



AIRBORNE BIOCONTAMINANTS AND THEIR IMPACT ON HUMAN HEALTH

EDITED BY

**RAJEEV SINGH
ANAMIKA SINGH**

WILEY

Airborne Biocontaminants and Their Impact on Human Health

Airborne Biocontaminants and Their Impact on Human Health

Edited by

Rajeev Singh

*Department of Environmental Science, Jamia Millia Islamia,
Delhi, New Delhi, India*

Anamika Singh

Maitreyi College, University of Delhi, Delhi, New Delhi, India

WILEY

Copyright © 2024 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. 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>.

Trademarks: Wiley and the Wiley logo are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates in the United States and other countries and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

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. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors 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.

Library of Congress Cataloging-in-Publication Data Applied for:

Hardback ISBN: 9781394178933

Cover Design: Wiley

Cover Image: © Sandipkumar Patel/Getty Images

Set in 9.5/12.5pt STIXTwoText by Straive, Pondicherry, India

This book is dedicated to our beloved parents:

Late Shri Keshav Singh Shri Paras Nath Singh
Smt Keshara Singh Smt Shailja Singh

Contents

About the Editors xx

List of Contributors xxii

Preface xxvii

1 Biocontaminants in Indoor Environments: Occurrence, Spread, and Prevention 1

Abhilasha Shourie, Anita Girdhar, Kriti Singhal, Chanchal Rawat, and Shilpa Samir Chapadgaonkar

- 1.1 Introduction 1
- 1.2 Indoor Microenvironments That Harbor Biocontaminants 4
 - 1.2.1 Bedding/Carpets/Furnishings 6
 - 1.2.2 ACs/Humidifiers 6
 - 1.2.3 AC Ducts/Outdoor Units/Centralized AC Units 7
 - 1.2.4 Fan/Exhaust 7
 - 1.2.5 Furniture Wooden/Metal Items/Decoratives 7
 - 1.2.6 Books/Stationery 7
 - 1.2.7 Electronics – TV, Mobile, and Laptop 8
 - 1.2.8 Refrigerator/Deep Freezer 8
 - 1.2.9 Kitchen Slab and Sink (Wet Surfaces) 8
 - 1.2.10 Kitchen Storage (Dry Surfaces) 8
 - 1.2.11 Bathroom Floor/Walls 9
 - 1.2.12 Toilet and Its Surfaces 9
 - 1.2.13 Basement/Attic 9
 - 1.2.14 Hospitals 10
- 1.3 Factors Influencing Biocontaminant Accumulation in Microenvironments 10
 - 1.3.1 Entry of Outdoor Microbes 10
 - 1.3.2 Resident Biocontaminants (in Dust) 11

1.3.3	Human Occupancy	11
1.3.4	Pets and Aquariums	11
1.3.5	Construction Materials and VOCs	12
1.4	Conditions Affecting Spread of Biocontaminants	12
1.4.1	Light (Sunlight and Artificial Light, Darkness)	12
1.4.2	Temperature	12
1.4.3	Humidity/Moisture	13
1.4.4	Air Circulation	13
1.4.5	Spores, Pollens, and Allergens	13
1.5	Preventing Biocontaminants in Microenvironments	13
1.5.1	Cleaning Habits – Thorough Cleaning, Disinfecting	13
1.6	Preventing Biocontaminants in Controlled Environments	14
1.6.1	Cleaning Protocols – Comprehensive Cleaning and Disinfection	14
1.6.2	Efficient Ventilation	14
1.6.3	HVAC Systems for Enhanced Air Quality	15
1.6.4	Optimizing Sunlight in Indoor Environments	15
1.7	Conclusion	15
	References	16

2 Estimation of Indoor Bioaerosols and Occurrence of Sick Building Syndrome Symptoms Within Office Premises in Urban Delhi 26

Arun Kumar Yadav and Chirashree Ghosh

2.1	Introduction	26
2.2	Methodology and Study Design	27
2.2.1	Sampling Sites	27
2.2.2	Site Description	27
2.2.3	Bioaerosol Sampling	28
2.2.4	Respondent Characteristics and Prevalence of Sick Building Syndrome Symptoms	28
2.2.5	Statistical Analyses	28
2.3	Results and Discussion	29
2.3.1	Seasonal Variation in Bioaerosol Distribution	29
2.3.2	Effect of Meteorological Parameters and Footfall Count on Bioaerosol Distribution	29
2.3.3	Association of Bioaerosol Count and Daily Footfall	30
2.3.4	Respondent Characteristics	31
2.3.5	Occurrence of SBS	31
2.3.6	Occupant Satisfaction	33
2.4	Conclusion	34
	Acknowledgments	34
	References	34

