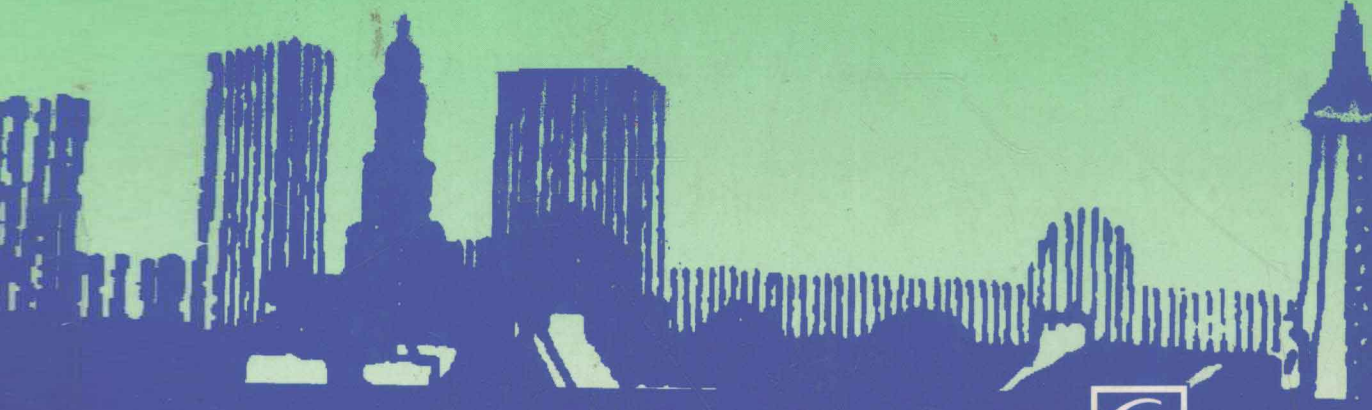
Second edition

CHEMICAL PRINCIPLES OF ENVIRONMENTAL POLLUTION

B.J. Alloway and D.C. Ayres



BLACKIE ACADEMIC & PROFESSIONAL

Chemical Principles of Environmental Pollution

Second edition

B. J. Alloway
University of Reading, UK
and
D. C. Ayres
Queen Mary and Westfield College,
University of London, UK

BLACKIE ACADEMIC & PROFESSIONAL
An Imprint of Chapman & Hall
London · Weinheim · New York · Tokyo · Melbourne · Madras

Published by Blackie Academic and Professional, an imprint of Chapman & Hall, 2–6 Boundary Row, London SE1 8HN, UK

Chapman & Hall, 2–6 Boundary Row, London SE1 8HN, UK

Chapman & Hall GmbH, Pappelallee 3, 69469 Weinheim, Germany

Chapman & Hall USA, 115 Fifth Avenue, New York, NY 10003, USA

Chapman & Hall Japan, ITP-Japan, Kyowa Building, 3F, 2-2-1 Hirakawacho, Chiyoda-ku, Tokyo 102, Japan

DA Book (Aust.) Pty Ltd, 648 Whitehorse Road, Mitcham 3132, Victoria, Australia

Chapman & Hall India, R. Seshadri, 32 Second Main Road, CIT East, Madras 600 035, India

First edition 1993
Reprinted 1994
Second edition 1997

Typeset in 10/12 pt Times by Thomson Press (I) Ltd, New Delhi
Printed in Great Britain by Clays Ltd, Bungay, Suffolk

ISBN 0 7514 0380 6

A catalogue record for this book is available from the British Library

Library of Congress Catalog Card Number: 96–85900

♾ Printed on permanent acid-free text paper, manufactured in accordance with ANSI/NISO Z39.48-1992 and ANSI/NISO Z39.48-1984 (Permanence of Paper)

Preface

Pollution is the most serious of all environmental problems and poses a major threat to the health and well-being of millions of people and global ecosystems. Other major environmental problems are also partly caused by pollution; these include global warming, climatic change and the loss of biodiversity through the extinction of many species. In the future, environmental pressures can only increase as a result of population growth and the expectation of higher living standards.

For at least thirty years people have become increasingly aware of these issues. As a result, governments and regulatory bodies have responded by taking action against grossly polluting activities and by enforcing tighter limits on the emission of pollutants into the environment. As the level of control improves so the financial costs increase exponentially, hence an effective limit must be enforced which does not impose unacceptable burdens on industrial producers.

As a consequence of the increasing economic and legal pressures which result from pollution control, there is a growing need for greater understanding of the scientific principles underlying environmental pollution. Appropriately qualified professionals will be needed in the energy, manufacturing, service and waste disposal industries and their regulatory authorities. They will be required to enforce increasingly strict standards and to monitor the environment for accidental pollution. The rapid growth in the numbers studying for undergradute and postgradute degrees and related qualifications in environmental science is a reflection of these requirements. Modules dealing with aspects of pollution have been introduced into many courses in the traditional disciplines of chemistry, biology, geography and civil engineering.

