The WSTA 13th Gulf Water Conference

"Water in the GCC: Challenges and Innovative Solutions"

State of Kuwait, 12-14 March, 2019

BOOK OF ABSTRACTS

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Preface

Despite the extreme scarcity of water resources in the region, the GCC countries have done well in providing water for their ever-increasing population and rapidly expanding economic base and activities. However, the GCC countries are faced with major challenges manifested by increasing financial, economic and environmental costs associated with providing water supplies. These challenges are expected to grow with time under the current policies and management approaches driven by many external and internal drivers, which include rapid population growth, changing consumption patterns, low management efficiencies, and the expected impacts of climate change.

In the municipal sector, to meet escalating water demands under the current rapid population and urbanization rates and changing consumption patterns the GCC has to resort to desalination which is financially and energy-intensive and is associated with many environmental externalities including greenhouse gases emissions. These challenges are exacerbated by two factors, the first is the relatively high subsidies of water supply that impact the financial sustainability of the sector, and the second is that the GCC are still importers of desalination technology. In the wastewater sector, although the GCC countries have been providing commendable rates for sanitation services and are operating modern treatment facilities, reuse of treated wastewater is not fully developed, which represents a major lost opportunity under the prevailing water scarcity conditions.

Moreover, despite the fact that GCC countries are among the poorest in the world in renewable water resources, the agricultural sector consumes more than 85% of the total water uses, and is the main cause for the mining and quality deterioration of groundwater resources in the region. Water uses in the agricultural sector are exaggerated due to low irrigation efficiencies, cultivating high water consuming crops, unrestricted abstraction rights, and absence of water metering and tariffs. Finally, the industrial sector has been expanding rapidly due to GCC economic diversification policies, and its water consumption as well as its wastewater discharge is increasing at an alarming rate.

The current water policies addressing these challenges in the GCC countries will require major shifts if we want to have a sustainable water sector to continue to serve the socio-economic development needs of the region. What is needed is to mainstream innovation in the water sector at strategy, management, and operation levels. In this context, investments in technological and non-technological (financial, institutional, management) innovation will be essential. Innovative proactive solutions are necessary to address the water challenges we are facing now and in the future and to keep the long-term cost of the solutions viable and cost-effective.

The WSTA 13th Gulf Water Conference will focus on identifying innovative sustainable solutions for the major water challenges facing the GCC countries. The conference invited top keynote speakers and experts in the conference theme and sub-themes to address the sustainability-innovation nexus, share their knowledge, and transfer their experience. The conference will present and share innovative solutions from different countries in improving water sustainability and overcoming the water challenges in the arid GCC and Arab countries.

The WSTA 13th Gulf Water Conference is organized in the State of Kuwait in collaboration with the Kuwait Institute for Scientific Research (KISR) represented by the Water Research Center. The conference is organized in close coordination with the GCC Secretariat General and with sponsorship by the Arab Fund for Economic and Social Development (AFESD), Islamic Development Bank (IDB), and Kuwait Foundation for the Advancement of Science (KFAS). The conference is strongly supported and endorsed by the active UN organizations in the region of UNESCO Cairo Office, UN ESCWA, CEHA/WHO, UN Environment, and FAO; and the international/regional organizations of ICBA, ICARDA, ACWUA, IDA and EDS.

The WSTA and KISR wish all participants to have a scientifically fruitful conference.

Prof. Waleed K Al-Zubari
Chairman, Conference Scientific Committee

Conference Objectives

- Evaluation and prioritizing of major water challenges facing the GCC countries.
- Presenting innovative technological and non-technological solutions implemented in the region and internationally to address water sector challenges.
- Facilitating an open discussion platform and network to share knowledge, experiences, and best practices between researchers, executives, decision and policy makers, private sector, and other stakeholders, on innovative water solutions in the GCC countries and other Arab countries and beyond.
- Recommendation of potential innovative solutions to eminent water challenges facing the GCC countries.

Conference Scientific Program

DAY ONE: TUESDAY 12 MARCH, 2019		
08:00-09:00	**CONFERENCE REGISTRATION**	
09:00-10:30	**OPENING CEREMONY & EXHIBITION OPENING & Refreshment Break**	
10:30-12:30	**SPECIAL SESSION S1: FUTURE OF DESALINATION IN THE GCC COUNTRIES** Co-Chairpersons: Dr. Mohammad Al-Rashidi & Eng. Khalifa Al-Freij	**SPECIAL SESSION S2: ACHIEVING THE WATER RELATED SDGS IN THE ARAB REGION** Co-Chairpersons: Dr. Mohammed Al-Rashed & Dr. Waleed Al-Zubari
	Mohamed Al-Rashidi, GCC Secretariat General *Desalination in the GCC Unified Water Strategy 2035* **Presentation by GCC Water Professionals on** - *GCC national Desalination visions* - *Local spare parts manufacturing* - *Role of Research Centers and University in advancing and localizing desalination technology* - *Capacity Development in Desalination* - *Desalination Success Stories in the GCC countries* (*Session details on presentation title and speakers will be posted in due time)*	**Ziad Khayat, UN ESCWA** *Pursuing Water Security within the context of the 2030 Agenda for Sustainable Development* **Nizar Zaied, Islamic Development Bank** *The Road to SDG6* **Hamed Bakir, CEHA/WHO, Amman** *WHO Efforts and Programs in Achieving the water-related SDGs* **Etaf Chehade, UN Environment, ROWA** *UN Environment's Freshwater Strategy 2017-2021: tackling global water quality challenges* **Ali Karnib, Lebanese University, UNESCO Consultant** *Interlinkages between SDG6 and the SDGs: A regional perspective* **Mubarak Al-Noaimi, Bahrain** *National experiences: SDG 6 Monitoring in the Kingdom of Bahrain (WRM-3)*
12:30-13:00	**Prayer and Refreshment break**	
13:00-15:00	**SESSION 1: MANAGEMENT OF INDUSTRIAL AND OIL WATER** Co-Chairpersons: Dr. Abdallah Al-Maatouq & Mr. Mohammed Qamber	**SESSION 2: WATER RELATED HEALTH AND ENVIRONMENTAL ISSUES** Co-Chairpersons: Dr. Adel Al-Haddad & Dima Faour-Klingbei
13:00-13:20	**Keynote Speaker: Walid Abderrahman, Saudi Arabia** Successful Implementation of Closed Water Cycle Approach for Industrial Wastewater Treatment and Reuse in Saudi Arabia: A Case Study	**Keynote Speaker: Hamed Bakir, CEHA/WHO** Risk-based management approach for drinking water and treated wastewater reuse
13:20-13:40	**Keynote Speaker: Hani Khalifa, Produced Water Society Middle East** The Role of Oil and Gas Industry in Groundwater Conservation	Analysis of Some Pharmaceuticals in surface water in Jordan (EH-5), Othman Almashaqbeh, Jordan
13:40-13:55	Assessment of Polar and Non-polar Material in the Groundwater of Raudhatain and Umm Al-Aish Fresh Groundwater Fields of Kuwait (IW-1), Tariq Rashid, Kuwait	Impact Assessment of Desalination Plants on Kuwait Bay using GIS/Water Quality Index Analysis (EH-9), Mohamed Hamouda, Kuwait
13:55-14:10	Study on the local sea water temperature variation for the industrial water use of Al-Zour coastal area in Kuwait (IW-2), Myung Eun Lee, Kuwait/Korea	Effect of Brine Discharge from Al-Dur RO Desalination Plant on the Infauna Species Composition in the East Coast of Bahrain (EH-10), Anwar Al-Osaimi, Kuwait
14:10-14:25	Meeting refinery wastewater challenges through membrane based biological treatment complemented by an	**التأثيرات البيئية لمحطة تحلية تاجوراء العاملة بتقنية التناضح العكسي (EH-3)** ، بشير بريكة، ليبيا

	integrated asset sustainability program (IW-4), Nauman Rashid, UAE	
14:25-14:40	NOGA experience in the management of produced water (IW-5), Hussain Makki, Bahrain	قياس نسبة البرومات في مياه الشرب المعبأة في أسواق السلطنة التحديات والحلول في المصانع(EH-6) ، فاطمة العريمي، عمان
14:40-15:00	Discussion	Discussion
15:00-	**Closing of Day 1 and Lunch**	
20:00-22:00	**Dinner Invitation by KISR**	
DAY TWO: WEDNESDAY 13 MARCH, 2019		
08:30-10:30	**SESSION 3: GROUNDWATER RESOURCES MANAGEMENT** Co-Chairpersons: Dr. Khalid Hadi & Dr. Rashid Al-Abri	**SESSION 6A: DESALINATION MANAGEMENT** Co-Chairpersons: Dr. Abdulmajeed Al-Awadhi & Dr. Yousef Al-Wazzan
08:30-08:50	**Keynote Speaker: Ali Al-Maktoumi, Sultan Qaboos University** Aquifer Storage and Recovery and Managed Aquifer Recharge of Reclaimed Water for Management of Coastal Aquifers (GW-2)	**Keynote: Ibrahim Almuataz, King Saud University, Saudi Arabia** Future Prospects for Desalination in the GCC Courtiers
08:50-09:05	**Keynote Speaker: Ralf Klingbeil, BGR, Germany** Managed Aquifer Recharge in Coastal Aquifers, in Brackish and Saline Groundwater	Towards Efficient Water Management in Nuclear Power Plants (WRM-2), Ibrahim Khamis, Austria
09:05-09:20	Managed aquifer recharge - from a global perspective to local planning instruments (GW-7), Catalin Stefan, Germany	Development of mobile stand-alone solar driven reverse osmosis groundwater desalination plants for sustainable development (DS-4), Hosam Shawky, Egypt
09:20-09:35	Groundwater Economics in Arid Regions: Abu Dhabi Emirate Case Study (GW-4), Mohamed Dawoud, UAE	Modeling of temperature governed saturation states and metal speciation's in the Marine waters of Kuwait Bay- a concern to the desalination process (DS-21), Chidambaram Sabarathinam, Kuwait
09:35-09:50	Trends in Groundwater Observation Data and Implications - A case study from Batinah plain, Sultanate of Oman (GW-9), Ahmed Hadidi, Oman	Extraction of Valuable Minerals from Reverse Osmosis Brine in Kuwait (DS-22), Mohammad Safar, Kuwait
09:50-10:05	Evaluation of the Nubian Sandstone Aquifer System (NSAS) in Al Kufra Oasis, Southeast Libya (GW-13), Salah Hamad, Libya	A Comparative Study of Two Different Forward Osmosis Membranes Tested Using Pilot Plant System for Arabian Gulf Seawater Desalination (DS-3), Mansour Ahmed, Kuwait
10:05-10:20	Hydrogeochemical Modeling And Isotopic Assessment Of The Quaternary Aquifer At Ali Al-Garbi Area In Misaan Governorate, Iraq (GW-1), Hussein Ghalib, Iraq	Experimental study on effect of different mass flow rate in an inclined solar panel absorber solar still integrated with spiral tube water heater (DS-14), A Muthu Manokar, India
10:20-10:30	Discussion	Discussion
10:30-11:00	**Refreshment Break**	
11:00-12:30	**SESSION 4: SURFACE WATER MANAGEMENT** Co-Chairpersons: Dr. Abdulaziz Al-Turbak & Dr. Jasim Al-Kandari	**SESSION 6B: DESALINATION MANAGEMENT** Co-Chairpersons: Dr. Ghada Al-Nwaibet & Eng. Tawfeeq Al-Ghasham
11:00-11:20	**Keynote Speaker: Mohamed Mustafa Abbas, UNESCO Regional Centre for**	**Keynote Speaker: Mohamed Al-Abri, Sultan Qaboos University**

	Capacity Development and Research in Water Harvesting, Sudan Using Satellite Rainfall Data to Estimate Direct Flow (SW-1)	Water Treatment Using Nanotechnology Enhanced Membranes
11:20-11:35	العلاقة بين وجود الآبار أعلى أمهات الأفلاج واستدامة تدفق الفلج (SW-2) ، دعاء السعيد، سلطنة عمان	Direct Solar Desalination Using Nano/Micro-porous Polymeric Membrane via Thin Film Evaporation (DS-19), Mona Bahman, UAE
11:35-11:50	Rainfall-Runoff Estimation and Comparative Analysis Using SCS method based on GIS (SW-10), Mubaraka Alghariani, Libya	Assessment of Performance Recently Developed Acriflavine Thin Film Composite Nanofiltration Membrane for Seawater Treatment and RO Brine Concentration (DS-2), B. Garudachari, Kuwait
11:50-12:05	Importance of Water Resources Management; An Overview on Oman's Experience (WRM-9), Aisha Al-Qurashi, Oman	Synthesis and evaluation of nanocomposite forward osmosis membranes for Kuwait seawater desalination (DS-1), Rajesh Kumar, Kuwait
12:05-12:20	The Role of Oman Water Society in Water Resources Conservation (WRM-4), Ahmed Al-Barwani, Oman	Reverse Osmosis Seawater Desalination: Qatar Experience and Vision (DS-24), Nasser Alnuaimi, Qatar
12:20-12:30	Discussion	Discussion
12:30-13:00	**Prayer and Refreshment Break**	
13:00-15:30	**Session 5: AGRICULTURAL WATER MANAGEMENT** Co-Chairpersons: Mr. Habib Al-Qallaf & Dr. Alaa El-Sadek	**Session 7: MUNICIPAL WATER MANAGEMENT** Co-Chairpersons: Mr. Abdulateef Al-Mogrin & Dr. Mishari Khajah
13:00-13:20	**Keynote Speaker: Abdulrasoul Alomran, King Saud University** Improving Irrigation Efficiency and Conservation using Modern Irrigation Programs in Saudi Arabia	**Keynote Speaker: Mohammed Al-Rashid, KISR, Kuwait** Sustainable Cities in the GCC countries
13:20-13:40	**Keynote Speaker: Thameur Chaibi, Tunisia** Research Priorities and Actions for Sustainable Agriculture Water Management in MENA region	**Keynote Speaker: Mohammad Al-Hmaidi, Palestine** Water and Wastewater Service Performance Monitoring in Palestine, an Economic Instruments for Service Efficiency Improvement and Sustainability
13:40-14:00	**Keynote Speaker: Faraj Al-Awar, ICARDA** Leveraging Research for Sustainable Development in the Arab Region	**Keynote Speaker: Issam Nouiri, Tunisia** Drinking Water Demand Forecasting Using Artificial Neural Network in Tunisia
14:00-14:15	Improving the Irrigation Efficiency of Kuwait Native Shallow Groundwater (AG-4), Amjad Aliewi, Kuwait	Strategic Water Reserve using Aquifer Recharge with Desalinated Water in Abu Dhabi Emirate (GW-3), Mohamed Dawoud, UAE
14:15-14:30	Improving Water Use Efficiency of Crops for Sustainable Agriculture in Dry Lands (AG-7), Ahmed Al-Busaidi, Oman	Reduction of the Technical Losses Component of the NRW in water Networks in Sultanate of Oman (MW-9), Yousuf Al-Siyabi, Oman
14:30-14:45	Water saving in arid irrigated lands: comparison of different irrigation techniques adopted under date palms in Tunisian oasis (AG-9), Latifa Dhaoudi, Tunisia	Energy Consumption in the Municipal Water Sector in the Kingdom of Bahrain (MW-4), Maryam Helal, Bahrain
14:45-15:00	Using Bayesian Networks for Mapping Stakeholders Behaviours in Integrated Water Resource Management with a Focus on Irrigated Agriculture in Al	Energy Optimization in Water Supply System in the Sultanate of Oman (MW-10), Abdullah Al Arafati, Oman

	Batinah Region, Oman (WRM-5), Ayisha Al-Khatri, Oman	
15:00-15:15	Analysis of the impact of sprinkler irrigation performance on energy requirements under semi-arid conditions (AG-5), Samir Yacoubi, Tunisia	Evaluation of municipal water supply system options using WEAP System (MW-8), Ahmed E. Aljuaidi, Saudi Arabia
15:15-15:30	Seasonal Variation of Remotely Sensed Water Radiometric Indices in Soil Moisture Content Estimation in Arid Environments (AG-1), Mohamed Elhag, Saudi Arabia	Developing Deterioration Prediction Model for the Potable Water Pipes Renewal Plan – Case of Jubail Industrial City, KSA (MW-1), Ali Al-Ali, Saudi Arabia
15:30-15:45	Discussion	Discussion
15:45	**Closing of Day 2 and Lunch**	
DAY THREE: THURSDAY 14, 2019		
08:30-10:45	**SESSION 8: MANAGEMENT OF WASTEWATER TREATMENT AND REUSE** Co-Chairpersons: Dr. Ali Al-Jaloud & Hussain Abdulla	**SPECIAL SESSION S3: IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN THE ARAB REGION** Moderator: Ziad Khayat, UNESCWA
08:30-08:50	**Keynote Speaker: Redouane Choukralla, Morocco** The potential of wastewater reuse in the Arab region as a management option for water security under climate change condition	**Organized by WSTA and UN ESCWA** The session will include keynote speakers presentations on the latest development in scientific research on the vulnerability of water resources to climate change by the UNESCWA and international and regional experts. **Carol Chouchani Cherfane, UNESCWA** *Regional Initiative for the Assessment of Climate Change Impacts on Water Resource and Socio-Economic Vulnerability in the Arab Region (RICCAR): Overview and Assessment Highlights and Introduction to Arab Center for Climate Change Policies* **Marlene Ann Tomaszkiewicz, UNESCWA** *RICCAR: Integrated Vulnerability Assessment, Extreme Climate Events and Case Study Findings with a focus on the Mashreq and Arabian Gulf* **Ahmed Khater, Egypt** *Water Security and Climate Change* **Abdulkader Larabi, Morocco** *Modeling the Impacts of Climate Change on Water Resources in Mediterranean and Atlantic Hydraulic Basins in Morocco* **Rashyd Zaaboul, ICBA** *Climate change impacts on the agricultural sector in the Arab region* **Dima Faour-Klingbeil, Germany** *The Impact of Climate Change on Raw and Untreated Wastewater Use for Agriculture, Especially in Arid Regions (CC-4)*
08:50-09:10	**Keynote Speaker: Salah Al-Mutawaa, Bahrain** Development of a Benchmarking System for the Wastewater Sector in the Kingdom of Bahrain (WW-10)	
09:10-09:25	**Keynote Speaker: Nizar Zaied, Islamic Development Bank** Wastewater Programs of the Islamic Development Bank	
09:25-09:40	Virus Removal From Treated Wastewater In Modified Garden Soil Columns, Kuwait (WW-2), Adel Al-Haddad, Kuwait	
09:40-09:55	A practical step towards sustainability: Decentralized Wastewater Management in Oman (WW-7), Mohamed Al-Rawahi, Oman	
09:55-10:10	Seasonal Variations of the Growth of Filamentous Bacteria in Kuwait's Wastewater Treatment Plants (WW-6), Abdallah Abusam, Kuwait	
10:10-10:25	Removal of odorous compounds from hospital wastewater (WW-5), Andrzej Mydlarczyk, Kuwait	
10:25-10:40	Discussion	
10:40-11:00	**CONFERENCE CONCLUDING SESSION** Abdurrahman Al-Mahmoud, WSTA President, Conference Co-Chairperson Mohamed Al-Rashid, Chairman, Organizing Committee, Conference Co-Chairperson Waleed Al-Zubari, Chairman, Conference Scientific Committee Chairman	

11:00-11:15	**Short Refreshment Break**	
11:15-14:15	**TRAINING WORKSHOPS (3 hours, registration required, free of charge to participants and students)**	
	Training Workshop I: Modeling the Water-Energy-Food Nexus, by UNESCO Cairo Office *Trainer* **Ali Karnib, Lebanese University, UNESCO Consultant**	**Training Workshop II: Climate Change and Water Resources in the Arab Region, by ESCWA** *Trainers* **Carol Chouchani Cherfane, ESCWA** **Marlene Ann Tomaszkiewicz, ESCWA** **Ziad Khayat, ESCWA**
11:15-15:00	**FIELD TRIPS organized by KISR (registration required)**	
	Kabd Artificial Recharge Site	Sulaybiya Wastewater Treatment Plant
Note: Prayer time is during the training workshops breaks		

Sessions Details & Abstracts

SPECIAL SESSION S1: FUTURE OF DESALINATION IN THE GCC COUNTRIES

Organized by the GCC SG and the GCC Water Resources Committee

The session will present current and future trends of the desalination sector in the GCC countries, the desalination related strategic objectives of the "*Unified GCC Water Strategy 2035*", and national GCC countries visions. In addition, GCC desalination experts will be presenting experiences and best practice in local manufacturing, research, and national capacity development in the GCC countries.

Session speakers

Desalination in the GCC Unified Water Strategy 2035
Mohamed Al-Rashidi, GCC Secretariat General

Presentation by GCC Water Professionals on
- *GCC national Desalination visions*
- *Local spare parts manufacturing*
- *Role of Research Centers and University in advancing and localizing desalination technology*
- *Capacity Development in Desalination*
- *Desalination Success Stories in the GCC countries*

SPECIAL SESSION S2: ACHIEVING THE WATER RELATED SDGS IN THE ARAB REGION

Organized by WSTA in cooperation a number of UN organization related to the SDG6

The UN custodian agencies for the various indicators will make presentation on their efforts in helping achieve the water-related Sustainable Development Goals (SDGs) with regional and national experts input on the interlinkages, monitoring and analysis of the SDG6 targets and indicators.

Session speakers

Pursuing Water Security within the context of the 2030 Agenda for Sustainable Development
Ziad Khayat, UN ESCWA

The Road to SDG6
Nizar Zaied, Islamic Development Bank Group, Jiddah

WHO Efforts and Programs in achieving the water-related SDGs
Hamed Bakir, CEHA/WHO, Amman

UN Environment's Freshwater Strategy 2017-2021: Tackling Global Water Quality Challenges
Etaf Chehade, UN Environment, ROWA

Interlinkages between SDG6 and the SDGs: A regional perspective
Ali Karnib, Lebanese University, UNESCO Consultant

National experiences: SDG 6 Monitoring in the Kingdom of Bahrain
Mubarak Aman Al-Noaimi, Bahrain

Pursuing Water Security within the context of the 2030 Agenda for Sustainable Development

Ziad Khayat
First Economic Affairs Officer, Water Resources Section, Sustainable Development Policies Division, ESCWA; email: khayat@un.org

The Arab States are among the most water scarce in the world with nearly 362 million people in the Arab region under water scarcity to absolute scarcity conditions. The freshwater scarcity situation in the Arab region is aggravated by several factors such as dependency on shared water resources, occupation and conflict, climate change, water pollution, aging water systems, inefficient use of water and high population growth rates. Constructing a conceptual framework for moving towards achieving water security in the Arab region requires first putting people at the center of water issues and secondly a solid understanding of the main systemic conditions that hamper its achievement.

A conceptual framework for moving towards achieving water security in the Arab Region is presented by ESCWA. It considers the regional systemic conditions of water stress and scarcity, shared water and climate change that hinder the achievement of water security. This is done through a sustainable development lens where water is critical and central to the three dimensions of sustainable development, economic, social and environmental dimensions. This is combined with a human rights-based approach to examine water security implications at all scales including at the community and household level in order to ensure that water security in the Arab region is fully grounded in efforts to ensure that no one is left behind. It does so in view of an enabling environment based on a set of means of implementation addressing systemic conditions at various scales.

UN Environment's Freshwater Strategy 2017-2021: Tackling Global Water Quality Challenges

Etaf Chehade
UN Environment, Regional Office for Western Asia, Kingdom of Bahrain; Email: etaf.chehade@un.org

When healthy and functional, freshwater ecosystems provide key ecosystem services that include water storage and purification, climate and water regulation, natural hazard regulation and a variety of other provisioning, regulating, cultural and supporting services. Freshwater bodies provide critical life support for humans and all human activity – essential for daily drinking and food production needs, but also for energy and industrial processes. Freshwater ecosystems also provide habitats for 10% of all living species – 80% of which have disappeared since 1970, thus making them one of the most critically endangered forms of ecosystems on Earth.

