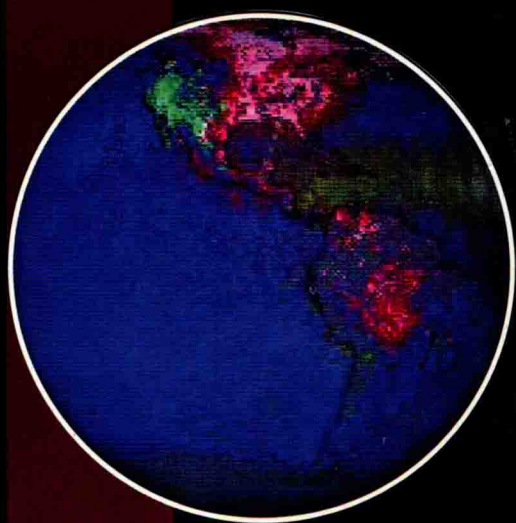


Third Edition

# ENVIRONMENTAL TOXICANTS

Human Exposures and  
Their Health Effects



Edited by  
Morton Lippmann

# **ENVIRONMENTAL TOXICANTS**

---

## **Human Exposures and Their Health Effects**

Third Edition

Edited by

**MORTON LIPPMANN**



**WILEY**  
A JOHN WILEY & SONS, INC., PUBLICATION

Copyright © 2009 by John Wiley & Sons, Inc. All rights reserved

Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at [www.wiley.com](http://www.wiley.com).

***Library of Congress Cataloging-in-Publication Data:***

Environmental toxicants : human exposures and their health effects / [edited by] Morton Lippmann. – 3rd ed.

p. ; cm.

Includes bibliographical references and index.

ISBN 978-0-471-79335-9 (cloth)

1. Environmental health. 2. Environmental technology. I. Lippmann, Morton.

[DNLM: 1. Environmental Pollutants—adverse effects. 2. Environmental Exposure. 3. Environmental Health. 4. Environmental Pollutants—toxicity. WA 671 E615 2009]

RA565.E58 2009

363.7—dc22

2008036266

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

**ENVIRONMENTAL  
TOXICANTS**

## PREFACE

This is the third edition of *Environmental Toxicants: Human Exposures and Their Health Effects*. It provides updated versions of chapters that appeared in the first (1992) and second (2000) editions, and it broadens the coverage to include two new toxicant categories (one is arsenic and its compounds, and the other is endocrine disrupting chemicals). As before, it is focused on providing current knowledge on environmental health challenges to people in our homes and communities resulting from exposures to chemical and physical agents that they encounter in the course of their daily lives. This book remains unique in terms of its depth of coverage on a limited number of environmental agents that are known to have, or are highly likely to have, adverse health effects following exposures that are within the ranges that occur in contemporary populations in economically developed countries. Extrapolation of likely effects in developing countries, where toxicant exposures may be substantially higher, need to be made with caution, since susceptibility to adverse effects may differ as a result of differences in diet, pre-existing diseases, thermal stresses, and access to modern health care. Chapter 1 has been expanded to include discussions of study options for increasing our knowledge of biological responses to environmental toxicant exposures, as well as of new and developing methods for the elucidation of responses at the molecular level.

I gratefully acknowledge the outstanding contributions of the other chapter authors who are my colleagues and peers. They are all outstanding and widely recognized professionals with many demands on their time, and this unique book would not have been possible without their generous commitment.

Periodic revisions of the content of the chapters herein are necessary because of our ever-increasing knowledge base, which has been facilitated by the development of new and improved measurement and modeling, and data management technologies. These technologies, and the growth of interdisciplinary investigations of complex phenomena, have enabled investigatory teams to go beyond the identification of statistically significant associations between environmental exposures and health-related responses in human populations, laboratory animal cohorts, and cell cultures *in vitro*, to the underlying biological pathways and mechanisms that are applicable to realistic exposure levels. While

notable progress has been made in environmental health sciences in recent years, significant challenges remain, not the least of which is access to research funding from government and private sources at a time when our collective capacities are increasing for characterizing (1) exposures and their geographic and temporal distributions; (2) biological mechanisms responsible for the adverse effects produced by environmental exposures; (3) susceptibility factors that account for the generally large interindividual variability in responses to exposure; and (4) exposure–response relationships for sensitive population segments. Another challenge is that the populations of both the general public and the environmental health research community are aging. Older people are clearly a susceptible population to many environmental toxicants, and the research needed to identify means of recognizing, evaluating, and controlling exposures to these toxicants will require both additional research funding and recruitment and training of young investigators who can carry out such research over at least several decades into the future. Some of these new trainees may well be the authors of chapters in future editions of this reference volume.

