Contents

Part I  The Essentials of Dissolved Species Transport in the Subsurface Environment: Basic Definitions, Fundamental Mechanisms and Mathematical Formulation

1  Advection and Dispersion of Dissolved Species in Aquifers .......... 3
   1.1 Governing Equations and Solute Transport Parameters .......... 3
       1.1.1 Advection of Conservative Components in Porous and Fractured Media .................. 4
       1.1.2 Molecular Diffusion and Hydrodynamic Dispersion (Microdispersion) ..................... 11
       1.1.3 Initial and Boundary Conditions; Definitions of Concentration Functions ................... 18
   1.2 Models for Advective Transport in Homogeneous Isotropic Media ........................................ 20
       1.2.1 A Characteristics-Based Method for Solving the Transport Equations ...................... 20
       1.2.2 Solute Transport Process Analysis in Curvilinear Coordinates ....................... 24
   1.3 A One-Dimensional Model of Microdispersion ................. 33
       1.3.1 Solutions for Infinite Porous Domain ........................................ 34
       1.3.2 A Basic (Fundamental) Solution for Semi-Infinite Porous Domain ................. 36
       1.3.3 On the Solution and Analysis of Solute Transport Problems by Applying the Laplace Transform . 38
       1.3.4 Quasi-One-Dimensional Solution of Microdispersion Problems in Deformed Flows in Porous Media ........................................ 45
   1.4 Spatial (2D and 3D) Models of Microdispersion in Unidirectional Steady-State Flow .......... 46
       1.4.1 Basic Solutions for a Point Source ........................................ 47
       1.4.2 Approximate Solutions for 2D and 3D Solute Transport Problems ......................... 50
       1.4.3 Steady-State Asymptotics ........................................ 52
1.4.4 Approximate Solutions for a Finite-Size Source .......... 54
1.4.5 Exact Solutions for 3D Problem .......................... 57
1.4.6 The Influence of Geological Boundaries ............... 58
1.5 Equations for Simplest Chemical Reactions and Transformations .. 60
   1.5.1 Sorption ................................................. 60
   1.5.2 Decay .................................................. 64
References .................................................................. 70

2 Water Movement and Solute Transport in Unsaturated Porous Media .................................................................. 77
   2.1 Basic Soil-Water Movement and Infiltration Models .......... 78
      2.1.1 Governing Functions and Parameters ........................ 79
      2.1.2 Continuity Equation and its Major Representations ...... 85
      2.1.3 Particular Solutions for Moisture Migration and Their Analysis ............................................... 88
   2.2 On Models Coupling Water Infiltration and Solute Transport ......106
      2.2.1 Advection: A Characteristic Solution .......................107
      2.2.2 Dispersion During Adsorption of Water by Soil ..........111
      2.2.3 Advection–Dispersion Transport ............................114
References ..................................................................116

Part II Conceptual Models for Regional Assessment of Solute Transport (Under Homogeneous Liquid Flow Conditions)

3 One-Dimensional Hydrodynamic Mixing Models for Regional Flow Systems Under Areal Recharge Conditions and Their Application to the Interpretation of Isotopic Data ..............123
   3.1 Stable Component Migration .......................................124
      3.1.1 Flow and Mass Balance Under Confined Flow Conditions ...............................................124
      3.1.2 Basic Analytical Solutions .................................125
      3.1.3 Correspondence with a Reservoir Model: Transit Time and Transit Time Distribution ...............128
   3.2 Transport of a Solute Subject to First-Order Single-Stage Decay ...131
      3.2.1 Basic Analytical Solutions .................................131
      3.2.2 Variable Boundary Conditions ............................132
   3.3 Migration of a Solute Subject to Chain Decay ....................135
      3.3.1 Two-Stage Chain Decay of an Unstable Isotope Coming into an Aquifer with Infiltration Recharge .......................136
      3.3.2 Two-Stage Chain Decay in Aquifer with a Radioactive Element in Solids as the Only Source of Radioactivity ..................................139
      3.3.3 Two-Member Chain Decay in Aquifer Solids Containing Several Radioactive Elements ...............141
3.3.4 Basic Concept and Model Development for $^4$He Groundwater Dating ........................................ 143
3.3.5 Converting Physical Units ........................................ 146