3	Sources and Transmission of Bio-Contaminants in Indoor Areas	37
	<i>P. Kavita and Priti Giri</i>	
3.1	Introduction	37
3.2	Sources of Bio-contaminants in Indoor Areas	38
3.2.1	Bacteria in Indoor Air	38
3.2.2	Virus in the Indoor Air	39
3.2.3	Fungi in the Indoor Air	39
3.2.4	Mycotoxins in the Indoor Air	40
3.2.5	(1, 3)- β -D glucans in the Indoor Air	40
3.2.6	Endotoxins in the Indoor Air	40
3.2.7	Volatile Organic Compounds (VOCs) and Fungi in the Indoor Air	40
3.2.8	Allergens in the Indoor Air	41
3.2.9	Bioaerosols in the Indoor Air	41
3.3	Mode of Transmission of Bio-Contaminants in Indoor Air	42
3.3.1	Humans	42
3.3.2	Building Systems	43
3.3.3	Pets	43
3.3.4	Healthcare Facilities	43
3.3.5	Ventilation Facility and Sunlight	44
3.3.6	Plants	44
3.4	Health Consequences of Bio-Contaminants in Indoor Air	44
3.4.1	Asthma	44
3.4.2	Rhinitis	45
3.4.3	Tuberculosis	45
3.4.4	Leprosy	45
3.4.5	Legionellosis	46
3.4.6	Mycosis	46
3.4.7	Mycotoxicosis	46
3.4.8	Influenza Virus (H1N1)	47
3.4.9	Coronavirus Disease (COVID-19)	47
3.4.10	Chronic Bronchitis	47
3.4.11	Organic Dust Toxic Syndrome	48
3.4.12	Hypersensitivity Pneumonitis or Extrinsic Allergic Alveolitis	48
3.4.13	Sick Building Syndrome	48
3.4.14	Chronic Airflow Obstruction	48
3.5	Method of Detection and Control of Bio-Contaminants	48
3.5.1	Detection of Bio-Contaminants	48
3.5.2	Control of Biological Contaminants	49
3.5.3	Control Measures for Reducing Bioaerosols	50
3.6	Summary and Conclusion	50
	References	51

4	Climatic/Meteorological Conditions and Their Role in Biological Contamination: A Comprehensive Review	56
	<i>Pankaj Bhatt, Vipin Kumar, Suruchi Singh, and Kunal Kanojia</i>	
4.1	Introduction	56
4.2	Microbial Ecology and Climatic Factors	57
4.2.1	Overview of Microbial Communities	57
4.2.2	Influence of Temperature on Microbial Growth and Survival	58
4.2.3	Effect of Humidity on Microbial Proliferation	59
4.2.4	Precipitation and Its Role in Microbial Dissemination	59
4.2.5	Wind Patterns and Their Impact on the Spread of Contaminants	60
4.3	Climatic Conditions and Waterborne Contamination	60
4.3.1	Rainfall and Surface Water Contamination	60
4.3.2	Floods and Their Role in Waterborne Pathogen Transmission	61
4.3.3	Drought and Its Influence on Water Quality	61
4.4	Climatic Conditions and Airborne Contamination	62
4.4.1	Aerosolized Microorganisms and Atmospheric Conditions	62
4.4.2	Dust Storms and Their Role in Microbial Dissemination	63
4.4.3	Pollen and Allergenic Contaminants Influenced by Weather	64
4.5	Climatic Conditions and Soil Contamination	65
4.5.1	Temperature and Its Impact on Soil Microbial Communities	65
4.5.2	Moisture and Soilborne Pathogen Survival	65
4.5.3	Erosion and Its Connection to Soil Contamination	66
4.6	Climatic Conditions and Food Contamination	66
4.6.1	Temperature and Food Spoilage	66
4.6.2	Humidity and Microbial Growth in Food Products	67
4.6.3	Impacts of Extreme Weather Events on Food Safety	67
4.7	Impact of Climate Change on Biological Contamination	68
4.7.1	Long-Term Effects of Climate Change on Microbial Ecosystems	68
4.7.2	Altered Climatic Patterns and Their Consequences for Contamination	69
4.7.3	Strategies for Mitigating Climate Change-Related Contamination Risks	69
4.8	Case Studies and Examples	70
4.8.1	Documented Instances of Climatic/Meteorological Conditions and Biological Contamination	70
4.8.2	Lessons Learned and Potential Interventions	71
4.9	Detection and Monitoring of Climatic-Related Contamination	72
4.9.1	Methods for Identifying and Quantifying Biological Contaminants	72
4.9.2	Remote Sensing and Technological Advancements	72
4.9.3	Surveillance Systems for Early Detection and Response	73
4.10	Future Research Directions and Recommendations	74

- 4.10.1 Identifying Research Gaps and Unanswered Questions 74
- 4.10.2 Integration of Climatic Data Into Contamination Risk Assessments 75
- 4.10.3 Strategies for Adapting to Changing Climatic Conditions 75
- 4.11 Conclusion 76
- References 77

5 Role of Gases, VOC, PM2.5, and PM10 in Biological Contamination in Indoor Areas 89

Pradeep Kumar, Sevaram Singh, Ekta Tyagi, Vinay Mohan Pathak, Shiwangi Gupta, and Rajeev Singh

