
Contents

Preface, xiii

Contributors, xvii

PART I: INTRODUCTION

- 1 General Design Considerations** **3**
William M. Alley
Introduction, 3
Target and Candidate Populations, 4
Issues of Scale, 6
Use of Existing Wells Compared with Specially
Constructed Wells, 14
Documentation of Wells and Well Sites, 17
Quality Assurance, 18
Concluding Remarks, 19
References, 19
- 2 Establishing a Conceptual Framework** **23**
William M. Alley
Introduction, 23
The Vadose Zone, 23
Ground-Water Flow Systems, 27
Uses of Geochemical Data in Regional Conceptualizations, 42
Concluding Remarks, 55
References, 56

PART II: STATISTICAL CONCEPTS

- 3 Ground-Water-Quality Surveys** **63**
William M. Alley
Introduction, 63
Some Preliminary Concepts, 64
Special Considerations for Ground-Water-Quality Surveys, 66
Probability Sampling Approaches, 69
Grid-based Search Sampling, 81
Concluding Remarks, 84
References, 85
- 4 Geostatistical Models** **87**
William M. Alley
Introduction, 87
Some Preliminary Concepts, 88
Regionalized Variables and the Intrinsic Hypothesis, 89
Variograms, 90
Ordinary Kriging, 94
Kriging Variants, 99
Concluding Remarks, 106
References, 106

PART III: WATER-QUALITY CONCEPTS

5	Scales in Chemical Hydrogeology: A Historical Perspective	111
	<i>William Back, Mary Jo Baedeker, and Warren W. Wood</i>	
	Introduction, 111	
	Historic Evolution of Scale in Chemical Hydrogeology, 113	
	Chemical Hydrogeology on a Regional Scale, 116	
	Chemical Hydrogeology on a Local Scale, 121	
	Chemical Hydrogeology at the Site Scale, 123	
	Concluding Remarks, 126	
	References, 128	
6	Inorganic Chemical Processes and Reactions	131
	<i>Donald D. Runnells</i>	
	Introduction, 131	
	Physical and Chemical Properties, 133	
	Chemical Elements of Significance, 141	
	Types of Chemical Reactions, 142	
	Kinetic versus Equilibrium Considerations, 148	
	Concluding Remarks, 149	
	References, 149	
7	Organic Chemical Concepts	155
	<i>Paul D. Capel</i>	
	Introduction, 155	
	Organic Chemicals and Their Nomenclature, 155	
	Physical/Chemical Properties of Organic Chemicals, 162	
	Environmental Processes Affecting Organic Chemicals in Ground Water, 166	
	Concluding Remarks, 176	
	References, 176	
8	Subsurface Microbiology	181
	<i>Francis H. Chapelle, Paul M. Bradley, and Peter B. McMahon</i>	
	Introduction, 181	
	Microbial Ecology of Ground-Water Systems, 183	
	Distribution of Terminal Electron-Accepting Processes (TEAPs) in Ground-Water Systems, 186	
	Biodegradation of Atrazine in Alluvial-Aquifer Sediments, 194	
	Concluding Remarks, 196	
	References, 196	
9	Geochemical Models	199
	<i>D. L. Parkhurst and L. N. Plummer</i>	
	Introduction, 199	
	Inverse Modeling, 199	
	Forward Modeling, 214	
	Concluding Remarks, 222	
	References, 223	
10	Uses of Environmental Isotopes	227
	<i>Tyler B. Coplen</i>	
	Basic Concepts, 227	

Review of Selected Isotopes, 231
 Applications, 241
 Concluding Remarks, 249
 References, 249

11 Environmental Tracers for Age Dating Young Ground Water 255

L. N. Plummer, R. L. Michel, E. M. Thurman, and P. D. Glynn

Introduction, 255
 Tritium, 256
 Tritium–Helium-3, 265
 Krypton-85, 266
 Chlorofluorocarbons, 268
 Comparison among Environmental Tracers, 277
 Selected Nuclear Event Markers, 279
 Organic Compounds as Event Markers: Selected Examples, 280
 Concluding Remarks, 287
 References, 288

PART IV: SELECTED WATER-QUALITY ISSUES

12 Nitrate 297

G. R. Hallberg and D. R. Keeney

Introduction, 297
 Nitrogen Cycling, 297
 Sources of Nitrate to Ground Water, 300
 Nitrate Distribution and Variability, 307
 Concluding Remarks, 316
 References, 317

13 Organic Contaminants 323

Douglas M. Mackay and Lynda A. Smith

Introduction, 323
 Hydrogeology, 324
 Types of Organic Pollutants, 325
 Pollutant Sources, 325
 Approaches to Monitoring of the Subsurface, 328
 National Surveys of VOC Contamination, 332
 State Surveys of Ground-Water Contamination, 335
 Limitations of Existing Ground-Water Quality Data, 339
 Concluding Remarks, 340
 References, 341

14 Pesticides 345

P. S. C. Rao and William M. Alley

Introduction, 345
 Factors Influencing Contamination Potential, 345
 Regional Assessment of Ground-Water Vulnerability, 360
 Selected Studies of Pesticides in Ground Water, 366
 Implications for Regional-Scale Studies, 373
 References, 377