I hereby recognize the contributions of those who, in addition to writing chapters, made substantial contributions to the completion of this edition. In particular, I want to recognize Toni Moore, Anita Parkhurst, and Angela Muniz for their diligent and effective management of the text preparation and presentation, and Gordon Cook for the preparation of many of the figures. Finally, my own contributions would not have been possible without the cooperation and patience of my wife, Janet.

*New York University School of Medicine*

MORTON LIPPMANN

# CONTRIBUTORS

**Donald R. Bergfelt**, Division of Exposure Assessment, Office of Science Coordination and Policy, Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, USA

**Arline L. Bronzaft**, 505 East 79th Street, 8B, New York, NY 10021, USA

**Richard J. Bull**, MoBull Consulting, 1928 Meadows Drive North, Richland, WA 99352, USA

**James S. Bus**, Toxicology Research Laboratory, Dow Chemical Co., 1803 Building, Midland, MI 48674, USA

**Luz Claudio**, Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York, NY 10029, USA

**Mitchell D. Cohen**, Nelson Institute of Environmental Medicine, New York University School of Medicine, 57 Old Forge Road, Tuxedo, NY 10987, USA

**Norman Cohen**, New York University (Retired)

**Francis Colville**, Radiofrequency Program, U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD, 21010-5403, USA

**Nigel Cridland**, National Radiological Protection Board, Chilton, Didcot, Oxon OX11 0RQ, UK

**Colin Driscoll**, National Radiological Protection Board (Retired)

**Michael A. Gallo**, Environmental & Occupational Health Science Institute, 681 Frelinhuysen Road, Piscataway, NJ 08855-1179, USA

**Eric Garshick**, Pulmonary and Critical Care Medicine Section, VA Boston Healthcare System; Channing Laboratory, Brigham and Women's Hospital; and Harvard Medical School, Boston, MA, USA

**Bernard D. Goldstein**, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA, 15261, USA

**Philippe Grandjean**, Department of Environmental Medicine, Odense University, Winslowparken 17, DK-5000 Odense, Denmark

**Lester D. Grant**, 517 Colony Woods Drive, Chapel Hill, NC, USA

**K. Christiana Grim**, Division of Exposure Assessment, Office of Science Coordination and Policy, Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, USA

**Naomi H. Harley**, Department of Environmental Medicine, New York University Medical School, 550 First Avenue, New York, NY 10016, USA

**Fred D. Hoerger**, Dow Chemical (Retired)

**Michael T. Kleinman**, Department of Community and Environmental Medicine, University of California at Irvine, Irvine, CA 92697-1825, USA

**Philip J. Landrigan**, Department of Community Medicine, Mount Sinai Medical Center, Box 1057, New York, NY 10029-6574, USA

**George D. Leikauf**, Department of Environmental and Occupational Health, Graduate School of Public Health, Bridgestone Point Bldg, Suite 359, 100 Technology Drive, Pittsburgh, PA 15219, USA

**Morton Lippmann**, New York University School of Medicine, 21 Old Forge Lane, Tarrytown, NY 10591, USA

**Raymond C. Loehr**, 19360 Magnolia Grove Square No. 405, Lansdowne, VA 20176, USA

**Kathryn R. Mahaffey**, Office of Science Coordination and Policy, Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, USA

**Joe L. Mauderly**, Inhalation Toxicology Research Institute, P.O. Box 5890, Albuquerque, NM 87185, USA

**John J. Mauro**, 209 Ueland Road, Red Bank, NJ 07701, USA

**Jessica C. Meiller**, Division of Exposure Assessment, Office of Science Coordination and Policy, Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, USA

**Lars Mølhave**, Institute of Environmental and Occupational Medicine, University of Aarhus, DK-8000 Aarhus C, Denmark

**Gila I. Neta**, Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA

**Jesper B. Nielsen**, Institute of Public Health, University of Southern Denmark, Winslowparken 17, DK-5000 Odense, Denmark