- 5.1 Introduction 89
- 5.2 Gases and Biological Contamination 91
 - 5.2.1 Carbon Dioxide (CO₂) 91
 - 5.2.2 Carbon Monoxide 93
 - 5.2.3 Nitrogen Dioxide (NO₂) 94
 - 5.2.4 Sulfur Dioxide (SO₂) 95
 - 5.2.5 Volatile Organic Compounds (VOCs) 96
 - 5.2.5.1 Common VOC in Indoor Air 97
 - 5.2.6 Radon (Rn) 98
 - 5.2.7 Ozone (O₃) 98
- 5.3 Particulate Matter 100
 - 5.3.1 PM2.5 100
 - 5.3.2 PM10 101
- 5.4 Human Health Effects and Toxicity Mechanisms 102
- 5.5 Mitigation Strategies Reducing Indoor Gases and Particulate Matter 103
- 5.6 Conclusion 104
- References 105

6 Indoor Contaminants Based on Fungi 108

Anchal Chaudhary, Anamika Bhardwaj, Nikhil Sharma, Manandeep Kaur, Shalini Kaushik Love, and Arti Mishra

- 6.1 Introduction 108
- 6.2 Fungal Diseases 110
 - 6.2.1 Mycosis 111
 - 6.2.2 Mycotoxicosis 111
 - 6.2.3 Respiratory Symptoms 111
- 6.3 Factors Affecting the Colonization of Fungi 112
- 6.4 Fungal Quantitation 113
- 6.5 Methods for Quantitation 115
 - 6.5.1 Liquid Impingement 115

- 6.5.2 Impaction 115
- 6.5.3 Electrostatic Precipitation 116
- 6.5.4 Gravitational Settling/Sedimentation 116
- 6.5.5 Filtration 116
- 6.6 Determination of Fungal Components in Indoor Conditions 116
- 6.7 Methodologies for Fungal Analysis 117
- 6.8 Practices that Contribute to the Biotic Indoor Pollution 118
- 6.9 Removing Fungal Material and Cleaning 119
- 6.10 Conclusion and Future Perspectives 120
- References 120

7 Health Implications Related With the Presence of Waste Sorting Plants and Biological Contaminants 123

Samina Mazahar

- 7.1 Introduction 123
- 7.2 Waste Sorting Plants 124
- 7.3 Biological Contaminants 125
- 7.4 Major Bio-Contaminants 125
 - 7.4.1 Viruses 125
 - 7.4.2 Bacteria 126
 - 7.4.3 Fungi 126
 - 7.4.4 Mycotoxins and Endotoxins 127
 - 7.4.5 Allergens 127
- 7.5 Effect of Biological Contaminants and Waste Sorting Plants on Health 127
 - 7.5.1 Bacterial Diseases 127
 - 7.5.2 Diseases Caused by Viruses 128
 - 7.5.3 Disease Spread Through Fungi 129
- 7.6 Conclusion 129
- References 129

8 Neurological Health Hazards Associated with Biological Contaminants 133

Shweta, Himanshi Yadav, Jaldhi, Anurag Thapliyal, Amrita Bakshi, Anamika, and Shashank Kumar Maurya

- 8.1 Introduction 133
- 8.2 Occupational Hazards and Neurological Disorders 135
- 8.3 Occupational Hazards Associated with Risk Factors Linked to Neurological Disorders 135
- 8.4 Neurological Diseases Associated with Occupational Hazards 138
- 8.5 Prevention and Treatment Strategies 143

- 8.6 Conclusion and Future Directions 146
 Acknowledgments 146
 Conflict of Interest 146
 References 146
- 9 Effect of Bioaerosols Exposure on Acute Exacerbation Among Individuals with COPD in Urban India 151**
Chirashree Ghosh, Arun Kumar Yadav, Rajnish Awasthi, Arun Kumar Sharma, Shukla Das, B. D. Banerjee, and Palak Balyan
- 9.1 Introduction 151
 9.2 Methodology 152
 9.3 Results 153
 9.3.1 Effect of Aerosolized Microbes on COPD Exacerbation 154
 9.4 Meteorological Variables 156
 9.4.1 Temperature 156
 9.4.2 Relative Humidity 158
 9.4.3 Particulate Matter 158
 9.5 Discussion 161
 9.6 Conclusion 164
 Conflict of Interest 164
 Disclosure of Interest 164
 Acknowledgments 165
 References 165
- 10 The Crucial Role of Pollen Grains, (1 → 3)-β-D-Glucan and Endotoxin in Triggering Respiratory Diseases 168**
Khencha Aran, Twinkle Chetia, Priti Giri, Bitupan Deka, and Ravi Kumar Goswami
- 10.1 Respiratory Diseases 168
 10.2 Pollen Grains and Their Role in Triggering Respiratory Diseases 169
 10.2.1 Pollen Grains 169
 10.2.2 Pollen and Respiratory Diseases 170
 10.2.3 How Pollen Triggers Respiratory Diseases 171
 10.2.4 Respiratory Diseases Caused by Pollens 173
 10.2.5 Mitigating the Impact of Pollen on Respiratory Health 175
 10.2.6 Future Directions in Research on Pollen and Respiratory Diseases 175
 10.3 (1 → 3)-β-D-Glucan and Its Role in Triggering Respiratory Diseases 176
 10.3.1 (1 → 3)-β-D-Glucan 176
 10.3.2 Toxic Effects of (1 → 3)-β-D-Glucans 176
 10.3.3 Immune System-Modulating Properties of (1 → 3)-β-D-Glucan 177
 10.4 Endotoxin and Role in Triggering Respiratory Diseases 178

