to obtain an MSc while qualifying as an Environmental Health Officer. The core Environmental Protection module covers aspects of environmental chemistry relevant to pollution control and monitoring. Major research project topics frequently cover aspects of environmental chemistry, particularly air quality management.

MSc/PG.Dip in Air Pollution Management and Control

This new programme – commencing September 2000 – provides students with a comprehensive understanding of the causes and effects of air pollution, and of the management measures and engineering technologies available for its control.

Course Outline:

- Atmospheric physics and thermodynamics
- Air pollution meteorology
- Air pollution chemistry

- Causes and effects of air pollution
- Air quality management
- Industrial gas discharge control
- Extended literature review
- Tutorial and seminar programme/ research techniques
- Major research project.

Research

The Institute is one of the UK's top centres for air pollution research, and provided a secretariat and research unit for the UK government's Quality of Urban Air Review Group (QUARG). In addition to the seven permanent staff members, the Division hosts around 20-25 postdoctoral research fellows, research associates, and PhD students. Funding for this research programme comes from UK and overseas industry, the NERC, the Royal Society, the EU, the DETR, the Department of Health, and the Ministry of Agriculture, Fisheries, and Food. Current and recent research topics include:

- Processes affecting the size distribution of fine particles in diesel exhaust
- Processes responsible for the formation of new particles within the atmosphere
- Studies of the atmospheric bio-aerosol
- Development of air quality management models for the West Midlands
- Improved parameterisation of atmospheric chemistry in numerical models
- Oxidant and particle chemistry in the marine atmosphere
- Source apportionment of airborne particulate matter
- Temporal trends in lead exposure and population blood leads
- Processes affecting fine and ultrafine particles in the urban atmosphere
- Personal exposure to airborne particulate matter, volatile organic compounds and nitrogen dioxide
- Indoor-outdoor relationships of particulate air pollutants and VOC
- Epidemiological studies of the effects of particulate matter on human health
- Clinical studies of the effects of particulate matter on human health
- The effect of airports on respiratory health in the general population
- The atmospheric chemistry of nitrogen compounds
- Processes influencing contrail formation in jet engine exhaust
- Composition, sources and properties of the organic component of urban airborne particulate matter
- Bioavailability of human dietary intakes of PCDD/Fs, PCBs, phthalates, PAH, and monoaromatic hydrocarbons
- Source apportionment of urban airborne PAH
- Understanding air-to-pasture transfer of PCBs and organochlorine pesticides
- Source apportionment of atmospheric PCB – this involves utilising enantiomeric ratios of atropisomeric PCBs, and interpreting field measurements of enthalpies of surface: air exchange
- Developing understanding of the relationship between temporal trends in human exposure to oestrogenic chemicals and indices of human reproductive health.

Facilities

Our environmental chemistry research activities are housed in new, purpose-built laboratory accommodation. In addition to excellent computing facilities, our laboratories contain an extensive range of state-of-the art analytical instrumentation, including:

- 3 chemiluminescent analysers for nitrogen oxides
- 3 Scintrex nitrogen dioxide analysers
- a U.V. photometric analyser for ozone
- a U.V. fluorescence analyser for sulphur dioxide
- a gas filter correlation analyser for carbon monoxide
- GCs with electron capture, nitrogen/ phosphorus and flame ionisation detectors
- 3 GC/mass spectrometers - one with both negative and positive chemical ionisation facilities
- 2 GC/automatic thermal desorption facilities
- a GC interfaced with atomic absorption detection
- a graphite furnace atomic absorption spectrometer
- an HPLC with U.V. absorption fluorescence detection
- a Dionex ion chromatograph.

In addition to the above, a mobile laboratory for air quality research is available and we have access to X-ray power diffraction through the School of Physics. Our instrumentation for characterisation of atmospheric particles includes:

- 2 Scanning Mobility Particle Sizers
- 4 Condensation Nucleus Counters
- 2 MOUDIs
- Andersen and Research Engineers impactors
- an Electrical Low Pressure Impactor
- 4 TEOMs
- a multi-sample Partisol
- an epiphaniometer
- a thermophoretic precipitator and many conventional air samplers.

DR. STUART HARRAD,
Senior Lecturer in Environmental Chemistry,
Division of Environmental Health & Risk Management,
School of Geography & Environmental Sciences,
The University of Birmingham,
Birmingham B15 2TT
S.J.Harrad@bham.ac.uk

Pesticides Residues in Food

Consumers are becoming more concerned about food contaminants; pesticide residues feature high in their list of worries. In this overview by Professor IAN SHAW, who recently left the UK to join the Environmental Science and Research Institute, Christchurch, New Zealand as their Food Safety Programme Manager, an attempt is made to put these concerns into perspective. Food monitoring and human exposure data illustrate the endeavours of analytical chemists, toxicologists and regulators to ensure that the food we eat is safe.

This article was originally published in the *Journal of Environmental Monitoring*, 2000, **2**, 34N-37N, and is reproduced with the kind permission of The Royal Society of Chemistry.

Introduction

Food safety is an emotive issue in most developed countries, although concern amongst consumers about the food they eat varies according to the trust that they have in their countries' regulatory systems and the persuasive powers of their press.

The UK's love affair with food safety issues began in earnest when in 1986 Edwina Currie, the then Minister of Health, brought to the country's attention that Salmonella was a common contaminant of poultry and that its presence in eggs could lead to severe food poisoning. The press seized this issue and created a furore, which raged for months and resulted in the temporary demise of the British egg industry. Since then there have been many food scares, all fuelled by a press eager to amplify the issues. These scares, including the effects of bacteria of the genus *Listeria* on the consumers of soft cheeses and, of course, Bovine Spongiform Encephalopathy (BSE) which has destroyed the British beef industry and had significant political repercussions throughout Europe. The crescendo of concern about food safety was born when consumers and activists objected to the introduction of genetically modified food. This battle will rage for many years as the apparently feeble David-like activists fight the Goliath global companies who stand to make vast sums of money out of their ingenious inventions and have enormous political power in countries such as the USA.

The regular press interest in food scares has heightened the consumer's awareness of food safety. As a result of this, they have begun to question how food is produced and what it contains even though they have been unaware of, or even accepted, these issues previously. One such issue is the use of pesticides in farming[1] and the consequent presence of pesticide residues in food.[2]

The hidden risks in food

I recently asked shoppers in a supermarket whether they were concerned about residues of pesticides in their food. They all said, Yes! When asked about natural toxins no one knew what I meant. This is an interesting paradox because it is likely that the natural toxins in food are present a greater risk to the consumer than pesticide residues.

Psoralens, a group of naturally occurring pesticides in parsnips, celery, parsley and related vegetables are photoactivated carcinogens often present at levels of about 10-100 mg kg^{-1}. They are present in every parsnip, stick of celery and leaf of parsley that we eat. On the other hand pesticide residues are not omnipresent and their residues are generally at exceptionally low concentrations. Perhaps the press should make an issue of this hidden risk rather than focusing on other food related issues. Of course this would be futile because natural toxins are uncontrollable - except by genetic modification! Continuing with the psoralen example, psoralens must present a greater risk to the consumer of parsnips than any of the pesticide residues that are likely to be present in parsnips simply because psoralens are carcinogens. The testing necessary before a pesticide is approved for use in countries of the developed world makes it very unlikely indeed that a carcinogenic pesticide will be approved.

It is important that specific risks (e.g. pesticides in food) are considered in the context of related unavoidable or accepted risks (e.g. natural toxins in food). Pesticides are likely to be very low in the hierarchy of life's risks.

Assuring the consumer that food is safe

Governments are keen to assure national consumers, and potential international importers, of their food that it is safe. From the point of view of pesticide residues this generally involves the operation of surveillance schemes. Such schemes generally comply with national legislation and involve the analysis of prescribed numbers of samples of food for selected pesticides on an annual basis.

The number of samples analysed varies greatly from country to country. For example, in Europe the greatest number of samples analysed on a *per capitum* population basis is in Sweden (1001×10^{-6} *per capitum* in 1996 - total number of samples analysed = 8908[2]) and the smallest is in the UK (15×10^{-6} *per capitum* - total number of samples analysed = 878[2]). Whether this reflects the individual country's concern for consumer well-being is uncertain! Countries that rely on fruit and vegetable exports often appear towards the top of the samples analysed *per capitum* league table. For example, Holland analysed 706×10^{-6} samples *per capitum* in 1996 (Total number of samples analysed = 11015[2]) and was 2nd in the European league.

A third of food consumed in the UK contains pesticides

The UK runs a pesticide residues food surveillance programme via the independent Pesticide Residues Committee [PRC; formerly the Working Party on Pesticide Residues (WPPR)].

The independence of the Committee is important because it gives credibility to published data – there can be no massaging of data by government officials! The budget for the Programme in 1999/2000 is £1.67million most of which will be spent on analysis.

