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Ministry of Environment Water & Agriculture

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جمعية علوم وتقنية المياه
Water Sciences and Technology Association

Under the Patronage of H.E.
ENG. ABDULRAHAMAN BIN ABDULMOHSEN AL-FADLEY
The Minister of Environment, Water & Agriculture

مؤتمر الخليج الرابع عشر للمياه

14th Gulf Water Conference

Water in the GCC... Towards Economic Efficiency and Financial Sustainability

13th - 15th FEBRUARY, 2022 | HILTON HOTEL, RIYADH

Scientific Program and Abstracts

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The Minister of Environment, Water & Agriculture

مؤتمر الخليج الرابع عشر للمياه

"المياه في دول مجلس التعاون.... نحو كفاءة اقتصادية واستدامة مالية"

14th Gulf Water Conference

"Water in the GCC... Towards Economic Efficiency and Financial Sustainability"

13-15 February, 2022 - Hilton Hotel, Riyadh, Kingdom of Saudi Arabia

البرنامج العلمي وملخصات البحوث

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Introduction

The GCC countries are situated in one of the most water scarce regions of the world and have one of the lowest per capita share of freshwater resources globally, with values much below the threshold of absolute water scarcity of 500 m^3/year. In the last few decades, the GCC countries have witnessed an accelerated socio-economic, agricultural, and industrial development growth, which was associated with substantial increase in water demands. To provide these water demands, the GCC countries have primarily focused their efforts on the development and supply augmentation aspects of water management, manifested by development of groundwater, installation of desalination plants, expansion in the reuse of treated wastewater, in addition to dams construction.

To meet increasing domestic water demands, the GCC countries have resorted heavily to desalination. Currently, almost all of the municipal water supply systems rely on desalination in the majority of the GCC countries. However, desalination is associated with substantial financial cost and are energy-intensive affecting both the economies and the environment of the GCC countries. In addition to the challenges of meeting the rapid growth of municipal water demands, rates of per capita domestic water consumption in many GCC countries are considered excessive and are ranked among the highest in the world. This is attributed mainly to the provision of high quality domestic water supply service coupled with very heavy blanket non-targeted subsidies, which gives the consumers the false impression of water abundancy.

To fulfil the requirements of agricultural water demands, the GCC countries have relied on groundwater resources and to a lesser extent on treated municipal wastewater. A major concern is that the majority of groundwater resources in the region are non-renewable and are being extensively mined and rapidly depleting. Furthermore, renewable groundwater resources are being over-exploited beyond their replenishment rates leading to quality degradation due to saltwater intrusion. The loss of groundwater resources assets will have dire consequences on the GCC countries in terms of the loss of a long-term strategic water supply and the cost of the replacement water. Groundwater excessive withdrawal is attributed to many factors, the most important is poor irrigation practices with irrigation efficiencies ranked among the lowest in the world. Some of the reasons for such practices is inadequate monitoring of groundwater abstraction and absence of charges for groundwater withdrawal, providing no incentive for water conservation.

Notably, to meet the ever-increasing demand for water, the GCC countries have adopted a supply-side management approach for securing water supplies. This has forced the countries, increasingly, into more expensive and costly investments in water supply sources and infrastructure. The heavy financial, economic and rising environmental costs associated with such approach cannot be over-

emphasized. Clearly, such approach cannot be a long-term solution to water scarcity in the GCC countries, and a new conceptual approach in managing the countries' limited and costly water resources will be required. The GCC countries will need to shift their emphasis from ensuring "**sustainability of supply**" to ensuring "**sustainability of consumption**", while achieving economic efficiency and financial sustainability as core objectives.

To achieve such shift, there are basically three types of policy instruments that can be implemented: **structural & operational** (e.g., metering, retrofitting water saving devices, flow control, recycling,), **sociopolitical** (e.g., education and awareness, building codes, appliances labeling,), and **economic** (incentives and disincentives). In this regard, economic policies instruments are more effective in achieving economic efficiency and financial sustainability and can complement and reinforce the use of the other two policy instruments.

In general, economic instruments involve the use of prices and charges to provide incentives to water users to utilize water efficiently and rationally. The purpose of water pricing policies is three-fold: 1) cost reflectivity (signal to users the true scarcity value of water and the cost of service provision as an incentive for more efficient water use); 2) environmental and resource protection (encouraging conservation and efficient use and recognizing environmental co-benefits); and 3) cost recovery (generation of revenues for the efficient operation of the present system, its maintenance, modernization and future expansion). A properly designed water pricing policy will direct subsidies towards guaranteeing water as human rights and that pricing is set proportional to volume of usage with heavy water users paying the most to achieve social equity.

On the other hand, one of the main problems threatening the sustainability of the water services in the GCC countries is the low cost recovery. Although water supply utilities in the GCC countries are considered among the top-ranked service providers in the world, the existing very high rates of subsidies result in very low cost recovery percentages. Moreover, unlike the water supply utilities, the wastewater sector in the majority of the GCC countries has literally zero cost recovery due to the absence of wastewater tariff for collection, treatment, and reuse. This creates a heavy financial burden on the countries fiscal budget, and holds the sector captive to government allocations, which are susceptible to oil-prices volatility, eventually influencing the general water services performance.

One of the measures that have been taken towards reducing the cost and alleviating the financial burden of water services is privatization. The majority of the GCC countries have moved to privatizing production where many desalination plants are built as independent water and power projects (IWPP), with desalinated water purchased by the government through a long-term plan. Still, the municipal water sector can benefit from the many advantages privatization can offer in the whole water supply chain, which has not been adequately investigated in the region yet.

The WSTA 14th Gulf Water Conference is advocating for a paradigm shift in the management of water resources in the GCC countries to move from the current emphasis on supply sustainability approach to a consumption sustainability approach, with its core objectives of economic efficiency of water uses and financial sustainability of water services. Moreover, the conference deliberations and results will be the GCC countries contribution to the selected UN Water topic for 2021 "Valuing Water" and for 2022 "Groundwater: making the invisible visible".

The WSTA 14th Gulf Water Conference is organized in the Kingdom of Saudi Arabia in collaboration with the Saudi Ministry of Environment, Water and Agriculture. 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) and the Saline Water Conversion Corporation (SWCC). The conference is supported and endorsed by the active UN organizations in the region of UNESCO Cairo Office, ESCWA, and FAO; and the international and regional organizations of IWMI, ICBA, IDA, AGU, OWS, and EDS.

On behalf of the Conference Scientific Committee, I would like to thank all authors and panelists from various parts of the world for joining us in our Fourteenth Gulf Water Conference and sharing their experiences and innovative solutions in improving water sustainability and overcoming the water challenges in the arid GCC and Arab countries.

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

Conference Objectives

- REVIEWING current policies and strategies related to economic efficiency and financial sustainability in the water sector in the GCC countries.
- INFORMING policy and decision-making on the impacts of the use of economic instruments to achieve sustainable water consumption patterns in the GCC countries.
- IDENTIFYING challenges and opportunities in implementing economic instruments to achieve sustainable water consumption under the prevailing socio-economic, environmental, cultural, and political conditions in the GCC countries.
- EXCHANGING experiences and best practice case studies in the GCC countries and other countries in the region on achieving economic efficiency and financial sustainability in the water sector.

Conference Sessions & Training Workshops

Regular Sessions:

1) **Economics** of the Water Sector
2) Efficient Management of **Desalination**
3) Efficient Management of **Industrial** Water
4) Efficient Management of **Agricultural** Water
5) Efficient Management of **Wastewater**
6) Efficient Management of **Surface** and **Groundwater**
7) Efficient Management of **Municipal** Water Supply
8) **Hydro-Informatics** and Water Sector Monitoring Systems

Special Sessions:

1) **Economics and Financing** of the Water Sector

2) The Impact of **Climate Change** on Water Resources in the GCC Countries
   (Organized in cooperation with **UN-ESCWA**).

3) The Role of **Non-Traditional Water Resources** in the GCC Countries
   (Organized in cooperation with **UNESCO**).

4) **Innovation in Desalination**
   (Organized in cooperation with the Saline Water Conversion Corporation (**SWCC**)).

Short Training Workshops:

1) From Science to Analyses to Policymaking: Simplifying regional climate modelling outputs and their applications in the GCC and beyond (2 hours), offered by **UN-ESCWA**.

2) Water Accounting and Water Governance Analysis (3 hours), offered by **IWMI**.

3) Valuing Water (2 hours), offered by **UNESCO** (note: to be conducted through 4 session on the 15-16 and 21-22 February 2022).

Conference Program

DAY ONE: Sunday 13 February 2022		
08:00-09:00	Registration	
09:00-10:00	OPENING CEREMONY	
10:00-10:30	Refreshment Break	
SESSION 1	Economics of the Water Sector	
Co-Chairpersons: Abdulaziz Alshaibany & Abdulaziz Alturbak		
10:30-10:50	Keynote 1	Omar Ouda, MEWA, Saudi Arabia, Economic Sustainability of the water sector in GCC Countries
10:50-11:10	Keynote 2	Amgad Almahdi, IWMI/GCF, New Paradigm-"No Room for Business as Usual" to preserve and provide equitable access to the precious water resources
11:10-11:30	Keynote 3	Slim Zekri, SQU, Oman, Economic Instruments for Water Sustainability in the GCC Countries
11:30–11:35	Short Break	
SPECIAL SESSION S1	Economics and Financing of the Water Sector	
11:35-12:30	Coordinator/Moderator: Slim Zekri, SQU, Oman Speakers and Panelists: - Saud Al-Marshad, Ministry of Environment, Water, and Agriculture, KSA - Ali Al-Hamdi, AZER Group for Engineering and Investment, Oman - Abdulaziz Alturbak, King Saud University, KSA - Faisal Alfaisal, King Saud University, KSA - Buthaina Al Wahaibi, Oman Water and Wastewater Services Company, Oman	
12:30-13:00	Prayer & Refreshments Break	
SPECIAL SESSION S2	Climate Change Impacts on Water Resources in the GCC	
13:00-14:15	Coordinator/Moderator: Waleed Al-Zubari, AGU, Bahrain; Speakers and Panelists - Marlene Tomaszkiewicz, ESCWA, Bridging the Science-Policy Interface: From Climate Models to Regional Action - Mansour Al-Mazroui, KAU, Climate Change Possible Impacts on Water Resources in the GCC Countries - Fadi Comair, EEWRC, The Water Task Force Climate Change Initiative of The Cyprus Institute and The IHP-UNESCO ECOMED Academy Implementation Network in the GCC - Abdelkader Larabi, Morocco, Climate Change Impact on Groundwater Using Simulation Modeling - Walid Saleh, FAO, Economic Analysis of the Impact of Climate Change on Agriculture in Arid Regions	
SPECIAL SESSION S3	Role of Non-Conventional Water Sources in GCC (UNESCO)	
14:15-15:00	Coordinator/moderator: Bisher Imam, UNESCO Cairo Office Speakers - Bisher Imam, UNESCO Cairo Office - Mohammed Dawoud, EAD - Esra Aleisa, Kuwait University - Rashid Al-Abri, SQU	
16:00	Lunch	

DAY TWO: Monday 14 February 2022		
	SESSION 2A Desalination (08:30-14:05)	**SESSION 4A Agriculture (08:30-12:10)**
	Co-Chairpersons: Ahmed Al-Araifi & Ali Redha	**Co-Charipersons: Rasool Al-Omran & Hamad AlHatmi**
08:30 -08:50 **Keynotes**	**Hyuk Soo Son, KSA, Hybrid desalination technologies for sustainable water-energy nexus: Innovation in integrated membrane module development (#114)**	**Khalid AlRowais, KSA, The GCC Countries and the Water-Food Security Nexus**
08:50-09:05	Hassan Abdulrahim, Kuwait, Levelized Cost Analysis for Desalination using Renewable Energy in GCC (#71)	Mohammad Alomair, KSA, Cost-benefit analysis of the shift from traditional irrigation systems to modern irrigation methods by small farmers in Al-Ahsa and its role in the dissemination of modern irrigation techniques (in Arabic, #65)
09:05-09:20	Ahmed Al-Ghamdi, KSA, Prospect of Utilization of Solar Energy in SWCC Existing MED Desalination Satellite Plants (#84)	Latifa Dhaouadi, Tunisia, Natural resources management in southern Tunisia: sustainable exploitation an degradation issues of the oasis agro-systems (#35)
09:20-09:35	Kim Choon Ng, KSA, A Common Platform for Evaluating the Energy Efficiency of Power Generation and Desalination Plants (#110)	Ahmad Al-Busaidi, Oman, Risks Associated with Treated Wastewater in Greenhouse Cooling System (#116)
09:35-09:50	Raid Alrowais, KSA, Micro/Nano-bubble Assisted Direct Spray Method of Low Energy Thermal Seawater Desalination: - An Experimental Study (#112)	**Discussion**
09:50-10:10	**Discussion**	
10:10-10:30	**Break**	
	Cont., SESSION 2B Desalination	**Cont., SESSION 4B Agriculture**
	Co-Chairpersons: Mohammed Alrashidi & Mohammed Al-Arifi	**Co-Chairpersons: Ali Al-Jaloud & Hussain Al-Ghobari**
10:30-10:50 **Keynotes**	**Ibrahim Almuataz, KSA, Toward Developing Key Performance Indicators (KPIs) for Desalination Processes (#58)**	**Khalil Ammar, ICBA, Role of efficient management of non-conventional and brackish water resources in sustaining agricultural production and achieving food security in the United Arab Emirates**
10:50-11:05	Muhammad Shahzad, UK, Unlocking the Desalination Processes Future Roadmap (#55)	Samir yacoubi, Tunisia, Impact of deficit irrigation strategies on water use and productivity for vegetable crops in a semi-arid context of Tunisia (#19)
11:05-11:20	Amr Mahmoud, KSA, High Temperature Multi Effect Desalination 95°C demonstration in DTRI pilot plant (#82)	Mohammed Yousif Hachom, Iraq, Irrigation Efficiencies with Application of Five Irrigation Levels and Soil Texture In Dyala River Basin (#32)
11:20-11:35	Ridha Ben Mansour, KSA, Performance and cost analyses of hybrid diesel-PV powered small brackish water RO systems in Saudi Arabia (#94)	Ayisha Al-Khatri, Oman, The Practices Followed by Farmers and their Effects on the Water Situation in South Al Batinah Region, Sultanate of Oman (#95)
11:35-11:50	Slimane Gabsi, Tunisia, Integration of solar vacuum membrane distillation (#49)	Boubaker Dhehibi, Tunisia, Economic and Environmental Evaluation of Different Irrigation Systems for Date Palm Production in the GCC Countries: The case of Oman and Saudi Arabia (#57)
11:50-12:10	**Discussion**	**Discussion**
12:10-12:30	**Prayer**	

	Cont., SESSION 2C Desalination	SESSION 5A Wastewater (12:30-15:15)
	Co-Chairpersons: Ibrahim Almutaz & Ali Redha	**Co-Chairpersons: Walid Zahid & Rashid Al-Abri**
12:30-12:50 **Keynotes**	**Robin Morelissen, The Netherlands, Sustainable Desalination: How to produce sufficient water towards the future, while protecting the marine environment**	**Asad Qureshi, ICBA, Challenges and Prospects of Using Treated Wastewater to Manage Water Crises in the GCC countries**
12:50-13:05	Thamer Ali, Bahrain, The Characterization of the Water Mass Dynamic Changes Surrounding an SWRO Desalination Plant on the East Coast of the Kingdom of Bahrain (#118)	Mohamed Dawoud, UAE, The Future of Wastewater Treatment and Reuse in Kingdom of Saudi Arabia (#20)
13:05-13:20	Ahmed Abuouf, KSA, Governing Business in the Sea-Water Desalination Sector Through Tero-Technology (#81)	Abdullah Abusam, Kuwait, Fate of Estrogens in Kuwaiti Municipal Wastewater Treatment Plants (#80)
13:20-13:35	Bashir Brika, Libya, Reuse of Reverse Osmosis Membranes in Tajoura's RO Desalination Plant (in Arabic, #39)	Adel Al-Haddad, Kuwait, Investigations on Pharmaceuticals and Radioactive Elements in Wastewater from Hospitals in Kuwait (#74)
13:35-13:50	Yousef Alwazzan, Assessment of Freeze Melting Technology for Brine Concentration (#76)	Ali AlJaloud, Saudi Arabia, Technical and economic viability of the reuse of treated wastewater in the Kingdom of Saudi Arabia
13:50-14:05	**Discussion**	**Discussion**
14:05-14:20	**Break**	
	SESSION 3 Industrial Water Management (14:20-15:15)	**Cont., SESSION 5B Wastewater**
	Chairperson: Arif Alkalali	**Chairperson: Adnan Alsaati**
14:20-14:35	Syed Ahmed, KSA, Produced Water Reuse towards Circularity: Case Study in Oil Facilities (#106)	Faisal Alfaisal, KSA, Testing an Optimization Model for Optimal Sewer Layout and Wastewater Treatment Locations (#69)
14:35-14:50	Adel Al-Haddad, Kuwait, Database for Total Petroleum Hydrocarbon in Industrial Wastewater Generated at Sabhan Area in Kuwait (#75)	Sumaya Hasan, Bahrain, Feasibility of Anaerobic Digestion as an Option for Biodegradable and Sewage Sludge Waste Management in the Kingdom of Bahrain (#68)
14:50-15:05	Emad Aboukila, Egypt, The effect of industrial activities on the heavy metals contamination of irrigation waters, soils, and plants in Kafr El-Dawar district, Egypt (#52)	Wafa Al-Rawahi, Oman, Adsorptive Removal of Chromium (VI) Using Cu/Fe Impregnated Activated Carbon Prepared from Solid Sludge (#115)
15:05-15:15	**Discussion**	**Discussion**
15:15	**Lunch**	

DAY THREE: Tuesday 15 February 2022		
	SESSION 6A Surface & Groundwater (08:30-12:35)	**SESSION 7 Municipal Water Supply (08:30-10:10)**
	Co-Chairpersons: Mansour Al-Qarni & Mohammed Swar	**Co-Chairpersons: Mohammed Alrashid & Raed Alharbi**
08:30-08:50 **keynotes**	**Yousry Mattar, KSA, Hydrometeorological study on the impact of the weather condition "Rahw" (#93)**	**Ali Al-Hamzah, KSA, Monitoring of Inorganic and Organic Pollutants in the Desalinated Water from SWCC Plants (#96)**
08:50-09:05	Ali Al-Maktoumi, Oman, A hydroecological technique to improve infiltration of clogged bed of recharge dam (#54)	Hamad Alazmi, Kuwait/UK, Investigating Water Conservation Strategies in Kuwait: A Micro-component Backcasting Approach (#70)
09:05-09:20	Afrah Al-Shukaili, Oman, Experimental and Numerical Modelling of Constructed Channels in the Desert Sand Dunes for MAR Applications (#67)	Sadeq Sulaiman, Iraq, Optimal management of multiple water sources to supply drinking water distribution networks in the desert cities of western Iraq (in Arabic, #54)
09:20-09:35	Ibrahim Elsebaie, KSA, Flood damage assessment of vulnerable area in Riyadh city, Saudi Arabia (case study: Al-Thumama Bridge) (#85)	Abdullah Saghir, Turkey, How Syria Crisis Affects the Potable Water System Efficiency in Non-State Armed Group Controlled Areas (#28)
09:35-09:50	Ghadeer M. Kadhem, Bahrain, Identifying Optimal Locations for Managed Aquifer Recharge by Rainfall in the Kingdom of Bahrain Using MCDM and GIS Techniques Adel Bashnaq, KSA, Sky Tap, Rain making technology using natural resources and solutions	Tariq Bawazir, Qatar, Efficient Municipal Water Supply through Optimum Distribution Pressure
09:50-10:10	**Discussion**	**Discussion**
10:10-10:30	**Break**	
	Cont., SESSION 6B Surface & Groundwater	**SESSION 8 Hydro-informatics (10:30-11:35)**
	Co-Chairpersons: Ali Al-Maktoumi & Abdulaziz Albassam	**Chairperson: Abdulhakeem Al-Turki**
10:30-10:50 **Keynotes**	**Ziad Khiyat, ESCWA, Groundwater in the Arab Region: Making the invisible visible**	**Nagaraja Rao Harshadeep, World Bank, Disrupting HydroInformatics: Reimagining Water Planning and Management Insights**
10:50-11:05	Mohamed Dawoud, UAE, Using Electricity Consumption as a Tool for Groundwater Abstraction in Abu Dhabi Emirate Farms, UAE (#37)	**David Yates, SEI, Advancing Water Sustainability in Bahrain through Water Resource Management Knowledge Platforms**
11:05-11:20	Amjad Aliewi, Kuwait, A numerical approach for the evaluation of sustainable yield of shared aquifer basins: case studies from the Arabian Gulf and Eastern Mediterranean countries (#72)	Mubarak Al-Noaimi, Bahrain, Development of Water Information System for the Kingdom of Bahrain (#89)
11:20-11:35	Shahad Al-Yaqoubi, Oman, Understanding Saline Water Dynamics in Coastal Aquifers Using Sand Tank Experiment and Numerical Modeling (#91)	**Discussion**
11:35-11:50	Mahad Shamas, Oman, Artificial Recharge via Injection Wells for Salinity Ingress Control of Salalah plain aquifer, Oman (113)	**SPECIAL SESSION S4 Innovation in Desalination (11:35-12:35)**

