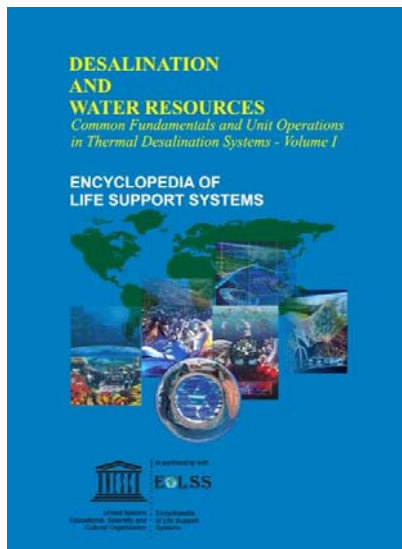


CONTENTS

DESALINATION AND WATER RESOURCES COMMON FUNDAMENTALS AND UNIT OPERATIONS IN THERMAL DESALINATION SYSTEMS



Common Fundamentals and Unit Operations in Thermal Desalination Systems - Volume 1

No. of Pages: 406

ISBN: 978-1-84826-421-2 (eBook)

ISBN: 978-1-84826-871-5 (Print Volume)

Common Fundamentals and Unit Operations in Thermal Desalination Systems - Volume 2

No. of Pages: 386

ISBN: 978-1-84826-422-9 (eBook)

ISBN: 978-1-84826-872-2 (Print Volume)

Common Fundamentals and Unit Operations in Thermal Desalination Systems - Volume 3

No. of Pages: 380

ISBN: 978-1-84826-423-6 (eBook)

ISBN: 978-1-84826-873-9 (Print Volume)

For more information of e-book and Print Volume(s) order, please [click here](#)

Or [contact : eolssunesco@gmail.com](mailto:eolssunesco@gmail.com)

DESALINATION AND WATER RESOURCES (DESWARE)

International Editorial Board

Editor-in-Chief: Al-Gobaisi, D. M.K.

Members

Al Awadhi, A. Ali	Hammond, R. P.	Morris, R.
Al Radif, Adil	Hanbury, W. T.	Nada, N.
Al-Mutaz, I. S.	Harris, A.	Ohya, H.
Al-Sofi M.	Harrison, D.	Peluffo, P.
Andrienne, J.	Hassan, A. M.	Rao, G. P.
Awerbuch, L.	Hodgekiess, T.	Rautenbach, R.
Balaban, M.	Husain, A.	Reddy, K. V.
Beraud-Sudreau, D.	Ismat, K.	Saal, D.
Birkett, James D.	Karabelas, A.J.	Sadhukhan, H.K.
Blanco, J.	Kesou, A.	Sage, A.P.
Bodendieck, F.	Krause, H. P.	Sarkodie-Gyan,
Borsani , R.	Kubota, S.	Thompson
Bushnak, A. A.	Kumar, A.	Sommariva, C.
Capilla, A. V.	Kurdali, A.	Strathmann, H.
Catanzaro, E.	Laborie, J.	Temperley, T.
Damak, S.	Leitner, G. F.	Tleimat B.
Darwish, M. Ali	Lennox, F. H.	Todd, B.
Delyannis, E.u E.	Lior, N.	Tony F.
Dempsey J.	Ludwig, H.	Tusel, G.
El-Din, S.	Lukin, G.	Belessiotis, V.
El-Mahgary, Y.	Magara, Y.	Veza, J. M.
El-Nashar, A. M.	Makkawi B.	Vigneswaran, S.
El-Sayed, Y. M.	Malato, S.	Wade, N. M.
Finan, M. A.	Mandil , M.A.	Wang, S.
Furukawa, D.	Marquardt, W.	Wangnick, K.
Genthner, K.	McArthur,N.	Woldai A.
Germana, A.	Meller, F. H.	Watson, I. C.
Ghiazza, E.	Mewes, V.	Wessling, M.
Glade, H.	Michels, T.	Winters, H.
Goto, T.	Miyatake, O.	
Grabow, W. O.K.	Morin, O. J.	

CONTENTS

VOLUME I

Survey of Long Time Behavior and Costs of Industrial Fluidized Bed Heat Exchangers 1
 R. Rautenbach and T. Katz, *Institut für Verfahrenstechnik der RWTH Aachen, Turmstraße 46, Aachen, Germany*

1. Introduction
2. Design
3. Heat Transfer of a Fluidized Bed
 - 3.1. Without a Fluidized Bed (Laminar/Turbulent Pipe Flow)
 - 3.2. Circulating Fluidized Bed in the Tubes
4. Prevention of Fouling
5. Operating Experiences with Commercial Units
6. Costs
7. Summary and Overview

Entrainment in Evaporators 16
 C.D. Hornburg, *Water Consultants International, Inc. Fort Lauderdale, Florida, USA*

1. Introduction
2. Fundamentals
3. Configuration and Parameters
 - 3.1. Flash Evaporators
 - 3.2. HTME and VTE Evaporators

Mist Eliminators 28
 Andreas Hambach, *Max Rhodius GmbH Weissenburg Bayern Germany*

1. Introduction
2. Knitted Wire Mesh Mist Eliminators
 - 2.1. Design velocity
 - 2.2. Separation efficiency
 - 2.3. Pressure Drop
 - 2.3.1. Dry Pressure Drop
 - 2.3.2. Wet Pressure Drop
3. Wave Plate Separator
 - 3.1. Efficiency
 - 3.2. Gas Capacity
 - 3.3. Pressure Drop
 - 3.4. Solids and Clogging Particles

The Problem of Non-Condensable Gas Release in Evaporators 39
 Heike Glade and Klaus Genthner, *University of Bremen, Germany*

1. Introduction
2. Sources of Non-condensable Gases in Evaporators
3. Effects of Non-condensable Gases in Evaporators
4. Summary of Cases that Require Consideration of Non-condensable Gas Release

Analysis, Approaches, and Models for the Release of Carbon Dioxide, Nitrogen, Oxygen, and Argon in Evaporators **44**Heike Glade and Klaus Genthner, *University of Bremen, Germany*