- 10.4.1 Endotoxins 178
- 10.4.2 Endotoxin Exposures 180
- 10.4.3 Impact of Endotoxins in Respiratory Diseases 180
- 10.4.4 Mitigating the Impact of Endotoxin on Respiratory Health 181
- 10.4.4.1 Quantitative Endotoxin Testing Assay 181
- 10.5 Implications for Public Health Policy and Individual Behavior 182
- 10.6 Conclusion 182
- References 183

11 Problems of Drug Resistance in Indoor Biological Contaminants 196
Kalpna Sagar and K. Priti

- 11.1 Introduction 196
- 11.2 Drug Resistance: A Major Problem in Indoor Biological Contaminants 199
- 11.3 Genetic Basis of Antimicrobial Resistance 200
- 11.4 Mutational Resistance 200
- 11.5 Horizontal Gene Transfer 201
- 11.6 Mechanisms of Resistance 201
- 11.6.1 Drug Inactivation 202
- 11.6.2 Limiting Drug Uptake 205
- 11.6.3 Modification of Drug Targets 206
- 11.6.4 Drug Efflux 207
- 11.7 Conclusion 209
- References 210

12 Methicillin Resistant *Staphylococcus aureus* (MRSA): An Underestimate Threat 214
Sudeshna Mandal, Anirban Kundu, Dhriti Borah, Mou Singha Ray, and Chandrani Mondal

- 12.1 Introduction 214
- 12.2 Epidemiology 216
- 12.2.1 Pathophysiology of Bacterial Colonization and Transmission 218
- 12.2.2 Virulence Factors and Toxins 221
- 12.2.3 Mechanisms of Drug Resistance 226
- 12.2.4 Genomic Regulation 231
- 12.2.5 Pathogenesis 232
- 12.2.5.1 Pneumonia 232
- 12.2.5.2 Endocarditis 232
- 12.2.5.3 Bacteremia 233
- 12.2.5.4 Skin and Soft Tissue Infections 233
- 12.2.5.5 Bone and Joint Infections 233

12.2.6	Diagnosis, Screening, and Prevention	233
12.2.7	HA-MRSA	233
12.2.8	CA-MRSA	234
12.2.9	LA-MRSA	234
12.2.10	Microbiological Diagnosis	234
12.2.10.1	Phenotypic Methods	234
12.2.10.2	Non-Phenotypic Methods	235
12.2.11	Prevention	236
12.2.11.1	Hand Hygiene	236
12.2.11.2	Contact Precautions and Isolation	236
12.2.11.3	Active Surveillance	237
12.2.12	Management	237
12.2.12.1	Decolonization of Carriers	237
12.2.12.2	Short-Term Decolonization	237
12.2.12.3	Permanent Decolonization	237
12.2.13	Treatment	238
12.2.13.1	Bacteremia	238
12.2.13.2	Endocarditis	238
12.2.13.3	Skin and Soft Tissue Infection	239
12.2.13.4	Osteomyelitis	239
12.2.13.5	Pneumonia	240
12.2.13.6	Vaccine Development	240
	References	240

13 Immunological and Molecular Mechanism Induced by Indoor Bio-contaminants 258

Ravi Kumar Goswami, Mohit Kumar, Atavika Chandan, Sudeshna Mandal, Pratibha Kumari, and Varunendra Singh Rawat

13.1	Introduction	258
13.2	Sources of Biocontaminants in Indoor Environment	259
13.2.1	Humans	261
13.2.2	Building Systems	262
13.2.3	Pets	262
13.2.4	Healthcare Facilities	262
13.3	Detection Techniques for Quantification of Biocontaminants	263
13.3.1	Sampling Methods	264
13.3.1.1	Passive Sampling	264
13.3.1.2	Active Sampling	264
13.4	Biocontaminants and Immunological Responses	265
13.4.1	Immune Receptors that Recognize Fungal Molecules	265
13.4.1.1	Pattern Recognition Receptors	266

