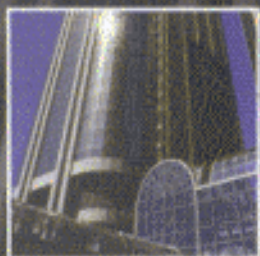


HANDBOOKS

*McGraw-Hill*

# INDOOR AIR QUALITY HANDBOOK



JOHN D. SPENGLER, JONATHAN M. SAMET,  
JOHN F. McCARTHY

# CONTENTS

<b>Contributors</b>	xxv
<b>Acknowledgments</b>	xxix

## **Part 1 Introduction**

<b>Chapter 1. Introduction to the IAQ Handbook</b>	<i>John D. Spengler, Jonathan M. Samet, and John F. McCarthy</i>	<b>1.3</b>
--	--	------------

---

- 1.1 Introduction to the Handbook / 1.3
- 1.2 Organization of the *Indoor Air Quality Handbook* / 1.4
- 1.3 History of Research on Indoor Air Quality / 1.7
- 1.4 The Roles of Professionals in Indoor Air Quality / 1.13
- References / 1.17

<b>Chapter 2. The History and Future of Ventilation</b>	<i>D. Michelle Addington</i>	<b>2.1</b>
---	------------------------------	------------

---

- 2.1 The History of Building Ventilation / 2.2
- 2.2 The Contemporary Approach to Ventilation / 2.7
- 2.3 Future Directions in Ventilation / 2.11
- References / 2.15

<b>Chapter 3. Sick Building Syndrome Studies and the Compilation of Normative and Comparative Values</b>	<i>Howard S. Brightman and Nanette Moss</i>	<b>3.1</b>
--	---	------------

---

- 3.1 Introduction / 3.1
- 3.2 European Studies / 3.6
- 3.3 United States Studies / 3.16
- 3.4 Discussion / 3.27
- References / 3.28

<b>Chapter 4. Estimates of Potential Nationwide Productivity and Health Benefits from Better Indoor Environments: An Update</b>	<i>William J. Fisk</i>	<b>4.1</b>
---	------------------------	------------

---

- 4.1 Introduction / 4.2
- 4.2 Approach / 4.2
- 4.3 Linkage of Building and Indoor Environmental Quality Characteristics to Health and Productivity / 4.3
- 4.4 Example Cost-Benefit Analysis / 4.26
- 4.5 Conclusions / 4.29
- 4.6 Implications / 4.29
- References / 4.31

- 5.1 Introduction / 5.1
- 5.2 IAQ Health Factors / 5.3
- 5.3 The Building Construction Process / 5.9
- 5.4 Healthy Building Design / 5.10
- 5.5 Tools for Designing Ventilation / 5.19
- 5.6 Conclusion / 5.25
- References / 5.26
- Internet Resources / 5.29

## **Part 2 Building Systems**

---

**Chapter 6. An Overview of the U.S. Building Stock** *Richard C. Diamond* **6.3**

---

- 6.1 Introduction to the U.S. Building Stock / 6.3
- 6.2 Characteristics of the Existing U.S. Housing Stock / 6.5
- 6.3 Characteristics of the New U.S. Housing Stock / 6.9
- 6.4 Trends in New Housing Construction / 6.9
- 6.5 Characteristics of Existing U.S. Commercial Buildings / 6.10
- 6.6 Characteristics of New U.S. Commercial Buildings / 6.15
- 6.7 Trends in New Commercial Construction / 6.16
- References / 6.17

---

**Chapter 7. HVAC Systems** *David W. Bearg* **7.1**

---

- 7.1 Descriptions of HVAC Systems / 7.1
- 7.2 Individual Components of HVAC Systems / 7.2
- 7.3 Functions of HVAC Systems / 7.8
- 7.4 Overview of Types of HVAC Systems / 7.9
- 7.5 Control of the HVAC System / 7.15
- References / 7.17

---

**Chapter 8. HVAC Subsystems** *Jerry F. Ludwig* **8.1**

---

- 8.1 Ducts, Plenums, and Diffusers / 8.1
- 8.2 Heat Exchangers / 8.21
- 8.3 Humidification and Building Envelope / 8.24
- 8.4 Dryers / 8.31
- 8.5 Cooling Towers / 8.33
- 8.6 Summary / 8.36
- References / 8.36

---

**Chapter 9. Air Cleaning—Particles** *Bruce N. McDonald and Ming Ouyang* **9.1**

---

- 9.1 Introduction / 9.1
- 9.2 Brief Description of Aerosols / 9.1
- 9.3 Particle Removal by Filters, Electronic Air Cleaners, Cyclones, and Scrubbers / 9.4
- 9.4 Filter Types by Filter Media and Construction / 9.10
- 9.5 Rating Filter and ESP Performance: Test Methods and Standards / 9.12