1. Introduction
2. Fundamentals of Desorption with and without Chemical Reaction
3. Release of Oxygen, Nitrogen and Argon
4. Release of Carbon Dioxide
 - 4.1. The CO₂ System in Seawater
 - 4.1.1. Chemical Reactions and their Kinetics
 - 4.1.2. Parameters of the CO₂ System in Seawater
 - 4.1.3. Relative Distribution of the Carbonic Acid Species
 - 4.2. Model of the CO₂ Release in the Individual Stages of MSF Distillers
 - 4.3. Modeling of the CO₂ System in the Pre-heaters of MSF Distillers
5. Simulation Results with the Gas Release Model
 - 5.1. Difference between CO₂ Release and O₂, N₂, and Ar Release
 - 5.2. The Effect of the Mass Transfer Coefficient and the Phase Interface Area on CO₂ Release
 - 5.3. The Effect of the Top Brine Temperature on CO₂ Release
 - 5.4. The Concentrations of the Carbonic Acid Species in the Pre-heaters

Interstage Brine Flow in MSF Chambers **68**R. Rautenbach and S. Schäfer, *Institute für Verfahrenstechnik, RWTH Aachen, Aachen, Germany*

1. Introduction
2. Open Flow in Horizontal Channels and Through Orifices
 - 2.1. Open Channel Flow
 - 2.2. Hydraulic Jump
 - 2.2.1. Types of Hydraulic Jump
 - 2.2.2. Hydraulic Jumps enforced by Weirs (Sill)
 - 2.3. Interstage Flow through Orifices
 - 2.3.1. The Rectangular Orifice (slot)
 - 2.3.2. Combination Orifice/Weir
 - 2.3.3. Thermo-Syphon
- 2.4. Flow Instabilities and Blowthrough
 - 2.4.1. Flow Instabilities
- 2.5. Blowthrough
- 2.6. Future Aspects

Design Data for Non-Condensable Gas Release Rates in Flash Chambers **87**Heike Glade and Klaus Genthner, *University of Bremen, Germany*

1. Introduction
2. Design Assumptions Regarding the Release of O₂, N₂, and Ar
3. Design Assumptions Regarding the Total CO₂ Release
 - 3.1. Decomposition of the Bicarbonate Ions
 - 3.2. Semi-empirical Approach by Watson Desalination Consultants
 - 3.3. Semi-empirical Approach by Water Consultants International
 - 3.4. Model developed at the University of Bremen
4. Design Assumptions Regarding the Distribution of the CO₂ Release Between the Individual Stages
 - 4.1. CO₂ Release Determined by Chemical Reaction Kinetics
 - 4.2. Retarded Release of CO₂
 - 4.3. CO₂ Release Determined by Chemical Reaction Kinetics, Mass Transfer, and Physical Phase Equilibrium
5. Measurements of the CO₂ Release in the Individual Stages of MSF Distillers
6. Comparison of the Approaches to CO₂ Release Computation with the Measurement Results
7. Dimensioning of Design Venting Rates

Heat and Mass Balances in the Evaporator Components Group: Stage Heat and Mass Transfer Balance **105**M.A. Darwish and Faisal Al-Juwayhel, *Mechanical Engineering Department, Kuwait University, Kuwait*

1. Introduction
2. Factors Affecting the Brine Flow to the Stage
 - 2.1. The Hydrodynamic of Inter-stage Brine Transfer
 - 2.1.1. Region from Upstream the Orifice to the Vena Contracta
 - 2.1.2. Flow from Vena Contracta to Upstream the Weir with Hydraulic Jump
 - 2.1.3. Flow Upstream and Downstream the Weir (Weir Overflow)
3. Stage Analysis
 - 3.1. Brine Pool Compartment (SSSF Analysis)
 - 3.1.1. The Last Stage
 - 3.1.2. The First Stage
 - 3.2. The Vapor Space
 - 3.3. The Distillate Product Tray
 - 3.4. The Cooling Brine
4. Heat Transfer Calculations
 - 4.1. Condensing Heat Transfer Coefficient
 - 4.2. Inner-Side (Water) Heat Transfer Coefficient
 - 4.3. The Fouling Factor

A Case Study: Performance and Acceptance Test of a Power and Desalination Plant **134**Atef M Al Baghdadi, *Water and Electricity Authority Abu Dhabi, U.A.E*

1. Introduction
2. Guaranteed Values
 - 2.1. Power Plant Capacity
 - 2.2. Net Specific Heat Consumption of the Power Plant
 - 2.3. Boiler Capacity
3. Guarantee Conditions
4. Measuring Equipment
 - 4.1. Measurement of Temperature
 - 4.2. Measurement of Pressure
 - 4.3. Measurement of Flows
 - 4.4. Measurement of the Boiler Fuel Flow
 - 4.5. Sampling of Fuels
 - 4.6. Measurement of Electrical Power
5. Isolation of the Cycle
6. Frequency of Readings and Duration of the Tests
7. Diagrams and List of Measuring Points
8. Evaluation of Test Results
 - 8.1. Determination of the Net Power Output
 - 8.2. Determination of Net Specific Heat Consumption (PL115, PL85, PL65)
 - 8.3. Determination of the Distillate Production
 - 8.4. Determination of Steam Flow at Boiler Outlet
 - 8.5. Guarantee Comparison

Separation **178**Vega-Mercado Humberto, *Bio Sterile Validation, Merck & Co., Inc., West Point, Pennsylvania, USA*

1. Liquid-Liquid Extraction
 - 1.1. Introduction
 - 1.2. Theoretical Aspects
 - 1.2.1. Triangular Coordinates and Equilibrium Data
 - 1.3. Selection of Solvent