Data from the PRC show that approximately 30% of food consumed in the UK contains measurable residues of pesticides (Table 1) and that approximately 1% contains residues above the Maximum Residue Limit (MRL – a statutory limit based on Good Agricultural Practice (GAP) – compliant use of pesticides. MRL is NOT a safety parameter because toxicological considerations are not taken into account in its derivation).

Table 1. Frequency of residues of pesticides in food determined as part of the UK's monitoring programme.

Year	% with Residues	% Above MRL
1994[3]	30	<1
1995[4]	31	<1
1996[5]	34	<1
1997[6]	29	<1
1999[7]	26	1.3

The frequency of food contamination by pesticides is remarkably stable. This suggests that if we accept the use of pesticides in food production in the way in which they are currently used then we must also accept these residues. Indeed, from the point of view of human health there is perhaps good reason to accept the situation because Acceptable Daily Intake (ADI; the intake necessary each day of an entire lifetime to result in harm - this IS a safety parameter) exceedences are very rare. Indeed, in the UK there have been no exceedences in the past 4 years. ADIs are based on single pesticides, but our diet contains complex cocktails of pesticide residues and there are no data to allow us to decide what effect these might have on the consumer in the long term. Despite this, it is likely that such effects will be minimal because the total intake of pesticides with food is very low (and not continuous) when compared with other toxins (e.g. natural plant toxins).

Perhaps the best argument for reducing the use of pesticides is the proven deleterious effect that pesticides have on the environment. The rapidly increasing anti-pesticide lobby are having an effect upon pesticide use. For example public concern about pesticide residues in food has led to supermarkets controlling the use of particular pesticides by their growers (e.g. Alar, a plant growth regulator) in order to present a market advantage over their rivals. Supermarkets are very powerful in this respect and can result in significant changes in pesticide usage both nationally and internationally. This combined with the Organic Movement and environmental lobby will almost certainly reduce pesticide use by farmers over the coming years. It will be interesting to see if this is reflected in a reduced residues frequency.

Problematic Pesticides in 1998

Yams and Carbendazim

The recently published results of the UK's 1998[7] monitoring programme have highlighted areas of concern. In 1998 there was an apparent rise in the frequency of residues above MRLs (Table 1). This was because 75% of Yams contained residues of the fungicide, Carbendazim above its MRL (none exceeded the ADI). On the face of it this is a significant problem, particularly for West Indian families who might include Yams as a major carbohydrate source in their diet. However, the reason for these MRL exceedences was that a default MRL (based on the analytical limit of determination for Carbendazim) had been set for Carbendazim in Yams because GAP trials data were not available. These were therefore technical exceedences. Discussions between the UK government and the Yam exporting countries will hopefully result in an Import Tolerance being set which means that even though the Yams imported into the UK in 1999 might contain residues of Carbendazim similar to those for 1998 they will not exceed MRLs. If a correction is made to the MRL exceedance frequency for 1998 (i.e. Yam data are removed) the value is <1% and therefore does not represent an increase over previous years (Table 1).

Illegal chlormequat in UK pears

Residues data cannot all be explained away. In the 1998 UK survey[7], 80% of UK-grown pears were found to contain the growth regulatory pesticide, Chlormequat. Chlormequat is not approved for use in the UK, therefore this represented an illegal use of the pesticide. There are two issues here, the fact that growers were using a pesticide illegally, and the potential harm that this might cause the consumer of pears. The latter is particularly important because pears and pear juice are commonly used in proprietary and home-prepared infant foods. Infants are an important high-risk group because their food intake per unit body weight in high. ADI calculations showed that one of the pears was only marginally below the ADI (residues in pear = 11 mg kg^{-1}; ADI = 15 mg kg^{-1}). This is a situation that regulators and government take very seriously. On this occasion a follow-up study was initiated and legal action taken against the offending growers. Unfortunately the follow-up study showed no improvement in the situation. It is to be hoped that the legal action against growers will 'fire a shot across the bows' of other potential illegal users. We will not know whether the strategy has been successful until the 1999 survey is complete. In the meantime the consumer might be being exposed to unacceptably high residues of chlormequat. But, in terms of risk, this pales into insignificance when considered in the context of other high-risk essential activities (e.g. driving a car).

Lindane in continental-style chocolates

A rather unexpected residue problem arose in 1998[7]; 73% of high-quality continental-style chocolate on sale in the UK was found to contain lindane (γ-hexachlorocyclohexane; γ-HCH), an organochlorine (OC) pesticide banned in many countries. There were no ADI exceedences, and from the point of view of human health there was little or no concern because most people would only eat small quantities of this expensive commodity on a relatively irregular basis. The lindane originated from the cocoa butter used in the manufacture of the chocolate. Cocoa is grown in parts of the world where pesticide regulation and use is poor and therefore residues are difficult to control. This is an example where the power of the supermarkets

might eliminate the problem; press interest[9] in the issue led to public concern which in turn meant that supermarkets were forced to assure their customers that *their* chocolates were safe. I have no doubt that the supermarkets will put considerable pressure on their suppliers to ensure that their source of chocolates are not lindane residue-containing. In turn, the suppliers will pressurise the manufacturers and the manufacturers only buy cocoa butter from growers who do not use lindane. This is a useful chain reaction to minimise pesticide use that even affects countries where pesticide use is poorly controlled.

Lindane in Milk in 1995

Lindane is a hydrophobic OC which has an affinity for lipids and therefore is commonly found in high lipid content foods. For many years UK milk has contained just detectable residues of lindane, partly due to its continued use in the UK (particularly in sugar beet growing) and partly because its residues are relatively long-lived in the environment. In 1995[4] unexpectedly high lindane residues were found in milk sampled in June. Lindane residues in subsequent months' samples continued to rise, reaching a peak in September. The milk levels in September were only marginally below the ADI. Residues near to the ADI in a staple dietary commodity (i.e. milk, potatoes, bread) are worrying. Fortunately October's residues were significantly reduced and therefore a potential crisis did not come to fruition. In such cases it is important to explain the effect in order to attempt to prevent its re-occurrence. In this case there were several important contributory factors. 1995 was a hot summer and it is possible that milking cows were marginally malnourished and so in order to maintain their milk output it is likely that they mobilised fat reserves. It is well known that animal fat reserves contain long-lived lipid-soluble residues (e.g. lindane, DDT), therefore lindane from fat reserves might have been mobilised and incorporated into milk. In addition, since the summer's drought had resulted in a poor cereal, grain and forage crop that these commodities were imported. It is possible that such imports contained lindane and were incorporated into compound feed which was fed to dairy herds. These explanations could not be proved, or even investigated. However in 1996[5] a slight increase in milk lindane levels occurred at approximately the same time as the previous years enormous increase. This was possibly due to farmers feeding their cattle left over compound feed from the previous year. Surprisingly, the 1998 survey[7] showed, for the first time, that no milk samples contained detectable lindane residues.

Vinclozolin in lettuce - an ongoing problem

Vinclozolin is a fungicide used in lettuce growing. Its approval for use in the UK was revoked because of its potential toxicity to workers applying it to lettuces in greenhouses. It is an androgen receptor blocker and therefore might interfere with sexual development in boys, and have effects on sperm production and secondary sex characteristics in men. Despite this toxicity it is still approved for use in several European countries, including France. Warmer countries probably do not grow their lettuces in greenhouses and therefore the exposure risk to workers applying the viclozolin in the open air is lower than within the confined space of a greenhouse; this may explain why vinclozolin is approved in some EU member states.

Despite its ban in the UK, residues of vinclozolin have been detected in UK-grown winter lettuce for at least 6-years (Table 2). These residues present a negligible risk to the consumer because their concentration is far too low to result in an anti-androgen effect. Nevertheless, residues indicate that UK growers have used the pesticide illegally and therefore action must be taken.

Table 2. Residues of vinclozolin in UK winter lettuce.

Year	% Samples with Viclozolin Residues
1997[5]	3.2 (n = 94)
1998[6]	5.7 (n = 70)

Much to the chagrin of the lettuce growers, lettuce imported from countries where vinclozolin is approved for use is legal in the UK providing its residues do not exceed the MRL. This illustrates well that the MRL is a trading standard rather than a safety factor. At no time have vinclozolin residues exceeded the ADI and so have not presented a risk to the consumer. The only injured party in this incident is MAFF whom some UK growers seem reluctant to obey.

