# POLLUTANTS, HUMAN HEALTH AND THE ENVIRONMENT

## A RISK BASED APPROACH

EDITORS | JANE A. PLANT | NIKOLAOS VOULVOULIS | K. VALA RAGNARSDOTTIR

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**Editors**

Jane A. Plant
*Imperial College London*

Nikolaos Voulvoulis
*Imperial College London*

K. Vala Ragnarsdottir
*University of Iceland*



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The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
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# Pollutants, Human Health and the Environment

*The book is dedicated to Charlotte Rich, a PhD student and friend of many of the authors of the book, who died tragically in 2007 and Michael Gillott who died of cancer. Michael had the utmost respect for scientific research and the quest for truth. He persuaded us of the need to inform a wide audience, including health professionals, of the hazards and risks of pollutants.*

# Forewords

## *A Foreword by Lord Selborne*

Over the past century a large number of man-made chemical substances have been widely dispersed into our environment, both by accident and design, raising concerns about their adverse effects on human health and the environment. There is no doubt that there has been a worrying increase in health problems that are related, at least in part, to these substances and their release from manufacturing processes, spills, inadequate handling, storage and use, and careless after-use disposal.

Over the past 30 years or so there has been a plethora of legislation at international and national levels aimed at controlling and regulating the production, use and disposal of chemicals. The introduction of the REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) by the EU in 2007 has provided the innovative concept that the burden of proof is now on manufacturers to provide evidence of the safety of their products before supplying them: a practical example of the so-called precautionary principle. It also provides rules for the phasing out and substitution of the most dangerous substances already in circulation, though this, unfortunately, is likely to be a protracted process. The main objective of REACH is to improve risk management of industrial chemicals by banning their manufacture or importation into Europe.

One concern about the REACH legislation is that it will drive research and development and manufacturing involving chemicals to parts of the world where legislation is weak or non-existent. This would be highly unsatisfactory, since chemical pollution is a global issue. For example, the use of arsenical groundwater to grow crops in south-east Asia has resulted in health warnings on rice, especially warning against feeding it to babies in the USA and Europe; persistent organic pollutants such as pesticides and plasticisers, despite being used mainly at low latitudes, are accumulating in marine fish and mammals in polar and sub-polar regions; and the manufacture of pharmaceuticals in countries where environmental legislation fails to require the clean-up of waste water has the potential to increase the antibiotic resistance of pathogens.

This book provides a balanced view of the risks and benefits of several groups of substances: essential, toxic trace and radioactive elements; synthetic organic agricultural and industrial chemicals and pharmaceuticals; and particulates and nanomaterials. Most of these substances are important to modern industrialised societies but can have adverse impacts on the environment and human health. It also deals with risk reduction and the future role of chemicals in achieving sustainable development. The issue of sustainability in a world of finite resources is likely to become ever more important in considering the use of chemicals in the twenty-first century.

The book uses a risk-based approach for industrial and other chemicals. It includes a discussion of the potential use of chemicals in sustainable development and suggests that in the future there will be more emphasis on green chemistry and biomimicry, which involve learning from nature, with industry developing clean cycles of production that are built on natural processes whereby waste from one process is feed for another – the cradle-to-cradle concept.

The book includes well-researched material, with references to the latest published work. It is written in accessible English and provides an excellent introduction to anyone wishing to know more about the increasingly important subject of chemicals in the environment. The information it contains will be particularly useful to everyone affected by recent legislation including the REACH legislation.

The Earl of Selborne GBE FRS
Chair of the Council of Science and Technology

## *A Foreword by Professor Karol Sikora*

Global warming has captured the attention of the world's media, public and politicians, but although the dramatically increasing carbon footprint we are leaving is important it is not the only effect of the twenty-first century on the environment. Many diverse pollutants have the potential to cause lasting damage to our environment. Processes that may make a quick buck today could cause untold difficulties for our successors who will inherit the challenge. We have already seen an inexorable rise in cancer incidence in the world. Although an increasingly aging population is the main driver, there is no doubt that other more subtle influences are at work. The incidence of cancer acts as a litmus test for the deleterious effects of the environment and lifestyle changes on our bodies.