- 1.4. Thermodynamic Aspects of Liquid-Liquid Equilibria
 - 1.4.1. Single Stage Equilibrium Extraction
 - 1.4.2. Multistage Crosscurrent Extraction
 - 1.4.3. Countercurrent Multistage Extraction
- 1.5. Equipment for Liquid-Liquid Extraction
 - 1.5.1. Stagewise Systems
 - 1.5.2. Continuous Contact Equipment – Differential Contactors
 - 1.5.3. Selection of Liquid-Liquid Extraction Equipment
2. Solid Liquid Separation
 - 2.1. Introduction
 - 2.2. Theoretical Aspects
 - 2.3. Types of Processes (Unit Operations)
3. Mechanical Separation
 - 3.1. Introduction
 - 3.2. General Principles for Centrifuges and Cyclones
 - 3.3. Equipment
4. Membrane Processing
 - 4.1. Introduction
 - 4.2. Physical Chemistry of Membrane Processes
 - 4.3. Membrane Types and Configurations
 - 4.3.1. Hollow Fibers
 - 4.3.2. Dead-End Membranes or Screen Filters
 - 4.3.3. Depth Filters
 - 4.3.4. Plate Units
5. Column Chromatography
 - 5.1. Introduction
 - 5.2. Equipment and Commercial Resins
 - 5.2.1. Ion Exchange Chromatography
 - 5.2.2. Size Exclusion or Gel Filtration Chromatography
 - 5.2.3. Affinity Chromatography
 - 5.2.4. Hydrophobic Interaction Chromatography
 - 5.2.5. Reversed Phase Chromatography
 - 5.2.6. Hydroxyapatite Chromatography
6. Distillation
 - 6.1. Interphase Mass Transfer Separation Processes
 - 6.2. Thermodynamic Aspects of Vapor-Liquid Equilibrium
 - 6.3. Bubble and Dew Points
 - 6.4. Distillation Methods
 - 6.4.1. Flash Distillation
 - 6.4.2. Differential Distillation
 - 6.4.3. Simple Steam Distillation
 - 6.4.4. Continuous Distillation of Binary Systems
 - 6.4.5. McCabe-Thiele Method
 - 6.5. Recent Advances in Distillation

Membrane Separation Technologies

252

Takeshi Matsuura, *Department of Chemical Engineering, University of Ottawa, Ottawa, Ont. Canada*

1. History
2. Definition and classification
3. Performance parameters
4. Membrane separation processes where the driving force is pressure
 - 4.1. Reverse osmosis
 - 4.1.1. Principle of reverse osmosis
 - 4.1.2. Membrane materials and membrane structure
 - 4.1.3. Transport
 - 4.1.4. Concentration polarization

- 4.1.5. Membrane modules
- 4.1.6. Applications
- 4.2. Nanofiltration, ultrafiltration and microfiltration
 - 4.2.1. Description of the processes
 - 4.2.2. Membrane materials and membrane structure
 - 4.2.3. Gel model for ultrafiltration
 - 4.2.4. Brownian diffusion, lateral migration and shear induced diffusion in microfiltration
 - 4.2.5. Applications
- 5. Membrane separation processes where the driving force is partial pressure
 - 5.1. Membrane gas separation
 - 5.1.1. Description of the process
 - 5.1.2. Transport model
 - 5.1.3 Applications
 - 5.2. Pervaporation
 - 5.2.1. Description of the process
 - 5.2.2. Transport
 - 5.2.3. Applications
 - 5.3. Recovery of vapor from air
- 6. Membrane separation processes where the driving force is difference in electrical potential
 - 6.1. Electrodialysis
 - 6.2. Bipolar membrane
- 7. Other membrane processes
 - 7.1. Membrane distillation
 - 7.2. Membrane extraction
 - 7.3. Membrane reactor
 - 7.4. Hybrid processes

Mass Transfer Operation–Membrane Separations

289

Enrico Drioli, Efram Curcio and Enrica Fontananova, *Institute on Membrane Technology, ITM-CNR, c/o University of Calabria, Rende (CS), Italy*
Department of Chemical Engineering and Materials, University of Calabria, Rende (CS), Italy

- 1. Introduction
- 2. An overview on the most industrialized membrane separation processes and emerging applications
 - 2.1. Pressure driven membrane processes
 - 2.1.1. Reverse osmosis
 - 2.1.2. Nanofiltration
 - 2.1.3. Ultrafiltration
 - 2.1.4. Microfiltration
 - 2.2. Electrodialysis
 - 2.3. Gas separation
 - 2.4. Pervaporation and vapor permeation
 - 2.5. Membrane contactors
 - 2.5.1. Membrane distillation
 - 2.5.2. Membrane crystallization
 - 2.5.3. Membrane emulsification
 - 2.6. Catalytic membranes reactors
- 3. Sustainable growth and integrated membrane operations
 - 3.1. Case study 1: Membrane technology in desalination
 - 3.2. Case study 2: Membrane technology in fruit juices industry
 - 3.3. Case study 3: Membrane technology for wastewaters treatment in the leather industry
- 4. Conclusions

- 4.2 Water from Springs and Roofs
- 4.3 Clear Surface Water
- 4.4 Turbid or Colored Surface Water
- 4.5 Eutrophied Surface Water
- 5. Handling Purified Water
- 6. Conclusions

Conventional Water Treatment Technologies

65

S. Vigneswaran and H.H. Ngo, *Faculty of Engineering, University of Technology, Sydney, Australia*

C. Visvanathan, *Asian Institute of Technology, Bangkok, Thailand*

M. Sundaravadivel, *Graduate School of the Environment, Macquarie University, Australia*

- 1. Introduction
- 2. Treatment Processes
- 3. Rapid Mixing
 - 3.1 Hydraulic Mixers
 - 3.2 Mechanical Mixers
- 4. Flocculation
 - 4.1 Types of Flocculators
- 5. Sedimentation
 - 5.1 Tube Settlers
 - 5.2 Sludge Blanket Clarifiers
- 6. Filtration
 - 6.1 Slow Sand Filtration
 - 6.2 Rapid Sand Filtration
 - 6.2.1 Improvements on Rapid Filters
- 7. Disinfection

Hazardous Waste Treatment Technologies

85

G. Eduljee, *ERM, Eaton House, Wallbrook Court, North Hinksey Lane, Oxford, UK*

- 1. Introduction
- 2. Biological Treatment
 - 2.1 Aerobic and Anaerobic Systems
 - 2.2 Design Issues
- 3. Physical and Physicochemical Processes
 - 3.1 Process Selection
 - 3.2 Example Applications
- 4. Thermal Treatment
 - 4.1 Dedicated Waste Incinerators
 - 4.2 Combustion in Industrial Furnaces
 - 4.3 Controlled Air Incinerator
- 5. Technological Advances
 - 5.1 Biological Treatment
 - 5.2 Physicochemical Processes
 - 5.3 Thermal Processes
- 6. Conclusions

