

Contents

List of Contributors xv

Preface xxi

Acknowledgments xxv

Section 1 Geochemistry and Health 1

1 Medical Geology: Biosphere, Geosphere, and Noosphere Interface 3

Majeti Narasimha Vara Prasad

1.1 Introduction 3

1.2 Medical Geology in Russia and Newly Independent States (NIS) 3

1.2.1 Linking Geology to Soils – Minerals and HealthCare (Medicine) 5

1.3 Medicinal Value of Metals in Ancient Indian System of Medicine (After Charaka Samhita) 19

1.3.1 Parada (Mercury) 19

1.3.2 Swarna (Gold) Bhasma 19

1.3.3 Rajata (Silver) Bhasma 19

1.3.4 Tamra (Copper) Bhasma 20

1.3.5 Aayasa or Loha (Iron) 20

1.3.6 Mandura Bhasma 20

1.3.7 Naga/Sisaka (lead) Bhasma 20

1.3.8 Vanga/Trapu (tin) Bhasma 20

1.3.9 Pittala (Brass) 21

1.4 Linking Geology to Medicine? 21

1.5 Mineral-Enriched Yeast: Vehicles of Nutrition 21

1.6 Trace Elements/Functional Foods 23

1.6.1 Antidiabetic Plants – The Chromium Connection 23

1.6.2 Lithium 23

1.7 Public Health Informatics (PHI) 24

1.7.1 Medicinal–Mineral Resources 24

1.7.2 Balneotherapy 24

1.8 Use of Clay Minerals in Water Purification 25

1.9 Bathing in Radioactive Monazite-Rich Sands 27

Glossary 28

References 30

2 Biogeochemistry: Essential Link Between Geosphere and Biosphere 37

Dilan Ranaweera, Udayagee Kumarasinghe, Chathuri Senanayake, Rohan S. Dassanayake, Pasan Chinthana Bandara, and Pabasari Arundathi Koliyabandara

2.1 Introduction to Biogeochemistry 37

2.2 Geosphere: Formation, Evolution, and Isotopes 38

2.2.1	Evolution of the Geosphere	38
2.3	Biosphere	40
2.3.1	Evolution of the Biosphere	40
2.3.2	Bacteria: The Most Primitive Organisms on Earth	41
2.4	Natural Biogeochemistry Cycles (C, N, P, and S)	42
2.4.1	Carbon Cycle	42
2.4.2	Nitrogen Cycle	42
2.4.3	Phosphorous Cycle	43
2.4.4	Sulfur Cycle	44
2.5	Artificial Biogeochemistry Cycles	45
2.6	Soil Biogeochemistry	46
2.6.1	Introduction to Soil Biogeochemistry	46
2.6.2	Soil Formation and Evolution	47
2.6.3	Soil and Ecosystem Balancing	47
2.7	Impact of Natural and Anthropogenic Activities on Biogeochemical Processes	48
2.7.1	Landslide	48
2.7.2	Volcanic Eruptions	49
2.7.3	Industrial Activities	49
2.7.4	Intensive Agriculture	49
2.7.5	Greenhouse Gas Emissions	50
2.7.6	Ocean Acidification	50
2.8	Conclusion and Future Perspectives	50
	References	51

3 Geochemical Release and Environmental Interfaces 55

C. C. Kadigamuwa, Nuwan T. Perera, and B. S. S. Perera

3.1	Introduction	55
3.1.1	Mineral Release	55
3.1.1.1	Dissolution	56
3.1.1.2	Oxidation and Hydration	56
3.1.1.3	Hydrolysis	56
3.1.2	Gas Release	57
3.2	Environmental Interfaces	59
3.2.1	Atmospheric Aerosol Interface	59
3.2.2	Nanomaterial Interfaces	60
3.2.3	Effect of Geochemical Release on Environmental Interfaces	61
3.2.3.1	Adverse Effects of Geochemical Release on Environmental Interfaces	61
3.2.4	Benefits of Geochemical Releases on Environment	62
	References	62

Section 2 Dust Storms and Health 65

4 Minerogenic Dust and Human Health 67

Majeti Narasimha Vara Prasad

4.1	Introduction	68
4.2	Tree "Bark Pockets" as Pollution Time Capsules	69
4.3	Asbestosis	73
4.4	Phosphogypsum Dust (Anthropogenic Radioactivity)	74
4.5	Silicosis	76
4.6	Volcanic Ash	76
4.7	Dust and Gases from Volcanic Eruptions	77