- 9.6 Applications / 9.17
- 9.7 Additional Considerations / 9.25
- References / 9.26
- Suggestions for Further Reading / 9.28

---

**Chapter 10. Removal of Gases and Vapors** *Dwight M. Underhill* **10.1**

---

- 10.1 Introduction / 10.1
- 10.2 Adsorption / 10.2
- 10.3 Chemisorption / 10.14
- 10.4 Other Processes / 10.16
- 10.5 Resources for Further Reading / 10.18
- References / 10.18

---

**Chapter 11. Disinfecting Air** *Edward A. Nardell* **11.1**

---

- 11.1 Introduction and Historical Background / 11.1
- 11.2 Air Disinfection Strategies / 11.2
- 11.3 Droplet Nuclei Transmission / 11.3
- 11.4 Principles of Air Disinfection / 11.3
- 11.5 Current Methods of Air Disinfection / 11.3
- 11.6 Ventilation for Control of Airborne Infection / 11.4
- 11.7 Source Strength and the Concentration of Droplet Nuclei / 11.6
- 11.8 Air Sampling for Tuberculosis / 11.7
- 11.9 Air Filtration for Control of Airborne Infection / 11.7
- 11.10 Ultraviolet Germicidal Irradiation / 11.8
- 11.11 Novel Approaches to Air Disinfection: Displacement Ventilation / 11.11
- References / 11.12

---

**Chapter 12. Controlling Building Functions** *Clifford C. Federspiel, John E. Seem, and Kirk H. Drees* **12.1**

---

- 12.1 Introduction / 12.1
- 12.2 HVAC Components / 12.1
- 12.3 HVAC Control Functions / 12.6
- 12.4 Individual Control / 12.13
- 12.5 Lighting Controls / 12.14
- 12.6 Smoke and Fire Control / 12.15
- References / 12.15

---

**Chapter 13. Ventilation Strategies** *Martin W. Liddament* **13.1**

---

- 13.1 Summary and Introduction / 13.1
- 13.2 Natural Ventilation / 13.1
- 13.3 Mechanical Ventilation / 13.11
- References / 13.23

---

**Chapter 14. Building Fires and Smoke Management** *John H. Klote* **14.1**

---

- 14.1 Introduction / 14.1
- 14.2 Tenability / 14.2

- 14.3 Pressurization Systems / 14.2
- 14.4 Computer Analysis of Pressurization Systems / 14.3
- 14.5 Stairwell Pressurization / 14.4
- 14.6 Elevator Smoke Control / 14.7
- 14.7 Zoned Smoke Control / 14.7
- 14.8 Atrium Smoke Management / 14.8
- 14.9 Scale Modeling / 14.13
- 14.10 CFD Modeling / 14.15
- References / 14.16

## **Part 3 Human Responses**

### **Chapter 15. Thermal Comfort Concepts and Guidelines**

*Alison G. Kwok*

**15.3**

---

- 15.1 Introduction / 15.3
- 15.2 A Definition of Thermal Comfort / 15.4
- 15.3 Heat Transfer Mechanisms / 15.6
- 15.4 Basic Parameters / 15.6
- 15.5 Physiological Basis for Comfort / 15.8
- 15.6 Psychological Basis for Comfort / 15.8
- 15.7 Standards and Guidelines / 15.10
- 15.8 Current Models / 15.11
- References / 15.14

### **Chapter 16. Thermal Effects on Performance** *David P. Wyon*

**16.1**

---

- 16.1 Introduction / 16.1
- 16.2 The Mechanisms That Cause Thermal Effects / 16.2
- 16.3 Thermal Effects on SBS and on Sensations of Dryness / 16.4
- 16.4 Thermal Gradients / 16.5
- 16.5 Thermal Effects on Performance in Vehicles / 16.6
- 16.6 Thermal Comfort and Its Relation to Performance / 16.6
- 16.7 Thermal Effects on Accidents in Industry / 16.7
- 16.8 The Effects of Cold on Manual Dexterity / 16.7
- 16.9 The Effects of Heat on Light Industrial Work / 16.8
- 16.10 Thermal Effects on Mental Performance / 16.8
- 16.11 The Need for Individual Control / 16.10
- 16.12 Estimating Productivity from Performance / 16.12
- References / 16.14

### **Chapter 17. The Irritated Eye in Indoor Environment**

*Soren K. Kjaergaard*

**17.1**

---

- 17.1 Morphology and Physiology of the Outer Eye / 17.1
- 17.2 Eye Irritation and Indoor Air Pollution / 17.5
- 17.3 Physiological Changes of the Outer Eye Measured in Indoor-Related Studies / 17.8
- 17.4 Irritation Indoors and Relation to Airborne Pollutants / 17.11
- References / 17.11