It was announced this year that the lifetime risk of breast cancer in the UK has gone up from 1 in 9 women to 1 in 8 women, a rate comparable to that in the USA. Rates of this and many other types of cancer have risen dramatically since reliable cancer registries were first developed in the 1950s and they are projected to continue to do so in the future – according to the World Cancer Research Fund Report, cancer rates worldwide could increase by a further 50 per cent to 15 million new cases a year by the year 2020. Rates of many other chronic diseases, from Alzheimer's disease to Parkinsonism, as well as mood disorders such as anxiety and depression are also increasing across the globe following industrialisation and development, at a time when many of the costs of health care are becoming unaffordable. It is clear that we must learn how to reduce the risks of such diseases and prevent the human and economic toll that they are taking on society worldwide.

Effective prevention requires a detailed understanding of the pathogenesis of disease and the dissection of the positive and negative drivers that influence the process. Cancer is a disease of cumulative somatic mutations leading to disruption in cellular growth control. It is not surprising that many pollutants can influence this process. By understanding the detailed factors involved in the aetiology of cancer it may be possible to devise public-health strategies to minimise the overall burden of disease. Furthermore, our increasing knowledge of the molecular mechanisms involved in the interplay of the environment and our genetic background may make it possible to personalise prevention strategies at some future point. This individualisation is far more likely to achieve wider compliance amongst the population rather than bland generic messages.

While it is widely acknowledged that the causes of many chronic conditions are multifactorial, attention is being directed increasingly to the role of chemicals in our diet and the wider environment – especially following the understanding of the important role of epigenetics in disease progression. For example, the role of endocrine-disrupting substances in hormone-dependent cancer, asbestiform particulates in mesothelioma and particulates generally in chronic lung disease has been established. It has even been suggested that chemicals found in certain plastics, as well as in cigarette smoke, may increase the risks of obesity or diabetes. It is clear that greater efforts should be made to reduce exposure and hence the risk to human health of potentially hazardous substances beyond those associated simply with smoking and alcohol consumption.

This book, *Pollutants, Human Health and the Environment,* equips health professionals with an up-to-date knowledge of hazardous substances to help them limit the risks to human health and prevent many chronic diseases. It explains clearly the difference between hazard and risk, and goes on to discuss groups of hazardous substances, chapter by chapter. It includes discussions of many controversial issues, including: toxic trace elements such as arsenic, cadmium and mercury; radiation and radioactive elements such as naturally occurring radon gas and other natural and artificial fission products; industrial chemicals such as benzene and trichloroethylene; pesticides and pharmaceuticals, which enter water supplies and the wider environment; and particulates, including asbestos. It also includes chapters on engineered nanomaterials, essential and beneficial trace elements such as selenium, copper and zinc, and natural oestrogens.

The book contains some striking information, for example: the numbers of people at risk of skin or bladder cancer from increased exposure to arsenic; the number of conditions for which there is evidence that selenium deficiency is a cause or a factor; the fact that the greatest exposure of US citizens to ionising radiation is from medical diagnostics and treatment and that this is 500 times the dose from the nuclear industry; the increased amount of oestrogen in our food because of changes in farming practices; our increased exposure to neurotoxic substances used as pesticides or preservatives; and the fact that mercury levels have increased by a factor of four over the last 100 years.

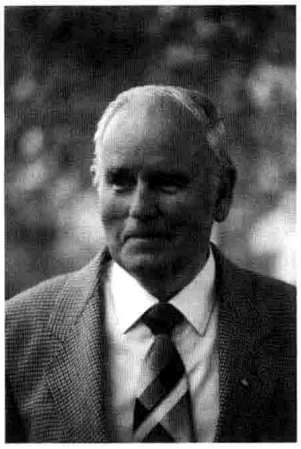
This book is highly recommended to all health professionals who wish to play an effective role in reducing the risk to human health of chemicals in the environment. For the sake of our children's children we all need to understand the footprint we are leaving for them. The knowledge, understanding and information in this book are the key to developing effective action plans across the globe.

Karol Sikora

Professor of Cancer Medicine, Hammersmith Hospital and
Dean, University of Buckingham Medical School

# Tribute

## Professor Stanley Bowie FRS, 1917 to 2008



### *Stanley Hay Umphray Bowie FRS, FRSE FEng, FIMM*

Stanley Bowie was a scientist of international standing who, as Chief Geochemist, established and led the highly successful Geochemical Division of the British Geological Survey (BGS, formerly the Institute of Geological Sciences, IGS), which became a model for similar divisions in geological surveys throughout the world. He and his staff made major contributions in isotope geology, fluid-inclusion studies, trace-element geochemistry (including high-resolution geochemical mapping), ore mineralogy, economic geology and analytical chemistry. The first inductively coupled plasma mass spectrometer was developed by Alan Gray of the University of Surrey and Alan Date in the IGS with funding from the European Commission, negotiated by Stanley. Later he was involved in further instrument development, including the portable XRF analyser and the first towed seabed gamma spectrometer.

