## 24 June 2021 (Thursday)

**6.00pm-6.30pm (SGT) (GMT +8)**
**Poster Session 2**

### Advanced Nephelometry Coupled with Real Time Membrane Integrating Turbidity Monitoring

V. Rajasekharan, C. Jackson, R. Leggett. Hach Co (United States)

Increasing water costs, climate change, ageing infrastructure, water scarcity and increasing compliance regulations have led to rise of water re-use in many sectors of the water industry. Even-though water re-use appears like a promising way forward there are several caveats that needs to be addressed before widespread adoption. Towards this end advanced monitoring techniques are required to ensure that the treated water quality meets the strict compliance discharge requirements. To achieve this, we have developed a real time monitoring turbidity solution for wastewater and drinking water effluent to provide the operators with information that they need to assess the effluent quality and provides them with decision to improve the efficiency of the treatment processes. This talk will discuss the turbidity technology that can be used for these purposes.

### An Integrated Approach To Smart Water Remineralization

SY. Chew. Pro-health Water Technologies Pte Ltd (Singapore)

The provision of high quality urban water services, the assets of which are often conceptualised as 'blue infrastructure', is essential for public health and quality of life in the cities. On the other hand, parks, recreation grounds, gardens, green roofs and in general 'green infrastructure', provide a range of (urban) ecosystem services (including quality of life and aesthetics) and could also be thought of as inter alia contributors to the mitigation of disaster-relief operations so as to support affected nations or areas in a risk-based, comprehensive emergency management system, improvement of biodiversity, amenity values and human health. Currently, these 'blue' and 'green' assets/infrastructure are planned to operate as two separate systems despite the obvious interactions between them (for example, provision of potable mineral water from mountain top to blue and green areas)

### Automated Nutrient Loading Computation for Identification of Hotspots in Catchments

J. Wang, A. Mahadevan. PUB, Singapore's National Water Agency (Singapore)

Catchment nutrient loading analysis is a crucial step in devising effective and targeted source control plans for tackling pollution sources. Computation of nutrient loading is laborious and currently done manually. This study looks into the development of an additional functional unit for catchment loading computation that is to be integrated into an existing real-time operational management system (OMS). Automatic and real-time computation of nutrient loading could be achieved. Such information enables efficient decision-making and caters to operational needs.

### Beyond Ultra-low Effluent Phosphorus Concentration: The Benefits Of Using Rare Earth Elements In Wastewater Treatment

M. Haneline, S. Ng. Neo Chemicals & Oxides (United States)

As environmental regulations restrict the discharge of phosphorus, traditional methods of phosphorus removal are proving inadequate. The use of rare earth chloride has been studied and implemented in several municipal and industrial wastewater treatment facilities required to meet a phosphorus discharge limit of 0.5 mg/L or lower. Some facilities have been able to achieve a 0.04 mg/L total phosphorus in the effluent with only the addition of a rare earth chloride. This reduction is due to the unique ability of rare earth chloride to preferentially react with phosphorus to form an insoluble inert rare earth phosphate. Additional benefits such as a reduction in sludge volume, enhanced clarifier performance, and improved dewatering capabilities have been observed at these facilities. These results have been achieved with a fraction of the dose of traditional phosphorus removal chemicals and allowed facilities to meet lower phosphorus discharge limits without additional equipment.

### Cities Of The Future -- What Role Does Water Play?

F. Barbour. Mott Macdonald (United Kingdom)

This paper will present the case for a digital twin to allow a more catchment wide management of the water system in response to future pressure on Singapore from changing climate and the growth of Singapore. Initially outlining the problem, some examples of more solutions that could be implemented and then demonstrating the catchment operator model. Examples where the current practice misses out on opportunities will be outlined to demonstrate the benefit in investing in this approach.

### Efficient 3D Printed Electrodes For Water Desalination -- Membrane Capacitive Deionization

S. Vafakhah, HY. Yang. Singapore University of Technology and Design (Singapore)

Due to the growth in demand for high efficiency and low energy consumption technology for brackish water desalination, many research efforts have been devoted to exploring new methods to overcome the water scarcity. Reverse osmosis (RO) is one of the conventional techniques used to revitalize freshwater supplies. However, high energy consumption puts restrictions on its application in many areas. Therefore, the development of alternative techniques with low energy consumption is strongly encouraged. Capacitive Deionization (CDI) is an emerging technology that is suitable to remove the salt from brackish water. Despite the successful application of several electrode materials to enhance the salt removal capacity, the necessity of using a binder is a limitation that imposes an extra step in the assembling process. In this study, we investigate the desalination performance of 3D printed free-standing electrodes to use as the binder-free cathode and anode in Membrane CDI.