Treatment of Industrial Wastewater by Membrane Bioreactors

102

Chettiyappan Visvanathan, *Environmental Engineering and Management Program, School of Environment, Resources and Development, Asian Institute of Technology, Thailand*

- 1. Introduction
- 2. Design of MBR system
 - 2.1 Membrane System Design
 - 2.2 Reactor Design for MBR System

Mass Transfer Operations: Hybrid Membrane Processes	347
Enrico Drioli, Efrem Curcio and Enrica Fontananova, <i>Institute on Membrane Technology, ITM-CNR, c/o University of Calabria, Rende (CS), Italy</i> <i>Department of Chemical Engineering and Materials, University of Calabria, Rende (CS), Italy</i>	

1. Introduction
2. Hybrid Membrane Desalination Systems
 - 2.1. MSF/RO Systems
 - 2.2. NF/MSF Systems
 - 2.3. MF and UF as Pretreatment Processes
3. Integrated membrane systems in agrofood industry
4. Hybrid membrane operations for wastewater treatment
5. Integrated membrane operations in Gas Separation
6. Integration of molecular separation and chemical/energy conversion
 - 6.1. Catalytic Membrane Reactors
 - 6.2. Fuel Cells
7. Conclusions

Index	371
--------------	------------

About DESWARE	375
----------------------	------------

VOLUME II

Distillation OR Rectification	1
J. G. Stichlmair, <i>Department of Chemical Engineering, Technische Universität München, Germany</i>	

1. Introduction
2. Fundamentals
 - 2.1. Vapor Liquid Equilibrium
 - 2.1.1. Binary Mixtures
 - 2.1.2. Ternary Mixtures
 - 2.1.3. Multicomponent Mixtures
 - 2.2. Continuous Distillation Processes
 - 2.2.1. Binary Mixtures
 - 2.2.2. Ternary Mixtures
 - 2.2.3. Multicomponent Mixtures
 - 2.3. Batch Distillation
 - 2.4. Reactive Distillation
3. Equipment
 - 3.1. Tray Columns
 - 3.2. Packed Columns
4. Separation Processes
 - 4.1. Processes for Separating Zeotropic Mixtures
 - 4.2. Processes for Separating Azeotropic Mixtures

Unconventional Sources of Water Supply	26
P.E.Odendaal, <i>Consultant, Pretoria, South Africa; Former Executive Director, South African Water Research Commission; Former President, International Water Association.</i>	

1. Introduction
2. Water Reclamation
 - 2.1. Factors Promoting Water Reclamation
 - 2.2. Direct and Indirect Reuse

- 2.3. Water Reclamation Technology
- 2.4. Health Considerations in Water Reclamation
- 2.5. Applications of Water Reclamation
 - 2.5.1. Agricultural Irrigation
 - 2.5.2. Groundwater Recharge
 - 2.5.3. Industrial Reuse
 - 2.5.4. Environmental and Recreational Reuse
 - 2.5.5. Non-potable Urban Reuse
 - 2.5.6. Potable Reuse
- 2.6. Public Acceptance
- 3. Desalination of Seawater
 - 3.1. Desalination Technology
 - 3.1.1. Multistage Flash
 - 3.1.2. Multi-effect Distillation
 - 3.1.3. Vapor Compression Distillation
 - 3.1.4. Reverse Osmosis
 - 3.1.5. Electrodialysis
 - 3.1.6. Freezing
 - 3.1.7. Membrane Distillation
 - 3.2. Quality of Product Water
 - 3.3. Comparison of Distillation Processes and Reverse Osmosis
 - 3.4. Dual Purpose Systems

Guidelines for Potable Water Purification

41

Willie M. Malan, *Civil Engineering Department, University of Stellenbosch, South Africa*

- 1. Introduction
- 2. Water Quality
 - 2.1 Microorganisms
 - 2.2 Physical Characteristics
 - 2.3 Chemical Constituents
 - 2.4 Trace Organics
- 3. Overview of Unit Processes in Water Purification
 - 3.1 Screening
 - 3.2 Aeration
 - 3.3 Flocculation
 - 3.3.1 Chemical Dosing
 - 3.3.2 Flash Mixing
 - 3.3.3 Floc Formation
 - 3.3.4 Floc Conditioning
 - 3.3.5 Plant Layout for Flocculation
 - 3.4 Sedimentation
 - 3.5 Filtration
 - 3.5.1 Slow Sand Filter
 - 3.5.2 Rapid Sand Filter
 - 3.5.3 Gravity Filters
 - 3.5.4 Pressure Filters
 - 3.5.5 Multimedia Filter
 - 3.5.6 Diatomaceous Earth Filter
 - 3.6 Chlorination
 - 3.6.1 Gaseous Chlorine
 - 3.6.2 Chlorine Granules
 - 3.6.3 Chlorine Solutions
 - 3.6.4 Chlorine Tablets
 - 3.7 Sludge Disposal
- 4. Process Selection
 - 4.1 Groundwater

3. Operation of the Membrane System in MBR
4. Application of MBR in Industrial Wastewater Treatment
5. Conclusions

Sludge Treatment Technologies**124**

S. Vigneswaran and J. Kandasamy, *Faculty of Engineering and Information Technology, University of Technology, Sydney, Australia*

1. Introduction
2. Sludge Stabilisation
3. Sludge Dewatering
 - 3.1 Belt Presses
 - 3.2 Pressure Filters
 - 3.3 Centrifuges
 - 3.3.1 Costs
4. Sludge Incineration

Advanced Treatment Technologies for Recycle/Reuse of Domestic Wastewater**140**

H. H. Ngo and S. Vigneswaran, *Faculty of Engineering, University of Technology, Sydney, Australia*
 M. Sundaravadivel, *Graduate School of the Environment, Macquarie University, Sydney, Australia*

