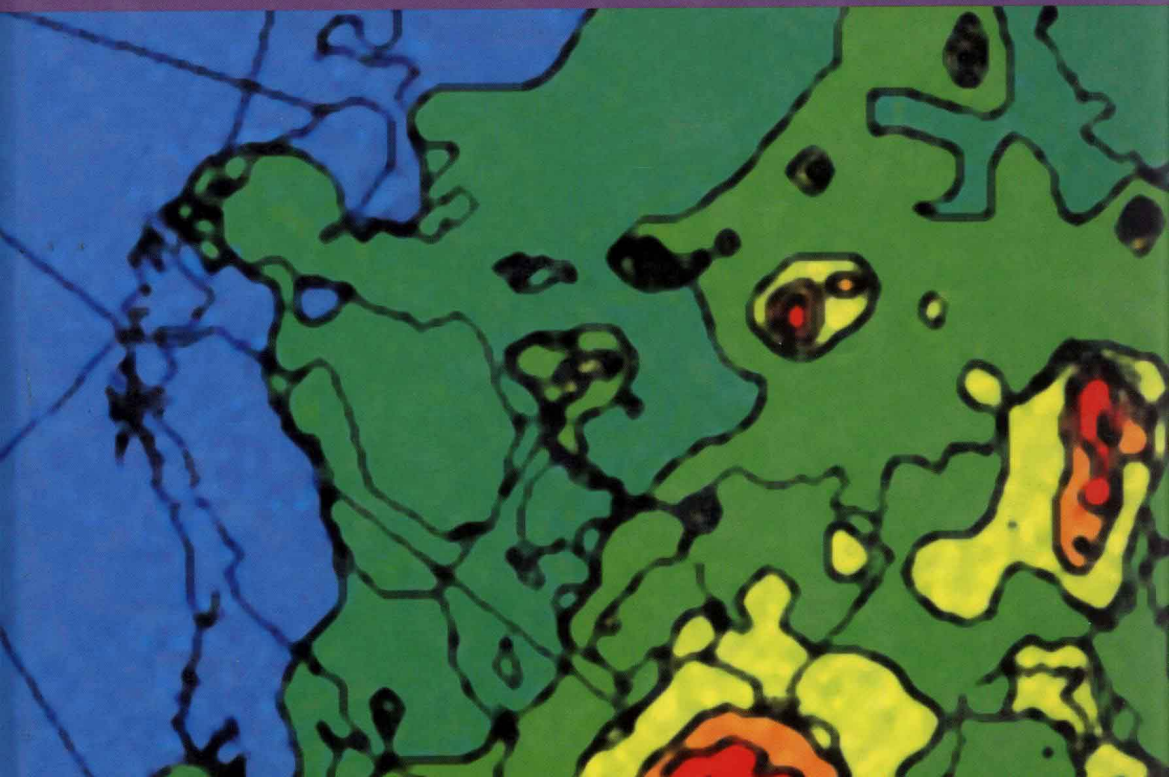
Clay's Library of Health and the Environment

AIR POLLUTION

SECOND EDITION

Jeremy Colls



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Clay's Library of Health and the Environment

An increasing breadth and depth of knowledge is required to tackle the health threats of the environment in the twenty-first century, and to accommodate the increasing sophistication and globalisation of policies and practices.

Clay's Library of Health and the Environment provides a focus for the publication of leading-edge knowledge in this field, tackling broad and detailed issues. The flagship publication *Clay's Handbook of Environmental Health*, now in its 18th edition, continues to serve environmental health officers and other professionals in over 30 countries.

To Mum and Dad

Acknowledgements

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Introduction

Air pollution has been with us since the first fire was lit, although different aspects have been important at different times. On the small scale, point source releases of individual pollutants can cause localised responses ranging from annoyance to physical injury. In urban areas, high concentrations of gases and particles from coal combustion and, more recently, motor vehicles have produced severe loss of air quality and significant health effects. On a regional scale, tropospheric ozone formation and acid deposition have been the major threats. Finally, emissions of carbon dioxide and other radiatively active gases, together with stratospheric ozone depletion, represent planet-scale assaults on the quality of our atmospheric environment.