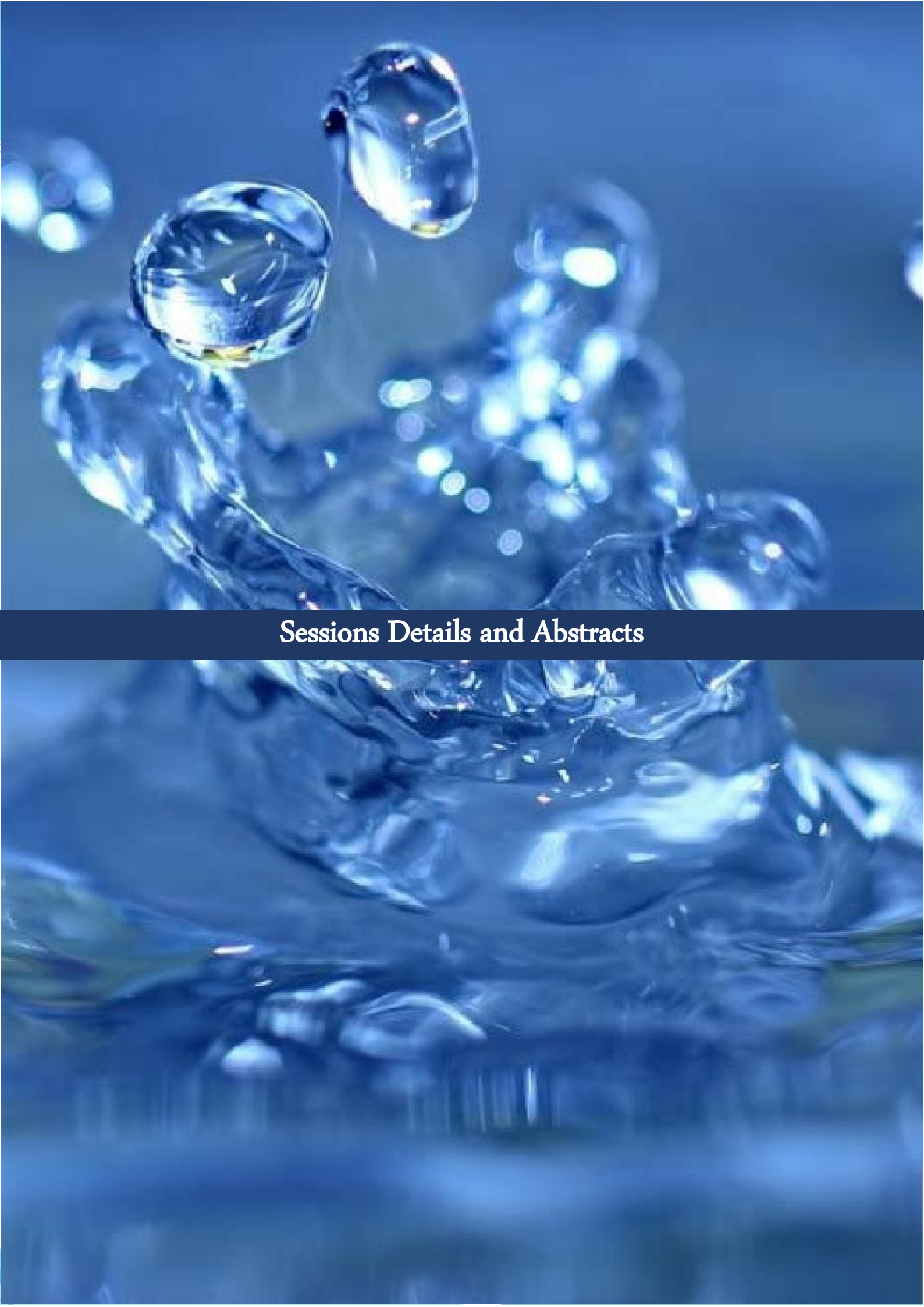
11:50-12:05	Chidambaram Sabarathinam, Kuwait, Equilibrium states of groundwater chemistry in coastal region of Kuwait (#103)	**Coordinator Dr. Ahmed Aloraifi, SWCC, KSA** **Moderator: Ahmed Alamoudi, KSA** **Speakers and Panelists:** - **Seungwon Ihm, SWCC, Multistage Nanofiltration System for Supplementing Drinking Water with Magnesium Extracted from Bine** - **Byungsung Park, SWCC, Optimizing Pretreatment Performance** - **Nikolay Voutchkov, SWCC, Brine Mining – the Path Forward**
12:05-12:20	Khalid Rasheed, Qatar, Promoting Rainwater Harvesting Techniques in Qatar and Its Role in Increasing Recharge to the Aquifer System	
12:20-12:35	**Discussion**	
12:35-13:00	**Prayer & Refreshment Break**	
13:00-14:00	**CONFERENCE CONCLUSION SESSION**	
14:00-16:00	Lunch	
16:00-19:00	**POST CONFERENCE TRAINING WORKSHOPS**	
POST CONFERENCE WORKSHOPS	**Training Workshop 1** **From Science to Analyses to Policymaking: Simplifying regional climate modelling outputs and their applications in the GCC and beyond** **Organizer:** ESCWA & WSTA **Duration**: 1.5 hours **Trainer**: Marlene Ann Tomaszkiewic	Climate change impacts affect many sectors including water resources and agriculture. However, many studies either use climate modelling outputs incorrectly or use observed data to conduct trend analyses. In this workshop, offered by UN-ESCWA, we'll explore the advantage of using regional climate modelling outputs, why multiple models should be considered, and the advantages of using modelled data instead of observed data. We will also simplify access and usability of regional climate modelling outputs. Government officials and researchers working in the environmental, water
	Training Workshop 2 **Water Accounting concept and sharing experience** **Organizer:** IWMI & WSTA **Duration:** 3 hours **Trainer:** Marwa Ali	Water accounting provides comprehensive information related to hydrological processes and water consumption for better communication, policy, and decision-making in a geographical domain. The training workshop, offered by IWMI, will introduce state-of-the-art knowledge on Water Accounting (WA) concept and will discuss challenges in developing and implementing water accounting cycles (Rapid and Advanced). In addition, the workshop will highlight the need to apply water accounting for efficient water resources management at different geographical scales (from farm to catchment). The workshop will be interactive, include short exercises, and create awareness about the benefit of implementing WA systems and lessons learned from the international pilot projects.
	Training Workshop 3 **Valuing Water** **Organizer:** UNESCO **Duration:** this training will be conducted through 4 session each with 2 hours. The first and second sessions will be conducted on the 15-16 February 2022 (the third and fourth will be on 21-22 February 2022); the session will start at 10am **Trainer:** Ali Karnib	This activity is funded by Sultan bin Abdulaziz Al-Saud Foundation of the Kingdom of Saudi Arabia, The training is developed to improve participants' knowledge and understanding on methodologies and approaches to valuing water across different use sectors and how these tools have been applied to improve water management. The desired outcome is that the trainees would understand how valuation can potentially lead to better decision-making in terms of financing, governance, and knowledge and capacity-building and implement what they learned in their professional activities.

Note: Virtual presentations are in "Green" color.

14th Gulf Water Conference

"Water in the GCC… Towards Economic Efficiency and Financial Sustainability"

The conference proceedings, i.e., the full text of the papers presented in the conference, will be published in a special volume of the **Desalination and Water Treatment Journal, Science and Engineering** (www.deswater.com)



Sessions Details and Abstracts

SESSION 1: ECONOMICS OF THE WATER SECTOR

Keynote Speaker

1) Economic Sustainability of the Water Sector in GCC Countries

Omar K M Ouda

National Centre for Water Research and Studies, Ministry of Environment, Water and Agriculture, KSA.

Email: oouda@mewa.gov.sa; okouda@hotmail.com

Abstract:

GCC countries have witnessed significant growth in population, urbanization and economic development over the last four decades. Water is central to economic and social development and is vital to basic human needs, managing the environment, and sustaining economic growth. The GCC Countries are facing serious challenges from the unsustainable use of water resources because all are experiencing extreme water stress conditions. Accordingly, they are heavily dependent on costly seawater desalination to meet the ever-increasing water demand. The total amount of desalinated water treated was around 5.8 billion m^3 in 2016, about 295 liter/day/capita. The cost of producing desalinated water has been a key challenge to the fiscal budgets of GCC countries, given the historically low cost recovery rates and water tariffs for all users. Furthermore, the low water tariffs have resulted in high water consumption, coupled with a relatively low water use efficiency and minimal economic return of water usage activities. This paper provides an overview of the water tariff systems currently implemented in the GCC countries. It highlights the social and economic impacts of low tariffs and low cost recovery, and provides recommendations for enhancing the economic sustainability of water resources management, based on international best practices.

Keynote Speaker

2) New Paradigm-"No Room for Business as Usual" to preserve and provide equitable access to the precious water resources

Amgad Elmahdi

Director of MENA Region, International Water Management Institute-IWMI.

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Abstract:

Four years since the adoption of the Sustainable Development Goals, UN-Water reports show the **world is off track** to achieve the water goal – the heart of the SDGs-, thus the same goes for all water related SDGs (only 10 years to harvest SDGs). Amid lots of highlights on what we need to do, governments must decide how to incorporate SDG 6 targets into national planning processes, policies and strategies and set their own targets, taking into account local circumstances and contexts including cultural. Localization of SDGs has received a great deal of attention among the government officials and policymakers. While MENA countries are the front-runners in presenting their voluntary national reviews (VNRs), **there is still a long way to go in terms of localization process in MENA countries and implementation of the SDGs**. The SDGs are not just a global reporting exercise, however, but rather involve a global program that embraces country-led efforts. Guided by the ideas contained in the 2030 Agenda, each nation must seek to become more prosperous and sustainable, while contributing to the global effort at the same time. To preserve and provide equitable access to the precious water resources and achieve SDG 6 in the MENA region, there is call for new paradigm:

Changing minds:

- Move from linear systems of use and dispose to circular system with zero waste
- Treat water with its economic value.
- Water and sanitation is one system not two separate systems,
- Wastewater is a resource of low quality before it is treated.

"Wastewater is an untapped resource to close the gap of supply of demand" Dr Elmahdi.

Integration and Connection:

- Water is not a sector but a connector
- The water goal SDG6 is also interconnected with all SDGs.
- Water policies and planning is an integrated action by all actors
- Shift from social production to productive production system
- Shift from centralize to decentralize water management and governance

Circular economy and Inclusive gender Business model:

- Go beyond water supply actions into demand management
- Circular economy and inclusive gender business are offering alleviation and support sustainability for future generations.
- Introduce water recycling into established businesses.
- Shift from more production per drop to more per drop and Kilowatt

- Engaging private sectors in water and agriculture sectors.
- Shift to water as economic goods
- Introduce service delivery cost

Digital transformation and technology for saving water:

- Allow equal access to water data to improve the ability to respond to growing water challenges and to meet the SDGs.
- Open the shell for data sharing and technologies for data collection
- Seize the potential of the increased availability of water data and big data tools to catalyze change.
- Enhance knowledge of decision making and investors by identifying how to channel multiple streams and sources of data into products

Localizing SDGs goals:

- Implementing global agendas at the local level to achieve local and global goals.
- Achieving the SDG6 relies on a responsive approach to farmers and the community
- Empowering people and end users
- Shift from state-run institutions to the water user organization
- Expanding more inclusive partnership
- Fostering adaptation

Planning and sustainability:

- *Change the way the water system is managed 'from linear system to circular system'*
- *turning risks into opportunities,*
- *Shifting from infrastructure delivery to more resilient services, and*
- *Shifting from silo to integrated and holistic policies with integrated actions.*

"Sustainability is a collective of integrated actions, and can be secured in the MENA region, only if each country plays its role" Dr Elmahdi.

Keynote Speaker

3) Economic Instruments for Water Sustainability in the GCC Countries

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Abstract:

GCC countries depend on seawater desalination for their urban water. Based on a water supply policy the GCC water utilities keep building more desalination plants to face the ever-increasing demand. In January 2022 the GCC population was estimated at 59 million people with 60% living in Saudi Arabia. One million babies are annually born in the GCC and around 300 thousand expatriate workers were added to the local population in 2021. With an average consumption of 260 l/cap/day the annual demand increase is estimated at 125 MCM. The supply policy is putting pressure on the energy demanded for desalination and increasing the GHG emissions. Few years ago, the GCC countries started reforming their water prices. The main driver was to strike a budget balance of the water utilities and stop or reduce the high subsidy paid by the respective governments due to the oil prices crisis. Currently prices for domestic water in the municipal sector vary widely among the GCC countries in structure and value even though billing is based on metering and volumetric uses. Bahrain, Oman, Saudi Arabia, and the UAE emirates (except for Abu Dhabi Emirate) have adopted progressive block price system, whereas Kuwait, Abu Dhabi Emirate, and Qatar use flat rate systems. Qatar and UAE exempt their national citizens from municipal water charges where the nationals, the wealthiest, are given free access to water without any limit. Though the proportion of nationals to total population is 11% and 14% for the UAE and Qatar, respectively the total nationals are 1.09 and 0.4 million respectively. Free water conjugated with high income resulted in very high water use exceeding 500 l/cap/day for Qatar, UAE and Kuwait.

The water price is a very commonly used instrument to manage demand. Even with the price increase in Saudi Arabia, the first block of water is priced at only 0.04 $/m^3 and the second block' price is 0.4$/m^3 (up to 30 m3/month). Considering an average household size of 6.4 this would mean a consumption of up to 156 liters/capita/day at a very low price, not conducive to water saving. In Oman prices are the highest, among GCC, and citizens pay 1.43 $/m^3 and 1.72 $/m^3 for the 1st and 2nd block respectively. As a result, Omanis have the lowest water consumption per capita with 200 l/cap/day among all GCC countries. The government in Oman is also planning to target the water subsidy to the needy and will apply the same principle used for electricity and fuel prices subsidy. The subsidy will be given according to the household income and number of people in the family. For instance, households earning more than 1250 OMR (12500 SAR) will not be eligible for subsidy regardless of the household size. GCC countries can improve considerably their water pricing policies. For that the first and most important step to undertake consists in exploring and using properly the large data sets available to them to estimate robust water demand functions based on the thousands of observed behaviors. Since all GCC countries base their billing on meter readings then data is available at household level. Census data is also available, which merged with household water monthly consumption could be used to generate detailed responses to changes in water prices and guide the water policy makers. On the other side, Outreach communications are needed in order

for a price change to lead to wasting less. Households should be taught on how to waste less water without sacrificing their comfort. Well-designed attractive short videos, infographics, short documentaries and movies should be diffused through social media and TVs. Virtual reality could also be used to reach people during special events. Example of messages are how to reduce the volume of a flush toilet without plumbing, the installation of sensor faucets, plumbing codes for greywater recycling at home and automated garden irrigation. In cities equipped with smart meters, alarms are sent to households in case a daily consumption is abnormally high leading to rapid leaks detections. Only if you give the households information, options, and support, they'll reduce waste and save water.,

In Zaragoza, Spain, the water utility offered a 10% discount on the water bill for any household that reduces their water use by at least 40% within the first year of the new pricing scheme (Stavenhagen et al. 2018). Water saving devices were showcased in public places. In order to increase adoption of water saving devices by households some water districts, in California, offered rebate programs that reduce the prices. Example of these programs covered low flow showerheads, automatic garden irrigation devices, landscape transformation and low flow toilets. Pérez-Urdiales, and Baerenklau, 2019 showed that the rebate programs generated higher investments in water-efficient technologies and resulted in additional water savings.

Water utilities in the GCC have no incentives to save water or to encourage users to save water given the constrained type of contracts with the private desalination plants. The "take-or-pay" type of contract makes it almost useless, in the short run, to save water as the water not taken by the water utility will have to be paid in all cases, even though at 85% of the full price. Hence, it is fundamental to consider taking the full volume and storing in an aquifer for later recovery to be able to bear the benefits of a potential water saving program. Finally, water utilities should measure the non-paid for water not only in cubic meters but in forgone revenue in monetary terms. Incentives to the public utility direct staff involved in such operations should be put in place to reduce the non-paid for water. The incentives should be as percentage of the net extra revenue generated, after deducting the costs spent on leakage control for instance.

Less water waste in the GCC will result in a cascade of benefits: (1) postponing the building of new desalination plants and wastewater treatment plants as the current ones can respond to the growth in demand due to population growth if consumption of current customers is lowered, (2) improvement of the water security via storage and recovery of excess desalinated water, (3) lowering the total cost to utilities and to users, (4) less energy consumption in the water sector, (5) less GHG emissions and above all (6) less brine disposal and enhanced sustainability. One major obstacle to shifting to a demand policy is the existence of vested interests to build more plants and create more projects which generate substantial benefits to private owners.

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SPECIAL SESSION 1: ECONOMICS AND FINANCING OF THE WATER SECTOR

Coordinator/Moderator:

Slim Zekri, Sultan Qaboos University, Oman.

Speakers and Panelists:

- Saud Al-Marshad, Ministry of Environment, Water, and Agriculture, KSA
- Ali Al-Hamdi, AZER Group for Engineering and Investment, Oman
- Abdulaziz Alturbak, King Saud University, KSA
- Buthaina Al Wahaibi, Oman Water & Wastewater Services Company, Oman
- Faisal Alfaisal, King Saud University, KSA

SPECIAL SESSION 2: CLIMATE CHANGE IMPACTS ON WATER RESOURCES IN GCC

Coordinator/Moderator:

Waleed Al-Zubari, Arabian Gulf University, Bahrain.

Speakers and Panelists

- **Marlene Tomaszkiewicz,** *ESCWA* "Bridging the Science-Policy Interface: From Climate Models to Regional Action"
- **Mansour Al-Mazroui,** *KAU* "Climate Change Possible Impacts on Water Resources in the GCC Countries"
- **Fadi Comair,** *EEWRC* "The Water Task Force Climate Change Initiative of The Cyprus Institute and The IHP-UNESCO ECOMED Academy Implementation Network in the GCC"
- **Abdelkader Laarabi,** *Morocco* "Climate Change Impact on Groundwater Using Simulation Modeling"
- **Walid Saleh,** *FAO* "Economic Analysis of the Impact of Climate Change on Agriculture in Arid Regions"

1) Bridging the Science-Policy Interface: From Climate Models to Regional Action

Marlene A. Tomaszkiewicz

Climate Change Data and Geospatial Analysis Expert,

Economic and Social Commission for Western Asia (UN-ESCWA). Email: tomaszkiewiczm@un.org

Abstract:

The Arab region with its diverse and complex geopolitical and socioeconomic landscape has faced several challenges to ensure sustainable water management and services. Freshwater scarcity, population growth, urbanization, and regional conflicts impede water resources, adversely affecting differing population groups. Climate change is expected to exacerbate pressures on systems, giving rise to food security, energy resources, human health, and ecosystems concerns.