13.4.1.2	Toll-Like Receptors	266
13.4.1.3	C-Type Lectin Receptors	266
13.4.1.4	Recognition of Proteases	267
13.4.2	Innate Immune Responses	267
13.4.2.1	Epithelial Barrier and Epithelial Cells	267
13.4.2.2	Group 2 Innate Lymphoid Cells	267
13.4.2.3	Natural Killer Cells	267
13.4.2.4	Dendritic Cells	268
13.4.2.5	Neutrophils and Eosinophils	268
13.4.3	Adaptive Immune Response	269
13.4.3.1	Th1/Th17 Cell Response	269
13.4.3.2	Th2 Cell Response	269
13.5	Potential Role of Biocontaminants in Increasing Risk of Diseases and Disorders	269
13.5.1	Role of Fungi in Diseases	270
13.5.2	Role of Viruses in Diseases	271
13.5.3	Role of Bacteria in Diseases	271
13.5.4	Allergens	271
13.6	Cell Signaling Pathways Alterations and Endocrine Disruption	272
13.6.1	Changes in Cell Signalling Pathways	272
13.6.2	Endocrine Disruption	273
13.7	Probable Methods of Detoxification	274
13.7.1	Humidity Control	275
13.7.2	Biofumigation	275
13.7.3	Hybrid Biomembrane-Functionalized Nanorobots	275
13.7.4	Silver Nanoparticles	276
13.7.5	Air Filters	276
13.7.6	Probiotics-Combating Biofilms	276
13.8	Conclusion	277
	References	278

14 Indoor Airborne Insect Allergens: Environmental Evaluation and Health Implications 288

Mohd Adnan Kausar, Sadaf Anwar, Mohammad Zeeshan Najm, Sadaf, Simran Kaur, Samir Qiblawi, and Vinita Katiyar

14.1	Introduction	288
14.2	Classification of Allergens	289
14.2.1	Allergens Based on Environment	289
14.2.2	Allergens Based on Route of Exposure	290
14.3	Airborne Insect Allergens	290
14.3.1	Mosquitoes	292

14.3.2	Cockroaches	292
14.3.3	House Dust Mite	293
14.3.4	Storage Mite	294
14.4	Allergens and Immune Response	295
14.5	Allergens and Disease	297
14.5.1	Mosquito Allergen: Immune Response and Disease	298
14.5.2	House Dust Mite Allergen: Immune Response and Disease	300
14.5.3	Cockroach Allergen: Immune Response and Disease	302
14.6	Environment and Allergens: Ways to Control	305
14.7	Conclusion	308
	References	308
15	Diagnosis and Treatment of Health Effects Caused by Airborne Contaminants	319
	<i>Sujata Adhana, Anil Kumar Mavi, Umesh Kumar, Garima Rathi, and Devendra Kumar</i>	
15.1	Introduction	319
15.2	Airborne Contaminants	320
15.3	Common Airborne Contaminants	321
15.3.1	Particulate Matter	321
15.3.2	Allergens	322
15.3.3	Fumes and Gases	322
15.3.4	Biological Agents	323
15.4	Specific Airborne Contaminants and Their Impact on Health	323
15.4.1	Asbestos	323
15.4.2	Radon	324
15.4.3	Mold	324
15.4.4	Volatile Organic Compounds (VOCs)	324
15.4.5	Allergens Such as Pollen	324
15.5	Health Effects Caused by Airborne Contaminants	325
15.6	Identifying Health Effects	326
15.6.1	Patient History and Symptoms	326
15.6.2	Physical Evaluation	326
15.6.3	Diagnostic Tests and Procedures	327
15.7	Health Consequences and Related Signs and Symptoms	328
15.7.1	Cardiovascular System	328
15.7.2	Respiratory System	328
15.7.3	Neurological System	329
15.7.4	Skin and Eyes	329
15.8	Treatment Approaches	330
15.8.1	Exposure Control	330

15.8.2	Immunotherapy	330
15.8.3	Medications and Therapies	330
15.8.4	Lifestyle Changes and Preventive Measures	331
15.8.5	Supportive Care	331
15.9	Effects on Occupational Health	331
15.9.1	Airborne Contaminants Associated With the Workplace	332
15.9.2	Occupational Exposure Limits	332
15.9.3	Control and Prevention Measures	332
15.10	Special Implications for Vulnerable Groups	332
15.10.1	Children	333
15.10.2	Senior Citizens	333
15.10.3	People With Pre-Existing Conditions	333
15.11	Evaluation and Improvement of Indoor Air Quality	333
15.11.1	Ventilation Systems	334
15.11.2	Techniques for Filtration and Purification	334
15.12	Regulatory Standards and Guidelines	335
15.12.1	Significance of Regulatory Standards and Guidelines	335
15.12.2	Illustrations of Regulatory Standards and Guidelines	336
15.13	Research and Future Management	336
15.14	Conclusion	338
	References	339

16 Strategies for Reducing Exposure to Airborne Biological Contaminants in Indoor Environments 341

Maneet Kumar Chakrawarti, Madhuri Singh, and Kasturi Mukhopadhyay

16.1	Introduction	341
16.2	Engineering Controls and Real-Time Air Quality Monitoring	342
16.2.1	Ventilation Strategies	342
16.2.2	Air Filtration and Purification	343
16.2.3	Real-Time Indoor Air Quality Monitoring	343
16.3	Personal Protective Strategies	343
16.3.1	Respiratory Protection	344
16.3.2	Eye and Face Protection	344
16.4	Behavioral and Hygiene Practices	344
16.4.1	Respiratory Etiquette and Personal Hygiene	344
16.4.2	Minimizing Contaminant Generation	344
16.5	Public Health Strategies	345
16.5.1	Disease Outbreak Preparedness	345
16.5.2	Communication and Education	345
16.6	Current Air Decontamination Techniques to Reduce Airborne Biological Contaminants	345