**Larry W. Rampy**, Dow Chemical (Retired)

**Douglas A. Rausch**, Dow Chemical (Retired)

**Joseph V. Rodricks**, The Life Sciences Consultancy LLC, 750 17th Street, NW, Suite 1000, Washington, DC 20006, USA

**Toby G. Rossman**, Nelson Institute of Environmental Medicine, New York University School of Medicine, 57 Old Forge Road, Tuxedo, NY 10987, USA

**Jonathan M. Samet**, Department of Epidemiology, The Johns Hopkins University, Suite 6039, 615 N. Wolfe Street, Baltimore, MD 21205-2179, USA

**Richard B. Schlesinger**, Dyson College of Arts & Sciences, Pace University, 861 Bedford Road, Pleasantville, NY 10570, USA

**David H. Sliney**, 406 Streamside Drive, Fallston, MD 21047-2806, USA

**Shirlee W. Tan**, The Smithsonian Institution, National Zoological Park, 3000 Connecticut Avenue, NW, Washington, DC, USA

**Arthur C. Upton**, 250 East Alameda, Apartment 636, Santa Fe, NM 87501, USA

**Mark J. Utell**, Pulmonary Unit, University of Rochester Medical Center, Box 692, Rochester, NY 14642-8692, USA

**Sophia S. Wang**, Division of Cancer Epidemiology and Genetics, National Cancer Institute, Washington, DC, USA

**Gisela Witz**, Department of Environmental and Occupational Medicine, Robert Wood Johnson Medical School, Piscataway, NJ, USA

# CONTENTS

<b>PREFACE</b>	<b>xv</b>
----------------	-----------

<b>CONTRIBUTORS</b>	<b>xvii</b>
---------------------	-------------

<b>1 Introduction and Background</b>	<b>1</b>
--------------------------------------	----------

- 1.1 Characterization of Chemical Contaminants, 2
- 1.2 Human Exposures and Dosimetry, 7
- 1.3 Chemical Exposures and Dose to Target Tissues, 8
- 1.4 Concentration of Toxic Chemicals in Human Microenvironments, 9
- 1.5 Inhalation Exposures and Respiratory Tract Effects, 12
- 1.6 Ingestion Exposures and Gastrointestinal Tract Effects, 18
- 1.7 Skin Exposure and Dermal Effects, 19
- 1.8 Absorption through Membranes and Systemic Circulation, 20
- 1.9 Accumulation in Target Tissues and Dosimetric Models, 21
- 1.10 Indirect Measures of Past Exposures, 22
- 1.11 Characterization of Health, 23
- 1.12 Exposure–Response Relationships, 25
- 1.13 Study Options for Health Effects Studies, 31
- References, 35

<b>2 Perspectives on Individual and Community Risks</b>	<b>39</b>
---	-----------

- 2.1 Nature of Risk, 39
- 2.2 Identification and Quantification of Risks, 41
- 2.3 Risk Communication, 46
- 2.4 Risk Reduction, 49
- References, 52

<b>3</b>	<b>Reducing Risks—An Environmental Engineering Perspective</b>	<b>55</b>
3.1	Introduction, 55	
3.2	Environmental Risk-Based Decision Making, 56	
3.3	Applications and Use, 60	
3.4	Recent Information, 67	
3.5	Integrated Assessments, 71	
3.6	Summary, 72	
	References, 73	
<b>4</b>	<b>Clinical Perspective on Respiratory Toxicology</b>	<b>77</b>
4.1	Concepts of Exposure, 78	
4.2	Tools for Studying Individuals, 79	
4.3	Tools for Studying Populations, 88	
4.4	Cardiovascular Responses, 95	
4.5	Limitations of Clinical and Epidemiological Assessments of the Effects of Inhaled Agents, 96	
4.6	Advice and Counseling of Patients, 97	
4.7	Summary, 99	
	References, 100	
<b>5</b>	<b>Industrial Perspectives: Translating the Knowledge Base into Corporate Policies, Programs, and Practices for Health Protection</b>	<b>107</b>
5.1	The Life Cycle of a Chemical: Many Points for Possible Intervention, 108	
5.2	The Knowledge Base for the Identification of Hazard Control Strategies, 109	
5.3	Industrial Hygiene and Occupational Health Programs: Implementing the Knowledge Base, 111	
5.4	Product Stewardship, 114	
5.5	Responsible Care®, 117	
5.6	Concluding Perspective, 119	
<b>6</b>	<b>Drinking Water Disinfection By-Products</b>	<b>121</b>
6.1	Introduction, 121	
6.2	Chemical Methods of Disinfection, 122	
6.3	Chemical Nature and Occurrence of Disinfectant By-Products, 124	
6.4	Associations of Human Disease with Drinking Water Disinfection, 132	
6.5	General Toxicological Properties of Disinfectants, 144	
6.6	General Toxicological Properties of Disinfectant By-Products, 145	
6.7	Carcinogenic Properties of Disinfectants, 154	
6.8	Carcinogenic By-Products of Disinfectants, 154	
6.9	Effects of Disinfectants and Their By-Products on Reproduction, 165	
6.10	Effects on Development, 168	
6.11	By-Products of Potential Interest, 170	