4.8	Artisanal and Small-Scale Gold Mining Activities in Nigeria	77
	Acknowledgments	78
	References	79
5	Silicosis and Asbestosis	83
	<i>Mapa S. T. Mapa and Rangika S. Hikkaduwa Koralege</i>	
5.1	Introduction	83
5.2	Silicosis	83
5.2.1	Structure and Properties of Silica	83
5.2.2	Environmental Occurrence of Silica	84
5.2.3	Industrial Applications and Human Exposure to Silica	84
5.2.4	Silicosis and Its Pathologic Mechanisms	84
5.2.5	Prevention and Treatment of Silicosis	87
5.3	Asbestosis	87
5.3.1	Structure of Asbestos	87
5.3.2	Properties of Asbestos	89
5.3.3	Sources of Asbestos Fiber	89
5.4	Industrial Application	90
5.5	Exposure to Mineral Fiber	90
5.6	Disease Description and Mechanisms of Action	91
5.7	Prevention and Treatment Plans	92
	References	93
6	Radon and Health	95
	<i>Dinusha Peramune, Niwanthi Dissanayake, Vidura D. Thalangamaarachchige, Mohamed N. M. Farhath, and Rohan S. Dassanayake</i>	
6.1	Introduction	95
6.2	Radon Chemistry	96
6.3	Sources of Radon	96
6.4	Radon Measurement Units	98
6.5	Safe Radon Levels	98
6.6	Radon Detection Methods	100
6.7	Detection of Radon and Radon Decay Products by Grab Sampling Method	100
6.7.1	Ionization Chambers	100
6.7.2	Scintillation Cell Method	100
6.7.3	Liquid Scintillation Counting (LSC)	101
6.7.4	Gross Alpha Counting	101
6.7.5	Alpha Spectrometry	101
6.8	Detection of Radon and Radon Decay Products by Integrated Measurement Methods	101
6.8.1	Solid-State Nuclear Track Detector	102
6.8.2	Activated Carbon Method	102
6.8.3	Electret-Ionization Chamber (EIC) Method	102
6.8.4	Solid-State Detection Monitors	102
6.9	Detection of Radon and Radon Decay Products by Continuous Monitors	103
6.9.1	Continuous Scintillation Cell Monitor	103
6.9.2	Passive Continuous Radon Monitor	103
6.9.3	Continuous Radon Monitors for Radon Progeny	103
6.10	Health Effects of Radon	104
6.10.1	Lung Cancer	104
6.10.2	Leukemia	105
6.10.3	Skin Cancer	106
6.10.4	Circulatory System Diseases (CSDs)	106

- 6.11 Prevention and Mitigation of Radon in Indoor Settings 106
- 6.12 Conclusion 106
- References 107