Human exposure monitoring

It is difficult to assess human exposure to pesticides. Several studies have measured pesticide residues in human fat[5] or milk[6,10], both matrices are good indicators of long-term exposure, but tell little of the subject's exposure to short lived pesticides such as the OPs or pyrethroids. In a MAFF study[5] of pesticides in human fat in the UK, 99% of samples analysed (n = 203) had detectable residues of DDT (as *p,p'*-DDT, *o,p*-DDT, *p,p'*-TDE and/or *p,p'*-DDE). Since the fat samples were taken at routine autopsy, it is likely that most of the subjects were at least 70 years old and therefore had lived through times when DDT was permitted in the UK. Their residues reflect their lifetime exposure. Twenty-three percent of the subjects had DDT fat residues between 1 and 9.3 mg kg^{-1} which suggests higher exposures. These people might have been exposed directly during DDT's hey day, or might have been fond of oily fish which contains higher residues of OCs than most other foods.

In the same MAFF study[5] other long half-life OCs were also found in human fat (Table 3). Again these residues are indicative of the subjects' lifetime exposures to these pesticides rather than indicating recent exposure. It is interesting that the shortest environmental half-life OC, namely lindane, has the lowest human fat residue frequency.

Table 3. Frequency of OC residues in human fat (n = 203) in a MAFF study.[5]

Pesticide	% Samples with Detectable Residues
Chlordane	53
DDT	99
Dieldrin	59
β-HCH	98.5
Lindane (γ-HCH)	3
Heptachlor	30
Hexachlorobenzene	94

Pesticides in human milk

Levels of pesticide residues in human milk from women from different countries give an indication of exposure to pesticides in their respective countries. For example, in the USA, *p,p'*-DDT was found at 0.039 mg kg^{-1} [11] in human milk, whereas in milk from women in Faridok in India a residue level of 13.81 mg kg^{-1} was reported[12]. This, perhaps, illustrates the difference in DDT use policies between the two countries. This point is illustrated very well indeed if women from the former East Germany are compared with women from West Germany. Milk *p,p'*-DDT residues in the former have been reported[13] at 2.28 mg kg^{-1}, whereas in the latter a value of 0.81 mg kg^{-1} is reported[13]. In this example, even though the women originated from bordering countries, their countries' national policies on DDT use is likely to account for the vast difference in pesticide residues found in their milk.

Very recent studies[10] in Indonesia have shown human milk DDT residues as high as 17.7 mg kg^{-1}, even though the country insists that DDT is no longer used. During my last trip to Indonesia I spent time talking to farmers in the Puncak region 50 miles outside Jakarta. I talked with 4 farmers, 3 of whom regularly used DDT on their crops. Clearly government policy has not filtered through to the farmers!

Should we ban pesticides?

The consumers' perception of the risk of pesticides residues in food is far greater than the actual risk. Indeed, it is likely that natural toxins in food present a far greater risk. Driving to the shop to buy food represents orders of magnitude greater risk than the toxic effects of pesticides in food. Therefore it is folly for the lobby groups to use residues in food as part of their argument to reduce the use of pesticides. They would be much wiser to concentrate their campaigning efforts on the effects of pesticides on the environment. The environmental impact of pesticides is a far sharper nail for the pesticides coffin than residues in food.

***Professor Ian Shaw** is Chairman of the UK Government's Pesticide Residues Committee (formerly the Working Party on Pesticide Residues). His current address is:*

Environmental Science & Research Institute,
Christchurch Science Centre,
Christchurch,
New Zealand.

References

1. Sharpe, M (1999) Towards sustainable pesticides. *J. Environ. Monit.* **1**, 33N-36N

2. Shaw, I.C (1999) Pesticides in Food. *In Pesticide Chemistry & Bioscience - the Food Environment Challenge.* Eds G T Brooks & T R Roberts, RSC, London

3. MAFF (1995) *Annual Report of the Working Party on Pesticide Residues - 1994.* MAFF Publications, London

4. MAFF (1996) *Annual Report of the Working Party on Pesticide Residues - 1995.* MAFF Publications, London

5. MAFF (1997) *Annual Report of the Working Party on Pesticide Residues - 1996.* MAFF Publications, London

6. MAFF (1998) *Annual Report of the Working Party on Pesticide Residues - 1997.* MAFF Publications, London

7. MAFF (1999) *Annual Report of the Working Party on Pesticide Residues - 1998.* MAFF Publications, London

8. Organic food - the way to go? *Health Which?* February 2000, 8-11

9. Blythman J (1999) Toxic shock. *The Guardian* 16th September, 14-15

10. Shaw IC, Burke E, Suharyanto F and Sihombing G (2000) Residues of *p,p'*-DDT and hexachlorobenzene in human milk from Indonesian women. *Env. Sci. Poll. Res.* in press

11. Mattison DR, Wohlleb T, To Y, Lamb S, Faitak MA, Walls RC & Selevan SG J. Pesticide concentration in Arkansas breast milk. *Ark. Med. Soc* (1992) **88**, 553-557

12. Kalra RL (1994) *Environ Pollut* **85**, 179-188 Organochlorine pesticide residues in human milk in Punjab, India.

13. *New Scientist* (1991) **130**, 19

14. Shaw IC and Murad J (1998) Pesticides: valuable poisons when kept under control. *Jakarta Post*, March 10th.

Professor Ian Shaw

Professor Ian Shaw obtained a 1st Class Honours degree in Biochemistry from the University of Bath and gained his PhD in Biochemistry (Toxicology) at the University of Birmingham. He is a Fellow of both The Royal Society of Chemistry and Institute of Biology and for two years served as a JP (Justice of the Peace). His various occupations have led him from University Lecturer, to a short time in industry, and to the Central Veterinary Laboratory where he became Head of the Biochemistry Department. At the time of writing Professor Shaw has just taken up a new appointment in New Zealand. He has been a member of a range of UK committees and held a number of Honorary Positions, too many to list here, but these have included the Working Party on Natural Toxicants in Food, the Working Party on Veterinary Residues in Animal Products and he is a Visiting Consultant Toxicologist to Preston Health Authority in the UK. He is currently a Member of the UK Government's Advisory Committee on Pesticides, a Member of the UK Government's Advisory Committee on Animal Feedingstuffs and he is Chairman of the UK Government's Working Party on Pesticide Residue. It is in this latter capacity that he wrote this article.

The Environmental Chemistry Group is also grateful to Dr. Terry Clarke, *Pesticide Column Editor* of the *Journal of Environmental Monitoring* for the biographical details.

The Federation of European Chemical Societies (FECS) Division for Chemistry and the Environment (DCE)

JOHN HOLDER, a Committee Member of the Environmental Chemistry Group, reports on the current activities of the FECS Division for which he is Secretary.

The Committee met in London on Saturday 4th March 2000 at Burlington House where the hosts were The Royal Society of Chemistry.

The major theme of the meeting was Education in Environmental Chemistry. Professor Miltiades Karayannis, Professor of Analytical Chemistry, University of Ioannina, Greece and Chairman of the European Chemistry Thematic Network (ECTN) Working Group on Chemistry and the Environment and Dr. Michael Gagan of the UK Open University and Chairman of the FECS Education Division were among the guests attending.

Professor Karayannis described the contents of the final report of the ECTN Working Group that can be viewed / downloaded at the ECTN website http://www.cpe.fr/ectn. Plans were announced to establish a Subcommittee of the FECS DCE to consider education. The Chair will be Professor Uri Zoller of the University of Haifa, Israel. The first formal meeting of the sub-committee will be held in conjunction with an agenda-setting workshop, probably in Copenhagen in September 2000.

Dr Gagan noted that in the UK the Open University is producing for the first time a degree course in Environmental Chemistry.

Arrangements were discussed for the FECS International Conference on Chemistry and the Environment in Porto, 27-30 August. The topic is **Metal Speciation in the Aquatic Environment.** Invited speakers include leading Europeans plus American experts Russell Erickson of the US EPA, Allen Burton, John Donat, François Morel and William Sunda. Over 110 abstracts have been submitted from 22 countries. To allow for difficulties experienced in some countries the deadline for submission of abstracts has been extended and a substantial number of additional papers are expected. Abstracts will be published in a special edition of the journal Environment Science and Pollution Research (ESPR) published by Ecomed and will also be available in extended form together with late submissions on the Ecomed website http://www.ecomed.de. The updated second call for papers will be published in the March edition of ESPR. Peer reviewed proceedings will be issued following the conference.

Preliminary arrangements for the 8th FECS International Conference to be held in Athens in 2002 were discussed. The conference will be a wide ranging one around the theme of chemistry for sustaining the quality of the environment and life. The timing is likely to be in early September. Details will appear on the Division website: http://www.scientificjournals.com/espr/fecs.

A Sub-committee of the Division dealing with Atmospheric Chemistry will be established under the Chairmanship of Professor Hartmut Frank of the University of Bayreuth, Germany. Objectives of the subcommittee were agreed and include the promotion of co-operation in research and education, organisation of events, dissemination of information, identification of priority research areas for funding and advising EU administrators.

The next Atmospheric Reactive Substances Conference will be held in Bayreuth in April 2001 and this will also be the venue for a meeting of the sub-committee.

