Day 1

Course Title: Design of Coastal Intakes and Brine Outfalls for Seawater Reverse Osmosis (SWRO) Desalination Plants

Sea water desalination with Reverse Osmosis (SWRO) is an increasingly popular option to augment the water supply for many expanding coastal cities. Significant advancements have occurred in the last few decades in membrane technology, process control and brine management, and together they have led to a considerable reduction in the water production cost. At the same time, the production capacity of SWRO plants is also expanding rapidly to achieve the economy of scale, and the intake and brine flow rates have increased significantly.

The design of coastal intakes needs to take into account the environmental and maintenance considerations, while the design of brine outfalls needs to ensure a good mixing of the brine discharge with the ambient water throughout the flow range. For both, a good knowledge of the environmental hydraulics involved is essential.

Instructor: Professor Adrian Law, Associate Professor, School of Civil and Environmental Engineering; Director, Environmental Process Modeling Centre (EPMC), Nanyang Environment and Water Resources Institute (NEWRI), Nanyang Technological University, Singapore

A/P Adrian Law Wing Keung received his PhD from the University of California at Berkeley. He was a practicing engineer in the USA for more than 7 years, before joining the academic faculty of the School of Civil and Environmental Engineering, Nanyang Technological University (NTU), Singapore. His current research focuses on the expert knowledge of environmental hydraulics to improve the design of membrane and desalination systems. He was recognized with the Karl Emil Hilgard Hydraulic Prize as well as the Wesley Horner Award by the American Society of Civil Engineers (ASCE), and two Outstanding Technical Paper Awards by the Bechtel Corporation, USA. Currently, he is the Executive Committee Member of the International Association of Hydro-environment Engineering and Research (IAHR) Asian Pacific Division, Past-Chair of the Joint IAHR-IWA Committee on Marine Outfall Systems, as well as in the Editorial Board of related journals in this area. In Singapore, he is also the Director of the Environmental Process Modelling Centre (EPMC) in the Nanyang Environment and Water Research Institute (NEWRI), as well as an active research member in the Singapore Membrane Technology Centre.

08:30 – 08:45 Overall Introduction of Course
09:00 – 10:45 Course in Session
10:45 – 11:15 Refreshment Break
11:15 – 12:30  Course in Session

12:30 – 13:30  Lunch Break

Course Title:  Strategies to Control Organic and Biological Fouling Of Reverse Osmosis (RO) Membranes and Use of High Permeable Membranes in Seawater RO

This course will provide students with a working knowledge of the causes of organic and microbial fouling of reverse osmosis (RO) membranes used in wastewater reclamation and seawater desalination (SWRO). The role of lectin-like substances in RO feed water in initiating organic and microbial membrane fouling will be described. Case studies on the control of organic and microbial membrane fouling at a wastewater reclamation plant and sea water desalination plant will be discussed.

The use of high permeable RO membranes in SWRO to lower energy costs will be evaluated and the use of hybrid design to control organic and microbial membrane fouling will be discussed.

Instructor:   Professor Harvey Winters, Professor Emeritus, Fairleigh Dickinson University, USA

Professor Harvey Winters is Professor Emeritus at Fairleigh Dickinson University, Teaneck, New Jersey, USA in the School of Natural Sciences.

Professor Winters received his PhD degree (1970) from Columbia University, New York in Chemical Biology and did Post-Doctoral Fellowship at Columbia University (1970-72) on micro-fouling of marine surfaces supported by the Office of Navy Research.

Professor Winters began his research interests into Reverse Osmosis (RO) desalination in 1976 and eventually became Director of Desalination Technology Transfer Center at Fairleigh Dickinson University in 1980. His research has focused on microbial fouling of RO membranes in seawater applications. His research has been supported by the National Science Foundation (NSF), Office of Navy Research (ONR), U.S. Bureau of Reclamation (USBR) and Middle East Desalination Research Center (MEDRC) in Muscat, Oman. He has over 60 research publications and holds one patent in RO desalination.

Professor Winters is a reviewer for Journal of Membrane Science and IDA Journal of Desalination and Water Reuse. He has been Director of the International Desalination Association (IDA) and has been awarded two prestigious awards from IDA for most outstanding research papers at the 1995 and 2005 IDA World Congresses on Desalination and Water Reuse.
Course Outline:

13:30 – 15:30

I. Definition of RO membrane fouling
   A. Types of membrane fouling
   B. Organic fouling
   C. Microbial fouling
   D. Colloidal fouling
   E. Particulate fouling

II. Microbial (Biological) Fouling
   A. History
   B. Involvement in thermal processes
   C. Involvement in membrane (RO) desalination
      1. Affects flux
      2. Affects salt passage
      3. Affects pressure drop across the permeators
   D. Stages in microbial fouling
      1. Chemical conditioning of membrane surface by organics
      2. Primary attachment by colonizers- primary film
      3. Secondary attachment by bacteria & algae-secondary film
      4. Dispersal stage
   E. Quorum Sensing (QS) in biofilm formation
   F. Quorum Quenching (QQ) in biofilm control
   G. Viable But Not Culturable (VBNCh) bacteria
   H. Revised paradigm (TEP is responsible for biofilm formation)
   I. Lectin-like humics not TEP is important in biofilm formation