Climate models are effective tools which can help quantify the magnitude of change. Programs such as the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) help bridge the gap between climate science and effectual policymaking. In 2017, RICCAR released the first trans-Arab regional climate models (at 50 km scale) to support regional action. Subsequently, to facilitate more detailed analyses and inform regional action, climate models were finalized for the Mashreq Domain in 2021. The Mashreq Domain transcends beyond the Mashreq to include the entire Arabian Peninsula, contributing transboundary waters, as well as north-eastern Africa and is available at a 10 km resolution. Within the next 20 years (2021-2040), results from the Mashreq Domain signal an average increase of 0.8 °C compared to just over a decade ago (1995-2014) in the GCC during the winter season (November-April). By mid-century (2041-2060), the projected increase is 1.9 °C. During the summer (May-October), the rise in temperature is expected to be slightly higher; in the GCC, projected changes are 0.9 °C and 1.9 °C by near-term (2021-2040) and mid-term (2041-2060), respectively.

With regard to precipitation, although the volume is projected to increase slightly, spatio-temporal variability will exacerbate. Rather than alleviate water scarcity, such irregularity will induce floods as well as droughts.

Climate science and resultant modelling outputs are not necessarily cause for alarm. Bridging the science-policy interface is rather a call for effective action.

2) Climate Change over the GCC Countries: Possible Changes to Water Resources

Mansour Almazroui

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Abstract:

The evidence of climate change is a matter of great concern for the socio-economic stability and sustainable development of nations around the world. The already very limited availability of fresh water is likely to be stressed even more by the negative impact of climate change, particularly over the semi-arid and arid region where the GCC countries are located. Our current research focusses on the projection of water resource changes, along with water scarcity and vulnerable mappings over the GCC countries, using state-of-the-art climate change scenarios. The research will provide recommendations on the future availability and management of water resources for different GCC countries for use in long-term planning.

3) Water Task Force in the Cyprus Institute in connection with The "Environmental Coastal Cooperation for Metropolitan Eco-sustainable Development" - Mediterranean Region

Fadi Georges Comair

Director of EEWRC, Cyprus Institute; Chair, UNESCO-IHP. Email: director.eewrc@cyi.ac.cy

Abstract:

Today more than ever, the metropolitan governments of the MENA region have been increasingly challenged with rising shortage of water resources, global extreme events and lack of regional coordination.

The IHP Mediterranean member states recognize that those challenges will have most significant environmental, societal and economic impacts on the sustainable development of the Mediterranean Region and must be addressed through Environmental Coastal Cooperation for Metropolitan Eco-sustainable Development ("ECO-MED") strategies to be jointly embraced and implemented by all the regional member states.

It is noteworthy that the sustainable development strategies are a must in order to promote consensus among all MENA communities and to support local governance capacity building for responding to the priority regional Eco-Sustainable Development Goals (Eco-SDGs). Nevertheless, the goal of regional hydro-diplomacy driven eco-sustainable development strategies is to create the necessary dynamics of regional cooperation for trans-boundary pollution monitoring of the coastal ecosystem, securing adequate pre-disposal treatment of wastewaters, undertaking depollution measures and promoting integrated water resources management, consistently with the COP's recommendations.

The ACADEMY's Network of "ECO-MED" Centers for Local Governance Capacity Building

UNESCO-IHP Metropolitan "ECOMED" Academy is a UNESCO-IHP initiative that will be hosted at the Cyprus Institute and will constitute a network of Local "ECOMED" Centers, established at the initiative of the interested Local Governments of the Mediterranean member-states concerned with the support of UNESCO-IHP experts and the collaboration of other UN agencies and International Organizations.

These centers involve local, regional and global partnerships with the coastal metropolitan stakeholders who will actively participate in the Center Governance for establishing its goals, resources, co-financing strategies, priority programs, info-systems, knowledge bases and strategic development roadmaps for meeting the regional SDGs of the Mediterranean coastal region.

While the initial phase of the UNESCO-IHP initiative will focus on the Mediterranean coastal region it is expected to provide a pilot model for other regions in the world.

"ECO-MED" Project Development Phase 1 - Feasibility Assessment & Pilot Program Development

Main Deliverables:

1. Academy's Governance Structure, Terms of Reference and initial Pilot Programs
2. Feasibility assessment of creating 5 pilot "LoG" Centers in the Mediterranean member-states
3. Academy's program presentation

4. Planning & Organization of the Stakeholders' Colloquium for Launching the UNESCO-IHP Metropolitan "ECO-MED" Academy
5. Creating the Academy's Governance Structure
6. Post-colloquium Proceedings

The Water Resources Task Force Report

The Water Resources Task Force Report surveys the state of water resources in the Eastern Mediterranean and Middle East and the challenges imposed by climate change on a water-scarce region. Reviewing national climate change adaptation strategies and evaluating the effectiveness of water-related adaptation policies and measures across the countries of the region, the report identifies gaps in research, policy and knowledge related to climate adaptation in the water sector.

The report applies a conceptual framework for achieving climate resilience and water security in the region, which recognizes the systemic aspects of climate change, water scarcity and shared water resources in the region. The framework's six lines of action for climate resilience and water security are governance; regional cooperation; finance; research and technology; reconstruction and resilience; and capacity development. Research initiatives should consider the application of the climate-water-energy-food nexus for improving water governance and achieving climate resilience and water security.

Solutions exist!

Our actions in facilitating multi-level and interdisciplinary dialogues are the only means of fostering peace, cooperation and development related to the management of water resources and to building a resilient and sustainable future for the forthcoming generations.

Bigger challenges are awaiting us! Greater cooperation is needed!

Together we can do it!

4) Climate Change Impact on Groundwater Using Simulation Modeling

Abdelkader LARABI

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Abstract:

The UN-Water Summit on Groundwater 2022 aims to bring attention to groundwater at the highest international level and to define actions towards more responsible and sustainable use and protection of this vital natural resource targeted by the Sustainable Development Goals (SDG-6). For the Mediterranean and Arab region, its water security is threatened by significant challenges such as population growth, urbanization, economic expansion, agricultural development and climate change (CC). Indeed, climate projections predict reduced precipitation, increased temperatures and a sharp decline in water resource availability. The region should enter a situation of extreme water stress in a few years. However, the water sector still faces challenges related mainly to the scarcity of water resources under the effect of CC and the overexploitation of groundwater resources.

Faced with this situation, the region must promote water resource management integrating the CC dimension and aiming not only at the optimal, economical and rational use of this resource, but also at its preservation. The objective of such an approach is to measure the current and future vulnerability to CC of a watershed/or an aquifer in order to identify relevant adaptation and resilience building options. This approach is based on coupling climate and hydrological modeling to study long-term natural aquifer recharge from precipitation and interaction between sea level rise SLR, discharge variations and coastal aquifer flow dynamics and the 3D seawater intrusion model. In addition, CC forcing scenarios are also used based on SLR and salinity of seaside boundary and natural aquifer recharge from precipitation. Based on this approach, an assessment was performed to evaluate CC impacts on groundwater resources availability and use in Morocco, specifically groundwater abstraction from the Tadla aquifer that supplies domestic water as well as large irrigation schemes in the Beni Amir agricultural area (Atlas), the Sahel coastal aquifer south of Casbalance and the coastal aquifer of Foum El Oued (Laâyoune) located on the desert south of Morocco. These pilot studies were based on projections of the Regional Initiative for the Assessment of CC Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR). Digital databases for the study areas were generated and a 3D conceptual groundwater model was also designed and simulated using a comprehensive set of physical processes. The model was calibrated and verified with observation data. Anthropogenic and climate forcing based on RCP 4.5 and RCP 8.5 scenarios were implemented in order to project impacts of CC on the groundwater system and long-term impacts on water and crops.

The main results confirm that groundwater resources in these aquifer systems will be affected by CC due to a reduction in natural recharge from reduced precipitation for both RCP scenarios, except for the Foum El Oued aquifer, where natural aquifer recharge will slightly increase. However, MSL rise will affect more seawater intrusion in the coastal aquifers. This is evident in a reduction of the water balance accompanied by a groundwater table decline for both scenarios which makes some aquifer areas completely dry, especially for the RCP8.5 scenario. These results are of great importance as key information for decision-makers regarding the future of the sustainable exploitation of groundwater resources in these aquifers. For instance, the results of the RCP 8.5 scenario present a great concern for the future of irrigation and agriculture in the Beni Amir area since some farms would be abandoned due to the unavailability of groundwater. On the other hand, the results of the RCP 4.5 scenario are less severe but will require rational and economical management of water resources. Adaptation measures that account for these impacts of CC on groundwater resources specifically in improving productivity in the agriculture sector are urgently needed.

5) FAO, Economic Analysis of the Impact of Climate Change on Agriculture in Arid Regions

Walid Saleh

Ph.D., PENG, Chief Technical Advisor, FAO Yemen. Email: Walid.Saleh@fao.org

Abstract:

Climate change is complex and far unpredictable as the most challenging environmental problem. The economic effects of climate change on agricultural production are a complex multidimensional issue. The consequences of climate change are therefore diverse, while populations in low-income countries are increasingly exposed to its negative effects. While food security can be enhanced by increasing agricultural production, this is affected under unsustainable circumstances such as water scarcity. FAO stated that the impacts of climate change on agriculture and the implications for food security are already alarming. Through its impacts on agriculture, livelihoods and infrastructure, climate change threatens all dimensions of food security. It will expose both urban and rural poor to higher and more volatile food prices. It will also affect food availability by reducing the productivity of crops, livestock and fisheries, and hinder access to food by disrupting the livelihoods of millions of rural people who depend on agriculture for their incomes.

While information about water scarcity in the MENA region is available, there is little knowledge of what this increasing scarcity means for Middle Eastern economies, employment, and food security. Water scarcity could lead to land-use change and deforestation. If water availability decreases by 20 percent, then a study of six countries (Iran, Syria, Lebanon, Jordan, Iraq, and Turkey-carried by the World Bank) could face an annual drop in GDP of between 5 percent to 10 percent compared to 2016 levels. Water scarcity could lead to land-use change and deforestation. Agriculture will suffer because of climate change and water scarcity, and crop prices are expected to increase for both crop producers and consumers.

According to RICCAR, additional information related to variations in extreme weather indices was also considered for a better understanding of the impacts of climate change on water supply in the region until the period 2030-2050. The results showed that drier winters and increased incidence of flash floods and surface run-off during the summer season are envisaged. In many subdomains, the moderate climate change scenario generated increasing run-off forecasts compared to the baseline values.

This situation is very clear in the Yemen case as the country is classified as one of the severely affected countries by climate change. Recently the rain pattern is highly vulnerable to climate change-related impacts because of its fragile socio-economic development and inadequate adaptive capacity as one of the least developed countries in the Arab region. Rural livelihoods are expected to decline due to decreasing water access and agriculture productivity, severe natural disasters including floods. Further, Yemen has only very limited adaptive capacities including weak governance structures while experiencing tremendous development challenges compounded by potential climate change-associated impacts. In this paper, a case study from Yemen showed one flooding event in Ma'rib that caused widespread destruction to irrigation canals was estimated at $50 million. That is besides the loss of human lives, livestock, and farmers' fields. Ma'rib was hard hit currently there are 90,000 families currently classified as Internally Displaced People (IDPs).

SPECIAL SESSION 3: ROLE OF NON-CONVENTIONAL WATER SOURCES IN GCC

Coordinator/Moderator:

Bisher Imam, UNESCO Cairo Office.

Session Speakers:

- **Bisher Imam, UNESCO Cairo Office.**
- **Mohammed Dawoud, Environment Agency-Abu Dhabi (EAD).**
- **Esra Aleisa, Kuwait University.**
- **Rashid Al-Abri, Sultan Qaboos University (SQU).**

Keynote Speaker

1) Hybrid desalination technologies for sustainable water-energy nexus: Innovation in integrated membrane module development

Hyuk Soo Son[1,2], Muhammad Saqib Nawaz[1], Sofiane Soukane[1], Noreddine Ghaffour[1]

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Abstract:

Global water scarcity is an imminent problem caused by the increasing water demand arising from population and economic growth. Against this background, technologies for water resource management and treatment have been developed steadily to meet the water demand targets. However, further advances are necessary for securing environmental and economic sustainability. The management of saline water and wastewater is one of the focus areas to tackle the problems of water scarcity and sustainability in the context of water desalination.

Hybrid desalination is one of the most practical and efficient technologies that can afford environmental and economic sustainability. Hybridization of multiple processes maximizes the advantages of individual technologies and minimizes their drawbacks. The overall research on desalination and research on hybrid desalination, in particular, increased by a compound annual growth rate of 16.6% and 21.8%, respectively, from 2011 to 2020. Meanwhile, in 2020, 10.7% of scientific articles and reviews dealt with hybrid technologies. Moreover, the advances in hybrid technology are not limited to academic research; they been widely implemented in the desalination industry. Reverse osmosis–multistage flash (RO-MSF) hybrid technology has been adopted for the largest desalination plant in the world, with a total water production of 1,036,000 m^3/day in Ras Al-Khair, Saudi Arabia.

The synergetic impacts of hybridization have various benefits depending on the desalination processes selected. In an RO-MSF system, the hybridization leads to additional water production with higher water recovery compared to a standalone RO system. Improvement in energy efficiency is another advantage of hybrid technologies as observed in the case of membrane distillation–adsorption (MD-AD) hybrid system. However, the challenges of hybrid desalination technologies are the complexity of process design, optimization, and operations. In this paper, the case of a forward osmosis–membrane distillation (FO-MD) hybrid system is presented to identify the challenges and potential solutions for hybrid desalination technologies.

An FO process is driven by the osmotic pressure difference between two streams and produces water across a hydrophilic polymeric membrane. By using a saline solution, known as the draw solution, freshwater may be recovered from a targeted feed solution stream with relatively lower salinity. MD is a thermal membrane process that makes use of the difference in vapor pressure between hot and cold streams to transport water vapor across the membrane to a cold permeate solution. These two membrane processes (FO and MD) are selected to treat the produced water, which is a byproduct in the oil and gas industry; produced water has extremely high salinity and complex organic composition and hence is one of the most challenging wastewater streams for water treatment.

Since FO and MD employ two different energy potentials (i.e., osmotic and thermal energies, respectively), hybridization allows maximizing the use of available energy in target streams (i.e., produced water). To solve the challenge of complexity of hybridization, a novel integrated membrane module was developed for an FO-MD hybrid system.

To evaluate the performance of the FO-MD hybrid system for produced water treatment, synthetic produced water streams were prepared according to water quality references from a conventional oil and gas production facility. Separate FO and MD experiments were conducted to study the membrane-fouling phenomena of different produced water qualities. In addition, the FO-MD hybrid system is operated with varied combinations of produced water streams for sustainability evaluation. The average values of initial FO and MD water fluxes were measured as 49.9 and 19.3 $kg/m^2/h$, respectively, and the average FO/MD energy consumption ratio was 0.70. The experimental results demonstrate the great potential of the FO-MD hybrid system for sustainable produced water treatment. Long-term operation of the hybrid system and experiments with real produced water samples are necessary for scaling up and optimizing the technology.

Investigating the water–energy nexus related to the desalination technologies integrated with renewable energy is one approach to broaden the applications of hybrid desalination technologies. Such a study will emphasize the advantages of hybridization despite the complex challenges. The benefits of hybrid technologies in terms of greater water production, higher recovery, and cleaner water quality will be synergized with less energy consumption by their integration with renewable energy. Meanwhile, artificial intelligence (AI)-based process design, optimization, and control will be an important tool to address the complexity of hybrid desalination technologies and will provide a comprehensive understanding on the challenges, for which the conventional experimental and theoretical studies are still limited. AI algorithms, such as machine learning and artificial neural network algorithms, are the leading approaches for the advancement of AI-assisted smart desalination.

2) Levelized Cost Analysis for Desalination using Renewable Energy in GCC

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Abstract:
Seawater desalination plants are considered the main source of fresh water in most of the GCC countries. Desalination is an energy-intensive process, where energy price represents more than 44% of the cost of desalinated water. Almost all commercial desalination plants rely on fossil fuel to secure the energy requirements either in thermal or electrical form. GCC countries are gifted with consistent and predictable solar energy that can be used to power the desalination processes and to improve their sustainability and to reduce their environmental impacts. Solar energy can be harvested using Photovoltaics (PV) panels or different forms of Concentrated Solar Power (CSP). In this paper, the energy cost in the form of Levelized Cost of Energy (LCOE) was calculated for a PV solar energy generation plant and hence, the Levelized Cost of Water (LCOW) for a Reverse Osmosis reference desalination plant in the six GCC countries had been estimated and compared. System Advisor Model (SAM) is a comprehensive renewable energy analysis software developed by the National Renewable Energy Laboratory (NREL) and is used in this work. SAM relies on the metrological weather data for the evaluation of solar energy. The included financial model within SAM was used to estimate the LCOE and the Power Purchase Agreement (PAA) price.
A reference RO desalination plant of a capacity of 400,000 m^3/day (88 MIGD) has been used in this study. The power consumption of the plant is estimated as 76 MW at 4.56 kWh/m^3. A Photovoltaic Power Plant (PVPP) of capacity 76 MW was designed and the LCOE produced by this pant was estimated. The LCOE was different according to the PV plant location in GCC countries. The obtained LCOE is used to estimate the LCOW produced by this plant using Desalination Economic Evaluation Program (DEEP) software. The LCOE for the studied locations ranged from 8.46 to 9.11 ¢/kWh (1.0 USD $ = 100 ¢), and the LCOW ranged from 103.0 to 105.0 ¢/m^3, compared to 10.737 ¢/kWh and 110.1¢/m^3 for the conventional Combined Cycle Power Plant (CCPP)

Keywords: Levelized Cost of Energy (LCOE), Levelized Cost of Water (LCOW), Desalination Processes, Renewable Energy, Solar Desalination, System Advisor Model (SAM), Desalination Economic Evaluation Program (DEEP).

3) Prospect of Utilization of Solar Energy in SWCC Existing MED Desalination Satellite Plants

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Abstract:

The shortage of drinking water source limits the socio-economic development of many areas of the world. Saudi Arabia has very limited resources in fresh water source and around 40 to 50 % of portable water in Saudi Arabia is produced by desalination technology which depends on using fossil energy. As the high cost of water and electricity production reflects depleting oil resources of the country, which is nonrenewable, solar energy would be a good alternative since Saudi Arabia has abundant free solar energy. This study investigates the feasibility of using concentrated solar power system (CSP) for thermal desalination. The study is conducted for CSP coupled with multi effect desalination with thermal vapor compressor (MED-TVC) existed in western province Saudi Arabia in five locations with various DNI, for two cases, without storage and with 16 hours storage. The total saving from coupling solar collectors to all five plants shows around 20.45 million $ per year. Using of solar energy can reduce carbon dioxide emission to the environment by 420 thousand ton per year for all selected plants.

Keywords: MED-TVC, Solar, Desalination, Cost of Water (LCOW)

4) A Common Platform for Evaluating the Energy Efficiency of Power Generation and Desalination Plants

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Abstract:

The energy efficiency of seawater desalination processes is usually expressed in terms of the consumption of derived energy, either kWh electricity or low-grade heat per m^3 of water produced. Such an approach, unfortunately, has omitted the embedded energy quality consumed by multifarious methods underlying the generation processes. To avoid thermodynamic misconceptions, it is important to recognize both the quality and quantity or the absolute energy that were consumed by assorted desalination methods. An inadequate efficacy analysis, based merely on quantitative apportionment, may result in an unjust comparison of desalination methods leading to economic burden and excessive emission of pollutants. This article clarifies misapprehensions regarding any seeming parity between electricity and thermal heat sources that are sequentially cogenerated within the power plants. A common energy platform to address the quantity and quality of energy consumption is associated with the derived energy via a thermodynamic framework. Firstly, the classical heat engines relate to maximum (Carnot) work for all processes of a power plant, operating at designed conditions whilst producing electricity and thermal heat sources concurrently. Secondly, the maximum work ascribed to a derived energy type is delineated to the standard primary energy (Q_{SPE}) consumption by characterizing the latter to maximum fuel and the ambient temperatures. By affixing Q_{SPE} consumption to the best available power plants, hitherto, two types of benchmark ratios of standard primary energy to actual work and heat input are prudently defined, i.e., Q_{SPE}/W_a for electricity and Q_{SPE}/Q_a for thermal sources. These yield correspondingly the useful conversion factors (CF_{elec} & CF_{ther}) that are applicable to all known performance data of desalination processes either kWh_{elec} or kWh_{ther} per m^3, as reported in literature or measured in-situ. A reverse appraisal of the equivalent Q_{SPE}, i.e., $Q_{SPE}/m^3 = CF_{elec}$ x [kWh_{elec}/m^3] or CF_{ther} x [kWh_{ther}/m^3] is retrospectively obtained. By collating Q_{SPE} consumption at a common energy platform, the thermodynamic framework provides a judicious and meaningful energy efficacy comparison of all desalination methods.