This book is designed to cover the whole gamut of air pollution issues from a quantitative standpoint. In Chapters 1 and 2, the major sources of gaseous and particulate air pollution, together with an outline of possible control measures, are described. Mobile sources, which have taken over from stationary ones as the major threat to local air quality, get their own space in Chapter 3. Chapter 4 describes the most widely-used methods for measuring these pollutants. The temporal and geographical variations of concentrations and deposition on a national and international scale are outlined in Chapter 5. Once released, the effects of these pollutants depend critically on their dilution during dispersion, a process which is covered in Chapter 6. Chapter 7 gives an extended example of the data processing techniques that can be used to extract different types of information from a set of air pollution measurements. Although people tend to associate air quality, or the lack of it, with the outdoors, most of us spend most of our lives indoors, and specific aspects of this specialised environment are highlighted in Chapter 8. The effects of air pollution on plants, animals, materials and visual range are described in Chapters 9 and 10, and the recent issues of climate change and ozone depletion in Chapters 11 and 12. Finally, the effects of pollutants on the environment have led to a wide variety of standards and legislation for their control, and these are reviewed in Chapter 13.

With such a broad spectrum of topics, there is inevitably a considerable variation in the depth of coverage that reflects my own professional interests and experience. I have used as much original research material as possible, since that

is where the knowledge comes from in the first place and it is important for the reader to keep in touch with that process. I have also given relevant equations and tables of data to support the statements made in the text; there is little purpose in writing out the content of these in longhand as well, so they will usually repay more detailed examination. Although air pollution is a wholly international issue, my own access to data has resulted in a UK bias, followed in order of emphasis by Europe, the USA and the world at large. Readers are encouraged to pursue other sources for greater depth of coverage on any particular issue. Some suggestions are given as 'Further Reading' at the end of each chapter. These are not only useful documents in their own right, but also contain references to many more specialist research papers. Similarly, the figure captions cite many books, reports and research papers from which Figures for this book have been taken. If further information is required on a particular topic, then simply entering that phrase into a good Web search engine will usually provide some leads.

This book is aimed at a wide target audience – much of the material has been taught on both undergraduate and taught Masters programmes at Nottingham to students from a wide range of academic backgrounds. I hope it will be useful to as wide a range of readers elsewhere.

Acronyms and abbreviations

AA	ambient air – usually refers to plants growing in the open for comparison with those in chambers
AAS	atomic absorption spectroscopy
ACE	aerosol characterisation experiment
ACH	air changes per hour – an estimator of building ventilation rate
AES	atomic emission spectroscopy
AGCIH	American Conference of Government Industrial Hygienists
AMIS	air management information system
ANC	acid neutralising capacity
AOT40	accumulation over threshold – the measure currently favoured by UNECE for estimating ozone impact on plants
APHEA	air pollution and health – european approach
AQCD	air quality criteria document (US)
AQI	air quality index
AQMA	air quality management area (UK)
AQRV	air quality related value (US)
AQS	air quality standards (US)
ARN	automated rural network
AUN	automated urban network
BAF	biological amplification factor – used to describe the overall response of biological systems to ozone changes
BaP	benzo[*a*]pyrene
BART	best available retrofit technology
BATNEEC	best available techniques (or technology) not entailing excessive cost
BC	black carbon
BCC	basal cell carcinoma
BFO	bunker fuel oil
BPEO	best practicable environmental option
BPM	best practicable means – the long-established UK philosophy for pollution control
BS	British Standard