16.6.1	High-Efficiency Particulate Air Filtration	346
16.6.2	Ultraviolet Germicidal Irradiation	346
16.6.3	Photocatalytic Oxidation	346
16.6.4	Electrostatic Precipitation	347
16.6.5	Portable Air Purifiers	347
16.6.6	HVAC System Upgrades	347
16.7	Challenges in Controlling Exposure to Airborne Biological Contaminants	348
16.8	Conclusion	349
	References	350
17	Guidelines for the Biological Contaminants in Indoor Areas	357
	<i>Pradeep Kumar, Sevaram Singh, Vinay Mohan Pathak, Rajiv Kumar Singh, Shiwangi Gupta, and Rajeev Singh</i>	
17.1	Introduction	357
17.2	Existing Quantitative Regulations and Recommendations from Different Countries and Agencies	359
17.3	Regulatory Frameworks and Standards	361
17.4	Basic Guidelines for Controlling Biological Contamination	362
17.4.1	Ventilation	362
17.4.2	Role of Plants in Reducing the Biological Contaminants	364
17.4.3	Reducing Pollution Sources	365
17.4.4	Controlling the Pest Infestations	366
17.4.5	Humidity Control	367
17.4.6	Bio-fumigation	367
17.4.7	Design and Construction of a Building	369
17.4.8	Social and Behavioral Factors	370
17.4.9	Future Trends and Emerging Technologies	371
17.4.10	Risk Assessment and Management	372
17.5	Conclusion	373
	References	373
	Index	378

About the Editors



Dr. Rajeev Singh is Associate Professor at Department of Environmental Science, Jamia Millia Islamia, New Delhi. He is working in the area of environmental health. He is Founder Secretary of the Bio-electromagnetic Society of India. Dr. Singh is member of several scientific and academic bodies. He has organized and participated in several international and national conferences and delivered invited talks. He has published around 100 research papers, chapters in books,

conference proceedings, etc., of international repute. He is also a principal investigator of several major research projects funded by various government agencies. He has published a good number of research articles in reputed journals of high impact, namely *Seminars in Cancer Biology* (impact factor – 17), *Scientific Reports* (impact factor – 4.9), *Bioresource Technology* (impact factor – 11.8), *Science of the Total Environment* (Impact factor – 10.7), *Environmental Pollution* (impact factor –9.98), *Cells* (impact Factor – 7.6), *Chemosphere* (impact factor – 8.9), *Environmental Research* (impact factor – 8.4), *Fuel* (impact factor – 8.0), *Biomedicine and Pharmacotherapy* impact factor – 7.4), *International Journal of Hydrogen Energy* (impact factor – 7.1), *Journal of Cancer Research and Clinical Oncology* (impact factor –4.5), *Air Quality Atmosphere and Health* (impact factor –5.8), *Aerobiologia* (impact factor –2.7), *Reproductive Toxicology* (impact factor –3.4), and *International Journal of Environmental Health Research* (impact factor –4.4), among several others. He has edited a number of books published by Springer Nature. He is also a reviewer of several high-impact journals like *Environmental International*, *PLOS One*, *Free Radical Research*, *Mutation Research*, etc. Dr. Singh is recipient of Young Scientist Award of Federation of European Microbiological Societies (FEMS), Gold Medal for best oral presentation, etc.



Dr. (Mrs.) Anamika Singh is currently working as Assistant Professor (Selection grade) in Maitreyi College, University of Delhi. She holds a PhD degree in bioinformatics from the Indian Institute of Information Technology, Allahabad (IIIT-A). She has 12 years of teaching and research experience. Her areas of research interest are genetic engineering, bioinformatics, Phytomolecular analysis, biological databases, phylogeny, molecular modeling, drug designing,

computer-based drug designing, computational biology, etc. Dr. Singh is member of the Indian Bioinformatics Society, APBioNet, the European Federation of Biotechnology, and IAENG. She is also actively involved in the review of research articles for various journals. She has organized national and international conferences, faculty development programs, and workshops in different platforms. She has published several research articles in reputed journals and book chapters with leading publishers. She has also authored a book in biochemistry and medicinal botany.