Poor land and water management, degradation of water-related ecosystems, and the loss of their critical services, is a growing concern worldwide with an important role to be played by the UN Environment, embedded in the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) and forming the core of UN Environment's Global Strategy for Freshwater 2017-2021. The mandate and urgency for UN Environment to take a lead in specific areas relating to freshwater ecosystems including water quality, water ecosystem protection and restoration, and water resources management, was explicitly reinforced at the 3rd UN Environment Assembly in December 2017 in a comprehensive resolution towards the protection and restoration of water-related ecosystems from pollution and other threats.

It is estimated that the world has already lost at least 60% of its natural water bodies since wide-scale development began in 1900, and that one-third to one-seventh of rivers in developing countries face severe pathogenic and organic pollution, including from a lack of safely managed wastewater and from run-off from land-based activities. Growing water stress in many parts of the world, as well as drought and desertification, are further serious concerns which the World Economic Forum among has identified as some of the most serious threats facing our current and future societies and businesses. Robust and abundant evidence also exists that freshwater resources are particularly vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. More erratic precipitation and climatic patterns, including both drought and flood, are expected to be the result. The integrated management of water resources to ensure the sustainability of freshwater ecosystems and their services is therefore of utmost importance given future trends of population growth, development, and climate change.

The core of UN Environment's Freshwater Strategy 2017-2021: tackling global water quality challenges (corresponding to SDG indicator 6.3.2), protecting and restoring freshwater ecosystems (SDG 6.6.1), advancing integrated water resources management (IWRM) approaches (SDG 6.5.1), and addressing water-related conflict and disasters in support of peaceful and resilient societies (SDGs 11, 13 and 16). The Strategy provides actionable guidance to support countries' implementation of sustainable freshwater management practices globally. Achievement of these targets is essential for implementing the entirety of SDG 6 dedicated to water and sanitation, in addition to other SDGs closely linked to freshwater such as those on water-related disasters and climate change, food and energy security and terrestrial and marine ecosystems, and peaceful and inclusive societies, among many others.

Along these lines, UN Environment provides global leadership in four strategic areas:

- Meeting the global water quality challenge (SDG target 6.3): The importance of reversing water quality degradation in the world's freshwater systems is recognized by governments, businesses and communities and steps are taken to improve ambient freshwater quality and reduce the impact of discharge of untreated wastewater into water bodies;

- Protecting and restoring freshwater ecosystems (SDG target 6.6): Services provided by ecosystems are recognized and valued as part of sustainable development and the benefits are shared equitably;
- Advancing the Integrated Water Resources Management approach (SDG target 6.5): Integrated Water Resources Management (IWRM) underpins the coordinated development and management of water, land and related resources to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystemsi; and
- Promoting resilience and addressing the environmental aspects of water-related disasters and conflict (SDG targets 11.5 and 16.1): The capability to mitigate and adapt to current and future water-related hazards and risks facing ecosystem functions and human communities is strengthened and embedded into existing environmental planning and management systems.

Interlinkages between SDG6 and the SDGs: A regional perspective

Ali Karnib
Lebanese University, UNESCO Consultant; Email: karnib.ali@gmail.com

Many Arab states have started developing plans and policy settings for the implementation of the SDGs within their national development strategies. Water has a centrality in achieving the 2030 Agenda because of its importance to each of the four dimensions that cut across all SDGs (society, economy, environment and governance). The development and implementation of effective national strategies necessitates to inform policy makers on the importance of water for the achievement of the SDGs. Informing policy makers will help to maximize synergies and address trade-offs between SDG 6 and other SDGs.

Firstly, the interlinkages between SDG 6 (Clean water and sanitation) and the other SDGs will be explored. The presentation will discuss how SDG 6 connects and contributes to implementing the SDGs for review by HLPF in 2019: SDG 4 (Quality education), SDG 8 (Decent work and economic growth), SDG 10 (Reduced inequalities), SDG 13 (Climate action), SDG 16 (Peace, justice and strong institutions) and SDG 17 (Partnerships for the Goals). Regional challenges, water dependency levels and policy recommendations will be presented to promote discussions on effective water use in implementing the SDGs. Secondly, the presentation will discuss how the quantitative water, energy and food (WEF) nexus approach is helping to achieve the SDGs by ensuring coherent and integrated SDGs achievement policy settings.

SDG Goal 6 Monitoring in the Kingdom of Bahrain

Mubarak Aman Al-Noaimi
Freelance Consultant, Kingdom of Bahrain; Email: malnoaim@batelco.com.bh

The 2030 Agenda for sustainable development goals (SDGs) is an ambitious, aspirational, and transformational in nature global development plan. It is comprised of 17 holistic, indivisible, and universally applicable goals that embed and integrate the three dimensions of sustainable development - the economic, social, and environmental dimensions. These goals are supported by 169 integrated targets and 232 global indicators to enable global monitoring and reporting on their implementation progress. Goal 6 (SDG 6) of this agenda - the water and sanitation goal - aims to ensure availability and sustainable management of water and sanitation for all. As opposed to goal 7 of the Millennium Development Goals (MDGs), which was limited to access to water and sanitation facilities, SDG 6 of the sustainable development goals covers the entire water - cycle in an integrated manner. It is extended to address drinking water, sanitation and hygiene, protection of water-related ecosystems, water use efficiency and scarcity, and water management at both national and transboundary levels. Water and sanitation services are at the very core of the 2030 Agenda; thereby SDG 6 is cutting across all the other goals on both targets and indicator levels. This paper attempts to establish a baseline and methodological mechanism for monitoring and reporting on SDG 6 in the Kingdom of Bahrain. A trend analysis approach was used for tracking progress towards meeting the SDG 6 targets. According to the monitoring results, progress varies considerably. Bahrain has fully achieved the targets of increasing the coverage of the population having access to safely managed drinking water and sanitation services, and halving the proportion of untreated wastewater, well ahead of the agenda deadline. Progress on attaining the targets associated with the protection of water-related ecosystems and water use efficiency and water scarcity are, however, falling short at various degrees of implementation. The monitoring efforts also reveal that, despite the modest progress made on enhancing the institutional structures and capacity building in the water sector, implementation of integrated water resources management (IWRM) is still facing enormous challenges. In general, our analyses have shown that the natural water scarcity, high population growth rates, accelerated socio-economic development, non-efficient water use, shortages in financial outlays, and the lack of adequate technical and institutional capacities are the crucial factors hindering or decelerating progress on achieving SDG 6. Although sufficient data were made available for our analysis, data gaps were inevitable and require focused attention during the 2030 Agenda time frame. Among others, a set of potential management measures and policy interventions that may help fill these gaps and accelerate progress are recommended.

Keywords: Sustainable Development Goals; SDG 6; Kingdom of Bahrain; Water and Sanitation; Sustainable Water Management.

SESSION 1: MANAGEMENT OF INDUSTRIAL AND OIL WATER

Keynote Speaker

Successful Implementation of Closed Water Cycle Approach for Industrial Wastewater Treatment and Reuse in Saudi Arabia: A Case Study

Walid Abderrahman
Ex-Professor of Water Resources Management, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia; Email: walid.abderrahman@yahoo.com

During the past three decades, and with increasing water shortages in GCC and most Arab countries, the use of non-conventional water resources (NCWR) such as treated industrial and domestic wastewater has been an integral component of every water strategy in the region. This has been to reduce the gap between increasing demands and limited fresh water supplies, to achieve sustainable water and wastewater services, and to meet Sustainable Development Goals (SDG) by 2030. In spite of above facts, the planned targets for the reuse of wastewater effluents remains limited and far below the expectations of the water planners and decision makers in many Arab countries including some GCC countries. This has been mainly due to several factors such as deficiencies in policies, strategies, and technical capabilities, weak governance frameworks including organizational structures, institutional and legal issues, and lack for enough financial and technical supports.

Saudi Arabia has been among few Arab countries that succeeded in adoption and implementation of full-scale industrial wastewater treatment and reuse (closed water cycle) in all industrial cities on national level. This paper describes the adopted policies and executed plans utilizing integrated water resources management tools that enabled Saudi Arabia to achieve such success. It also defines the positive impacts and benefits of such large-scale implementations of wastewater reuse on conservation and sustainability of water and energy.

Adopted policies and executed plans utilizing integrated water resources management tools for industrial wastewater treatment and reuse in Saudi Arabia

The remarkable successes of Saudi Arabia in large-scale implementation of treatment and reuse of industrial wastewater in industrial cities have been due to comprehensive adoption and implementation of sound governance frameworks utilizing integrated water resources management tools since the beginning of the new century. These comprised of three main components: Creation of Enabling Environment, Development and implementation of sound institutional and legal frameworks and Development and implementation of sound management instruments for successful utilization of Public Private Partnership (PPP) in implementation of Closed Water Cycle approach (CWC) contracts.

Creation of Enabling Environment included: i) development of National Water Strategy and action plans in accordance with KSA 2030 Vision which emphasized the reuse of wastewater utilizing PPP schemes, ii) a Royal decree was issued in 2002 approving the recommendation of the Higher Economic Council to adopt PPP schemes in six sectors including the water sector, iii) strong political support was given by higher authorities for the adopted strategy, iii) development of legal frameworks including national water law and enforcement measures that facilitated the execution of the action plans, iv) identification of investment and financial structures to support action plans.

Development and implementation of wastewater reuse market included: i) development of sound institutional and legal frameworks for sound treatment and reuse of industrial wastewater, that included the establishment of the Saudi Industrial Property Authority (MODON) in 2001 to be responsible for the development of industrial cities including integrated infrastructure and services

working in partnership with the private sector, ii) development of Water Regulator as regulatory body and enforcement agency for protection of interests of all stakeholders, iii) creation of industrial cities hosting thousands of industrial plants, iv) development of required infrastructure including water supplies and wastewater collection and treatment facilities, v) implementation of capacity building and training programs for different levels of technicians, managers and water professionals.

Development and implementation of sound management instruments included: i) attraction of private sector to participate in PPP contracts by development of bankable BOT projects and mobilization of additional financing for PPP projects, ii) selection of proper entity from experienced and qualified private sector that fit for PPP through BOT schemes, iii) development and execution of transparent and sound PPP contracts, iv) selection of sound, economic and effective technology to maximize wastewater treatment and reuse such as Closed Water Cycle (CWC) that leads to zero liquid discharge (ZLD) in industrial plants and cities, v) development of proper legal frameworks for effective control on qualities of wastewater influents and effluents, vi) setting of sound KPIs for effective implementation of PPP schemes, vii) development of fair and regulated water reuse tariff, viii) development of sound customer services for serving various industrial clients within the industrial cities.

The CWC approach has been introduced and implemented successfully to industrial cities in Saudi Arabia to maximize wastewater reuse, to reduce consumption of conventional water resources, desalinated seawater and electricity, in addition to protection of the environment in accordance with Saudi Arabia's 2030 Vision. In 2008, the first BOT contract for duration of 25 years was agreed and signed with local specialized company for industrial wastewater treatment and reuse in Jeddah Industrial City. This was followed by a second BOT contract for 25 years in 2012 for Dammam and Al-Hassa Industrial Cities between MODON and specialized private sector company. Similar BOT schemes for other extensions and other industrial cities have been implemented during the past three years. In 2012, MODON was overseeing 29 cities, hosting more than 4,700 factories with investments exceeding SR250 billion, and more than 300,000 employees. The number of the industrial cities shall reach 40 by 2019. The produced industrial wastewaters from each factory are monitored to meet special set of quality guidelines prior to be discharged into the wastewater collection networks. The collected industrial wastewater is subjected to conventional preliminary and primary treatment facilities including fine screening, grit removal, and rectangular primary clarifier. This is followed by secondary treatment including Anti-Bulking Reactor (ABR), aeration tanks and clarifiers. After passing through Balance Tanks, influents enter the tertiary treatment stage, which is comprised of sand filter, followed by chlorination system. This stage is followed by the quaternary treatment by reverse osmosis (RO) desalination process to reduce the salinity to acceptable levels.

Results of Implementation of CWC in Industrial Cities

The implementation of CWC within the First and Second Industrial Cities of Dammam and Al-Hassa during the past three years has resulted in saving of about 28.72 million m^3/year, of desalinated and transported seawater. This is in addition to saving of electricity consumption of about 855,742 MWh/year, which is equivalent of saving 1,608,555 barrels per year, worth about US$ 96.5 million at oil price of US$ 60/barrel.

Conclusion and Recommendations

The successful experience of Saudi Arabia in full-scale treatment and reuse of industrial wastewater in industrial cities utilizing CWC has been attributed to successful adoption and execution of comprehensive and sound governance frameworks utilizing integrated water resources management tools since the beginning of the new century. The gained substantial benefits represented by savings of significant values of conventional fresh water resources, desalinated sea water, electricity and oil consumption has been a major step forward toward achieving sustainable

water and energy security in the Kingdom. The Saudi experience is a good model for other GCC and Arab countries to adopt for achieving sustainable water and energy security.

Keynote Speaker

The Role of Oil and Gas Industry in Groundwater Conservation

Hani Khalifa
President, Produced Water Society Middle East; Email: hkhalifa@producedwatersociety.com

The oil and gas industry is the main industry in the GCC. It is also a main consumer and a major producer of water in these countries, as well as at the global level. In GCC, oil and gas operations consumes about 50 to 80 billion gallons (about 200 to 300 Million cubic meters) of ground water annually and it generate about 300 billion gallons (1.1 billion cubic meters) of water every year and increasing. With the increasing global energy demand, the GCC oil and gas industry is on the verge of a rapidly increasing its water production. Over the next 10 years, it is forecasted that the generated water from the oil and gas industry may double in volume.

Produced water is mostly reinjected into the crude producing reservoirs for enhanced oil recovery. However, this task consumes a substantial amount of energy, which requires additional amount of fresh water. The reinjection process consumes 400 to 700 MW annually, which is equivalent to several decent size power plant productions.

Produced water has a very wide range of chemistry. It includes oil, heavy metals and naturally radioactive elements. This makes it unfeasible for many applications. However, technological development is closing this gap very fast.

Is produced water a burden or a resource?

Fresh water resources in the GCC are highly stressed. In addition, increasingly stringent laws are forcing GCC producers to actively look for alternatives for consuming precious ground water. Oman has been leading the exploration of produced water reuse. At Nimr Field, PDO successfully tested the use of Reed beds to treat 240,000 Barrels per day of produced water to recover oil and produced water with a quality that can be reused in other oil operations. This project used 90% less power should conventional methods were adopted. Similarly, other efforts are ongoing to explore desalination high hypersaline produced water to generate wash water for oil processing. Several universities are researching the use of advanced ceramic membranes to desalinate produced water.

Concluding Thoughts

Oil and gas industry is the main user of scarce ground water and a major producer of a water that is not yet very attractive as a source of usable water. A lot of research is still required in order to change this reality. Lowering cost of desalination of hypersaline produced water can results in significant reduction in ground water consumption by the oil and gas industry. Oil and gas companies are continuously working with regulatory bodies in the region to conserve precious ground water.

Investigation of Polar and Nonpolar Material in the Groundwater of Raudhatain and Umm Al-Aish Fresh Groundwater Fields of Kuwait

Tariq Rashid, A. Al-Haddad, B. Al-Salman, and A. Bushehri
Water Resources Development and Management Program, Water Research Center, Kuwait Institute for Scientific Research, State of Kuwait; Email: trashed@kisr.edu.kw

Parts of the fresh groundwater of Raudhatain and Umm Al-Aish freshwater fields have been contaminated with petroleum hydrocarbons leached from petroleum lakes and petroleum-contaminated soil resulting from the 1991 Gulf War. Pump and treat methodology has been suggested for treatment of contaminated groundwater. Selection and designing of methodologies for the treatment of contaminants require knowledge related to types and physiochemical properties of contaminants. Therefore, as a preliminary step toward treatment of contaminated water, a study was conducted in order to identify and quantify contaminants in terms of polar and nonpolar material of contaminated water. Groundwater samples were collected from 10 monitoring wells (nine contaminated and one uncontaminated) of water fields. Collected samples were analyzed for Total Petroleum Hydrocarbon (TPH), Total Organic Carbon (TOC), phenol, tannin and lignin, volatile acids and Ultraviolet (UV)-induced fluorescence before and after activated silica gel. The silica gel splits aggregated polar and nonpolar material by retaining polar material on its activated surfaces. The results of the study indicated that both polar and non-polar materials are present in the contaminated groundwater. TPH, UV-induced fluorescence, phenol, and volatile acid contents were dominantly composed of polar material at 86%, 84%, 73%, and 90%, respectively; whereas TOC, tannin and lignin contents were dominantly composed of nonpolar material at 58% and 60%, respectively. The results suggest treatment techniques specific for polar and nonpolar contents will be required for the treatment of petroleum hydrocarbon-contaminated groundwater.

Keywords: Fresh groundwater, contamination, petroleum hydrocarbons, treatment.

Study on the local seawater temperature variation for the industrial water use of Al-Zour coastal area in Kuwait

Myung Eun Lee[1], Jungwook Lee[2], Yousef Al-Osairi [3]
[1] *Manager, R&D Division, Hyundai Engineering and Construction Co.; Email: melee@hdec.co.kr*
[2] *Assistant Manager, R&D Division Hyundai Engineering and Construction Co.*
[3] *Associate Research Scientist, Coastal and Air Pollution Department, Kuwait Institute for Scientific Research (KISR), State of Kuwait*

Ras Al-Zour coastal area, located in southern part of Kuwait, is the region of concentrated industrial water use and sea intake-outfall of existing power plants. There are some of undergoing construction projects such as Al-Zour Refinery, Al-Zour LNG import facility projects, and the expansion planning of existing power plant is also in progress. The site of Al-Zour LNG import facility project is located close to the power plant in north direction approximately 0.6 km away from the shore between the Sulphur pier and the small boat harbor north of the breakwater. Being located only 3 km away from the massive thermal and brine discharge from power plants, the future water use of LNG regasification facility will be under the direct influence of thermal discharge from power plants and the further development of seawater resources within this area like as Al-Zour North power plant project. There are two issues regarding the seawater temperature in this area to be considered: 1) Variations in background water temperature mostly under combined effect of local meteorology and global climate change; 2) Increase of temperature due to the expansion of the thermal discharge of expanded power plant. Annual water temperatures of two candidate locations of the seawater intake for Al-Zour LNG regasification facility was measured during 2017, which shows a typical seasonal variation of a local seawater temperature with an added effect of the neighboring thermal outfall. The numerical model study was performed by using MIKE3-DHI to reproduce 2017-measurement of the sea water temperature during June ~ July based on the meteorological hindcast data from ECMWF (European Centre for Medium-Range Weather Forecasts) and the thermal discharge input from the southern power plants. It was found that the daily sea water temperature at the measurement location is mainly affected by thermal plume dispersion oscillating with the phase of tidal current. Thermal discharge expansion plan in ~10 km area around the new facility should be considered to obtain the exactly estimated intake water temperature limit during the design life of the facility.

Keywords: Al-Zour area, Industrial water use, Thermal discharge, Seawater temperature, Heat exchange.

Meeting refinery wastewater challenges through membrane based biological treatment complemented by an integrated asset sustainability program

Nauman Rashid
SUEZ Water Technologies & Solutions, United Arab Emirates; Email: nauman.rashid@suez.com

The Middle East and North Africa region is blessed with many natural resources, but it is no secret that when it comes to freshwater, scarcity is abundant. Potable water supply to industries needs to be curtailed and industry needs to meet its regular needs through alternate reuse methodologies. Adequate quantities. scaling, corrosion and microbial fouling can all be the concerns of intrepid operators, but the use of wastewater that is treated to an advanced level using proven technologies can offer all the benefits of pristine freshwater without the issues of supply constraints and cost overburden. In designing a water reuse system in industrial applications, a holistic approach requires looking at water balance calculations covering availability, makeup and blow down, water quality considerations, ease of system operation, power consumption and capital and operating costs. With these considerations in mind, well-designed systems may incorporate any or a combination of reverse osmosis, ultrafiltration, and membrane bioreactor solutions supported by the right chemistry, delivered in the right quantity at the right spot under a smart digital Internet of Things (IoT) approach. With the right engineered and chemical systems in fixed or packaged mobile configuration, there is no reason why the bar can't be set higher today in attaining improved onsite water and wastewater operations. The BAPCO Sitra refinery in Bahrain is a good example of a holistic approach to addressing water and wastewater needs in industry. The refinery upgraded its existing wastewater treatment plant to improve the quality of its effluent and comply with stricter requirements using the best available technology in biological membrane-based treatment for its challenging operations. It further engaged packaged mobile water desalination to streamline its water supply challenges.

Keywords: Refinery, MBR, Mobile Water, IoT, Water Balance.

Initiatives of the Petroleum Sector for Efficient Water Management to Enhance Water Sector Climate Resilience in Bahrain

Hussain Makki
National Oil and Gas Authority, Kingdom of Bahrain; Email: hssn_makki@yahoo.com

The water sector of the Kingdom of Bahrain, a Small Island Developing State, is severely threatened by multiple climate change impacts and a growing population. The main climate change threats are: i) sea level rise causing saline intrusion into aquifers; ii) rising temperatures and greater intensity of rainfall causing reduced rates of aquifer recharge; and iii) rising temperatures causing increases in water demand across all sectors. In combination, these threats are likely to reduce Bahrain's freshwater supplies by at least 50 to 100 million m^3 of water per year in the short-term.
Securing water and energy needs represents a critical issue, which has not yet received the attention that it merits. Energy production consumes significant amounts of water; providing water, in turn, consumes energy. In Bahrain like other countries in the region, confronting the issues of water scarcity and the increasing demand on energy to realize sustainable development plans represents a challenge that needs to be tackled through an integrated set of wise energy and water policy decisions.

Focusing on using efficient technologies in relevance to water usage in the production process of energy is an important issue. In the oil and gas sector for example, water is used in upstream oil and gas exploration and production for purposes such as injection water for wells and to assist in the recovery of crude oil and gas. In the process of electricity generation, water is essential for the production of all conventional fuels, where it is needed as part of almost every step in the production processes. It is noted that raw water usage for cooling in the various fossil fuel-powered power plants constitutes around 79-99% of total water usage; the remaining water is used for applications such as ash and ling, in the humidifier and condenser and in flue-gas desulfurization (FGD) at combustion-steam plants. Consequently, due considerations have to be given for improving cooling process to make the electricity production more water efficient.

Thus, Bahrain petroleum sector assessed all available options to efficient use of water and treated wastewater and has started executing some water projects such as construct a 110 ha wetland to replace the mechanical and chemical treatment processes that are currently being used to treat ~80,000 m^3 of produced water per day. The system will reduce the oil in water (OiW) concentration of the produced water from ~500 ppm to under 5 ppm. The improved quality of the treated water and absence of potentially harmful added chemicals will make the water treated in the wetland suitable for managed aquifer recharge. While there will be some loss as a result of evapotranspiration, a substantial proportion of the water entering the wetland will be available for injection into the Rus-UER aquifer after it leaves the wetland. The quantity of water treated through the wetland will vary by season, ranging from 62,000 m^3 per day in summer (April to October) to 72,000 m^3 per day in winter (November to March), and totaling 24.5 million m^3 annually. 80–100% of the treated water will be injected into the Rus-UER aquifer to mitigate the extraction impacts of the Abu-Jarjur Reverse Osmosis Desalination Plant. This project will enhance directly the climate resilience of water resources in Bahrain.

This paper will shed light on assessment outcomes and sector project including wetland, planting mangrove using STP water, and other related projects.

Keywords: oil-associated-water, mangroves, wetland, aquifer recharge.