- 18.1 Introduction / 18.1
- 18.2 Lighting System Technology / 18.5
- 18.3 Basic Lighting Concepts / 18.7
- 18.4 Distribution / 18.9
- 18.5 Color / 18.10
- 18.6 Visibility / 18.11
- 18.7 Glare / 18.12
- 18.8 Luminance Ratios / 18.13
- 18.9 Measurement Tools / 18.14
- 18.10 Measurement Techniques / 18.15
- 18.11 Lighting for Subjective Effect / 18.16
- 18.12 Psychological Aspects of Lighting / 18.17
- References / 18.19

**Chapter 19. The Acoustic Environment: Responses to Sound**

Tyrrell S. Burt

**19.1**

- 19.1 Introduction / 19.1
- 19.2 Acoustic Fundamentals / 19.2
- 19.3 Noise from HVAC Systems / 19.5
- 19.4 Infrasound / 19.8
- 19.5 The Effects of Indoor Noise / 19.11
- 19.6 Acceptable Indoor Noise Levels / 19.14
- 19.7 Acoustic Measurements / 19.15
- 19.8 Concluding Remarks / 19.19
- References / 19.21

**Chapter 20. Physicochemical Basis for Odor and Irritation Potency of VOCs**

J. Enrique Cometto-Muñiz

**20.1**

- 20.1 The Sensory Receptors for Olfaction and Chemesthesis / 20.1
- 20.2 Functional Separation of Odor and Irritation / 20.3
- 20.3 Chemosensory Detection Thresholds along Chemical Series / 20.5
- 20.4 Description and Prediction of Chemosensory Thresholds via Physicochemical Properties / 20.11
- 20.5 Chemosensory Detection of Mixtures / 20.16
- 20.6 Needs for Further Research / 20.17
- 20.7 Summary / 20.18
- References / 20.19

**Chapter 21. Response to Odors** Richard A. Duffee and Martha A. O'Brien **21.1**

- 21.1 The Nose and How It Serves Us / 21.1
- 21.2 How Do We Smell? / 21.2
- 21.3 Application of Odor Measurements in Indoor Environments / 21.6
- 21.4 Indoor Odor Sources, Odor Compounds, and Their Characteristics / 21.8
- 21.5 Summary / 21.8
- References / 21.11

- 22.1 Historical Background / 22.2
- 22.2 Bioeffluents / 22.2
- 22.3 Sensory Units / 22.3
- 22.4 Sensory Pollution Load / 22.5
- 22.5 Ventilation Requirement / 22.6
- 22.6 A Generalized Comfort Model / 22.7
- 22.7 Adaptation / 22.8
- 22.8 Enthalpy / 22.8
- 22.9 Measurements / 22.9
- References / 22.10

**Chapter 23. Animal Bioassays for Evaluation of Indoor Air Quality****Yves Alarie, Gunnar Damgard Nielsen, and Michelle M. Schaper**

- 23.1 Introduction / 23.1
- 23.2 Bioassay for Evaluation of Sensory and Pulmonary Irritation / 23.2
- 23.3 Technical Description of the Sensory and Pulmonary Irritation Bioassay / 23.5
- 23.4 Validation of the Sensory and Pulmonary Irritation Bioassay and Applications / 23.5
- 23.5 Calibration of the Sensory and Pulmonary Irritation Bioassay and Applications / 23.7
- 23.6 Adaptation of the ASTM E 981 Standard Method for Investigating Mixtures / 23.13
- 23.7 Mixture Generating Systems / 23.14
- 23.8 Nature of Sensory Irritating VOCs / 23.17
- 23.9 Nature of the Trigeminal Receptor or Receptor Phase / 23.17
- 23.10 Estimating Equations to Derive the Sensory Irritating Potency of NRVOCs / 23.27
- 23.11 Estimating Equations to Derive the Sensory Irritation Potency of RVOCs / 23.33
- 23.12 Bioassays to Evaluate Asthmatic Reactions and Airways Hyperreactivity or Hyperresponsiveness (AHR) / 23.35
- 23.13 Recognition of Rapid, Shallow Breathing (P1) and Airflow Limitation or Bronchostriction (A) Effects / 23.37
- 23.14 Coughing / 23.40
- 23.15 Conclusions / 23.42
- References / 23.42

**Chapter 24. Computerized Animal Bioassay to Evaluate the Effects of Airborne Chemicals on the Respiratory Tract****Yves Alarie**