3.4 Hydrodynamic Interpretation of Isotopic Groundwater Monitoring Data: Case Studies ........................................ 149
3.4.1 On Groundwater Dating Using Global Isotopes ............ 149
3.4.2 Calculated Distributions of Atmospheric $^3$H and Its Decay Product $^3$He in Groundwater (Typical Curves) ........................................ 152
3.4.3 A Case History of $^3$H–$^3$He Groundwater Analysis and Data Interpretation (Izhora Plateau, Leningrad Region, Russia) ........................................ 157
3.4.4 Hydrodynamic Interpretation of Groundwater Isotopic Data from a Site of Deep Liquid Radioactive Waste Disposal, Siberia Chemical Combine, Russian Federation ........................................ 159

References ....................................................................... 168

4 Profile (Two-Dimensional in Vertical Cross-Section) Models for Solute Transport in Regional Flow Systems .................. 173
4.1 Problem Statement .......................................................... 173
4.2 Homogeneous Confined Aquifer ......................................... 175
  4.2.1 Flow Velocity Field ..................................................... 175
  4.2.2 Flow Kinematic Equations and Concentration Distributions .................................................. 177
  4.2.3 Semi-Analytical Solution for the Distribution of Global Tritium over the Aquifer Depth (Typical Curves) ........................................ 181
4.3 Two-Layer Confined Aquifer .............................................. 183
  4.3.1 Model ................................................................. 183
  4.3.2 An Illustrative Example .............................................. 186
4.4 Multi-Layer (Stratified) Aquifer ......................................... 187
  4.4.1 Hydrodynamic Features of Flow ............................. 187
  4.4.2 Characteristic-Based Relations ................................... 192

References ....................................................................... 196

5 Models for Assessment of Transverse Diffusive and Advective Transfer in Regional Two-Layer Systems .................. 199
5.1 Diffusion-Dispersion Interlayer Exchange ......................... 200
  5.1.1 Balance Estimation for Layer-by-Layer Mass Transport Scheme ........................................... 201
  5.1.2 A Case of Two-Layer Stratum with Sharp Permeability Contrast Between Layers ....................... 202
5.1.3 The Case of a Reservoir Consisting of Two Permeable Layers .............................................207

5.2 Combined Influence of Vertical Advection and Diffusion in a Two-Layer Leaky System on Solute Transport ..........208
5.2.1 Derivation of Analytical Solution ............................208
5.2.2 A Case Study: The Formation and Degradation of a Subsurface Iodine-Water Deposit (Paleohydrogeology Reconstruction) ................213

References ......................................................................217

6 Analytical Models for Solute Transport in Saturated Fractured-Porous Media .....................................................219
6.1 Governing Parameters and Conceptual Model Formulation ........220
6.1.1 Parameters and Topological Presentation of Fractured Rock Continuum ...............................220
6.1.2 Mass Transfer Functions ......................................222
6.1.3 Basic Analytical Solutions (for Asymptotic Models) ........228
6.2 Generalized Solutions ..................................................237
6.2.1 A Streamline-Based Approach ...............................237
6.2.2 Application of the Convolution Property of the Laplace Transform for Solving the Problem of Solute Advective Dispersion in Dual Porosity Systems .....................................238
6.3 Solute Transport in Heterogeneous Dual Porosity Media (Qualitative Analysis) ........................................243
6.4 Adsorption and Decay .................................................245
6.4.1 Adsorption ....................................................245
6.4.2 Decay ..........................................................246
6.4.3 Migration of Unstable Components Under Areal Recharge ...............................................253

References ......................................................................255

7 Flow and Transport Through Unsaturated Fractured-Porous Rocks .....................................................259
7.1 Problem Conceptualization ...........................................259
7.2 Saturation Profile at Steady-State .................................262
7.3 Solute Transport Under Steady-State Moisture Distribution Condition .................................................264
7.4 Nonequilibrium Flow and Transport Processes .............266
7.4.1 Model-Based Approaches .....................................267
7.4.2 A Solution Describing the Early Stage of Wetting Front Propagation ........................................269
7.4.3 The Integral Mass Balance Approach .......................272
7.4.4 A Solution for Leading Front Propagation  
Under Exponentially Damped Regime  
of Water Imbibition into a Gas-Saturated  
Matrix Block ..................................................273

7.4.5 A Generalized Solution .........................................274

7.4.6 Kinematic Wave Approximation .............................278

7.4.7 Solute Transport Problem Formulation ......................282

References .....................................................................282