SESSION 2: WATER RELATED HEALTH AND ENVIRONMENTAL ISSUES

Keynote Speaker

THINK BIG, START SMALL and SCALE UP: A road map to support country-level implementation of water safety plans and sanitation safety plans

Hamed Bakir
Coordinator, Environmental Health Interventions & Regional Advisor on Water, Sanitation, Climate Change and Health, World Health Organization Eastern Mediterranean Regional Office/Centre for Environmental Health Action, Amman, Jordan; Email: bakirh@who.int

In 2004, the 3rd edition of WHO Guidelines for Drinking Water Quality recommended the use of Water Safety Plans (WSPs). In 2015, WHO introduced the Sanitation Safety Planning (SSP) manual. The use of comprehensive risk-based management framework is considered a very effective means of managing water supply and sanitation systems. There are many risk-based systems available to water and sanitation utilities such as ISO9001 and Hazard Analysis and Critical Control point (HACCP).

In 2004, WHO guidelines on Drinking Water Quality recommended the Water Safety Plans (WSPs). In 2015, WHO introduced the Sanitation Safety Planning (SSP) manual. Both approaches are promoted by WHO and the International Water Association (IWA) as the most reliable and effective approaches for managing water and sanitation systems and for ensuring reliable drinking water safety and sanitation safety. WSPs and SSPs are risk assessment and risk management tools comprising:

1. A systematic process of hazard identification along the entire chain of a specific drinking water supply system and the entire chain of a specific sanitation system;
2. Implementation and monitoring of risk management control measures (improvement plan) by the service providers;
3. Independent verification by a surveillance agency

WSPs and SSPs are adaptable to all types and sizes of water supply, and can be effectively applied in all socioeconomic settings. The WSPs and the SSPs approaches are increasingly being adopted globally as best practices for managing water and sanitation systems.

Yet promoters of WSPs and SSPs must overcome barriers based on misconception such as: developing a WSP make it seem as though water is not safe; utility will incur high cost of WSP or SSP development; SSP or WSP is additional workload; SSP or WSP is a plan to be developed by a hired consultant.

Driving forces to introducing WSPs and SSPs within a country may include: a) Commitment to public health and safety of water and sanitation. For this purpose national regulators and health authorities may promote supportive legislation and policies; and b) Enhanced performance, compliance to regulations and reduced costs of the water and sanitation systems. For this purpose, an active surveillance system is necessary. A benchmarking system helps utilities to measure progress over time and compare the performance of utilities.

A strategic roadmap to introducing and scaling up the use of WSPs & SSPs in a country involves several steps that can be implemented in a manner adapted to the country context: 1) Understand and appreciate the benefits; 2) establish a national preliminary vision with milestones and timelines; 3) attain practical experience through demonstration intervention; 4) review the preliminary visions and establish a national plan for scaling up; 5) Establish supportive mechanisms (e.g. training programmes, codes of practice, tools, utility-utility partnerships) 6) Establish policy and regulatory instruments (empower institutions, legislative instruments, financial instruments); 7) implement WSPs and SSPs and verify their effectiveness; 8) Review experience periodically, share lessons and improve.

Analysis of Some Pharmaceuticals in Surface Water in Jordan

Othman A, Al-Mashaqbeh[1], Ayoup M. Ghrair[1], Diya Alsafadi[2], Sahar S. Dalahmeh[3], Shannon L. Bartelt-Hunt[4], Daniel D. Snow[5]
[1] *Water and Environment Centre, Royal Scientific Society, Amman. Jordan; Email: othman.mashaqbeh@rss.jo*
[2] *Testing Sector, Royal Scientific Society, Amman, Jordan*
[3] *Department of Energy and Technology, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden*
[4] *College of Engineering, University of Nebraska–Lincoln, Omaha, USA*
[5] *Water Sciences Laboratory, University of Nebraska, Lincoln, USA*

A quantitative assessment of pharmaceuticals in surface water in Jordan was conducted using liquid chromatography-tandem mass spectrometry (LC-MS/MS) to evaluate the occurrence, source and distribution of 18 pharmaceutical compounds. Grab samples were collected in the summer from the effluent of two dams in Jordan. Among all of the pharmaceuticals analyzed, the results showed that 10 pharmaceutical compounds were detected in the effluent of King Talal Dam including 1,7-dimethylxanthine, acetaminophen, amphetamine, caffeine, carbamazepine, cotinine, phenazone, sulfamethoxazole, sulfamethazine, trimethoprim. However, four pharmaceutical compounds were detected in the effluent of Mujib Dam include 1,7-dimethylxanthine, caffeine, cotinine, phenazone. Moreover, eight pharmaceutical compounds were not detected in both dams (<0.005 µg/l) including cimetidine, diphenhydramine, MDA, MDMA, methamphetamine, morphine, sulfachloropyridazine and thiabendazole. The results also indicated that the compound detected at the highest concentration levels in King Talal Dam was carbamazepine at concentration of 0.358 µg/L. It is very clear that the occurrence of pharmaceuticals at King Talal Dam is higher than in Mujib Dam. This is mainly due to the fact that King Talal Dam is receiving runoff water and treated wastewater from the wastewater treatment plant, while the Mujib Dam is only receiving surface runoff water. This is consistent with many studies reported in the literature that municipal wastewater treatment plants (WWTPs) are considered a primary source for the discharge of pharmaceuticals and personal care products PPCPs into surface waters.

Keywords: Pharmaceuticals and personal care products, surface water, Jordan.

Impact Assessment of Desalination Plants on Kuwait Bay using GIS/Water Quality Index Analysis

Mohamed F. Hamoda [1], and Noha S. Donia [2] Ikram M.S. Al-Attar [3]
[1] *Professor, Civil Engineering Department, Kuwait University; Email: mfhamoda@gmail.com*
[2] *Professor and Head, Environmental Engineering Sciences, Institute of Environmental Studies and Research, in Shams University, Cairo, Egypt*
[3] *Ph.D. Candidate, Ain Shams University, Cairo, Egypt*

Desalination plants are located along the Kuwait Bay which receives the hypersaline brine effluent discharged from such plants. Kuwait Bay is a semi-enclosed water body that suffers from various pollution loads. The bay covers an area of 735 km^2 and has 130 km coastline. It is a unique ecosystem in Kuwait's territorial waters. This study presents a new approach, which integrates the water quality index with the GIS technology, to assess the impact of desalination plants on Kuwait Bay. The water quality of the bay was determined by a number of parameters. The Water Quality index (WQI) was used to translate a set of a large number of variables to a single value describing the water quality to be used in the management of the bay's water, as communicated to policy makers, service personnel, and the public. In this study, the World Health Organization maximum permissible limit values and Kuwait Environment Public Authority water quality standards were used to compare with the results of GIS analysis. The water quality index was consistently higher than 75 in the winter season and higher than 100 in the summer season, showing that the Kuwait Bay is suffering from a very poor to unsuitable water quality all over the year due to the discharge of desalination plants brines and other polluted effluents. GIS mapping was used to indicate the most affected areas in the Bay. For a rehabilitation plan, new locations for the outfalls are proposed based on GIS mapping.

Keywords: Brine discharge; desalination plants; GIS, water quality index.

Effect of Brine Discharge from Al-Dur RO Desalination Plant on the Infauna Species Composition in the East Coast of Bahrain

Anwar Al-Osaimi[1], Thamer Salim Ali[1], Waleed Al-Zubari[1], Humood Nasser[2]
[1] *Department of Natural Resources and Environment, Arabian Gulf University, Kingdom of Bahrain; Email: thamersa@agu.edu.bh*
[2] *Department of Biology, College of Science, University of Bahrain, Kingdom of Bahrain*

The GCC countries have been experiencing an accelerated socio-economic development process since the 1970s, resulting in rapid demographic and urbanization growth and associated with rapidly increasing municipal water demands. To meet these demands' quantity and quality, the GCC countries resorted to desalination. Currently, the GCC countries collectively possess the largest desalination capacity in the world (~ 45%), and based on the current urbanization trends, it is expected that current rates in desalination capacity growth will continue in the future. However, desalination has a number of environmental externalities on the marine, and their severity will depend on various factors (i.e., site-specific). As a pre-requisite for designing and implementing programs to minimize these environmental externalities, the impact of desalination has to be investigated and characterized. The study objective is to investigate the impacts of Al-Dur RO desalination plant on the coastal infauna benthic species composition on the east coast of Bahrain. The *In Situ* measurements over high and low tide cycles in winter and summer were conducted at 42 selected locations for surface and bottom waters. Sediment samples were collected from 10 locations selected at different distances from the discharge outlet. The species composition of infauna was investigated using the univariate analysis (number of species and individuals, species richness, evenness index and diversity index). The results showed an extreme elevation in temperature (> 38 °C) and hypersaline waters (> 55 ‰) at locations nearby the discharge outlet, and also at bottom waters of depths more than 3 m during the high and low tide cycles in both seasons with exceptional levels in summer. Four main groups of benthic infauna identified are represented by Polycheates (12 taxa), Bivalves (4 taxa), Gastropoda (2 taxa) and Amphipoda (3 taxa) including 256 specimens. The univariate analysis indicated spatial variations in infauna species composition where the lower diversity indices were found at locations close to the discharge outlet and at station 5 at which noticeable vertical differences were observed indicating exceptional elevation of temperature and hypersaline waters at bottom layer. However, the highest species diversity indices characterized the most offshore stations. Polychaetes are considered as the most useful bio-indicator to reveal any contamination from desalination brine discharge, due to their sensitivity and their capability to adopt to any environmental alteration.

Keywords: RO desalination, univariate analysis, infauna, species diversity, Bahrain

التأثيرات البيئية لمحطة تحلية تاجوراء العاملة بتقنية التناضح العكسي

بشير بريكة
المعمل المتقدم للتحاليل الكيميائية، هيئة أبحاث العلوم الطبيعية والتكنولوجيا، طرابلس، ليبيا؛ بريد الكتروني:
bashirforlibya@gmail.com

تعاني ليبيا التي تقع ضمن نطاق مناخ شبه صحراوي من مشكلة حقيقية في المياه، وتتمثل هذه المشكلة في نقص شديد في المياه الصالحة للشرب. حيث يعتمد السكان على المياه الجوفية التي تعتبر هي المصدر الرئيسي للمياه في ليبيا، غير أن هذا المصدر غير كافي لتغطية احتياجات السكان، ويعود هذا النقص في المياه الصالحة للشرب لعدة أسباب، منها تداخل مياه البحر مع المياه الجوفية وخاصة على طول الساحل الليبي، وكذلك تداخل مياه الصرف الصحي والمياه المصاحبة من الإنتاج النفطي مع المياه الجوفية في مناطق أخرى من البلاد.

وتعد تقنية تحلية المياه هي أحد الخيارات البديلة لتعويض الفاقد من المياه الجوفية في ليبيا وفي باقي دول الشمال الإفريقي. وعلى الرغم من أن تقنية تحلية المياه تعد خيارا مهما لتوفير مياه الشرب والمياه الصناعية، إلا أن هذه التقنية لها بعض التأثيرات السلبية على البيئة المحيطة إذا لم تُشغل محطات التحلية بأسس علمية وسليمة.

وتعد محطة تاجوراء لتحلية المياه إحدى أقدم محطات تحلية المياه العاملة بطريقة التناضح العكسي في ليبيا، وتتجاوز فترة تشغيلها حتى الآن الثلاثة عقود، ولذلك فهي تعد أرضاً خصبة لإجراء العديد من الدراسات والأبحاث عليها. وتعتبر هذه الدراسة المتمثلة في دراسة التأثيرات البيئية لمحطة تاجوراء لتحلية المياه هي إحدى هذه الدراسات التي قام بها الباحث في هذا الصدد.

خلال هذه الدراسة قام الباحث بعدة زيارات ميدانية وتفقدية إلى محطة تحلية المياه في تاجوراء، وأجرى العديد من النقاشات مع بعض العاملين بالمحطة. وبناء على الزيارات الميدانية والنقاشات الحوارية ومن خلال الوصف والتدقيق والرجوع للدراسات السابقة على محطة تحلية المياه في تاجوراء وبعض محطات التحلية في الدول الأخرى يستعرض الباحث خلال هذه الورقة البحثية مجموعة من العوامل والمؤثرات التي ساهمت وتساهم في بعض التأثيرات السلبية على البيئة المحيطة للإنسان والحيوان والنبات والناتجة عن تشغيل هذه المحطات.

وأهم نتائج هذه الدراسة تتركز في أن نقطة ترجيع المحلول الملحي (brine disposal point) هي أحد المواقع التي تساهم في بعض التأثيرات السلبية على الإنسان والكائنات البحرية على الشاطئ القريب، كما أن مخازن المواد الكيميائية داخل محطة تحلية تاجوراء والظروف التخزينية بداخلها لا تعد بيئة صحية سواء للعاملين داخل المحطة أو حتى للمقيمين في المناطق القريبة من محطة التحلية. هذا بالإضافة لتأثيرها على بنية المناطق المحيطة نفسها، حيث تعد المنطقة المجاورة لمحطة تحلية تاجوراء من المناطق الأثرية ذات القيمة التراثية المهمة وقد بدأت هذه المنطقة تتأثر بالنشاطات التي تجرى بالقرب منها مما يستلزم إجراء بعض الأعمال المسحية عليها من قبل المهتمين للمحافظة على قيمتها الأثرية.

الكلمات الدالة: تحلية المياه، التناضح العكسي، تصريف الرجيع الملحي، الضجيج والضوضاء.

قياس تركيز البرومات في مياه الشرب المعبأة في أسواق السلطنة: التحديات والحلول في المصانع

سعيد بن علي الشبلي، **فاطمة بنت يوسف العريمية**، ومتعب بن راشد المعمري
دائرة الرقابة الغذائية بوزارة البلديات الإقليمية وموارد المياه، قسم الصناعات الغذائية والتراخيص، سلطنة عمان؛ بريد الكتروني: alaraimi-99@hotmail.com

يلجأ أغلب الناس في البلدان المتقدمة الى استخدام مياه الشرب المعبأة في حياتهم باعتبار أن الماء شريان الحياه وكذلك يتم استخدامه في الطبخ باعتقادهم بأنه أكثر أمانًا وعالي الجودة وأنه أفضل من مياه الشبكة الذي توفره الحكومة أو الشركات لذلك انتشرت مصانع ومعامل تعبئة مياه الشرب في قوارير بلاستيكية أو زجاجية وبأحجام وأشكال مختلفة وتشرف على هذه المصانع الجهات الرقابية في السلطنة لتأكد من التزامها بكافة الاشتراطات الصحية للمصانع ومراقبة سلامة و جودة هذه المنتجات لعدم الإضرار بصحة المستهلك حيث في حالة عدم الالتزام لا تتردد الجهات المختصة باتخاذ الإجراءات اللازمة لردع المخالف بأشد العقوبات وقد تتطرق الإجراءات الى غلق المنشأة.

وقد ظهرت مع التقدم والتطور في مجال تعقيم المياه أن لجات الكثير من المصانع الى استخدام محاليل الهيبوكلورايت والبعض استخدام الاوزون لتعقيم مياه الشرب ومنها قد ظهرت إملاح البرومات في مياه الشرب ولكثرة ما أثير حول الاشتباه بقدرة مادة البرومات في التسبب بالسرطان، فقد عمدت الكثير من الجهات الرقابية في البلدان في العالم على تحديد تركيز وجود هذه المادة في مواصفات مياه الشرب المعبأة لديها على أن لا تزيد عن 10 جزء بالمليون، ومن منطلق التأكد من صحة وسلامة المنتجات المتداولة في الأسواق للاستهلاك الادمي حسب المواصفات والمقاييس المعتمدة، وعليه فقد تطرقت هذه الدراسة الى قياس نسبة تركيز البرومات في مياه الشرب المعبأة في أسواق السلطنة من المنتجات المستوردة والمحلية خلال ثلاثة أشهر وتم التركيز خاصة على المياه المعبأة محليا ليتم التأكد من مدى مطابقة العناصر الموجودة في المياه للحدود المسموح بها حسب المواصفة القياسية لمياه الشرب المعبأة (GSO 1025-2014) وبالتحديد عنصر البرومات، حيث تم سحب عينات عشوائية لمنتجات مختلفة من المياه وبتواريخ صلاحية مختلفة وبأحجام مختلفة خلال فترة الدراسة وتحليلها في مركز المختبرات للأغذية والمياه التابع للوزارة خلال عام 2018م وأظهرت النتائج مطابقة جميع العينات للمواصفة القياسية لمياه الشرب المعبأة لجميع أنواع المنتجات المستوردة والمحلية التي وقعت تحت نطاق الحدود المسموح بها من تراكيز البرومات حيث كانت جميعها أقل عن (10ميكروجرام/لتر)، وبالتالي التأكد من خلو أسواق السلطنة من منتجات المياه المخالفة والغير مطابقة لحدود البرومات حسب المواصفة القياسية ومنها تم التطرق الى التحديات التي تواجه المختصين على الرقابة على مصانع مياه الشرب والحلول المقترحة لتلك التحديات ،حيث كانت أهم التوصيات عدم توزيع المنتجات في الأسواق قبل التأكد من مطابقتها للمواصفات المعتمدة وتوفير الكادر المختص بالمختبرات التابعة للمصانع وتفعيلها، وتطبيق أنظمة تحليل المخاطر ونقاط التحكم الحرجة (HACCP) ونظام ايزو 2200.

الكلمات الدالة: برومات، المواصفة القياسية (GSO 1025-2014)، الرقابة الغذائية 2018، تحديات وحلول.

SESSION 3: GROUNDWATER RESOURCES MANAGEMENT

Keynote Speaker

Aquifer Storage and Recovery and Managed Aquifer Recharge of Reclaimed Water for Management of Coastal Aquifers

Ali Al-Maktoumi[1], Slim Zekri[1], Mustafa El-Rawy[2], Osman Abdalla[1], Rashid Al-Abri[3,4], Chefi Triki[1], Mohammad Reza Bazargan-Lari[5]
[1]*Sultan Qaboos University, Alkhoud Muscat, Oman; Email: ali4530@squ.edu.om*
[2]*Department of Civil Engineering, Faculty of Engineering, Minia University, Egypt*
[3]*Ministry of Regional Municipality and Water Resources, Muscat, Oman*
[4]*Oman Water Society, Muscat, Oman*
[5]*Department of Civil Engineering, Islamic Azad University, East Tehran Branch, Tehran, Iran*

The hydrological and economic feasibility of Aquifer Storage and Recovery (ASR) of excess desalinated water and Managed Aquifer Recharge (MAR) using tertiary treated wastewater (TTWW) to manage stressed coastal aquifers in Oman has been studied numerically using the code, MODFLOW 2005 and the different transport packages MT3DMS, and MODPATH. The current ASR study aims to assess the feasibility of saving and recovering water for the purpose of supply to the city of MUSCAT during high demand periods by banking excess-desalted water during winter and recover it during the rest of the year. The second objective of the study is to explore the feasibility of MAR using TTWW to mitigate salinity in two costal aquifers in North of Oman exploited for different purposes: domestic water supply (Al-Khod aquifer), and for irrigation purposes (Jamma aquifer). ASR in the Al-Khod Aquifer was explored using Simulation Optimization multi-objective modeling using evolutionary algorithm NSGA-II (namely, the Non-dominated Sorting Genetic Algorithm-II), to generate the set of Pareto optimal solutions according to recharging scenarios. The results show that the potential net benefit of storage and recovery might reach as high as $ 17.80 million/year. The maximum profitable volume that can be recharged into the aquifer, given the limited number of wells and their locations, is estimated at 8.4 Mm^3/year, which is lower than the current excess estimated of 10 Mm^3/year. For MAR using TTWW, different managerial scenarios were simulated and analysis of the results reveals that the Jamma aquifer will further deteriorate in the next 20 years if it remains poorly managed. The groundwater level will decline further to exceed 3 m on average, and the iso-concentric salinity line of 1500 mg/l will advance 2.7 km inland that will severely affect farming activities in the area. However, MAR using TTWW when integrated with the management of groundwater abstraction (e.g., smart water meter, higher irrigation efficiency to reduce the abstraction rate) becomes hydrologically feasible to augment the aquifer storage and controlling seawater intrusion, and hence sustains farming activities. The economic analyses of such situation recommend: (1) injecting TTWW in the vicinity of irrigation wells; (2) investing in smart water meters and online control of pumping from the wells to reduce the abstraction rate by 25%; and (3) a combination of both are feasible scenarios with positive net present values. Recharge in upstream areas is found not economically feasible because of high investment cost of the installation of pipes to transport the TTWW over a distance of 12.5 km. Because the financial resources for investments are limited, scenario (2) shows a Net Benefit Investment Ratio of 4.41 (i.e., investment of a $1 yields $4.41). Although option (3) shows the lowest Net Benefit Investment, it is very attractive from a social perspective because it entails an integrated demand and supply management of groundwater. Farmers are requested to reduce pumping, and the government will invest in injecting TTWW to improve groundwater quality in the vicinity of irrigation wells and to form a hydrological barrier to control seawater intrusion in the long run. The primary objective of MAR for the Al-Khod aquifer is to increase the urban water supply and to sustain the aquifer service with the lowest possible damages from seawater intrusion. A

number of managerial scenarios were simulated and progressively developed to reduce seawater intrusion and outflow of the groundwater to the sea. An economic analysis was conducted to characterize the trade-off between the benefits of MAR and seawater inflow to the aquifer under increased abstraction for domestic supply. The results show that the abstracted volume for domestic supply can be doubled under MAR practices if irrigation wells are properly managed and public wells are better located. Even though injection of TTWW is more expensive (due to the injection cost), will result in higher benefits. The results indicate that managing the aquifer would produce a net benefit ranging from $8.22 million to $15.21 million compared to $1.57 million with the current practice. MAR using TTWW is feasible to develop water resources in arid regions, and the best scenario depends on the decision maker's preference when weighing the benefits of MAR and the level of damage to the aquifer. MAR, as a smart water governance technology, mitigates stresses on aquifer systems in arid zones, maximizes the benefit of using groundwater for both agricultural and domestic purposes while minimizing the adverse socio-hydrological and agricultural consequences of mismanagement of commingled groundwater-TTWW resources at all scales (national, catchment, metropolitan area, village, farm).

Keywords: Managed Aquifer Recharge, Aquifer Storage and Recovery, Salinity, Coastal Aquifer, Oman.

Keynote Speaker

Managed Aquifer Recharge in Coastal Aquifers, in Brackish and Saline Groundwater

Maike Groeschke[1], **Ralf Klingbeil[1]**
[1]Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg, Germany; Email: Maike.Groeschke@bgr.de

Managed aquifer recharge (MAR), the intentional recharge of water into an aquifer, has been generally shown to work in different geological settings – in soft and hard rock aquifers, porous and fractured media, and under confined and unconfined conditions. The origin of the source water for MAR applications depends on local water availability, and to date many successful MAR schemes apply water from alternative sources, e.g. desalinated seawater or treated sewage effluent. An adequate treatment of the water prior to recharge, and hydrochemical mixing reactions and water-rock interactions within the aquifer after recharge have to be considered for all MAR applications regardless of their scope. The application of MAR for water storage in coastal aquifers in saline or brackish groundwater poses additional challenges: The mixing of the recharge water with native brackish and saline groundwater, either in the aquifer or during abstraction may render the abstracted water unfit for most intended purposes. Therefore, the aim of MAR applications under such conditions must be to recover the recharged water with little mixing.

Members of the SUBSOL project – bringing subsurface water solutions to the market –, financed by the European Commission, have modified conventional MAR techniques to make them more efficient in saline or brackish groundwater settings. The so called subsurface water solutions (SWS) provide different building blocks to minimize the mixing of freshwater with the native groundwater: Multiple partially penetrating wells can be used to control the upward movement of freshwater bubbles caused by buoyancy, smart configurations of interception wells can be applied to prevent up-coning of saltwater during freshwater abstraction, and automated control units are utilized to optimize pumping schemes.

In the framework of the SUBSOL project, further exchanges have been developed between the SUBSOL consortium and institutions from GCC countries. The GCC countries are one of seven regions where so called “regional assessments” were conducted to evaluate the potential of SWS. Besides hydrogeological and technical matters, a number of other issues are included in these studies. One aspect is the regional perspective, whether subsurface solutions are considered as suitable tools in the repertoire of the water management schemes. Another aspect is the regulatory framework, especially the legislation on water – e.g. regulations on injection, abstraction and quality of water. Based on preliminary assessments, first positive results give way to the hope that the regional studies in the GCC countries will help to establish a solid base for common future projects.

