

# *Contents*

Preface.....	xv
Acknowledgments .....	xvii
About the Author .....	xix

## **Section I The Starting Line**

<b>1. Historic Overview .....</b>	<b>3</b>
Evolution of Indoor Air Quality Investigations .....	3
Litigation .....	5
Differences in Health Effects .....	6
A Misguided Premise .....	7
Regulations, Requirements, and Guidelines .....	7
U.S. Government Directives .....	8
EPA National Ambient Air Quality Standards .....	8
OSHA Workplace Standards.....	9
ACGIH Workplace Guidelines .....	10
ASHRAE Criteria for General Public .....	10
ACGIH Guidelines Revisited in Older ASHRAE Standard.....	11
International Enforcement and/or Guidelines .....	12
ASHRAE Criteria for Residences.....	12
ASHRAE Criteria for High Performance Buildings .....	12
Summary.....	13
References .....	13
<b>2. Investigation Plan.....</b>	<b>15</b>
Documents Review .....	17
Building a Walk-Through .....	18
Occupied Areas .....	18
Air Handling System.....	19
Bathroom Air Exhaust.....	20
Sewer System .....	21
Occupant Activities .....	21
Interviews with Facilities Personnel .....	21
Maintenance Staff .....	21
Custodial Staff .....	22
Observation of Surrounding Areas.....	23
Assessing Occupant Complaints.....	23
Questionnaires .....	24

Types of Questionnaires.....	24
Questionnaire Response Rate .....	24
Informational Data.....	25
Interviews.....	27
Summary.....	27
References .....	27
<b>3. The Hypothesis .....</b>	<b>29</b>
Information Review.....	30
Building Assessment .....	30
Complaint Occupant.....	31
Hypothesis Development .....	34
The Proactive Approach .....	36
Beyond the Scope.....	37
Medical Physicians .....	37
Industrial Hygienists and Toxicologists .....	38
Psychiatrists .....	38
Summary.....	39
References .....	39

## **Section II   Omnipresent Bioaerosols**

<b>4. Pollen and Spore Allergens .....</b>	<b>43</b>
Occurrence of Pollen and Spore Allergens .....	43
General Information .....	44
Spore-Producing Fungi and Bacteria .....	49
Fungi .....	49
Molds.....	49
Mushrooms .....	52
Rusts and Smuts .....	53
Slime Molds.....	54
Bacteria .....	55
Indoor Source Information .....	55
Sampling Strategy.....	56
Sampling and Analytical Methodologies.....	57
Slit-to-Cover-Slip Sample Cassettes .....	57
Slit-to-Slide Samplers.....	58
Analytical Methods .....	59
Commercial Laboratories.....	59
Helpful Hints .....	59
Interpretation of Results .....	60
Summary.....	66
References .....	66

<b>5. Viable Microbial Allergens .....</b>	67
Occurrence of Allergenic Microbes.....	67
Fungi.....	68
Molds .....	68
Yeast.....	72
Bacteria .....	72
Bacillus.....	73
Thermophilic Actinomycetes .....	74
Air Sampling Methodologies.....	74
Sampling Strategy .....	75
When and Where to Sample.....	75
Equipment .....	76
Sample Duration.....	78
Sample Numbers.....	78
Culture Media.....	79
Procedural Summary.....	83
Diagnostic Sampling Methodologies.....	83
Sampling Strategy .....	84
Where to Sample .....	84
What to Sample .....	85
Sampling Supplies .....	85
Procedural Summary .....	86
Interpretation of Results .....	86
Genus Variability .....	87
Airborne Exposure Levels .....	89
Bulk and Surface Sample Results .....	89
Helpful Hints.....	90
Summary.....	90
References .....	91
 <b>6. Pathogenic Microbes.....</b>	93
Airborne Pathogenic Fungi .....	94
Disease and Occurrence.....	94
<i>Aspergillus</i> .....	94
<i>Histoplasma capsulatum</i> .....	96
<i>Coccidioides immitis</i> .....	97
<i>Cryptococcus neoformans</i> .....	99
Other Pathogenic Fungi .....	99
Sampling and Analytical Methodologies.....	102
Interpretation of Results .....	103
Airborne Pathogenic Bacteria .....	103
Pathogenic <i>Legionella</i> .....	104
Sampling and Analytical Methodologies for <i>Legionella</i> .....	105
Interpretation of Results.....	106
Helpful Hints .....	107