- 6.12 Summary and Conclusions, 172
- Glossary, 174
- References, 176

## **7 Food 197**

- 7.1 Introduction, 197
- 7.2 Legal and Regulatory Framework in the United States, 201
- 7.3 Toxicity Test Requirements and Safety Criteria, 203
- 7.4 Substances Intentionally Added to Food, 208
- 7.5 Food Contaminants of Industrial Origin, 216
- 7.6 Constituents and Contaminants of Natural Origin, 219
- 7.7 Food Safety in the European Union, 229
- 7.8 Summary and Conclusion, 234
  - Acronyms, 235
  - References, 235

## **8 Volatile Organic Compounds and Sick Building Syndrome 241**

- 8.1 Introduction, 241
- 8.2 Prevalence of Exposures to Volatile Organic Compounds, 242
- 8.3 Health and Volatile Organic Compounds, 245
- 8.4 Prevalence of the Sick Building Syndrome, 247
- 8.5 Dose–Response Relationships for Health Effects Caused by Low-Level VOC Exposure, 249
- 8.6 Guidelines for Volatile Organic Compounds in Nonindustrial Indoor Environments-Principles for Establishment of Guidelines, 251
  - References, 254

## **9 Formaldehyde and Other Aldehydes 257**

- 9.1 Background, 257
- 9.2 Single-Exposure Health Effects, 269
- 9.3 Effects of Multiple Exposures, 281
  - References, 292

## **10 Ambient Air Particulate Matter 317**

- 10.1 Sources and Pathways for Human Exposure, 318
- 10.2 Ambient Air PM Concentrations, 323
- 10.3 Extent of Population Exposures to Ambient Air PM, 326
- 10.4 Nature of the Evidence for Human Health Effects of Ambient Air PM, 328
- 10.5 Epidemiological Evidence for Human Health Effects of Ambient Air PM, 329
- 10.6 Discussion and Current Knowledge on the Health Effects of PM, 354

10.7 Standards and Exposure Guidelines, 356	
References, 359	
<b>11 Arsenic</b>	<b>367</b>
11.1 Introduction, 367	
11.2 Physical and Chemical Properties of Environmental as and Its Compounds, 368	
11.3 Environmental Exposures to the General Population: Sources and Standards, 371	
11.4 Pathways and Kinetics for <i>in vivo</i> Uptake, Distribution, and Elimination, 374	
11.5 As Essentiality, 375	
11.6 Health Effects and Exposure–Response Relationships, 376	
11.7 Biomarkers of Exposure, Susceptibility, and Effect, 380	
11.8 Mitigating Effects and Controlling Exposures, 381	
References, 383	
<b>12 Asbestos and Other Mineral and Vitreous Fibers</b>	<b>395</b>
12.1 Important Special Properties of Fibers, 395	
12.2 Exposures to Fibers, 399	
12.3 Fiber Deposition in the Respiratory Tract, 402	
12.4 Fiber Retention, Translocation, Disintegration, and Dissolution, 404	
12.5 Properties of Fibers Relevant to Disease, 413	
12.6 Fiber-Related Diseases/Processes, 413	
12.7 Review of Biological Effects of Size-Classified Fibers in Animals and Humans, 415	
12.8 Critical Fiber Parameters Affecting Disease Pathogenesis, 420	
12.9 Exposure–Response Relationships for Asbestos-Related Lung Cancer and Mesothelioma: Human Experience, 429	
12.10 Risk Assessment Issues, 438	
12.11 Key Factors Affecting Fiber Dosimetry and Toxicity: Recapitulation and Synthesis, 443	
Acknowledgments, 446	
Acronyms, 446	
References, 446	
<b>13 Benzene</b>	<b>459</b>
13.1 Benzene Exposure, 460	
13.2 Uptake, 462	
13.3 Metabolism and Disposition, 462	
13.4 Mechanisms of Toxicity, 471	
13.5 Risk Assessment, 482	
References, 486	
<b>14 Carbon Monoxide</b>	<b>499</b>
14.1 Introduction, 499	
14.2 CO Exposure and Dosimetry, 500	