15	Pathogens	383
	<i>Marylynn V. Yates and Scott R. Yates</i>	
	Introduction, 383	
	Factors Affecting Microbial Fate and Transport, 388	
	Modeling Microbial Transport, 395	
	Concluding Remarks, 400	
	References, 400	
16	Acid Precipitation	405
	<i>Gunnar Jacks</i>	
	Introduction, 405	
	Soil Acidification, 406	
	Weathering, 408	
	Plant Uptake of Nutrients, 410	
	Relation between Ground-Water and Surface-Water Acidification, 410	
	Observed Trends in Ground-Water Composition as Influenced by Acidic Deposition, 411	
	Health Effects of Acidic Ground Water, 413	
	Modeling of Soil and Ground-Water Acidification, 414	
	Critical Loads of Sulfur and Nitrogen for Ground Water, 416	
	Amendments for Acidic Ground Water, 417	
	Concluding Remarks, 417	
	References, 418	
17	Natural Radionuclides	423
	<i>Richard B. Wanty and D. Kirk Nordstrom</i>	
	Introduction, 423	
	Radiochemistry, 425	
	Geochemistry of U, Th, Ra, and Rn, 430	
	Case Studies of Natural Radionuclides, 432	
	Concluding Remarks, 436	
	References, 436	
18	Analysis of Ground-Water Systems in Freshwater-Saltwater Environments	443
	<i>Thomas E. Reilly</i>	
	Introduction, 443	
	System Definition, 443	
	Field Measurements Required for Analysis, 453	
	The Use and Misconceptions Regarding Freshwater-Equivalent Heads, 455	
	Summaries of Selected Studies Using the Different System Conceptualizations, 457	
	Monitoring Strategies in Freshwater-Saltwater Systems, 465	
	Concluding Remarks, 466	
	References, 466	
19	Analysis of Karst Aquifers	471
	<i>William B. White</i>	
	Introduction, 471	
	Permeability in Karst Aquifers, 471	
	Karstic Ground-Water Basins, 472	
	Dynamical Response of Karst Aquifers, 480	
	Sediment Transport in Karst Aquifers, 484	
	Evolution of Karst Aquifers, 486	

Water-Quality Problems in Karst, 487
 Concluding Remarks, 488
 References, 488

PART V: CASE STUDIES

- 20 Implementation of a Statewide Survey for Agricultural Chemicals in Rural, Private Water-Supply Wells in Illinois** **493**
Dennis P. McKenna, Thomas J. Bicki, and Warren D. Goetsch
 Introduction, 493
 Project Organization and Responsibilities, 495
 Study Design, 498
 Implementation, 501
 Results, 510
 Concluding Remarks, 511
 References, 511
- 21 Ground-Water-Quality Monitoring in The Netherlands** **515**
Willem van Duijvenbooden
 Introduction, 515
 Environmental Monitoring, 515
 Hydrogeologic Situation, 516
 The Dutch National Ground-Water Quality Monitoring Network, 517
 Provincial Ground-Water-Quality Monitoring Networks, 522
 Soil-Quality and Shallow-Ground-Water Monitoring, 526
 Monitoring of Drinking-Water Quality, 531
 Interpretation Tools and Presentation Techniques, 533
 Integrated Monitoring, 533
 Concluding Remarks, 534
 References, 534
- 22 Multiscale Approach to Regional Ground-Water-Quality Assessment: Selenium in the San Joaquin Valley, California** **537**
Neil M. Dubrovsky, Steven J. Deverel, and Robert J. Gilliom
 Introduction, 537
 Valleywide Sampling, 539
 Areal Distribution of Selenium in Shallow Ground Water, 543
 Depth Distribution of Selenium in Ground Water, 548
 Site-specific Study of Selenium Mobility in Chemically Reduced Sierra Nevada Sediments, 556
 Concluding Remarks, 560
 References, 561
- 23 Multiscale Approach to Regional Ground-Water-Quality Assessment of the Delmarva Peninsula** **563**
Robert J. Shedlock, Pixie A. Hamilton, Judith M. Denver, and Patrick J. Phillips
 Introduction, 563
 Hydrogeomorphic Regions in the Surficial Aquifer, 564
 Design of Study, 568
 Ground-Water-Quality Patterns, 572
 Concluding Remarks, 585
 References, 586

24	Ground-Water Quality in the Oklahoma City Urban Area	589
	<i>Scott C. Christenson and Alan Rea</i>	
	Introduction, 589	
	Design of the Sampling Program, 591	
	Methods Used for Characterizing Urban Land Use, 595	
	Ground-Water Quality, 598	
	Factors Related to Ground-Water Quality, 601	
	Possible Sources of Contaminants, 606	
	Concluding Remarks, 609	
	References, 610	
25	Uses and Limitations of Existing Ground-Water-Quality Data	613
	<i>Pixie A. Hamilton, Alan H. Welch, Scott C. Christenson, and William M. Alley</i>	
	Introduction, 613	
	Sources of Ground-Water-Quality Data, 616	
	Data Screening, 616	
	Suitability of Data for Regional Water-Quality Assessment, 616	
	Applications, 619	
	Concluding Remarks, 621	
	References, 622	
	Index, 623	