This book was written, in sympathy with these trends, for students and others with a basic knowledge of chemistry. It provides an introduction to the principles, and adopts a pollutant-oriented approach, rather than the more common one based on specific media such as air or water. All the main groups of substances are covered, and the principles relating to their nature, sources, transport, environmental behaviour and effects on targets. It is expected that readers will want to consult more advanced specialized texts dealing with particular topics, and an extensive bibliography has been included to further their studies.

The authors have been involved in teaching and researching this subject for many years and both have directed a BSc Environmental Science degree programme (at Westfield and Queen Mary and Westfield Colleges in the University of London). Their research interests include heavy metals and contaminated land (BJA), and organic pollutants and their analysis (DCA). Although both authors have come into environmental science from different subject backgrounds, in due course they both developed an interdisciplinary perspective. Nevertheless, it must be stressed that the investigation and management of environmental pollution requires the rigorous application of scientific principles. The theoretical basis of environmental pollution problems is intellectually demanding, and environmental scientists need to be able to understand the underlying principles in order to make effective decisions.

The advice of Dr Trevor Toube concerning mass spectrometry, of Dr Roger Brown on pollution monitoring and of Dr Peixun Zhang on emission spectroscopy, is gratefully acknowledged. We also thank Mr John Cross of the NRA and Ms Elizabeth Ayres for their help with the manuscript

BJA
DCA

Glossary of acronyms and abbreviations

AAS	Atomic absorption spectrophotometry (analysis)
ACGIH	American Conference of Govermental Industrial Hygienists
ADI	allowable daily intake (toxicology)
AEA	Atomic Energy Authority (UK)
AGR	advanced gas-cooled reactor
ALARA	as low as reasonably achievable
ALARP	as low as reasonably possible
AMU	atomic mass unit
ANOVA	analysis of variance (statistical test)
APEs	alkyl phenol ethoxylates (chemicals)
AQA	analytical quality assurance
BATNEEC	best available technology not entailing excessive cost
BBP	butyl benzyl phthalate (chemical)
BCF	biological concentration factor
BHA	butylated hydroxyanisole (chemical)
BHC	benzene hexachloride (chemical)
BHT	butylated hydroxytoluene (chemical)
BOD	biochemical oxygen demand
BPEO	best practicable environmental option
BPM	best practicable means
BSI	British Standards Institution
BTEX	benzene, toluene, ethyl benzene and xylene (suite of organic chemicals)
BWR	boiling water reactor (nuclear)
CAMP	Continuous Air Monitoring Programme (USA)
CANDU	Canadian Deuterium Uranium Reactor
CEC	cation exchange capacity (soil chemistry)
CEC	Commission of the European Communities
CERCLA	Comprehensive Environmental Response Compensation and Liability Act (US) (1980) ('Superfund') – see also SARA
CFCs	chlorofluorocarbons (chemicals)
CHCs	chlorinated hydrocarbon compounds (chemicals)
Ci	curie

CIMAH	Control of Industrial Major Accidents Regulation (1984) (UK)
CNS	central nervous system
COD	chemical oxygen demand
COPA	Control of Pollution Act (UK) (1974)
COSHH	Control of Substances Hazardous to Health (UK)
CPs	chlorophenols (chemicals)
CRM	certified reference material (analytical)
CTB	chemical time bomb
DBP	di-*n*-butyl phthalate (chemical)
DCE	dichloroethene (chemical)
DDE	dichlorodiphenyl dichloroethene (chemical)
DDT	dichlorodiphenyl trichloroethane (chemical)
DEHP	bis(2-ethylhexyl) phthalate (chemical)
DNA	deoxyribonucleic acid (biochemical: genetic code material)
DNAPL	dense non-aqueous-phase liquid
DOCs	dissolved organic compounds
DoE	Department of the Environment (UK)
DoE	Department of Energy (US)
DTPA	diethyltriaminepentaacetic acid (chemical reagent)
EDTA	ethylenediaminetetraacetic acid (chemical reagent)
EIA	Environmental Impact Assessment (also EA: environmental assessment)
EPA	Environmental Protection Agency (US)
EPA	Environmental Protection Act (UK) (1990)
EQO	environmental quality objective
ETA–AAS	electrothermal activation–atomic absorption spectrometry (elemental analysis)
EU	European Union (formerly European Community)
FGD	flue gas desulphurization
GC	gas chromatography (analysis)
GC–MS	GC combined with mass spectrometry (analysis)
GDP	gross domestic product
GFAAS	graphite furnace atomic absorption spectrophotometry (also referred to as ETA–AAS) (analysis)
GIS	geographical information systems
GLC	gas–liquid chromatography (analysis)
GLP	good laboratory practice
Gy	the Gray (100 rads)
HCFC	hydrogen-containing chlorofluorocarbon (chemical)
HCH	hexachlorohexane (chemical)
HMIP	Her Majesty's Inspectorate of Pollution (UK)
HPLC	high-pressure liquid chromatography (analysis) *also* high performance liquid chromatography