14.3	Mechanisms of CO Toxicity, 501	
14.4	Populations at Risk of Health Effects Due to CO Exposure, 502	
14.5	Regulatory Background, 503	
14.6	Health Effects of CO, 505	
14.7	Summary and Conclusions, 515	
	Acknowledgments, 517	
	References, 517	
<b>15</b>	<b>Chromium</b>	<b>529</b>
15.1	Introduction, 529	
15.2	Essentiality, 529	
15.3	Environmental Exposures, 530	
15.4	Toxicological Effects, 535	
15.5	Exposure Guidelines and Standards, 543	
	References, 544	
<b>16</b>	<b>Diesel Exhaust</b>	<b>551</b>
16.1	Historical Overview, 551	
16.2	Composition of Diesel Exhaust, 553	
16.3	Exposures to Diesel Exhaust, 559	
16.4	Health Effects, 561	
16.5	Current Issues, 609	
	Acknowledgments, 613	
	References, 613	
<b>17</b>	<b>Dioxins and Dioxin-Like Chemicals</b>	<b>633</b>
17.1	Introduction, 633	
17.2	Sources, 634	
17.3	Toxicological Effects and Mechanisms of Action, 640	
17.4	Mechanisms of Action, 643	
	References, 651	
<b>18</b>	<b>Endocrine Active Chemicals: Broadening the Scope</b>	<b>661</b>
18.1	Introduction, 661	
18.2	Biomarkers: Terminology from Various Disciplines, 664	
18.3	End Points and Clinical Signs Associated with Endocrine Activity, 666	
18.4	Environmental Chemicals and End Points: Case Examples, 675	
18.5	Developmental Origins of Health and Disease, 681	
18.6	Transgenerational Effects, 684	
18.7	Conclusion, 686	
	References, 687	

<b>19</b>	<b>Secondhand Smoke</b>	<b>703</b>
19.1	Exposure to Secondhand Smoke, 705	
19.2	Health Effects of Involuntary Smoking in Children, 711	
19.3	Health Effects of Involuntary Smoking in Adults, 722	
19.4	SHS and Coronary Heart Disease, 730	
19.5	Respiratory Symptoms and Illnesses in Adults, 734	
19.6	Summary, 740	
	References, 741	
<b>20</b>	<b>Lead and Compounds</b>	<b>757</b>
20.1	Introduction, 757	
20.2	Physical/Chemical Properties and Behavior of Lead and Its Compounds, 758	
20.3	Lead in the Environment and Human Exposure, 761	
20.4	Lead Absorption, 766	
20.5	Distribution, 771	
20.6	Kinetics, 774	
20.7	Biomarkers, 781	
20.8	Health Effects, 785	
20.9	Mechanisms Underlying Lead Toxicity, 792	
20.10	Treatment of Lead Toxicity, 796	
	References, 798	
<b>21</b>	<b>Mercury</b>	<b>811</b>
21.1	Introduction, 811	
21.2	Chemistry, 811	
21.3	Sources, 812	
21.4	Environmental Exposures, 813	
21.5	Occupational Exposures, 815	
21.6	Kinetics and Metabolism, 816	
21.7	Health Effects, 818	
21.8	Prevention, 820	
	References, 821	
<b>22</b>	<b>Nitrogen Oxides</b>	<b>823</b>
22.1	Introduction, 823	
22.2	Sources, 823	
22.3	Nitrogen Dioxide, 824	
22.4	Nitric Oxide, 845	
22.5	Nitric/Nitrous Acid, 848	
22.6	Inorganic Nitrates, 849	
	References, 851	
<b>23</b>	<b>Ozone</b>	<b>869</b>
23.1	Introduction, 869	
23.2	Background on Exposures and Health-Related Effects, 873	