Section 3 Medical Geology of the Hydrosphere 111

- 7 Water–Rock Interactions: Mineral Dissolution 113**
Huaming Guo, Zhipeng Gao, and Shiping Xing
 - 7.1 Introduction 113
 - 7.2 Congruent (Simple) Dissolution 113
 - 7.2.1 Simple Dissolution of Minerals in Groundwater System 113
 - 7.2.2 Saturation Index 114
 - 7.2.3 Chemical Evolution of Groundwater Controlled by Congruent Dissolution 114
 - 7.3 Incongruent Dissolution 115
 - 7.3.1 Incongruent Dissolution in Aquifer Systems 115
 - 7.3.2 Weathering of Silicates 116
 - 7.3.3 Consequence of Incongruent Dissolution of Silicates 118
 - 7.4 Reductive Dissolution of Fe(III) Oxides 119
 - 7.4.1 Fe(III) Oxide Mineral and Reductive Dissolution 119
 - 7.4.2 Cause of Reductive Dissolution of Fe(III) Oxides 120
 - 7.4.3 Consequence of Reductive Dissolution of Fe(III) Oxides 121
 - 7.5 Conclusion Remarks 122
 - Acknowledgments 122
 - References 123
- 8 Water Hardness and Health 129**
W. P. R. T. Perera
 - 8.1 Water Hardness – Overview 129
 - 8.2 Origin of Water Hardness 130
 - 8.3 Water Hardness and Health Influence – Background 131
 - 8.3.1 Cardiovascular Diseases and Water Hardness 131
 - 8.3.2 Prevention Mechanism of CVD by Water Hardness 131
 - 8.3.3 Kidney Disease and Water Hardness 134
 - 8.3.4 Protective Competence of the Hard Water Against Cancer Development 134
 - 8.3.5 Calcium and Magnesium Intake and Other Health Effects 135
 - 8.3.6 Physiological Significance of Magnesium 136
 - 8.3.7 Health Drawbacks of Water Hardness 137
 - 8.4 Mitigation of Water Hardness 137
 - 8.5 Conclusions 138
 - References 138
- 9 Geochemistry of Fluoride in the Environment and Human Health 143**
Rohana Chandrajith, C.B. Dissanayake, and Johannes A.C. Barth
 - 9.1 Introduction 143
 - 9.2 Geochemistry of Fluoride 143
 - 9.3 Fluoride in Rocks 144
 - 9.4 Fluoride in Soil 145
 - 9.5 Fluoride in Plants 145
 - 9.6 Fluoride in Natural Water 146
 - 9.7 Fluoride and Human Health 147
 - 9.8 Conclusions 149

Acknowledgments	149
References	149

10 Iodine Essentiality for Human Health: Sources, Toxicity, Biogeochemistry, and Strategies for Alleviation of Iodine Deficiency Disorders 155

Majeti Narasimha Vara Prasad

10.1	Introduction	155
10.2	Iodine Essentiality for Human Health	156
10.3	Role of Iodine in Thyroid Function	156
10.4	Iodine Sources in Biogeosphere and Hydrosphere	158
10.5	Iodine in Diets	159
10.6	Iodine in Watersheds	162
10.7	Iodine Deficiency Disorders	163
10.8	Biogeochemical Cycling of Iodine	165
10.9	Conclusions	167
	Acknowledgments	170
	References	170

11 Understanding Nexus Between Hydrogeochemical Cycling and Medical Geology of Arsenic 175

Muhammad Mahroz Hussain, Natasha, Irshad Bibi, Hamna Bashir, Muhammad Shahid, and Nabeel Khan Niazi

11.1	Introduction	175
11.2	What Is Medical Geology?	175
11.3	Arsenic Release Mechanisms	177
11.4	Exposure and Effects of As on Humans and Plants	180
11.5	Conclusions and Outlooks	181
	Acknowledgments	181
	References	181

12 Potentially Toxic Metals and Health 187

Pelin Yapıcıoğlu, Mehmet İrfan Yeşilnacar, and Engin Tutkun

12.1	Introduction	187
12.2	Toxic Metals and Their Resources	188
12.2.1	Arsenic (As)	189
12.2.2	Cadmium (Cd)	189
12.2.3	Chromium (Cr)	189
12.2.4	Lead (Pb)	189
12.3	The Effects of Toxic Metals on Human Health	190
12.4	Toxic Metal Removal with Biochar Adsorption	190
12.5	Conclusions and Recommendations	193
	References	193

Section 4 Medical Pedology: Health Effects from Soils and Sediments 203

13 Dynamics of Trace Element Bioavailability in Soil: Agronomic Enhancement and Risk Assessment 205

Rohan D'Souza, Paulo J. C. Favas, Mayank Varun, and Manoj S. Paul

13.1	Introduction	205
13.2	Bioavailability of Trace Elements in Contaminated Soils	206
13.3	Case Study	207
13.3.1	Experimental Design	208
13.3.2	Target Hazard Quotient	208