Keywords: Managed aquifer recharge, Water management, Coastal aquifers, Brackish and saline groundwater, Subsurface water solutions.

Managed Aquifer Recharge (MAR): from Global Perspective to Local Planning

Catalin Stefan, Jana Glass, Jana Sallwey, Ralf Junghanns, Thomas Fichtner, Felix Barquero
Research Group INOWAS, Technical University of Dresden (TUD), Helmholtzstr. Dresden, Germany; Email: catalin.stefan@tu-dresden.de

Global and regional changes have significant financial, socio-economic and environmental impact on water resources. This is manifested in severe depletion of groundwater levels, salinization of soils and aquifers, and increased water pollution levels. In many cases though, this can be compensated through carefully designed adaptation measures. One such example is represented by managed (artificial) aquifer recharge (MAR), method which implies the purposeful recharge of groundwater with surface water for subsequent recovery or environmental benefits. Over decades, MAR schemes were successfully installed worldwide for a variety of reasons: to maximize the natural storage capacity of aquifers (i.e. seasonal water storage), physical aquifer management (restoration of groundwater levels in overexploited aquifers, reduction of land subsidence and prevention of saltwater intrusion), water quality management (improvement of water quality though soil percolation), ecological benefits (such as maintaining the groundwater levels and flow requirements) and other benefits (such as saving on evaporation, storage of reclaimed water etc.). The economic feasibility of MAR schemes increases for projects with high-value uses such as potable supply while the projects with low-value uses such as irrigation are usually characterized by low capital and operating costs. To emphasize the important role of MAR in the mitigation of global change impacts, the first part of this presentation brings evidence collected from over 1,200 MAR case studies from 60 countries, including data on historical development, site characterization, operational scheme, objectives and recharge methods used, as well as quantitative and qualitative characterization of both influent and effluent. In the second part, the talk will include also an overview on different planning and optimization approaches with special emphasis on the newly developed web-based groundwater modeling platform for MAR applications (the INOWAS platform). The core of the system is represented by a compilation of public domain models of different levels of complexity ported on a web server for best data accessibility. The INOWAS framework presented includes several advantages over conventional simulation approaches: a) allows the use of various model complexities; b) provides best accessibility of project data and multi-institutional collaboration through web-based implementation; c) makes use of a combination of widely available open-source tools; and d) promotes the case-based reasoning approach as additional support for parameter estimation and solution finding. Overall, the paper emphasizes the relevance of MAR for groundwater replenishment around the world with specific focus on the Arabian Gulf Region and introduces new tools aimed at boosting the uptake of MAR in the near future.

Keywords: managed aquifer recharge, groundwater, INOWAS, MAR.

Groundwater Economics in Arid Regions: Abu Dhabi Emirate Case Study

Mohamed A. Dawoud
Environment Agency, Abu Dhabi, United Arab Emirates; Email: mdawoud@ead.ae

In arid and semiarid regions, groundwater is scarce, limited and non-renewable but it is a vital resource that supports a variety of societal uses and benefits. With growing demand due to extension in agriculture and domestic sectors, groundwater resources are coming under greater pressure following reductions in surface water yields, due to reduced rainfall and over abstraction. Over abstraction due to increasing demand or climate, change-driven changes in spatial distribution of precipitation can result in a reduction in groundwater quantity and deterioration in quality. Increased population and economic development inevitably result in an increase in the generation of waste products and, if disposed of inappropriately, these have the potential to contaminate groundwater resources and lead to degradation and economic costs. This creates the need for a higher profile regulatory and management regime for this limited groundwater resources. Given climate variability and the environmental challenges, the importance of groundwater as a resource is ever increasing in arid regions. Abu Dhabi emirate is an arid region facing the challenges of renewable fresh water scarcity. At present (2014), groundwater use accounts for about 63% of total water demand in the Emirate, with the remaining portion of demand being met through desalinated (28%) and recycled water (9%). Groundwater is used mainly for agriculture, forestry sectors, which together have accounted for over 95% of total annual withdrawals. Agriculture alone has accounted for 80% of total recent withdrawals. The total present annual abstraction form the groundwater aquifers is about 2,300 million cubic meters. However, the annual natural recharge to the aquifer systems ranges between 90 to 140 million cubic meters only. Numerous wellfields abstract groundwater of various qualities and in some areas massive over-abstraction has resulted in alarming groundwater declines and a severe deterioration in groundwater quality. This policy has led to a reduction in the groundwater table which caused numerous shallow wells to go dry and impact the farms. It is estimated that there is still 641 km^3 groundwater resources available (saline, brackish and fresh), but only less than 3% of this reserve is fresh and, based on current abstraction rates, both fresh and brackish reserves will be depleted within the next 50 years. The purpose of this study is to assess the economic value of groundwater resources in the Abu Dhabi Emirate. A dynamic hydro-economic optimization model was developed and applied. This model evaluates the net benefits and economic tradeoffs across alternative water by simulating groundwater reserves and withdrawals for different regions, time periods, and development sectors. Using this model, we estimate the value of Abu Dhabi's groundwater resources (in total and per cubic meter).

Keywords: Groundwater, Recharge, Groundwater economics, Groundwater management, Desalination, Treated wastewater

Trends in Groundwater Observation Data and Implications: A case study from Batinah plain, Sultanate of Oman

Ahmed Hadidi[1], Ekkehard Holzbecher[1], Andrea Zirulia[2]
[1] *German University of Technology in Oman (GUtech), Muscat, Oman; E-mail: ahmed.hadidi@gutech.edu.om*
[2] *CGT Center for GeoTechnologies, University of Siena, Via Vetri Vecchi, San Giovanni Valdarno (AR), Italy- Department of Chemical and Geological Sciences, University of Cagliari, Via Trentino, Cagliari, Italy - GeoExplorer Impresa Sociale Srl, Via Bruxelles, Cavriglia (AR), Italy*

The Batinah plain in the North of the Sultanate of Oman is undergoing several severe changes. Growing population, accompanied by urbanization and industrial activities conflict with the traditional agricultural imprint. The development stresses the regional water resources. The vast aquifer, located between the Hajar mountain chain and the Oman Sea, is exploited by increased withdrawal for domestic, agricultural and industrial purposes. Especially in the highly populated coastal region the reduced pressure due to the decreasing groundwater table leads to enlarged saltwater intrusion from the seaside. We explore time-series of water table and salinity from 29 wells in Maawil catchment, South Batinah, some of them recorded for more than 30 years. Typical patterns in the measured data reflect the profound changes of the aquifer, related to saltwater intrusion, extreme rainfall events and dam construction. The analysis confirms the effectiveness of recharge dams for harvesting flash floods and implies the importance of integral management of groundwater resources. The exemplary case study shows trends that can generally be observed in stressed coastal aquifers.

Keywords: Groundwater observation, Seawater intrusion, Time Series, South Batina.

Evaluation of the Nubian Sandstone Aquifer System (NSAS) in Al Kufra Oasis, Southeast Libya

Salah M Hamad[1], Younes A Ahweej[2]
[1] *Lecturer, Faculty of Natural resources and Environmental science, Omar Al Mukhtar University, Al Baydah, Libya*
[2] *Researcher, Libyan Agriculture Research Center*

Groundwater resources, developed in the Nubian Sandstone Aquifer System (NSAS), in Al Kufra Oasis in Libya are becoming increasingly vulnerable due to increasing pressures to meet the demand for economic development. These activities are represented mainly by agriculture activities in addition to the inefficient water use by other consuming sectors. Their misuse and violations are a result of the country political instability, in addition to the lack of effective legislation, policies, strategies, and law enforcement instruments in current Libyan water management practices. This research investigates, examine and brings to the fore the groundwater conditions in Al Kufra oasis in terms of water quantity and quality, and evaluates the current management practices of water resources.

Evaluation of groundwater resources in terms of quantity is made by analyzing depth to water level in 10 monitoring wells for the period from 2005 to 2015, which showed a drawdown value of about 20 meters during ten years in the urban area and the agriculture projects areas. In term of water quality, water samples were collected from 16 water wells, and chemical analysis was conducted for the concentration of major Anions and Cations. The result showed increase in the value of total dissolved solids in the urban area and the agriculture projects areas, which can be interpreted as the result of the increase in the amount of water extraction or the contamination by urban activities. Groundwater classification by Piper diagram and Wilcox diagram indicated the water indicates that water is still suitable for agricultural purposes. Evaluation of the water resources management practices was undertaken through a survey examining the efficacy of water institutions relative to institutional framework, functions, activities, and their influence in the current management. The results indicate that current inadequacy of water management is due to many reasons, including: centralized planning and financing, limited financial resources, overlap of water institutions, lack of stakeholders' participation, lack of coordination, and organizational instability. It is clear that the current water challenge is a managerial rather than a technical one. A comprehensive reform of the water sector is needed, based on the following recommended set of actions: institutional integration and engagement of stakeholders; evaluation of the current status of the NSAS beneath the main oases in term of groundwater quality and quantity assessment of the environmental impacts of different water uses on NSAS; and, assessment of socioeconomic conditions for the oases, and their direct and indirect relationship to the ecosystem.

Keywords: Groundwater, IWRM, Transboundary aquifer**.**

Assessment of the Groundwater at Ali Al-Garbi area, Iraq using Geochemical modeling and Environmental isotopes

Hussein B. Ghalib, Mohsin Baqer Yaqoob and Alaa M. Al-Abadi
Geology Department, Science College, Basrah University, Basrah, Iraq; Email: hbggeo@gmail.com

Geochemical modeling and environmental isotopes (deuterium, oxygen-18, and tritium) were used to determine the hydrogeochemical evolution and the main factors controlling the groundwater chemistry in Misaan, South of Iraq. Groundwater samples were collected and analyzed for major ions at 20 sites for two periods in 2016. Moreover, 6 rainfall samples were collected to determine local meteoric water line. The main water types are Ca-SO_4, which is the dominate type for two periods, while a few wells were (Na-SO_4) or (Mg-SO_4) dominate. All available $\delta^{18}O$ and δD data for the study area are plotted to the global meteoric water line (GMWL) and Local meteoric water line (AMWL). They indicated to the meteoric origin of all waters. They are exposed to evaporation before entering the aquifer. Using PHREEQC, Geochemical modeling was conducted to calculate mineral saturation indices for all water samples. These results show that dissolution of dolomite, gypsum, halite and siderite and precipitation of calcite, Sylvie and hematite are the main chemical reactions in the first period, whereas there are no specific reactions can be shown in the second period. Hydrogeochemical evolution of groundwater as modeled with NETPATH-WIN, the inverse geochemical modeling results showed that the main reaction controlling the groundwater quality is Dedolomitization process (dolomite dissolution driven by anhydrite dissolution and calcite precipitation).

Keywords: Geochemical modeling, Environmental isotopes, Groundwater geochemical evolution.

SESSION 4: SURFACE WATER MANAGEMENT

Keynote Speaker

Using Satellite Rainfall Data to Estimate Direct Flow

Mohamed Mustafa Abbas, Prof. Abdin M. A. Salih, Dr. Adil M. Elkhider, Dr. Salih H. Hamid
Capacity Development and Training Coordinator, UNESCO-RCWH; Email: moh_abb@hotmail.com

The main objective of this paper is to develop methodology for obtaining basin hydrological data for the Blue Nile sub-basins. As well to establish different types of data bank for the Blue Nile River Basin (BNRB). Data scarcity has been regarded as a huge problem in modeling the water resources of the Blue Nile River Basin. Satellite rainfall data together with the evapotranspiration have been used to calculate the runoff data. However, in data-scarce regions such as in a transboundary basin, remote sensing data could be a valuable option for hydrological predictions when ground rainfall stations are not available. As well as the remote sensing data can use to fill gaps in the ground rainfall stations. The satellite rainfall data for all Blue Nile sub-basins were downloaded in a monthly basis for the period 1980-2010 from the Global Weather Data for the National Centres for Environmental Prediction (NCEP) from its website (www.globalweather.tamu.edu). This data was modified with the actual measured rainfall from near gauge stations for the period 1993-1999 by using a weighting factor depending on the distance between satellite data, by using inverse equation and the distances between the middle of sub-basins and the first and second nearest measured rainfall stations respectively, the modified satellite rainfall data have been found. The selection of the boundary coordinates are used for each sub-basin to set the nearest rainfall satellite station in the middle of each sub-basin and, this is done by using the global weather and Google earth capability. The relation between modified rainfall data and the satellite rainfall data have been found. Different types of input data are used in the WEAP model after being modified and calibrated, such as satellite rainfall data, ET_{ref}, effective precipitation, and crop coefficient K_c in the upper Blue Nile basin. The study area has been divided into 16 sub-basins. WEAP model has been applied to the whole Blue Nile basin, keeping the monthly values of K_c same among the different sub-basins for the whole simulated period of 1980-2010. The observed stream flows, using rainfall-runoff relationship, have been simulated with the measured flows by using WEAP model at the four river gauging stations (El-deim, Giwiasi, Hawata and Khartoum) in a monthly time step yielded reasonable values. By evaluating the Blue Nile River Basin at the calibration period (1980-1995) in a monthly time step, the NSE, r^2, and d results for the Blue Nile River at the gauging stations showed a very good model performance.

Key word: Satellite, Rainfall, Blue Nile River, and Flow.

العلاقة بين وجود الآبار أعلى أمهات الأفلاج واستدامة تدفق الفلج: (دراسة تحليلية لفلج الخطمين وفلج الملكي)

دعاء بنت زياد السعيد
*رئيسة قسم صيانة الأفلاج، **دائرة الأفلاج، وزارة البلديات الإقليمية وموارد المياه، سلطنة عُمان***

إن فترات الجفاف الطويلة التي قد تستمر لعدة سنوات تؤكد الحاجة إلى إدارة فعالة للموارد المائية تمكن من تخزين المياه والاستفادة منها في المستقبل وهذا هو جوهر فكرة الأفلاج التي تعد نمطاً من الأنماط التقليدية للاستخدام المستدام للمياه في سلطنة عمان. فكان لهذه الأفلاج الدور الفاعل في تكوين التجمعات السكانية المنتشرة في ربوع السلطنة والتي لا تزال قائمة إلى الآن. ونظراً لما سببته ندرة الأمطار وقلة اهتمام الأهالي بالأفلاج من انخفاض منسوب مياه الأفلاج وحدوث جفاف عام شمل الكثير من الأفلاج، جاءت فكرة حفر الآبار لتعزيز العجز المائي لهذه الأفلاج ولتلبية الاحتياجات القائمة عليها ولكن جاء ذلك على حساب التدفق الطبيعي للفلج.

بالرغم من كون الآبار المساعدة للأفلاج هي الحل الوحيد لحياة واستمرار تدفق الفلج إلا أن هناك العديد من السلبيات التي تخلفها الآبار وفي هذه الورقة تم التطرق إلى تأثير وجود الآبار أعلى وداخل إحرامات أمهات الأفلاج واستدامة تدفق الفلج لفلجين من الأفلاج بمحافظة الداخلية (فلج الخطمين وفلج الملكي)، حيث اثبتت النتائج بانخفاض تدفق فلج الملكي بسبب كثرة الآبار المحيطة بأم الفلج مقارنة مع فلج الخطمين.

إن الحفر العشوائي للآبار ساهم في انخفاض المخزون الجوفي من المياه والذي بدوره يشكل تأثيراً مباشراً على تدفق الفلج، فكان لا بد من سن التشريعات والقوانين التي تحمي هذه الأفلاج من النضوب والحد من الحفر العشوائي لهذه الآبار والضخ الجائر من قبل الآبار الخاصة، هذا فضلاً عن أن كثرة الآبار يشكل ضغطا كبيرا على المخزونات الجوفية على حساب مصادر مائية أخرى قد تكون أكثر أهمية. ولتفادي مثل هذه المشاكل لا بد التقليل من حفر الآبار على أن تكون وفق معايير ثابتة وحسب حالات معينة بحيث تتخذ لتنفيذها طرق وخطوات مدروسة حتى تكون نتائج ذلك مضمونة وخالية من المشاكل ومقللة من الأعباء والضغط على الخزان الجوفي.

الكلمات الدالة: الأفلاج، الآبار، التدفق الطبيعي للفلج، المخزون الجوفي

Rainfall-Runoff Estimation and Comparative Analysis using SCS method based on GIS

Mubaraka Saad Alghariani
Water Department, Faculty of Agriculture, Tripoli University, Tripoli, Libya; Email: Sa.Alghariani@gmail.com

Accurate estimation of runoff and sediment yield amount is not only an important task in physiographic but also important for proper watershed management. Watershed is an ideal unit for planning and management of land and water resources. Direct runoff in a catchment depends on soil type, land cover and rainfall. Of the many methods available for estimating runoff from rainfall, the curve number method (SCS-CN) is the most popular. The curve number depends upon soil and land use characteristics. This study was conducted in the Kaam watershed in north western Libya using remote sensing and GIS. SCS-CN method has been used for surface runoff estimation for five sub-watersheds of Kaam. The soil map, land use and slope map were created in the GIS environment, because the curve number method is used here as a distributed model, it is necessary to obtain information on a large number of sub-catchments in the basin. Therefore, remote sensing and GIS techniques were used. The major advantage of employing GIS in rainfall -runoff modelling is that more accurate sizing and catchment characterization can be achieved. Furthermore, the analysis can be performed much faster, especially when there is a complex mix of land use classes and different soil types, Landsat satellite image was used to obtain ground cover information. The thematic layers such as the soil map, elevation map, rainfall map and ground cover map were created in Arc GIS 10.3. Then was set the values of Curve numbers in the study area, and by applying the SCS-CN method, the results showed that the surface runoff ranged from 94 - 165 mm in the study area, when rainfall rates were received from 204.07 - 284.6 mm. To find the relationship between rainfall and runoff rates, The straight line equation was used, That was found there a strong correlation between Runoff and precipitation rates, The value of the determination coefficient was 73% and the correlation coefficient between them 85%. Through of these results, the study recommends take advantage of runoff rates by reserving them at collection of sub basins and then using them for agricultural purposes in the vicinity. This would be better than reserving water from the total area of the basin, which is 2283 square kilometers, and then will evaporate or infiltrate before reaching the dam lake.

Key words: GIS, SCS method, Rainfall-Runoff, watershed, land use

Importance of Water Resources Management: An Overview on Oman's Experience

Aisha Mufti Al-Qurashi
Expert, Floods and Arid Zone Hydrology, Oman Water Society, Sultanate of Oman

Oman is an arid country where the annual average rainfall is less than 50 mm per year in most areas. The country mainly depends on groundwater that depends on recharge from rainfall. As the activities in different sectors has increased in the last decades, the water has increased highly. The average water demands have increased by 35% compared to the 2000s. The increase is attributed to the growing economic activities in all sectors. The many uses of water include agricultural, industrial, household, recreational and environmental activities. The agricultural demand has increased with 36% compared to that of 2000, representing about 95% of the abstractions from the natural resources, as the latest study shows, compared to only 5% for other sectors. The urban demands have increased four times more compared to 2000.

Currently, desalination is used, mainly, for drinking and other domestic use, to minimize the pressure on natural water resources. However, this does not solve the problem as the increase in demand is rapid with very limited resources, and the available data indicate that the quantities of consumed water exceed the available resources. Hence, integrated water resources management is essential, where all affecting factors and riparians are considered.

Oman has dealt with the challenge imposed by the continuing increase of demand on water resources from all sector through the adoption of an approach that seeks to harmonize the requirement of development and the available water resources and achieving sustainable development which aims at conservation, rational exploitation of natural resources and strict quality control for present and future benefits. The supply management emphasis on executing the national water resources assessment to identify all possible resources, the development of the infrastructure, regulation of water use, and the expansion of the water monitoring network. The demand management promotes all activities aimed at water resources conservation in all sectors, the increase of efficiency in water supply and water usage and the promotion of seawater desalination and wastewater treatment.

The paper highlights the water situation and presents the water management importance, particularly in the Sultanate of Oman, the government efforts, and water management strategies to achieve water resources sustainability, considering the economical social and environmental aspects and characteristics of the Sultanate of Oman.

Keywords: arid zone, water resources, water management, Oman.

The Role of Oman Water Society in Water Resources Conservation

Ahmed Said Al Barwani
Water Resources Expert, Oman Water Society, Al Ghubra, Sultanate of Oman; Email: ahmed.albarwani@gmail.com

Oman Water Society (OWS) is a non-profitable non-governmental organization (NGO) found by professionals working in both the Government and Private Sectors who are involved in the water management, water supply, and water projects. OWS was an official launch on April 14, 2010. The Society aims s to establish a platform for professionals with interest in water to exchanging ideas, researches, discuss challenges, enhancing their knowledge and expose themselves to the latest technology in the field. It is to the interest of the Country as well as the Water Sector to have all (stakeholders) or at least most of the professionals working in the water and wastewater field in this Society. Being an NGO, Oman Water Society (OWS) is becoming the focal point for all water-related issues to be discussed. Local, regional as well as International organizations are participating in events organized by the Society.

Oman Water Society organized a series of Seminars conducted by experts in the water sector. It has also organized several workshops in water-related issues and training programs to the young engineers in the on-going projects by coordination with the Consultants and Contractors working the Water projects. The society is encouraging all interested parties to participate in the above-mentioned events. In addition to that, the Public sector very well addresses to take part in such activities although for non-members.

Country related topics are given priority in delivering the water seminars and events. For instance cyclones, climate changes, groundwater, desalinization, agricultural development and other new water resources te innovations. OWS believes such related topics will not only encourage professionals to participate but also the other stakeholders (i.e., public, farmers, etc.). Moreover, young professionals are considered to be an available source to increase the number of associates within the society. Therefore, OWS is focusing on such new/young professionals by introducing society to them. The society is offering them associates membership until they obtain the full membership after their graduation.

Oman Water Society is working hard to achieve its goals by approaching specialists in the concerned public and private sectors. As well, it is looking forward to connecting with all segments of society in order to create a link between all partners concerned with the water sector, whether they are from the water consumers or decision makers. The OWS is doing this in order to intensify efforts in all aspects of water resources and its preservation. The venues of most of the symposiums and seminars, organized by OWS are selected at the governorate where particular water-related problem or challenges in order to have all concerned stakeholders including the general public. As a result of these efforts, it has been possible to tackle many water-related challenges and come up with good recommendations. Furthermore, good networking is taking place during the OWS events, which are playing a role in setting goals for water management and conservation in the country.

Key Words: Oman Water Society (OWS), water conservation, public participation.

Session 5: AGRICULTURAL WATER MANAGEMENT

Keynote Speaker

Improving Irrigation Efficiency and Conservation using Modern Irrigation Programs in Saudi Arabia

Abdulrasoul Al-Omran
College of Food and Agricultural Sciences, King Saud University, Riyadh; Email: rasoul@ksu.edu.sa

The continued expansion of agriculture and urban development in the GCC countries, (which is located within the arid regions), accompanied with growing demand for water supply in different sectors, all of this calls for agricultural sector to look for practices that increase the irrigation efficiency and water conservation and increasing water productivity of crops.

In this presentation, we will explore some of the efforts in the determination of the actual water requirements as an introduction to water conservation with deficit irrigation (DI) programs and partial root drying system (PRD) using different soil conditioners such as polymers, compost and biochar. The crop water requirement is the core to establish water conservation program. The crop evapotranspiration (ETc) was assessed through Pan Evaporation method (PE) and estimation based upon Penman-Monteith equation (PM). The results revealed good agreement between PE and PM *ETc*. The irrigation treatments consisted of four levels of *ETc* (40, 60, 80, and 100% of ETc) in addition to the traditional one as practiced by local farmers. At the 60 and 80% *ETc* treatments, the deficit irrigation was tested at different growth stages (Initial, developmental, middle, and late stages of crop growth). Each of the treatments was carried out in three replicates. The results showed that soil salinity in general increased with decreasing level of applied water. The crop cucumber could tolerate shortage of water during the middle season growth stage, when the *Ky* values ranged between 0.57 and 0.76. The level of water used up in 100% *ETc* treatment was much lower than that in the traditional drip irrigation as practiced by farmers. In other words, the *CWP* values increased with water consumption being decreased. The results also indicated that the highest values for *CWP* were found for the most stressed treatment of 40% *ETc*, while on the other hand the overall crop productivity had decreased.

