CONTENTS

PREFACE xiii
ACKNOWLEDGMENTS xv
CONTRIBUTORS xvii

1 OVERVIEW OF MERCURY IN THE ENVIRONMENT 1
Guangliang Liu, Yong Cai, Nelson O’Driscoll, Xinbin Feng, and Guibin Jiang
1.1 Introduction / 1
1.2 Toxicity and Health Risks of Mercury Exposure / 2
1.3 Sources of Mercury / 2
1.4 Overview of Mercury Biogeochemical Cycling / 7
1.5 Structure of the Book / 8
1.6 Concluding Remarks / 9
References / 9

PART I ANALYTICAL DEVELOPMENTS 13

2 ADVANCES IN SPECIATION ANALYSIS OF MERCURY IN THE ENVIRONMENT 15
Yanbin Li, Yongguang Yin, Guangliang Liu, and Yong Cai
2.1 Introduction / 15
CONTENTS

2.2 Sample Preparation for Hg Speciation in Environmental Samples / 16
2.3 Application of GC Technique in Hg Speciation Analysis / 32
2.4 Application of HPLC Technique in Hg Speciation Analysis / 36
2.5 Application of Capillary Electrophoresis Techniques in Hg Speciation Analysis / 39
2.6 Application of X-Ray Absorption Spectroscopy in Probing Chemical Microenvironment of Hg / 40
2.7 Application of Stable Isotope Dilution Technique in Mercury Speciation Analysis / 41
2.8 Summary / 43
References / 44

3 MEASURING GAS PHASE MERCURY EMISSIONS FROM INDUSTRIAL EFFlUENTS 59
Samuel J. Ippolito, Ylias M. Sabri, and Suresh K. Bhargava
3.1 Introduction / 59
3.2 Standardized Methods for Measuring Mercury / 72
3.3 Mercury Continuous Emission Monitors (CEMs) / 81
3.4 Future Outlook / 95
References / 96

PART II SPECIATION AND TRANSFORMATION 111

4 ATMOSPHERIC CHEMISTRY OF MERCURY 113
Che-Jen Lin, Pattaraporn Singhasuk, and Simo O. Pehkonen
4.1 Introduction / 113
4.2 The Overall Picture / 114
4.3 Chemical Transformations in the Gas Phase / 118
4.4 Chemical Transformations in the Aqueous Phase / 131
4.5 Redox Chemistry at the Interface Between the Atmosphere and Earth’s Surfaces / 136
4.6 Atmospheric Implications of the Identified Redox Pathways / 139
4.7 Future Research Needs / 143
References / 144
5 MICROBIAL TRANSFORMATIONS IN THE MERCURY CYCLE 155

Chu-Ching Lin, Nathan Yee, and Tamar Barkay

5.1 Introduction / 155
5.2 Mercury Methylation / 158
5.3 Methylmercury Degradation / 168
5.4 Redox Cycling of Inorganic Hg / 169
5.5 Conclusions / 179
References / 180

6 PHOTOREACTIONS OF MERCURY IN AQUATIC SYSTEMS 193

Emma E. Vost, Marc Amyot, and Nelson J. O’Driscoll

6.1 Significance of Mercury Photoreactions / 193
6.2 Concepts in Mercury Photoreactions / 194
6.3 Current Methods in Mercury Photochemistry / 209
6.4 Summary / 211
References / 212

7 CHEMICAL SPECIATION OF MERCURY IN SOIL AND SEDIMENT 219

Ulf Skyllberg

7.1 Introduction / 219
7.2 Physicochemical Properties, Oxidation States, Chemical Forms, Structures, and Concentrations of Mercury in the Environment / 220
7.3 Aqueous Phase: Major Ligands and Their Affinities for Mercury(II) / 222
7.4 Liquid and Solid Phases of Mercury in Soils and Sediments / 229
7.5 Reactions of Mercury(II) with Soil and Sediment Particle Surfaces / 231
7.6 Stabilization of Nanoparticulate Mercury(II) Sulfides by Natural Organic Matter / 237
7.7 Solubility and Chemical Speciation of Mercury(II) in Soils and Sediments / 237
7.8 Methods for Studying the Chemistry of Mercury(II) in Soils and Sediments / 248
CONTENTS

7.9 Future Research Needs / 249
References / 252

8 THE EFFECTS OF DISSOLVED ORGANIC MATTER ON MERCURY BIOGEOCHEMISTRY 259
Chase A. Gerbig, Joseph N. Ryan, and George R. Aiken

8.1 Introduction / 259
8.2 Dissolved Organic Matter / 260
8.3 Field Observations / 263
8.4 Effects of DOM on Mercury Distributions Between Solution and Particles / 265
8.5 Mercury Binding Strength / 268
8.6 Mercury Binding Environment / 271
8.7 Methylmercury Binding Strength and Environment / 274
8.8 DOM and Mercury Mineral Dissolution / 276
8.9 DOM and Mercury Mineral Precipitation / 280
References / 284

9 TRACKING GEOCHEMICAL TRANSFORMATIONS AND TRANSPORT OF MERCURY THROUGH ISOTOPE FRACTIONATION 293
Holger Hintelmann and Wang Zheng