13.4	Uptake of Trace Elements: Change in Bioavailability	208
13.5	Trace Element Accumulation in Vegetable/Fodder	210
13.6	Human Health Risk Assessment	212
13.7	Conclusion	212
	References	212
14	Geochemical Provenance of Metalloids and Their Release: Implications on Medical Geology	217
	<i>S. Keerthanan, Prosun Bhattacharya, and Meththika Vithanage</i>	
14.1	Medical Geology of Metalloids	217
14.2	Role of Natural Geologic Materials and Processes on Releasing of Metalloids to the Environment	217
14.2.1	Release to Hydrosphere	218
14.2.2	Release to Lithosphere	218
14.2.3	Release to Atmosphere	218
14.2.4	Mechanism of the Release of the Metalloids to the Environment	220
14.2.4.1	Mechanisms on Arsenic Release	220
14.2.4.2	Mechanisms on Antimony Release	220
14.3	Bioavailability and Bioaccessibility of Metalloids	221
14.3.1	Soil	221
14.3.2	Aquatic Environment	221
14.3.3	Atmosphere	221
14.4	Human Exposure of Metalloids	222
14.5	Toxicity of Metalloids to Human and Prevention	223
14.6	The Risk Management Strategies to Reduce the Bioavailable of Metalloids in the Environment	224
14.6.1	Remediation of Metalloids from the Water Bodies	224
14.6.1.1	Performance of Biochar on Metalloids Adsorption	225
14.6.1.2	Performance of Soil and Clay Minerals on Metalloids Adsorption	225
14.6.1.3	Performance of Biosorbents on Metalloids Adsorption	225
14.6.1.4	Performance of Nanomaterials on Metalloids Adsorption	225
14.6.1.5	Performance of Other Materials on Metalloids Adsorption	226
14.6.2	Remediation of Metalloids from the Soil Matrices	226
14.6.2.1	Stabilization/Immobilization	226
14.6.2.2	Electrokinetic Approaches	226
14.6.2.3	Phytoremediation	226
14.6.2.4	Microbial-Assisted Remediation	227
14.6.2.5	Integrated Remediation	227
14.7	Summary and Future Development	228
	References	229
15	Cobalt and Copper Deficiency and Molybdenosis	235
	<i>Sandali Ranaweera, Sachira Sadhana Hewawardhana Silva, and Danushika C. Manatunga</i>	
15.1	Introduction	235
15.2	Role of Co, Cu, and Mo as Micronutrients	235
15.2.1	Role of Cu as a Micronutrient in Plants	235
15.2.1.1	Involvement of Cu in Photosynthesis	236
15.2.2	Role of Cu as a Micronutrient in Animals	236
15.2.2.1	Copper as a Pro-Oxidant	236
15.2.2.2	Copper as an Antioxidant	237
15.2.3	Role of Co as a Micronutrient in Plants	237
15.2.3.1	Importance of Co for Plant Metabolism and Physiology	237
15.2.3.2	Role of Cobalt in Biological Nitrogen Fixation	237
15.2.3.3	Cobalt-Dependent Proteins in Plants	237
15.2.4	Role of Co as a Micronutrient in Animals	237

15.2.4.1	Cobalt in Nutrition of Animals	238
15.2.5	Co and Cu Micro-Deficiency	238
15.2.5.1	What Is Co and Cu Deficiency?	238
15.2.5.2	Common Ways Leading to Cu and Co Deficiency	238
15.2.5.3	Effect of Cu and Co Deficiency	239
15.3	Molybdenum (Mo) as a Cause for Micro-Mineral Deficiencies – Molybdenosis	241
15.3.1	Importance of Mo	241
15.3.2	Role of Molybdenum in Plant health	241
15.3.3	Role of Molybdenum in Human and Animal Health	242
15.3.4	Micro-Mineral Deficiencies Induced by Mo	242
15.3.4.1	Mechanism of Mo's Action/Etiology of Molybdenosis	242
15.3.4.2	Effect of Mo in the Availability of Cu and Co	243
15.3.4.3	Impact of Molybdenosis	243
15.4	Sources Leading to Molybdenosis	244
15.4.1	Soil and Sediments	244
15.4.2	Water	245
15.4.3	Industry	245
15.5	Diagnosis and Treatment	245
15.5.1	Diagnosis of Cu and Co Deficiencies	245
15.5.2	Treatment of Molybdenosis-Associated Cu and Co Deficiency	247
15.6	Conclusions	248
	References	248
16	Healing Clays Structure and Functions	253
	<i>Nadun H. Madanayake and Nadeesh M. Adassooriya</i>	
	Abbreviations	253
16.1	Introduction	253
16.2	Classification and Commonly Used Nanoclay Types as Biomedical Applications	254
16.3	Application of Nanoclays as Healing Clays	254
16.4	Healing Clays as Antimicrobial Agents	254
16.5	Wound Healing and Tissue Engineering	255
16.6	Bone Cement	256
16.7	Drug Delivery	256
16.8	Conclusion and Future Perspectives	257
	References	258
	Section 5 Case Studies	261
17	Chronic Kidney Disease of Unknown Etiology (CKDu) – The Search for Causes and the Impact of Its Politicization	263
	<i>M. W. C. Dharma-wardana</i>	
17.1	Introduction	263
17.2	Conceptual Issues	263
17.3	Misuse of Disease Nomenclature	265
17.4	Is CKDu a Disease Associated with Agricultural Communities?	265
17.5	Is CKDu a Disease Associated with the Use of Agrochemicals?	267
17.5.1	Impurities in Fertilizers	267
17.6	Are Pesticide Residues Implicated?	268
17.7	Consequence of Dubious Etiological Claims Causing Public Fear	269
	References	270