On studies of water conservation using deficit irrigation and partial root drying of various crops, including tomatoes, cucumbers, potatoes. All of these studies have shown that reducing water use by 20% did not significantly affects productivity, and water productivity rose much with deficit when compared to traditional irrigation on farms as well as the provision of water, there was also significant savings in fertilizers and pesticides used.

Keynote Speaker

Research Priorities and Actions for Sustainable Agriculture Water Management in MENA region

Thameur Chaibi
National Research Institute for Rural Engineering, Water, and Forestry, Tunisia; Email: chaibithameur@yahoo.fr; chaibi.medthameur@iresa.agrinet.tn

The MENA region is naturally exposed to chronic shortage of water and almost all available water resources have been already exhaustively used. Agricultural is the most important sector with respect to consumptive water use, equals about 80% of the total water resources. Global climate change and pollution, coupled with increasing population pressure, rapid economic growth, have a major impact on water resources and their availability. The complexity of these global issues and the need for developing and implementing appropriate ways to manage agriculture water resources presents a multitude of challenges to the scientific community and research to advance the current thinking on the technical, economic, environmental, social, and political dimensions of sustainably managing agriculture water demand and supply at local, regional, and basin levels. This paper provides valuable insights into the current research landscape, in the enormous diversity of situations across the NENA region, as well as drawing attention to the existing trends and research gaps in terms of irrigation water security and multiple challenges in this field.

In light of the considerable expertise already present in the region, potential for research in three main categories are highlighted:(1)policy issues composed of research topics in relation with water law/governance/policy and water economics in the context of transition and dynamic change of the region's countries,(2)water resources management that integrate water quality and quantity, and (3)water management technologies providing innovative solutions that meet the challenge of agriculture sector in producing more food with less resources(water and energy)and less environment impact.

Research topics are explored from three point perspectives: "Relevance", "Gaps" and "Priorities". The paper presents some considerations about the relevance of the knowledge and skills in the domain of agriculture water management in the different context of the region. Basic research gaps, that receive little attention but are potentially important in the region such as crop productivity linked to water use efficiency, and unconventional water use, as key priorities for future research in the field have been addressed. More importantly, this work emphasizes the opportunities for potential research growth and knowledge transfer for a production and sustainable agriculture water management in MENA region.

To be competitive at the international level, research in the field of water management needs to be focused on local MENA problems and to take cognizance of a country's political context, local knowledge, skills and culture. Particular efforts should be placed on generating collaborative research projects that is of relevance for the region rather than following a specific research agenda dictated by funding opportunities. It is through such approach that MENA region will be able to make its own valuable contributions to the global scientific community.

Keywords: MENA Region, Research, Water Management, Agriculture, Sustainability.

Keynote Speaker

Leveraging Research for Sustainable Development in the Arab Region

Faraj El-Awar
Director, Resource Mobilization, Partnerships, and Outreach, International Center for Agricultural Research in Dry Areas (ICARDA), Cairo, Egypt; Email: felawar@yahoo.com

The Arab region is the driest in the world, and it is home to 14 of the 33 most water-stressed countries on the planet. Additionally, low level of natural water abundance is intensified by wasteful approaches to water management and pollution from untreated wastewater. Several Arab countries have nearly exhausted their resources of renewable water, and some of them are facing frequent and prolonged water shortages that force them to make hard choices, regarding the management and allocation of these limited resources, in order to ensure the achievement of the sustainable development goals on national level. Prioritization of various demands for water resources, in such countries, is a complicated multi-dimensional process that entails not only national policies but also science-based solutions.

The International Center for Agricultural Research in Dry Areas (ICARDA) has conducted research, for more than forty years, in the Arab region with an overall objective of enhancing food security and sustaining livelihoods of local rural communities through integrated agricultural production systems. Since its establishment in 1977, ICARDA has worked on the development of scientific approaches for the optimization of water and energy use for food production. Such approaches are instrumental for halting the alarming process of natural resources degradation, and ultimately breaking the vicious cycle connecting such degradation to poverty, in the Arab region.

ICARDA Research findings have been used throughout the Arab region within national and regional interventions aimed at enhancing agricultural productivity while ensuring the long-term sustainability of the natural resources base in the region. Some of these interventions have led to significant improvements both in terms of efficiency gains in natural resources use and in terms of national policies. This presentation aims at showing these findings, how they are being used in various ICARDA interventions, how they contribute to improved national policies, and ultimately how they contribute to sustainable development in the region.

Improving the Irrigation Efficiency of Kuwait Native Shallow Groundwater Using Phytoremediation Technology

Hana'a Burezq[1], **Amjad Aliewi[2]**
[1]Associate Research Scientist, Desert Agriculture and Ecosystems Program (DAEP), Environment and Life Sciences Research Center (ELSRC), Kuwait Institute for Scientific Research (KISR), Shuwaikh, State of Kuwait; Email: haborizq@kisr.edu.kw
[2]Research Scientist, Water Resources Development and Management Program (WRDMP), Water Research Centre (WRC), Kuwait Institute for Scientific Research (KISR), State of Kuwait; Email: aaliewi@kisr.edu.kw

In Kuwait, shallow groundwater is used mainly for irrigation purposes. This groundwater is however brackish with TDS values range from 4,000 to 15,000 mg/l. Also, this groundwater is normally subjected to industrial and agricultural pollution increasing the concentration of heavy metals, nitrogen compounds and salt ions. The aim of this paper is to illustrate through field experiments that the roots of the Reeds Plants (which are common in Kuwait) are capable to improve the efficiency of irrigation by reducing the concentration of some pollutants in the native groundwater in Kuwait. Two basins were constructed in the fields of KISR premises then Reeds plants were allowed to grow up under climatic conditions of Kuwait until they were 2.5 m tall. Then the Reeds plants were irrigated with native shallow groundwater from Kuwait aquifers. Samples of inflowing irrigating water and out-flowing water from the bottom of the basins were taken over a period of 3 months. The water quality between the two waters were compared. The results show that the Reeds roots are capable of reducing the concentration of salt ions by about 70%, and removing completely heavy metals from the irrigating groundwater and hence improving the irrigation efficiency considerably.

Keywords: phytoremediation, reeds roots, salts ions and heavy metals.

Improving Water Use Efficiency of Crops for Sustainable Agriculture in Dry Lands

Ahmed Al-Busaidi[1], Mushtaque Ahmed[1], Hashel Al-Maskari[1], Shihab Al-Maamari[2]
[1]*Department of Soils, Water and Agricultural Engineering*, *College of Agricultural & Marine Sciences*, *Sultan Qaboos University, Sultanate of Oman; Email: ahmed99@squ.edu.om*
[2]*Applied Biotechnology Department, Sur College of Applied Sciences*, *Sultanate of Oman*

Improving water use efficiency in agriculture especially in dry countries is the dire need of the day. Oman has limited groundwater and in many places it is saline water. Therefore, various approaches could be used to improve plant productivity in saline dry lands. One approach to overcome the limitation of plant growth due to shortage of water and soil drying could be to promote root growth for efficient uptake of water from greater soil volume. Ethylene is a plant hormone that is involved in the regulation of many plant physiological responses especially under stress conditions. Water stress has been extensively associated with elevated release of endogenous ethylene by the plant which results in root growth inhibition dramatically. Therefore, there are certain plant growths promoting rhizobacteria (PGPR) which contain a unique enzyme that decreases ethylene in the inoculated plant roots. The main aim of this project was to isolate and evaluate plant growth promoting rhizobacteria for increasing plant growth and water use efficiency of crops. Moreover, different compost could enhance the growth of bacteria and save water for better growth. For this purpose, different bacteria were isolated from saline soil of Barak, Oman. The best bacteria that gave better growth in saline media were selected. The best two bacteria were reproduced and used for field trials. They were compared with two bio-stimulants (Stimpo and Regoplant) and grown in three different composts (Kala, Growers and Al-Mukhasib). The study was done in greenhouse using Radish and Okra plants grown in pots and irrigated with freshwater and saline (4dS/m) treated waste water waters.

Plant showed the best growth under freshwater irrigation compared to saline water. This happened due to salinity stress that affected water and nutrients movements from the soil to the plant. All used composts were positively affected plant growth. However, Kala compost gave the best growth and productivity even under saline irrigation. The most important thing was how bacteria and bio-stimulants could improve plant growth and give significant effect especially under saline conditions. It was observed that Regoplant was good and gave better results for plant growth (plant height, fresh weight and fruit weight) with freshwater irrigation compared to saline condition. Whereas, Stimpo and bacteria showed positive effect under saline condition and they supported plant growth much better than Regoplant. However, Stimpo is still chemical compound and could have some side effects with long term applications. Therefore, bacteria could be the best option for improving plant growth under saline conditions because it is from nature and could adapt with soil-water-plant conditions. Using these bacteria under Oman saline condition will improve the growth and productivity of different plants that could not survive under saline conditions.

Keywords: Enriched compost, Plant growth promoting rhizobacteria, Bio-fertilizers, Organic fertilizer.

Water Saving in Arid Irrigated Lands: A comparison between different irrigation techniques adopted under date palms in the Tunisian Oasis

Latifa Dhaoudi
Regional Research Center for Oasis Agriculture, Tozeur, Tunisia; Email: latifa_hydro@yahoo.fr

Water irrigation resources scarcity combined with the problem of poor quality of most of these resources known by their high salinity, present a great threat for the oasis agriculture sustainability. Hence, improvement of water saving technologies is imperative to ensure the better oasis productivity. The main objective of this work is to identify the efficiency of the irrigation technique for date palm trees through the assessment of irrigation technologies newly introduced by a few farmers in some of the Tunisian oasis regions.

The three irrigation techniques, which were evaluated by applying the same volume water irrigation under date palm trees are the bubbler, the mini diffuser and the subsurface drip irrigation systems. The irrigation assessment showed that the uniformity in water irrigation distribution of the soil after irrigation is around 90% for the three techniques. The water irrigation losses after irrigation were 42mm, 63mm and 72mm respectively by bubbler, by mini diffuser and by subsurface drip irrigation. The irrigation water application efficiency is the best for the bubbler irrigation (62%). The water use productivity is also the highest for the bubbler (0.66kg/m^3). In addition to the desalination efficiency noted as one of the bests for the technique by bubbler, it was 63%. The results of this study showed that the bubbler irrigation system is the most efficient technique which will be the best technology practice under date palm trees in the Tunisian Oasis conditions.

Keywords: Tunisian Oasis, Date palm, bubbler irrigation, mini diffuser, subsurface irrigation.

Using Bayesian Networks for Mapping Stakeholders Behaviours in Integrated Water Resource Management with a Focus on Irrigated Agriculture in Al Batinah Region, Oman

Ayisha Al-Khatri[1,2]; J. Grundmann[2]; R. v.d.Weth[3]; N. Schütze[2]
[1]*Ministry of Regional Municipalities and Water Resources, Ruwi, Sultanate of Oman; Email: ayisha.khatri@hotmail.com*
[2]*Technische Universität Dresden, Institute of Hydrology and Meteorology, 01062 Dresden, Germany*
[3]*Dresden University of Applied Sciences, Work Science & Human Resources Management and Industrial Science, 01069 Dresden, Germany*

The problems of water resource management and its interaction with society have to be tackled from an integrated perspective taking into account the interdependence of environmental, political, social and economic factors. The conventional approaches being currently used, to study water resources management, lack to reflect the mutual relationship between water resources and societies. However, varieties for approaches to developing models of complex systems are available. Bayesian Networks (BNs), is an approach, which can integrate data and knowledge of different types and from different sources in which, causal links join the variables. A BN is a type of Decision Support System (DSS) based on a probability theory that implements Bayes' rule. This work is focusing on the case of Al-Batinah coastal plain in Oman where lots of small-scaled farms practice agriculture. There is no control over the water amounts abstracted from the coastal aquifer. Therefore, the coastal aquifer is at risk due to seawater intrusion. Since groundwater replenishment is limited, the region is facing a problem of water deficit, which also influences the sustainability of agricultural production. Based on a social survey conducted regarding the Al Batinah case, the existing situation generates conflicts between different stakeholders (SHs) which have different interests regarding water availability, sustainable aquifer management, and profitable agricultural production. Therefore, the development of appropriate management strategies for a transition towards a stable and sustainable future hydrosystem states is required. This work aims to evaluate the implementation potential of several management interventions and their combinations by analyzing behaviors and opinions of relevant SHs (farmers and decision makers) in the region. This should support decision makers (DMs) in taking more informed decisions. Data were collected through a social survey. Differences were examined statistically between opinions of farmers and decision makers regarding potential interventions.

Additionally, the approach of BN was used for mapping stakeholders' behaviors and to show the strength of a relationship between dependent and predictor variables. The findings suggest that BNs provided an enhanced understanding of the presence and strength of causal relationships. The hypothesis for most of the variables, in the structure of the network, worked logically.

Moreover, it is possible to determine the implementation potential of management interventions regarding their acceptance, and additionally, triggers can be identified to increase this potential. Nevertheless, management interventions should also be evaluated regarding economic and environmental criteria.

Keywords: Decision support System (DSS), Stakeholder, Potential Interventions, Bayesian Network, Oman.

Improvement of water and energy use in sprinkler irrigation under semi-arid conditions

Samir Yacoubi[1], Adel Slatni[1], Ali Chebil[1], Khemaies Zayani[2]
[1] *National Research Institute for Rural Engineering, Water and Forestry, INRGREF, Ariana, Tunisia*
[2] *Ministry of Agriculture, Water Resources and Fisheries/ National Agronomic Institute of Tunisia (INAT), Tunis, Tunisia*

This study aims to assess the impact of sprinkler irrigation performance on the energy requirements of solid-set sprinkler irrigation systems. For this purpose, a methodology to evaluate the energy requirements for solid-set sprinkler systems was proposed. Experimental and simulated irrigation data were used to analyze the impact of water application efficiency on the energy required to distribute water on soil surface. Results show that the decrease in the water application efficiency from 81 to 69% due to deep percolation losses over the potato irrigation season greatly increases the water distribution energy (34.4%) with an increase in the energy coast (kWh per ton) of 22.4% as well as a reduction of 18% in the water use efficiency. Results indicate also that improvement of water application efficiency of irrigated tomato from 74.1% (day irrigation) to 86.8% (night irrigation) induced a reduction in the energy cost (kWh per ton) of 22.8% although the net seasonal irrigation depth for night time was larger than that for day time due to the decrease in wind drift and evaporation losses.

Keywords: Sprinkler irrigation, Energy, Application Efficiency, Water Distribution.

Consideration of Seasonal Variations on Water Radiometric Indices Estimation of Soil Moisture Content in Arid Environment in Saudi Arabia

Jarbou Bahrawi, **Mohamed Elhag**
Department of Hydrology and Water Resources Management, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University, Kingdom of Saudi Arabia; Email: melhag@kau.edu.sa

Remote Sensing applications in agricultural practices are comprehensively reliable and cover a multidisciplinary fundamental interest both in local and regional level. Significantly, vegetation indices are the foremost essential in remote sensing applied for agricultural activities related to vegetation and/or water, particularly in an arid environment. Adequate water resources management plans are based on better fulfilling the water demand and supply equation. In arid environments, this equation is barely achieved due to water resources limitations. Remote sensing techniques improve the water resources management schemes by using five different water radiometric indices of Sentinel-2. Each of them plays a specific role in the quantification of soil/plant water content based on the interpretation of map surface water features and monitors the dynamics of surface water. The study area is located within the main agricultural region of Wadi As-Sirhan. The area is characterized by flourishing agricultural activities. Remote Sensing data acquired by Sentinal-2 proved to be statistically sufficient to estimate soil water content in two different climatic conditions. Statistically, estimated winter indices are with better fit than summer indices. MNDWI and NDWI-2 best fitted winter soil water content estimations. Meanwhile, RMSE showed no differences between NDWI and NDTI for both climatic conditions.

Keywords: Integrated Water Resources Management, Sentinel-2, Soil Water Content, Remote Sensing, Water Radiometric Indices.

SESSION 6A: DESALINATION MANAGEMENT

Keynote Speaker

Future Prospects for Desalination in the GCC Courtiers

Ibrahim Al-Muataz
Chemical Engineering Dept., College of Engineering, King Saud University, Saudi Arabia; Email: almutaz@ksu.edu.sa

The total area of the Gulf Cooperation Council (GCC) countries is about 2.6 million km^2 with an approximate total population of 53.4 million in 2016. The per capita total renewable water resources (TARWR) in GCC countries in 2014 was just 86.6 cubic meters, compared to the global average of almost 17,575 cubic meters. It is predicted that water availability in the GCC countries will be reduced significantly by 2030.

Desalination is considered the major water supply in the GCC countries. About 63% of the water supply in GCC countries comes from desalination. The current GCC seawater desalination capacity is nearly 18.2 million m^3/d (4,000 MIGD). Conventional water resources such as fresh surface water and renewable groundwater are limited. Reuse of treated wastewater is about 900 million cubic meters, which is equivalent to 31.0% of the total treated wastewater. Treated wastewater is used mainly for irrigating green areas.

It is expected that the total annual GCC water demand will increase by 40% in 2030 and may reach more than 50 billion cubic meters (Bcm). This may lead to a large deficit in the GCC water resources of about 20 billion cubic meter. The GCC countries plan to install and expand more desalination plants to meet the growing domestic water demands.

In this work, the contribution of desalination plants in bridging the gap between supply and demand in the GCC countries will be examined. The future prospects for desalination in the GCC courtiers depend on integrating established and emerging desalination technologies. Several recently developed desalination technologies promote lower energy consumption based on renewable energies. Nuclear energy offers an attractive and economical alternative source for power generation and water desalination for sustainable development in the energy and water sector.

Towards Efficient Water Management in Nuclear Power Plants

Ibrahim Khamis, R. El-Emam
International Atomic Energy Agency (IAEA), Vienna International Centre, Vienna, Austria;
Email: I.Khamis@iaea.org

Nuclear power plant projects require securing a sustainable source of water for the different stages of the projects, including construction and flushing, cold and hot testing, the condenser cooling operation, including the primary coolant make-up system, as well as the safety inventory and discharge from the radioactive liquid waste treatment system. Hence, efficient water management is crucial during all phases of construction, operation, and maintenance of any nuclear power plant. In some cases, the use of water resources has developed into an environmental issue resulting in stringent regulations which limit the possibility of water withdrawal as well as water discharge. Recent experience has shown that nuclear power plants are susceptible to prolonged drought conditions, forcing shut down of the reactors or reduction of power to a minimal level. Due to water scarcity and concerns associated with climate change affecting available water resources, nations of the world are operating or considering nuclear power plants should assess the different strategies of efficient use of existing water supplies for the needs of nuclear power plants. Also, the consideration of alternative water sources; including desalination, water reclamation, or other water recycling strategies should be considered in securing sustainable water supply for the nuclear power project.

Due to the importance of efficient management of water at nuclear power plants during the entire phases of construction, operation, and maintenance; the IAEA Water Management Program (WAMP) was developed to enable Member States to assess various types of cooling systems and the need for cooling water and other essential systems in water-cooled nuclear power plants. The program estimates the water needs for cooling and other essential systems. Moreover, it helps in the selection process of cooling systems by assessing three different criteria: water resources, the environment, and economics. WAMP enables users to perform comparisons of different cooling systems, reactor technologies, and at different site conditions. The reported results include water withdrawal and consumption estimation; and estimation of economics (capital and operating costs) for cooling systems.

This paper highlights the aspects of and strategies towards efficient water management in nuclear power plants, focusing on two crucial strategies: the use of nuclear desalination and water reclamation for achieving efficient water management in nuclear power plants. Also, the main features of the IAEA tools in support of on nuclear desalination and water management are discussed.

Keywords: nuclear, desalination, water management.

Development of mobile stand-alone solar driven reverse osmosis groundwater/seawater desalination plants for sustainable development in Egypt

Hosam A. Shawky[1], Amr A. Abdel Fatah[2], Moustafa M. S. Abo ElFadl, Abdel Hameed M. El-Aassar[1]
[1]Egyptian Desalination Research Center of Excellence (EDRC), Desert Research Center, Cairo, Egypt; E-mail: Shawkydrc@hotmail.com, Hashawky@edrc.gov.eg
[2]Brithish University in Egypt, Cairo, Egypt

Egypt is experiencing a fresh water crisis. Many large and small communities in Egypt are suffering an acute shortage of fresh water that complies with minimum health requirements. Water desalination projects based on reverse osmosis technology are being introduced in Egypt to combat drinking water shortage in remote areas. Reverse osmosis (RO) desalination is a pressure driven process. This work focuses on the design of an integrated brackish water and seawater RO desalination and solar Photovoltaic (PV) technology. Two small mobile PV driven RO desalination plants prototype were designed, deployed and applied into two areas in Egypt. Solar-driven reverse osmosis desalination can potentially break the dependence of conventional desalination on fossil fuels, reduce operational costs, and improve environmental sustainability. Moreover, the innovative features incorporated in the newly designed PV-RO plant prototype are focusing on improving the cost effectiveness of producing drinkable water in remote areas. This is achieved by maximizing energy yield through an integrated automatic single axis PV tracking system with programmed tilting angle adjustment. Mobility of the systems provide potable water to isolated villages and population as well as ability to provide good drinking water to different number of people from any source that is not drinkable. In the first project a mobile battery-less photovoltaic powered groundwater reverse-osmosis (MSRO) desalinating unit was designed, manufactured and deployed in the Northwest coast of Egypt. This unit is capable of desalinating the brackish and saline groundwater as well as it was considered to produce 11 m^3/day of drinkable water for the Bedouins community. The second project focuses on designing, building and field-tested of an integrated mobile saline groundwater and seawater RO desalination and solar photovoltaic (PV) technology. The system was designed to produce 21 m^3/day of fresh water in Shalateen area, Southeast coast of Egypt.

Key words: Design, Mobile, Reverse Osmosis, Photovoltaic, Desalination, Northwest Coast, Shalateen, Egypt.

Modeling of temperature governed saturation states and metal speciation's in the Marine waters of Kuwait Bay- concern to the desalination process.

Chidambaram Sabarathinam, Harish Bhandary, Asim Al-Khalid
Water Research center, Kuwait institute for scientific research, Safat, State of Kuwait.

There is a change in temperature in the marine waters of Kuwait bay with respect to season and daily temperature. This variation in temperature affects the saturation and the speciation states of ions the marine waters, which serve as the main source of desalination. The change in the saturation states of compounds constituted by major ions and the speciated metal ligands cause a differential impact on the RO membranes. This variation in temperature was considered and modelled using the average bay water composition to determine the saturation state of minerals concerning temperature. This composition was studied for variation from 10ºC to 50ºC using geochemical model PHREEQC. The metals like metals like B, Li, Sr, Ba, Fe, Mn, Be, Co, Cr, Ni, Se, Al, Mo and As were analyzed in these water and the predominant species of these metals along with their variation with respect to temperatures considered were studied. The saturation states of calcium carbonates and calcium sulfates were considered as they form the significant major ions of marine waters. The order of state of saturation index (SI) is observed to be as, $SI_{Dol} > SI_{Cal} > SI_{Ara} > SI_{Gyp} > SI_{Anhy}$. There is a sharp decrease of pH with respect to increase in temperature was observed. The observation indicates the fact that beyond 25ºC there is a decrease in the SI_{Cal}, SI_{Ara}, SI_{Dol} and there is an increase in the SI Anhy. Hence, it is inferred that the SI of Carbonate minerals beyond 25ºC is slightly reduced and that of Sulfate minerals with respect to Ca are increased. This is mainly due to the preferential attraction of Ca to SO_4^{2-} than to CO_3^{2-} above this temperature, which is a reflex of common ions effect. Further it should be noted that pH of the water decreases with temperature and this indirectly affect the HCO_3 concentration in water. So, it is inferred that the carbonate salts are more prominent during winter and the sulfates during summer, and the pre-treatment should also be planned considering the saturation states of water with respect to season.