Keywords: Standard primary energy, Energy efficiency, Desalination, thermally-driven MED.

5) An Innovative Direct-contact Spray Evaporation and Condensation (DCSEC) with Micro-Bubble Enhancement for Low-Costand Renewable Energy Thermal Seawater Desalination: An Experimental Study

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Abstract:

All practical seawater desalination methods available hitherto are energy intensive and hence, there is much motivation for greener desalination processes, requiring mainly low temperature heat sources as well as reducing chemical use in the pre-treatment of seawater feed. In this paper, a direct-contact spray-assisted evaporation and condensation (DCSEC) is presented as a greener approach to seawater desalination and yet with lower CAPEX and OPEX. It can mitigate major issues associated with existing desalination processes such as excessive chemical use for pre-treatment of seawater feed and excessive emission of CO_2 from the intensive use of electricity in desalination processes. Also, an experimental investigation on the simple and hybrid DCSEC designs is discussed, incorporating a novel micro/nano-bubbles(M/NBs) generator device that could enhance the distillate production by flashing of seawater feed vis-à-vis by as much as 34%. The measured performance of DCSEC is highlighted for two design configurations, namely the single and multi-stage arrangements. The latter configuration recorded higher energy efficacy by recovering latent heat of distillate condensation up to 70% of the total specific energy consumption. The figures of merit for quantifying DCSEC performance, such as the distillate production and the performance ratio (PR) of desalination, are presented with respect to assorted feed temperatures varying from near ambient up to 60°C, and the seawater(feed) flow rates changing from 4 to 8 L/minute in finite size evaporator/condenser chambers. From these experiments, optimum design parameters of the DCSEC are also resolved.

Keywords: Thermal desalination, direct contact evaporation and condensation, liquid flashing, micro-bubble enhancement, internal latent heat recovery, low CAPEX and OPEX operation.

Keynote Speaker

6) Toward Developing Key Performance Indicators (KPIs) for Desalination Processes

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Abstract:

Key performance indicator (KPI) is a discipline that involves articulating what an organization is trying to accomplish and afterward identifying the most meaningful and useful indicators of success. KPI is a key part of a strategic management system. Noteworthy KPIs provide information into whether strategies are working, and programs, objectives and goals are accomplished.

In this work, KPIs principles will be reviewed. Then the strategic objectives and goals for operating desalination plants in effective manner will be utilized to develop viable strategic plan, set initiatives and programs to achieve certain objectives and goals in the field of water desalination. Operational performance measures will be used to identify the applicable and appropriate KPIs. KPIs for water desalination plants are convenient tools in assisting to manage practical operation of the plants.

Keywords: Performance, Metrics, Key Performance Indicators, Performance Indicators, Strategic Plan, Water Strategic Plans, Desalination.

7) Unlocking the Desalination Processes Future Roadmap

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Abstract:

Energy-water-environment nexus is very important to attain COP21 goal, maintaining environment temperature increase below 2°C, but unfortunately two third share of CO_2 emission has already been used and the remaining will be exhausted by 2050. A number of technological developments in power and desalination sectors improved their efficiencies to save energy and carbon emission but still they are operating far from their thermodynamic limits. The theoretical thermodynamics limit for seawater desalination at normal conditions is about 0.78 kWh per m^3 depending on the initial salt contents. However, practical plants are operated at several folds higher than this limit due mainly to inherent losses in the processes that were incurred in removing dissolved salts. Technological advancement in thermally driven processes hybridization have set the new benchmark for lowest energy consumption that has boosted the water production trend of desalination industry. In this paper, we presented multi-effect desalination (MED) hybridization with Pressure Swing Adsorption (PSAD) cycle to overcome lower brine temperature limitations to boost overall performance of the system. The synergetic effect from hybridization of MED-PSAD permits a higher overall operational range and inter-stage temperature differences, leading to a boost in water production up to 2-3 folds. We showed that the proposed hybrid cycle can achieve highest performance SUPR=20% of thermodynamic limit: one of the highest performance reported in the literature up till now. These figures can be translated to less than US$ 0.47/m^3: a lowest specific cost ever reported in the literature. The proposed cycle is not only tested at pilot scale, but also successfully commercialized into industry and received many international awards as one of the most efficient and sustainable desalination technology.

Keywords: Hybrid desalination, energy efficiency, desalination sustainability, thermodynamic limit.

8) High Temperature Multi Effect Desalination 95°C demonstration in DTRI pilot plant

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Abstract:
Multi Effect Distillation (MED) is one of the most efficient thermal desalination technologies. Efficiency improvements in MED systems have been brought forth through the use of Thermo Vapor Compression (TVC), Mechanical Vapor Compression, MED-Adsorption Desalination (AD) and MED- Absorption Desalination (AB). However, these systems have been operated within the conventional Top Brine Temperature (TBT) range i.e. below 66°C. In the present study, a successful demonstration has been made, wherein the TBT was increased to 95°C without any adverse effect on the integrity of the MED unit. The methodology adopted, performance seen and the potential benefits of the system in terms of the levelized cost and the energy saved are discussed.

Keywords: MED, thermal desalination, efficiency, saving energy, Techno economic.

9) Performance and cost analyses of hybrid diesel-PV powered small brackish water RO system in Saudi Arabia

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Abstract:

The need for water is certainly very alarming in the Middle East and North Africa (MENA) region where water demand for domestic, agriculture, and industrial applications continue to increase, and on the other hand, water resources are increasingly becoming scarce (low precipitation and depletion of renewable groundwater). Inland desalination process in off-grid or remote areas contributes a significant portion to the water supply in Saudi Arabia. However, inland desalination systems have many challenges to be well implemented such as limited water distribution, water transmission cost from seawater desalination plants to the inland area. Many wells in Saudi Arabia have relatively high salinity water, which is not directly usable. This study aims to find the best hybrid diesel-PV powered reverse osmosis (RO) system to desalinate brackish water that has 6000 ppm salinity for a remote area near Ummluj city in the kingdom. Each RO system produces 202 m^3/day for two purposes: drinking and household purposes. A batch mode that operates 5 hours a day is studied. The hybrid system composed of conventional and renewable energy systems driven brackish RO system are modelled using ROSA and HOMER software. Besides, the advantages of adding a pressure exchanger (PX) and a second stage are investigated. Further, the effect of the fuel price on the cost of water production is analyzed. It was found that adding a second storage tank for household applications with 1000 ppm reduces the levelized cost of water (LCOW) by 11%. Furthermore, using a pressure exchanger leads to 26% reduction in the specific energy consumption (SEC) while adding a second stage reduces the SEC by 22%. However, adding PX is economically feasible for fuel price higher than 40 USD/l.

Keywords: Solar energy, fresh water, optimization, desalination, batch mode, remote areas.

10) Integration of solar vacuum membrane distillation to treat seawater reverse osmosis brines

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Abstract:

Reverse osmosis (RO) desalination technology is widely used for drinking water with relatively low energy consumption, but it results high rejected brine volume inducting negative environment impact. The objective is to study the feasibility of integrating of solar vacuum membrane distillation to concentrate RO brine. The goal is to reach concentrations to the very high ranging from 30 $g.l^{-1}$ to 300 $g.l^{-1}$ (concentration factor 10). This study has allowed to study different operating parameters on the process performance. The comparison between the performance of a reverse osmosis plant and a plant coupling reverse osmosis with vacuum membrane distillation showed that the water recovery increases from 40 to 89%, and the brine volume could be reduced by a factor of 5.5.

Keywords: Vacuum membrane distillation, osmosis brines, treatment, solar energy, integrated approach.

Keynote Speaker

11) Sustainable Desalination: How to produce sufficient water towards the future, while protecting the marine environment

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Abstract:

The population in the Middle East Gulf area is growing and with that the water demand. In a region with very little rainfall and almost no rivers, this presents a challenge. Over the past decades, groundwater has been used as a water supply for drinking water as well as agriculture, but in many places, the groundwater reserves have been depleted. Towards the future, the dependency on seawater desalination will become larger and some areas will completely depend on this source of produced water.

The total amount of desalination plants and their capacity has risen exponentially over the last few decades, whereas the current production of desalinated water from reverse osmosis accounts for approximately 69% (~66 million m3/day) of the global volume of desalinated water (~95 million m3/day; Jones et al., 2019).

A clear trend from thermal desalination technologies (MSF, MED) to seawater reverse osmosis (SWRO) can be observed, globally and in the Middle East Gulf region specifically. This shift in technology also results in a trend in the market to decouple energy from water production. Power and desalination plants were commonly co-located in the past due to the use of thermal energy from the power production process for thermal desalination. However, an RO plant only uses electricity and can therefore be decoupled from the powerplant, both technically and economically.

The main difference between the different desalination technologies in relation to the marine environment is the type and amount of brine effluent these technologies produce. Thermal desalination typically has a larger brine flow (often with elevated temperature and slightly elevated salinity of about 10%). SWRO effluent typically has no elevated temperature, but strongly elevated salinity (of about 50% or more), but the discharge rate is much less. The SWRO effluent thus provides a smaller, denser effluent plume that could result in high salinity levels near the bed, if not properly diluted by the outfall (e.g. by a diffuser).

For sustainable desalination, it is important to be able to predict the effects on the environment of the discharged brine effluent when designing new desalination plants or planning plant capacity around the Gulf. Questions about this environmental impact play on different spatial and temporal scales and should be considered accordingly with suitable models and methodologies. Close to the desalination brine outfall, near field effects play an important role in the initial mixing of the effluent. Near field mixing models, like CORMIX and CFD are required to compute these non-hydrostatic effects accurately. However, these models use a simplified geometry and ambient flow conditions, relevant close to the outfall (typically about 100m). Further away from the outfall, a far field model like

Delft3D is required to predict the outfall plume dispersion and possible effects on the environment in more detail and to ensure a good, compliant outfall design. On an even larger scale, the combined effects of the desalination industry (i.e. multiple plants) should be considered, e.g. on a Gulf-wide scale. Here, also the longer-term natural effects like evaporation, large-scale circulations and climate change effects play a role. Large-scale models, like the open Gulf Community Model, are available to investigate and study long-term scenarios as input to a sustainable national desalination strategy.

Here also important questions currently play in the Gulf region that are still subject to research: Does climate change have a larger impact on the Gulf's salinity or does the increasing desalination capacity have a larger impact? Our research shows that closer to desalination plants, an increase in capacity shows a larger impact and that in areas without brine discharges, climate change has the larger impact. On a Gulf-scale, differences average out more, but regional differences can be expected, as well as possible changes in circulations that could increase salinity and its variability in some regions, but also reduce salinity on average slightly in other areas. Knowledge from such research could also inform a sustainable desalination strategy and be downscaled to plant level again.

Back to the current market dynamics for desalination plants. It is a point of attention that independent water plants (built and operated by a consortium of partners for decades) are still granted the project at the lowest metre cube water price, rather than the most sustainable design and operation. It is a challenge, but also opportunity, for water companies to put projects on the market that demand the highest levels of sustainability (in conjunction with different stakeholders like environment agencies, local communities, looking at employment etc.) in addition to an economic preference. Steps are being made in the right direction and many innovations are being developed and tested that can promote this further, like sustainable outfall designs.
An example of such sustainable outfall designs could be an outfall that can double as an artificial reef. The impacts of brine discharges on the marine environment may not be as high as thought before according to our and Australian research, although it still needs careful consideration. Outfalls are often observed as covered with marine life, as being a hard substrate for life to settle on. Outfalls (and intakes) could also be designed specifically with this (additional) function in mind.

Furthermore, not all sites around the World are equal and it is important to adopt site-specific and ecologically relevant criteria for a desalination brine outfall. Often mixing zone criteria are adopted from other parts in the world, with different ecosystems that could be either harmful to local ecosystems or be overly restrictive. Research is needed and useful to develop more relevant criteria that could be adopted by regulators and increase the sustainability of desalination in relation to the marine environment, while ensuring sufficient water for everyone in the future.

12) The Characterization of the Water Mass Dynamic Changes Surrounding an SWRO Desalination Plant on the East Coast of the Kingdom of Bahrain

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Abstract:

Desalination in the GCC countries is essential in the provision of drinking water supply and in achieving the targets of the UN Sustainable Development Goals (SDGs), particularly SDG6.1 aiming at achieving access for all to safe drinking water. On the other hand, desalination process is associated with several environmental externalities that have adverse impacts on the coastal and marine environments. The aim of this research is to assess the dynamic changes of the water mass quality parameters resulting from a seawater reverse osmosis (SWRO) desalination plant located on the east coast of Bahrain, in relation to the tide cycle on seasonal basis. The evaluation is based on the spatial differences in water temperature and salinity in the surrounding areas of the plant outlet within about 2.5 km2. Water samples were collected at 42 locations for both surface and bottom waters over high and low tide cycle during winter and summer. The results revealed an extreme elevation in temperature (>38°C) and hypersaline waters (>55‰) at locations nearby the discharge outlet as well as at bottom waters of depths >3 m in both seasons with exceptional levels in summer particularly during high tide cycle. Thermocline and halocline formations were noticeably occurred particularly during high tide in both seasons due to vertical differences in temperature (>3°C) and salinity (>1‰) at several locations associated with depths more than three meters. The thermocline and halocline formations indicate the path by which the thermal and hypersaline water mass fluxed by the desalination plant sinking out towards the open water. The impacts of Al-Dur SWRO desalination need to be minimized to maintain the seagrass habitat around the coast to support the marine biodiversity, particularly the megafauna endangered species associated with seagrass, (dugongs, green turtles and dolphins) and other finfish and shellfish species.

Keywords: Environmental Impacts, Temperature, Salinity, Tide Cycle, Thermocline, Halocline, Al-Dur.

13) Governing Business in the Seawater Desalination Sector through TeroTechnology

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Abstract:

The business sector of seawater desalination is composed of three major sectors in the MENA Region and World-Wide: Public Sector, Private Sector and Public-Private Partnership. Regardless of the desalination process whether it is based on thermal principle or reverses osmosis principle, the Terotechnology had approved itself as a key-tool in controlling the whole life-cycle of the process from asset management point of view. The Terotechnology, which is composed of seven major phases including: Specification, Engineering, Manufacturing, Installation, Commissioning, Operation & Maintenance and finally the Asset Obsoleteness or Replacement, can be used as a tool to govern the Desalination Business in all its three forms. The objective of this paper is to illustrate how to implement this in practice; "how to govern the desalination business through Terotechnology" and will be supported with real cases from the Public Sector, Private Sector and the PPP Sector from IWPP cases whether it is BOOT or BOO.

Keywords: Desalination, governance, life cycle costing, privatization, public-private-partnership, Terotechnology.

14) Reuse of Reverse Osmosis Membranes in Tajoura's RO Desalination Plant

إعادة استخدام الأغشية الأسموزية المستهلكة في محطة تحلية تاجوراء العاملة بتقنية التناضح العكسي

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الملخص:

تواجه ليبيا حاليا تحدياً كبيراً فيما يتعلق بالإمداد المائي، وذلك بسبب عدة عوامل منها: الانخفاض الملحوظ في جودة المياه الجوفية ولا سيما في الأقاليم والمدن الساحلية. هذا التحدي من المحتمل أن ينتج عنه مشاكل في توفير المياه الصالحة للشرب، وكذلك المياه اللازمة للزراعة. من الممكن أن تكون تقنية تحلية مياه الآبار ومياه البحر الصديقة للبيئة وإعادة استخدام مياه الصرف الصحي والمياه العادمة أحد البدائل والحلول الرئيسة لهذه المشاكل. يوجد حاليا عدد 21 محطة تحلية عاملة في ليبيا، بسعة تصميمية كلية 525,680 م^3/اليوم. تمثل تقنيات التحلية بالطرق الحرارية 95% من التقنيات المستخدمة، بينما تمثل تقنيات التحلية بواسطة الأغشية الأسموزية (التناضح العكسي) 5%. تعد محطة تحلية تاجوراء إحدى أقدم محطات تحلية المياه العاملة بطريقة التناضح العكسي في ليبيا، وتتجاوز فترة تشغيلها الآن الثلاثة عقود، إلا أنه لم يتم إجراء أي دراسات شاملة حول المحطة تتعلق بالآثار البيئية أو إعادة استخدام أغشيتها القديمة، والتي لا تزال كميات كبيرة منها مخزنة في أماكن معينة داخل المحطة. لا يتم الفحص الدوري الدقيق على مدى جودة وصلاحية الأغشية الأسموزية المستخدمة في محطة تحلية تاجوراء، ولا يتم استبدالها بأخرى جديدة في الوقت المناسب. الهدف الرئيس من هذه الورقة هو تسليط الضوء على مسار وتاريخ الأغشية الأسموزية المستخدمة في محطة تحلية تاجوراء منذ بداية إنشائها، ظروف تخزينها، كمية الأغشية المتهالكة (المعدومة)، وأخيراً اقتراح عدداً من الخيارات والبدائل التي من خلالها يمكن إعادة استخدام هذه الأغشية. وأهم مخرجات هذه الدراسة تتركز في أن هناك قيمة اقتصادية لا تزال كامنة في بعض مكونات الأغشية الأسموزية القديمة، وبالتالي هناك بعض خيارات الاستفادة من هذه المكونات بطرق كثيرة، وفي تطبيقات مختلفة. تحويل الألياف الزجاجية المكونة للغلاف الخارجي للغشاء الأسموزي إلى قطع صغيرة أو طحنها في شكل مسحوق لتكون مواداً خاماً لإنتاجات بلاستيكية جديدة من البدائل الرئيسة التي ينصح بها الباحثون بشدة، بينما توفر بعض المكونات الأخرى مثل الشبكات المصنوعة من البولي بروبيلين (polypropylene spacers) فرصاً جيدة للاستفادة منها في التطبيقات المنزلية والزراعية.

الكلمات الدالة: تحلية المياه، التناضح العكسي، الأغشية الأسموزية، إعادة تدوير البوليمر.

15) Assessment 0f Freeze Melting Technology for Brine Concentration

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Abstract:

High saline waters are produced in large volumes in Kuwait from various industrial applications, including desalination and petroleum sectors. These types of waters as a waste have a significant impact on the surrounding environment, and some of which may pose a number of threats to human health. Freeze Melting (FM) technology is considered a novel desalting process that can be further developed for innovative saline water desalination. This paper aimed at evaluating the viability and efficiency of FM process under static and dynamic influences for brine concentration. The dynamic crystallization process was investigated with three agitation systems, which are: A Bubbling System (BS), a Mechanically Stirred System (MSS), and an Ultrasonic System (US). The results of dynamic crystallization process were compared to the results of the static crystallization process. The results of the experimental works showed that the most effective crystallization processes were the mechanically stirred agitation system followed by bubbling agitation process and the ultrasonic system using a single-stage of freeze crystallization. The promising results obtained, will lead to a future hybrid system of near zero liquid discharge that combine Reverse Osmosis (RO) and FM process to concentrate the volume of brine to the minimum level possible and simultaneously produce high quality product water, which will eventually lead to enhance the overall permeate water recovery of the integrated technologies.

Keywords: Freeze-melting process, nucleation, melt crystallization, freezing desalination, ice crystallization, static freeze crystallization.