HSE	Health and Safety Executive (UK)
IAEA	International Atomic Energy Authority
IARC	International Agency for Research on Cancer
ICP–OES	inductively coupled plasma optical emission spectrometry (analysis)
ICP–MS	inductively coupled plasma mass spectrometry (analysis)
ICRP	International Commission for Radiological Protection
INES	International Nuclear Event Scale
IPC	Integrated Pollution Control (Europe)
IPCC	International Panel for Climate Change
ISO	International Standards Organization
JET	Joint European Taurus
LAAPC	Local Authority Air Pollution Control
LC_{50}	lethal concentration for 50% survival
LD_{50}	lethal dose for 50% survival
LFG	landfill gas
LMFBR	liquid metal fast-breeder reactor
LNAPL	light non-aqueous-phase liquid
LOAEL	lowest observable adverse effect level (toxicology)
LOEL	lowest observable effect level (toxicology)
LPG	liquefied petroleum gas
LULU	locally unwanted land use
LUST	leaking underground storage tank
MAC	maximum allowable concentration (USA)
MAFF	Ministry of Agriculture, Fisheries and Food
MCP	monochlorophenol (chemical)
MEL	maximum exposure limit (toxicology)
MSW	municipal solid waste
NAAQS	National Air Quality Standards (USEPA)
NAPL	non-aqueous-phase liquid
NBS	National Bureau of Standards (US): supplier of CRMs
MCP	monochlorophenol (chemical)
NIMBY	'not in my back yard'
NIOSH	National Institute of Occupational Safety and Health (USA)
NOAEL	no observable adverse effects level (toxicology)
NOEL	no observable effects level (toxicology)
NPEs	nonyl phenol ethoxylates (chemicals)
NRA	National Rivers Authority (UK) (Incorporated into Environmental Agency 1996)
NRPB	National Radiological Protection Board (UK)
NTA	nitriloacetic acid (chemical)

NTP	normal temperature (273.15 K) and pressure (101/325 Pa)
ODP	ozone depletion potential
OECD	Organization for Economic Co-operation and Development
OEL	occupational exposure limit (toxicology)
OES	occupational exposure standard
OP	organophosphorus
OSHA	Occupational Safety and Health Administration
PAH	polycyclic (or polynuclear) aromatic hydrocarbon (chemical)
PAN	peroxyacetyl nitrate (chemical)
PCB	polychlorinatedbiphenyl (chemical)
PCDD	polychlorodibenzo-*p*-dioxin (chemical)
PCDF	polychlorodibenzofuran (chemical)
PCP	pentachlorophenol (chemical)
PEL	permissible exposure limit (toxicology)
PM_{10}	particulate matter smaller than 10 μm
PMTWI	provisional maximum tolerable weekly intake (toxicology)
POMP	persistent organic micropollutant
PRA	probabilistic risk analysis
PTWI	provisional tolerable weekly intake (toxicology)
PVC	polyvinyl chloride (chemical)
PWR	pressurized water reactor
QA	quality assurance
QC	quality control
QSAR	quantity, structural activity relationship
Rad	absorbed radiation of 0.01 J/kg
RCRA	Resource, Conservation and Recovery Act (US) (1976)
Rem	Roentgen equivalent humans
RNA	ribonucleic acid (biochemical: genetic code material)
SARA	Superfund Amendments and Reauthorization Act (US) (1986): amendment to CERCLA (1980)
SMR	standardized mortality ratio (epidemiology)
STP	standard temperature and pressure
STEL	short-term exposure limit (toxicology)
TBT	tributyltin (chemical)
TCB	trichlorobiphenyl (chemical)
TCDD	tetrachlorodibenzo dioxin (chemical)
TCE	trichloroethene (chemical)
TDI	tolerable daily intake (toxicology)
TDS	total dissolved solids
TEF	toxic equivalent factor (toxicology)

TEL	tetraethyl lead (chemical)
TEQ	toxic equivalent quantity (TEF × concentration)
THORP	thermal oxide reprocessing plant
TLV	threshold limit value
TOMP	toxic organic micropollutant
TSP	total suspended particles
TWA	time-weighted average
UARG	Urban Air Review Group
VCM	vinyl chloride monomer (chemical)
VOC	volatile organic compound
Waldsterben	forest death
WDA	Waste Disposal Authority (UK)
WHO	World Health Organization
XRD	X-diffraction (mineralogical analysis)
XRF	X-ray fluorescence (elemental analysis)

Contents

Part One
Basic Principles