Key words: pH, Saturation, Carbonate, sulfate, season.

Extraction of Valuable Minerals from Reverse Osmosis Brine in Kuwait

Mohammad Safar, Bhadrachari Garudachari, Safeyah Al-Muqahwi, Mansour Ahmad
Water Research Center, Kuwait Institute for Scientific Research, Safat, State of Kuwait; Email: msafar@kisr.edu.kw

The availability of freshwater on earth is very less and a noticeable worry about the shortage of freshwater has emerged during the last decade especially in the Middle East and North Africa (MENA) countries. Most of freshwater demands are provided by the desalination of seawater both thermal or membrane desalination technologies and desalination plants produce huge volumes of concentrated brine which are discharged back to the sea. This brine contains greater concentration of commercially valuable minerals than that in seawater. The literatures reported that the current disposal options have a number of severe limitations that are associated with technical challenges and environmental issues. As such, research studies have remarkably carried out into the development of mineral extraction processes with aim of producing valuable minerals from desalination brine. Therefore, this paper will review the appraisal of extraction of valuable minerals from Kuwait seawater desalination brine. To achieve this goal, bench scale experiments were conducted by adopting suitable technologies present in the recent literature. Chemical precipitation method was experimentally implemented at Water Research Center (WRC) of Kuwait Institute for Scientific Research (KISR) with aim of extracting valuable minerals, including magnesium, calcium, boron, sulphate, and strontium, from the rejected brine of the main SWRO desalination units of Desalination Research Plant (DRP) and Shuwaikh Water Distillation Plant (SWDP). The mineral extraction experiments were performed by using sodium hydroxide as base at different processing temperature and pH. The results showed that the amount of extraction of minerals from Doha RO brine was 7.280 gm/L. The major extracted mineral was magnesium is about 98% and other minerals are lithium 78%, boron 51%, sulfate 18%, calcium 15% and strontium 14%. For Shuwaikh brine, percentage of extracted minerals are boron 83%, magnesium 78%, lithium 34%, strontium 21%, calcium 18% and sulfate 11% at 90 °C at 10.0 pH. Based on the experimental data and mathematical calculations, the production of magnesium oxide from DRP and Shuwaikh RO plants is around 231 and 97,910 ton per year. The annual benefit from magnesium oxide production using Doha and Shuwaikh brine are 577,500 US$/Y and 244,775,000US$/Y respectively.

Keywords: Desalination brine, chemical precipitation, solubility, brine management.

A Comparative Study of Two Different Forward Osmosis Membranes Tested Using Pilot Plant System for Arabian Gulf Seawater Desalination

Mansour Ahmed, Yousef Al-Wazzan, Rajesha Kumar, Garudachari B, Jibu P.Thomas
Water Research Center, Kuwait Institute for Scientific Research, Safat, State of Kuwait; Email: mahmed@kisr.edu.kw

A pilot scale forward osmosis (FO) desalination system of capacity 10m^3/day was successfully established at Doha Desalination Research plant (DRP) of Kuwait Institute for Scientific Research (KISR), during October, 2016. The pilot plant system has access to evaluate the performance of different FO membranes developed by world leading manufacturers and also the efficiency of different draw solutions (DS). The current study was aimed at evaluating the performance of two different hollow fiber FO membranes with different bore diameters of 135 and 230 µm respectively. The DS consisted of high osmotic polyelectrolyte thermoresponsive polymer; whereas the feed solution (FS) was Arabian Gulf seawater supplied from the beach well of DRP, to demonstrate the direct application of pilot plant FO system for desalination application. The FS was passed through the bore side and polymer DS was passed through the shell side of the membrane. The DS which was diluted due to the water permeated through the membrane as a result osmotic pressure difference was sent to the coalescer at 85° C, where the diluted polymer DS was separated into supernatant water and concentrated polymer DS. The membrane performance was evaluated in terms of FO flux, salt rejection and water recovery. The membrane with 230 µm has observed highest performance during FO operation with water recovery of around 30% and by reducing the total dissolved solids from 40,000 to 130 ppm. The high performance associated with 230 µm membrane is attributed to the more diffusion of the highly concentrated DS towards membrane lumen side. Such diffusion resulted in high osmotic pressure difference which is considered as the driving force across the membrane. Additionally, less pressure-drop experienced by the 230 µm membrane between its bore side and outer shell side could be the reason for its high-water recovery. The results of this study demonstrated the potential of using FO membrane with larger bore diameter with controlled flow rate to attain high performance in the thermal based FO seawater desalination.

Keywords: Forward osmosis, polymer draw solution, hollow fiber membrane, bore diameter, Arabian Gulf seawater desalination.

Experimental study on effect of different mass flow rate in an inclined solar panel absorber solar still integrated with spiral tube water heater

A. Muthu Manokar
Department of Mechanical Engineering, BS Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai, India

This paper aims to analyze the performance of the Inclined Solar Panel Basin (ISPB) still integrated with a Spiral Tube Collector (STC) at diversified mass flow rate of water (m_f). The maximum freshwater obtained at the m_f at 1.8, 3.2 and 4.7 kg/hr is 8.1, 6.9 and 6.1 kg, respectively. The daily average thermal and exergy efficiency of the ISPB still integrated with the STC at the m_f at 1.8, 3.2 and 4.7 kg/hr is 47.9, 39.3 and 31.02% and 9.8, 7.9 and 5.6%, respectively. When the m_f increases, there are a decreases in the still distillate yield, thermal and exergy efficiency.

Keywords: active inclined solar panel basin solar still, effect of mass flow rates, freshwater

SESSION 6B: DESALINATION MANAGEMENT

Keynote Speaker

Water Treatment Using Nanotechnology Enhanced Membranes

Mohamed Al-Abri[a,b],
[a] *Nanotechnology Research Center, Sultan Qaboos University, Alkhoudh, Sultanate of Oman*
[b] *Petroleum and Chemical Engineering Department, College of Engineering, Sultan Qaboos University, Alkhoudh, Sultanate of Oman; Email: alabri@squ.edu.om*

Membrane filtration has seen an increased demand in recent years especially in water treatment and desalination due to population growth, stringent drinking water and wastewater disposal legislations, and emergence of non-conventional wastewater such as produced water from oil and gas fields. Membranes are used in pre- and post- water treatment as well as in water desalination. In addition, membranes are used in a wide range of industrial, medical and environmental applications. Polymeric membranes are still prevailing in such applications because of their high permeability, low cost, mechanical strength, ease of fabrication, and thermal and chemical stability. In addition, polymeric membranes are diverse in their fabrication processes, membranes' properties and applications making them the best choice for a wide range of natural or wastewater treatment. However, membrane fouling is a major obstacle reducing the efficiency of membrane water treatment. Fouling is the accumulation of matter at the surface of the membrane. It causes rapid increase in differential pressure, reduction in water production, lower water quality and shorter membrane lifetime.

There is an emerging interest towards the modification of membranes using semiconductor metal oxides nanomaterials such as zinc oxide, titanium dioxide, iron (III) oxide (α-Fe_2O_3) and zinc sulfide. These nanomaterials enhance the physical and chemical properties of the membranes to ensure high membrane performance. Specific chemical species in the nanomaterials functionalizes the membranes by interacting with the polymeric membrane chemical groups. Controlled synthesis of functionalized membranes is essential to fabricate membranes with high permeability and salt rejection as well as better resistance to fouling and scaling at reasonable costs.

Direct Solar Desalination Using Nano/Micro-porous Polymeric Membrane via Thin Film Evaporation

Mona Bahman, Arwa AlShareif, Faisal AlMarzooqi, Ibrahim Mustafa
Khalifa University, Abu Dhabi, UAE; Email: mona.bahman@ku.ac.ae

Thin film evaporation from nanoporous membranes is a promising thermal desalination approach because it utilizes the passive capillary pumping of liquid to the evaporating interface and allows for high heat transfer rates due to the large evaporating area in addition to the capillary pumping driving force. In this study, solar energy was used as a heat source to evaporate seawater through in-house fabricated polyvinylidene fluoride (PVDF) nano/micro-porous membranes incorporated with nanoparticles. Compromising between the available area for evaporation via changing pore size and the available material for conductive transfer of heat to the liquid thin film is complicated and require a deep study experimentally and theoretically. The objectives of this study is to investigate the pore size effect and thermal conductivity on the vapor flux by fabricating fumed silica and carbon nanotube membranes. The fabricated membranes were characterized by scanning electron microscopy (SEM), contact angle analyzer (CA), capillary flow porometery (CFP) and porosity to further understand the observed thin film evaporation effects. The preliminary results showed CNT is an effective nanoparticle to obtain higher vapor flux (18.48903 g/min.m^{-2}) in thin film evaporation that incorporated with solar simulator this is due to good ability of CNT to absorb light and converted to thermal energy. It's recommended to investigate more membranes with deep analysis to achieve the paper objective.

Keywords: Thin film evaporation, nanoparticles, Carbon nanotube, Fumed silica, pore size, thermal conductivity.

Assessment of Performance Recently Developed Acriflavine Thin Film Composite Nanofiltration Membrane for Seawater Treatment and RO Brine Concentration

B. Garudachari, M. Ahmed, K. A. Rajesha, J. Thomas
Kuwait Institute for Scientific Research, Water Research Center, Safat, State of Kuwait; Email: bgarudachari@kisr.edu.kw

To enhance the permeation and salt rejection properties of polysulfone membrane, novel TiO_2 nano particle incorporated acriflavine thin film composite (TFC) was fabricated. Fabricated TFC membranes were characterized thoroughly using Fourier Transform Infra Red (FT-IR), Atomic Force Microscope (AFM), Field Emission Scanning Electron Microscope (FESEM) and contact angle (CA). The signature peaks in FT-IR spectral was identified to confirm the interfacial polymerization of acriflavine and TMC. TiO_2 nano particle incorporation in the TFC layer was analysed using elemental mapping analysis and EDX. The addition of TiO_2 nano particle in acriflavine TFC layer resulted change in morphology of membrane and contact angle. The highest pure water flux was reached up to 67.1 $Lm^{-2}h^{-1}$ with 0.1 weight percentage of TiO_2 nano particle dosage (TFC 4). The water flux of 53.0, and 44.5 $Lm^{-2}h^{-1}$ were achieved for TFC 4 membrane using Arabian Gulf Seawater (AGS), and Reverse Osmosis (RO) brine, respectively. Most importantly, TFC 4 membrane showed less fouling with more than 99 % of ionic rejection for magnesium, calcium, and sulfate ions. From the studies it was concluded that, novel TiO_2 nano particle incorporated acriflavine TFC membranes are having high capability of rejecting divalent ions and suitable for seawater treatment and RO brine concentration applications.

Key words: Desalination, TiO_2 nano particle, salt flux, water flux.

Synthesis and evaluation of nanocomposite forward osmosis membranes for Kuwait seawater desalination

Rajesh Kumar, Mansour Ahmed, Garudachari, B., Jibu P. Thomas
Water Research Center, Kuwait Institute for Scientific Research, Safat, State of Kuwait; Email: ralambi@kisr.edu.kw

Multistage flash (MSF) and Reverse osmosis (RO) are the two major desalination technologies currently serving the needs of freshwater in Kuwait. MSF is energy intensive and suffer from low water recovery, while RO desire energy to fulfill its pressure requirement for the process. Thus, globally the scientists are focusing on the innovative desalination technologies which could be operated at low cost and environmentally friendly. In this regard, Forward Osmosis (FO) is one such emerging technology which can be operated under "Non-Pressure" requirement conditions to reduce the energy/cost of the desalination process. The principle of FO involves flow of the pure water across the semi-permeable membrane by maintaining an osmotic pressure gradient between the feed solution (low concentration solution) and draw solution (high concentration solution). Related to this concept, a project was conducted at Kuwait Institute for Scientific Research to fabricate potential and fouling control membranes for the FO desalination. The aim of this paper is to present the important outcomes of the project in fabricating different types of membranes and results related to the high-performance thin film nanocomposite (TFN) membranes obtained in the project compared to commercial FO membranes. The TFN membrane with 0.05 wt.% nanoparticle composition resulted in high flux of versus the commercial CTA membrane. Therefore, this wok concluded that a suitable selection of nanoparticles and their proper modification is essential to fabricate potential membranes for FO application. Further, a nano-based FO membrane showed a potential application in FO desalination compared to commercial FO membranes.

Keywords: Membrane fabrication, flux, reverse salt flux, nanoparticles, chemical modification

Reverse Osmosis Seawater Desalination: Qatar Experience and Vision

Nasser Alnuaimi, Syed Javaid Zaidi
Center for Advanced Materials, Qatar University; Email: anasser@qu.edu.qa

Water desalination and clean water has been identified as one of the grand challenges in Qatar National Vison 2030. As Qatar economy is based on seawater desalination to overcome the water shortages, reduce the carbon footprint, preparation for FIFA 2022 World cup while achieving the goal of vision 2030 Qatar is shifting from the energy-intensive convention thermal desalination process to a much cleaner membrane based reverse osmosis (RO) process for seawater desalination. Two major RO desalination projects are underway in Qatar. The Ras Abu Fontas project built at a cost of QR1.75 billion will have a capacity to provide 36 MIGD (164,000 m3/day) of desalinated water daily to meet the needs of about 1 million people in the country. Umm Al Houl will produce 284,000 m3 /day and will reach 614,000 m3 per day after the start-up of the new facility. This is the first time that reverse osmosis technology has been implemented on a large-scale production plant in Qatar. Previous implementation of RO in Qatar has been limited and on small scale, such as the trial in Dukhan, where 750 m3/day of high salinity water was treated for boiler feed water. This presentation focusses on the RO desalination plants implementation in Qatar and its challenges such as turbidity issues, membrane fouling and pretreatment. Qatari waters are very complex with high salinity in the GCC region and high level of colloids and organic matter. Qatar University is also in the process of establishing a Water Center/Unit to support the water desalination industry in Qatar and provide futuristic benefits.

Keywords: Reverse osmosis, thermal desalination, seawater desalination, water problems, Qatar national vison 2030, new desalination plants

SESSION 7: MUNICIPAL WATER MANAGEMENT

Keynote Speaker

Sustainable Cities in the GCC countries

Mohammed Al-Rashed
Water Research Center, Kuwait Institute for Scientific Research, State of Kuwait; Email: mrashed@kisr.edu.kw

Water Sectors are under pressure from growing demand, cost of new infrastructures, increasing energy prices and aging water systems. Through Intelligent Water Network solutions known as Water-Smart Cities, water utilities will be, remotely, monitored, maintained and managed, and consumption will be evaluated, assessed and optimized. These solutions will, accurately, map Losses due to leaks, waste and evaporation, and take targeted corrective action.

Smart Cities is a new concept for modern cities using cutting edge technologies to monitor and supply information which is used to manage assets and resources efficiently. This includes water and power plants, water supply networks, wastewater management, traffic and transportation systems, information systems, government and private buildings, and other community services.

This paper will highlight the effects of poor management of water resources on the sustainability and prosperity of cities. Without proper water quality and quantity no civilization will be initiated or even maintained. Smart water policy is the first step towards water-smart city; it will promote water efficiency regulations and improve water management practices. New technologies, strategic policies and effective implementation of demand management are the key issues for a successful water-smart city.

Climate change effects resulted in more frequent droughts & floods, unpredictable temperature variations, in addition to growing populations and high consumption would led to insecure water resources. Therefore, the need for rapid, cost-effective actions that can save water on a large scale became a necessity.

Combination of information and communication technologies (ICT) and Internet of things (IoT) is the heart of smart cities to optimize the operation efficiency of the city services and connect officials and citizens to consumption data and other data, allowing for real-time responses.
The Internet of Things (IoT) as a technology holds great potential to solve water scarcity through Smart, Instant and Predictable Management. In every part of the water cycle, IoT can be utilized to manage water resources better and reach efficient and optimal Results. It includes cloud connection for real-time analyses and automated alerting sensors and meters that enable data capture over Large Distances.

Water-Smart City includes all related sectors; residential, industrial and agricultural. The three sectors share the main features of water-smart city including remote alert, quality track, central control and smart metering systems. Water solutions are one of the main solutions of the smart city concept and should have more emphasis from the water specialists as it is the future management tool for water resources.

Keynote Speaker

Water and Wastewater Service Performance Monitoring in Palestine: An Economic Instruments for Service Efficiency Improvement and Sustainability

Mohammad Al-Hmaidi
CEO, Water Sector Regulatory Council, Palestine; Email: Mohd.hmaidi@wsrc.ps

The water sector in Palestine as well as in a number of Arab Countries is highly fragmented with approximately 500 water and wastewater service providers in the West Bank and Gaza Strip of varying types including utilities, municipal departments, joint service councils, NGOs and private service providers.
Given all above, the sector and in addition to the Israeli control over water resources is facing serious challenges including:

- One of the lowest per capita water availabilities in the region
- Territorial fragmentation leading to different approaches and different water service providers
- Operational inefficiencies lead to interruption, high NRW and pollution
- Insufficient customer satisfaction
- Chronic under investment for infrastructure development
- Insufficient ring-fencing of revenues in the water sector
- Insufficient corporate governance

It is clear from the foregoing that the country needs a well-defined regulatory framework that can respond to the challenges facing the sector, in particular if the long-term vision of "access to safe, adequate and sustainable water supply for all by 2025" is to be achieved.
In December 14th. 2009, the Cabinet of Ministers of the Palestinian National Authority endorsed the "Action Plan for Reform" towards the definition and implementation of a comprehensive program of institutional and legislative reform in the Palestinian water sector. The establishment of a Water Sector Regulatory Council was proposed. WSRC is to monitor operational performance related activities of water service providers including production, transportation, distribution, consumption, wastewater collection, treatment and disposal, and reuse of treated wastewater for irrigation.

Basic Functions of the Economic Regulator in Palestine:

- Approval of water prices and construction costs of water and sanitation services.
- Issue operational licenses to S.P's
- Supervise and Inspect compliance with the conditions, requirements and indicators stipulated in the licenses.
- Develop performance incentives systems.
- Monitor operation processes related to the production, transport, and distribution of water and wastewater
- Make sure that costs of production, transport, distribution and wastewater treatment protect the interests of all concerned parties
- Monitor Water Supply Agreements,
- Set and disseminate quality assurance standards for technical and administrative services provided by S.Ps
- Create a database with technical, financial and statistical information.
- Addressing complaints between service providers and consumers.

Characteristics of a Sound Economic Regulatory Framework:
The WSRC has completed reporting the "financial and commercial viability of water and wastewater service providers in Palestine" describing the findings and recommendations for developing the

Action Plan (Road Map) for a fully sustained service. This road map, although prepared for Palestine, still, other SP can make use of it, and drivers for improvements can be implemented elsewhere.
Effective economic regulation benefits the sector through improved performance, increased coverage and enhanced private sector participation

Performance Monitoring aiming at SP Sustainability:
The WSRC performance monitoring, although covers technical, financial, quality and other indicators including gender and governance, it gives high attention to economic related issues and indicators including: Tariff calculation, reviews and adjustments, Collection efficiency, Operational costs (personnel, energy, purchased water cost, O&M, and working efficiency), Service Providers indebtedness, Incentives, and Israeli deductions from the general taxes.

Based on all above, the council has completed the 2014, 2015 ,2016 and 2017 service providers Performance Reports coupled with time based comparative reports for the same period. The 2017 performance report issued in December 2018 has covered 90 water and wastewater service providers in the West Bank and the Gaza strip; 22 key performance indicators were used in addition to 9 sub indicators covering the technical, financial and quality issues. In addition, indicator on staff efficiency and gender are included.

A decline in the percentage of collection of water fees for a large percentage of service providers was noted, this will inevitably have a negative impact on the overall performance and increase the burden of debt whether for the PA, and the decline in the follow up on maintenance of water systems or the capacity to develop and improve performance in general. The noticeable decline was in the increase in water losses which we noted for most of the service providers. Cost of energy and staff per cubic meter of water is still on a rise for several service providers. This is one of the direct reasons behind the increase of the total cost per cubic meter of water, and necessitates an immediate audit of the electricity systems and a quick review of the employment policy of SPs.

Summary of the above can be as follows:
Low fees collection rates, limited cost coverages, non-approved tariff structures, unsuitable billing and accounting systems, limited assets and depreciation data, limited water quality in a number of localities including Gaza. The Above findings are key instrument for prioritization of interventions, planning and policy update. The presentation will show data regarding the above and a list of recommendations and follow up measures to be considered by related stakeholders.

Drivers for SP sustainability and Economic Viability:
The council has recommended the following drivers for service providers:

1. Regrouping service providers in larger and autonomous units, like utilities and JSC;
2. Defining SP individual targets based on National targets and benchmarks,
3. Strengthening public awareness and stimulating client orientations;
4. Increase the prepaid meters coverage;
5. Strengthening management and operational capacities;
6. Strengthening billing and collection procedures and system, including updating customer database;
7. Carry out value chain analysis of the operators to see where cost reduction and performance improvement could be achieved;
8. Review the options for outsourcing activities and possibly PPP;
9. Target asset management and valuation, which would form the basis for defining the depreciation of assets;
10. Reduce the percentage of non-revenue water, through institutional, operation and maintenance planning.

Keynote Speaker

Drinking Water Demand Forecasting Using Artificial Neural Network in Tunisia

Issam Nouiri
Hydraulics, Irrigation, Water Resources Management and DSS, Tunisian Agronomic Institute, Tunisia; Email: inouiri@yahoo.fr

Managers of Drinking Water Systems hardly work to supply consumers with appropriate quality, quantity and pressure with the least treatment and management costs. This task can be strongly enhanced if the Water Treatment Plant (WTP) production is accurately known in advance as long as possible (exp. One week).

The stochastic nature of Drinking Water Demand (DWD) at daily and hourly time step is an evidence and was largely studied by managers and researchers for characterization. Cities DWD patterns depend on socio-economic rhythms, sizes (population), supply network proprieties and climate. DWD long-term (Annual) trend can be identified using statistical analyses seen the dominance of the population annual growth. Short-term (daily and hourly) patterns of DWD are more influenced by climatic conditions and socio-economic rhythms, difficult to fit with statistical approaches.

This research is designed to develop robust models to forecast short-term DWD using Artificial Neural Network (ANN). A daily database of drinking water supply and the lowest and heighted temperatures was elaborated (January 2008 to December 2017). This database was subject of pre-processing and statistical analysis to identify the explanatory variables of the drinking water demand used as inputs to train and validate the designed ANN using MATLAB script.

The proposed methodology is applied for two supply networks in Tunis city feed by two tanks: “Belvedere” and “Manouba”, each of them have a capacity of 10 000 m^3. Their respective maximal daily supplies are estimated to 50 000 and 25 000 m^3.

Forecasts DWD showed acceptable results proving that ANNs are successful in predicting daily DWD supplied by the studied tanks. Only the maximum temperatures and the supply of the previous day are used as input to accurately forecast DWD for seven following days. It was demonstrated that 92% and 84% of the observations have errors less than 15%, for respectively “Belvedere” and “Manouba” tanks.

The main conclusion of the present research is the robustness of ANN to forecast daily DWD for one following week using one endogen (historical demand) and one exogenous (temperature) variables. Long time series and good quality of the input data are necessary to succeed the training and the validation of the ANN.