18	Uraniferous Province of Lagoa Real: Routes, Dispersion, and Impacts on Health 273
	<i>Lander de Jesus Alves, Fábio Carvalho Nunes, Joel Augusto Moura Porto, Rodrigo Gibaut de Souza Gois, Edvaldo Cruz dos Santos, Hector Hugo Silva Medrado, and Majeti Narasimha Vara Prasad</i>
18.1	Introduction 273
18.2	Lagoa Real Uraniferous Province 274
18.3	Dispersion and Routes of Uranium in the Environment 274
18.3.1	Routes and Dispersion Through Water and Air 277
18.3.2	Soil–Plant–Animal Transfer 282
18.3.2.1	Impacts on Agriculture and Livestock 283
18.4	Uranium Impacts on Human Health 284
18.5	Final Considerations 285
	Acknowledgment 286
	References 286
19	Defluoridation 291
	<i>Benan Yazici-Karabulut, Perihan Derin, Abdullah İzzeddin Karabulut, Ayşegül Demir-Yetis, Ayşe Dilek Atasoy, and Mehmet İrfan Yeşilnacar</i>
19.1	Defluoridation of High Fluoride Groundwater 291
19.2	Adsorption 292
19.3	Electrocoagulation 292
19.4	Coagulation/Precipitation 293
19.5	Nanofiltration 293
19.6	Ion Exchange 293
19.7	Comparing to Several Techniques for Defluoridation 294
19.8	Fluoride Health Risk Assessment 295
19.9	Risk Characterization from Fluoride Exposure 296
	References 298
20	Pharmacology, Toxicology, and Therapeutic Effects of Metals and Minerals Used in Traditional Medicine 303
	<i>Pathirage Kamal Perera, Jeevani Maheshika Dahanayake, and Jalathge Isurika Dilanthi Diddeniya</i>
20.1	Introduction 303
20.2	Objectives 303
20.3	Methods 304
20.4	Results 304
20.4.1	Pharmacological Effects of Metals and Minerals 304
20.4.2	Toxicological Effects of Metals, Minerals, and Drug Preparations 304
20.4.2.1	Toxicological Effects of Cinnabar 304
20.4.2.2	Toxicological Effects of Mercury 308
20.4.2.3	Toxicological Effects of Arogya Vardhana Vati 308
20.4.2.4	Toxicological Effects of Rasa Manikya 308
20.4.2.5	Toxicological Effects of Sameerpannag Ras 308
20.4.2.6	Toxicological Effects of Bhasmas 308
20.4.2.7	Toxicological Effects of Chondrokola Rosh 308
20.4.2.8	Toxicological Effects of Arsenicals 308
20.4.3	Therapeutic Uses of Metals and Minerals 309
20.4.4	Purification, Detoxification, and Incineration Procedures of Commonly Used Metals and Minerals 309
20.4.4.1	Parada – Mercury (Hg) 311
20.4.4.2	Abhra – Mica 311
20.4.4.3	Vaikrantha – Tourmaline (CaF ₂) 311
20.4.4.4	Swarna Makshika – Copper Pyrite (CuFeS ₂) 311