Other Pathogenic Bacteria .....	108
Disease and Occurrence of Prominent Airborne Pathogenic Bacteria .....	108
Sampling and Analytical Methodologies.....	111
Interpretation of Results.....	112
Pathogenic Protozoa.....	113
Sampling and Analytical Methodology .....	113
Interpretation of Results .....	114
Viruses.....	114
Summary.....	115
References .....	115
<b>7. Toxigenic Microbes .....</b>	<b>119</b>
Mycotoxins.....	119
Disease and Occurrence.....	121
Sampling and Analytical Methodologies.....	123
Fungi Identification.....	123
Toxin Identification .....	124
Interpretation of Results .....	126
Bacterial Endotoxins.....	127
Sampling and Analytical Methodology .....	128
Interpretation of Results .....	130
Summary.....	131
References .....	131

### **Section III Chemical Unknowns and Gases**

<b>8. Volatile Organic Compounds .....</b>	<b>135</b>
Health Effects and Occurrences .....	136
Air Sampling Strategy.....	139
When to Sample .....	139
Where to Sample .....	140
How to Sample .....	141
Rationale for Total VOC Screening (As Opposed to Component Identification).....	141
Air Sampling and Analytical Methodologies.....	143
Solid Sorbents and Air Sampling Pumps.....	145
NIOSH Method 1500.....	145
EPA Method TO-17.....	147
Passive Organic Vapor Monitors.....	149
Evacuated Ambient Air Containers .....	151
Whole Air Canisters .....	152
Ambient Air Sampling Bags .....	154

## *Contents*

Analytical Comparisons .....	156
Helpful Hints .....	158
Interpretation of Results.....	159
Summary.....	161
References .....	161
<b>9. Mold Volatile Organic Compounds and Mold Detection.....</b>	<b>163</b>
Health Effects and Occurrences .....	163
Sampling for MVOCs .....	166
Sampling Strategy.....	166
Sampling Methodology.....	167
Screening Methodologies .....	168
Visual Observations.....	168
Odor Tracking.....	170
Moisture Testing .....	171
Interpretation of Results .....	173
Summary.....	174
References .....	174
<b>10. Carbon Dioxide .....</b>	<b>177</b>
Occurrence of Carbon Dioxide .....	178
Sampling Strategy.....	179
Sampling Methodologies.....	180
Direct Reading Instrumentation.....	180
Colorimetric Detectors .....	180
Helpful Hints.....	182
Interpretation of Results .....	183
Summary.....	184
<b>11. Carbon Monoxide .....</b>	<b>185</b>
Occurrence of Carbon Monoxide .....	185
Sampling Strategy.....	187
Sampling Methodologies .....	188
Direct Reading Instrumentation.....	188
Colorimetric Detectors .....	188
Helpful Hints.....	190
Interpretation of Results .....	190
Summary.....	191
Reference .....	191
<b>12. Formaldehyde .....</b>	<b>193</b>
Occurrence of Formaldehyde .....	194
Sampling Strategy.....	196
Sampling Methodologies .....	197
Analytical Methodologies .....	201

Helpful Hints.....	202
Interpretation of Results .....	202
Summary.....	203
References .....	203
<b>13. Product Emissions .....</b>	<b>205</b>
Global Response and Product Labelling .....	206
Product Emissions Awareness.....	208
Sensory Irritation Testing in Environmental Chambers .....	211
Product Collection .....	212
Environmental Chamber and Analytical Methodology.....	216
Measurements of Product Emission Factors.....	219
Interpretation of Results .....	220
Summary.....	223
References .....	225
<b>Section IV Identification of Dusts</b>	
<b>14. Forensics of Dust .....</b>	<b>229</b>
Occurrences of Forensic Dust .....	230
Sampling Methodologies.....	232
Settled Surface Dust Sampling .....	234
Specialty Tape .....	234
Clear Tape.....	235
Post-it Paper.....	235
Micro-vacuuming.....	235
Airborne Dust Sampling.....	236
Spore Trap .....	236
Membrane Filters.....	237
Cascade Impactors .....	238
Other Methods.....	238
Bulk Sampling .....	239
Textile/Carpet Sampling.....	239
Analytical Methodologies .....	240
Visible Light Microscopy .....	240
Specialized Microscopic Techniques .....	241
X-Ray Diffraction.....	241
Scanning Electron Microscope.....	242
Transmission Electron Microscope.....	243
Electron Microprobe Analyzer.....	244
Ion Microprobe Analyzer.....	244
Commercial Laboratories .....	245
Summary.....	245
References .....	246