### Encouraging Prudent Water Use: Do Prosocial Incentives Encourage Water-Saving Behavior?

T. Lai, Y. Lu. Institute of Water Policy, Lee Kuan Yew School of Public Policy (Singapore)

With a randomized field experiment, this study examines how smart phone applications, through the use of prosocial incentives and forms of social interaction, may encourage water-saving behavior. In our study, participants report their water meter readings weekly, and receive points according to the degree of their water-saving efforts. In the control group, these points are symbolic, and are not converted into monetary donations. In the first treatment group, points will be converted into monetary donations to social causes in Singapore. Here we test if prosocial incentives will make a difference in water-saving behavior. In the second treatment group, we convert points to monetary donations, but also introduce forms of digital social interactions by allowing participants to "gift" their points, or "steal" points from each other. Through this design, we investigate if such a mechanism will increase the participants' attention, and encourage them to save more water. This experiment may lead to better mobile application designs, and apply core principles of behavioral nudging to influence and encourage prudent water use.

### Flood Risk Assessment in Ungauged Catchment: Open Data and Open Models

A. Saha, Y. Zhang, A. Goedbloed, S. Tay, G. Pijcke, R. Karanam. Hydroinformatics Institute (Singapore)

The study presents a scalable framework to utilize high-resolution satellite imagery for flooding assessment together with shallow water hydraulic models to simulate flood models scalable to any region in the world. A case study is presented demonstrating the efficiency of this approach. The methods use clustering for flood delineation with terrain and hydraulic flow-based correction. The hydraulic model used is implemented on GPU with subgrid approach.

### Fuzzy Logic-based Geographic Network Reconstruction Planning

Z. Toth. Budapest Waterworks Private Company Limited by Shares (Hungary)

In order to operate water supply networks efficiently and economically as well as to utilize available financial resources successfully, the continuous and planned reconstruction of the pipe network is required, with the help of which the network aging and subsequently the faults and pipe bursts become avoidable and manageable. Budapest Waterworks has developed and utilised a condition-driven network reconstruction method, using the so-called network reconstruction planning tool embedded in our geographical information system. The methodology starts with data collection and acquisition, followed by application of the risk assessment model to assess the collected data. From the start of it's development in 2002 the application of the condition driven methodology has proven to give more efficient utilization of the available reconstruction funds, lower number of pipe bursts and failures in the public areas and as a result lower rate of NRW.

### How Water Sensitive Is Your City? Benchmarking And Navigation In Planning For Climate Adaptation Of Midsize Cities In The North Sea Region.

N. Dolman, G. Özerol, H. Bormann, S. Lijzenga. Royal HaskoningDHV (Netherlands)

How can we benchmark climate action and navigate in climate resiliency pathways? Inspired by the 'Water Sensitive City' approach, a www-based decision support tool (DST) is being developed in the EU-Interreg CATCH project that can primarily support small and medium-sized cities to become water sensitive and climate adaptive. Within the CATCH-project, a partnership of seven 'early adaptor' cities in the North Sea region is established, which already gained experience in developing adaptation measures. They acknowledge the need of an integrative DST that is applicable for midsize cities to assist in taking the right strategic decisions and to develop tailor made, long term adaptation strategies. Recently a test version of the www-based DST has been made available, capturing two guiding functionalities: (1) Self-assessment -- How climate resilient and water sensitive is my city, and (2) Navigate -- How to navigate to a climate resilient and water sensitive future?

### Looking In From Space To Detect Leaks In Rand Water Drinking Water Pipelines Using Satellite Technology

M. Padayachee. Rand Water (South Africa)

The aim of the study is to validate the performance of satellite technology in detecting leaks in the drinking water pipeline network of Rand Water, South Africa. The use of satellite based technologies to detect leaks in drinking water pipelines using a patented algorithm has been developed and demonstrated by Utilis in many parts of the world and now being tested at Rand Water. Rand Water is the largest water utility in Africa. Our customer base includes metropolitan municipalities, local municipalities, mines and large industries. We have an internationally acknowledged reputation for providing water of high quality that ranks among the best in the world and has consistently met national accredited standards on water quality. Water loss through leakage remains a key challenge at Rand Water and the use of exponential technologies to identify leaks and to reduce leakage is advocated. This aim of this pilot project is to demonstrate proof of concept of the technology in South African conditions. The project will be conducted in 2019 at Rand Water and will span a portion of the network (scan area for pilot is 1000km).