BTX	benzene, toluene and xylene
BUN	basic urban network – urban sites in the UK national network of eight-port 24-h samplers for black smoke and SO_2
CAA	Clean Air Act (US)
CAAA	Clean Air Act Amendments (US)
CALINE	California line source model – one of the most widely used dispersion models for vehicle emissions
CARB	California Air Resources Board
CCN	cloud condensation nuclei – the particles on which condensation initially occurs to form cloud droplets
CEC	Commission of the European Communities
CEH	Centre for Ecology and Hydrology (UK)
CF	charcoal-filtered – an OTC supplied with cleaned air
CFC	chlorofluorocarbon – family of chemicals responsible for depleting ozone in the stratosphere
CHESS	Community Health and Surveillance System (US)
CLRTAP	Convention on the Long Range Transport of Air Pollutants
CNC	condensation nucleus counter
COH	coefficient of haze
COHb	carboxyhaemoglobin – produced when blood haemoglobin absorbs CO
COMEAP	Committee on the Medical Effects of Air Pollutants (UK)
COP	Conference of Parties (for UNFCCC)
COPD	chronic obstructive pulmonary disease
CORINAIR	The EU programme to collect and map emissions data for all significant sources of eight gaseous pollutants
CPB	Canyon Plume Box model for calculating dispersion in urban areas
CPC	condensation particle counter
CPF	clothing protection factor
CRT	continuously regenerating trap
DALR	dry adiabatic lapse rate – the rate of decrease of temperature with height in the atmosphere applicable to a parcel of air that contains no liquid water. Value 9.8 °C km^{-1}
DEFRA	Department for the Environment, Food and Rural Affairs (UK)
DEP	diesel exhaust particles
DI	direct injection
DIAL	differential absorption lidar
DMA	differential mobility analyser
DME	dimethylether
DMS	dimethyl sulphide – organic sulphur compound released from marine phytoplankton that is eventually oxidised to sulphur dioxide and particulate sulphate in the atmosphere
DOAS	differential optical absorption spectroscopy

DOC	diesel oxidation catalyst
DoE	Department of the Environment (UK)
DOM	dissolved organic matter
DRAM	direct reading aerosol monitor
DTLR	Department for Transport, Local Government and the Regions (UK)
DU	dobson unit – for the column depth of ozone in the atmosphere
DVI	dust veil index
EA	Environment Agency (UK)
EAA	electrical aerosol analyser
EC	European Community
ECD	electron capture detector
ECE	Economic Commission for Europe (same as UNECE)
EDAX	energy dispersive analysis of X-rays
EDU	ethylenediurea – a chemical that protects plants from ozone
EEA	European Environment Agency
EEC	European Economic Community
EER	erythemally effective radiation – sunburning potential of a given radiation environment
EESC	equivalent effective stratospheric chlorine
EF	emission factor – e.g. g km^{-1}
EGR	exhaust gas recirculation
EIONET	European Environmental Information and Observation Network
ELISA	enzyme-linked immunosorbent assay
ELPI	electrostatic low pressure impactor
ELR	environmental lapse rate – the vertical profile of temperature in the atmosphere
EMEP	European Monitoring and Evaluation Programme
ENSO	El Niño southern oscillation
EPA	Environmental Protection Act (UK)
EPA	Environmental Protection Agency (US)
EPAQS	Expert Panel on Air Quality Standards (UK)
ERBS	Earth Radiation Budget Satellite
ESP	electrostatic precipitator
ETC/AQ	European Topic Centre on Air Quality
ETS	environmental tobacco smoke – the combination of MTS and STS that makes up the atmospheric load
EU	European Union
EUDC	extra-urban drive cycle (EC)
EUROAIRNET	European Air Quality Monitoring Network
FACE	free-air carbon dioxide enrichment – the system developed in the US for elevating the CO_2 concentration above field crops