1. Introduction
2. Advanced Wastewater Treatment Technologies
3. Biological Nutrient Removal Processes
 - 3.1 Intermittently Decanted Aeration Lagoon (IDAL) System
 - 3.2 Biologically Enhanced Phosphorus Removal (BEPR) System
4. Physicochemical Processes
 - 4.1 Deep Bed Filtration for Wastewater Treatment and Reuse
 - 4.1.1. Direct Filtration (DF)
 - 4.1.2. Contact-flocculation Filtration (CFF)
 - 4.1.3. Mobile Bed Filter (MBF)
 - 4.1.4. Floating Medium Filters
 - 4.2. Deep Bed Filtration for Wastewater Reuse—A Case Study of Rouse Hill STP, Sydney, Australia
 - 4.3. Membrane Filtration Processes
 - 4.4. Membrane Filtration for Wastewater Reuse—Case Studies
 - 4.4.1. Water Reclamation at Eraring Power Station, New South Wales, Australia
 - 4.4.2. ‘Water mining’ plant at Canberra, Australia
 - 4.4.3. Wastewater Reuse Plant at Taronga Zoo, Sydney, Australia
 - 4.5. Hybrid Processes

The Potential for Industrial Wastewater Reuse**162**

C. Visvanathan, *Environmental Engineering Program, Asian Institute of Technology, Pathumthani, Thailand*

Takashi Asano, *Department of Civil and Environmental Engineering, University of California at Davis, California, USA*

1. Introduction
2. Water Availability and Consumption
3. Industrial Wastewater Reuse: Present Status, Trends and Issues
 - 3.1. Internal Wastewater Recycling
 - 3.2. Reuse of Treated Industrial Wastewater
4. Available Treatment Technologies
 - 4.1. Pulp and Paper Industries
 - 4.2. Power Plants
 - 4.3. Textile Industries
 - 4.4. Food Processing Industries

- 4.5. Other Industries
- 5. Policy and Institutional Aspects
- 6. Conclusions

Deep Bed Filtration: Modelling Theory and Practice

180

G. Keir and V. Jegatheesan, *School of Engineering, James Cook University, Australia*
 S. Vigneswaran, *Faculty of Engineering, University of Technology, Sydney, Australia*

- 1. Introduction
 - 1.1. Conditions of Deep Bed Filtration
 - 1.2. Stages of Deep Bed Filtration
 - 1.3. Transport Mechanisms
 - 1.3.1. Interception
 - 1.3.2. Inertial Impaction
 - 1.3.3. Sedimentation
 - 1.3.4. Diffusion
 - 1.3.5. Hydrodynamic Action
 - 1.3.6. Straining
 - 1.4. Attachment Mechanisms
 - 1.4.1. Long-Range Forces
 - 1.4.2. Short-Range Forces
 - 1.4.3. Presence of Primary and Secondary Minima
 - 1.4.4. Effect of Surface Blocking and Particle Size
 - 1.5. Detachment Mechanisms
 - 1.6. Modeling Approaches
 - 1.6.1. Microscopic Modeling
 - 1.6.2. Macroscopic Modeling
- 2. Mathematical Models for the Initial Filtration Stage
 - 2.1. Removal Efficiency
 - 2.2. Model Representation of Porous Media
 - 2.3. Classification of Microscopic Models
 - 2.4. Eulerian Methods (Convective Diffusion Analysis)
 - 2.4.1. Perfect-Sink Models
 - 2.4.2. Non-Penetration Models
 - 2.5. Lagrangian Methods (Trajectory Analysis)
 - 2.6. Semi-Empirical Formulations
 - 2.6.1. Correlations for the Collision Efficiency α
 - 2.6.2. Correlations for the Initial Collection Efficiency η_0
 - 2.7. Limitations of Initial Stage Models
- 3. Mathematical Models for the Transient Filtration Stage
 - 3.1. Macroscopic Models
 - 3.1.1. Methods of Solution to Macroscopic Equations
 - 3.2. Transient Stage Models
 - 3.2.1. Retained Particle Detachment Models
 - 3.2.2. Deposition Site Saturation Models
 - 3.2.3. Particle Blocking Models
 - 3.2.4. Surface Charge Models
 - 3.3. Limitations of Macroscopic and Transient Stage Models
 - 3.4. The Effect of Particle Size Distribution
- 4. Conclusion

Raw Water Pre-Treatment: Introduction and Overview

225

Heinz Ludwig, *Fichtner, Stuttgart, Germany*

- 1. Pollution of Raw Water and its Measurement
- 2. Raw Water Extraction Installations
- 3. Measures to Prevent Biofouling

4. Pre-cleaning - Flocculation/Filtration and Sedimentation
5. Extended Pre-cleaning - Microfiltration, Ultrafiltration, and Nanofiltration
6. Prevention of Scaling
 - 6.1. Thermal Processes
 - 6.2. Membrane Processes
7. Further Pre-treatment Measures - Ion Exchange and Precipitation Methods

Pre-Cleaning Measures: Filtration

234

Dieter Saal, *Darmstadt, Germany*

1. General
2. Basic Principles of Filtration
3. Particle Transport and Agglomeration Mechanism
 - 3.1. Sedimentation
 - 3.2. Diffusion
4. Filter Systems and Selection
 - 4.1. Filtering Through a Bed of Granular Material
 - 4.2. Low-rate Filters
 - 4.3. Rapid Filters
 - 4.4. Open filters
 - 4.5. Closed Vertical Pressure Filters
 - 4.6. Closed Horizontal Filters
5. Filter Dimensioning Principles
6. Filter Media and Selection
7. Filter Backwash Principles
 - 7.1. Cleaning of Single-layer Filters
 - 7.2. Cleaning of Multi-layer Filters
8. Operation of Filter Equipment

Microfiltration and Ultrafiltration

257

Ata M. Hassan, *Saline Water Conversion Corporation, RDC Al-Jubail, Saudi Arabia*
Kevin Price, *U.S. Bureau of Reclamation, Denver, U.S.A.*

1. Introduction
2. RO Feed Pretreatment by the Membrane Filtration Process

Flocculation and Flocculation Filtration

272

Dieter Saal, *Darmstadt, Germany*

1. Flocculation
 - 1.1. Basic Principles of Flocculation
 - 1.2. Effects of Flocculants and Coagulants
 - 1.3. Types of Flocculants and Coagulants
 - 1.4. Design Principles and Equipment of Dosing Systems
 - 1.5. Storing and Preparing Flocculants
 - 1.6. Operation of Equipment
2. Flocculation Filtration
 - 2.1. Basic Principles of Floc-filtration
 - 2.2. Design of Floc-filters
 - 2.3. Control and Operation of Floc-filtration Systems