9.1 Introduction / 293
9.2 Fractionation of Mercury Isotopes in Environmental Processes / 300
9.3 Hg Isotope Variations in Nature / 315
9.4 Summary / 319
References / 320

PART III TRANSPORT AND FATE 329

10 ATMOSPHERIC TRANSPORT OF MERCURY 331
Oleg Travnikov

10.1 Introduction / 331
10.2 General Concepts of Mercury Cycling in the Atmosphere / 331
10.3 Methods for Studying Atmospheric Mercury Transport / 336
CONTENTS

10.4 Assessments of Airborne Mercury Pollution / 342
10.5 Knowledge Gaps / 354
References / 356

11 ADSORPTION OF MERCURY ON SOLIDS IN THE AQUATIC ENVIRONMENT 367
Guangliang Liu, Yanbin Li, and Yong Cai

11.1 Introduction / 367
11.2 Adsorption of Mercury on Solids / 369
11.3 Role of Colloids in Mercury Adsorption / 374
11.4 Concluding Remarks / 380
References / 381

12 EXCHANGE OF ELEMENTAL MERCURY BETWEEN THE OCEANS AND THE ATMOSPHERE 389
Asif Qureshi, Matthew Macleod, Elsie Sunderland, and Konrad Hungerbühler

12.1 Introduction / 389
12.2 Models of Gas Exchange of Elemental Mercury at the Air–Sea Interface / 390
12.3 Field Studies of Ocean-To-Air Fluxes of Mercury / 398
12.4 Rate Constants for Reduction and Oxidation of Mercury Species in Ocean Waters / 400
12.5 Modeling Studies Estimating Oceanic Air–Sea Exchange / 411
12.6 Conclusions and Future Directions / 415
References / 416

13 EXCHANGE OF MERCURY BETWEEN THE ATMOSPHERE AND TERRESTRIAL ECOSYSTEMS 423
Mae Sexauer Gustin

13.1 General Overview / 423
13.2 Methods and Tools Applied for Measurement and Understanding of Air–Terrestrial Surface Exchange / 425
13.3 Measured Fluxes / 433
13.4 Conclusions / 442
References / 444
PART IV BIOACCUMULATION, TOXICITY, AND METALLOMICS 453

14 BIOACCUMULATION AND BIOMAGNIFICATION OF MERCURY THROUGH FOOD WEBS 455
Karen Kidd, Meredith Clayden, and Tim Jardine

14.1 Introduction / 455
14.2 Mercury in Aquatic and Terrestrial Organisms / 457
14.3 Mercury within Organisms / 464
14.4 Factors Affecting Mercury in Biota / 465
14.5 Biomagnification of Mercury Through Food Webs / 474
14.6 Mercury Stable Isotopes in Bioaccumulation Studies / 481
14.7 Case Study—Kejimkujik National Park and Historic Site, Nova Scotia, Canada / 482
14.8 Conclusions / 484
References / 485

15 A REVIEW OF MERCURY TOXICITY WITH SPECIAL REFERENCE TO METHYLMERCURY 501
Mineshi Sakamoto, Katsuyuki Murata, Akiyoshi Kakita, and Masanori Sasaki

15.1 Introduction / 501
15.2 Global Mercury Emission into the Atmosphere / 502
15.3 Metabolism and Toxicity of Chemical Forms of Mercury / 503
15.4 Risk Assessment of Prenatal Exposure to Methylmercury / 509
15.5 Risks and Benefits of Fish Consumption for Brain Development / 510
15.6 Exceptional Methylmercury Exposure Through Rice / 510
15.7 Summary / 511
References / 511

16 METALLOMICS OF MERCURY: ROLE OF THIOL-AND SELENOL-CONTAINING BIOMOLECULES 517
Feiyue Wang, Marcos Lemes, and Mohammad A.K. Khan

16.1 Introduction / 517
16.2 Metallomics of Mercury / 517
16.3 Mercury and Methylmercury Complexes with Thiol-Containing Biomolecules / 519
16.4 Mercury and Methylmercury Binding to Selenol-Containing Biomolecules / 522
16.5 Lability of Mercury or Methylmercury Complexes with Thiols or Selenols / 524
16.6 Thiol-Containing Biomolecules in the Uptake and Metabolism of Mercury / 526
16.7 Selenium Aided Biomineralization of Mercury and Methylmercury / 529
16.8 Analytical and Modeling Approaches / 531
16.9 Conclusion / 538
References / 538

17 HUMAN HEALTH SIGNIFICANCE OF DIETARY EXPOSURES TO METHYLMERCURY
Anna L. Choi and Philippe Grandjean
17.1 Introduction / 545
17.2 Methylmercury Exposure / 546
17.3 Nutrients in Fish and Seafood / 548
17.4 Major Prospective Cohort Studies / 549
17.5 Health Effects / 552
17.6 Cardiovascular Outcomes / 555
17.7 Nutrient and Methylmercury Exposure as Predictors of Developmental Outcomes / 556
17.8 Confounding Variables / 557
17.9 Risk Assessment and Exposure Imprecision / 558
17.10 Conclusions / 559
References / 561

INDEX 569