Part III Solute Transport Processes Induced by Recharge and Discharge Wells

8 Models for Tracer Test Analysis and Interpretation ...............287

8.1 Tracer Migration in a Radially Divergent Flow Field ........288
  8.1.1 Mathematical Background .......................................288
  8.1.2 Microdispersion: A Full Analytical Solution ...........293
  8.1.3 Approximate Solutions ........................................295
  8.1.4 Tracer Tests in Fractured-Porous Aquifers ............299

8.2 Tracer Migration in a Radially Convergent Flow Field .......302
  8.2.1 On the Application of Approximated Models  
      with Linear Geometry and the Assessment  
      of Distorting Factors ........................................303
  8.2.2 Microdispersion of Tracer in a Homogeneous  
      Single Porosity Aquifer ...................................306
  8.2.3 Tracer Transport in a Fractured-Porous Aquifer ......309

8.3 The Time Lag for Breakthrough Curves and Tracer  
Dilution in a Source Well .............................................311
  8.3.1 The Time Lag for Breakthrough Curves  
      Detected in an Observation Well ............................311
  8.3.2 Effect of Tracer Dilution in the Source Well ..........315

8.4 Analytical Models for Doublet Tracer Testing ................316
  8.4.1 Flow Field and Travel Time Between  
      Recharge and Discharge Wells ............................317
  8.4.2 Piston-Like Tracer Displacement  
      in a Homogeneous Single Porosity Aquifer ............318
  8.4.3 An Approximate Solution for Microdispersion  
      in a Homogeneous Aquifer ................................321
  8.4.4 Solutions for Mass Transfer in a Fractured-  
      Porous Aquifer ............................................322

8.5 Problems Related to the Subvertical Migration  
of Tracers in a Field of Recharge and Discharge Wells ........323
  8.5.1 Problem Conceptualization ..................................323
  8.5.2 Partially-Penetrating Well Operation  
      Under the Condition of Nonuniform Initial  
      Concentration Profile .....................................325
8.5.3 Plots and Formulas for the Analysis of Vertical Dipole Tests ........................................329

References ........................................................................................................335

9 Models for Prediction of Effects of Pumping on Groundwater Quality at Well-Fields ........................................339

9.1 Change in the Groundwater Quality in Leaky Aquifer Systems ....................................339
  9.1.1 Flow and Mass Balance Equations ...........................................340
  9.1.2 Solutions of Radial Flow Problems ........................................342
  9.1.3 Solution of Solute Transport Problems ................................344

9.2 Change in the Water Quality of Unconfined Producing Aquifer Under the Influence of Weathering Sulphide Mineral Products in Vadoze Zone ....................................................351
  9.2.1 Governing Factors and the Scale of the Process .................351
  9.2.2 Thermodynamics of Chemical Weathering Process ............354
  9.2.3 Sulfide Oxidation Kinetics ..................................................355
  9.2.4 Distribution of Oxygen and Sulfates in the Vadoze Zone ...................................................356
  9.2.5 Sulfate Migration in an Aquifer ..........................................359

References ........................................................................................................365

Part IV Lumped-Parameter Models for Flow and Solute Balance in Coupled Surface-Water/Groundwater Systems

10 Conceptual Lumped-Parameter Models for Coupled Transient Flow and Solute Transport in Catchments ..........................369

10.1 Basic Concepts and Definitions ......................................................369

10.2 A Two-Layer Model with Lumped Parameters for Lateral Subsurface Flow and Base Flow ........................................372

10.3 Basic Analytical Functions ..........................................................375
  10.3.1 Steady-State Flow ..........................................................375
  10.3.2 Unsteady-State Flow .......................................................375

10.4 Time-Varying Infiltration .............................................................377
  10.4.1 Computation Algorithm ..................................................377
  10.4.2 An Illustrative (Synthesized) Example .............................378

10.5 A Coupled Solution of Fluid Flow and Solute Transport Equations for Time-Independent Boundary Conditions ...379
  10.5.1 Steady-State Flow Field ..................................................379
  10.5.2 Transient Flow Field .......................................................380

10.6 A Coupled Solution of Fluid Flow and Solute Transport Equations for Time-Variable Input Functions ..............383
  10.6.1 Numerical–Analytical Solution Algorithm .........................383
  10.6.2 An Illustrative (Synthesized) Example ...............................384