A Sub-committee of the Division has been established dealing with green and sustainable chemistry. The Chairman is Allan Astrup Jensen of dk-Teknik, Copenhagen, Denmark.

The final report of the European Environment Agency on a European Green and Sustainable Chemistry Award has been published and is available in full at http://service.eea.eu.int/environwindows/management_concepts.shtml.

It is expected that the FECS DCE Sub-committee will be responsible for selection of the judges for the award.

At the annual meeting of the Italian Green Chemistry Consortium (INCA), three awards were made to Italian industry. Further national awards in the UK, Gemany and Greece are planned.

It was agreed that the Division will produce a 25 year Anniversary booklet outlining the history and development of the Division to coincide with the Athens Conference in 2002. Co-ordination of the production of the booklet will be by Professor Jan Skramstad of the University of Oslo, Norway, one of the Committee's longest serving members.

Membership of the Division has now increased to 34, the latest additions being from Romania and a second Italian representative. Both Chemical Societies in Italy will now be represented. The Division's Annual Report has been published and is on the Division website together with a full membership list and contact details.

The next meeting of the Committee will be on Saturday 26th August 2000 in Porto, Portugal prior to the 8th International Conference.

JOHN HOLDER
University of Central Lancashire.
March 2000

Environmental Information on the Web

Web site locations for a large number of environmental organisations were published in an earlier *ECG Newsletter* (Issue No. 5, January 1997). These links, which have been rechecked, are still available as part of the Environmental Chemistry Group's homepage on the RSC Web site. (http://www.rsc.org/lap/rsccom/dab/scaf003links.htm. We would welcome suggestions for supplementing and updating this list.

Alternatively, the ECG homepage can be accessed *via* the Web links section of *chemsoc*, the chemistry societies network: www.chemsoc.org/links/links.htm. Links are also provided by *chemsoc* at this site to a collection of environmental addresses and sites, which includes the addresses on the ECG site.

Three Web sites have recently caught our attention because of their breadth of coverage and interest to environmental scientists:

1. A list of discussion groups and news sites concerned with the environment and collated by the University of Alberta at http://www.ualberta.ca/~ersc/level2group.html

2. A hyperlinked directory of organisations and institutes located worldwide who undertake environmental monitoring http://www.gsf.de/UNEP/contents.html

3. A series of free databases for estimating the environmental fate of compounds http://esc.syrres.com/

1. Discussion Groups, Environmental News, Newsletters and Journals

http://www.ualberta.ca/~ersc/level2group.html

The University of Alberta provides links to the following Environmental News Groups:

Discussion Groups

- ONE-L Network
- Bioremediation Discussion Group
- Environmental Studies Association of Canada
- Environmental Protection Agency - United States
- The Natural Resources Defense Council
- The Sierra Club

Environmental News

- News Index Search Engine
- CNN Environmental News Page
- Greenwire
- Environment News Services

Environmental Journals and Newsletters

- Alternatives Journal
  Alternatives Journal is a Canadian Quarterly that examines and reports on environmental controversies and related social and technological issues. Since 1971, *Alternatives* has engaged a mixed audience of environmental professionals, academics, and researchers, activists and policy-makers in a continuing dialogue on the issues that are shaping our world and our future.
- American Chemical Society Journal and Magazine Home Pages
- The Arid Lands Newsletter: Published by The Office of Arid Lands Studies at The University of Arizona / Tucson, Arizona USA
- The Bulletin:
  A quarterly of the Regional Environmental Center for Central and Eastern Europe
- Business and the Environment Monthly Global News and Analysis from Cutter Information Corporation
- BWZine:The Online Better World Magazine
- CATF Review: Center for Alternative Transportation Fuels, Canada
- Chemistry & Industry Magazine
- CNN Interactive: Environment Main Page
- Consequences:A publication of Saginaw Valley State University
- Conservation Ecology
- Corporate Environmental Strategy: The Journal of Environmental Leadership
- R.A.I.N. Regional Alliance for Information Networking
- Developing Ideas: A Bi-Monthly Digest by the International Institute for Sustainable Development
- Earth First! Journal
- Earth Observation Magazine
- The Earth Times
- Eco: The Climate Action Network Newsletter
- Eco-Compass:Newsletter featuring Web sites of interest to professionals, academics, and citizen activists concerned with the environment
- Eco Region:Newsletter of the Secretariat of the Commission for Environmental Cooperation
- Ecocycle
- EcoLink
  An Ecological Web Journal
- Ecological Economics, ISEE
- EcoNews Africa
- The Economist
- EcoSite:The World Wide Resource for LCA
- EDF Letter:Environmental Defense Fund
- The Electronic Green Journal, University of Idaho
- ENDS Report
  Reliable, independent and relevant coverage of UK and international environmental affairs
- eNetDigest
  Bi-monthly electronic guide to environmental, natural resources and agricultural Internet resources from around the world.
- Environment Matters: A World Bank magazine
- Environment Views: Alberta's Magazine On the Environment
- Environment Watch: Latin America
- Environmental Building News: A Newsletter on Environmentally Sustainable Design and Construction
- Environmental News:Palouse-Clearwater Environmental Institute
- Environmental Protection, Management and Problem Solving for Environmental Protection
- Environmental Research Newsletter: Environment Institute, Joint Research Centre of the European Commission
- Finance & Development: A quarterly publication of the International Monetary Fund and the World Bank
- Financial Flows and the Developing Countries, The World Bank:
- Florida Enviroworld: Daily Environmental Industry News
- Global Change: A Review of Climate Change and Ozone Depletion
- Global Environment Facility Newsletter: The World Bank
- GreenClips Environmental Journal

- Hazardous Substances Review
- International Journal of Environmentally Conscious Design and Manufacturing
- Journal of Industrial Ecology
- Nature, International weekly journal of science
- Nautilus Bulletin: Nautilus Institute for Security and Sustainable Development
- Net Rag Environmental Issues
- Newsletter: Sustainable Developments: President's Council on Sustainable Development
- Newsletter of the Working Group on Environmental Studies:At the European University Institute, Florence, Italy
- One World Magazine
- ORNL Review
  Oak Ridge National Laboratory's Research and Review Magazine
- Our Environment
- Our Planet: UNEP' s magazine for sustainable development
- Recycling World: The United Kingdom's magazine for commercial recyclers
- SEED Newsletter:The Sustainable Energy and Environment Division of UNDP
- Sustainable Energy News:Newsletter for the International Network for Sustainable Energy
- Tiempo: Global Warming and the Third World
- Waste & Environment Today: by AEA Technology's National Environmental Technology Centre
- Waste Not: The Reporter for rational resource management
- Women & Environments Magazine
- The World Bank Economic Review
- The World Bank Research Observer
- World Rivers Review: International Rivers Network. Quarterly newsletter. Contents of the latest edition and headline index

2. Environmental Monitoring

http://www.gsf.de/UNEP/contents.html

Organisations and Institutes from around the world (Albania to Western Samoa) who undertake environmental monitoring are each classified under one of six headings:

1. United Nations Organisation
2. Inter-Governmental Organisation
3. Governmental Organisation
4. Non-Governmental Organisation
5. Academic Organisation
6. Industrial or Commercial Organisation

3. Environmental Fate of Organic Compounds

http://esc.syrres.com/

The *Environmental Fate Data Bases* **(EFDB)** can be accessed for free at http://esc.syrres.com/. The project is supported by the U.S. EPA, Proctor & Gamble and Du Pont. These online databases identify or provide all of the information necessary for assessing human or environmental exposure to chemicals from occupational and consumer use, environmental contamination, and food consumption. This is an excellent way to identify physical properties (e.g. water solubility, vapour pressure, log P, pKa, Henry's law constants), degradation or transport information, and ambient and effluent monitoring data.

EFDB consists of several interrelated files – **DATALOG, BIOLOG, CHEMFATE** and **BIODEG** - and has been developed under the sponsorship of the EPA since 1979.

DATALOG is a bibliographic file that contains 18 types of environmental fate data, including information about physical properties, environmental degradation, transport processes and monitoring. The file is indexed by CAS Registry Numbers and contains over 350,000 records on over 16,000 chemicals.

BIOLOG provides sources of microbial toxicity and data concerning biodegradation. It contains 60,000 records on 7,600 chemicals.

CHEMFATE contains 23 data categories relating to commercially important chemical compounds, including information on environmental fate, chemical and physical properties, and monitoring data. Actual experimental values are abstracted and retained in the file. CHEMFATE contains 17,214 records on 1,728 chemicals.

BIODEG contains experimental values derived from biodegradation studies and includes evaluation codes that can be used for predicting biodegradability. This file contains actual experimental results for approximately 1,000 chemicals.