23.3	Effects of Short-Term Exposures to Ozone in Humans, 877	
23.4	Factors Affecting the Variability of Responsiveness in Humans, 890	
23.5	Studies of Populations Exposed to Ozone in Ambient Air, 892	
23.6	Effects Observed in Studies in Laboratory Animals, 900	
23.7	Determinants of Responsiveness to Ozone Exposures in Animal Studies, 901	
23.8	Effects of Multiple Day and Ambient Episode Exposures, 908	
23.9	Chronic Effects of Ambient Ozone Exposures, 910	
23.10	Ambient Air Quality Standards and Guidelines, 917	
23.11	Summary and Conclusions, 920	
	Acknowledgment, 922	
	References, 922	
<b>24</b>	<b>Pesticides</b>	<b>937</b>
24.1	Evolving Patterns of Pesticide Use, 938	
24.2	Export of Hazardous Pesticides, 939	
24.3	Exposure to Pesticides, 939	
24.4	Epidemiology of Acute Pesticide Poisoning, 942	
24.5	Toxicity of Pesticides, 943	
24.6	Pesticides and Endocrine/Reproductive Toxicity, 949	
24.7	Pesticides and Childhood Cancer, 950	
24.8	Legislative Framework, 950	
24.9	Conclusion: Issues for the Future, 952	
	References, 953	
<b>25</b>	<b>Sulfur Oxides—SO<sub>2</sub>, H<sub>2</sub>SO<sub>4</sub>, NH<sub>4</sub>HSO<sub>4</sub>, and (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub></b>	<b>957</b>
25.1	Sources and Exposures, 957	
25.2	Health Effects, 961	
25.3	Ambient Air Quality Standard and Guidelines, 989	
	Acknowledgments, 991	
	References, 991	
<b>26</b>	<b>Microwaves and Electromagnetic Fields</b>	<b>1001</b>
26.1	Background, 1003	
26.2	Philosophical Approaches, 1004	
26.3	Standards Development, 1005	
26.4	Current Developments, 1010	
26.5	Protective Measures, 1012	
26.6	Conclusions, 1014	
26.7	Glossary, 1015	
	References, 1016	
<b>27</b>	<b>Sources, Levels and Effects of Manmade Ionizing Radiation and Radioactivity</b>	<b>1021</b>
27.1	Source Documents, 1021	
27.2	Special Units, 1022	

27.3	Sources of Manmade Radioactivity and Radiation, 1024	
27.4	Nuclear Fuel Cycle, 1025	
27.5	Discussion of Radiation Doses from the Nuclear Fuel Cycle, 1038	
27.6	Nuclear Weapons Complex, 1043	
27.7	Local, Tropospheric, and Global Fallout, 1048	
27.8	Medical Exposures, 1050	
27.9	Industrial Uses (Other than the Nuclear Fuel Cycle), 1054	
27.10	Consumer Products, 1055	
27.11	Overview of Potential Health Impacts of Natural and Manmade Sources of Radioactivity, 1057	
	References, 1066	
<b>28</b>	<b>Noise: Its Effects and Control</b>	<b>1071</b>
28.1	Definitions of Sound and Noise, 1071	
28.2	Noise Exposure is Widespread and Annoying, 1072	
28.3	Effects of Loud Sounds and Noise on Hearing, 1075	
28.4	Noise as a Stressor, 1076	
28.5	Noise and Sleep Interference, 1077	
28.6	Noise and Mental Health, 1077	
28.7	Noise Affects Children's Cognitive, Language and Learning Skills, 1078	
28.8	Impacts of Low-Frequency Noise, 1079	
28.9	Civility, Responsibility, and Noise, 1079	
28.10	Controlling Noise, 1080	
28.11	Education and Public Awareness, 1084	
28.12	Summary, 1084	
	References, 1085	
<b>29</b>	<b>Radon and Lung Cancer</b>	<b>1089</b>
29.1	Radon and Lung Cancer, 1089	
29.2	Outdoor Radon, 1093	
29.3	Indoor Radon, 1097	
29.4	The Other Radon, <sup>220</sup> Rn, Thoron, 1100	
29.5	Radon Epidemiology in Underground Mines, 1100	
29.6	Residential Epidemiology, 1102	
29.7	Lung Dosimetry, 1104	
29.8	Lung Cancer Models for Humans, 1107	
29.9	Childhood Exposure, 1113	
29.10	Animal Studies, 1114	
29.11	Smoking and Radon, 1114	
29.12	Summary, 1115	
	References, 1116	
<b>30</b>	<b>Ultraviolet Radiation</b>	<b>1121</b>
30.1	Introduction, 1121	
30.2	Pathways for Human Exposure, 1122	
30.3	Sources of Ultraviolet Radiation, 1124	