### Microbubble Ozonation - Biological Activated Carbon System For Reverse Osmosis Concentrate Treatment

WH. Loh, J. Lakshmi, R. Li, J. Guo, S. Ong, J. Hu. National University of Singapore (Singapore)

Reverse osmosis (RO) has been widely applied as the tertiary treatment in wastewater treatment plant (WWTP) to produce high quality reclaimed water. While RO membranes can remove efficiently most of the organic and inorganic materials, these rejected compounds are concentrated in the RO concentrate (ROC). Many of the organics in ROC are bio-accumulative and disposal via surface discharge may result in adverse implications on the receiving aquatic ecosystem. Hence, proper treatment and management of ROC is required before discharging into the receiving water body. In this study, a combined system of microbubble ozonation-biological activated carbon (BAC) system was used to treat ROC. This combined system was able to achieve about 55.4% of COD removal, meeting the discharge objectives of the study. Further cost analysis was carried out to develop a cost-effective combined system for treatment of ROC.

### Prediction Accuracy And Effectiveness Of ICT Systems For Urban Flood Control

Y. Sakae, T. Matsuura. NJS Co.,Ltd. (Japan)

This study was carried out to evaluate the prediction accuracy and effectiveness of "ICT operation support system for urban flood control facilities" which is installed in Eba catchment area in Hiroshima city. This system consists of Real-time monitoring technology for the facilities, rainfall data from eXtended RAdar Information Network (XRAIN), and Real-time flood prediction technology. Effective existing urban flood control facilities management will be possible on the information. High prediction accuracy is necessary for effective facility management on the ICT operation support system. In this study, the prediction accuracy and effectiveness of ICT operation support system were evaluated based on the past rainfall record from XRAIN.

### Replaceable Skin Layer Membranes™- Manipulating The Electric Double Layer On Colloidal Solids To Create 10-fold Improvement In Flux Rates

D. Bromley. DBE Hytec Ltd (Canada)

All conventional low pressure and dynamic membrane configurations rely on pore size (barrier) of the membrane surface for the separation of solids. The Replaceable Skin Layer Membranes™ (RSL Membranes™) do not rely on the barrier approach for the separation of solids. In fact, the actual pore size of the replaceable skin layer is 100 times larger than the solids being separated. RSL Membranes accomplish the separation of solids by using a highly ionic powder for the skin layer that manipulates the electric double layer (EDL) around the colloidal solid. Through this EDL manipulation, solids are repelled from each other as would be typical for stable solids in suspension. However, these same colloidal solids also repel from the replaceable skin layer powder on the surface of the membrane substrate due to the EDL created by the highly ionic RSL powder. The theory behind this phenomenon is called the DVLO Theory. The data has confirmed the impact on flux rate and energy reduction is 10-fold.

### Selection And Operation Of SWRO Energy Recovery Devices For Maximum Operational Flexibility And Reliability

E. Tynes. Energy Recovery (United States)

The most critical unit operation in a desalination plant is the SWRO train. From an equipment standpoint the most critical pieces of equipment are the high-pressure pump and the energy recovery devices (ERDs) as they are the highest power delivering or recovering units in the plant. A typical high-pressure pump and ERD system will deliver or recover on the order of 1-2 MW each in train in a large-scale desalination plant. Pump and motor design operation and maintenance are well known and techniques from pump users in other industries can be used in SWRO applications. Energy recovery systems, particularly systems that use the most efficient and state of the art positive displacement systems, is less understood, as the are unique to SWRO. An energy recovery system for a plant with variable production must be made up of ERDs that can operate in variable service conditions, and are simple to operate and maintain, and are able to be easily taken out an put back into service. By the end of 2020 Singapore will have five large scale desalination plants, The newest plants have been designed to operate at various capacities, thus it was necessary to select ERDs suited to this.

### Shouldn't Ground Water Be Stable And Easy To Treat? Or Why Full Cycle Water Quality Monitoring Matters

V. Malkov. Hach (United States)

Water utilities worldwide are looking for alternative water sources to address population growth and freshwater scarcity. Utilities are trying to accommodate various types of ground water, including brackish, as well as reclaimed water. The alternative water sources may help with water supply, but they can bring more challenges to the treatment process. Monitoring water quality and comparison between field and online measurements is a common practice and may be revealing. Issues with produced water quality were discovered at a facility in Southern California (USA), where the source ground water was classified as freshwater under influence of agricultural runoff. A comprehensive investigation revealed a multifaceted issue related to the source water quality and the treatment process. On an example of chloramination control, this study revealed trends typical for the industry and highlighted challenges and major misconceptions related to water analysis.