List of Contributors

Sujata Adhana

Bhaskaracharya College of Applied Sciences, University of Delhi, Delhi
New Delhi, India

Anamika

Department of Zoology, Ramjas College, University of Delhi, Delhi
New Delhi, India

Sadaf Anwar

Department of Biochemistry, College of Medicine, University of Ha'il, Ha'il
Saudi Arabia

Khencha Aran

Department of Botany, Cotton University, Guwahati, Assam, India

Rajnish Awasthi

Faculty in University College of Medical Sciences, University of Delhi
Delhi, New Delhi, India

Amrita Bakshi

Department of Zoology, Ramjas College, University of Delhi, Delhi
New Delhi, India

Palak Balyan

Environmental Pollution Laboratory
Department of Environmental Studies
University of Delhi, Delhi
New Delhi, India

B. D. Banerjee

Faculty in University College of Medical Sciences, University of Delhi
Delhi, New Delhi, India

Anamika Bhardwaj

Department of Microbiology
Guru Nanak Dev University, Amritsar
Punjab, India

Pankaj Bhatt

Lloyd Institute of Management and Technology, Greater Noida
Uttar Pradesh, India; Department of Pharmaceutical Sciences, Gurukul Kangri (Deemed to be University)
Haridwar, Uttarakhand, India

Dhitri Borah

Department of Zoology
Biswanath College, Biswanath Charali
Assam, India

Maneet Kumar Chakrawarti

Antimicrobial Research Laboratory
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi, India

Atavika Chandan

Department of Zoology, Hindu
College, University of Delhi, Delhi
New Delhi, India

Shilpa Samir Chapadgaonkar

Department of Biosciences and
Technology, Dr. Vishwanath Karad
MIT World Peace University, Pune
Maharashtra, India

Anchal Chaudhary

Department of Microbiology
Guru Nanak Dev University, Amritsar
Punjab, India

Twinkle Chetia

Department of Botany, Cotton
University, Guwahati, Assam, India

Shukla Das

Faculty in University College of
Medical Sciences, University of Delhi
Delhi, New Delhi, India

Bitupan Deka

Department of Botany, Cotton
University, Guwahati, Assam, India

Chirashree Ghosh

Environmental Pollution Laboratory
Department of Environmental Studies
University of Delhi, Delhi
New Delhi, India

Anita Girdhar

Department of Environmental
Sciences, J.C. Bose University of
Science and Technology, YMCA
Faridabad, Haryana, India

Priti Giri

Department of Botany, Maitreyi
College, University of Delhi
New Delhi, India

Ravi Kumar Goswami

Department of Zoology, Hindu
College, University of Delhi, Delhi
New Delhi, India

Shiwangi Gupta

Department of Environmental Studies
Satyawati College, University of Delhi
Delhi, New Delhi, India

Jaldhi

Biochemistry and Molecular Biology
Laboratory, Department of Zoology
Faculty of Science, University of
Delhi, Delhi, New Delhi, India

Kunal Kanojia

Department of Pharmaceutics, KIET
Group of Institutions (KIET School of
Pharmacy), Muradnagar, Ghaziabad
Uttar Pradesh, India

Vinita Katiyar

Regional Services Division, Indira
Gandhi National Open University
(IGNOU), Maidan Garhi, Delhi
New Delhi, India

Manandeep Kaur

Department of Microbiology
Guru Nanak Dev University, Amritsar
Punjab, India

Simran Kaur

School of Biosciences, Apeejay Stya
University, Gurugram, Haryana, India

Mohd Adnan Kausar

Department of Biochemistry, College
of Medicine, University of Ha'il, Ha'il
Saudi Arabia

P. Kavita

Department of Botany, Maitreyi
College, University of Delhi
New Delhi, India

Devendra Kumar

Department of Environmental
Science, Ramanujan College
University of Delhi, Delhi
New Delhi, India

Mohit Kumar

Department of Zoology, Hindu
College, University of Delhi, Delhi
New Delhi, India

Pradeep Kumar

Department of Environmental Studies
Satyawati College, University of Delhi
Delhi, New Delhi, India; Department
of Agricultural and Biosystems
Engineering, South Dakota State
University, Brookings, SD, USA

Umesh Kumar

Department of Biosciences,
Institute of Management Studies
Ghaziabad (University Courses
Campus) Ghaziabad, Uttar
Pradesh, India

Vipin Kumar

Department of Pharmaceutical
Sciences, Gurukul Kangri
(Deemed to be University),
Haridwar Uttarakhand, India

Pratibha Kumari

Department of Botany, Daulat Ram
College University of Delhi, Delhi
New Delhi, India

Anirban Kundu

Department of Zoology, Laboratory of
Helminth Parasitology, Visva-Bharati
University, Shantiniketan
West Bengal, India

Shalini Kaushik Love

Department of Botany, Hansraj
College, University of Delhi, Delhi
New Delhi, India

Sudeshna Mandal

Department of Zoology, Laboratory of
Helminth Parasitology, Visva-Bharati
University, Shantiniketan
West Bengal, India

Shashank Kumar Maurya

Biochemistry and Molecular Biology
Laboratory, Department of Zoology
Faculty of Science, University of
Delhi, Delhi, New Delhi, India

Anil Kumar Mavi

Department of Botany, Sri Aurobindo
College, University of Delhi, Delhi
New Delhi, India

Samina Mazahar

Department of Botany, Dyal Singh
College, University of Delhi, Delhi
New Delhi, India

Arti Mishra

Department of Botany, Hansraj College, University of Delhi, Delhi New Delhi, India; Umeå Plant Science Center, Department of Plant Physiology, Umeå University Umeå, Sweden

Chandrani Mondal

Department of Zoology, Laboratory of Helminth Parasitology, Visva-Bharati University, Shantiniketan West Bengal, India