1) Produced Water Reuse enabling Circularity in Oil Operations

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Abstract:
Saudi Aramco conducted comprehensive a field-testing program of produced water desalination technologies primarily targeted for produced water reuse as process/utility water and other industrial purposes with low TDS (<1000 mg/l). The main driver for the produced water re-use program was due to, firstly transition from linear model of economic growth, which is based on "take-make-dispose", which is not sustainable to Circular Economy (CE) model supporting "closing the loop" of recovering value from produced water considered waste stream and secondly the conservation of Saudi Arabia's precious non-renewable ground water resources which are currently used for crude washing in desalting across Saudi Aramco. The program will reuse produced water in its oil operations, with potential ground water savings up to several billion gallons annually post implementation and also enable circularity sustainably in its oil operations. The objectives of the program were to evaluate the produced water desalination with minimum 70% recovery factor as performance for two different configurations i.e. desalination of low salinity (TDS) produced water (<15,000 mg/l) and high salinity (TDS) produced water (<120,000 mg/l). A US patent 10,703,989 was also granted for the concept of produced water reuse. Produced water desalination testing was conducted at two different produced water streams in Arab Light crude oil at two different sites with gravities of 36-41 API, to determine the desalination performance and challenges with pre-treatment. Variation in feed conditions such as flow rate, temperature, inlet oil in water concentration and H_2S in water, recovery factor were introduced to establish operating envelopes for the produced water desalination systems. The performance of two field produced water desalination technologies was evaluated by determining the Salinity (TDS) and oil in water concentration at different operating conditions. Prior to piloting the laboratory bench test were conducted at lab scale to characterize the performance of produced water. The lab test helped identify the challenges during pilot testing and demonstrated that produced water desalination for sustained flow conditions. This paper presents the key results of produced water re-use program along with two field tests as well as the path forward to deployment of these technologies to unlock the value for produced water as resource in circular economy. The implications of this program success extend beyond Saudi Aramco. By increasing produced water reuse in the oil and gas processing, more groundwater will be available for non-industrial applications in Saudi Arabia, which reduces reliance on seawater desalination.

Keywords: Produced Water, Desalination, Sustainability, Produced Water Reuse, Circularity, Arab Light.

2) Database for Total Petroleum Hydrocarbon in Industrial Wastewater Generated at Sabhan Area in Kuwait

A. Al-Haddad, M. E. Ahmed, A. Abusam, A. Al-Matouq, M. Khajah and R. Al-Yaseen
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Abstract:
A research study was carried out to collect data on the quality and quantity of petroleum and non-petroleum industrial wastewater from different sources in Kuwait over a period of one year as well as developing a database of such characteristics and attributes using geographic information system (GIS) technique. During the field visits, a specially designed field surveys were submitted to the owners of industrial facilities in three industrial areas in Kuwait, namely, Sabhan, Kuwait City, and Shuaiba Industrial Areas. In this study, Wastewater samples were collected and analysed on monthly and biweekly basis from 14 non-petroleum factories of Sabahan industrial areas. This paper was targeting assessment of total petroleum hydrocarbon in the raw wastewater for factories of Sabhan industrial area. The field wastewater data indicated presence slightly acid to slightly alkaline (4.9-10.8), reduced to oxidized environment (-410 mv-538 mv) and freshwater to brackish water (120µS/cm-8,673µS/cm). The laboratory results revealed that total petroleum hydrocarbon concentrations for wastewater of 14 factories ranged between 0.3 mg/l and 19 mg/l. The mean values of total petroleum hydrocarbon concentrations for wastewater of 14 factories were meeting the maximum limit (5 mg/l) set by KEPA for irrigation water purposes except those values of TPH (> 5 mg/l) for three factories. The mean value of quantities of wastewater generated from 14 factories was found 55,894 m^3/week. The large quantities of raw wastewater generated from these factories can be used safely as irrigation water for landscaping and greenery with respect to total petroleum hydrocarbon concentrations.

Keywords: Sample collection, laboratory results, field survey, non-petroleum and reduced.

3) The effect of industrial activities on the heavy metals contamination of irrigation waters, soils, and plants in Kafr El-Dawar district, Egypt

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Abstract:

The aim of this research was to evaluate the effect of industrial activities on the heavy metal contamination of irrigation water, soils, and plants in Kafr El-Dawar district, Egypt. An environmental monitoring of the pollution sources carried out in the study area through collection and analyses of water, soils, and plant samples in the representative locations. The results revealed that: a) The qualities of all measured parameters of the fresh Mahmoudia canal water were within the recommended limits; b) The amounts of heavy metals in Kafr El-Dawar drain water before receiving the outlet effluents of industrial companies ranged from 3 to 4 times higher than those in Mahmoudia canal; c) The concentrations of heavy metals in the industrial outlet waste effluents for all studied companies were much higher than the permissible limits; d) The concentrations of heavy metals at the mixing points between the industrial waste effluents and Kafr El-Dawar drain water were relatively low than that of the industrial outlet waste effluents, but still very high compared to that of Kafr El-Dawar drain water and permissible limits; e) Heavy metals contents in soils adjacent to industrial companies were very high compared with that irrigated from Mahmoudia canal; f) Soils adjacent to Textile and Spinning Company had toxic level of Cd, while the soils adjacent to Tinting and Chemicals, Industrial Silk Egyptian, and Al-Bayda Dyers Companies had toxic level of Pb, Cd, and Zn; g) The grown plants in Textile and Spinning soil had toxic level of Ni, plants grown in Tinting and Chemicals and Al-Bayda Dyers soils suffer from Pb, Ni, and Co toxicity, while the growing plants in Industrial Silk soil suffer from Pb and Ni toxicity.

Keywords: Contamination, Industrial Wastewater, Lead, Cadmium, Nickel, Cobalt, Zinc.

Keynote Speaker

1) The Gulf Countries and the Water-Food Security Nexus
دول الخليج العربية ومتلازمة (الأمن المائي والغذائي)

خالد الرويس

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الملخص

يوجد ارتباط وثيق واعتماد واضح بين المياه وإنتاج الغذاء، حيث يســـتهلك القطاع الزراعي كميات كبيرة من المياه لتلبية الطلب على الغذاء، والماء مدخل أساسي على طول المراحل المختلفة من سلسلة إمداد الزراعة-الغذاء وتتسم دول المجلس بندرة المياه، وشُح الغذاء، كما أنها عُرضة بدرجة كبيرة لتغير المناخ. الاستخدام المفرط للأسمدة والكيماويات الزراعية خلق احتمالية خطر تلوث موارد المياه الجوفية وتأثيرات بيئية وصحية محتملة، كما تمثل مياه الصرف الصحي مصدرا مائيا هاماً ومتجددا للقطاع الزراعي إذا تمت معالجتها بالشكل المطلوب واتخذت الاحتياطات السليمة لاستخدامها، ولكن من الصعب الاستمرار في توفير المياه للقطاع الزراعي في ظل تدهور موارد المياه الجوفية وزيادة المنافسة مع القطاعات الأخرى (البلدية والصناعية).

لقد أدى تبني مفهوم الاكتفاء الذاتي إلى خلق تعارض واضح بين الأمن المائي والأمن الغذائي في دول المنطقة، وتزداد حدة روابط المياه والغذاء مع الوقت بسبب زيادة الطلب على هذه الموارد والمحددات الأخرى، وبالتالي فإن محاولة تحقيق الأمن في أي من هذه القطاعات بشكل مستقل وبدون النظر إلى تأثير ذلك على القطاع الآخر من الممكن أن يُعرض أمن واستدامة القطاع الآخر للخطر.

2) Cost-benefit analysis of the shift from traditional irrigation systems to modern irrigation methods by small farmers in Al-Ahsa and its role in dissemination of modern irrigation techniques

تحليل التكلفة والفوائد للتحول من نظم الري التقليدية إلى طرق الري الحديث من قبل صغار المزارعين بالأحساء ودور ذلك في نشر تقنيات الري الحديث

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الملخص:

قامت هذه الدراسة بالنظر في جدوى الاستثمار في طرق الري الحديثة من قبل صغار المزارعين الذين يعتمدون على النخيل كمحصول رئيسي. وأثبت التحليل المالي وتحليل التكلفة والفوائد الجدوى العالية لذلك الاستثمار وإمكانية استرداد كافة التكلفة في نهاية السنة الأولى ومن ثم تحقيق فوائد. وكانت الجدوى هي الأعلى للمزارعين الذين يستفيدون من مياه ري المؤسسة. كما يشكل التخفيض في فاتورة الكهرباء المقدر بحوالي 40% نتيجة لترشيد استخدام المياه حافزا مقدرا لأصحاب الآبار الخاصة للتحول لطرق الري الحديث، وتكون فوائدهم هي الأعلى في حالة إيقاف آبارهم والتحول للري من المؤسسة. وفيما يخص اختبار مدى مقدرة صغار المزارعين على دفع تعرفة مياه الري المتوقع تطبيقها مستقبلا، أوضحت الدراسة أن السعر الأعلى الذي يمكن لمزارع النخيل دفعه يقدر بحوالي 0.06 ريال للمتر المكعب من المياه وهو مؤشر على قدرتهم على الاستجابة في حالة فرض تعرفة المياه. وبناء على كمية المياه التي وفرتها المؤسسة للمزارعين خلال عام 2019 إذا اعتمد المعدل المذكور لقيمة المياه كتعرفة، يقدر العائد لها بحوالي 8-9 مليون ريال سنويا.

الكلمات الدالة: ترشيد استخدام المياه، تحليل التكلفة والفائدة، طرق الري الحديثة، المؤسسة العامة للري - السعودية، القدرة على الدفع، تعرفة المياه.

3) Natural resources management in southern Tunisia: sustainable exploitation and degradation issues of the oasis agro-systems

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Abstract:

In southern Tunisia, as in the major part of agro-based countries under arid and semi-arid climate, the growing water dependent-economies, the increasing scarcity of freshwater resources amplified by the frequent dry climatic episodes and the continuous aquifer decompression define huge challenges for sustainable agricultural development. Multiple environmental issues have been observed related principally to natural resources degradation. Besides to the ecological value, the decreasing of agro-systems production has crucial social, economic and health repercussions. Thus, the present study aims the assessment of the sustainability of different natural resources in the oasis lands, the principal agro-system in southwestern Tunisia.

The collected data from field investigations and farming surveys have been completed by analytical laboratory work and literature review. The obtained results indicate that groundwater resources are highly mineralized with doubtful to locally unsuitable quality to be used in irrigation according to the different calculated ionic indices (EC > 3000 µs/cm; SAR from 6.7 to 9.5; TH between 48 and 69; PI from 46 to 58 %) suggesting severe recommendations to be used especially for long term irrigation. The physic-chemical analyses of the soil samples highlight, furthermore, the progressive degradation of these agricultural lands characterized by high EC values above 3.6 $mScm^{-1}$ and 5.8 $mS.cm^{-1}$ threatening the safe production of many crop yields. In addition to the difficult natural conditions, farming practices are the most influential factors governing the distribution of water quality related issues and soil hydrodynamic and physico-chemical proprieties.

A comprehensive flexible adaptation management measures are required in the study area as the degradation issues have reached tolerance limits of different ecological systems and many irreversible alteration have been observed. These strategies should be evaluated as a shared task between the different parts relative to water consumption and agro-based activities

Keywords: Water quality, irrigation, oasis agro-systems, soil degradation, Southern Tunisia.

4) Risks Associated with Treated Wastewater in Greenhouse Cooling System

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Abstract:

The hot climate in the Gulf region is forcing many farmers to use controlled environment agriculture by using evaporative coolers inside greenhouses. These coolers are consuming around 60% of the water used for the greenhouse. Replacing groundwater with treated wastewater will have a good impact in saving freshwater for other different applications. The problem is that treated wastewater is rich of nutrients that can support algae growth, block the cooling pads, and reduce the efficiency of the cooling system. Moreover, it is unclear if the water can be a source of any airborne diseases that could affect human health and crop quality. Unfortunately, few or no data is available related to the applications of treated wastewater in greenhouse cooling system. Therefore, the aim of this study is to evaluate the possibility of using treated wastewater in greenhouse cooling system and asses any potential risk to the environment that could affect human health and crop quality and safety. The greenhouse cooling system was connected to tertiary treated wastewater and the system was left to run for two months. Algae growth was observed in cooling pads. Samples from cooling pads, air, and water were taken for microbial analysis. The same sampling was made from other greenhouse running with freshwater. Using treated wastewater in cooling system did not show any negative impacts in plant growth. However, rapid growth of algae in cooling pad of treated wastewater was noticed compared to the groundwater cooling system. This could be minimized by covering cooling pads with shade net, or adding some anti-algae growth ($CaSO_4$) in cooling tanks, or using plastic cooling pads, or cleaning cooling pads from time to time. Moreover, more types of bacteria were found in treated wastewater cooling system but were not harmful for human and plants. Almost similar microbes were found in the air and water running in all greenhouses. Therefore, the study recommends the use of treated wastewater in the greenhouse cooling system with application of antifouling compounds or using plastic cooling pads that can be easily cleaned.

Keywords: Treated wastewater, Non-conventional water resources, Cooling pad, Algae growth, Gulf Region.

Keynote Speaker

5) Role of efficient management of non-conventional and brackish water resources in sustaining agricultural production and achieving food security in the United Arab Emirates

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Abstract:

Water scarcity is the main limiting factor to food production in the United Arab Emirates. The country is located in an arid to hyper-arid zone with limited renewable natural freshwater resources due to limited rainfall. Other considerable limiting factors include low agricultural water productivity, salinization of farmed areas, and low soil suitability for agricultural production. The agricultural sector is the highest water consumer, with more than 56% of total water use, while its contribution to the GDP is less than 1%. The total agricultural area is about 1.1 million dunums. Only 51% of the agricultural area is cultivated with crops, including 1) fruit trees of more than 400,000 dunums (mainly date palm trees); 2) field crops and fodders of about 109,000 dunums; and 3) vegetables of about 66,000 dunums. Although most farmers are using modern irrigation systems in their farmed areas, mainly drip irrigation, the agricultural water productivity is still low. Many farmers are not aware of the practical irrigation scheduling based on the actual crop water needs according to the growing stages of the crops and therefore over-irrigate their crops. Groundwater is the main source of agricultural water in farming areas where the annual water use exceeds 2,500 million cubic meters. Usable groundwater is mostly non-renewable and brackish, with different levels of salinity ranging from low salinity of 2 ds/m to more than 15 ds/m. Groundwater quality degradation and declining groundwater levels are well-known problems in many farmed areas. The soil is generally poor and lacks necessary natural soil elements and nutrients. Only about 13% of the UAE's existing farmed areas are located on suitable soil for agricultural production. The arable land is degrading in many locations mainly in the cultivated areas due to salinization. In parallel, the demand for food is steadily growing. Ninety percent of food in the UAE is imported as the local agricultural production cannot meet the current domestic demand, which is anticipated to increase substantially. However, UAE's economic and political stability and its geographic location with high accessibility to trade centers and markets have created a stable environment for food security.

This paper presents the optimal use of alternative and natural water resources through improving water use efficiency. It entails the best practices to use water based on crop water needs, most profitable crops, best match of water and soil, and when crops to be grown, hence reducing the use of water resources significantly and boosting agricultural water productivity. The paper will also highlight the importance of using these alternative water resources, particularly treated sewage effluent (TSE), in controlled-environment agriculture (CEA) and the expected benefits to farmers such as: saving freshwater resources, reducing water consumption, reducing crop loss, improving water productivity, and using less land. TSE is a reliable water supply source, particularly in water scarcity countries. The seasonal TSE supply can help bridge the seasonal gap of freshwater supply and reduce the use of fertilizers as it is rich with nutrients that are needed for plant growth. As such, the use of TSE in CEA could potentially increase agricultural productivity and economic return for farmers while reducing environmental pollution.

6) Impact of deficit irrigation strategies on water use and productivity for vegetable crops in a semi-arid context of Tunisia

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Abstract:

Irrigated agriculture in arid and semi-arid environments is characterized by acute imbalance between rainfall and evapotranspiration and tough competition for water. It is against this backdrop that water use efficiency is becoming a must. This study is targeted to evaluate the effect of deficit irrigation on water requirements, yield and water productivity of potato and tomato crops under average and very high climatic conditions of 2016 and 2017 respectively. The case study is the Cherfech irrigation district located in the northern of Tunisia. For this purposes, the FAO/CROPWAT irrigation scheduling and simulation model was used to identify appropriate deficit irrigation strategies for improving water conservation with acceptable impacts on yields. Deficit irrigation strategies were evaluated through parameters of irrigation, relative crop evapotranspiration, relative yield loss as well as water productivity and economic water productivity. Results indicate that deficit irrigation is practicable under average water demand for both potato and tomato crops. For tomato, adoption of deficit irrigation is less feasible particularly under very high demand. For a relative yield losses threshold of 25%, results show that for potato, optimal season irrigation could be reduced by 43.3% and 31.6 % respectively for average and very high climatic conditions. For tomato crop, optimal irrigation requirements could be reduced by 33.3% for average demand and 31% for very high water demand. Regarding the water use indexes, results show that water conservation due to deficit irrigation strategies improves water productivity under the average water demand more than the very high demand. This improvement was more noticeable for potato than tomato. Furthermore, economic water productivity is more affected by the difference in potato and tomato prices for average (2016) and very high (2017) water demand conditions.

Keywords: Deficit irrigation, Irrigation simulations, Relative yield loss, Water productivity.

7) Irrigation Efficiencies with Application Five Irrigation Level and Soil Texture in Dyala River Basin

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Abstract:

A field study was carried out in private orchards of Diyala province with the aim of identifying the effect of three types of soil texture and five levels of irrigation under the drip irrigation system on water use efficiency, water consumption and added water depth within the Diyala River basin. The study area is of strategic importance for its agricultural production, especially fruit production, especially the pomegranate, as well as other fruit species (oranges, dates, figs), and also the study area is characterized by abundance of fresh water and its multiple sources (rivers, wells). Diyala River is the vital water tributary of Diyala province for agriculture, health and industrial consumption. Several equations were used for calculating the requirements of field irrigation and estimating the five irrigation levels by depletion from available water (soil moisture (PW%)), homogeneity factor was used for drip irrigation system at the beginning and end of the experiment, and three different soil texture types were selected randomly from 15 sites for the study area. The factorial experiment was carried out by using Randomized Complete Block Design (RCBD) with the effect of the study factors and by three repeats. The first factor included three types of soil texture (clay loam, loam, sandy loam) and the second factor included five levels of water addition after (40, 50, 60, 70 and 80%) depletion. From available water, the Genstat statistical computer program was used to estimate the study factors. The clay loam soil (S1) showed a significant increase in water use efficiency to 10.75 kg.m^3/$water^{-1}$, a significant reduction in the amount of water consumption and a reduction in added water depth to 126.64 m^3.Water.$donum^{-1}$ and 667.01 mm respectively compared to other soil textures. Irrigation level after 40% depletion from available water (R1) showed a high significant superiority in increasing the water use efficiency to 13.08 kg.m^3/$water^{-1}$, and the effect of this factor reduced the amount of water consumption and reduced the added water depth to 132.40 m^3.Water.$donum^{-1}$, and 654.0 mm respectively compared with the other irrigation levels. In addition, the Bilateral interference (irrigation levels + soil type), especially treatment of the irrigation level after 40% depletion from available water in combination with the clay loam soil (R1+S1), showed a significant superiority in increasing water use efficiency and reducing both water consumption and the added water depth compared with the other interference treatments.

Keywords: Water efficiency, water consumption, irrigation levels, agriculture, soil type, available water.

8) Impact of Farmers practices on Groundwater in South Al-Batinah Region, Sultanate of Oman

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Abstract:

Water scarcity is threatening world's population lives. Agriculture uses 70% of global freshwater withdrawals and is probably the sector where water scarcity is most critical. In arid regions, this fact is in conjunction with the severe depletion of groundwater aquifers. The problem becomes more serious with the limitation of water resources especially for the coastal agricultural areas. Many of the population in Al-Batinah region in Oman rely on agriculture. The source of irrigation water for almost all of the farms is the groundwater abstracted from the aquifer by private wells. The practices followed by farmers are generally affecting the water situation in the region, and particularly have an effect on food production and agriculture productivity. The imbalance between the abstraction rates and recharge rates led to a dramatic decline in groundwater levels accompanied with saltwater intrusion into the coastal aquifer of the region. With time, several agricultural lands of the coastal areas have become unsuitable for cultivation and some farms have become abandoned. All this makes the need for sustainable and smart water management strategies becoming more and more important to meet future water demands. This paper is focusing on analyzing the practices followed by farmers and their role in threatening the groundwater aquifer in South Al-Batinah region. Data were collected by questionnaires from different groups of stakeholders. These data were analyzed statistically for each group separately as well as relations among groups by using the SPSS (Statistical Package for Social Science) software package. Differences were examined between opinions of farmers and decision makers (DM's) regarding potential interventions. Farmers' frequency curves showed differences in opinions in some interventions, while differences in opinions were not so high within the group of DM's. Therefore, Cross Tabulation and Discriminant Analysis (DA) were performed to identify the drivers influencing farmers' opinions regarding the intervention measures.

Keywords: Farmers, groundwater Aquifers, Abstraction Rate, Discriminant Analysis, Sultanate of Oman.