Comments or suggestions from users of this site can be directed to:

Philip H. Howard, Ph.D., Director, Environmental Science Center,
Syracuse Research Corporation, 6225 Running Ridge Road, North Syracuse, NY 13212
Phone: 315-452-8417; Fax:315-452-8440
Email: howardp@syrres.com
Website http://esc.syrres.com/

Software Evaluation

An opportunity to evaluate a comprehensive modelling software package useful for all types of modelling is available. The software, *Modelmaker* is a Windows based modelling package that has been designed to remove the need to program models into computers. Using click, drag and drop functions, complex compartmental models can be constructed for virtually any situation, for example, population dynamics or pollution management. Features such as sensitivity analysis, Monte-Carlo simulation, and optimisation minimisation provide a comprehensive range of analytical tools to query models.

For further information and a free 30-day trial, check the Web site at http://www.modelkinetix.com and send an e-mail to dominic@cherwell.com

ModelMaker belongs to ModelKinetix.com a division of Cherwell Scientific Ltd.
tel: +44 (0)1865 784809

Forthcoming Symposium

PVC and Persistent Organic Pollutants in the Environment

RSC Environmental Chemistry Group 2001 Distinguished Guest Lecture and Accompanying Symposium

The RSC Environmental Chemistry Group 2001 Distinguished Guest Lecture will be held on Wednesday 7th March 2001 as part of a half-day symposium on "*PVC and Persistent Organic Pollutants in the Environment.*"

The 2001 Distinguished Guest Lecturer will be Dr. John Emsley, Science Writer in Residence, Department of Chemistry, University of Cambridge. The title of Dr.Emsley's lecture is "*What's so wrong with PVC?*"

Please note that the venue for this meeting differs from the past few years and will be at The Linnean Society of London, Burlington House, Piccadilly, London, W1V 0LQ. The symposium will begin at 13.30. The 28th Environmental Chemistry Group AGM will be held at 15.05 during an interval of the meeting.

Two supporting lectures will be given at the symposium: "*POPMOBILITY: Persistent Organic Pollutants in the Environment.*" (Professor Kevin Jones, Institute of Environmental and Natural Sciences, Lancaster University) and "*Degradation of Xenobiotics: Surfaces and Biofilms and their Relevance to Bioavailability and Bioremediation*" (Professor Richard Burns, Department of Biosciences, University of Kent).

Book Reviews

The following reviews appear on the Web site for *The Analyst*, February 2000.

Environmental Radiochemical Analysis

Edited by G. W. A. Newton, Royal Society of Chemistry, Cambridge, 1999. £79.50. ISBN 0085404-734-4.

Radiochemical analysis suffers from the same problems encountered in all analytical chemical methods namely quality control, the selection of manual and instrumental protocols in method development, and identification of the most appropriate analyte detection system. In addition, the environmental context for radionuclide analysis offers on one hand the challenge of improving risk assessment and dose prediction *versus* improvements in our understanding of environmental transfers of the chemical elements from the unique tracers provided by the planned and unplanned discharges from the nuclear fuel cycle. This volume, compiled from the VIIIth International Symposium on Radiochemical Analysis, Blackpool, September 1998, provides a flavour of all of these issues.

Forty papers are included in the compilation and a detailed summary of the topics addressed is not feasible in this short review. However, the range of material covered has been broken into a series of sections which include:

- A consideration of radium and radon in the phosphate industry and military contaminated sites, the assessment of radon doses in Brazilian homes and an interesting study of bio-indicators of radionuclide contamination.
- A section on analytical method development, this includes new protocols in liquid scintillation and actinide separations for a number of environmental matrices coupled with information on uranium behaviour in wastes.
- Methods for isotopes of sulphur, carbon, strontium, technetium and rare earth isotopes applied in atmospheric, aquatic and biological systems.
- Specific radiometric issues in the quality of detection systems and the role of quality assurance in all aspects of environmental radiochemical analysis.
- The transfer and uptake of radionuclides in vegetation and potential intake by critical groups and implications for population dose.

The papers are on the whole well presented and diagrams are clear, as a compilation of topics reflecting a snap shot of activities in the radiochemical analysis community, the volume is a reasonable and useful addition. However, I am a little disappointed that there is little to guide the reader through the volume and an introductory section by the editorial team would add a lot and broaden the impact of the material. As it stands, it provides valuable practical information for researchers in the field.

Andrew Hursthouse
Chemistry & Chemical Engineering
University of Paisley, UK

Analytical Solid-phase Extraction

James S Fritz, John Wiley & Sons, Chichester, 1999. £41.95. ISBN 0-4712-4667-0.

This is a handy book, summarising the current state of solid-phase extraction (SPE) from a practical, analytical perspective. It can be recommended to a wide audience of students and practising analysts.

The book starts with a general chapter introducing in a simple and clear way some basic concepts and principles, including a quite thorough treatment of the breakthrough volume concept (in fact originating from the reviewer). The introductory chapter ends with a list of advantages of SPE over liquid–liquid extraction. A critical treatment of some disadvantages could be expected, but is not provided.

The second chapter presents a historic background to the SPE field, which is interesting to read. Of course one hopes that less careful readers do not start working according to the historical protocols given.

Some chapters (4, 6, and 8) are mainly devoted to the practice of SPE. Chapter

4 starts with pictures of the simple apparatus needed as well as descriptions of the various steps of conditioning, adsorption, washing and elution. The adsorption step is described in terms of breakthrough volume, but unfortunately, the treatment here is quite a simplistic one, in fact equal to the simplest model described in Chapter 1 (model 1 in Figure 1.4). These theories apply basic chromatographic equations to relate the breakthrough volume to the plate number N, and if N ~ 4 the simplest one breaks down completely, predicting breakthrough even before the start of the experiment. Those low plate numbers are not unrealistic, especially for the membrane-type of SPE. By the way, Equation 4.2 is wrong, which any undergraduate student in chromatography should spot. Chapter 6 deals with an alternative format for SPE, namely the so-called membrane disks, both intact for large volume samples and as raw materials for producing tailor-made extraction cartridges by stacking a number of small disks cut from such membranes. This is followed up in Chapter 8 with some examples of semimicro and micro versions of essentially the same technique, recently described by the author. In that context, solid phase microextraction (SPME), which is a much more widely used technique than the semimicro and micro versions of disk SPE, is shortly described. Potential users of the SPME technique should consult more comprehensive texts on the matter.

Most of the remaining chapters (3, 5, and 7) deal with the materials and chemistry for the SPE techniques. The third chapter is a detailed review of different types of solid sorbent particles, together with some discussions on the required properties of these materials. Most types of sorbents (except ion-exchange materials) are covered and extensively compared for different analytes. A separate chapter (5) describes in some detail the use of ion exchange materials in SPE. This is motivated, as the chemistry of these materials is quite different from the typically hydrophobic materials described in Chapter 3. The principles of group separation of bases from neutrals and acids from neutrals using cationic and anionic resins, respectively, are clearly described. Then, Chapter 7 is a detailed account of metal ion extraction by SPE. Three different approaches are described: by means of ion exchange resins, with hydrophobic adsorbents after complexation and with special chelating resins.

The last chapter is a review of a number of examples from various application areas. Naturally, this treatment is far from complete (which was not intended), but it illustrates the wide field of application of the SPE techniques.

There are some aspects of SPE that are missing in the book and that could be expected also in a practically oriented book. The main concern is that with very few exceptions only manual handling of SPE is assumed. There is a very short section on automation, with very little substance and there is no discussion at all on matters like pre-column techniques for HPLC (but admittedly for GC, which is considerably less applied and more complicated). Additionally, there is no mention of newer developments like immunosorbents.

Throughout the book, the terms "capacity factor" and "retention factor" with the same meaning are both used, sometimes one, sometimes the other (according to the IUPAC terminology, the second one is correct). The same ambiguity is found for the symbols κ and κ'. Also, there are a number of other notation errors and many names in the reference lists are misspelled. The references to EPA methods are not complete. All this is probably a matter of proof-reading errors, but it could be confusing and detracts somewhat from the otherwise positive impression of this book.

Jan Åke Jönsson
Analytical Chemistry
Lund University
Lund, Sweden

These two reviews are reproduced from *The Analyst* by permission of The Royal Society of Chemistry. More reviews of general-interest analytical science books are available at www.rsc.org/analyst

New Publications on the Environment from The Royal Society of Chemistry

The Royal Society of Chemistry has recently published a number of new books on topical issues which are of relevance to environmental scientists.

The popular **Issues in Environmental Science and Technology** series has two new titles this year: *Chemistry in the Marine Environment* and *Causes and Environmental Implications of Increased UVB Radiation*. A subscription to the series includes free site-wide electronic access, as with other serial publications from the RSC. Discounts for RSC members purchasing individual books have now been introduced.