Post-Treatment of Distillate and Permeate: Introduction and Overview

288

Heinz Ludwig, *Fichtner, Stuttgart, Australia*

1. Purpose of Post-treatment

2. Composition of Desalinated Water
3. Standards and Guidelines for Composition of Potable Water
4. Processes for Potabilization of Distillate and Permeate

Composition of Desalinated Water

295

Heinz Ludwig, *Fichtner, Stuttgart, Australia*

1. Distillate
 - 1.1. Ionogenic Composition
 - 1.2. Trace Substances
 - 1.2.1. Metals
 - 1.2.2. Organics
 - 1.3. Hygienic Conditions
2. Permeate
 - 2.1. Ionogenic Composition
 - 2.2. Trace Substances
 - 2.2.1. Metals
 - 2.2.2. Organics
 - 2.3. Hygienic Conditions
3. Product Water of the Hybrid RO/MSF Process
4. Dialysate

Supercritical Extraction

308

Jonin T.M., *Nestle, Switzerland*

Adjadj L.P., *Laboratorium für Technische Chemie/LTC, Switzerland*

Rizvi S.S., *Food Science Department, Cornell University, USA*

1. Introduction
2. Concepts of Supercritical Fluids
3. Solubility Measurement Techniques
 - 3.1. Dynamic Systems for the Determination of Solubility in Supercritical Fluids
 - 3.2. Static Systems for the Determination of Solubility in Supercritical Fluids
 - 3.3. Dynamic Systems vs. Static Systems
4. Solubility Measurements
5. Applications of Supercritical Fluid Extraction
 - 5.1. Decaffeination
 - 5.1.1. Decaffeination of Coffee
 - 5.1.2. Cocoa Bean Extraction
 - 5.2. Hop Extraction
 - 5.3. Spice Extraction
 - 5.4. Fractionation
 - 5.5. Analysis of Wine Aroma
6. Other Applications of Supercritical Fluids
 - 6.1. Supercritical Fluid Extrusion (SCFX)
 - 6.2. Supercritical Water Oxidation

Crystallization

325

Hartel, R.W., *Department of Food Science, University of Wisconsin, USA*

1. Introduction
2. Crystallization Principles
 - 2.1. Phase/State Behavior
 - 2.2. Nucleation
 - 2.3. Crystal Growth
 - 2.4. Recrystallization
3. Controlling Crystallization in Foods

- 3.1. Control for Product Quality
- 3.2. Control for Separation
- 3.3. Control to Prevent Crystallization
- 4. Factors Affecting Control of Crystallization
 - 4.1. Heat and Mass Transfer Rates
 - 4.1.1. Rate of Cooling
 - 4.1.2. Crystallization Temperature
 - 4.1.3. Agitation
 - 4.1.4. Drying
 - 4.2. Product Formulation

Index **349**

About DESWARE **355**

VOLUME III

Concentration of Liquid Foods **1**

Hernandez, Ernesto, *OmegaPure Technology and Innovation Center, Houston, Texas, USA*

- 1. Introduction
- 2. Physical Properties of Liquid Foods
- 3. Concentration by Evaporation
 - 3.1. Evaporator Types and Applications
 - 3.2. Design of Evaporators
 - 3.2.1. Multiple-Effect Evaporators
 - 3.3. Fouling
 - 3.4. Food Applications
- 4. Concentration with Membranes
 - 4.1. Concentration by Reverse Osmosis
 - 4.2. Design Considerations
 - 4.3. Construction Materials
 - 4.4. Membrane Configurations
 - 4.5. Concentration by Direct Osmosis
 - 4.6. Concentration by Membrane Distillation
 - 4.7. Concentration by Osmotic Distillation
- 5. Combined Technologies in the Concentration of Liquid Foods
- 6. Freeze Concentration

Environmental Impacts of Intakes and Out Falls **25**

Marinus Vis, *Water Resources and Environment Division, Delft Hydraulics, the Netherlands*

- 1. Introduction
- 2. Types of Impacts
 - 2.1. Physical Changes
 - 2.2. Introduction of Heat and Salt
 - 2.3. Introduction of Toxins
- 3. Impacts on Specific Coastal Ecosystems
 - 3.1. Introduction
 - 3.2. Mangrove Forests
 - 3.2.1. Salinity
 - 3.2.3. Pollutants
 - 3.2.4. Hydrodynamics
 - 3.2.5. Seagrass Beds

- 3.2.6. Salinity
- 3.2.7. Temperature
- 3.2.8. Sedimentation
- 3.2.9. Hydrodynamics
- 3.2.10. Turbidity
- 3.2.11. Pollutants
- 3.3. Impacts of Construction and Operation of Desalination Plants
- 3.4. Coral Reefs
 - 3.4.1. Salinity
 - 3.4.2. Temperature
 - 3.4.3. Pollutants

Environmental Impact of Seawater Desalination Plants

39

I.S. Al-Mutaz, *King Saud University, Saudi Arabia*

1. Introduction
2. Pollutants from Desalination Plants
3. Thermal Impact
4. Air Pollution Problem
5. Pollutants Emitted from Power Plants
 - 5.1. Sulfur Oxides
 - 5.2. Nitrogen Oxides
- 5.3. Carbon Monoxide
 - 5.4. Hydrocarbons
 - 5.5. Particulates
6. Methods of Air Pollution Control at the Power Plant
7. Pollution from the Jeddah Desalination Plant
8. Conclusions

Chemical Hazards in Seawater Desalination by The Multistage-Flash Evaporation Technique

53

A.M. Shams El Din, *MTL, Abu Dhabi Water and Electricity Authority (ADWEA), Abu Dhabi (UAE)*

1. Introduction
2. Seawater Chlorination
3. Scaling and Anti-scale Agents
4. Acid Wash of Distillers
5. Air (Oxygen)
6. Anti-corrosion Agents
7. Impact of Seawater Desalination on the Environment
8. Oil Dispersants
9. Water Conditioning