10.7 Runoff, Infiltration, and Groundwater Recharge ..................385
  10.7.1 Water Budget .................................................................386
10.7.2 Infiltration Models and Conceptual Scenarios for Runoff Generation ........................................388
10.8 A Modified SCS-CN Model ...........................................390
10.8.1 A Basic Semi-Empirical Formula for Runoff Calculation .390
10.8.2 Basic Relationships for Flow Characteristics ............392
10.8.3 Concentration Response Function ...........................393
10.8.4 Illustrative Examples .........................................394
References ......................................................................402

11 Unsteady-State Hydrogeological Model of Evaporation-Induced Sedimentation in a Surface Reservoir ........................................405
11.1 Problem Formulation ...................................................405
11.2 Basic Balance Equation ................................................407
11.2.1 The Case of $C_1 < C_1^*$ .........................................407
11.2.2 The Case of $C_1 \geq C_1^*$ .........................................409
11.3 Numerical Solutions of the Problem and Their Analysis ..........410
References ......................................................................413

Part V Variable-Density Flow and Solute Transport: Physical Phenomena and Mathematical Formulation

12 Dynamic Equilibrium of Freshwater–Saltwater Interface ........417
12.1 Basic Steady-State Models .............................................417
12.1.1 Interface Between Two Immiscible Liquids in Equilibrium ...........................................417
12.1.2 Menken–Herzberg Ratio (Approximation) ...........................................419
12.2 Approximate Solutions of the Problem of the Shape of the Seawater–Fresh Groundwater Interface ...........................................421
12.2.1 A Confined Coastal Aquifer .........................................421
12.2.2 A Leaky Confined Coastal Aquifer .................................423
12.2.3 A Phreatic Coastal Aquifer Under Recharge Conditions ...426
12.2.4 Freshwater Lens on an Elongated Oceanic Island ........427
12.3 Equilibrium for Saltwater Upconing Beneath a Partially Penetrating Well ...........................................429
12.3.1 Problem Setting and Analysis of Existing Approaches and Solutions ...........................................430
12.3.2 Analytical Solutions for the Critical Pumping Rate and the Critical Interface Rise ...........................................432
References ......................................................................436

13 Dynamics of Saltwater–Freshwater Interface ...............439
13.1 Two-Dimensional Profile Models for Immiscible Fluids Interface Displacement ...........................................439
13.1.1 Linear Displacement ................................................440
13.1.2 Radial Displacement ................................................447
13.2 Application of Two-Phase Flow Approach for Brine Transport in Porous Media Description ...............................453
13.2.1 Physical and Mathematical Basis ............................453
13.2.2 Properties of Particular Solutions ............................455

References .....................................................................460

14 Studying Subsurface Density-Induced Phenomena Using Numerical Modeling ..........................................................463
14.1 On Physical Approaches to Mathematical Programming Formalism .........................................................464
14.2 Brine Migration in Idealized Aquifer Systems .................468
   14.2.1 Numerical Simulators’ Performance Capabilities and Their Testing ........................................468
   14.2.2 Physical Phenomena Analysis for Migration of a Brine Released from a Surface Reservoir ..............473
   14.2.3 Solute Concentration in a Pumping Well Affected by Saltwater–Freshwater Interface Upconing ....481

References .....................................................................489

Part VI Case Histories of Subsurface Contamination by Industrial and Environmental Brines: Field Data Analysis and Modeling of Migration Processes

15 Radioactive Brine Migration at the Lake Karachai Site (South Urals, Russian Federation) ..........................................495
15.1 Introduction Remarks ..................................................495
15.2 Hydrogeological Setting and General Description of the Migration Process ...............................................498
15.3 Groundwater Contamination Plume ................................500
   15.3.1 A Structure of Groundwater Flow at the Site ............500
   15.3.2 The Distribution of the Radionuclides and Principal Ions Within Contamination Plume .............501
15.4 Overview of Modeling Analysis Approach .......................508
15.5 Model Setup and Calibration ...........................................509
   15.5.1 Model Design .....................................................510
   15.5.2 Sharp-Interface Approach ....................................511
   15.5.3 Fully Miscible Transport Modeling Approach .............513
   15.5.4 Brine Plume Simulation and Prediction .................515

References .....................................................................517

16 Modeling of Seawater Intrusion in Coastal Area of River Andarax Delta (Almeria, Spain) ............................................519
16.1 Study Area ................................................................519
   16.1.1 Brief Geological Description of the Site ...............520
   16.1.2 Hydrogeological Setting .......................................521
16.2 Groundwater Salinization ......................................................523
  16.2.1 Spatial and Temporal Changes in Groundwater Quality ...523
  16.2.2 Major Results of Vertical Electrical Soundings ..........526
16.3 Conceptualization and Model Design of Seawater
            Intrusion Process .....................................................527
16.4 Modeling Results ..........................................................530
References .............................................................................534