9) Economic and Environmental Evaluation of Different Irrigation Systems for Date Palm Production in the GCC Countries: The case of Oman and Saudi Arabia

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Abstract:

This study evaluates the irrigation water volumes' effect on the date palm productivity and water use efficiency under several conventional and improved irrigation systems (surface, subsurface, bubbler, subsurface drip irrigation). The study is focusing on Oman and Saudi Arabia. Data on the water requirement, temperature, and evapotranspiration has been collected from the experimental study conducted at Al Kamil and Al Wafi Agricultural Research Station, Oman and Farm Al Briga – research station, Kingdom of Saudi Arabia. The socioeconomics data used was collected from several national and international sources. The partial budgeting method is used for economic comparison between different irrigation systems. In Oman, the performance of bubbler irrigation systems (BI) and subsurface drip irrigation systems (SDI) was studied in terms of water use efficiency, economic performance, and yield of date palms (Cv. *Khalas*). Three intervention levels on SDI have been used: at the rate of 60%, 40%, and 20% of water requirement. This experimental study showed that SDI under the three intervention uses water more efficiently than the BI system. The WUE of the SDI 20%, 40%, and 60% of water requirements were 2.0, 2.7, and 4.7 kg/m^3, respectively. Meanwhile, the BI water use efficiency was 1.3 kg/m^3. Economic findings confirmed using the SDI method versus the BI method increased the cost of establishment but is economical in the long term. Therefore, measures can be taken to reduce the cost of equipment by promoting the production and supply of low-cost SDI systems. In KSA, surface drip (SD) irrigation and SDI performance were evaluated in terms of water use efficiency, economic viability, and date palms yield (Cv. *Khalas*). The results showed that SDI was more efficient in comparison to the DI technology. The SDI could save about 27% of irrigation water compared to SD. The results also confirmed that the SDI system produced the same date palm yield while saving the irrigation water. Findings indicate that the SDI compared to the DI could save between 125 $/ha and 205 $/ha. This result suggests water economic profitability by using the SDI system in date palm farming. These findings indicate a significant difference in net profit. Overall, the adoption of modern irrigation techniques such as drip and subsurface drip irrigation is essential today for this very arid region. This is mainly to increase WUE and Yield. In a short time, the capital cost associated with installing such a system limits adopting this technology. Thus, to accelerate the adoption process of these technologies, it is imperative to create favourable conditions so that a more significant number of farmers can benefit from the benefits of such technologies. The creation of strong networking among different institutions related to applying this modern irrigation technology and public and private financial institutions and support services could be an example of mechanisms to enhance adoption.

Keywords: Economic evaluation, environmental evaluation, irrigation systems, Oman, KSA.

Keynote Speaker

1) Challenges and Prospects of Using Treated Wastewater to Manage Water Scarcity Crises in the Gulf Cooperation Council (GCC) Countries

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Abstract:

The Gulf Cooperation Council (GCC) countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates) are facing severe water shortages, which jeopardize sustainable development and restrict human, industrial, and agricultural expansion. Rapid urbanization and increasing living standards have further exacerbated the problem. Although arable land in GCC countries is averaging only 4.3% of the total land area, average water use for agriculture is 70% of the renewable water resources and is even higher in Saudi Arabia, UAE, and Oman. Despite this water use, the average contribution of agriculture to the gross domestic product (GDP) is only 0.8%. However, massive oil and gas reserves in the region compensate for the scarcity of land and water resources in GCC countries.

The increasing demand for water by domestic and industrial sectors is threatening the ecosystem services, food security, and the environment. The annual per capita water uses in the GCC countries is 560 L/day compared to the world average of 180 L/d. This four-fold increase in water consumption over the last two decades is caused by a rising population and unplanned agricultural expansion. Therefore, improving the productivity of marginal land and water resources in GCC countries is imperative to increase the food supply and avoid the adverse environmental effects of land degradation. The marginal water resources such as poor-quality saline water, treated wastewater, and produced water from the oil industry are now successfully used for agricultural crop production and aquaculture in many countries. Currently, an estimated 380 bm^3 of wastewater is collected annually across the globe and expected to reach 574 bm^3 by 2050. Currently, about 36 million hectares are irrigated with the wastewater, of which 29 million hectares are using untreated wastewater. Farmers in urban and peri-urban areas of nearly all developing countries are using untreated wastewater for irrigation.

The treated and untreated municipal wastewater is used for agriculture in several parts of the world because it supplies additional nutrients and improvements in crop production during the dry season. During the last two decades, the use of treated wastewater for agriculture has also increased in the GCC countries. The GCC countries are in the driest part of the world with an annual per capita water availability of 500 m^3 compared to the world average of 6000 m^3. Agricultural water demand, which is more than 80% of the total water consumption, is primarily met through the massive exploitation of groundwater. The imbalance between groundwater discharge (27.8 bm^3) and recharge (5.3 bm^3) is causing the excessive lowering of groundwater levels. Therefore, GCC countries are investing heavily in the production of nonconventional water resources such as desalination of seawater and treated wastewater (TWW).

Currently, 439 desalination plants are annually producing 5.75 bm^3 of desalinated water in the GCC countries. The annual wastewater collection is about 4.0 bm^3, of which 73% is treated with the help of 300 wastewater treatment plants. Despite extreme water poverty, only 39% of the treated wastewater is reused, and the remaining is discharged

into the sea. Currently, more than one-third of the available TWW is used to irrigate nonedible crops and fodder. However, TWW use is primarily restricted to landscaping, gardens, and road ornamentals. The use of TWW to irrigate food crops is minimal due to health, environment, social, and religious concerns. Farmers are hesitant to grow food crops using TWW due to the fear of losing customers for their products. In all GCC countries, the gap between water supply and agricultural water demand is met through extensive groundwater exploitation. Uncontrolled and unregulated groundwater abstraction has resulted in excessive lowering of groundwater levels, degradation of groundwater quality, salt-water intrusion into freshwater aquifers, and rising pumping costs. The current trends of groundwater exploitation are not sustainable and immediate action is required to put a brake on groundwater abstraction to protect this vital natural resource to ensure potable water supply to urban and rural communities.

The TWW represents one of the most promising alternatives to meet agricultural water demand and make more fresh water available for domestic and industrial uses. The use of TWW in agriculture can contribute positively to improve the socio-economic conditions in the GCC countries. This is very important considering that large volumes of TWW will become available in the future due to population increase and the expansion of urban sewage networks in the large cities of the GCC countries. Therefore, robust plans need to be developed for the sustainable use of TWW; otherwise, vast quantities will have to be discharged into the sea. Since water is the key driver in achieving Sustainable Development Goals (SDGs), developing a global vision on wastewater use is needed to improve the effectiveness of national policies.

This paper reviews the status of available water resources in the GCC countries. It considers the future water demands and discusses the challenges and opportunities to use the TWW in GCC countries to bridge the gap between supply and demand. The increased use of TWW is also vital for this region because groundwater is fast depleting due to overexploitation, which will have direct consequences for the food security of this region. To increase TWW use for agriculture, a comprehensive awareness campaign needs to be initiated to address the social and religious concerns of farming communities and consumers. Several internal and external risks can jeopardize the sustainable use of treated wastewater in the GCC countries. These include climate change, increasing costs, technological and market-driven changes, and regional security issues. Therefore, effective response mechanisms should be developed to mitigate future risks and threats. For this purpose, an integrated approach involving all concerned local and regional stakeholders needs to be adopted.

Keywords: wastewater reuse; agriculture; desalinated water; heavy metals; water scarcity.

2) The Future of Wastewater Treatment and Reuse in Kingdom of Saudi Arabia

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Abstract:

The Kingdom of Saudi Arabia (KSA) is an arid country facing the challenge of renewable freshwater availability. KSA has an area of about 2.25 million km^2. KSA has no perennial rivers or permanent freshwater bodies. KSA has low rainfalls with high evaporation rates which makes it very dry country. After discovering oil, KSA has witnessed remarkable economic development and rapid increase in population with migration to the urban areas in the past four decades. KSA population increased from about 4 million in 1960 to about 32.5 million in 2018. These developments lead to more pressure due to increased demand on the scarce freshwater resources. In order to meet the growing water demands, the limited renewable freshwater resources have been heavily overexploited. Groundwater aquifers are the main natural renewable freshwater source in the country. The average per capita municipal daily water use in KSA has been increasing since 2009 when it hit 227 l/day and recorded a gradual increase to touch 270 l/day in 2016 which is the 3rd highest in the world. Faced with increasing water scarcity and gaps between water supply and demand, policymakers in KSA started to consider the treated wastewater as a major renewable water source and aim to achieve full utilization and reuse of treated wastewater by 2025. With a desalination capacity of about 2500 million cubic meters per year which represents 30% of the world's desalination capacity, KSA is the largest seawater desalination producing country. However, desalinated water alone will not be able to supply enough freshwater to meet the increasing future water demand. However, with only 10% of the total municipal wastewater generated currently being reused, KSA is projected as the third largest reuse market after China and the USA, and reuse capacities are projected to increase by 800% by 2025. The projected growth and change in water portfolios offer tremendous opportunities to integrate novel approaches of water reclamation and reuse such as aquifer recharge and groundwater quality enhancement, district cooling and irrigation of reactional areas. Recent statistics in 2018 indicated that the volume of treated wastewater used to produce freshwater in KSA was approximately 390 million cubic meters per year. This statistic shows the revenue of the industry "sewerage" in Saudi Arabia from 2012 to 2017, with a forecast to 2024. It is projected that the revenue of sewerage in Saudi Arabia will amount to approximately 739,3 million U.S. Dollars by 2024. The KSA's treated wastewater utilization status up to date and the main key challenges facing KSA such as the substantial growth in wastewater services demand; low coverage of existing wastewater collection systems, treatment facilities, and reuse options; and the needed governmental capital investment in wastewater infrastructure development were analyzed. It has been recommended that there are initiatives that should be taken thus far to tackle these challenges towards successful achievement of KSA's efficient wastewater treatment and reuse.

Keywords: public acceptance, wastewater revenue, water quality, aquifer recharge, water reclamation.

3) Fate Of Estrogens in Kuwaiti Municipal Wastewater Treatment Plants

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Abstract:

Estrogens are endocrine disrupting chemicals (EDCs) that impact both human and animal health, even at very low levels. Fate of estrogens were evaluated for three municipal WWTPs in Kuwait, through determination of estrogens concentrations in influent and effluent streams. The solid-phase extraction gas chromatography-mass spectrometry method was used for analysis of estrogens concentrations in wastewater. Obtained results indicated that concentration of estrogens in the influent streams ranged from 0.0 to 474 ng/l, while that in the effluent streams were between 0.0 to 233 ng/l. Both influent and effluent concentrations showed high variations around mean values. Total removal of estrogens was found to be 13%, 79%, 68%, for Kabd, Suliabiya and Umm-Al-Haiman, respectively. Even with high influent loadings, Sulaibiya plant achieved the highest removal of all types of estrogens, except E1. The obtained results demonstrated that WWTPs require upgrading/optimization to maximize estrogens' removal. The study also discussed the potential impacts of estrogens in treated wastewater reused as irrigation water and recommended that Kuwait urgently needs to develop regulations for estrogens discharges from WWTPs in order to prevent further pollution of marine environment and groundwater with estrogens.

Keywords: Wastewater, Municipal plants, Treatment, Estrogens, Removal efficiency.

4) Investigations on Pharmaceuticals and Radioactive Elements in Wastewater from Hospitals in Kuwait

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Abstract:
A research studies were performed to characterize the wastewater generated from four hospitals located in Kuwait. In general, the wastewater generated from hospitals is discharged directly without any pre-treatment to public sewage treatment plants supervised by Ministry of Public Works (MPW). In this study, wastewater samples were collected on weekly basis from four hospitals (Al-Sabah, Al-Razi, Maternity and Chest Diseases). Field wastewater measurements were carried out onsite for all sites including temperature, pH, electrical conductivity (EC) and oxy-redox potential (ORP). The collected samples were analyzed for determination of chemical parameters (total suspended solids - TSS and total dissolved solids - TDS), organic parameters including TOC, COD, BOD and five dominate pharmaceutical compounds (four antibiotics sulfamethoxazol, metronidazole, ranitidine and trimethoprim plus paracetamol) and concentrations of radioactive elements in the wastewater (I-131, K-40, Tc-99m). The laboratory results indicated that all wastewaters from hospitals contained high levels of Tc-99m (0.14 - 14,151 Bq/l), I-131 (13.56 - 27.1 Bq/l), and low levels of K-40 (0.45 – 0.86 Bq/l). In addition, the pharmaceutics' concentration results revealed a high concentration of paracetamol (580 µg/l), where the maximum was detected in wastewater from Al-Razi hospital. The study recommends construction of onsite wastewater pre-treatment units.

Keywords: Radioactive isotopes, hospital wastewater, on-site wastewater pre-treatment, pharmaceutical compounds.

5) Technical and economic viability of the reuse of treated wastewater in Kingdom of Saudi Arabia

إعادة استخدام مياه الصرف الصحي المعالجة في قطاع الزراعة في المملكة العربية السعودية فنياً واقتصادياً

علي عبد الله الجلعود

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الملخص:

تعتبر المياه المعالجة أحد مصادر المياه المتجددة والتي يجب استغلالها الاستغلال الأمثل خاصة في المناطق الجافة مثل المملكة العربية السعودية، وعموم دول مجلس التعاون، التي تعاني من شح في مواردها المائية المتجددة. ولقد قدرت كميات المياه المعالجة في المملكة للعام 2020 بحوالي 5.1 متر مكعب يوميا (حوالي 1.8 مليار متر مكعب/السنة)، يتم إعادة استخدام ما يقارب 0.93 مليون متر مكعب منها (حوالي 339 مليون متر مكعب/السنة)، أي ما نسبته 18.2٪ من كمية المياه المنتجة، أي أن عملية إعادة استخدام هذه المياه ما زالت في بدايتها. هذا، ولقد افتى العلماء بجواز إعادة استخدام المياه المعالجة ثلاثيا وإنها بعد المعالجة الكاملة تصبح ماءً طهوراً. ولقد اهتمت المملكة العربية السعودية ممثله في وزارة البيئية والمياه والزراعة باستخدام مياه الصرف الصحي المعالجة للأغراض المختلفة وضمان الاستفادة منها كأحد المصادر الرئيسية غير التقليدية للمياه للأغراض المختلفة، وفق المعايير القياسية المعمول بها محلياً، وأصدرت المملكة عام 1421هـ نظام مياه الصرف الصحي المعالجة، وإعادة استخدامها، وذلك لتحقيق ما يلي: 1) التوصل إلى مستويات مقبولة للتخلص من مختلف أنواع الصرف الصحي العامة؛ 2) تحقيق مستويات آمنة لإعادة استخدامه في مجالات الري الزراعية وري الحدائق العامة والأماكن الترويحية، وتغذية المياه الجوفية والتبريد والأغراض الصناعية، وأي استخدامات أخرى. وتمتاز مياه الصرف الصحي عن المياه الأخرى بأنها تحتوي على عناصر غذائية للنبات، حيث تحتوي وسطياً على حوالي 20 جزء بالمليون نيتروجين، 7 جزء بالمليون فسفور، 15 جزء بالمليون بوتاسيوم، 0.24 جزء بالمليون حديد، 0.11 جزء بالمليون زنك، 0.4 جزء بالمليون منجنيز، 0.01 جزء بالمليون نحاس، وتعادل كمية الأسمدة المضافة من هذه العناصر للنخلة في السنة هي: 1.6 كجم نيتروجين، 0.5 كجم فسفور، 1.1 كجم بوتاسيوم، 17 جرام حديد، 7.7 جرام زنك، 3.5 جرام منجنيز، 0.6 جرام نحاس، وعلى سبيل المثال فإن هذه الكميات تكفي لاحتياجات النخلة من الأسمدة، ولن يحتاج المزارع إلى إضافة أي أسمدة مما يوفر له أيضاً في تكاليف السماد. ولقد أجريت العديد من الأبحاث والدراسات العلمية على إعادة استخدام المياه المعالجة على محاصيل النخيل والقمح والبرسيم وأثبتت التجارب بانه لا يوجد تأثير ضار على النبات والتربة بالإضافة إلى قيمتها الاقتصادية من حيث توفير الأسمدة.

الكلمات الدالة: مصادر المياه، الري الزراعي، الاستخدام الآمن لمياه الصرف الصحي، المعالجة الثلاثية، توفير المياه والأسمدة.

6) Testing an Optimization Model for Optimal Sewer Layout and Wastewater Treatment Locations

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Abstract:

Wastewater systems are one of the most crucial systems for urban infrastructure, especially in regions with large population density. The problem of wastewater systems planning is finding the optimal (minimum cost) sewer layout and wastewater treatment plants (WWTP) locations, taking into consideration economic, environmental, and hydraulic requirements. In this paper, we presented an optimization model for sewer layout and wastewater treatment plant's locations of wastewater systems planning. The model aimed to minimizes the total costs associated with a sewer network and WWTP by determining an optimal layout of sewer pipes' network and the locations of WWTP/s that meet connectivity, continuity, and capacity requirements. The model is developed in the general algebraic modeling system (GAMS) program, which is formulated as a mixed-integer nonlinear programming (MINLP) solver. The application of the model is illustrated through scenario analysis and the results are discussed. The simple scenario demonstrates that using the method allows for significant cost saving for large systems while further testing and developments might be needed.

Keywords: Water resources, optimization models, wastewater planning, urban infrastructure, MINLP.

7) Feasibility of Anaerobic Digestion as an Option for Biodegradable and Sewage Sludge Waste Management in the Kingdom of Bahrain

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Abstract:

Solid Waste Management (SWM) represents a main challenge to the developing countries. Almost all of the solid waste in these countries are dumped into landfills, which harms the environment, public health, as well as affecting the economy and society. Dumping of biodegradable waste including sewage sludge resulted from wastewater treatment plants into the landfill results in methane emission, which is a greenhouse gas 25 times more potent than carbon dioxide. Thus, finding a sustainable solution to manage the biodegradable and sewage sludge waste tend to be crucial. This study aims to explore the feasibility of Anaerobic Digestion (AD) technology to manage the biodegradable and sewage sludge waste in the Kingdom of Bahrain. AD is an important waste-to-energy technology that leads to produces biogas, an important and promising renewable energy resource for the country. Cost-Benefit Analysis (CBA) was used in this study that shows the feasibility of the AD project. In addition, the contribution in reduction of the landfill methane emission was estimated. The study may provide sufficient information for future adoption of evidence-based technology selection in order to adopt SWM technologies in Bahrain, which contributes to the decision and policy-making processes.

Keywords: Biodegradable Waste Management, Sewage Sludge, Anaerobic Digestion, Kingdom of Bahrain.

7) Adsorptive Removal of Chromium (VI) Using Cu/Fe Impregnated Activated Carbon Prepared from Solid Sludge

Wafa Al Rawahi, Amal Al Rahbi, Maryam Al Hashmi, Marwa Al Riyami, Hanadi Al Aameriya, Marwah Khamis Al-Hinai, Soumaya Sulaiyam Al-Hatmi, Maiya Hilal Al-Ismaili

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Abstract:

Chromium (VI) can be introduced to the environment from different industrial activities. This study focuses on the removal of chromium (VI) using activated carbon. In this work, solid sludge obtained from a treatment plant in Nizwa, Oman was used to prepare the activated carbon. The preparation was done following two processes. The first one was pyrolysis of dried solid sludge for two hours at a temperature of 700°C under nitrogen gas flow of 150 ml/min. The second process was physiochemical activation using potassium hydroxide (1:1) under nitrogen and carbon dioxide gases flow of 150 ml/min for two hours. Then, the activated carbon was analyzed using SEM and EDX to study the porosity, surface area, and chemical composition. Chromium (IV) optimum adsorption conditions using the prepared activated carbon were investigated. Chromium (VI) removal was performed at different dosages, concentrations, and pH at specific conditions (shaking speed = 170 rpm, T= 30°C and t= 6 hours). Chromium levels were analyzed using flame atomic absorption spectroscopy (FAAS). The results show that the highest removal of chromium (VI) was 23.39 % at 1.5 g of AC dosage. The highest removal of chromium (VI) was at pH 3. To increase the removal efficiency of sludge AC adsorbent, Fe (III) and Cu (II) metals were impregnated individually to the AC. The optimum conditions for chromium (VI) removal (dosage= 0.5 g, concentrations= 10 ppm, pH =3 or 7, shaking speed= 170 rpm, T= 30°C and t= 6 hours) were applied. The treated activated carbon with copper achieved the highest efficiency of 94.5% removal, at pH 3. Therefore, addition of Cu (II) metal to sludge AC is efficient in enhancing the removal of chromium (VI).