III. Organic Fouling of Membranes
   A. Types of organics present in wastewater and seawater
   B. Particulate organics (> 0.4 µm)
      1. Transparent exopolymer particles (TEP)
      2. Floating microbial biofilms (protobiofilms)
   C. Colloidal Organics (< 0.4 > 0.05 µm)
      1. Biopolymers
      2. Humics and building blocks
      3. Low molecular weight neutrals and acids
      4. TEP precursors (acidic polysaccharides)
      5. Lectin-like humics

IV. What Are Driving Forces That Cause Organic and Microbial Membrane (RO) Fouling
   A. Presence of TEP and/or floating microbial biofilms
   B. Presence of TEP Precursors and/or lectin-like humics
   C. Presence of Quorum Sensing substances
   D. Chlorination and biocide addition
E. VBNC bacteria
F. Concentration polarization (CP)

15:30 – 15:45 Refreshment Break

15:45 – 17:30 V. Assays for Measurement of Foulants in Raw Wastewater & Raw Seawater
   A. VBNC bacteria
   B. LC-OCD analyses of organics
   C. Alcian blue measurement for TEP and TEP precursors
   D. Coupling ammonium sulfate precipitation, LC-OCD/Alcian Blue and red cell agglutination for quantifying Lectin-like substances

VI. Pretreatment Analyses
   A. Disinfection
   B. Multi-media filtration
   C. Membrane (MF/UF)
   D. Dissolved Air Flotation (DAF)

VII. Case Studies
   A. Wastewater RO reclamation- Singapore
      1. Sites
      2. TEP & TEP precursor analyses
      3. LC-OCD organic analyses
      4. Bacterial analyses
      5. Floating biofilms (Protobiofilms)
      6. Lectin-Like humics
      7. Membrane pretreatment (MF/UF)
      8. Foulant analyses of RO membranes
      9. How to control RO membrane organic and microbial fouling
   B. Seawater RO Plants- Middle East & Singapore
      1. Open Intake versus seawells
      2. TEP & TEP precursors
      3. LC-OCD analyses
      4. Lectin-like substance analyses
      5. Membrane versus conventional pretreatment
      6. Control of seawater RO membrane fouling

VIII. Use of Highly Permeable Membranes in Seawater RO
   A. Energy consumption in SWRO and does use of highly permeable membranes significantly affects energy usage?
   B. Energy efficiency with use of more efficient high pressure pumps
   C. Control of organic and microbial RO membrane fouling
Day 2

Course Title: Operation and Maintenance of Seawater Reverse Osmosis Desalination Plants

This training program provides practical understanding of key desalination plant treatment processes and focuses on plant process and equipment operation, maintenance, monitoring, troubleshooting and optimization.

Instructor: Nikolay Voutchkov, PE, BCEE, Water Globe Consultants, LLC, USA

Nikolay Voutchkov has more than 25 years of experience in the field of desalination and water reuse as an independent technical advisor to public utilities implementing large desalination projects in Australia, USA, and the Middle East; and to private companies and investors involved in the development of advanced membrane technologies. He has extensive expertise with all phases of project delivery, from conceptual scoping, pilot testing and feasibility analysis to front-end and detailed project design; permitting; contractor procurement; project construction and operations oversight/asset management. For over 11 years, he served as a Chief Technology Officer and Corporate Technical Director for Poseidon Resources, a private company involved in the development of the largest seawater desalination projects in the USA.

Mr. Voutchkov has published over 30 technical articles and co-authored 10 books on membrane water treatment and desalination, including technology and design guidelines for the American Water Works Association and the Australian Water Association. In recognition research and engineering efforts in the field of seawater desalination, he has received a number of prestigious awards from the WateReuse Research Association, the International Desalination Association, the International Water Association and the American Academy of Environmental Engineers.

Course Outline:

08:30 – 09:30 1.1 Fundamentals of Desalination Plant Operations and Maintenance
  • Desalination Plant Treatment Process Overview
  • Criteria for Well Operating Plant/Common Maintenance Practices
  • Operation and Maintenance Costs

09:30 – 10:30 1.2 Intake Systems
  • Types, Purpose and Function
  • Source Seawater Data Collection
  • Performance Monitoring and Troubleshooting

10:30 – 10:45 Refreshment Break

10:45 – 12:00 1.3 Dissolved Air Flotation Clarifiers
  • Types, Purpose and Function
  • Performance Monitoring and Troubleshooting
12:00 – 13:00  Lunch Break

13:00 – 14:30  1.4 Granular Media and Membrane Pretreatment Filters
   • Types, Purpose and Function
   • Performance Monitoring & Troubleshooting of Granular Media Filters and Membrane Pretreatment Filters
   • Overview of Multi-facility Pretreatment Systems – Operations Challenges & Solutions

14:30 – 14:45  Refreshment Break

14:45 – 15:45  1.5 Seawater Reverse Osmosis Systems
   • Types, Purpose and Function
   • Performance Monitoring and Troubleshooting
   • Membrane Cleaning, Rotation and Replacement

15:45 – 16:30  1.6 Case Studies of Plant Performance Optimization
   • 136,000 m$^3$/day Fujairah SWRO Plant, UAE
   • 218,000m$^3$/day Al Dur Desalination Plant, Bahrain

16:30 – 17:00  Questions & Discussions