Contents

List of Contributors xi
Preface xv
Hunting fog xvii
It all happens up there ... xix
Cela se passe là-haut ... xxi

Part I Bioaerosols, Sampling, and Characterization 1

1.1 Main Biological Aerosols, Specificities, Abundance, and Diversity 3
1.1.1 Introduction 3
1.1.2 Pollen 4
1.1.3 Fungi 5
1.1.4 Bacteria 7
1.1.5 Archaea 9
1.1.6 Viruses 10
References 11

1.2 Sampling Techniques 23
1.2.1 Introduction 23
1.2.2 Passive and surface sampling 24
1.2.3 Filtration 25
1.2.4 Inertia-based samplers: sedimentation samplers, impactors, cyclones 28
1.2.4.1 Sedimentation samplers 28
1.2.4.2 Impactors 28
1.2.4.3 Centrifugal impactors 33
1.2.5 Impingement 34
1.2.6 Electrostatic sampling 36
1.2.6.1 Electrostatic samplers for improved detection sensitivity 37
1.2.6.2 Personal or portable samplers 38
1.2.6.3 Utilization of native microorganism charges 39
1.2.6.4 Concerns regarding electrostatic collectors 39
References 40

1.3 Quantification and Characterization of Bioaerosols (offline techniques) 49
J. Fröhlich-Nowoisky, P. Amato, P. Renard, E. Brisebois and C. Duchaine
1.3.1 Cultures and metabolic/phenotypic characterization of microbial isolates 49
1.3.2 Microscopy and flow cytometry 53
1.3.2.1 Light microscopy 53
1.3.2.2 Epifluorescence microscopy 54
1.3.2.3 Electron microscopy 55
1.3.2.4 Flow cytometry 56
1.3.3 Nucleic acid-based methods 56
1.3.3.1 DNA extraction and amplification 56
1.3.3.2 Quantification 57
1.3.3.3 Analysis of the diversity 58
1.3.3.4 Sequencing 59
1.3.3.5 Microarrays 60
1.3.4 Chemical and biological tracers 60
1.3.4.1 Biomarkers 61
1.3.4.2 Ice nucleation activity 62
1.3.4.3 Mass spectrometry 63
1.3.4.4 Spectroscopy 64
1.3.4.5 Immunoassay method 65
1.3.5 Biological activity-based methods 65
1.3.5.1 Supplementation with nutrients 65
1.3.5.2 Supplementation with radiolabeled precursors of anabolism 65
1.3.5.3 Enzymatic activity 66
1.3.5.4 Adenosine 5'-triphosphate 66
1.3.5.5 Virus infectivity 67
References 67

1.4 Online Techniques for Quantification and Characterization of Biological Aerosols 83
J.A. Huffman and J. Santarpia
1.4.1 Introduction 83
1.4.2 Single-particle fluorescence spectroscopy 84
1.4.2.1 Single-particle fluorescence spectrometer 86
1.4.2.2 Two-wavelength single-particle fluorescence analyzer 87
1.4.2.3 Fluorescence aerodynamic particle sizer (FLAPS)/ultraviolet aerodynamic particle sizer (UV-APS) 88
1.4.2.4 Wideband integrated bioaerosol sensor (WIBS+) and spectral intensity bioaerosol sensor (SIBS) 90
1.4.2.5 Other 93
1.4.2.6 Data analysis strategies 94
1.4.3 Bioaerosol mass spectrometry 94
1.4.3.1 Bioaerosol mass spectrometry (BAMS) 96
1.4.3.2 Aerosol time-of-flight mass spectrometer (ATOFMS) 96
1.4.3.3 Aerosol mass spectrometer (AMS) 97
1.4.3.4 Other 97
1.4.4 Other real-time bioaerosol detection techniques 97
1.4.4.1 Light detection and ranging (LIDAR) 97
1.4.4.2 Resource Effective Bioidentification System (REBS) 97
1.4.4.3 Molecular tracer techniques 98
1.4.4.4 PBAP detection via elemental analysis 98
1.4.4.5 Automated pollen counting 98
Acknowledgments 99
References 99

Part II Sources and Transport of Microbial Aerosols 115

2.1 Bioaerosol Sources 117
N. Wéry, A. Galès and Y. Brunet
2.1.1 Introduction 117
2.1.2 Emission mechanisms 119
2.1.2.1 Passive and active release 119
2.1.2.2 Erosion, abrasive dislodgment, and abrasive damage 120
2.1.2.3 Bubble bursting 121
2.1.2.4 Emissions from man-made systems 121
2.1.2.5 Differences in concentration factors between microorganisms: selection during aerosolization 122
2.1.3 Measuring emission fluxes 123
2.1.3.1 Introduction 123
2.1.3.2 Chamber measurements 123
2.1.3.3 Flux–gradient relationships 124
2.1.3.4 A novel method for measuring vertical atmospheric fluxes? 125
2.1.3.5 Downwind dispersion modelling 125
2.1.3.6 Conclusion 126
2.1.4 Impact of aerosol sources on the concentration and diversity of airborne microbial communities in the near-surface atmosphere 126
2.1.4.1 Effect of source type on microbial loads 126
2.1.4.2 Effect of source type on microbial diversity 127
2.1.4.3 Impact of meteorological factors on source contribution 128
2.1.5 Identifying predictors of bioaerosol emission and airborne community composition 129
2.1.5.1 Predictors of airborne community composition 129
2.1.5.2 Indicators for monitoring bioaerosol emission 129
2.1.6 Conclusion 130
References 131
2.2 Short-Scale Transport of Bioaerosols 137
Y. Brunet, N. Wéry and A. Galès
2.2.1 Introduction 137
2.2.2 Particle dynamics and deposition processes 138
2.2.3 Transport processes and dispersal scales 140
2.2.4 Survival of microorganisms during transport 142
2.2.5 Modeling tools for the transport of microbial aerosols 143
2.2.5.1 Gaussian approaches 143
2.2.5.2 Modeling dispersal in plant canopies 144
2.2.5.3 Toward larger scales 145
2.2.5.4 Modeling the survival of airborne microorganisms 146
2.2.6 Dispersal patterns 147
2.2.6.1 Release conditions 147
2.2.6.2 Concentration variations downwind from sources 147
2.2.6.3 Landscape-scale patterns 148
2.2.7 Conclusion 149
References 149