Keywords: Adsorption, chromium (VI), activated carbon, sludge, removal.

Keynote Speaker

1) Hydrometeorological study on the impact of the weather condition "Rahw" on the Water Resources in Southwestern Regions; Kingdom of Saudi Arabia

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Abstract:

The western and southwestern regions in the Kingdom of Saudi Arabia (KSA); Al Madinah, Makkah, Al Baha, Asir, Jazan, and Najran, as well as some parts of the neighboring countries such as Oman, United Arab Emirates, and Yemen have been exposed to a summer weather state which is locally named by Saudi Committee of Nomenclature of Distinguished Climate States as "Rahw. This weather state lasted for eighteen days started from 24 July 2020 to 10 August 2020 and resulted in moderate to heavy daily rains. The present study deals with the hydrometeorological impacts of the weather state"Rahw" depending upon the statistical analyses and ARC GIS spatial distribution of (193) rainfall and weather stations, as well as daily records of water levels in (165) constructed and under construction dams reservoirs. The total geographic areas of Al Madinah, Makkah, Al Baha, Asir, Jazan, and Najran regions attain (522,000) km^2, representing (26.6%) of the total area of KSA. According to the present study, the total geographic areas that have received rainfall precipitation in these regions during "Rahw" are estimated as (212,672) km^2 and the average total rainfall depth over these regions only is estimated as (69.59) mm, representing (45.8%) of the total annual average rainfall depth over these regions. Also, the average total rainfall depth over all KSA during "Rahw" is estimated as (32.56) mm, representing (30.1%) of the total annual average rainfall depth over all KSA regions. On the other hand, the calculated average precipitation depth in July (2020) only, attains (32.9) mm and (9.4) rainy days, compared to (20) mm and (5) rainy days of the same month during the interval from (2010-2019). Also, the present study concluded that the average precipitation depth in August (2020) is estimated as (27.5) mm and (9.2) rainy days, compared to (27) mm rainfall depth and (7) days rainy during August in interval from (2010-2019). The total rainfall volume received during "Rahw" weather stateis estimated as (10,894) million m^3 representing (20.2%) of the total annual average rainfall volume in these regions, and (7.2%) of the total annual average rainfall volume over all KSA regions. Also, the total rainfall volume received during "Rahw" weather stateresulted to (1,308) million m^3 direct surface runoff, among of these (352) million m^3 were retained behind (147) constructed dams, and (18) million m^3 behind (8) under construction dams, and the remaining (938) million m^3 is recharged in wadi deposits aquifers in those areas. Also, (201.6) million m^3 of water was released from dams' gates to meet the demands of farmers on the downstream of dams during the rainy state, in addition (8.3) million m^3 was supplied for drinking waters and treatment plants. The net increase in the water volume behind the dams as a result of "Rahw" weather stateis estimated as (142) million m^3. The present study recommends to develop and update the operational plans of dams in western and southwestern regions to maximize the benefits from the surface runoff and enhance the water resources during the occurrence of such weather states.

Keywords: Weather state, hydrometeorology, Water resources, Rainfall, Dams, Saudi Arabia.

2) A hydroecological technique to improve infiltration of clogged bed of recharge dam in Oman

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Abstract:

Recharge dams represent one of few engineering techniques to harvest flashfloods water in arid zones for augmenting the limited water resources. Formation of a low-permeable cake by deposition of suspended particles transported by ephemeral floods is a common problem for dams in arid regions (e.g., Oman, Saudi Arabia, Iran, and Tunisia). Accumulation of surface sediments affects many hydrological properties of dam's reservoir area, including reduced infiltration and deep percolation rates, higher water loss via evaporation, and ultimately lower aquifer recharge and higher flood peaks. The recharge basin downstream the dam receives pulses of suspended sediments after each major flashflood. This causes a "hopping" downward translocation of fine particles into the coarse-texture matrix of the alluvium bed, clogging of the pores which significantly reduces the saturated hydraulic conductivity (K_s). The intermittent flashfloods forms multilayered heterogeneous soil profile and a resultant non-monotonic cumulative infiltration curves have intricate hydro-engineering implications, e.g. we observed that the runoff water, released from the dam, instead of a fast vertical infiltration, forms a shallow quasi-horizontal Darcian flow that out-seeps further downstream into local topographic depressions and contributes to undesired runoff-evaporation. Hence, finding practical solutions to overcome the consequences of the siltation problem of dam beds is of a paramount importance. In this work, we investigated the possibility of applying a hydro-ecological method to combat the cake-clogging curse. We experimentally (using pots experiment) and numerically (using HYDRUS-2D code) quantified the effect of roots of indigenous trees, namely Sidr *(Ziziphus spina-christi)* grown in soil pots on increasing infiltration through a clogged layer. The pots were exposed to two flood events over 12 months period of cultivation. The average initial infiltration rates for vegetated pots (240 mm/hr and 147 mm/hr for F1 and F2, respectively) which is 2.4 and 2.1 times higher than that for pots without plants, bare soil (around 85 mm/hr in average). For vegetated pots, the final infiltration rates (K_s) were higher by 1.7 and 3.3 times than that for the control pots, ($p<0.05$). The numerical modeling illustrated the effect of the root system on the dynamics of soil water. The root system enhances the propagation of the soil water in both lateral and vertical directions. The results indicate the feasibility of this hydroecological technique in improving the infiltration rate and hence the recharge efficiency of recharge dams in arid areas.

Keywords: Clogging, pore space, infiltration, arid zone, recharge dams, HYDRUS-2D, root water uptake, *Ziziphus spina-christi.*

3) Experimental and Numerical Modelling of Constructed Channels in the Desert Sand Dunes for MAR Applications

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Abstract:

Hydrology of sand dunes in the deserts of arid regions, specifically, groundwater in aquifers underlying the sand fields (e.g., Wahiba Sands in Oman) has been studied since 1970th. Sustainable water resources management in the desert dunes is essential, particularly in Gulf countries, where no perennial streams exist. Interdunal areas can be explored and tested for managed aquifer recharge (MAR) if natural wadis or small-size constructed channels are used as surface water spreading systems. These channels would both transport and seep tertiary treated wastewater (TWW) into the vadose zone and enhance the amount of moisture content there. In this paper, a coupled surface-subsurface flow was experimentally and numerically studied in application to MAR through small-size triangular channels. In the field, experiments were done at the crest and slope of a selected dune, a triangular channel had a sand bed and a mild slope (S =5°). By applying a constant discharge at the inlet of the channel, the length, L, of the water "jets" propagating until their complete seepage extinction has been measured. Numerically, by HYDRUS2D, we simulated saturated-unsaturated transient infiltration by considering a cross-section of triangular channels of different bank slopes λ to find the maximum total volume of infiltrated water from the channel. The boundary condition was a hydrostatic pressure head along the wetted perimeters of the channels with water depth gradually dropping downslope. The Morel-Seytoux shape factor $\mu=q_i/(K_s A_0^{1/2})$ where q_i is the rate of infiltration as a function of λ is plotted. If $q_i X << Q$, where X is a characteristic size in the direction of surface flow in the channel, Q is the surface flow rate, i.e., for large channels and fast conveyance of surface water, q_i can be assumed independent of X. Then there is a unique minimum of $\mu(\lambda)$ at a given A_o. If q_i is not small, we determine the trench shape of a given A_o, which maximizes the total volume of water infiltrated from the trench. The results in this paper can be used in studies of furrow irrigation in desert agriculture and for evaluation of "transmission losses" from wadi channels flowing after flash floods.

Keywords: Sand dunes, Managed aquifer recharge, Surface-subsurface flow, Finite elements.

4) Flood damage assessment of vulnerable area in Riyadh city, Saudi Arabia (Case Study: Al-Thumama Bridge)

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Abstract:
Flood damage assessment is becoming now more important because of flooding disasters around the world. Severe rainstorms are common occurrences in some regions of Saudi Arabia that result in hazardous floods damaging the infrastructure and development plans. This study is applied in order to assess the flood hazards in the study area and to propose some countermeasures to reduce the flood damage. In recent years, Riyadh has experienced several flooding events that caused damages in and around the city in different locations due to the change in climate and land use. The paper presents a framework for a study of flood damage assessment of vulnerable area in Riyadh that was exposed to severe damages occurred by flash floods. As well as, conducting analyzes of morphology, metrology, hydrological and hydraulic analysis are included. Then, proposing a plan to mitigate the damages happened to the study area. The prediction of rainfall depths for 50 and 100-years were estimated using the frequency analysis to be 46.5.6 and 52.2 mm, respectively. The peak flow rates at the catchment outlet for 50- and 100-year return periods were estimated to be 256.0 and 291.0 m^3/s, respectively. The weighted Curve Number value of wadi basin was estimated to be 81. In the hydraulic modelling, the Manning roughness coefficient was increased to 0.03 to dissipate the energy at the Baffles and drops. The scour depths at the bridge piers were estimated assuming that the valley cross section does not tolerate the high water velocities. The study recommended taking into account the expected scour depth which obtained from the hydraulic modeling and the wadi bed condition to guide the designer to use deep foundations at the piers of the bridge to overcome and alleviate from the flash flood impact.

Keywords: Flood damage, Mitigation, Curve Number, Water flow.

5) Identifying Optimal Locations for Managed Aquifer Recharge by Rainfall in the Kingdom of Bahrain Using MCDM and GIS Techniques

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Abstract:

The Kingdom of Bahrain has extremely poor endowment of water resources. Beginning from the last four decades, the Kingdom has been experiencing fast-paced socio-economic development resulting in a significant increase in water demands. Water requirements are being met principally by expansion in desalination, reuse of treated wastewater, and increasing groundwater abstraction. The latter, has led to the over-exploitation of groundwater and resulted in a significant decline in groundwater levels, a radical storage reduction, and serious degradation in groundwater quality due to saltwater intrusion. To rehabilitate groundwater (SDG6.6), two approaches can be practiced, the first is to lower groundwater abstraction to its safe yield or to enhance groundwater storage by managed aquifer recharge (MAR) using either surplus unused treated wastewater, or using rainfall water during rainfall extreme events, where relatively large amounts of water accumulate in surface depressions in short period of time. This research identifies the optimal locations for MAR in the Kingdom of Bahrain by employing a multi-criteria decision-making (MCDM) methodology under a GIS environment, by using eight criteria: geology, geomorphology, soil type, land use/land cover, slope, curvature, drainage density, and distance from lineaments. The majority of the identified potential locations are validated by actual MAR field projects/pilots conducted by the water authorities. It is recommended that these locations undergo an in-depth investigation using higher-resolution satellite images with utilities infrastructure maps and depth to groundwater, and to be followed by MAR pilot field investigation, monitoring, and modeling for the highest potential locations.

Keywords: Groundwater, ASR, MCDM, DEM.

Keynote Speaker

6) Groundwater in the Arab Region: Making the invisible visible

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Abstract:

The Arab region is one of the most water scarce regions in the world with 19 States below the water scarcity threshold including 13 states below the absolute water scarcity. Groundwater is heavily relied upon and it is the primary source of freshwater in more than 11 Arab States, yet the invisible and complex character of groundwater being underground and out of sight has not given it the due attention it deserves. Hence, this report explores the importance of groundwater and the challenges it is facing, with the aim of bolstering its status to a strategic resource for the Arab region.

Amid the water scarcity situation, limited renewable groundwater resources continue to be exploited at an unsustainable rate, exceeding the natural recharge rates. Excessive use of groundwater, especially by the agricultural sector combined with low efficiency, has led to the decline in groundwater storage in more than two thirds of the Arab region, where the area of decline has doubled in 2018-2019 compared to 2002. In some countries over 88% of all irrigation water comes from groundwater compared to a global average of just over 37%. Moreover, it is projected that by 2050, available groundwater per capita will have decreased by more than half since the beginning of the century and 17 Arab States, accounting for 79% of the total population, will be below the absolute water scarcity threshold.

In addition to their excessive use, groundwater resources are also threatened by anthropogenic pollution sources, from agricultural and industrial practices and from sea water intrusion in coastal cities. The deterioration in the quality of groundwater resources, both due to overexploitation and pollution is aggravating the problem of water scarcity. For example, in Beirut, seawater intrusion has shifted inland between 500 and 1200 m from 1970 reference point. In Gaza, only 25% of wastewater is treated due the lack of proper wastewater collection and treatment infrastructure, which is further complicated by the occupation that has restricted access to natural resources.

This is alarming knowing that groundwater is central to achieving the Sustainable Development Goals (SDGs) and targets adopted in the 2030 Agenda for Sustainable Development in the region. It is directly linked to SDG6 and central to achieving many other SDGs such as SDG 2 for ending hunger. It is also an important component of climate change adaptation, having a high buffer capacity against drought. Accordingly, the projected impacts of climate change on water resources in the region, will further increase dependency on groundwater at a time when groundwater recharge is also projected to decrease, necessitating conjunctive management of surface water and groundwater. The impacts of climate change on groundwater at the aquifer level is showcased by ESCWA on the Beni-Amir aquifer, Morocco and the Eocene aquifer, Palestine. Results from the study on Beni-Amir aquifer indicate that the water table is expected to decrease 10 to 25 m (RCP4.5 and RCP8.5, respectively) by end of century, resulting in partial depletion of resources in the top three layers of the aquifer system, particularly in the northern Beni-Amir area. In the case of Palestine, the results on the Eocene aquifer showed that in the 2041-2060 horizon, the average precipitation is expected to decrease in all scenarios between 3% and 12%, whereas the recharge in 5

out of 6 precipitation scenarios showed a reduction by 12 to 16 per cent. Consequently, with no decrease in the aquifer pumping, the water levels in all scenarios will drop.

The declining availability of groundwater resources due to increased consumption, development demands, inefficient use and climate change should prompt Arab States to explore innovative and integrated governance frameworks to improve groundwater resources management and ensure equitable access for current and future generations to this strategic resource. Groundwater governance has been historically weak in the Arab region, characterized by fragmented legislations and policies, limited funding, lack of coordination and lack of data and knowledge. More recent evaluation of the management of groundwater resources through the SDG indicator 6.5.1 reporting mechanisms on the degree of implementation of IWRM has unfortunately reinforced some of the main challenges listed above in the Arab region mainly in terms of lack of implementation of management tools and proper financing. In response to the lack or fragmentation of groundwater management policies, ESCWA developed regional groundwater abstraction management guidelines offering a unified approach to deal with uncontrolled groundwater exploitation and use.

Groundwater governance is further complicated by transboundary aquifers. In fact, all countries, except for Comoros, share at least one aquifer with their neighboring countries. These transboundary aquifers cover almost 58% of the Arab region's total area. Some of these aquifers are directly connected to surface-water hydrological systems and should also be conjunctively managed. Other transboundary aquifers contain fossil groundwater reserves requiring specialized legal, policy and management frameworks that consider their non-renewable character. The status of regional transboundary water cooperation is captured in a recent regional report prepared by ESCWA on the progress on SDG indicator 6.5.2 in the Arab region for the year 2021. The report revealed the challenges faced by the Arab states that hinder the establishment of well-developed cooperation frameworks which are mainly linked to lack of knowledge and data exchange and financial constraints. However, there are encouraging signs where cooperation on transboundary aquifers has progressed, including a Joint Authority for the Nubian sandstone Aquifer, a cooperation framework for the Senegalo-Mauritanian Aquifer, a signed agreement for the Saq-Ram Aquifer, and a consultation mechanism on the North Western Sahar Aquifer System. These cooperation agreements should be maintained and further developed by holding regular meetings, coordinating objectives and management plans, and regularly exchanging data and information. Regional knowledge exchange around these agreements should be enforced.

Advances in technologies provide an opportunity to fill the data and information gap that hinders the management of groundwater. Integrated remote sensing data offer a solution to assess the groundwater status. In addition, Managed Aquifer Recharge (MAR) is one of the most important solutions to consider for securing water supply and for improving groundwater quality where it is deteriorating. MAR is already used in more than 44 sites across the Arab region. Technologies can assist in selection of where MAR can be a potential solution for the region and for improving the water security.

Furthermore, in response to the need for availing more data and information on groundwater and improving access to such data as established through the reporting on SDG indicators 6.5.1 and 6.5.2, ESCWA will be initiating an Arab Groundwater Digital Knowledge Platform. This platform aims to increase access to regional knowledge and information on groundwater resources through a dedicated digital interactive platform.

Finally, the relation of groundwater to water scarcity, human activity, transboundary water cooperation, climate change, and water governance is highlighted in the following key findings:

Groundwater and water scarcity

- *Action by countries has not been able to address the groundwater challenges yet, which underscores the need for immediate action on several fronts including socio-economic, environmental, and governmental.*

- *The use of integrated tools such as remote sensing data and in-situ data offers a great opportunity for adequate groundwater monitoring leading to improved management.*
- *Managed Aquifer Recharge is one the most promising approaches in the Arab Region to alleviate water scarcity impacts and improve water security.*

Groundwater and human activity

- *Management of groundwater must extend beyond water only into a coherent cross-sectoral governance approach.*
- *Food security is largely dependent on groundwater in many Arab countries. This necessitates improved efficiency and productivity through coherent management of water and agriculture sectors benefiting from enhanced use of technologies.*

Transboundary Groundwater

- *There are encouraging signs where cooperation arrangements in the region on groundwater have progressed.*
- *Transfer of experience and knowledge from regional groundwater cooperation arrangements are essential to accelerate progress at the full regional scale.*
- *Leveraging innovative approaches and technologies can help fill the information and knowledge gap.*

Climate change and groundwater

- *While it is well recognized that protecting and preserving groundwater contributes to increasing society resilience to climate change, there is still insufficient action recognizing and acknowledging this role for groundwater.*
- *In the face of projected climate variability in terms of availability and reliability of surface water and precipitation, groundwater can be used as a reliable buffer resource to offset climatic variability however its management has to be integrated across sectors such as water and agriculture with conjunctive management of surface water and groundwater.*

Groundwater governance

- *Good groundwater management requires good information based on sufficient and reliable data with the needed investment to produce useful knowledge to guide decision makers thus enabling informed decisions to be made and stakeholders behavior to adapt.*
- *ESCWA proposed regional groundwater abstraction management guidelines offer a unified approach to tackling overexploitation.*

The importance of groundwater for the Arab region's water security under a changing climate demands improved governance through innovative management approaches, enhanced use of technologies and dedicated funding for better understanding of the resource and heightened regional cooperation.

The above-mentioned findings are discussed in more details in the forthcoming ESCWA Water Development Report 9.

7) Using Electricity Consumption as a Tool for Groundwater Abstraction in Abu Dhabi Emirate Farms, UAE

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Abstract:

Farm irrigation for agricultural crops such as vegetables, palm trees for date production, and Rhodes grass for camel fodder, currently (2019) is the largest use of groundwater in Abu Dhabi Emirate. Each farmer was permitted to drill two wells within the farm boundary for irrigation groundwater supply. In practice, many farms have more than two wells because farmers drill new wells to replace dry or low-yielding wells, because of the belief that more wells increase the amount of groundwater available to the farm, and because there is no enforcement of the two-well rule. Because the farms are closely spaced in regular grids that extend over large areas, well interference can be substantial in and around the farming districts, and groundwater-level declines can be large. At present there are more than 24,000 farms in Abu Dhabi Emirate, consuming about 2100 million cubic meters of groundwater from more than 54,000 abstraction wells. Farm area in Abu Dhabi Emirate increased from 35,000 ha (hectares) in 1996 to 120,000 ha in 2006, with most of the increase occurring in Al Ain Region. The typical citizen farm was a 183-m (meter) by 183-m plot of leveled land surrounded by a concrete and block wall and date palm, fodders and vegetables were the primary crops. All of these have no water flow meters to measure the real abstraction. To estimate the groundwater abstraction, groundwater wells electric use records for 20011 to 2018 were used to estimate groundwater use at selected pilot farms in Al Ain Region. The high correlation between the amount of irrigation groundwater produced and the amount of electricity consumed at the studied farms offered the possibility of using farm electric records to estimate historical and current groundwater abstraction in farming districts that have substantial concentrations of farms. The compiled records begin in 2011 and includes historical meter readings for about 20,000 farms, forests, and rural wells, comprising about 940,000 total readings. The data was filtered to extract only data for farms that were constructed as typical citizen farms with the combination of date palm and grass crops similar to the mixed farms previously studied and for which irrigation efficiency was estimated. Electric use for these farms was estimated on an annual basis for 2011 to 2018 for each of 9 farming districts in the pilot project. More than 900,000 farm electric meter readings were collected and analyses during this study. Based on a previous investigation that showed groundwater use and electric use, it has been found that trends were linear at mixed palm and grass farms and that the ratios of the trends yielded an average irrigation efficiency of 0.77 m^3/kw.hr. During the 8-year period of records, total annual groundwater uses for farms irrigation in the 9 farming districts pilot project increased from 581 Mm^3 to 743 Mm^3, with about 28% increase in groundwater use.