A Shetlander by birth, Stanley Bowie graduated in 1941 with a first-class honours degree in geology from the University of Aberdeen where he had also studied chemistry and physics. He was awarded the Mitchell prize for the best Honours Geology student and the Senior Kilgour Research Scholarship.

In January 1942, during the Second World War, he joined the Meteorological Branch of the Royal Air Force and was commissioned flying officer a year later. He was stationed with Bomber Command in East Anglia, which was later the base for the first American B17 squadron stationed in Britain.

In 1946 he joined the Geological Survey of Great Britain (GSGB) with the Special Investigations Unit (renamed the Atomic Energy Division, AED, in 1951). This was the Unit which had been responsible for advising the British Government on the availability of uranium supplies for the Manhattan Project during the war and subsequently provided geological information for the UK's atomic-weapons and nuclear-energy programmes. It was Britain's knowledge and ownership of uranium reserves that ensured that the country remained in the American-led nuclear club after 1945. Stanley worked on autoradiography studies of uranium and thorium minerals in thin and polished sections and, in collaboration with the Atomic Energy Research Establishment (AERE) at Harwell, began a programme of instrument development for uranium exploration that helped to develop Geiger-Müller counters for use in uranium exploration, borehole logging and aero-radiometric surveys. He also developed an index of radioactive minerals, which remained classified until 1976.

In 1955 Stanley was promoted to Chief Geologist of the AED and represented the UK at international conferences on atomic energy, helping to develop advanced radiometric instrumentation. He also developed, with Ken Taylor, a new system of opaque-mineral identification based on the measurement of indentation hardness and reflectance – a major advance over previous complex systems – which gave Britain an important lead in economic geology. He used the system to investigate and document uranium deposits throughout the free world, and it remained in use by most ore mineralogists until the advent of the electron microprobe.

In 1968 he was appointed Chief Geochemist, in charge of the analytical, mineralogy and isotope-geology units as well as the field geochemistry programmes. From 1968 to 1973 he led a uranium reconnaissance programme on behalf of the UKAEA using many of the instrumental methods developed earlier in his career as well as newer geochemical methods based on the delayed-neutron method of analysis. In 1970 he was appointed by NASA as a principal investigator for returned lunar samples.

His work with Peter Simpson on the ore mineralogy of these samples and with Clive Rice on the distribution of uranium using fission-track analysis made an important contribution to understanding the lunar surface.

In 1972 he obtained funding for a programme of systematic geochemical mapping of Great Britain. This programme developed, for the first time, quantitative reproducible methods for the preparation of geochemical maps of similar standing to gravity, magnetic and other geophysical maps prepared by geological surveys. Led by Dr Jane Plant, this programme became the model for geochemical databases worldwide, and many of the sampling, analytical, quality-control and quality-assurance techniques and the methods of data processing form the basis of recommendations of the IUGS/IAGC Task Group on 'Global Geochemical Baselines' initiated by Dr Arthur Darnley, a former colleague.

In 1975 he established and led a Royal Society Working Party on Environmental Geochemistry and Health, which included other notable scientists such as Professor John Webb of Imperial College, Dr Colin Mills of the Rowett Institute of Nutrition and Health and Dr Gerry Shaper of the Royal Free and University College Medical School. The Working Party was in contact with national coordinating committees in the USA and USSR, the Academies of Science of the five Scandinavian countries and individuals elsewhere. The proceedings of a Royal Society discussion meeting in 1977 entitled 'Environmental Geochemistry and Health' continue to be regarded as a key scene-setting volume covering geochemistry and the health of man, animals and plants. He collaborated in 1990 with Dr Cameron Bowie (not a relative) of the Somerset Health Authority in a book on radon and health and in a paper on the same topic, published in the Lancet in 1991.

In 1959 he was awarded the Silver Medal of the Royal Society of Arts. In 1963 he was elected a Fellow of the Royal Society of Edinburgh. He was elected a Fellow of the Royal Society in 1976 and in the same year he became president of the Institution of Mining and Metallurgy.

In 1984 a new platinum-group mineral was named bowieite by the United States Geological Survey in recognition of Stanley's contribution to ore mineralogy. He was visiting Professor at Strathclyde University until 1985 and visiting Professor at Imperial College from 1985 until 1989, and he served on the Commission of Ore Mineralogy of the International Mineralogical Association until 1987.