### Singapore's Smart Shower Programme: Real-Time Feedback And Water Conservation

C. Leong, ML. Reganon, LF. Goette, J. Buurman, S. Seah, I. Toh. Public Utilities Board (Singapore)

In 2018, Singapore launched the Smart Shower Programme which aimed to install smart shower devices in 10,000 households over two years. These devices provide real-time feedback on water use and intend to encourage conservation during showers, the most water-intensive activity in a typical Singaporean household. Using shower data voluntarily synced by households and a sharp regression discontinuity design, we provide early evidence on the programme's effectiveness. We find that real- time feedback results in water savings of 4.4 liters per shower by encouraging people to take shorter showers. Households who initially used more water during showers also respond more to real-time feedback, by saving more. Smart shower devices have a strong potential to help Singapore achieve its target of 130 liters per person per day by 2030.

### Smart Filtration Suite, A Data Analytics Solution For Membrane Filtration Systems

D. Dominiak, V. Yangali-Quintanilla, C. Persner, M. Witte, H. Rehmeier. Grundfos Holding A|S (Denmark)

Smart Filtration Suite (SFS) is the answer to the problems of man-power, efficiency and cost in water treatment and reuse. Our eco-system of intelligent control algorithms effectively enhances capabilities of operators in membrane filtration systems, automates the complex commissioning process and assures significant operating cost savings, both in newly-built and retro-fitted installations. SFS currently includes three control algorithms covering micro- and ultrafiltration, as well as nanofiltration and reverse osmosis. The algorithms target the most challenging aspects of commissioning and process-control, assuring real-time and intelligent operation. The implementation of the algorithms is very flexible -- an inexpensive control box with remote access assures trouble-free installation and the possibility for hassle-free updates. The algorithms make it possible to take full advantage of the capabilities of any filtration system, effectively giving them extra processing capacity and real, tangible savings in terms of energy and chemical consumption, as well as supervision-related man-power.

### Tai Po Water Treatment Works: A Model Of Sustainability Innovation

S. Chan. Government of the Hong Kong Special Administrative Region (China)

Water supply is an indispensable part of the livelihood of the people of Hong Kong Special Administrative Region (HKSAR), China and critical to the territory's sustainable and long-term developments. The expansion of the Tai Po Water Treatment Works (Tai Po WTW) forms part of the Water Supplies Department's (WSD's) overall strategy to enhance the resilience of water supply in HKSAR. The output capacity has been increased from 400 million liters per day (MLD) to 800 MLD. Being keenly aware of the responsibility towards sustainability, the plant is designed to merge into the surrounding landscape harmoniously by adopting the stacked design of different treatment processes to minimize the plant footprint. Meanwhile, the plant has been integrating various sustainable features with the continuous emphasis on the sustainable core values of reserving the resources, protecting the environment and caring the people.

### The Bankable Resilience Tool (BaRT)

P. Dircke, E. Schellekens. Arcadis (Netherlands)

To implement urban climate resilience strategies successfully and efficiently, and help cities to adapt to a changing climate, financial barriers need to be overcome. This requires identifying and developing investable and bankable opportunities in early stages of project and program development. In this paper, the Bankable Resilience Tool (BaRT) is presented as a valuable tool to overcome these barriers. By monetizing all cost and benefits, including social and ecosystems benefits of blue-green resilience measures per stakeholder, BaRT can remove financial barriers for investors, be used as a decision support tool and accelerate implementation of climate resilience in urban areas.

### The Promises Of Next-Generation Membranes For Seawater Desalination

YJ. Lim, K. Goh, M. Kurihara, R. Wang. Nanyang Technological University (Singapore)

Seawater reverse osmosis (SWRO) is the key technology driving an energy-efficient and cost-effective desalination process. At the center of this technology are the thin film composite (TFC) membranes, which not only promise a stable operation but also high separation performances. The objective of this review is to consolidate recent advances in SWRO membranes from the standpoint of membrane materials, fabrication methodologies and applications. A comprehensive review of the membrane development is presented based on findings reported in research papers and patents. Lastly, we put together an outlook (long/short term strategies), featuring our perspectives on SWRO membrane development.