The recently launched **Clean Technology Monographs** series addresses major issues arising from the chemistry of waste minimisation. *Clean Synthesis Using Porous Inorganic Solid Catalysts and Supported Reagents* (J.H. Clarke and C.N. Rhodes, University of York, UK) and *The Sulfur Problem: Cleaning Up Industrial Feedstocks* (D. Stirling, University of Glasgow, UK) are the latest titles in the series.

Water: A Matrix of Life by Felix Franks is the second edition of an earlier best seller. Due to be published later in the summer, it discusses current scientific knowledge of water, and goes on to explore issues such as water quality, usage, economics and politics.

Membrane Technology in Water and Wastewater Treatment (edited by P. Hillis, Northwest Water Ltd, UK) covers all aspects of the technology and its applications in the water industry, and will be of particular interest to water companies, industrialists and legislative bodies.

Full details on all the above titles, including RSC members' prices where appropriate, can be obtained from the Sales and Customer Care Department, Thomas Graham House, Science Park, Milton Road, Cambridge, CB4 0WF. Tel: +44 (0)1223 432360 Fax: +44 (0)1223 423429 Email: sales@rsc.org. Alternatively the fully searchable online catalogue can be found at www.rsc.org/pubcat

Skin Cancer Research in Cornwall

The Cornwall Dermatology Research Project was established at the Cornwall Dermatology Unit in 1996. The Research Unit was primarily created as a part of The Royal Cornwall Hospitals' participation in the Plymouth Postgraduate Medical School (PPMS), and is currently the only laboratory-based medical research on that site.

The work has been given further impetus by plans to establish an undergraduate medical school of the South West Peninsula. A significant element of the proposed medical school will be based in Cornwall at Treliske Hospital. The research is funded by the Duchy Health Charity Limited, and this support is absolutely vital for the initiation and development of this research base in the far south west of the U.K.

Skin cancer research is particularly relevant to Cornwall because the prevalence of this disease is high in the county; in particular the incidence of melanoma skin cancer is the highest in the UK. In the beginning the clinical research interests of Dr David Gould (Consultant Dermatologist) were joined with those of Dr Leo Salter (DNA Photochemist) to develop work which could potentially be initiated from a zero base. Work performed previously by Leo Salter on the measurement and computer modelling of UV-induced lesions in DNA was too costly in terms of capital infrastructure and other resources for the project budget. Consequently the Comet Assay (single cell gel electrophoresis) was identified as a relatively inexpensive experimental technique, which could produce important insights into UV-based cellular phenomena. The equipment and methods were established and used successfully by a doctoral student who was awarded his PhD by the PPMS in December 1999 – a first for Treliske Hospital and Cornwall College.

Currently the laboratory work is being undertaken by a Post-Doctoral Research Associate and a Research Assistant and is being focused on those environmental insults which are thought relevant to skin cancer aetiology in Cornwall – arsenic and radiation.

Arsenic levels are high in the environment in Cornwall because of traditional commercial production in the past and also because of other mining activities. Radiation exposure is high due to the underlying geology of the region. Taken together with the predominantly Celtic population (for which skin cancer incidence is high) and an outdoor lifestyle it is easy to see why problems may occur in Cornwall.

The research is developing the Comet Assay as a sensitive technique for assessing low levels of cellular damage caused by visible and UV-light. The use of narrow bandpass filters allow differences between the effects UVA and UVB to be determined, and the use of different cell lines creates an opportunity to explore the differences between different skin types. It is hoped that the laboratory-based work will be translated into clinical advice which can then be offered to patients in the Dermatology Unit, and that the work may also reveal aspects of environmental influences which will lead to targeted advice for the populations in "at risk" areas.

Under the current funding rules there are great difficulties involved in establishing laboratory-based research in a setting which does not have the infra-structural support of a major university and which does not have a tradition of laboratory research. However, the development of The Royal Cornwall Hospital at Treliske Hospital (the major hospital in Cornwall) by attracting high-grade consultant staff and by supporting the medical school activity requires just that. The move from these initial stages to a fully resourced and funded research team will be a great challenge.

Dr. LEO SALTER
Research Director,
Cornwall College

Royal Society Statement on Endocrine Disrupting Chemicals (EDCs)

As part of their series of reports and statements on contemporary scientific issues, **The Royal Society** published in June 2000 a report on endocrine disrupting chemicals. We are grateful to The Royal Society for permission to reproduce from this report the Summary of the Statement on Endocrine Disrupting Chemicals.

Endocrine Disrupting Chemicals

- Environmental pollution has been the source of much public discussion and media attention. Endocrine disrupting chemicals (EDCs) have caused particular concern because they may interfere with the normal function of the hormonal systems of humans and animals. Endocrine disrupting properties are found in several classes of chemicals released into the environment such as some insecticides and fungicides, some phthalate plasticizers, dioxins and anti-fouling paints. Speculation has linked exposure to EDCs to a range of effects in humans and animals, from falling sperm counts and increases in testicular cancer to feminisation of fish, all of which has fuelled public concern.

- The Royal Society convened a Working Group, chaired by Professor Patrick Bateson (Vice-President and Biological Secretary), to consider the scientific evidence for a number of reproductive and developmental irregularities in humans and animals that have been associated with EDCs. The group examined the evidence and the useful future areas of research that would help address the current lack of knowledge. In addition the difficulties of carrying out risk assessment of EDCs were discussed. Finally, the current legislation governing EDCs was reviewed. The report emphasises the difficulties of making generalised assumptions based on isolated experiments and the problems of developing policy in areas in which scientific understanding is still being developed.

- Humans are exposed daily to chemicals that have been shown, or suggested, to have hormone-disrupting properties. Speculation has linked this to a range of disorders. Whilst high levels of exposure to some EDCs could theoretically increase the risk of such disorders, no direct evidence is available at present. Trends in the incidence of some of these disorders are difficult to discern and, when they are found, are difficult to interpret because of inconsistencies in method. EDCs are but one of a variety of potential risk factors, both environmental and genetic. Despite the uncertainty, it is prudent to minimise exposure of humans, especially pregnant women to EDCs.

- With regard to EDCs in the environment, firm assessment of the risk to humans is not possible because of a lack of relevant data about the effects of EDC exposure. On the basis of limited animal data, identified environmental EDCs appear to pose minimal risk to humans on their own, but the risk from mixtures of compounds is unknown. In order to improve our understanding of the relationships of EDCs to health and disease further investigation is needed.

- Despite the lack of information on the effect on humans of EDCs in the environment, strong evidence links EDC exposure to effects on some organisms in the environment, most notably the effect of tributyl tin on molluscs. The action of EDCs has resulted in the localised destruction of certain species and is a cause for grave concern. The case of intersex (having the characteristics of both sexes) fish in the UK has highlighted that a wide range of chemicals in the environment may exert an effect. Isolating any one chemical of concern is particularly difficult.

- Increased effort should be focused on the identification of potential EDCs and the assessment of the risk posed by individual chemicals or by combinations of chemicals, supported by rigorous epidemiological studies. Further research in this area must provide evidence on the following key issues:
  - the chemicals with endocrine disrupting properties
  - the interaction between chemicals
  - the longevity and action of these chemicals in the environment
  - the levels of exposure of humans and wildlife to these chemicals
  - the levels at which the chemicals are likely to cause adverse effects.

- Many regulations govern the use, manufacture and disposal of all chemicals, with specific regulations for chemicals such as pesticides. In the UK, such regulations are the responsibility of a number of different government departments. While the issue of EDCs is confused by serious gaps in our knowledge, policies to deal with the current concerns must be developed. Regulations cannot be 'put on hold' until all the evidence has been collected. Development of policies and regulations must go hand in hand with ongoing research and any legislation must be adaptable to rapid advances in scientific knowledge. Above all, there must be a co-ordination of both research funding and policy development between the different bodies responsible.

- Many questions about EDCs cannot be answered yet. Continued research, with the results made openly available, is essential if the uncertainties are to be properly addressed and the risks understood. Even though new evidence will affect government policy on EDCs, policy makers must appreciate that the concerns of the public already have some foundation.

For further information on this statement, please contact **Sarah Wright**, Science Policy Officer, Science Advice Section, The Royal Society: e-mail sarah.wright@royalsoc.ac.uk or visit The Royal Society Web site http://www.royalsoc.ac.uk

Meeting Report

Teaching the Environmental Sciences in the New Millennium

This symposium, which was jointly organised by the RSC's Environmental Chemistry Group, the RSC's Green Chemistry Network, and the Education Department of the RSC, was held at Burlington House, Piccadilly on March 25th, 2000. The attendance was good, and during the day six speakers examined ways in which environmental education should be changing to address issues of current concern.