17 Studying and Modeling of Uncontrolled Discharge of Deep
            Brine into Mine Drainage Systems at the Korshunovsky
            Iron Ore Mine (Eastern Siberia, Russian Federation) ...........535
  17.1 A Brief Description of the Geological and
       Hydrological Structure of the Site, Drainage Measures
       and Groundwater Regime Disturbed by Mining Operations ....536
  17.1.1 Hydrogeological Units ..............................................537
  17.1.2 Drainage of the Open Pit Mine .................................537
  17.1.3 Vertical Hydrogeochemical Stratification
            of the Groundwater System and Temporal
            Changes in Groundwater Quality .................................538
  17.2 Analytical Assessments ................................................539
  17.3 Numerical Modeling .....................................................541
  17.3.1 Process Conceptualization and Model Design ..........542
  17.3.2 Modeling Results ...................................................542
  17.3.3 Experimental Verification ..................................543
References .............................................................................544

18 Light Wastewater Injection into a Deep Geological
            Formation Containing Brine (“Volzhsky Orgsinte”
            Deep-Well Disposal Site, Central Russia Region) ...............545
  18.1 Hydrogeological Characteristics and Setting
            of the Geological Environment ....................................545
  18.1.1 Available Field Data ..............................................545
  18.1.2 Conceptualization of the Hydrogeological
            Setting and Model Description .................................551
  18.2 The Concept and Technique of Numerical Analysis ....552
  18.3 Numerical Solution of a Groundwater Transport Problem ....554
References .............................................................................556

Part VII Physicochemical Description and Mathematical Formulation
            of Sorption Processes

19 Conceptual Models for Sorption Under Batch Conditions .......561
  19.1 Sorption Equilibrium ..................................................561
  19.1.1 Principal Sorption Isotherms ..................................561
19.1.2 Principal Factors Affecting the Experimental Isotherm Data .................................................564
19.1.3 Hysteresis Phenomenon in Sorption .........................566
19.2 Models of Sorption/Desorption Kinetics .........................571
  19.2.1 Sorption Kinetics .............................................572
  19.2.2 A Generalized Nonequilibrium Sorption Model ............572
19.3 Models for Static (Batch) Sorption Experiments .................573
  19.3.1 Mass Balance in a Batch Experiment .........................573
  19.3.2 One-Site Kinetic Model of Sorption with Concomitant Mineral Dissolution ......................574
References ......................................................................580

20 Conceptual Transport Models for Adsorbable Solutes .............585
  20.1 Equilibrium Sorption in Groundwater Flow .................585
    20.1.1 Effective Transfer Parameters for Equilibrium Reversible Sorption ...........................................585
    20.1.2 The Influence of Nonlinear Sorption on Adve...
21.3 Hysteresis in Sorption ..................................................627
21.3.1 Experiments with Reference Samples of Cambrian Sands ...........................................627
21.3.2 Model Estimates of the Formation of Concentration Fronts ......................................633
21.4 Spatial Variability of Sorption Parameters .............................................634
21.4.1 A Review of Published Materials ..........634
21.4.2 Spatial Variability of Nonlinear Sorption Parameters for Sr-90 .............................636
References ..........................................................644

22.1 Introduction Remarks ..................................................647
22.2 The Structure, Chemical and Mineral Composition, and the Physical Properties of the Clays ......................................................649
22.3 Rock Mechanical and Hydraulic Properties ..........................................................652
22.4 Variations in Physical and Mechanical Properties over Depth .........................................653
22.5 A Comparative Analysis of the Clay Formations ..................................................657
22.6 Sorption–Desorption Experiments (Vkt Clay) ..................................................658
22.6.1 Sorption ..........658
22.6.2 Desorption ..........660
22.7 Diffusion Experiments .................................................662
22.7.1 Single-Chamber Diffusion Cell (In/Out-Diffusion) Tests with Packing Cambrian Clay .....662
22.7.2 Single-Chamber Diffusion Cell Tests with Undisturbed Vendian Clay Samples ..........669
22.7.3 A 3D Diffusion Test with a Cambrian Clay Sample of Natural Structure ..........................672
22.7.4 A Comparative Analysis .....................................677
References ..........................................................679