Strategic Water Reserve using Aquifer Recharge with Desalinated Water in Abu Dhabi Emirate

Mohamed A. Dawoud
Advisor, Water Resources Department, Environment Agency - Abu Dhabi, UAE; Email: mdawoud@ead.ae

United Arab Emirates (UAE) as well as other countries in arid region is mainly relay on desalinated water for domestic water supply. The challenges facing UAE, however, is the vulnerability of desalination plants to pollution and emergency conditions. There should be available alternatives for reserving freshwater sources for emergency and peak demand conditions. Aquifer Storage and Recovery (ASR) technique has been proposed as a cost-effective large water storage alternative that can help to meet the needs of domestic sector in crisis/emergency situations. ASR technique is used to store excess desalination water during non-peak hours for recovery during emergency or peak hours. In an attempt to capture, store and redistribute desalinated water and to regulate the quality, quantity, timing and distribution of water flows, Abu Dhabi Emirate started in 2002 to study and evaluate the construction of ASR pilot project in western region. The initial target injection of pilot ASR facilities is store 2.5 MIGD using five injection wells and one infiltration basin. Desalinated water is infiltrated into a desert dune sand aquifer using “sand-covered gravel-bed” recharge basins. In this study, we evaluate the hydrogeological and hydrogeochemical stratification of the (sub)oxic target aquifer, and water quality changes of DSW during trial infiltration runs. A three dimensional model was developed to assess the impact of hydrologic and operational parameters and factors on the recovery efficiency of the pilot ASR experiment. The model was integrated with geodatabase tool to produce an easily updateable model. Results from this study demonstrate the interaction between hydrologic and operational parameters on the predictions of recovery efficiency. The pilot observations and modeling results demonstrate that in scenario A recovered water quality still complies with Abu Dhabi’s drinking water standards (even up to 85% recovery).

Keywords: Three-dimensional modeling, Geodatabase, Visualization, Artificial recharge, Water supply, Abu Dhabi.

Reduction of the Technical Losses Component of the NRW in water Networks in Sultanate of Oman

Yousuf Al-Siyabi
Operation Performance Expert, Public Authority for Water (DIAM), Sultanate of Oman; Email: yousuf.alsiyabi@diam.om

This paper discusses challenges & solutions to reduce Non-Revenue Water (NRW) and unaccounted for Water (UFW) in water networks in sultanate of Oman by reducing the technical losses. Water supply system is one of the essential subjects for the governments and people in the main cities or rural villages, the water utilities must ensure continuous supply of clean and safe water in distribution with sufficient flow and adequate pressure with minimum failures. The world witnesses many instances of people lacking access to this essential commodity. (Water Partners Jp Co., 2017) This paper highlights the main issues, problems and solutions in water networks which are related to the water technical losses in NRW. Public Authority for Water (PAW/DIAM) is responsible for provide the potable water in all people in Oman as per the international standards. Reducing the water losses in the networks is one of the main challenges in Public Authority for Water. This paper is discussing the successful used methods and technologies in PAW to reduce the technical losses by 33,000,000 cubic meter in 2017 (DIAM, 2017). There are achievements in reducing the losses by controlling and managing the pressure in water networks. There are improvements in updating the specifications and standards of pipes rapiers and installations. Also the leak detection teams in PAW have used advanced technologies to find the invisible leaks in the water networks. The rehabilitation of old pipes is a major factor to reduce NRW. Finally, as a result of the done works in 2017 there are recommendations to ensure the reducing of water losses to reach to the acceptable level of Non-Revenue Water in future.

Keywords: pressure management, leaks detection, pipes rehabilitations, district metering area.

استهلاك الطاقة في قطاع المياه البلدية بمملكة البحرين

مها محمود الصباغ[1]، وليد خليل زباري[1]، **مريم جمعه هلال[2]**، رحاب عبدالمهدي محسن[3]
[1] قسم الموارد الطبيعية والبيئة، جامعة الخليج العربي، مملكة البحرين؛ البريد الالكتروني mahamw@agu.edu.bh
[2] هيئة الكهرباء والماء، مملكة البحرين
[3] وزارة الأشغال وشئون البلديات والتخطيط العمراني، مملكة البحرين

تعتبر قضية ترابط المياه والطاقة إحدى القضايا الهامة في دول مجلس التعاون لدول الخليج العربية لا سيما في ظل شح الموارد المائية ووفرة مصادر الطاقة الأحفورية والاعتماد عليها بشكل كبير في قطاع المياه. وهذا ما دفع دول المجلس إلى تبني مفهوم الترابط بين المياه والطاقة، الأمر الذي انعكس على أهداف الاستراتيجية الموحدة للمياه لدول المجلس. إذ ينص الهدف الاستراتيجي الأول على "تحسين كفاءة استهلاك الطاقة في قطاع المياه" وذلك عن طريق "تقييم وتدقيق استهلاك الطاقة في قطاع المياه في جميع دول المجلس وإعداد دراسة مرجعية حول استهلاك قطاع المياه من الطاقة". ويعتبر ذلك الخطوة الأولى نحو "إعداد البرامج والأهداف لتحسين كفاءة استهلاك الطاقة في قطاع المياه" بحسب الهدف الفرعي السادس المنبثق عن الهدف الاستراتيجي الأول. وفي هذا الإطار، تم حساب كمية الطاقة المستهلكة في قطاع المياه البلدية في مملكة البحرين ضمن مشروع إعداد استراتيجية المياه لمملكة البحرين. وتشير نتائج الدراسة إلى أن نحو 8% من إجمالي الطاقة الكهربائية في مملكة البحرين في عام 2017 قد تم استهلاكها في إنتاج مياه التحلية ومعالجة مياه الصرف الصحي. ولعل النصيب الأكبر من الطاقة قد تم استهلاكه في محطات تحلية المياه وذلك بنسبة 87% من إجمالي الطاقة الكهربائية المستهلكة في قطاع المياه البلدية. حيث بينت الدراسة احتمالية وجود فرص علاية نسبياً لتحسين كفاءة استهلاك الطاقة في قطاع المياه البلدية، ذلك أن كمية الطاقة الكهربائية المستهلكة في إنتاج مياه التحلية ومعالجة مياه الصرف الصحي تفوق مثيلتها في دول العالم وذلك بحسب نوع تقنية التحلية والمعالجة المستخدمة. وتوصي الدراسة بضرورة أخذ معيار الطاقة المطلوبة للتحلية أو معالجة مياه الصرف الصحي بعين الاعتبار عند تقييم خيارات التقنية المتاحة لإنشاء محطات جديدة. كما وتوصي الدراسة أيضاً بقياس وتجميع البيانات المتعلقة باستهلاك الطاقة بشكل دوري في قاعدة بيانات وطنية موحدة، وذلك لتسهيل عملية حساب مؤشرات الأداء المتعلقة بكفاءة استهلاك الطاقة، ومراقبة الأداء، وتقييم التقدم المحرز نحو تحقيق أهداف تحسين كفاءة الطاقة الموضوعة. وثمة توصية أخيرة تتعلق بضرورة توعية أصحاب المصلحة بأهمية قضية الترابط بين المياه والطاقة، ذلك أن خفض كمية الطلب على المياه تعني خفض كمية الطلب على الطاقة، الأمر الذي ينعكس بصورة إيجابية على البيئة، الاقتصاد، واستدامة التنمية الاجتماعية والاقتصادية في مملكة البحرين.

الكلمات الدالة: ترابط المياه والطاقة، كفاءة استهلاك الطاقة، معالجة مياه الصرف الصحي، المياه المحلاة.

Energy Optimization in Water Supply System in the Sultanate of Oman

Abdullah Al Arafati
Muscat Operation Senior Manager, Public Authority for Water (DIAM), Sultanate of Oman; Email: abdullah.alarafati@diam.om

In water supply systems, the power cost is one of the most important components in which large amounts of energy are required for production, pumping, transportation, and distribute the water in the networks. The water supply systems are the most important public utility for safe supply of potable water. Energy consumption in water supply system represents a major concern in The Sultanate of Oman. This paper discusses several studies and actions have been done in water operational assets to reduce and optimize the power consumption. The public authority for Water in Oman (Diam) have implemented many successful energy optimization methodologies and tools in desalination plants, pumping stations, wells & water distribution networks such as energy recovery devices, variable frequency drivers, pumps overhauling, rescheduling of pumping times, bypassing the pumping stations, maintenance of wells.

Keywords: water network, pumping stations, energy recovery device, variable frequency drivers, maintenance.

Evaluation of municipal water supply system options using Water Evaluation and Planning System (WEAP): Jeddah Case Study

Ahmed Al-Juaidi, Ahmed Al-Shotairy
Civil Engineering Department, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia; Email: aaljuaidi@kau.edu.sa

Jeddah City is expected to experience water supply stress due to rapid population growth and expansion of urban developments. This paper aims to assess the impact of possible water demand on Jeddah water resources in 2030. To facilitate the analyses, a scenario based modeling is used in conjunction with WEAP to find the best combination of scenarios that meet future water demands. For each scenario, the water resource implications were compared to a 2017 baseline. The model enabled analyses of unmet water demands, water demand, water delivered, and supply requirement for each scenario. The study identifies the year of unmet demand and calculates the reliability, resiliency, and vulnerability of the supply system. Results show that the gap between demand and supply will grow dramatically if current supply condition continues. An additional quantity of more than 504 MCM is needed in 2030 to satisfy water needs and development. The unmet water demand varies through years significantly according to the proposed scenario. The implementation of the leakage reduction measures proposed by the National Water Company (NWC), in conjunction with the application of reuse of treated wastewater and water conservation practices, can decrease the unmet demands and deficits to levels lower than, or similar to, those occurred in the 2017 baseline. However, in all cases, these involvements will be insufficient to completely meet the demands of all demand zones. A careful control of the population growth rate in future demands is necessary, although this may be difficult in a rapidly developing region like Jeddah of Saudi Arabia.

Keywords: Demand Management, Integrated water resources management (IWRM), desalinated water, TWW, water allocation, WEAP model, Jeddah.

Developing Deterioration Prediction Model for the Potable Water Pipes Renewal Plan – Case of Jubail Industrial City, KSA

Ali Madan Al-Ali, Jean Laurent, Jean Philippe Dulot
Marafiq-Saur Operation & Maintenance Company, Saudi Arabia; Email: aliam@marafiq.com.sa

The aim of this study is to identify the appropriate parameters for predicting the potable water pipes deterioration. The study evaluated the strength of some variables related to pipe breaks probability of failure based mainly on logistic regression model. The independent variables included in the study are static variables such as pipe diameter, pipe length and pipe material in addition to some dynamic (time-based) variables such as pipe age, water pressure and water velocity. The pipe break history (number of pipe breaks) for each pipe segment is used as dependent variable to be predicted in the statistical model. The resulted prediction equation is then used to calculate the failure probability for each pipe in the potable water network. Finally, prioritization of pipes is performed and the annual renewal plan is developed for the city of Jubail Industrial City in KSA based on the model results.

Keywords: GIS, Geographical Information Systems, Pipes, Renewal, Logistic, Regression.

Keynote Speaker

The potential of wastewater reuse in the Arab region as a management option for water security under climate change condition

Redouane Choukr-Alla
Environmental-Horticulture, Institut Agronomique et Vétérinaire Hassan II, Morocco; Email: redouane53@yahoo.fr

Water resources scarcity, accessibility, and environmental degradation are the major challenges facing most of the Arab region. This region has already run out of renewable freshwater decades ago and is unable to meet their food requirements using the available water resources. Water reuse features prominently amongst other innovative integrated water management approaches and reuse of treated domestic wastewater is becoming a common source for additional water in several Arab regions and many of these countries have included wastewater re-use in their water planning. This will narrow the gap between freshwater supply and demand in different water-use sector. The major challenge in using marginal-quality waters in agriculture is to maximize the benefits for the farmers and society while minimizing adverse environmental and health impacts. Therefore, pre-use treatment, and/or appropriate soil-water-crop management strategies are needed for using treated wastewater for irrigation in agriculture through efficient, environmentally acceptable, cost-effective and sustainable strategies, and enabling policies and institutional support. This paper will address the integrated approach for reclamation and reuse of treated wastewater? How wastewater has been managed successfully for safe reuse in some Arab countries? What are the institutional and the organizational involved in the safe reuse of wastewater? How some Arab policymakers adapted the wastewater management agenda to their country's economic context?

Findings demonstrate that water reuse can help in addressing water problems and challenges, particularly when decision-making is from a systems perspective. When ecosystem services are taken into account and are valued properly, water reuse is a sustainable practise that can also be financially profitable.

Keynote Speaker

Benchmarking System for the Wastewater Sector in Bahrain

Salah Al Mutawa[1], Sideeqa Al Jazeeri[1], Mohamed Kamil[1], Alaa El-Sadek[2] and Waleed Al-Zubari[2]
[1] *Sanitary Engineering Operation and Maintenance Directorate, Kingdom of Bahrain*
[2] *Water Resources Management Program, Arabian Gulf University, Kingdom of Bahrain*

International benchmarking procedures are useful and effective tools to assess the performance of wastewater services. Wastewater treatment plants are large resource consumers and are perceived as a promising effort to detain the global resources crisis through sustainable action. The economics of wastewater management and treatment is the subject of growing interest to protect the environment from the adverse effects. According to international water bodies, the challenges facing the governments are rapid population growth, worsening of the climate, severity of freshwater scarcity, rising costs, aging infrastructure, increasingly stringent regulatory requirements, and a rapidly changing workforce, varying influent due to storm water, etc. are global challenges. In this study, wastewater collection, treatment and discharge related to Tubli Sewage Treatment Plant (STP) at Tubli water pollution control center (TWPCC) were analyzed with the aim of developing key performance indicators, which are used for benchmarking purposes. This analysis helps improving the understanding of how individual scores of efficiency and operating variables are related. The study describes the development of a benchmark for the evaluation of control strategies in wastewater treatment plants. This study is intended to be useful to decision-makers in the wastewater treatment sector. The benchmarking methodology and empirical application developed by Performance Indicators for wastewater services published by IWA is used for improving the management of Wastewater Treatment Plant (WWTPs) and contribute to save operational costs. The study assessed the benchmarking of the wastewater services in the Kingdom of Bahrain. Performance assessment and benchmarking have developed as key aspects of WWTP management. Benchmarking is a data-driven process, and can only be successful if careful consideration is given to data availability and accuracy. Four teams have contributed to the development of the benchmark and have obtained results. The only data readily available and accurate are supplied for regulatory purposes. There are 184 performance Indicators detailed by IWA. In the study 25 performance indicators were analyzed for the year 2017 where the data are readily available. The results indicated that, without sufficient data, assessing the accuracy of the data and identifying comparable WWTPs, the performance indicators analysis becomes increasingly complex. Improved data management practices can be achieved through WWTP benchmarking. Enabling the successful benchmarking in the present-day can (i) accelerate the improvement of data collection practices, (ii) improve WWTP management practices and (iii) lead the way to the inclusion of more advanced benchmarking applications in the years to come, when data availability and accuracy issues are corrected. Optimizing the investments and developing regional experiences are key factors to promote the scientific research.

Keywords: benchmarking; treatment plant; efficiency and effectiveness; stakeholders; ACWUA; IWA

Virus Removal from Treated Wastewater in Modified Garden Soil Columns, Kuwait

Adel Al-Haddad, T. Rashid, B. Al-Salman, H. Naseeb
Kuwait Institute for Scientific Research, State of Kuwait; Email: ahadad@kisr.edu.kw

A research study was conducted to determine the addition of garden soil to natural soil for removal of coliphage viruses from treated wastewater. Treated wastewater containing viruses was passed through soil columns filled with soil collected from Sulaibiya area, Kuwait. The four soil column experiments were under operation for eight months. The first and second soil columns filled with natural soil, while the third and fourth soil columns filled with modified soil consist of Sulaibiya soil mixed with 1% garden soil. All soil columns had soil depth of 0.1 m and with constant hydraulic head of 0.1 m above soil surface. For each experimental condition, two identical columns were set up, so that the reproducibility of the results can be evaluated, producing four columns. For all columns, the tests were conducted under alternating 1 day flooding and 1 day drying conditions. Influent and effluent water samples were collected and analysed following cycles of flooding periods. The coliphage virus counts in the treated wastewater ranged between 0 and 62800 pfu/100 ml. The laboratory results revealed that coliphage removal for Sulaibiya soil ranged between 58 and 100% with average value of 88.4%, while their removal efficiency for modified columns was between 60% and 100% with average value of 92.3%. The presence of garden soil mixed with the soil relatively increased the coliphage removal from treated wastewater.

Keywords: Coliphage viruses, Treated wastewater, Soil Column experiments, Effluent.

A Practical Step towards Sustainability: Decentralised Wastewater Management in Oman

Mohamed Nasser Al-Rawahi[1, 2], Mi-Yong Lee[2], Jan Friesen[3], Ganbaatar Khurelbaatar[2], Roland *Mueller*[2]

[1] *The Institute of Advanced Technology Integration (IATI), The Research Council of Oman (TRC), Muscat, Sultanate of Oman; Email: mohammed.alrawahi@trc.gov.om*

[2] *Centre for Environmental Biotechnology (UBZ), Helmholtz Centre for Environmental Research UFZ, Leipzig, Germany*

[3] *Department Catchment Hydrology, Helmholtz Centre for Environmental Research UFZ, Leipzig, Germany*

Oman has undergone major transformations during the past few decades, which have resulted in growing water scarcity and an increase in the domestic wastewater production. To align with the UN Sustainable Development Goal (SDG) number 6: "Ensure availability and sustainable management of water and sanitation for all", the government spending on wastewater services dramatically increased over the past two decades aiming to extend sanitation services all over Oman. However, the expansion of the wastewater infrastructure will have to address the conditions of rural and suburban settlements in order to reduce network and pumping requirements and the risk of technical failure to the minimum and to ensure cost efficiency. To achieve this goal, a pilot project has been set up to develop an integrated system solution for decentralised wastewater management (DWWM) in Oman. The main objective of the project is to establish a research, demonstration and training facility aiming at developing, promoting and facilitating the implementation of sustainable and effective sewage and reuse management solutions for suburban and rural communities in Oman. The procedure applied for designing the facility was comprised of two parts; the comparative analysis, which gathers forms and ranks information into a knowledge basis, on which the designer can make a decision & the engineering design process. With the GIS-based assessment tool ALLOWS (Assessment of Local Lowest-Cost Wastewater Solutions) the project compares different scenarios for regional wastewater management options. ALLOWS features two main components: (1) Spatial analysis, and (2) cost assessment using net present value (NPV) calculation for different scenarios for a lifetime of 80 years. In a case study, different sanitation scenarios were developed for Al Mizarih village, near Qurayyat, Oman. This preliminary assessment indicates that under current conditions a solution on household level is the most cost-effective option. However, semi- and decentralised scenarios gain in cost-effectiveness, when future population growth and settlement patterns are anticipated in the analysis.

Keywords: GIS-based Assessment, ALLOWS, rural, sewage, suburban, wastewater management.

Seasonal Variations of the Growth of Filamentous Bacteria in Kuwait's Wastewater Treatment Plants

Abdallah Abusam[1], F. Al-Salmain[2] and A. Mydlarczyk[1]
[1] *Wastewater Treatment and Reclamation Technology (WTRT) Program, Water Research Center, Kuwait Institute for Scientific Research, State of Kuwait*
[2] *Department of Biotechnology, the Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, State of Kuwait*

If not controlled, excessive sludge bulking can lead to a complete failure of the entire wastewater treatment process. Selection of an appropriate control measure requires information about the filaments type, level of dominance and the most probable causes. The main aim of this paper is to present the filamentous bacteria identified in Kuwait's wastewater treatment plants and to compare their seasonal levels of dominance. Wastewater samples were collected weekly from Riqqa and Um-Al-Haiman activated sludge systems in Kuwait for eight months. Vermicon Identification Technology (VIT), a molecular method, was used for the identification and quantification of the following six filamentous bacteria: Type 1851, H. hydrossis, Nocardiaform, Type 021N/Thiothrix, N. Limicola and M. parvicella. The obtained results indicated that the rapid growth of the filaments was triggered by the sharp drop in water temperature during winter (January). Further, most of the filaments dominate the systems almost all through the year. Furthermore, Microthrix was found to have the highest rate of fluctuations.

Keywords: Wastewater, Activated sludge systems, Filamentous bacteria, Sludge bulking, Control measures.

Removal of Odorous Compounds from Hospital Wastewater

Andrzej Mydlarczyk, A. Al-Haddad, H. Abdullah
Kuwait Institute for Scientific Research, Wastewater Treatment & Reclamation Technologies Program, State of Kuwait

A study was carried out to assess the removal efficiency of odorous compounds from the wastewater of hospitals in Kuwait using aeration with activated sludge technique. Samples were collected from the outlet of wastewater from Maternity Hospital. The collected samples were transferred to the laboratory of Sulaibiya Research Plant (SRP) of KISR. Each sample was divided into three parts: the first part of the sample was analyzed to obtain characteristic of hospital wastewater, while the second and third samples were mixed with activated sludge from Kabd Wastewater Treatment Plant and underwent aerobic treatment for 12 and 24 hours periods in two bioreactors using a different intensity of aeration. In the first bioreactor, the dissolved oxygen was kept on the level of 2 mg/l, while in the second 4 mg/l. Wastewater and effluents samples were analyzed for the examination of the following parameters: temperature, pH, electrical conductivity (EC), COD, ammonium, nitrite, nitrate, organic nitrogen, total nitrogen (TN) and sulfides. Based on obtained results of analyses, the removal efficiency of wastewater parameters were calculated mainly for COD, NH4-N, sulfides and total nitrogen (TN). The laboratory results indicated that after a hydraulic retention time of 24 h, the mean values of sulfide removal efficiency increased from 82.54 to 93.85%, when DO increased from 2 to 4 mg/l, respectively. Under the same previous operating conditions, the mean value of ammonium removal efficiency was increased from 85.96 to 97.44%. To obtain the best effluents the biological process should be extended aeration type with HRT 24 h at DO 4 mg/l. The obtained results will be recommended as the base for treating wastewater from hospitals in package units before discharging to sewage network.

Keywords
Dissolved oxygen, aeration, ammonium, sulfides and wastewater.

SPECIAL SESSION S3: IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN THE ARAB REGION

Keynote Speakers

Regional Initiative for the Assessment of Climate Change Impacts on Water Resource and Socio-Economic Vulnerability in the Arab Region (RICCAR): Overview and Assessment Highlights and Introduction to Arab Center for Climate Change Policies
Carol Chouchani Cherfane, UNESCWA

RICCAR: Integrated Vulnerability Assessment, Extreme Climate Events and Case Study Findings with a focus on the Mashreq and Arabian Gulf
Marlene Ann Tomaszkiewicz, UNESCWA

Water Security and Climate Change
Ahmed Khater, Egypt

Modeling the Impacts of Climate Change on Water Resources in Mediterranean and Atlantic Hydraulic Basins in Morocco
Abdulkader Larabi, Morocco

Climate change impacts on the agricultural sector in the Arab region
Rashyd Zaaboul, ICBA

The Impact of Climate Change on Raw and Untreated Wastewater Use for Agriculture, Especially in Arid Regions
Dima Faour-Klingbeil, Germany

Water Security and Climate Change

Ahmed R. Khater
Professor, Water Resources Management, National Water Research Center, Egypt; Email: drkhater@nwrc-egypt.org

The term water security appears to have emerged at the 2nd World Water Forum in 2000. Shortly thereafter, water security achieved further prominence when it was identified, conceptualized and operationalized by the international water community. At present, water security is generally perceived as one of the main objectives of water resources management. As water security is a rather new concept, definitions of the term are evolving. Reviewing key definitions of the term, as introduced by international agencies, academic researchers and practitioners, suggests that water security refers to the "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water related risks to people, environments and economies". Water security can be thought of as the adaptive capacity expressing the status of water management, both to enhance its productive potential and to mitigate its destructive potential.

Water security is not only about having enough water. Water security goes beyond water scarcity to take into account not only availability of water resource but also the productive and protective actions to secure water. Water security has three key dimensions: social equity, environmental sustainability, and economic efficiency. Water security comprises complex and interconnected challenges and highlights water's importance for achieving a wider sense of security, sustainability, development and human well-being. Water security is therefore also about mitigating water-related risks, such as floods and droughts, addressing conflicts that arise from disputes over shared water resources, and resolving tensions among the various stakeholders who compete for a limited resource. Water security is addressed through two main approaches. One is a developmental approach that seeks to improve water security over time through a combination of policies, reforms, and investment projects. The second is a risk-based approach, which seeks to manage risks and reduce vulnerability to water-related disasters. However, the two approaches are complementary, and need to be pursued simultaneously and in a balanced manner. Addressing water security, therefore, requires interdisciplinary collaboration across sectors, communities and political borders.