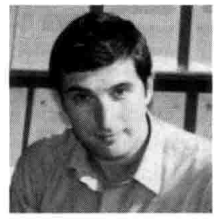
This book is a tribute to Professor Stanley Bowie FRS, honouring him as one of the pioneers of geochemistry as applied in the real world, recognising especially his role in establishing high-quality geochemical mapping, researching radioactivity and radio-elements in the Earth's crust, and applying these studies to the exploration and development of mineral resources and to the improvement of human health.

# The Editors

Professor Jane Plant CBE, DSc, FRSM, FRSE, FRSA, FRGS, FIMMM, FGS, CEng, CGeol holds the Anglo American chair of Geochemistry at Imperial College London. She was formerly Chief Geochemist and later Chief Scientist of the British Geological Survey. She has been awarded seven honorary doctorates and many prizes and distinctions for her contribution to science, including the prestigious Lord Lloyd of Kilgerran Award of the Foundation of Science and Technology, the Coke Medal of the Geological Society and the Tetleman Fellowship of Yale University. She formerly chaired the Government's Advisory Committee on Hazardous Substances and was a member of the Royal Commission on Environmental Pollution 2000–2006. She is presently on the Council of the UK All Party Parliamentary and Scientific Committee and the College of Medicine and is patron of several cancer charities, including the famous Penny Brohn Centre in Bristol.

She supervises and undertakes research in environmental geochemistry with particular reference to human health. She is an international expert on environmental pollution, specialising in understanding and modelling the sources and behaviour of essential, beneficial and toxic trace elements, radioelements and radioactivity in the environment. She established the world-renowned geochemical baseline programme of the UK (G-BASE), and subsequently co-led the global geochemical baseline International Union of Geological Sciences/International Association of GeoChemistry (IUGS/IAGC) Programme with Dr David Smith of the United States Geological Survey.

Professor Plant is the author of the internationally best-selling book *Your Life in Your Hands*, on overcoming breast cancer, and several other books on health including ones on osteoporosis and prostate cancer. Her latest popular health book, entitled *Beating Stress, Anxiety and Depression*, was published in 2009 and has been described as ground-breaking. These popular health books aim to empower sufferers by making available the latest scientific information on diet and lifestyle, as well as conventional medical treatments. She has played a leading role in developing this volume in order to help to communicate to others the significant health problems caused by chemicals in the environment.



Dr Nikolaos Voulvoulis is a Reader in Environmental Technology, leader of the Environmental Quality Research theme at the Centre for Environmental Policy and Director of the world-renowned MSc in Environmental Technology at Imperial College London. He supervises and undertakes research in the area of environmental analysis and assessment for environmental quality management. This focuses on the development of methods for assessing emerging environmental contaminants and their sources, pathways and fate in the environment, with emphasis on waste and waste-water-treatment processes. He is an international expert in environmental pollution by hazardous substances such as biocides, pesticides, endocrine-disrupting chemicals and pharmaceuticals, and on the associated policy and management issues. His research activities also involve the development and application of environmental-analysis tools, multi-criteria assessment, risk management and sustainability assessment. This research aims to develop methodologies that establish the influence of different parameters of environmental quality, process performance, and indicators of effects. His research has been having an impact on environmental decision-making and policy on environmental quality, climate change and human health nationally and internationally. Through surveys, environmental monitoring, modelling, laboratory experiments and lab-scale trials, he delivers high-quality research that has been published in some of the top journals in the field.

Dr Voulvoulis engages in a number of high-profile external teaching and research activities. Through such activities, he has developed strong links with industry, regulators, research organisations and NGOs. He is a member of the Steering Group of the Global Contaminated Land Network of the Chartered Institution of Water and Environmental Management and Director of the Opal Soil Centre responsible for the National Soil and Earthworm survey. This survey was recently included as an example of a science-based education programme and data-collection method in the European Atlas of Soil Biodiversity launched by the European Commission's Joint Research Centre in September 2010 as part of the International Year of Biodiversity. In addition, he has recently been in charge of the evaluation of over 1000 environmental projects that were co-financed by the Instrument for Structural Policies

Pre-Accession or Cohesion Fund by the European Commission, assessing the effectiveness of these projects and their contribution to the acquis communautaire in the field of the environment – specifically in the fields of water quality and management and waste collection and treatment.