23.1 Nonideal Behavior of Sorption Curves Observed in Batch Tests with Core Material from the Tomsk-7 Site ..........681
23.1.1 Materials, Methods, and Experimental Series ..................................................682
23.1.2 Results: Qualitative Analysis ..................................................684
23.1.3 Modeling Results and Discussion .........694
23.1.4 On the Direction of Processes Under Extremely High Temperatures ..........................698
23.2 The Influence of Mineral Transformation of Aquifer Matrix on Radionuclide Sorption in Batch Tests with Core Material from the Krasnoyarsk-26 Site ....................... 701
  23.2.1 General Information .................................................... 701
  23.2.2 Experimental Setup and Analysis of the Major Results .... 702
23.3 Radionuclide Sorption onto Fresh Fractures of Volcanogenic Metamorphized Rocks from the Lake Karachai Site ......................................................... 706
  23.3.1 Samples and Experimental Setup ................................. 707
  23.3.2 Sorption Parameters .................................................... 708
  23.3.3 Hysteresis in Sorption ................................................. 709
References ............................................................................ 710

Part IX Colloid-Facilitated Solute Transport in Aquifers

24 Colloidal Systems and Equilibrium in Such Systems ............... 715
  24.1 General Views on Colloids and Their Genesis .................. 715
  24.2 Properties of Colloidal Systems ....................................... 719
    24.2.1 Stability of Colloidal System ..................................... 719
    24.2.2 Mobility and Accumulation of Colloids in the Porous Media ................................................. 722
  24.3 Sorption of Chemical Species onto Colloids (Under Batch Conditions) ......................................................... 724
    24.3.1 Basic Reactions ......................................................... 724
    24.3.2 Governing Equations for Sorption Equilibrium ............ 726
    24.3.3 Sorption Kinetics and Some Experimental Data ............ 727
  24.4 Subsurface Behavior of Actinides at Existing and Proposed RW Disposal Sites ................................................. 731
    24.4.1 Sites Where Pu and Some Other Actinides Have Been Detected in the Environment ....................... 731
    24.4.2 Designed and Engineered Repositories for RW Disposal .......................................................... 733
References ............................................................................ 735

25 Experimental Study of Radionuclide Interaction with Colloids with Respect to Tomsk-7 Deep-Well RW Disposal in a Geological Formation ......................................................... 739
  25.1 A Study of Sorption of Plutonium on Colloids in Ultrafiltration Experiments with Synthesized Solutions .... 739
    25.1.1 Experimental Setup .................................................... 739
    25.1.2 Interpretation of Experimental Results ....................... 743
  25.2 A Study of Colloidal Forms of Radionuclide Migration at a Radioactive Waste Disposal Site .................... 750
    25.2.1 Experimental Setup .................................................... 750
    25.2.2 Calculation Algorithm and Obtained Parameter Values .......................................................... 752
Reference ............................................................................. 754
26 Models of Sorption Type for Colloid-Facilitated Transport in Aquifers

26.1 The Governing Equations for Migration of Colloidal Solutions
   26.1.1 A Dual-Species Model
   26.1.2 Transport of a Polydisperse Colloidal Solution

26.2 A Model with Effective Parameters
   26.2.1 Equilibrium Reversible Sorption
   26.2.2 Irreversible Sorption

26.3 Numerical Modeling and Illustrative Examples
   26.3.1 Introduction Comments
   26.3.2 Equilibrium Sorption
   26.3.3 The Influence of Sorption Kinetics

References

27 A Thermodynamics-Based Conceptual Model for Colloid-Facilitated Solute Transport

27.1 Surface Complexation Models (Static Formulation)

27.2 On Modeling Approach for Multicomponent Solute Transport
   27.2.1 Tests and Illustrative Examples
   27.2.2 Sample Problems and Analysis of Migration Process

27.3 A Conceptual Model for the Subsurface Transport of Plutonium on Colloidal Particles Involving Surface Complexation Reactions
   27.3.1 The Basic Chemistry of Plutonium
   27.3.2 Examples of Modeling Assessments for Migration of the Sodium Nitrate Solution Containing Pu(IV) and Colloids

References

Conclusion

Index
Subsurface Solute Transport Models and Case Histories
With Applications to Radionuclide Migration
Rumynin, V.G.
2011, XXI, 815 p. 309 illus., Hardcover