- 24.1 Introduction / 24.1
- 24.2 Description of the Method / 24.2
- 24.3 Acquisition and Processing of the Data / 24.6
- 24.4 Variables Measured, Data Management, and Data Presentation / 24.13
- 24.5 Breath Classification Diagnosis and Data Analysis / 24.13
- 24.6 Limit of Detection or Just-Detectable Effect (JDE) / 24.14
- 24.7 Typical Results / 24.15
- 24.8 Advantages of the Computerized Method / 24.19
- 24.9 Guidelines for Investigators Using the Computerized Method / 24.20
- 24.10 Problems to Be Expected with the Computerized Method and Their Solutions / 24.21
- 24.11 Conclusions / 24.23
- References / 24.24

**Chapter 25. Sensory Irritation in Humans Caused by Volatile Organic Compounds (VOCs) as Indoor Air Pollutants: A Summary of 12 Exposure Experiments** *Lars Mathave*

25.1

- 25.1 Introduction / 25.1  
25.2 Study Summaries / 25.2  
25.3 Dominating Subjective Symptoms of VOC Exposures / 25.10  
25.4 Discussion and Conclusions / 25.22  
References / 25.26

**Chapter 26. Methods for Assessing Irritation Effects in IAQ Field and Laboratory Studies** *Annette C. Rohr*

26.1

- 26.1 The Sensory Irritant Response / 26.2  
26.2 Use of Biologic Markers in Humans / 26.2  
26.3 Methods for Assessing Eye Irritations / 26.3  
26.4 Methods for Assessing Upper Respiratory Tract Irritation / 26.14  
26.5 Application to IAQ Field and Laboratory Studies / 26.20  
26.6 Summary / 26.27  
References / 26.27

**Chapter 27. Multiple Chemical Intolerance and Indoor Air Quality** *Claudia S. Miller and Nicholas A. Ashford*

27.1

- 27.1 Introduction / 27.1  
27.2 Historical Background / 27.2  
27.3 Defining Sensitivity and Intolerance / 27.3  
27.4 Phenomenology / 27.4  
27.5 Prevalence and Demographics / 27.7  
27.6 Symptoms / 27.9  
27.7 The International Experience with Multiple Chemical Intolerance / 27.9  
27.8 Relationship between Multiple Chemical Intolerance and Indoor Air Pollutants / 27.10  
27.9 Case Definitions / 27.11  
27.10 Proposed Mechanisms / 27.12  
27.11 Medical Evaluation and Treatment / 27.16  
27.12 Environmental Evaluation and Intervention / 27.20  
Appendix: The QUEESI / 27.24  
References / 27.27

**Chapter 28. Environmentally Induced Skin Disorders** *Johannes Ring*

28.1

- 28.1 Overview / 28.1  
28.2 Physical Factors Affecting the Skin / 28.3  
28.3 Chemical Agents / 28.6  
28.4 Biological Agents / 28.9  
28.5 Psychosocial Factors / 28.9  
28.6 Sick Building Syndrome and Multiple Chemical Sensitivity / 28.10  
28.7 Summary / 28.10  
References / 28.11



## Part 4 Indoor Pollutants

### Chapter 29. Combustion Products *Michael L. Burr* 29.3

---

- 29.1 Principal Combustion Products / 29.3
- 29.2 The Nature of the Evidence / 29.4
- 29.3 Carbon Monoxide / 29.6
- 29.4 Oxides of Nitrogen / 29.10
- 29.5 Sulfur Dioxide, Coal Smoke, and Oil Fumes / 29.16
- 29.6 Wood Smoke / 29.18
- 29.7 Summary / 29.19
- References / 29.20

### Chapter 30. Environmental Tobacco Smoke *Jonathan M. Samet and Sophia S. Wang* 30.1

---

- 30.1 Introduction / 30.1
- 30.2 Exposure to Environmental Tobacco Smoke / 30.2
- 30.3 Health Effects of Involuntary Smoking in Children / 30.10
- 30.4 Health Effects of Involuntary Smoking in Adults / 30.17
- 30.5 Control Measures / 30.22
- 30.6 Summary / 30.23
- References / 30.23

### Chapter 31. Volatile Organic Compounds *W. Gene Tucker* 31.1

---

- 31.1 Sources / 31.2
- 31.2 Emissions / 31.4
- 31.3 Indoor Concentrations / 31.14
- References / 31.17

### Chapter 32. Aldehydes *Thad Godish* 32.1

---

- 32.1 Introduction / 32.1
- 32.2 Sensory Irritation / 32.1
- 32.3 Formaldehyde / 32.3
- 32.4 Acetaldehyde / 32.10
- 32.5 Acrolein / 32.12
- 32.6 Glutaraldehyde / 32.13
- 32.7 Exposure Guidelines and Standards / 32.15
- 32.8 Measurement / 32.16
- 32.9 Indoor Air Chemistry / 32.18
- References / 32.19