Sustainable Development, Water Resources, and Desalination

64

Andrew P. Sage, *School of Information Technology and Engineering, Department of Systems Engineering and Operations Research, George Mason University, Fairfax, VA, USA*

1. Introduction
2. Sustainable Development
3. Sustainability Needs and Natural Resources in the World
 - 3.1. Population
 - 3.2. GDP Per Capita
 - 3.3. Energy
 - 3.4. Food and Agriculture
 - 3.5. Forests
 - 3.6. Water

- 3.7. Materials
- 3.8. Habitat
- 4. Contemporary Sustainability Threats and Associated Needs
 - 4.1. Structural Needs
 - 4.2. Human Needs
 - 4.3. Physical Needs
 - 4.4. Specific Strategies – Rural, Urban, and Private Sector
- 5. Information and Knowledge Imperfections and Sustainability

Industrial Ecology, Water Resources, and Desalination

91

Andrew P. Sage, *School of Information Technology and Engineering, Department of Systems Engineering and Operations Research, George Mason University, Fairfax, VA, USA*

- 1. Introduction
- 2. *Agenda 21* and the Need for Systems Engineering and Industrial Ecology
 - 2.1. Chapter 30. Strengthening the Role of Business and Industry
 - 2.2. Chapter 31. The Scientific and Technological Community
 - 2.3. Chapter 34. Transfer of Environmentally Sound Technology, Cooperation and Capacity-Building
 - 2.4. Chapter 40. Information for Decision-Making
- 3. Standards and Sustainable Water Resource and Desalination Efforts
- 4. Industrial Ecology and Sustainable Development
- 5. Water, Desalination, and Sustainability
- 6. Integration of Systems Engineering and Industrial Ecology Constructs with Water Resources and Desalination Applications
- 7. Conclusions

The Plight of Potable and Usable Water – Pollution, Health Hazards, Environmental Threats and Abatement Methods

136

Rajeswari Padmasola, née Ganti, *Bangalore, India*

- 1. Introduction
- 2. Some Physical Properties of Water
- 3. Some Chemical Properties of Water
- 4. Sources of Water
- 5. Degradation of Water Quality
 - 5.1. pH
 - 5.2. Suspended Solids
 - 5.3. Potential
- 6. Water Quality Criteria for Domestic Use
- 7. Toxicity of Pollutants
- 8. Pathogenic Pollution
- 9. Water Treatment

Energy

151

G. P. Rao, B. Makkawi, A. Woldai, R. J. Hornby and D. Al-Gobaisi, *International Center for Water and Energy Systems, Abu Dhabi, UAE*

- 1. Humanity's Need for Energy
- 2. Physical Concepts of Energy
- 3. Nonrenewable Energy Sources
 - 3.1. Fossil fuels
 - 3.1.1. Oil
 - 3.1.2. Coal
 - 3.2. Nuclear energy
- 4. The Earth's Resources of Renewable Energy

- 4.1. Solar energy
- 4.2. Hydroelectric energy
- 4.3. Wind energy
- 4.4. Geothermal energy
 - 4.4.1. Dry steam sources
 - 4.4.2. Wet steam sources
 - 4.4.3. Hot brine sources
 - 4.4.4. Hot dry rock sources
 - 4.4.5. Molten magma
- 4.5. Tidal energy
- 4.6. Wave energy
 - 4.6.1. Oscillating water column system
 - 4.6.2. Clam system
 - 4.6.3. The duck device
 - 4.6.4. Buoy mechanism
- 4.7. Biomass energy
- 5. Basic Concepts of Energy
 - 5.1. Mechanical energy
 - 5.2. Chemical energy
 - 5.3. Nuclear fission
 - 5.3.1. Nuclear fusion
 - 5.4. Electrical energy
 - 5.4.1. Faraday's laws of electromagnetic induction:
 - 5.4.2. Hall effect
 - 5.4.3. Energy storage in magnetic and electric fields
 - 5.4.4. Alternating current
 - 5.4.5. Conversion of mechanical energy into electricity
 - 5.4.6. Transmission of electrical energy
 - 5.4.7. Electric motors
 - 5.4.8. Alternating current motors
 - 5.4.9. Transformers
 - 5.4.10. Storage of electrical energy
 - 5.4.11. Batteries and fuel cells
 - 5.5. Heat
 - 5.5.1. Basic concepts of heat
 - 5.5.2. Thermodynamics
- 6. Thermal Energy Systems
 - 6.1. Thermodynamic cycles in heat engines
 - 6.1.1. Carnot cycle
 - 6.1.2. Rankine cycle
 - 6.1.3. Gas turbine cycle
 - 6.2. Isentropic efficiencies of individual components in the system
 - 6.2.1. The isentropic efficiency of a turbine
 - 6.2.2. The isentropic efficiency of a compressor
 - 6.2.3. Pumps
 - 6.2.4. Combustion chambers
 - 6.2.5. Internal combustion engines
 - 6.2.6. Refrigeration Cycle
 - 6.2.7. The Stirling Engine
- 7. Hydrogen Energy Systems
- 8. Magnetohydrodynamic (MHD) Generator
- 9. Appendix

2. Origin of Water and the Oceans on the Earth
3. Properties of Water
4. Molecular Structure of Water
5. Hydrogen Bond

Global Information and Data on Water Resources **210**

Bushara M. Ahmed, *International Center for Water and Energy Systems, Abu Dhabi, UAE*

1. Introduction
2. North America (USA and Canada)
3. West Asia
4. Africa
5. Asia and the Pacific
6. Europe and CIS countries
7. Latin America and the Caribbean
8. Economics of Water and Energy Technology

SI Units and Some Conversion Factors **219**

A. Woldai, B. Makkawi, and D. Al-Gobaisi, *International Center for Water and Energy Systems, Abu Dhabi, UAE*

1. Introduction
2. Names and symbols for basic SI units
 - 2.1. SI base units
 - 2.2. SI derived units
 - 2.3. Supplementary Units
3. Special names and symbols for derived SI units
4. Prefixes for SI units
 - 4.1. Units outside the SI
5. Conversion Factors
 - 5.1. Frequently used conversion factors seawater distillation
6. Standard Seawater
7. Physical properties of Seawater