Kasturi Mukhopadhyay

Antimicrobial Research Laboratory School of Environmental Sciences Jawaharlal Nehru University New Delhi, India

Mohammad Zeeshan Najm

School of Biosciences, Apeejay Stya University, Gurugram, Haryana, India

Vinay Mohan Pathak

Department of Microbiology University of Delhi (South Campus) Delhi, New Delhi, India; Department of Botany and Microbiology, Gurukul Kangri Deemed to be University Haridwar, Uttarakhand, India

K. Priti

Department of Microbiology Gurukula Kangri (Deemed to be University), Haridwar Uttarakhand, India

Samir Qiblawi

Medical and Laboratory Sciences Department, Palestine Technical University - Kadoorie, Tulkarm Palestine.

Garima Rathi

Delhi Public School Ghaziabad Ghaziabad, Uttar Pradesh, India

Chanchal Rawat

Department of Biotechnology School of Engineering & Technology Manav Rachna International Institute of Research and Studies, Faridabad Haryana, India

Varunendra Singh Rawat

Department of Zoology, Hindu College, University of Delhi, Delhi New Delhi, India

Mou Singha Ray

Department of Zoology, Laboratory of Helminth Parasitology, Visva-Bharati University, Shantiniketan West Bengal, India

Sadaf

Department of Biotechnology Jamia Millia Islamia, Delhi New Delhi, India

Kalpana Sagar

Department of Microbiology Gurukula Kangri (Deemed to be University), Haridwar Uttarakhand, India

Arun Kumar Sharma

Faculty in University College of
Medical Sciences, University of Delhi
Delhi, New Delhi, India

Nikhil Sharma

Department of Microbiology
Guru Nanak Dev University,
Amritsar Punjab, India

Abhilasha Shourie

Department of Biotechnology
School of Engineering & Technology
Manav Rachna International Institute
of Research and Studies, Faridabad
Haryana, India

Shweta

Biochemistry and Molecular Biology
Laboratory, Department of Zoology
Faculty of Science, University of
Delhi, Delhi, New Delhi, India

Madhuri Singh

Antimicrobial Research Laboratory
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi, India

Rajeev Singh

Department of Environmental
Science, Jamia Millia Islamia, Delhi
New Delhi, India

Rajiv Kumar Singh

Primary Health Center (PHC)
Government of Uttar Pradesh, Pali
Hardoi, Uttar Pradesh, India

Sevaram Singh

Translational Health Science and
Technology Institute, NCR Biotech
Science Cluster, Faridabad, Haryana
India; Jawaharlal Nehru University
Delhi, New Delhi, India

Suruchi Singh

Department of Pharmacology
Accurate College of Pharmacy
Greater Noida, Uttar Pradesh, India

Kriti Singhal

Department of Biotechnology
School of Engineering &
Technology, Manav Rachna
International Institute of Research
and Studies, Faridabad
Haryana, India

Anurag Thapliyal

Biochemistry and Molecular Biology
Laboratory, Department of Zoology
Faculty of Science
University of Delhi, Delhi
New Delhi, India

Ekta Tyagi

Department of Bioscience and
Biotechnology, Banasthali University
Banasthali, Rajasthan, India

Arun Kumar Yadav

Environmental Pollution Laboratory
Department of Environmental Studies
University of Delhi, Delhi
New Delhi, India

Himanshi Yadav

Biochemistry and Molecular
Biology Laboratory, Department
of Zoology, Faculty of Science
University of Delhi, Delhi
New Delhi, India

Preface

The primary objective of this book is to understand the indoor contaminants and why they are important with reference to their impact on human health. As this topic is very broad and every small scientific studies related to contaminants are very important, we are trying to focus on different parameters (from basic to advanced concepts). There are many expert contributors to this book who are all well known in the field. With the advancement of this topic as it is completely research based, we have touched upon different areas that helps readers understand the subject at its basic level.

Environmental studies related to human health itself is a broad term and includes all disease-related studies as well as environmental distortion that may cause diseases in animals and humans. In addition to this, consider the reciprocal impact between humans and the environment. Since the beginning of environmental research, outdoor contaminants and greenhouse gases have always been hot topics of study, but under adverse climatic conditions (COVID, pollution, etc.), we spent most of the time in our homes, so again this question arises: We are safe or not in our homes, or are we still under high risk due to some other pollutants present in our homes. The answer is yes. Pollutants of the second category, that is indoor pollutants, may be bacteria, virus, fungal spores, dust, etc. This book gives a clear insight of household or indoor pollutants and their impact. The book also attempted to address historical elements concerning contaminants, alongside their various types and methods of treatment. The connection between mental health and environmental contaminants, as well as the correlation between our professions and exposure to pollutants, is noteworthy. Exploring the impact of these associations on our well-being is essential.

In the last chapter, we have compiled the government guidelines and precautions for indoor contaminants. With this, all we wish is that the readers definitely get a clear-cut idea about the contaminants. This book also suggests some novel and untouched areas of environmental research.