A water-secure world harnesses the productive power of water and minimizes its destructive force. It is a world where every person has enough safe, affordable, clean water to lead a healthy and productive life. It is a world where communities are protected from water-related disasters. Water security promotes environmental protection as well as social justice, and addresses the consequences of poor water management. There is now growing international consensus for increasing water security in a sustainable manner and for building more resilient and robust water systems. However, challenges to increase water security are rooted in political, economic, social and environmental issues specific to each country.

Improving water security requires understanding and managing for a changing and unpredictable climate. Climate change will bring about severe economic, social and environmental effects, which require both mitigation and adaptation. The Intergovernmental Panel on Climate Change (IPCC) alerted the global community to the great vulnerability of freshwater resources as a result of climate change. The major impact of climate change will be on the water cycle, and water is the main way through which the impacts of climate change will be manifested around the world. Climate change inevitably will ultimately result in changes in the timing of delivery, availability, distribution and quality of water resources. These shifts severely impact lives and livelihoods. Decreased water supplies mean more human suffering and increased risk of instability, violent conflict and migration. In addition, climate change will result in increased uncertainties, stress and potential for conflicts in water management. These changes are expected to produce threats to

water security. Such threats are likely to be amplified by the related uncertainties. Hence, climate change is likely to increase the complexity and costs of ensuring water security.

The combination of hydrological variability and extremes, pertinent to climate change, is at the heart of the challenge of achieving basic water security. The water security challenge will therefore be aggravated by climate change and it will require significant adaptation. Achieving and sustaining water security against climate change is the immediate challenge of adaptation. Hence, the anticipated negative impacts of climate change on the functions and uses of water and on the associated risks to water security call for an adaptive management process. Resilience and adaptive capacity will become key attributes in the process and the relevance of security will simultaneously become greater.

The keynote speech discusses the concept of water security in the context of climate change with specific emphasis on Arab Region. Threats that climate change poses to water security will be examined. Giving more effort to measure water security and understand the climate change nexus is recommended. Since the context that informs water security is constantly changing, the need to adapt is clear. In the light of these, adaptation challenges to account for the risks posed by climate change to water security will be explored, along with the need for adaptive management as a possible solution.

Modeling the Impacts of Climate Change on Water Resources in Mediterranean and Atlantic hydraulic basins of Morocco

Abdelkader LARABI, Hanane El ASRI, Mohamed Jalal ELHAMIDI and Saloua ZHIM
Regional Water Centre of Maghreb, Ecole Mohammadia d'Ingénieurs, Mohammed V University of Rabat, Morocco; E-mail: larabi@emi.ac.ma

Extended Abstract
This research work investigates the climate change variability and its impact on water resources in hydraulic basins located in both Mediterranean and Atlantic fronts of Morocco, using climate and hydrological modeling. Several climate parameters and their projections in the future have been analyzed to assess climate changes, including wet and dry periods with focus on intensity and frequency. Furthermore, Modeling of the impact of this climate change on water resources based on climate scenarios is also studied to evaluate water balance components in the basin/aquifer, in addition to drawdown lowering, water table depletion and seawater intrusion extents into the coastal aquifer.

The Ghis-Nekkor plain, located in the north of Morocco is a vulnerable area for climate changes, due to its influence by the Mediterranean front to the north and its strong urbanization. In fact, a reduction in precipitation and increase of temperature due to climate change will affect the severity of drought in the plain. In this study, the influence of the decrease of precipitation (about 18%) and increase in average temperature (0.5 °C) on future drought conditions is assessed by the SPI index. This SPI is basically calculated for the period (1963-2013) at two-time scales (6 and 12 months), then it is used to assess future drought events in the study area under the Representative Concentrations Pathways (RCP 4.5) climate change scenario. The projected change in precipitation for the period (2020 - 2070) was simulated by the Regional Climate Model (RCM) Hirham5 from the Cordex Project. The results indicated that the Ghis-Nekkor plain experienced a dry period from 1980 to 1987. For the period 2040-2070, the drought severity and duration will increase under the RCP 4.5 scenario with 19% of severe dry. The rate predicted for the drought condition is about 12%, which represents the double compared to the reference period (1965 - 2013). The analysis of drought intensity showed that the study area is more prone to both moderate and severe droughts but less prone to extreme drought.

The Oum Er-Rbia hydraulic basin, located in the mid-west part of morocco (Atlas and Atlantic front), is one of the largest watersheds in the country (4800km²). Its strategic importance with economic activities and the rapid demographic change make it vulnerable to any fluid imbalance, especially climate change. Hence, the assessment of drought is crucial for many aspects notably water sectors. Thus, the objective of the present study is the estimation of the regional characteristics of drought, frequency and duration using the SPI index.

The results show that during these last forty years, the Oum Er-Rbia basin experienced dry periods from 1980 to 1987, from 1991 to 1995, from 1997 to 2002 and from 2006 to 2008, and their intensity varies from moderate to severe. They are remarkably composed of three, four and five consecutive dry years. Finally, based on the obtained results from the SPI mapping that the moderate and severe droughts occurred in the North East of the study area, characterized by topographic and geological conditions that are not in favor conditions as for water storage for long time. The results show also a relatively high frequency and large spatial extent of drought in the basin. During these periods, surface water and groundwater resources suffered from significant deficits, such as reduced water storage in dam reservoirs and groundwater table depletion in several aquifers.

Generally, the Oum Er-Rbia basin was affected by 53% of dry periods. The most dominant type of droughts is moderate (38%), while 15% is of severe droughts, and took place especially in North East of the study area. We can conclude that, based on the SPI values and their mapping, the Oum E-rRbia basin is highly vulnerable to drought for which the duration and intensity vary

considerably. Drought is therefore a recurrent phenomenon but difficult to predict over time for its mitigation. When it occurs, it has negative impact on water resources with less water storage causing water scarcity in several areas of the catchment. However, the results obtained from this study is of great importance for water resources management in the Oum Er-Rbia basin, as it will assist the regional water managers for water resources planning, protection and rational management. Further research work in the catchment is going on to assess the impact of climate change on water resources using climate modeling projections.

The Rmel-O. Ogbane is unconfined coastal aquifer situated near Larache city in the north of Morocco and is a part of the main sub-Atlantic coastal aquifers. The aquifer supplies good quality groundwater that is easily accessible. This favorable situation has increased pumping, and caused environmental problems, such as water table decline and saltwater intrusion. Moreover, the future precipitation decline is due to the impacts of CC and causes longer and more frequent droughts and less groundwater recharge, which directly affect the groundwater level. An integrated approach is developed for linking climate models and groundwater models to investigate future impacts of climate change on groundwater resources. Projected Temperature and precipitation values are obtained respectively from (RACMO22T and HIRHAM5) Regional Climate Models (RCMs) under Representative Concentration Pathways (RCP) 4.5 scenario. Those projections show an increase in temperature of about 0.45 °C and a reduction in precipitation of 16.7% for the period 2016-2040. Based on these results, the input parameters for the groundwater model are calculated, such as evapotranspiration and aquifer recharge, in addition to Sea Level Rise (SLR) variation, which rises up from ~6.45 cm by 2017 to ~21.3 cm by 2040. The simulation results show that groundwater extraction is the predominant driver of seawater intrusion in the study area. The aquifer area will be contaminated in the NW sector of the coastal part, where the toe interface will reach 5.8 km inland and will be intruded with high salinity concentrations ranging from 15 to 25 g/l by 2040. Beyond these zones, the contamination of the aquifer is limited, but the drawdowns remain significant in some sectors of the study area. Hence, implementation of efficient strategies by decision makers for groundwater development and management in this coastal aquifer are necessary to protect freshwater aquifers against seawater intrusion and groundwater overexploitation.

Climate change impacts on the agricultural sector in the Arab region

Rashyd Zaaboul
Modeler, Climate Change, International Center for Biosaline Agriculture (ICBA), Dubai, UAE; Email: r.zaaboul@biosaline.org.ae

The Arab region is one of the most water scarce regions in the world with more than 80% of its surface covered by deserts. Climate change projections for the Arab region are predicting a significant rainfall decrease and an increase of temperatures, which will lead to profound, non-linear effects on productivity. In this region as well as in different parts of the world, agriculture is one of the most vulnerable of all human activities to weather and climate variability. Any change in temperature, precipitation, soil moisture, carbon dioxide levels, and disease and pests (themselves largely climate-dependent) will have negative impacts on agricultural production in the region.

The IPCC Special report on Global Warming of 1.5 °C stated, "*Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (high confidence)*" and that some regions have already crossed the worming threshold of 1.5°C. The Arab region is one of the areas where temperature has already increased by more than 1.5°C above pre-industrial levels. It emerges also as one of the hotspots for worsening extreme heat, drought and aridity conditions under climate change.
The agricultural sector in the Arab region, of which 70% is rain-fed, is highly exposed to changing climatic conditions. Impacts will be high in a 2°C world, as the annual water discharge for example, already critically low, is projected to drop by another 15-45% (75% in a 4°C world) and unusual heat extremes projected to affect about one-third of the land area with likely consequences for local food production. The climate conditions projected in the future under different scenarios are unfavorable to grow staple crops to ensure food for a projected increased population that may double by 2070 in the Arab region.

Key messages:

- Human activities have already caused approximately 1.0°C of global warming above pre-industrial levels.
- Temperature in the Arab region has already increased by more than 1.5°C and, as consequence of this regional warming, many sectors including agriculture have already been impacted negatively.
- Future increase in temperature and decrease in rainfall in the Arab region are expected to shorten the growing season and to decrease production of some staple crops including winter wheat and barley.
- Extreme events such as extreme heat and drought are also expected to have negative impacts on food production which will exacerbate the region's vulnerability and its dependence on import to secure food for a growing population.

The Impact of Climate Change on Raw and Untreated Wastewater Use for Agriculture, Especially in Arid Regions

Dima Faour-Klingbeil[1,2] and Ewen C.D. Todd[3]
[1] *School of Biological Sciences, Plymouth University, Plymouth, United Kingdom*
[2] *DFK for Safe Food Environment, Hannover, Germany*
[3] *Ewen Todd Consulting, Okemos, Michigan*

Climate change is one of the major challenges of our time that pose unprecedented stress to the environment and threats to human health. The global impacts of climate change are vast, spanning from extreme weather events to changes in patterns and distribution of infectious diseases. Lack of rainfall associated with higher temperatures has a direct influence on agricultural production. This is compounded by a growing population forecasted to expand further with increasing needs for food and water. All this has led to the increasing use of wastewater worldwide. In this review, we more specifically discuss the use of untreated wastewater in agriculture in the Middle East and North Africa (MENA) countries, the most arid region in the world. This presents challenges for agriculture with respect to water availability and increasing wastewater use in agri-food chain. This in turn exerts pressures on the safety of food raised from such irrigated crops. Current practices in the MENA region indicate that ineffective water resource management, lack of water quality policies, and slow-paced wastewater management strategies continue to contribute to a decline in water resources and an increased unplanned use of black and gray water in agriculture. Radical actions are needed in the region to improve water and wastewater management to adapt to these impacts. In this regard, the 2006 WHO guidelines for the use of wastewater contain recommendations for the most effective solutions. They provide a step-by-step guide for series of appropriate health protection measures for microbial reduction targets of 6 log units for viral, bacterial, and protozoan pathogens, but these need to be combined with new varieties of crops that are drought and pest resistant. More research into economic local treatment procedures for wastewater in the region is warranted.

Keywords: climate change, wastewater, irrigation, agriculture, MENA, arid countries, pathogens

TRAINING WORKSHOP I: MODELING THE WATER-ENERGY-FOOD NEXUS

Date and Time: 14 March, 2019; 11:150-14:15

Objectives

The training workshop, provided by the UNESCO Cairo Office, will introduce the participants to the concepts of modeling and quantitative assessment of the water-energy-food (WEF) security nexus. The participants will learn about WEF interlinkages and how policy actions on one sector will lead to direct and indirect impacts on the other sectors. It will provide the participants with methodology to formulate and analyze WEF policy settings and plans to ensure improved and sustainable long-term outcomes.

Trainer

Prof. Ali Karnib, from the Lebanese University and UNESCO consultant, is working extensively in a wide range of areas in sustainable water resources management in the Arab region, such as studies on water-energy-food security nexus, assessment of the impact of climate change on water resources and water supply and sanitation. His experience is a combination of strong academic credentials as well as wide experience from projects and programs management and consultancy services both at policy level as well as from the field. In addition, he provides research results, technical advisory services and expertise to assist Arab countries to prepare for the formulation and follow-up to the water-related Sustainable Development Goals (SDGs). Prof. Ali Karnib holds a PhD in Civil Engineering from Artois University, France. He has a BE in Civil Engineering from Beirut Arab University in Lebanon. He has published over 50 scientific articles, international working papers, reports and technical manuals. He is member of the Editorial Board of the International Water Utility Journal published by EWRA and member of the international scientific committee of the WORLD CONGRESS OF EWRA on Water Resources and Environment and reviewer for several international water journals.

Agenda

Time	Subject
Hour 1	• Introduction to sustainability and systems • Introduction to WEF security nexus approach • Overview of WEF nexus challenges in the Arab region
10 Minutes Break	
Hour 2	• Mapping the WEF interlinkages: Interlinkage matrix, WEF production technologies, resources use intensities, trade-offs and synergies, data and information needs and information gaps • Quantitative WEF nexus methods and tools • Technology-Oriented WEF nexus approach
10 Minutes Break	
Hour 3	• WEF nexus solutions, policy making and implementation • Case study and practical application: Developing and analyzing WEF nexus scenarios and evaluating results

TRAINING WORKSHOP II: CLIMATE CHANGE AND WATER RESOURCES IN THE ARAB REGION

Date and Time: 14 March, 2019; 11:150-14:15

Objectives

This workshop is provided by the UN ESCWA. It will build on the findings of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), to provide the participants with:

1. An understanding of regional climate modeling of the Arab region;
2. Methodology for accessing climate data sets;
3. Opportunities for using climate modeling outputs to inform hydrological and agricultural modeling applications;
4. An understanding of the integrated vulnerability assessment methodology; and
5. Methodology for structuring and populating vulnerability assessment impacts chains, with case studies in selected sectors.

Trainers

Carol Chouchani Cherfane serves as Chief of the Water Resources Section in the Sustainable Development Policies Division at the United Nations Economic and Social Commission for Western Asia (ESCWA) in Beirut. Her work focuses on implementing regional initiatives and efforts to support Arab States in the areas of climate change assessment and adaptation, shared water resources management, the water-energy-food security nexus, and the water-related Sustainable Development Goals (SDGs). This includes coordinating the United Nations-League of Arab States Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR). Prior to joining ESCWA she worked for the Harvard Institute for International Development and the World Bank. She holds degrees from the Fletcher School of Law and Diplomacy in Boston and the Georgetown University School of Foreign Service in Washington, DC, where she focused on development economics, international law and international environmental policy.

Marlene Ann Tomaszkiewicz serves as Regional Advisor for Geographic Information Systems for Climate Change Analysis at the Economic and Social Commission for Western Asia (ESCWA), working in the Water Resources Section in the Sustainable Development Policies Division. Her work has included vulnerability assessment analysis as part of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR). Prior to joining ESCWA, she worked in the private sector as a water resources engineer coupled with extensive experience in GIS and climate change studies. She obtained her Ph.D. in water resources and environmental engineering from the American University of Beirut and also obtained degrees in civil engineering from the Illinois Institute of Technology (Chicago, Illinois) and Louisiana State University (Baton Rouge, Louisiana).

Ziad Khayat is a First Economic Affairs Officer at the Water Resources Section of the Sustainable Development Policies Division at the Economic and Social Commission for Wester Asia (ESCWA). Mr. Khayat joined ESCWA in 2015 focusing on water related sustainable development issues within the context of a nexus approach and on shared water resources opportunities and challenges in the Arab region. He has also been involved in the United Nations-League of Arab States Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) exploring climate change effects on groundwater. He previously worked with UNDP in Lebanon on a national groundwater assessment and with Dar Al-

Handasah Consultants on various hydrogeological assessments and groundwater management issues in the Arab region. He has also taught Hydrogeology graduate courses at the American University of Beirut in Lebanon. He holds degrees from the University of British Columbia in Vancouver and from the American University in Beirut with a focus on hydrogeology.

Agenda

Time	Subject
Hour 1	Introduction to climate change data in the Arab Region • General overview of climate change, RCPs, and regional climate modeling • CORDEX Regional Climate Modeling outputs vs RICCAR bias-corrected data • Climate change impacts: temperature and precipitation for RCP4.5 and RCP8.5 • Extreme event indices and their applications
10 Minutes Break	
Hour 2	Climate change data and agricultural/hydrological applications • Crop irrigation using CROPWAT • Drought planning using Standardized Precipitation Index (SPI) • Projected flood using hydrological modeling (HEC-HMS)
10 Minutes Break	
Hour 3	Integrated vulnerability assessments • Vulnerability assessment terminology • Indicator selection and weighting • Impact chains • Results from case studies

جمعية علوم وتقنية المياه
Water Sciences and Technology Association

Introduction

The Water Sciences and Technology Association (WSTA) was formed as a result of individual efforts of some of those concerned with water affairs in the Gulf Cooperation Council (GCC) Countries with an objective mainly to encourage and promote interest in water sciences and strengthen scientific ties among water professionals, encourage scientific research, training programs, and the development of local capabilities in the different fields of water sciences and technology.

The Government of Bahrain consented to register the Association in Bahrain, and the Association was formally founded in September 1987, to be the first scientific association in the field of water sciences and technology in the Arabian Gulf region. WSTA is a non-government organization and its membership is open to all water professionals in the GCC, water-related national and international organizations, educational institutes, consultants, and companies.

Activities & Achievements

A. Conferences

WSTA has organized a series of conferences under the title **Gulf Water Conference** where the First one held during the period 10-13 October, 1992 in Dubai, UAE, under the theme "Water and Development in the Gulf Region, Challenges of the Nineties" and following the success of its first conference, WSTA decided to organize this Regional conference biannually alternating in each of the GCC countries. **The 2nd Conference** was held in Bahrain during 5-9 November 1994, under the theme "Water in the Gulf, Towards an Integrated Management". **The 3rd Conference** was held in Muscat during 8-13 March 1997 under the theme "Towards Efficient Utilization of Water Resources in the Gulf". **The 4th Conference** was held in Bahrain again, during 13-19 February 1999, under the theme "Water in the Gulf, Challenges of the 21st century". **The 5th Conference** was held in Doha, during 24-28 March 200, under the theme "Water Security in the Gulf". **The 6th Conference** was held in Riyadh, during 8 – 12 March, 2003, under the theme "Water in the GCC… Towards Sustainable Development". **The 7th Conference** was held in Kuwait during 19-23 November 2005, under the theme "Water in the GCC- Towards an Integrated Water Resources Management". **The 8th Conference** was held in Bahrain during 3-6 March 2008, under the theme "Water in the GCC…Towards an Optimal Planning and Economic Perspective". **The 9th Conference** was held Muscat, during 22-25 March 2010 under the theme "Water Sustainability in the GCC Countries-The need for a Socio-Economic and Environmental Definition". **The 10th Conference** was held in the period 22-24 April 2012 in Doha, Qatar under the theme "Water in the GCC…Water-Energy-Food Nexus". The **11th Conference** was held in Muscat, Sultanate of Oman during 20-22 October 2014 under the theme "Water in the GCC States…Towards an Efficient Management". The **12th Conference** was held in Manama, Kingdom of Bahrain during 28-30 March 2017 under the theme "Water in the GCC …Towards an Integrated Strategy".

B. Symposiums & Workshops

The WSTA has organized many symposiums and training workshops. The followings are a list of these: "Symposium on Water Supply Floridation" held in October 1996, Kuwait; **"Future of Desalination in the GCC Countries Workshop"**, held on 8th March, 1998, Bahrain; **"The Future of Desalination Research Workshop"**. The WSTA organized in co-operation with the European Desalination Society (EDS) their first workshop on the subject of The Future of Desalination Research, held during 8-11 September, 2002, in La Quilla, Italy, titled **"Operation and Maintenance: Performance Problems Workshop";** the second workshop was held during 24-27 August, 2003, in

Amsterdam, Holland; the third workshop titled **"Capacity Building workshop",** was held during 1-2 December 2004, in Bahrain. the workshop **"Environmental Impact Assessment workshop"** was held in collaboration with UAE University during 3-4 April 2013, Al-Ain, UAE. Moreover, the WSTA conducted many training workshops, either during its conferences or separately. The Association recently held a workshop and training course on the "**Quality of Irrigation Water in Oman"** for a group of workers in the field of agriculture in April 2018, in cooperation with the Ministry of Agriculture and Fisheries in the Sultanate.

C. Affiliations

The Association is affiliated with a number of Regional and International NGO's and Institutions addressing the global water issues, most notably the European Desalination Society EDS. International Desalination Association IDA, Arab Countries Water Utilities Association ACWUA and Oman Water Society OWS. In addition, WSTA has established strong ties with many UN organizations (UNESCO, ESCWA, UNDP, UNEP, FAO and many more) working in the water sector to enforce its position as a pioneer in addressing the importance of conserving water and protecting water resources in the Gulf Region.

The WSTA Board of Directors

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For Further information, please visit the WSTA website at: www.wstagcc.org

The Kuwait Institute for Scientific Research (KISR)

KISR is a pioneering, independent, national institute of scientific excellence. It was established in 1967 by Japan's Arabian Oil Company Limited, in partial fulfillment of its obligations under an oil concession agreement with the government of the State of Kuwait. KISR's initial role was dedicated to developing three fields of national importance: petroleum, desert agriculture, and marine biology. Since then, KISR's role and responsibilities have expanded greatly to include the advancement of national industry and the undertaking of studies to address key challenges, such as the preservation of the environment, sustainable management of Kuwait's natural resources, responsible management of water and energy, and development of innovative methods of agriculture.

KISR was restructured by an Amiri decree issued in 1973, under which it became directly responsible, via its Board of Trustees, to the Council of Ministers. The main objectives of the institute, as specified in the decree, were to carry out applied scientific research. In 1981, KISR's status was further reviewed, and its role reconfirmed in the development of scientific research and technology in the country. In addition, the law broadened the mission and entrusted the institute with undertaking research and scientific and technological consultations for both the governmental and the private sectors in Kuwait, the Arabian Gulf region and the Arab world, and encouraged collaboration with international institutes.

KISR's approach to meeting challenges is distinguished by a culture of openness, a commitment to our clients, and an integrated, cross-disciplinary approach. KISR routinely embarks on strategic partnerships with other regional and international institutes, agencies, and academic bodies, allowing an exchange of knowledge and expertise. Today, KISR is home to over 580 researchers and engineers and over 100 laboratories, housed at 9 locations, with growth expected through the implementation of a new strategic plan. KISR conducts scientific research and performs technological consultations, often in partnership with other regional and international institutions, for governmental and industrial clients in Kuwait, the Gulf region, and the rest of the world. These partnerships, driven by a philosophy of collaboration that runs deep within our culture, help build up our knowledge base, and facilitate the free flow of information, data, and expertise.

At KISR, we take pride not only in our scientific achievements, but our diversity as well. We are a melting pot of cultures, ideas, and disciplines, all dedicated to one common goal: putting science in action.

VISION

By 2030, KISR will be acknowledged internationally as the region's most respected science, technology, and innovation (STI) and knowledge gateway, and recognized as a driving force for sustainable economic prosperity and enhanced quality of life.

MISSION

KISR leads and partners internationally to develop, deploy, and exploit the best science, technology, knowledge, and innovation for public and private sector clients, for the benefit of Kuwait and other countries facing similar challenges and opportunities.