FAR	First Assessment Report (by IPCC on climate change)
FEAT	fuel efficiency automobile test – an optical gas sensor that scans across the road width
FEV	forced expiratory volume – a measure of lung response to air pollutants
FGD	Flue gas desulphurisation – a range of chemical process plant that strips sulphur dioxide from flue gases before they are released to atmosphere
FID	flame ionisation detector
FTIR	Fourier transform infrared
FTP	Federal Test Program (US)
GC	gas chromatography
GCM	general circulation model
GCTE	Global Change and Terrestrial Ecosystems project
GHG	greenhouse gas
GWP	global warming potential
HAP	Hazardous Air Pollutants (US)
Hb	haemoglobin
HCFC	hydrochlorofluorocarbon – substitute for CFCs
HDV	heavy duty vehicle – such as a truck
HEPA	high efficiency particulate air
HFC	hydrofluorocarbon – substitute for CFCs
HGV	heavy goods vehicle
HMIP	Her Majesty's Inspectorate of Pollution (UK)
HPLC	high pressure liquid chromatography
HVAC	heating, ventilating and air-conditioning
ICAO	International Civil Aviation Organisation
ICP	inductively coupled plasma
IDI	indirect injection
IGAC	International Global Atmospheric Chemistry project
IPC	integrated pollution control
IPCC	intergovernmental panel on climate change
IPPC	integrated pollution prevention and control
IR	infrared
ISO	International Standards Organisation
ITE	Institute of Terrestrial Ecology (UK)
LA	local authority (UK)
LAPC	local air pollution control
LAQM	local air quality management (UK)
LCPD	large combustion plant directive (EC)
LDV	light duty vehicle – such as a van
LEV	low emission vehicle (US)
LGV	light goods vehicle
LIDAR	light detection and ranging

LNG	liquified natural gas
LRTAP	long-range transboundary air pollution
LTO	landing and take-off
MACT	maximum achievable control technology (US)
MATES	Multiple Air Toxics Exposure Study
MDO	marine diesel oil
MEET	methodology for calculating transport emissions and energy consumption
MOUDI	micro-orifice uniform deposit impactor
MRGR	mean relative growth rate – a measure of plant or animal vitality
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether
MTS	mainstream tobacco smoke – drawn from the cigarette during puffing
NAA	neutron activation analysis
NAAQS	National Ambient Air Quality Standards (US)
NAEI	National Atmospheric Emissions Inventory (UK)
NADP	National Atmospheric Deposition Program (US)
NAPAP	National Acid Precipitation Assessment Program – the major coordinated programme in the US to understand the processes of, and responses to, acid rain
NAQS	National Air Quality Strategy (UK)
NCLAN	National Crop Loss Assessment Network – the US experimental programme on plant responses to air pollutants
NETCen	National Environmental Technology Centre – performs a variety of air pollution services for the UK Government, including management and data processing for the AUN
NF	non-filtered – an OTC supplied with ambient air
NMHC	non-methane hydrocarbons – a sub-category of VOC, defined by compounds containing H and C but excluding methane because of its relatively high background concentration in the atmosphere
NMMAPS	National Morbidity, Mortality and Air Pollution Study (US)
NOTLINE	University of Nottingham line source dispersion model
NRPB	National Radiological Protection Board
OAF	optical amplification factor – used to describe the response of UV to ozone changes
OCD	ozone column depth
ODP	ozone depletion potential
OECD	Organisation for Economic and Cultural Development
OTC	open-top chamber – field chamber for plant pollution exposure
PAH	polycyclic aromatic hydrocarbons – a family of carcinogenic chemicals, including benzpyrenes
PAMS	particle analysis by mass spectroscopy