### Chapter 33. Assessing Human Exposure to Volatile Organic Compounds *Lance A. Wallace* 33.1

---

- 33.1 Introduction / 33.1
- 33.2 Measurement Methods / 33.2
- 33.3 Human Exposure / 33.4
- 33.4 Body Burden / 33.20

33.5	Carcinogenic Risk /	33.21
33.6	Acute Health Effects /	33.22
33.7	Discussion /	33.24
33.8	Summary /	33.25
	References /	33.25

---

## **Chapter 34. Polycyclic Aromatic Hydrocarbons, Phthalates, and Phenols** **34.1**

*Ruthann Rudel*

---

34.1	Sources and Measured Concentrations in Air /	34.2
34.2	Potential Health Effects /	34.18
	References /	34.22

---

## **Chapter 35. Pesticides** *Robert G. Lewis* **35.1**

---

35.1	Introduction /	35.1
35.2	Pesticide Regulation /	35.1
35.3	Residential and Commercial Building Use /	35.2
35.4	Monitoring Methods /	35.4
35.5	Occurrence, Sources, Fate, and Transport in the Indoor Environment /	35.9
35.6	Exposure Risks and Health Effects /	35.14
	References /	35.17

---

## **Chapter 36. Polychlorinated Biphenyls** *Donna J. Vorhees* **36.1**

---

36.1	What Are PCBs? /	36.1
36.2	PCBs in the Environment /	36.2
36.3	Historic Uses of PCBs that Could Impact Indoor Air Quality /	36.5
36.4	Health Effects of PCBs /	36.6
36.5	U.S. Environmental Protection Agency Toxicity Criteria for PCBs /	36.11
36.6	Indoor Air PCB Concentrations /	36.14
36.7	Reducing Exposure to PCBs in Indoor Air /	36.22
	References /	36.24

---

## **Chapter 37. Fibers** *José Vallarino* **37.1**

---

37.1	Introduction /	37.1
37.2	Asbestos /	37.2
37.3	Vitreous Fibers /	37.4
37.4	Cellulose /	37.6
37.5	Exposure Assessments /	37.5
37.6	Conclusion /	37.18
	References /	37.19

---

## **Chapter 38. Asbestos** *Stephen K. Brown* **38.1**

---

38.1	Commercial Asbestos and Health Risks /	38.1
38.2	Asbestos Building Products /	38.5
38.3	Asbestos Exposure to Building Occupants /	38.10
38.4	Building Inspection for Asbestos /	38.12
38.5	Recommended Practice for Managing Asbestos in Buildings /	38.15
	References /	38.15

- 39.1 Characterization / 39.1
- 39.2 Measurements / 39.3
- 39.3 Results / 39.13
- 39.4 Effects / 39.22
- 39.5 Guidelines / 39.23
- 39.6 Prevention / 39.24
- References / 39.26

---

**Chapter 40. Radon** *Jonathan M. Samet***40.1**

- 40.1 Introduction / 40.1
- 40.2 Measurement of Indoor Radon / 40.4
- 40.3 Sources of Exposure to Indoor Radon / 40.5
- 40.4 Concentrations of Indoor Radon / 40.6
- 40.5 Respiratory Dosimetry of Radon / 40.7
- 40.6 Epidemiologic Studies of Radon and Lung Cancer / 40.8
- 40.7 Animal Studies of Radon and Lung Cancer / 40.12
- 40.8 Risk Assessment for Radon and Lung Cancer / 40.12
- 40.9 Radon Control Strategies / 40.15
- 40.10 Summary / 40.16
- References / 40.16

---

**Chapter 41. Latex** *Mark C. Swanson, Charles E. Reed, Loren W. Hunt, and John W. Yunginger***41.1**

- 41.1 Definition / 41.1
- 41.2 Sources / 41.1
- 41.3 Clinical Manifestations / 41.4
- 41.4 Measurement of Antibodies / 41.6
- 41.5 Measurement of Allergen Concentration in Gloves / 41.6
- 41.6 Measurement of Allergen Concentration in Air / 41.7
- 41.7 Populations Affected / 41.8
- 41.8 Standards of Exposure / 41.9
- 41.9 Methods of Control / 41.11
- 41.10 Summary / 41.11
- References / 41.12