## The Water and Resources Refinery® Concept: Innovative Separation Technologies Enabling A Completely New Used Water Approach

A. van Nieuwenhuijzen, H. Evenblij, J. Dan, F. Visser. Witteveen+Bos Consulting Engineers | AMS-institute (Netherlands)

The Resource Refinery Factory® concept is an innovative water reuse and resource recovery plant ready to create high quality water and produce several circular material streams. To step away from biological treatment process is a paradigm change in used water treatment. The RRFÂ® includes fine screening to recover celluloses, electrocoagulation followed by dissolved air flotation to recover organics and phosphorus, direct nanofiltration and ion exchange unit to recover nitrogen. A large scale pilot test is currently running to proof the concept and first results will be presented. Contrarily to present uwtp's where biological process are applied that destroy the organic components, here only physical processes are applied. The organic matter and nutrients remain intact and can be upcycled to raw materials for several (bio based) value chains. In this way waste water will be used for the production of high quality water for: ecological development & recreation area's; industrial process water; agriculture/ horticulture and the the production/recovery of valuable products; like Cellulose, Ammonium, Phosphorous; Organic biomass (for further up-processing) and Minerals.

## Towards High Recovery In Water Reclamation Processes: High Performance NF-MBR+RO System

H. Xu, S. Lee, MF. Tay, K. Jeong, C. Liu, E. Cornelissen, B. Wu, TH. Chong. Nanyang Technological University (Singapore)

A hybrid NF-MBR+RO process was developed to achieve >90% of recovery in water reclamation. The results showed that the NF-MBR achieved superior permeate quality due to enhanced biodegradation and excellent rejection properties of the NF membrane, leading to high RO recovery rate of >90% (i.e., compared to 75% in conventional UF-MBR permeate as RO feed). Furthermore, the salt accumulation (i.e., build-up of divalent ions) observed in the NF-MBR did not have negative impact on the organics removal efficiency and biomass viability. However, more severe NF membrane fouling was observed in the NF-MBR at elevated salt levels, which was attributed to the greater formation of calcium phosphate scale and Ca-polysaccharides complex (i.e., irreversible fouling layer) as well as the cake-enhanced-osmotic-pressure (CEOP) effect. Since the salt accumulation in NF-MBR is a function of sludge retention time (SRT) as well as NF membrane rejection, the NF-MBR membrane fouling and permeate quality can be controlled through manipulation of these parameters.

### Use Of Simultaneous Absorbance-Transmittance And Excitation-Emission Matrix (A-TEEM) Spectroscopy To Monitor Source Water For Waterworks

A. Gilmore, L. Chen, S. Teng, C. Kow, E. Mok, N. Afira. HORIBA Instruments Inc. (United States)

Conventional oil-in-water analyzers used by waterworks have hydrocarbon detection limits at mg/L levels and do not identify the type of oil compounds. The primary objective of this study was to develop a more sensitive optical instrument and analysis method to 1) detect trace level (microgram/L range) of organic pollutants in raw and treated water, 2) identify the compounds and 3) alert plant operators. The patented simultaneous Absorbance-Transmittance Excitation Emission Matrix (A-TEEM) instrument method was used to identify and quantify low levels of organic contaminants present in a much higher background of other dissolved organic matter components in raw and treated water. Multivariate regression and machine learning techniques were applied and shown to have potential for alerting plant operators to organic contamination events.

### Water Quality Monitoring Using Machine Learning

T. Farahmand, S. Hamilton. Aquatic Informatics (Canada)

Monitoring the water quality of reservoirs increasingly conducted using automated in situ sensors, enabling timelier identification of unexpected values or trends enabling safe management of reservoirs in real-time. However, some critical water quality parameters such as phosphorus, chlorophyll (for detecting various types of algae) and E.coli can only be accurately measured in controlled laboratory conditions which make it impossible to be used in the real-time decision making. We presented a probabilistic machine learning framework for automated estimation of those critical water quality parameters for the safe management of rivers, reservoirs, lakes and public beaches in real-time. The results indicated that our framework using Gaussian Processes (GP) has two main advantages compared to traditional water quality surrogate modeling; 1) it minimizes the efforts to build, test and deploy the model and 2) it performs well for estimating the parameters with uncertainty in real-time capturing the dynamical changes in time and nonlinearities.

### WaterWise - An Operational Testbed For Real-Time Assessment Of A Drinking Water Distribution System

M. Leifels, D. Cheng, S. Wuertz. Nanyang Technological University (Singapore)

The innovative WaterWiSe test-bed allows for the real-time evaluation of physicochemical, biological and hydraulic parameters in two university-based drinking water distribution systems in Singapore through a network of water quality sensors. Initial results revealed the presence of bacteria and archaea associated with monochloramine degradation and pipe corrosion as well as biofilm formation.