2.3 Global-Scale Atmospheric Dispersion of Microorganisms 155
D.W. Griffin, C. Gonzalez-Martin, C. Hoose and D.J. Smith
2.3.1 Historical context 155
2.3.2 Mechanisms of dispersion 156
2.3.2.1 Natural sources 156
2.3.2.2 Anthropogenic sources 159
2.3.3 Microorganisms associated with long-range dispersion 161
2.3.3.1 Ubiquity 161
2.3.3.3 Long-range transport studies by method type 165
2.3.4 Residence time, transport history, and emission models 167
2.3.4.1 General principles 167
2.3.4.2 Global and regional models including biological aerosols 168
2.3.4.3 Determining transport history with proxy aerosols 172
2.3.5 Implications for planetary exploration 174
2.3.5.1 Aerobiology informs astrobiology 174
Acknowledgments 178
References 178

Part III Impacts of Microbial Aerosols on Atmospheric Processes 195

3.1 Impacts of Bioaerosols on Atmospheric Ice Nucleation Processes 197
T.C.J. Hill, P.J. DeMott, F. Conen and O. Möhler
3.1.1 Introduction 197
3.1.2 Measurements of ice-nucleating particles 199
3.1.2.1 Online and offline measurements of single ice-nucleating particles using diffusion chambers 199
3.1.2.2 Offline ice-nucleating particle measurements using bulk aerosol and precipitation samples 200
3.1.2.3 Cloud simulation laboratories 201
3.1.2.4 Contact freezing measurements 202
3.1.2.5 Compositional analyses of ice-nucleating particles 203
3.1.3 Findings from laboratory experiments, field collections, and field studies 203
3.1.4 Atmospheric implications 207
3.1.4.1 Ecological advantages of ice nucleation and the bioprecipitation hypothesis 207
3.1.4.2 Correlation with precipitation cycles (stimulation of ice-nucleating particle release by rainfall?) 208
3.1.4.3 A special role for bioaerosols in secondary ice generation and precipitation formation? 209
3.1.5 Conclusion and future needs 210
References 210

3.2 Impacts on Cloud Chemistry 221
A.-M. Delort, L. Deguillaume, P. Renard, V. Vinatier, I. Canet, M. Vaitilingom and N. Chaumerliac
3.2.1 Introduction 221
3.2.2 Chemical composition of clouds 222
3.2.3 Clouds as oxidative reactors 225
3.2.4 Clouds as spaces of biodegradation 227
3.2.4.1 Biotransformation of carboxylic acids, methanol, and formaldehyde 228
3.2.4.2 Comparison between biodegradation and radical chemistry 230
3.2.5 Interactions with cloud oxidants 232
3.2.5.1 Interactions with reactive oxidant species 232
3.2.5.2 Interactions with iron 233
3.2.6 Clouds as spaces of organic compound functionalization 235
3.2.6.1 Formation of high molecular weight compounds via chemical reactions 235
3.2.6.2 Formation of high molecular weight compounds via microbial activity 236
3.2.7 Conclusion 238
References 239

Part IV Impacts of Bioaerosols on Human Health and the Environment 249

4.1 Health Impacts of Bioaerosol Exposure 251
P. Blais Lecours, C. Duchaine, M. Thibaudon and D. Marsolais
4.1.1 Introduction 251
4.1.2 Hazardous potential of bioaerosols 251
4.1.2.1 Factors affecting the hazardous potential of bioaerosols 251
4.1.2.2 Epidemiological data in documented environments 252
4.1.3 Infectious diseases associated with bioaerosols 253
4.1.3.1 Identification of agents with infectious potential in bioaerosols 253
4.1.3.2 Determinants of maintenance of infectious potential in bioaerosols 254
4.1.4 Toxic and hypersensitivity disease-associated bioaerosols 254
  4.1.4.1 Balance of biological mechanisms determining toxic reactions and hypersensitivity 254
  4.1.4.2 Airborne agents responsible for immunogenic responses 254
  4.1.4.3 Pollen grain and fungal spore surveillance 255
  4.1.4.4 Diseases associated with non-infectious culturable and non-culturable fractions 256

4.1.5 Biological agents used for bioterrorism 258
  4.1.5.1 Bioterrorism 258
  4.1.5.2 Classification of bioterrorism agents 259
  4.1.5.3 Point detection of biological agents and exposure limit values of bioaerosols 263

4.1.6 Conclusion 263
References 263

4.2 Impacts of Microbial Aerosols on Natural and Agro-ecosystems: Immigration, Invasions, and their Consequences 269
  C.E. Morris and D.C. Sands

4.2.1 Introduction 269

4.2.2 Colonization of virgin and extreme habitats 270
  4.2.2.1 The emergence of terrestrial eukaryotes 270
  4.2.2.2 Modern rebirth of pristine land: colonization in the wake of volcanic eruptions 270
  4.2.2.3 The conquest of rocks: weathering and the liberation of mineral nutrients 272
  4.2.2.4 Colonization of sculpted and painted rocks: deterioration of cultural heritage 273
  4.2.2.5 High-altitude/latitude environments 273

4.2.3 Invasion of agriculture 274

4.2.4 Opportunities for research 276
References 277

Index 281