Session C Desalination: old concepts, new horizons

Prof. Jack Gilron / The evolution of modern membrane desalination

An enormous world-wide scientific and engineering effort has been invested during the last 70 years into finding cost-effective solutions for generating new, affordable water sources. This is motivated by the desperate need of a world with dwindling fresh water supplies facing increasingly frequent droughts. Substantial progress has been made in developing membrane-based desalination and water treatment technologies such as Ultrafiltration (UF), Nanofiltration (NF), Reverse Osmosis (RO) and Electrodialysis (ED) to produce safe potable water. Particularly, RO seawater desalination has largely replaced older, energy-intensive, and environmentally unfriendly thermal technologies, effectively drought-proofing many countries with access to the sea.

In this talk, we highlight key achievements in this field, starting from the 1950s when new approaches were introduced in the preparation of membranes and understanding of membrane-based separations, to the present day when mega-scale membrane-based desalination plants constantly supply fresh water world-wide. A special emphasis will be given to the unique contribution of the scientific and engineering community in Israel to membrane water treatment and membrane-based desalination in particular.

Prof. Menachem Elimelech / Next-generation desalination and water purification membranes: where are we now?

Water scarcity is one of the greatest global crises of our time. Increasing water supply beyond what is available from the hydrological cycle can be achieved by seawater desalination and wastewater reuse. Highly effective, low-cost, robust membrane-based technologies for desalination and wastewater reuse are needed, with minimal impact on the environment. However, progress in current state-of-the-art water purification membranes has been limited. This presentation will critically discuss and evaluate recent research efforts in the past 15 years to (i) lower energy consumption for water desalination by improving membrane water permeability, (ii) reduce the cost of water desalination via increased water-salt selectivity, and (iii) enhance membrane ion selectivity for applications at the water-energy nexus. The presentation will focus on the emerging area of ion selectivity where high precision ion separation is desired. We will highlight how insights from nanofluidics and ion-selective biological channels establish the basis for a new class of membranes with ion-ion selectivity. A few examples will be provided to elucidate the mechanisms of ion transport and selectivity in membranes with sub-nanometer pores. The presentation will conclude with a discussion on research directions and critical challenges for developing ion-selective membranes

Prof. Ori Lahav / Resource recovery from seawater: emphasis on selective separation of Mg(II) salts

The interest in separating valuable ions from seawater (Rb^+, Li^+, Mg^{2+}, Sr^{2+}, etc.) is on the rise. The talk will first focus on the incentive, and then on two different methods that were developed by us for selective separation of Mg(II) from seawater, where it is present at ~1400 mg/L. An example will be given for using the separated Mg(II) for promoting struvite precipitation from the anaerobic digester supernatant line in wastewater treatment plants. That said, most of the talk will address the option of using the separated magnesium for increasing its concentration in desalinated water, with as low as possible addition of unwanted seawater species. A case study will be presented, describing the results obtained from a recently erected full scale plant whose near-future aim is to add >20 mgMg/L to the water supplied to Kibbutz Maagan Michael (Israel) through its brackish water desalination plant.

Prof. Yoram Cohen / Autonomous optimal operation of distributed membrane-based water treatment and desalination systems

Water treatment and desalination via membrane-based separation processes are suitable for distributed deployment at various scales. However, operation of distributed water systems, particularly where 24/7 of operator availability is infeasible, requires system design and operational strategies that can autonomously respond (i.e., self-adaptive operation) to: (i) fluctuations in water feed quality, (ii) variability of product use patterns, (iii) real-time system performance monitoring, and (iv) regulatory requirements (setpoints) concerning product water quality and residual stream generation. Self-adaptive operation also requires: (i) mitigation of fouling and scaling,

(ii) handling of fault detection and isolation, (iii) data imputation to temporarily overcome limitations imposed by faulty sensors so as to allow for appropriate corrective actions, (iv) operation that provides for adjustable product water recovery that can be driven to minimize the volume of generated residual streams, (v) forecasting performance degradation, (vi) sensors fault detection and data imputation, and (vii) system configuration for energy optimal operation with considerations of system physical and operational constraints. In order to tackle the above needs a multi-pronged approach was undertaken that includes, but is not limited to, system design and configuration, local and supervisory control to handle and optimize operational strategies, and data-driven models of different modes of system operation capable of handling unsteady state behavior and water feed quality fluctuations. Accordingly, an integrated research effort will be described that considers the elements of autonomous operation of distributed water treatment and desalination systems. Specific examples will be provided of the development and implementation of flexible design and self-adaptive operation of integrated ultrafiltration (UF) and reverse osmosis (RO) for water desalination (seawater and brackish water) and purification, including the application of first-principle and machine-learning operational models.