---

**Chapter 42. Endotoxins** *Theodore A. Myatt and Donald K. Milton***42.1**

- 42.1 Introduction / 42.1
- 42.2 Sources of Endotoxin / 42.3
- 42.3 Health Effects of Endotoxin / 42.3
- 42.4 Sampling Methods / 42.7
- 42.5 Methods of Analysis / 42.9
- 42.6 Control Methods / 42.11
- References / 42.12

---

**Chapter 43. Allergens Derived from Arthropods and Domestic Animals**  
*Thomas A. E. Platts-Mills***43.1**

- 43.1 Introduction / 43.1
- 43.2 Dust Mites / 43.3

- 43.3 The German Cockroach: *Blattella germanica* / 43.6  
43.4 Animal Dander Allergens / 43.7  
43.5 Rats as a Source of Airborne Allergen: Laboratory Animals and Pests / 43.9  
43.6 Measures Used to Decrease Allergen Concentration in Domestic Buildings / 43.10  
43.7 Conclusions / 43.11  
References / 43.12

---

**Chapter 44. Pollen in Indoor Air: Sources, Exposures, and Health Effects** *Michael L. Mulenberg*

44.1

- 
- 44.1 Introduction / 44.1  
44.2 Pollen and Flower: Description and Function / 44.1  
44.3 Pollen Ecology / 44.3  
44.4 Indoor Pollen / 44.8  
44.5 Pollen Sampling / 44.10  
44.6 Health Effects / 44.14  
44.7 Summary / 44.14  
Appendix / 44.15  
References / 44.16

---

**Chapter 45. The Fungi** *Harriet A. Burge*

45.1

- 
- 45.1 Introduction / 45.1  
45.2 Nature of the Fungi / 45.1  
45.3 Airborne Fungi in the Indoor Environment / 45.7  
45.4 Fungi as Agents of Disease / 45.13  
45.5 Methods for Assessing the Fungal Status of Buildings / 45.16  
45.6 Controlling Fungal Exposure in Buildings / 45.27  
References / 45.30

---

**Chapter 46. Toxicogenic Fungi in the Indoor Environment** *Carol Y. Rao* 46.1

- 
- 46.1 Introduction / 46.1  
46.2 Mycotoxins / 46.2  
46.3 Exposure Assessment / 46.2  
46.4 Health Effects from Mycotoxin Exposures / 46.6  
46.5 *Stachybotrys chartarum* / 46.7  
46.6 Risk Assessment / 46.11  
References / 46.12

---

**Chapter 47. Tuberculosis** *Edward A. Nardell*

47.1

- 
- 47.1 Introduction / 47.1  
47.2 Tuberculosis as a Disease and Indoor Health Hazard / 47.2  
47.3 Tuberculosis Infection Control Recommendations: Overview / 47.9  
References / 47.12

---

**Chapter 48. Legionella** *Brenda E. Barry*

48.1

- 
- 48.1 Introduction / 48.1  
48.2 Background on *Legionella* Bacteria / 48.2

- 48.3 Exposure to *Legionella* Bacteria / 48.4
- 48.4 Methods for Detecting *Legionella* Bacteria / 48.7
- 48.5 Guidelines for Remediation of *Legionella* Bacteria / 48.8
- 48.6 Reducing Risks for *Legionella* Infections / 48.9
- 48.7 Summary / 48.12
- References / 48.13

## **Part 5 Assessing IAQ**

---

### **Chapter 49. Strategies and Methodologies to Investigate Buildings** ***Ed Light and Todd Nathanson***

**49.3**

- 49.1 Introduction / 49.3
- 49.2 Types of Investigations / 49.4
- 49.3 Initial Complaint Screening / 49.4
- 49.4 Detailed Assessment / 49.7
- 49.5 Quantitative Studies / 49.16
- 49.6 Communications / 49.17
- Bibliography / 49.18

---

### **Chapter 50. Tracking Ultrafine Particles in Building Investigations** ***Peter A. Nelson and Richard Fogarty***

**50.1**

- 50.1 Introduction / 50.1
- 50.2 Instruments / 50.2
- 50.3 Sources / 50.4
- 50.4 Methods / 50.6
- 50.5 Case Studies / 50.12
- 50.6 Conclusion / 50.17
- Bibliography / 50.18

---

### **Chapter 51. Instruments and Methods for Measuring Indoor** **Air Quality *Niren L. Nagda and Harry E. Rector***

**51.1**

- 51.1 Introduction / 51.1
- 51.2 Instrument Selection Process / 51.2
- 51.3 Measurement Technologies / 51.14
- 51.4 Quality Assurance Issues / 51.29
- Appendix: Example Vendors for IAQ Measurement Systems / 51.33
- References / 51.35

---

### **Chapter 52. Measuring Ventilation Performance *Andrew K. Persily***

**52.1**

- 52.1 Introduction / 52.1
- 52.2 Instrumentation / 52.5
- 52.3 Measurement Techniques / 52.8
- References / 52.19