John Westaway (QCA) ("*Education for Sustainable Development: a Whole School Perspective*") described how the requirements and opportunities for Environmental Education (EE) have been replaced by those requiring Education for Sustainable Development (ESD), and he elucidated the consequences of this for both curriculum delivery and the management of educational institutions. Opportunities for promoting ESD are identified in the National Curriculum (NC) Booklets for geography, science, D&T, history, art & design, ICT, PE and citizenship, and it is clearly expected to become an important part of the curriculum from September 2000. What is not so clear is the manner in which the messages of government and the Panel for Sustainable Development Education will be taken up. Indeed, there seems to be a lack of real understanding about what "sustainable development" actually means! In a study performed a few years go only 16% of school heads saw EE as essential and only 7% of schools had a single comprehensive EE policy document. The reality of the inclusion of EE/ESD into school curricula and planning seems to be resistant to government exhortations.

Colin Osborne (Royal Society of Chemistry) followed this opening presentation with a paper entitled, "*The Relevance of Environmental Chemistry to the Science Curriculum*" which began by pointing out that although England, Wales and Northern Ireland have broadly similar curricula, Scotland has a different system in which science for the 5-14 age group is taught under the heading of "Environmental Studies". Dr Osborne then directed attention to the detail of the NC in which sustainability issues are

ubiquitous. The curriculum describes a need to raise students' awareness that decision-making based on sound science is an integral part of the political agenda and he gave several examples of the way in which data and other facts could be used to offer learning and teaching contexts for delivery of these aspects of the NC. Global warming, ozone layer depletion and energy use were seen as topics which could be used especially when facts and data specifically designed for integration into classes are becoming available. Dr Osborne also presented draft material being prepared by the RSC's 1999-2000 Teacher Fellow (Dorothy Warren) at The University of York Science Education Group. It should be published in early 2001.

The two lectures following this opening session (Dr Rob Mackenzie, Lancaster University, "*The Stratospheric Chemistry of Ozone Depletion and Climate Change*" and Dr Tony Stebbing, Plymouth Marine Laboratory, "*Why Ecotoxicology is Important*") dealt with aspects of new research in environmental science.

Rob Mackenzie pointed out the advances that have been made in understanding the nature of stratospheric chemistry and the circulation of the atmosphere. Of major importance is a greater understanding of how cloud formation (PSCs - Polar Stratospheric Clouds) affects ozone depletion and how particles (from, for instance, volcanic eruptions) influence stratospheric chemistry. Several case studies are available for teachers and lecturers to develop these themes, (http://www.es.lancs.ac.uk/casestud/index.htm and http://atm.ch.cam.ac.uk).

Tony Stebbing used studies of the North Sea to illustrate the point that although ecotoxicology was an interdisciplinary subject its practitioners were groups of subject specialists (chemists, physiologists, computer modellers, physicists, biochemists, hydrodynamicists). The concern for the studies of the environment is that teaching science subjects within disciplines creates artificial barriers to those who in later life will be addressing environmental problems that are inherently interdisciplinary. If subjects are taught largely within disciplines, at what stage does one introduce interdisciplinarity? He also emphasised that sustainable development is implicitly connected with economic development – the assimilative capacity of coastal seas globally is estimated to be 7% of the global GNP and hence there will be substantial costs if unsustainable use is continued. Globally the monetary value of goods associated with the environment is $33 trillion pa (as compared to a global GNP of $18 trillion) – damage to the environment represents a continued undervaluing of the provision of "services" by the globe.

The last two lectures "*The Greening of Chemistry*" (Professor James Clark, York University) and "*Green Developments in Industrial Processes*" (Dr Mike Lancaster, Green Chemistry Centre, University of York)) discussed the ways the chemical industry has changed production methods because of economic pressures derived from environmental costs.

James Clark began by showing that the UK chemical sector had increased expenditure on environmental control from £547m in1994 to £1042m in 1997 and that this expenditure was chiefly in response to effects on profitability due to waste disposal costs – waste disposal costs were becoming more expensive than raw materials. In speciality chemicals (including pharmaceuticals) waste costs are greater than 50% of manufacturing costs! The industries which have traditionally been seen as the major polluters (oil refining, bulk chemicals) are now those with the highest manufacturing efficiency and have minimal waste. Public perceptions concerning environmental impact caused by the chemical industry have not kept pace with the changes that industry has (and is) making and, in education, these same perceptions are creating a dramatic shortfall in the supply of chemical engineers in the UK and the US. In the UK there has been a 20% decline in university applications to read chemical engineering over the last two years and a 20% decline for chemistry over the last 4 years; in chemistry applications in the current year are down by 7%. The Green Chemistry Network (www.rsc.org/greenchem) is designed to promote awareness of changes in the chemical industry and to facilitate the use and transfer of technologies within the industry itself.

Mike Lancaster followed James Clark's lecture with four case studies (phenol, sodium carbonate, detergents and nylon) of changes in chemical manufacturing processes, which were economically efficient and environmentally effective. The detail of the presentation highlighted the way in which textbooks and examination syllabi have failed to reflect the important changes in these classic processes – the increasing use of specialised zeolite technology and the potential for use of enzymes for nylon manufacture from glucose are but two examples of this.

The conference highlighted five issues:

1. The expectations of universities from their first year students and the substance of A-level syllabi are not seamless and more communication between the two sectors would be valuable.

2. Issues associated with sustainable development are not clearly defined by syllabi and consequently not examined significantly. This leads to their marginalisation by teachers and lecturers.

3. Because of time and cost, sustainable development initiatives are also marginalised by management.

4. The decline of recruitment into specialised subject areas (like chemistry) may have consequences for environmental research and for the chemical industries. A significant factor in this decline is the poor perceptions of school leavers about the chemical industry. In order to counteract these (increasingly erroneous) perceptions efforts should be made to design A-level Chemistry syllabi with better use of environmental contexts to deliver the necessary material.

5. A-Level examination boards and textbooks associated with A-level delivery need to be more aware of changes at the forefront of their disciplines – especially those changes which are relevant to the environment.

LEO SALTER
Cornwall College
Chairman, Environmental Chemistry Group

Recent Books on the Environment and on Toxicology at the RSC Library

The following books and monographs on environmental topics have been acquired by the Royal Society of Chemistry library, Burlington House, during the period January to May 2000. Recent additions on toxicology are also included in this list.

Azodicarbonamide

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241530162, 23 pp., Accession No: 20000193, West Gallery 628.5

Bacillus thuringiensis

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241572175, 105 pp., Accession No: 20000332, West Gallery 628.5

Boron

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241572043, 201 pp., Accession No: 20000043, West Gallery 628.5

Carbon Monoxide, 2nd edition.

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241572132, 464 pp., Accession No: 20000328, West Gallery 628.5

Chemistry of Pollution

Fellenberg, G., John Wiley, Chichester, 1999
ISBN/ISSN: 0471613916, 192 pp., Accession No: 20000027, West Gallery 628.54:504.054

Copper

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241572000, 360 pp., Accession No: 20000041, West Gallery 628.5

1,2-Diaminoethane (Ethylenediamine)

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241530154, 30 pp., Accession No: 20000192, West Gallery 628.5

3,3'-Dichlorobenzidine

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530022, 21 pp., Accession No: 20000184, West Gallery 628.5

1,2-Dichloroethane

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530014, 28 pp., Accession No: 20000183, West Gallery 628.5

ECETOC Joint Assessment of Commodity Chemicals No. 38: Monochloroacetic Acid (CAS No. 79-11-8) and its Sodium Salt (CAS No. 3926-62-3)

ECETOC, Brussels, 1999
ISBN/ISSN: 0773633938, 112 pp., Accession No: 20000081, West Gallery 615.9

Environment Business Directory 1999

Cassidy, J. (ed.), Information for Industry, London, 1998
ISBN/ISSN: 0651837567, 215 pp., Accession No: 20000300, REF 058.7:628.5 R

Environmental Protection (Restriction on Use of Lead Shot) (England) Regulations 1999

Stationery Office, London, 1999
ISBN/ISSN: 0110850564, 13 pp., Accession No: 20000213, A 100 SI 1999/2170

Environmental Sampling After a Chemical Accident

Watterson, J., Stationery Office, London, 1999
ISBN/ISSN: 0117534951, 354 pp., Accession No: 20000223, West Gallery 628.5:542.22

Environmental Soil Science, 2nd edition

Tan, K.H, Marcel Dekker, New York, 2000
ISBN/ISSN: 0824703405, 452 pp., Accession No: 20000169, West Gallery 631.4:628.5

Flame Retardants: Tris(2-butoxyethyl) phosphate, Tris(2-ethylhexyl) phosphate and Tetrakis(hydroxymethyl) Phosphonium Salts

International Programme on Chemical Safety (IPCS), WHO, Geneva, 2000
ISBN/ISSN: 9241572183, 130 pp., Accession No: 20000330, West Gallery 628.5