Rural and Urban Water Supply and Sanitation **235**

Yasumoto Magara, *Professor of Engineering, Hokkaido University, Sapporo, Japan*

1. Introduction
2. Water Treatment Technology
 - 2.1. Drinking Water Supply
 - 2.2. Sanitation technology
3. Social Aspects
 - 3.1. Priority of water supply and sanitation
 - 3.2. Institutional Development
4. Economic and Financing
 - 4.1. Cost of Water Supply and Sanitation
 - 4.2. Payment of Charges
5. Community Participation
6. Hygiene

Water Supply and Sanitation Technology **268**

Yasumoto Magara, *Professor of Engineering, Hokkaido University, Sapporo, Japan*

1. Introduction

2. Water supply technologies
 - 2.1. Water source management
 - 2.1.1 Rainwater harvesting
 - 2.1.2 Traditional wells
 - 2.1.3 Spring protection
 - 2.2. Water treatment
 - 2.2.1 Outlines
 - 2.2.2 System configuration
 - 2.2.3 Contaminant removal
 - 2.3. Leakage control
 - 2.3.1 Adverse effects of water leakage
 - 2.3.2 Pressure control
 - 2.3.3 Leakage detection and monitoring
 - 2.3.4 Piping material
3. Sanitation technologies
 - 3.1. System selection
 - 3.2. Nightsoil collection
 - 3.3. Anaerobic digestion
 - 3.4. Flush toilet
 - 3.5. Sewerage
4. Stepwise improvement planning
 - 4.1. Concept of stepwise improvement
 - 4.2. Development target in master plan
 - 4.3. Relevant information for adoption of stepwise improvement plan

Social Aspect**284**Yasumoto Magara, *Professor of Engineering, Hokkaido University, Sapporo, Japan*

1. Introduction
2. Priority of water supply and sanitation
 - 2.1. Large benefit against cost
 - 2.2. Repercussion effect
 - 2.3. Continuation
 - 2.4. Measurable revenue from charges
3. Institutional development
 - 3.1. Development of legal systems
 - 3.2. Payment by the users as beneficiary
 - 3.3. Interests in meter management system by the waterworks companies
 - 3.4. Human resource management
4. Environmental consideration in development projects

Economics and Financing**293**Yasumoto Magara, *Professor of Engineering, Hokkaido University, Sapporo, Japan*

1. Introduction
2. Development cost of water supply and sanitation
3. Economic analysis
 - 3.1. Evaluation procedure
 - 3.1.1 Identification of costs and benefits
 - 3.1.2 Pricing of costs and benefits
 - 3.1.3 Conversion of costs and benefits to present value
 - 3.1.4 Comparison of costs and benefits by investment criteria
 - 3.1.5 Sensitivity analysis by selected factors
 - 3.2. Pricing theory for economic analysis
 - 3.2.1 Shadow price
 - 3.2.2 Transfer payment

- 3.2.3 Externality
- 3.2.4 Opportunity cost
- 3.2.5 Sunk cost
- 3.2.6 Combine prices in different time period
- 3.2.7 Discount factor
- 3.2.8 NPV, B/C ratio, IRR
- 3.3. Estimating non-market values
- 4. Financial Management
 - 4.1 Cost recovery
 - 4.1.1 Community fund raising
 - 4.1.2 Indirect taxes
 - 4.1.3 Tariff
 - 4.1.4 Water kiosk/public lavatory
 - 4.1.5 Contribution in kind
 - 4.2. Examining financial state
 - 4.3. Governmental subsidies
 - 4.4. System failure
 - 4.4.1 Financial shortage
 - 4.4.2 Material shortage
 - 4.4.3 Unavailability or shortage of engineers
 - 4.4.4 Insufficient storage of basic materials
 - 4.4.5 Fixed water charges
 - 4.4.6 Extremely low water charges
 - 4.5. Ability to pay and percentage to be paid
- 5. System Options
 - 5.1. Water charge and price of bottled water
 - 5.2. On-site sanitation and off-site sanitation

Community Participation

311

Yasumoto Magara, *Professor of Engineering, Hokkaido University, Sapporo, Japan*
 Mitsugu Saito, *Technical Manager, Overseas Environmental Cooperation Center, Tokyo, Japan*

- 1. Introduction
- 2. Participation and development
 - 2.1. Development Cooperation and Participation
 - 2.2. Successful Participatory Development
 - 2.3. Participation in Water Supply and Sanitation Sector
- 3. Possibilities and limitations of participatory approach
 - 3.1. Several Degrees of Participation
 - 3.2. Typical Processes of Participation
 - 3.3. Participatory Evaluation
 - 3.4. Pros and Cons in Participation
- 4. Important viewpoints for water supply and sanitation
 - 4.1. Gender Issue
 - 4.2. Poverty Issue
 - 4.3. Conservation of Commons
- 5. Methodologies for participatory development
 - 5.1. Logical Framework Approach
 - 5.1.1. Logical Framework (Logframe)
 - 5.1.2. ZOPP
 - 5.1.3. PCM
 - 5.2. Participatory Rural Appraisal (PRA)
 - 5.3. Methodology for Participatory Assessment (MPA)

Hygiene	325
Yasumoto Magara, <i>Professor of Engineering, Hokkaido University, Sapporo, Japan</i>	
Mitsugu Saito, <i>Technical Manager, Overseas Environmental Cooperation Center, Tokyo, Japan</i>	

1. Introduction
2. Global statistics on hygiene
3. Water related infectious diseases
4. Pathogenic organisms
 - 4.1. Helminthiasis
 - 4.2. Protozoiasis
 - 4.3. Bacterial Diseases
 - 4.4. Viral Infections
5. Hygiene promotion
 - 5.1. Principles
 - 5.2. Target group
 - 5.3. Procedures
 - 5.4. Social Marketing Approach
 - 5.4.1. Key Component
 - 5.4.2. Programming
 - 5.5. Relation to other Components
6. School sanitation and hygiene
7. Hygiene evaluation
 - 7.1. Study Plan
 - 7.2. Training Study Team
 - 7.3. Methodologies and Tools
 - 7.4. Analysis and Interpretation

Index	343
About DESWARE	349