## **Chapter 53. Assessing Occupant Reaction to Indoor Air Quality**

**Gary J. Raw**

**53.1**

- 53.1 The Role of Occupant Surveys / 53.1
- 53.2 Deciding to Conduct an Occupant Survey / 53.6
- 53.3 Instruments for the Survey / 53.9
- 53.4 Procedures for the Survey / 53.15
- 53.5 Conclusion / 53.22
- Appendix: Revised Office Environment Survey / 53.23
- References / 53.29

## **Chapter 54. Building-Related Disease** *Michael Hodgson*

**54.1**

- 54.1 General Approaches / 54.4
- 54.2 Lung Disease Testing / 54.10
- 54.3 Interstitial Lung Disorders / 54.10
- 54.4 Allergic Airways and Upper Airways Disease / 54.13
- 54.5 Mucosal Irritation / 54.15
- 54.6 Headache / 54.16
- 54.7 Infections / 54.16
- 54.8 Dermatitis / 54.17
- 54.9 Miscellaneous Disorders / 54.17
- 54.10 The Residential Environment / 54.18
- 54.11 Conclusions / 54.19
- References / 54.19

## **Chapter 55. Methods to Assess Workplace Stress and Psychosocial Factors** *Barbara Curbow, David J. Laflamme, and Jacqueline Agnew*

**55.1**

- 55.1 Stress at Work / 55.2
- 55.2 The IAQ-Stress Link: Review of the Literature / 55.6
- 55.3 Instruments and Measuring Issues / 55.13
- 55.4 Implementation Issues / 55.17
- 55.5 Conclusion / 55.20
- References / 55.21

## **Chapter 56. Cost of Responding to Complaints** *Clifford C. Federspiel*

**56.1**

- 56.1 Introduction / 56.1
- 56.2 Statistical Methods / 56.2
- 56.3 Complaint Logs / 56.3
- 56.4 Relative Frequency of Complaints / 56.3
- 56.5 Temporal Variation in Complaint Frequency / 56.5
- 56.6 Complaint Temperatures / 56.7
- 56.7 Complaint-Handling Process / 56.11
- 56.8 Cost Avoidance Potential / 56.17
- 56.9 Conclusions / 56.18
- References / 56.18

## **Chapter 57. Modeling IAQ and Building Dynamics** *Philip Demokritou*

**57.1**

- 57.1 The Indoor Air Environment as an Integrated Dynamic System / 57.1
- 57.2 Mathematical Representation of the Indoor Air Environment / 57.3

---

**Chapter 58. Indoor Air Quality Modeling** *Leslie E. Sparks*

**58.1**

- 58.1 Introduction / 58.1  
58.2 Statistical Models / 58.2  
58.3 Mass Balance Models / 58.4  
58.4 Computational Fluid Dynamics Models / 58.22  
58.5 Summary / 58.23  
References / 58.23

---

**Chapter 59. Application of Computational Fluid Dynamics for Indoor Air Quality Studies** *Qingyan (Yan) Chen and Leon R. Glicksman*

**59.1**

- 59.1 Introduction / 59.1  
59.2 The Nature of Air Flow in Building Interiors / 59.2  
59.3 The Level of Understanding Required / 59.3  
59.4 Formulation of the CFD Approach / 59.5  
59.5 Governing Physical Relationships / 59.5  
59.6 CFD Techniques / 59.8  
59.7 Validation of Selected CFD Computations with Experimental Results / 59.10  
59.8 Flexibility and Rich Information from CFD Simulation / 59.13  
59.9 Problems Associated with the CFD Technique / 59.17  
59.10 Applications of the CFD Technique to Indoor Air Quality Design and Exposure Prediction / 59.19  
59.11 Conclusions / 59.22  
References / 59.22

---

**Part 6 Preventing Indoor Environmental Problems**

---

**Chapter 60. Indoor Air Quality by Design** *Hal Levin*

**60.3**

- 60.1 Introduction / / 60.3  
60.2 Major IAQ Design Strategies / 60.4  
60.3 Design Issues that Determine Indoor Air Quality / 60.6  
60.4 Design Services / 60.13  
60.5 Outline of Step-by-Step Process of Good IAQ Design / 60.14  
60.6 Conclusion / 60.18  
Suggestions for Further Reading / 60.19

---

**Chapter 61. Building Commissioning for Mechanical Systems** *John F. McCarthy and Michael J. Dykens*

**61.1**

- 61.1 Introduction / 61.1  
61.2 The Commissioning Process / 61.5  
61.3 Costs and Offsets / 61.7  
61.4 Recommissioning of Existing Buildings / 61.9