Flame Retardants: Tris(chloropropyl) phosphate and Tris(2-chloroethyl) Phosphate

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241572094, 106 pp., Accession No: 20000042, West Gallery 628.5

Green Chemistry: Challenging Perspectives

Tundo, P. (ed.), OUP, Oxford, 2000
ISBN/ISSN: 0198504551, 269 pp., Accession No: 20000290, West Gallery 628.5:54

Health Effects of Interactions between Tobacco Use and Exposure to other Agents

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241572116, 149 pp., Accession No: 20000333, West Gallery 628.5

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Volume 72: Hormonal Contraception and Post-menopausal Hormonal Therapy

International Agency for Research on Cancer (IARC), Lyon, 1999
ISBN/ISSN: 928321272X, 660 pp.,

Accession No: 20000045, West Gallery 616-006.6:061.3

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Volume 74: Surgical Implants and Other Foreign Bodies

International Agency for Research on Cancer (IARC), Lyon, 1999
ISBN/ISSN: 9283212746, 409 pp., Accession No: 20000301, West Gallery 616-006.6:061.3

Kyoto Protocol: International Climate Policy for the 21st Century

Oberthur, S., Springer, Berlin, 1999
ISBN/ISSN: 54066470X, 359 pp., Accession No: 20000095, West Gallery 628.5

Limonene

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530057, 32 pp., Accession No: 20000187, West Gallery 628.5

Manganese and its Compounds

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 924153012X, 42 pp., Accession No: 20000189, West Gallery 628.5

Methyl Methacrylate

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530049, 40 pp., Accession No: 20000186, West Gallery 628.5

Patty's Industrial Hygiene: Volume 1, 5th edition

Harris, R.L. (ed.), John Wiley, New York, 2000
ISBN/ISSN: 0471297844, 756 pp., Accession No: 20000248, West Gallery 615.9

Patty's Industrial Hygiene: Volume 2, 5th edition

Harris, R.L. (ed.), John Wiley, New York, 2000
ISBN/ISSN: 0471297542, 837 pp., Accession No: 20000249, West Gallery 615.9

Patty's Industrial Hygiene: Volume 3, 5th edition

Harris, R.L. (ed.), John Wiley, New York, 2000
ISBN/ISSN: 0471297534, 791 pp., Accession No: 20000250, West Gallery 615.9

Patty's Industrial Hygiene: Volume 4, 5th edition

Harris, R.L. (ed.), John Wiley, New York, 2000,
ISBN/ISSN: 0471297496, 1066 pp., Accession No: 20000251, West Gallery 615.9

Principles for the Assessment of Risks to Human Health from Exposure to Chemicals

Inter-Organization Programme for the Sound Management of Chemicals (IOMC), WHO, Geneva 1999
ISBN/ISSN: 9241572108, 110 pp., Accession No: 20000132, West Gallery 628.5

Principles and Methods for Assessing Allergic Hypersensitization Associated with Exposure to Chemicals

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241572124, 399 pp., Accession No: 20000327, West Gallery 628.5

1,1,2,2-Tetrachloroethane

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530030, 28 pp., Accession No: 20000185, West Gallery 628.5

Tetrachloroethylene

ECETOC, Brussels, 2000
271 pp., Accession No: 20000268, West Gallery 615.9

o-Toluidine

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1998
ISBN/ISSN: 9241530073, 18 pp., Accession No: 20000188, West Gallery 628.5

Tributyltin Oxide

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241530146, 29 pp., Accession No: 20000191, West Gallery 628.5

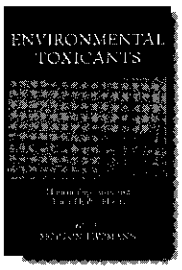
Triphenyltin Compounds

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN:9241530138, 40 pp., Accession No: 20000190, West Gallery 628.5

Vinyl Chloride

International Programme on Chemical Safety (IPCS), WHO, Geneva, 1999
ISBN/ISSN: 9241572159, 356 pp., Accession No: 20000329, West Gallery 628.5

New book information FROM WILEY



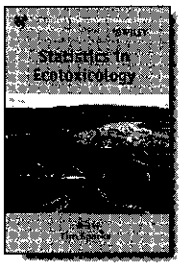
Environmental Toxicants

Human Exposures and their Health Effects
Second Edition
M. LIPPMANN, New York University of School of Medicine, USA

This work critically reviews the current knowledge on human exposure to selected chemical agents and physical factors in the ambient environment. It provides the most up-to-date information and research available for performing risk assessments, making it a key resource in the field.

This edition contains an additional 6 topic chapters each describing toxicants which have already, or are likely to have, a substantial impact on the health of the general population.

0471 29298 2 January 2000 1008pp (Hbk) £119.00



Statistics in Ecotoxicology

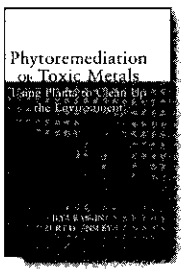
Edited by TIM SPARKS, Institute of Terrestrial Ecology, Monks Wood, Huntingdon, UK

Statistics in Ecotoxicology presents timely and comprehensive coverage of the material required by ecotoxicologists during both the planning and operation of laboratory and field ecotoxicological experiments.

- Presents an invaluable introduction to quantitative methods for the analysis of ecotoxicological data
- Features numerous tables, figures, case studies and worked examples
- Provides essential tips to prevent many of the common failings of design and analysis in ecotoxicology

Contents Basic Concepts; Exploring the Data; Field Experiments; The Analysis of Laboratory Toxicity Experiments; Analysis of Field Studies; Regression Analysis; Multivariate Techniques; Environmental Monitoring; Investigating Associations and Trends; Organochlorines in Bird of Prey Eggs: A Terrestrial Case Study; Statistical Techniques for the Ecological Risk Assessment of Chemicals in Freshwaters; Trying to Detect Impacts in Marine Habitats: Comparisons with Suitable Reference Areas.

0471 96851 X December 1999 334pp (Hbk) £60.00
0471 97299 1 December 1999 334pp (Pbk) £22.50

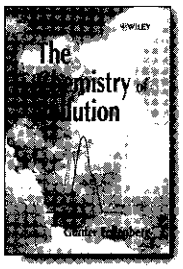


Phytoremediation of Toxic Metals

Using Plants to Clean Up the Environment
I. RASKIN, Rutgers University, USA and B. ENSLEY, Phytotech Inc., USA

- Provides extensive coverage of a rapidly developing area in biotechnology and environmental research
- Pays particular attention to several subsets of phytoremediation technology which are nearing commercialisation or are already commercialised including phytoextraction of metals, and phytostabilisation and phytodegradation of organic pollutants
- Discusses the transfer of phytoremediation from the laboratory to the field

0471 19254 6 November 1999 316pp (Hbk) £58.50



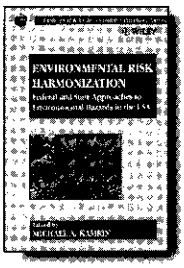
The Chemistry of Pollution

G. FELLENBERG, Formerly of Technical University Braunschweig, Germany

An excellent introduction to some of the main areas of environmental pollution where chemical reactions play a strong role. It demonstrates the multiplicity of environmental problems using many varied practical examples and their solutions. Containing a wide range of topics it provides a broad overview of the subject, which makes it a valuable reference guide across an extensive range of fields.

CONTENTS What is Pollution?; Changes in the Atmosphere; Impairment of Ground Water and Surface Water; Soil Pollution; Generally Distributed Materials (Ubiquists); Foods and Luxury Foods; Basic Consumer Goods; Radioactivity; Outlook; Glossary; Literature; Index.

0471 61391 6 December 1999 204pp (Hbk) £60.00
0471 98088 9 December 1999 204pp (Pbk) £24.95



Environmental Risk Harmonization

Federal/State Approaches to Environmental Hazards in the US
Edited by MICHAEL A. KAMRIN, Michigan State University, USA

- A unique and timely reference source providing accurate information on US proposals for improvements in the assessment and management of environmental risks
- Includes case studies and examples with direct parallels to the situation in Europe
- With contributions from the US-EPA, WHO and US State Department

0471 97265 7 1997 328pp (Hbk) £70.00

Send for your FREE Environmental Science Catalogue

All these titles are available from your bookseller

To order direct:

WRITE to James Martin, John Wiley & Sons, Baffins Lane, Chichester, West Sussex PO19 1UD enclosing a cheque payable to John Wiley & Sons Ltd

TELEPHONE with your credit card details on DIAL FREE (UK only) 0800 243407 or (for overseas orders) +44 1243 843294
FAX +44 (0) 1243 843296

E-MAIL envsci@wiley.co.uk including your credit card details and delivery address

WILEY

1650

This issue of the ECG Newsletter was printed by Griffin House Printers, Haywards Heath, West Sussex RH16 3NG Tel: 01444 456673