Professor Kristín Vala Ragnarsdóttir is the Dean of Engineering and Natural Sciences at the University of Iceland. She was a Professor of Environmental Geochemistry and Environmental Sustainability at the University of Bristol, UK until 2008. Educated in Geochemistry and Petrology at the University of Iceland, Reykjavík (BSc) and Geochemistry at Northwestern University, Evanston, Illinois (MS, PhD) she changed her focus a decade ago from Earth Sciences to cross-disciplinary Sustainability Science. Her research pertains to sustainability in its widest context, including nature protection, economics, society and the wellbeing of citizens. She is currently developing a framework for the establishment of sustainable communities. Vala is also working on soil-sustainability indicators for land management and undertaking a comparative study of the relative fertility of conventionally versus organically managed land to ensure future food security. Her activities also include the establishment of a framework for a sustainable financial system and natural-resource use, and she is investigating the factors involved in complex multi-factorial disease development. Previously she studied the behaviour of pollutants in the natural environment and the link between environment and health.

Professor Ragnarsdóttir was a member of the Scientific Advisory Board for Framework 7 Environment Programme from 2006 to 2008. She has been a member of grant research panels for the EC (Brussels), NERC (UK), NSF (USA) and ESA (Netherlands). Vala is a past Director of the Geochemical Society and was a member of the Board of the European Association for Geochemistry and the Geological Society of Great Britain. She was the chair of the Schumacher Society and is a current board member of the Balaton Group. Professor Ragnarsdottir is a past Associate Editor of *Geochimica Cosmochimica Acta*, *Chemical Geology* and *Geochemical Transactions*. She is a current Guest Editor of *Solutions*.

# Contributors


E. Louise Ander
British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG

Aldo R. Boccaccini
University of Erlangen-Nuremberg, Department of Materials Science and Engineering, 91058 Erlangen, Germany

Pamela Castle
Former Chair of the Environmental Law Foundation

Mark R. Cave
British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG

Ho-Sik Chon
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Alexandra Collins
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Jason Dassyne
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Edward Derbyshire
Centre for Quaternary Research, Royal Holloway, University of London, Egham, Surrey, TW20 0EX

Danelle Dhaniram
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Mustafa B. A. Djamgoz
Department of Life Sciences, Imperial College London, Prince Consort Road, London SW7 2AZ

Sally Donovan
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Richard M. Evans
Centre for Toxicology, School of Pharmacy, University of London, 29–39 Brunswick Square, London

Claire J. Horwell
Institute of Hazard, Risk and Resilience, Department of Earth Sciences, Durham University, Science Laboratories, South Road, Durham, DH1 3LE

Timothy P. Jones
School of Earth and Ocean Sciences, Main Building, Cardiff University, Cardiff, Wales, CF10 3YE

Qin-Tao Liu
Current address: Dow Corning (China) Holding Co., Ltd.

Olwenn V. Martin
Institute for the Environment, Brunel University, Kingston Lane, Uxbridge, Middlesex, UB8 3PH

Rebecca McKinlay
Centre for Toxicology, University of London School of Pharmacy, 29–39 Brunswick Square, London

Superb K. Misra
Natural History Museum, Mineralogy, London SW7 5BD

Christopher J. Oates
Applied Geochemistry Solutions, 49 School Lane, Gerrards Cross, Buckinghamshire, SL9 9AZ

Dieudonné-Guy Ohandja
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Richard Owen
University of Exeter Business School, Streatham Court, Rennes Drive, Exeter, EX4 4PU; European Centre for Environment and Human Health, Peninsula College of Medicine and Dentistry, Royal Cornwall Hospital, Truro, TR1 3HD

Jilang Pan
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Xiyu Phoon
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Jane A. Plant
Centre for Environmental Policy and Department of Earth Science and Engineering, Imperial College London, Prince Consort Road, London SW7 2AZ

K. Vala Ragnarsdottir
Faculty of Earth Sciences, School of Engineering and Natural Sciences, Askja, University of Iceland, Reykjavik 101, Iceland

Khareen Singh
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Barry Smith
Intelliscience Ltd, 38A Station Rd, Nottingham, NG4 3DB

Teresa D. Tetley
Section of Pharmacology and Toxicology, National Heart and Lung Institute, Imperial College London, London SW3 6LY

Andrew Thorley
National Heart and Lung Institute, Imperial College London, London SW3 6LY

James Treadgold
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

Eugenia Valsami-Jones
Natural History Museum, Mineralogy, London SW7 5BD

Nikolaos Voulvoulis
Centre for Environmental Policy, Imperial College London, Prince Consort Road, London SW7 2AZ

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