61.5 Recommissioning: A Case in Point / 61.11

61.6 Conclusion / 61.12

References / 61.13

---

## **Chapter 62. Prevention during Remodeling Restoration**

**Kevin M. Coghlan**

**62.1**

---

62.1 Introduction / 62.1

62.2 Material Selection / 62.3

62.3 Engineering Controls / 62.13

62.4 Work Practices / 62.18

62.5 Sensitive Environments / 62.22

62.6 Special Situations / 62.24

62.7 Monitoring Devices / 62.29

62.8 Summary / 62.29

References / 62.31

---

## **Chapter 63. Prevention and Maintenance Operations** *Tedd Nathanson* **63.1**

---

63.1 Introduction / 63.1

63.2 Statistics on the Cause of IAQ Problems / 63.3

63.3 Prevention / 63.3

63.4 Conclusion / 63.10

References / 63.11

---

## **Chapter 64. Prevention with Cleaning** *Jan Kildesø and*

**Thomas Schneider**

**64.1**

---

64.1 Introduction / 64.1

64.2 Indoor Surface Pollutants / 64.2

64.3 Dust Sources / 64.2

64.4 Transport Mechanisms / 64.3

64.5 Health Effects / 64.6

64.6 Cleaning Methods / 64.7

64.7 Assessment of Cleaning Quality / 64.9

64.8 Cleaning Research / 64.13

64.9 Cleaning as a Source of Indoor Pollutants / 64.15

64.10 Occupational Health of Cleaning Workers / 64.15

References / 64.16

---

## **Part 7 Special Indoor Environments**

---

### **Chapter 65. Indoor Environmental Quality in Hospitals**

**John F. McCarthy and John D. Spengler**

**65.3**

---

65.1 Introduction / 65.3

65.2 Exposure Types / 65.4

65.3 Emerging Hazards / 65.7



65.4 Environmental Controls / 65.10

65.5 Conclusion / 65.14

References / 65.14

---

**Chapter 66. Residential Exposure to Volatile Organic Compounds from Nearby Commercial Facilities** *Judith S. Schreiber, Elizabeth, J. Prohonic, and Gregory Smead* **66.1**

---

66.1 Introduction / 66.1

66.2 New York Department of Health Indoor Air Studies / 66.3

66.3 NYSDOH and USEPA Results / 66.6

66.4 Discussion / 66.13

66.5 Conclusions / 66.17

References / 66.18

---

**Chapter 67. Recreation Buildings** *Michael Brauer* **67.1**

---

67.1 Introduction / 67.1

67.2 Ice Arenas / 67.1

67.3 Other Indoor Vehicle Exposures / 67.5

67.4 Swimming Pools / 67.6

67.5 Restaurants/Bars / 67.9

67.6 Libraries / 67.11

67.7 Museums / 67.12

67.8 Conclusion / 67.15

References / 67.15

---

**Chapter 68. Transportation** *Clifford P. Weisel* **68.1**

---

68.1 Introduction / 68.1

68.2 Automobiles / 68.2

68.3 Exposures in Buses, Trains, Motorcycles, Pedestrians, and Bicycles / 68.10

68.4 Airplanes / 68.12

68.5 Ancillary Facilities and Impact on Surroundings / 68.13

68.6 Relative Importance of Exposure during Transportation Activities Related to Total Exposure / 68.16

References / 68.17

---

**Chapter 69. Day-Care Centers and Health** *Jouni J. K. Jaakkola* **69.1**

---

69.1 Children's Health Problems and Form of Day Care / 69.1

69.2 The Day-Care Center Environment / 69.3

69.3 Environmental Conditions and Health / 69.6

69.4 Toward a Better Day-Care Center Environment / 69.15

References / 69.16

## **Part 8 Risk Assessment and Litigation**

### **Chapter 70. The Risk Analysis Framework: Risk Assessment, Risk Management, and Risk Communication** *Pamela R. D. Williams*

---

**70.3**

- 70.1 Introduction / 70.3
- 70.2 Risk Assessment / 70.4
- 70.3 Risk Management / 70.5
- 70.4 Risk Communication / 70.22
- References / 70.33

### **Chapter 71. IAQ and the Law** *Mark Diamond*

---

**71.1**

- 71.1 Introduction / 71.1
- 71.2 Indoor Air Legal Suits / 71.2
- 71.3 Legal Theories / 71.3
- 71.4 Indoor Environmental Cases / 71.5
- 71.5 How to Prevent an Indoor Environmental Lawsuit / 71.6
- 71.6 Conclusion / 71.9
- References / 71.9

**Index follows Chapter 71**