## *Contents*

<b>15. Animal Allergenic Dust.....</b>	247
Animal Allergens .....	248
Mites/Spiders.....	248
Booklice .....	251
Cockroaches and Other Insects .....	251
Domestic Animals .....	254
Cats.....	255
Dogs.....	255
Rodents .....	256
Farm Animals .....	257
Other Animals .....	257
Occurrence of Animal Allergens.....	257
Sampling Strategy.....	258
Screening for Rodents .....	260
Sampling Methodologies.....	260
Analytical Methodologies .....	263
Human Testing.....	263
Allergenic Dust Testing.....	264
Interpretation of Results .....	265
Other Types of Allergenic Substances .....	268
Summary.....	269
References .....	270

## **Section V Building Systems and Materials**

<b>16. HVAC Systems .....</b>	275
The Basic Design .....	275
HVAC Visual Inspection.....	278
Outdoor Air Intake .....	278
Outdoor Air in the Vicinity of Air Intake .....	279
Indoor HVAC Equipment Rooms .....	279
Filters.....	279
Condensate Drain Pan.....	282
Fan Housing.....	284
Unit and Duct Liner.....	284
Supply Registers and Return Air Grills.....	286
Level of Maintenance .....	288
Air Duct.....	289
Strategy and Sampling.....	290
Analyzing the Unknown .....	292
Interpretation Not So Simple .....	292
Summary.....	293

<b>17. Sewage Systems and Sewer Gases .....</b>	295
Occurrence of Sewer Gases .....	296
Hazardous Gases .....	296
Biological Components.....	297
Noxious Odor Confusion.....	297
Investigation Procedures .....	298
Air Sampling.....	299
Identification of Components .....	299
Tracking Sewer Gases.....	299
Sewage System Inspection Awareness .....	300
Poorly Installed Sewer Vents .....	300
Plumbing Fixtures and Associated Traps.....	301
In-Foundation Line Breaks .....	301
Septic/Sewage Drains and Lines .....	302
Interpretation of Results .....	302
Summary.....	303
<b>18. Tainted Chinese Drywall .....</b>	305
Health Effects .....	306
Screening Considerations .....	308
Homeowner Assessment .....	308
Inspection Screening .....	308
Components of Chinese Drywall .....	309
Sampling and Analytical Methodologies.....	311
Bulk Sample Collection and Analysis for Identification of Chinese Drywall.....	311
Sample Collection.....	311
Sample Analysis .....	312
Suspect Air and Headspace Sampling for Off-Gassing Components.....	313
Sample Collection.....	313
Sample Analyses .....	314
Corrosion Testing.....	315
Sample Collection.....	315
Microbiological Testing .....	316
Interpretation of Results .....	317
Chinese Manufactured Drywall.....	317
Off-Gassing Sulfur-Containing Gases.....	317
Causes Corrosion .....	318
Summary.....	318
References .....	319
<b>19. Green Buildings.....</b>	321
21st Century Green.....	322
Green Flush-Out Protocols .....	323

## *Contents*

LEED Indoor Air Quality Management Plan .....	324
ANSI/ASHRAE Standard 189.1—Construction and Plans for Operation .....	324
Sampling and Analytical Methodologies.....	325
Interpretation of Results .....	331
Summary.....	334
References .....	334
<b>Glossary .....</b>	<b>335</b>
<b>Appendix A: Abbreviations/Acronyms.....</b>	<b>345</b>
<b>Appendix B: Units of Measurement .....</b>	<b>347</b>
<b>Appendix C: Allergy Symptoms.....</b>	<b>349</b>
<b>Appendix D: Classification Volatile Organic Compounds.....</b>	<b>353</b>
<b>Index .....</b>	<b>357</b>