20.4.4.5	Vimala – Iron Pyrite (FeS_2)	311
20.4.4.6	Shilajathu	311
20.4.4.7	Sasyaka ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)	311
20.4.4.8	Gandhaka	311
20.4.4.9	Gairika – Hematite (Fe_2O_3)	311
20.4.4.10	Kasisa ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)	312
20.4.4.11	Kankshi ($\text{K}_2\text{SO}_4 [(\text{Al}_2\text{SO}_4)_3] \cdot 24\text{H}_2\text{O}$)	312
20.4.4.12	Harithala – Orpiment (As_2S_3)	312
20.4.4.13	Manosheela – Realgar (As_2S_2)	312
20.4.4.14	Anjana	312
20.4.4.15	Gauri Pashana (As_2O_3)	312
20.4.4.16	Navasadara – Ammonium Chloride (NH_4Cl)	312
20.4.4.17	Hingula – Cinnabar (HgS)	312
20.4.4.18	Swarna – Gold (Au)	312
20.4.4.19	Thamra	312
20.5	Discussion	312
20.6	Conclusion	312
	References	312
21	Understanding the Etiology of Trace Element-Related Noncommunicable Diseases – Reviewing the Ghanaian Situation	315
	<i>Raymond Webrah Kazapoe, Elikplim Abba Dzikunoo, Ebenezer Ebo Yahans Amuah, and Paul Dankwa</i>	
21.1	Introduction	315
21.2	Materials and Methods	316
21.2.1	Research Approach	316
21.2.2	Regional Geology of Ghana	316
21.3	Results and Discussion	317
21.3.1	Prevalence of Noncommunicable Diseases and Their Linkage to Medical Geology	317
21.3.1.1	Arsenic	317
21.3.1.2	Fluoride	319
21.3.1.3	Selenium	321
21.4	Conclusion	322
	References	322
22	Dental Fluorosis Cases in Turkey	325
	<i>Perihan Derin, Benan Yazici-Karabulut, Aysegul Demir-Yetis, Abdullah İzzeddin Karabulut, Ayse Dilek Atasoy, Mehmet Irfan Yeşilnacar, İbrahim Bayhan, Seda Alp, and Hazal Ozer</i>	
22.1	Distribution of Fluoride and Dental Fluorosis in the World	325
22.2	Distribution of Dental Fluorosis in Turkey	326
22.3	Evaluation of Dental Fluorosis Cases in Turkey	327
22.3.1	Clinical Appearance of Dental Fluorosis	330
22.3.2	Classification of Dental Fluorosis	332
22.4	Development of Sustainable Oral Health Improvement and Strategies in Turkey	333
22.4.1	Classification of Oral and Dental Health in Turkey	334
22.4.1.1	Protective Oral and Dental Health Services	334
22.4.1.2	Therapeutic Oral and Dental Health Services	334
22.4.1.3	Rehabilitation Oral and Dental Health Services	334
22.4.1.4	Oral and Dental Health Promotion Services	334
22.4.2	Current Data on Oral and Dental Health Services in Turkey	334
22.4.3	Treatment Options for Dental Fluorosis	335
	References	335

23	Environmental and Medical Geology of the Lead Mining and Metallurgical Complex of Bahia, Brazil: The Case of the Boquira Lead Mines	339
	<i>José Ângelo Sebastião Araujo dos Anjos, Fernanda Gonçalves da Cunha, Eduardo Paim Viglio, and Fábio Carvalho Nunes</i>	
23.1	Introduction	339
23.2	Results and Discussions	339
23.2.1	Subsequent Studies on Environmental and Medical Geology	343
23.2.1.1	Study 01 – Chemical Characterization of the Tailings	343
23.2.1.2	Study 02 – Groundwater	345
23.2.1.3	Estudo 03 – Sedimento de rua	345
23.2.1.4	Study 04 – Dust Samples from Households	349
23.2.1.5	Study 05 – Territorial Planning	351
23.3	Conclusions	351
	References	353
24	Uncontrolled Coal Fires: How Medical Geology Can Save Lives	355
	<i>N.T. Nichols and R. B. Finkelman</i>	
24.1	Introduction	355
24.2	What are Uncontrolled Coal Fires?	357
24.3	Location – A Global Problem	357
24.4	Dangers of Coal Fires	358
24.5	Why Medical Geology Is Relevant for Coal Fires – Jharia Coal Fires Case Study	361
24.6	Why Has Not More Research Been Done on the Topic?	363
24.7	Conclusion	364
	References	364
	Index	369