PAN	peroxyacetyl nitrate – an irritant gas formed by the same photochemical processes as ozone
PAR	photosynthetically active radiation – in the waveband 400 –700 nm
PBL	planetary boundary layer – the vertical region of the Earth's atmosphere from ground level up to about 1500 m within which the physical and chemical interactions with the surface mainly occur
PCB	polychlorinated biphenyls – carcinogenic pollutants released from PCB handling and poor PCB incineration
PCDF	polychlorinated dibenzofurans (known as furans for short) – a toxic pollutant produced in small quantities by incinerators
PCDD	polychlorinated dibenzodioxins (known as dioxins for short) – a toxic pollutant produced in small quantities by incinerators
PCR	polymerase chain reaction
PEC	particulate elemental carbon
PIB	polyisobutylene – a 2-stroke petrol additive to reduce smoke production
PIXE	proton-induced X-ray emission
PM	particulate matter
PM_{10}	particulate matter having an aerodynamic diameter less than 10 μm
$PM_{2.5}$	particulate matter having an aerodynamic diameter less than 2.5 μm
POP	persistent organic pollutant
ppb	parts per billion, or parts per 10^9, by volume
ppm	parts per million, or parts per 10^6, by volume
ppt	parts per trillion, or parts per 10^{12}, by volume
PSC	polar stratospheric cloud–ozone depletion reactions occur on the surfaces of cloud particles
PSI	Pollution Standards Index (US)
PTFE	polytetrafluorethylene – an inert plastic used for sample pipes when reactive gases such as ozone are present
PVC	polyvinyl chloride
QALY	quality-adjusted life years – method for assessing benefits of air quality improvements
QA/QC	quality assurance/quality control
RAF	reactivity adjustment factor – a measure of the ozone-forming potential of different fuel mixtures
RAG	radiatively active gas
RCEP	Royal Commission on Environmental Pollution (UK)
Re	Reynolds number
RH	relative humidity
RPK	revenue passenger kilometres
RVP	Reid vapour pressure

SAGE	Stratospheric Aerosol and Gas Experiment
SALR	saturated adiabatic lapse rate – the rate of decrease of temperature with height in the atmosphere applicable to a parcel of air that contains liquid water. Typical range 4–9.8 °C km^{-1}
SAR	Second Assessment Report (by IPCC on climate change)
SBLINE	University of Nottingham (Sutton Bonington campus) vehicle emission and dispersion model
SBS	sick building syndrome
SCA	specific collection area
SCC	squamous cell carcinoma
SED	standard erythemal dose (of UV radiation)
SEM	scanning electron microscopy
SI	Système International – the internationally recognised system of physical units based on the metre, kilogram, second and Coulomb
SIP	State Implementation Plan (US)
SMPS	scanning mobility particle sizer
SOF	soluble organic fraction
SOI	southern oscillation index
SOS	Southern Oxidants Study (US)
SST	supersonic transport
Stk	Stokes' number
STP	standard temperature and pressure – 0 °C and 1 atmosphere
STS	sidestream tobacco smoke – released from the cigarette between puffing
SUM60	sum of hourly-mean ozone concentrations >60 ppb
SUV	sport utility vehicle
SVP	saturated vapour pressure
TAR	Third Assessment Report (by IPCC on climate change)
TEA	triethanolamine – a strong absorbent for NO_2
TEAM	Total Exposure Assessment Methodology
TEM	transmission electron microscopy
TEOM	tapered element oscillating microbalance
TEQ	toxic equivalent – a standardisation of the toxicity of TOMPS
TOMPS	toxic organic micropollutants – generic term that includes PCDD, PCDF and other minority chemicals with recognised toxicity at low (ppt) concentrations
TOE	tonnes oil equivalent
TRL	Transport Research Laboratory (UK)
TSP	total suspended particulate – all the particles in the air, regardless of diameter
TWC	three-way catalyst – converts the three harmful gases in petrol-engined vehicle exhaust to carbon dioxide, nitrogen and water
UARS	upper atmosphere research satellite
ULPA	ultra low penetration air

ULSP	ultra low sulphur petrol
UNECE	United Nations Economic Commission for Europe – a group of countries, larger than the EU and including the US, that has a wide ranging remit to organise joint ventures in European affairs
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	*see* EPA
UV	ultraviolet radiation, conventionally defined as occurring in the wavelength range below 400 nm. Subdivided into UVA, UVB and UVC
VEI	volcanic explosivity index
VOC	volatile organic compound – molecules, mostly containing hydrogen and carbon, that are released from sources such as motor fuels and solvents. They are toxic in their own right and serve as precursors for ozone formation
WHO	World Health Organisation
WTP	willingness to pay – method for assessing the benefits of air quality improvements
XRF	X-ray fluorescence
ZEV	zero emission vehicles – presumed to be electric, and required by law to make up a certain proportion of the fleet in California