Keywords: Groundwater Use, Water Demand, Irrigation, Electrical Use.

8) A numerical approach for the evaluation of sustainable yield of shared aquifer basins: A case study from the Mediterranean countries

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Abstract:

The aim of this research is to illustrate that developing steady state models for shared aquifer basins will provide an opportunity to better manage these shared aquifers by realizing the transboundary fluxes between sharing countries. This study addresses a case study in the Eastern Mediterranean Countries. The addressed case study is a source of high level of disputes between sharing countries with regards of water rights. Therefore, this study provides an important methodology to evaluate the sustainable yield of the shared aquifers in order to help develop optimum utilization plans especially for domestic and agricultural uses. An understanding of the regional scale hydrogeological processes and assessing their impact on the aquifer basins will lead to a significant improvement in the determination of the sustainable yield of the shared aquifer basins. A numerical model (GMS-MODFLOW) was developed for the shared aquifer addressed in this study which is the Western Aquifer Basin (WAB) in Eastern Mediterranean Countries. The model was calibrated using historic and recent data. The sustainable yield of the WAB has been considered as the calibrated long-term discharge of the main springs (Timasah and Ras Al-Ain) of the aquifer basin before its development. The results of the study show that the steady state sustainable yield of WAB was 357.9 Mm^3/yr respectively.

Keywords: steady state flow model, sharing countries, utilization plans, springs discharge.

9) Understanding Saline Water Dynamics in Coastal Aquifers Using Sand Tank Experiment and Numerical Modeling

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Abstract:

A better understanding of seawater intrusion (SWI) problem in coastal aquifers is important for a perspicacious management of groundwater resources. SWI is affected by various hydrogeological and hydrological parameters such as: hydraulic conductivity (K_{sat}) of the aquifer, abstraction rate, recharge rate, density of seawater, etc. The objective of this paper is to explore saline water dynamics in an unconfined aquifer under different hydraulic gradients and under managed aquifer recharge (MAR) by using sand tank experiments and numerical simulations using SEAWAT code. Also, the efficiency of MAR in countering SWI malady was explored under different values of K_{sat} by using SEAWAT code. Numerical modeling is an effective tool to investigate the effect of K_{sat} on seawater dynamics. Modeling is cheaper and required less time as compared to the sand tank experiment. The sand tank experiment showed that the retreat rate of the saline water interface is always higher than the intrusion rate. As the hydraulic gradient across the sand tank increases, the saline water interface recedes further in the seaward direction. Injection of 1060 cm^3 freshwater into a well located at the toe of a saline water interface caused its retreat seaward by 40%. The calibrated model was used to simulate the effect of aquifer's hydraulic conductivity on the dynamics of saline water under MAR. The results show that MAR practiced in highly conductive aquifers was less effective in combatting SWI because the injected water discharges rapidly from the aquifer. A small water table mound develops when MAR is practiced in a highly conductive porous medium and hence there is only a small effect in controlling SWI. In contrast, a low aquifer's hydraulic conductivity slows down water flow, develops a higher water table mound and thus induces a significant effect on controlling SWI. Therefore, optimizing MAR requires close consideration of geological settings and hydrological conditions to ensure high efficiency of MAR in mitigation of salinized aquifer.

Keywords: managed aquifer recharge, injection wells, seawater intrusion, sand tank experiment, SEAWAT.

10) Artificial recharge via injection wells for salinity ingress control of Salalah plain aquifer, Sultanate of Oman

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Abstract:

Seawater intrusion (SWI) has been considered one of the most widespread environmental problems that deeply threatened the quality and sustainability of fresh groundwater resources along coastal aquifer in Salalah. The main objective of this study is to determine the results of the same investigation conducted in 2008 by the same author with the results of the current actual transient scenario for the same period of years 2006-2020.

The developed 3D flow showed that the wedge of the SWI in 2020 could possibly be tracked up to 2 km and less than 500 m from the shoreline under the predictive scenario and current actual transient scenario, respectively under constant underflow. The findings of the modeling simulation explained that the maximum path lines of the injection fluids were able to reach the abstraction wells located more than 1.2 km southward of the injection bores in one year travel time under the current actual transient scenario under constant underflow. In 2020 the injection of MTEs was found to be effective in pushing back the SWI zone front by more than 1.2 km under the current actual transient scenario compares to less than 500 m under predictive scenario under constant underflow, especially at the middle of the injection boreholes of the aquifer. This study revealed that the application and simulation of the method helped increase the groundwater levels and decrease the salinity (TDS) levels along the vicinity of the injection line.

Keywords: Salalah plain aquifer, SWI, 3-D groundwater modeling simulation, injection boreholes, artificial groundwater recharge, MTEs.

11) Equilibrium states of groundwater chemistry in coastal region of Kuwait

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Abstract:

Groundwater samples were collected along the coastal region of Kuwait to determine the geochemical nature of the ions and their thermodynamic states. The state of thermodynamic equilibrium predicts the nature of reaction in the aquifer. The geochemical nature was determined by standard plots and ion ratios. The geochemical results of the groundwater samples were then studied with stability plots for silicate and carbonate equilibrium and later they were compared with the saturation states with the aid of geochemical model (PHREEQC). The samples reflect higher EC values with greater values of Na and Cl ranging from brackish to hypersaline nature. The silicate stability plots with respect to major cations reflect that the samples were stable with respect to K-felspar and Kaolinite composition. The carbonate stability plots reflect the stability of the composition predominantly with respect to Calcite and Dolomite fields. Subsequently the saturation states of silicates and the carbonate minerals were determined by using PHREEQC. The saturation index values indicate these samples were consistent with the observations made by plotting in the stability plots with minor variations. Though lithology plays a critical role the minor variations were mainly due to the consideration of temperature and the impact of the associated ionic species in the model. The variations were more significant in the carbonate mineral saturation as carbonates react and attain saturation faster than the silicate minerals. The study also infers that the "*Common Ion Effect*" governs the saturation of these carbonate minerals. Hence, the study reveals the fact that the carbonate minerals are more saturated than the silicate minerals in the groundwater and it is mainly governed by the lithology the associated ions.

Key words: Hydrogeochemistry, Stability plots, Saturation states, PHREEQC.

Keynote Speaker

1) Monitoring of Inorganic and Organic Pollutants in the Desalinated Water from SWCC Plants

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Abstract:

A comprehensive study lasting 20 years, for monitoring of inorganic and organic pollutants in the produced water from Saline Water Conversion Corporation (SWCC) plants in the Eastern and 8 years in the Western provinces was done to identify the compounds of health and aesthetic concern. Water samples from SWCC plants were analyzed with an emphasis on the toxic elements such as mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), selenium (Se), chromium (Cr) and toxic disinfection by-products (DBPs) such as trihalomethanes (THMs) arising due to sea water chlorination. Considering the Saudi Arabian Standards Organization (SASO) and World Health Organization (WHO) guidelines for drinking water, results show compliance with all the values for the components analyzed and found to be under the SASO and WHO regulations while some components were below the detection values.

Keywords: Toxic elements, drinking water, desalinated water, heavy metals, DBPs, SWCC.

2) Investigating Water Conservation Strategies in Kuwait: A Micro-Component Backcasting Approach

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Abstract:

Household water demand has dramatically increased in Gulf Cooperation Council (GCC) countries in the last few decades, due to rapid population growth and changing lifestyles. Growing demand has been met by increasing supply capacity, largely via new desalination plants and over-abstracting groundwater. The continuous investment in water supply to avoid a supply - demand gap has been the default strategy in the GCC, yet reliance on a supply side approach is unsustainable, and associated with declining groundwater, and reliance on desalination that results in major carbon emission and environmental impact whilst also taking a large and growing share of oil revenues. This paper examines the main issues associated with water scarcity in the GCC region, then determines the scale of conservation measures that will be needed to reduce water demand to a more sustainable level. The paper focuses on Kuwait which shares the hydrological characteristics of GCC countries but is the most challenging case, experiencing extreme water stress, due to its very high per capita consumption (PCC), but lowest per capita freshwater availability in the world. The research focuses on the household sector which represents 60% of total water demand in Kuwait. Based on the initial 'Business As Usual' demand forecast of 664 MCM in 2050, annual demand must reduce to 456 Million Cubic Meter (MCM) under a *no new water* target (c 1% saving per annum), to 345 MCM under an *intermediate* target (1.5% saving), and to 239 MCM (2% saving) to meet the most *Aggressive/optimistic* target for 2050. To identify how to meet these targets, the study is using a backcasting approach whereby water conservation scenarios are examined for their ability to reduce demand to the 2050 target. Scenarios will be modelled using a Micro Component (MC) demand model, able to address specific household uses (e.g., bathing, toilet flushing) linked to conservation interventions. The research seeks to understand what uptake of conservation measures is needed to meet 2050 targets, and the wider economic and environmental benefits of doing so. GCC countries need to adopt long term demand management policies, with targets of breaking trends, in order to achieve a desired future situation. A comprehensive policy that covers different aspects (e.g., socioeconomic and environment) and ensures the public participation in decision-making process. Household water sector has a considerable demand share, yet very limited studies have discussed the reasons for such high demand share and explored future demand management outlook. Thus, a key need is to conduct studies regarding demand management in this sector; data on household sector is very limited (e.g., end-use components consumption), therefore, it is advantageous to water research centers to conduct surveys investigating one of the major water consumer sectors.

Keywords*:* Household water demand, water scarcity, water conservation; backcasting, micro-component model, desalination, Kuwait, Gulf Cooperation Council.

3) Optimal management of multiple water sources to supply drinking water distribution networks in the desert cities of western Iraq

الإدارة المثلى لمصادر المياه المتعددة لتزويد شبكات توزيع مياه الشرب في المدن الصحراوية: (مدينة الرطبة غرب العراق كحالة دراسية)

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الخلاصة:

إن لمصادر الموارد المائية المتمثلة بالأنهار والبحيرات والآبار أهمية كبيرة في النمو والتطور الحضاري من خلال تلبية الاحتياجات المختلفة للسكان. نظرا للتغيرات المناخية والبيئية التي تشهدها مناطق مختلفة من العالم بالإضافة الى النمو المتزايد للسكان أصبح من الضروري إدارة المصادر المائية المختلفة بشكل يحقق توازن ما بين العرض والطلب خاصة في المناطق الجافة التي تعاني من محدودية الأمطار المتساقطة ومعدلات التبخر المرتفعة نتيجة لارتفاع درجات الحرارة. العراق كغيره من البلدان يمتلك مصادر مائية سطحية تعتبر المجهز الرئيسي لمواقع الطلب الزراعية والصناعية والمنزلية بالإضافة الى خزين استراتيجي من المياه الجوفية يمكن الاستفادة منها خلال فترات الشحة المائية. في هذه الدراسة تم استخدام نموذج تقييم وتخطيط المياه (WEAP) لتقييم الطلب الحالي والمستقبلي لقضاء الرطبة الواقع غرب العراق للفترة (2020-2030). حيث أظهرت الدراسة وجود زيادة سكانية بلغت 20.9% للفترة 2021-2030 تتطلب كمية مائية تصل الى (4.43) مليون متر مكعب سنويا بحلول عام 2030. كذلك وجود عجز حالي في تجهيز إمدادات المياه للمدينة والذي يتم حاليا من ثلاث مصادر مختلفة وهي عن طريق سحب المياه من نهر الفرات عبر موقعي القائم وهيت وكذلك عن طريق سحب المياه من مجموعة آبار مكمن الضبعة شرق المدينة وضخها الى مدينة الرطبة بواسطة الأنابيب، الأمر الذي يتطلب إدارة مثلى لمصادر تزويد المدينة بالمياه لسد الاحتياج السكاني خصوصا في ضل التكاليف السنوية العالية لعملية نقل تجهيز إمدادات المياه للمدينة. تم تقييم التكاليف والأرباح الممكن تحقيقها من خلال اقتراح أكثر من سيناريو للمنطقة تضمنت الكلف التشغيلية لمصادر التزويد المائي الموجودة حاليا بالإضافة الى اقتراح إنشاء مشروع لتجهيز المدينة بالمياه على سد الرطبة والذي يعتبر مصدر المياه الأقرب والأقل كلفة بالنسبة للقضاء. أظهرت نتائج السيناريو الأول الذي تمثل با ستخدام آبار الضبعة بالتزامن مع مشروع سد الرطبة المقترح تلبية الاحتياج السكاني حتى عام 2030 مع تسجيل عائد اقتصادي إجمالي للفترة 2021-2030 بلغ ($9,289,039) مع تكاليف تشغيل يومية 475 دولار / لليوم. أما السيناريو الثاني فيقترح استخدام الخط الناقل قرب مدينة القائم مع سد الرطبة لتحقيق أرباح إجمالية لنفس الفترة بلغت ($8,796,289) يرافقها تكاليف تشغيل سنوية بلغت ($2,226,500) نظرا للمنسوب المرتفع للمنطقة والذي يصل الى (185 متر). كذلك الحال بالنسبة للسيناريو الثالث الذي تضمن استخدام الخط الناقل قرب مدينة هيت مع سد الرطبة لتحقيق عائد اقتصادي بلغ ($7,372,789) مع تكاليف تشغيل يومية 945 دولار / لليوم والذي يعتبر الأعلى قياسا بباقي السيناريوهات بسبب المنسوب المنخفض لمنطقة التجهيز في مدينة هيت وطول مسار الأنبوب الناقل مما يتطلب تكاليف ضخ مرتفعة.

الكلمات الدالة: الإدارة المثلى للمياه، مصادر المياه المتعددة، المدن الصحراوية، غرب العراق.

4) How Syria Crisis Affects the Potable Water System Efficiency in Non-State Armed Group Controlled Areas

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Abstract:

The purpose of this study/technical assessment was understanding the effects of the crisis of Syria on water sector in the area out of the control of Syria regime (Non-State Armed Group controlled areas), and defined the worst communities, located in Daret Azza sub district/Aleppo governorate, which need urgent technical and financial assistance in the fields of water and sewage sectors. The study showed that 100% of wastewater was not treated because of lack of wastewater treatment plants. There was no water distribution network and also 91% of the people in the community has not accessed to the public water network. The water-supply infrastructure was not efficient. Therefore, all water-supply infrastructure in Daret Azza subdistrict was needed to rehabilitate and maintenance. The people of Daret Azza subdistrict spent about 8-13% of their income for purchasing unsafe water while the people living in the Regime-controlled areas spent about 0.5-1% of their income for purchasing safe water. For this reason, the people of Non-State Armed Group controlled areas needed urgent and sustainable technical and financial supports, especially for obtaining potable water.

Keywords: Water supply, Syria crisis, water system, Daret Azza.

5) Application of Optimum Distribution Pressure in Qatar

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Abstract

Kahramaa, Water Operation and Control Department (WOCD) has implemented new reliable fully automatic technique for water network operation that guarantees a required residual pressure at network lowest pressure point (critical points). This also safeguard pump operation within manufacturer recommended range of operation and without continuous area pressure monitoring and without stopping pumps when demand deviates out recommended operation range.

Keywords: Kahramaa, drinking water, municipal water supply, water demand, water pumping to network, water distribution.

Keynote Speaker

1) Disrupting Hydroinformatics: Reimagining Water Planning and Management Insights

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Abstract:

Effective water resources planning and management is critical for all systems (regions, nations, basins/watersheds of all levels, aquifers, coasts or other landscapes), especially given the increasing and often conflicting water demands, depleting and increasingly polluted water supplies, and increasing climate risks. A critical need in this regard is the availability of information on all key aspects of the hydrologic cycle, as well as associated information on water quality, water infrastructure, and system attributes.

Modern technology is rapidly evolving to "disrupt" all aspects of hydroinformatics to provide better insights to monitor, plan, and manage this scarce resource. This includes new ways of collecting data from in-situ sensors (in gauges, portable equipment, surveys, water drones, and Apps), earth observation (from satellites and aerial including drone surveys), cloud analytics (moving decision support systems to the cloud and leveraging the power of AI including machine learning), interactive dashboards and evolving access platforms (including AR, VR, and Chatbots). This is also leveraging and contributing to a new world of open data and analytics in the public domain. In particular, Earth Observation from satellites is helping provide a near global view of hydroinformatics – including related to climate (precipitation, temperature), snow, glaciers, water levels, evapotranspiration, and even some aspects of water quality, groundwater change, and streamflows, especially when combined with in-situ data. These resources are also providing excellent insights into the systems for the hydroinformatics – e.g. the basin or watershed context (including information on topography, land cover, cropping patterns, urban growth, etc.) and are also being used to adjust population and other data to a scale relevant for water planning and operations.

These approaches can help us reimagine hydroinformatics for a modern age. Countries around the world are beginning to leverage these tools to develop new national frameworks for water information management, including in the public domain, and using it to unleash a new generation of insightful analytics. A new set of approaches merging global data and tools with local data, needs, and insights can help achieve more accurate results. New weather, hydrologic, or inundation forecasting systems could help revolutionize early warning. Water infrastructure (e.g. surface and groundwater system storage, bulk water management, irrigation systems, etc.) can be operated with better system insights and forecast intelligence. Reconstructed longer-term time series of hydrologic cycle variables and water accounting can help water planners gain a longer-term insight of key indicator variability and trends to support longer-term planning that is especially important in a changing climate. These approaches could be further enhanced by institutional and policy upgrades relating to capacity building, open data ecosystems, institutional ecosystems including private sector especially startup innovation, and facilitating an overall culture of hydroinformatics innovation especially amongst the youth.

The Gulf region could leverage these advances to modernize all aspects of the hydroinformatics data value chain – from data to information to knowledge to generating insights for decision support at all levels for planning and day-to-day operations. These systems could support not only water resources management, but also water supply and sanitation systems and coastal resilience where relevant. The region can build on local, regional, and global good practices to learn from, and contribute to, this rapidly evolving global modern hydroinformatics ecosystem.

The presentation will showcase some of the more promising hydroinformatics technologies and approaches. It will also showcase examples from around the world where such approaches are being developed and used and useful resources to learn more about these aspects.

Keynote Speaker

2) Advancing Water Sustainability in Bahrain through Water Resource Management Knowledge Platforms

Dorren Salazar, Marisa Escobar, and **David Yates**
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Mohamed Aljanahi and Ahmed Alqattan
Water Resources Management Ministry of Oil (*WRM/MOO)*

Abstract:

Water management poses a critical challenge for Bahrain, as demonstrated by the country's integrated water resources management SDG 6.1.5 scoring of 39/100 for 2020. However, the Kingdom is engaging progressive and proactive institutions, such as the Ministry of Oil of Bahrain (MOO), to respond to these challenges. MOO is working to implement a countrywide Integrated Water Resources Management (IWRM) program with the aim of building a resilient water sector for future development and climate change in the Kingdom of Bahrain. To this end MOO is hosting the Water Resources Management Unit (WRM) to implement this project. Through this activity, MOO has identified specific IWRM needs such as tool development and practical process support to address the country's sustainability goals. MOO / WRM and their partners are developing and implementing core building blocks for monitoring and analysis of water resources information, scenarios and alternatives, which should help guide their IWRM efforts. These tools and capabilities, strengthened by a targeted capacity-building program, will assist the Kingdom to improve water sector data information sharing, to open doors for improved public participation in IWRM dialogue, while actively identifying, designing, and evaluating the potential impacts of water management policies and projects.

Developing new IWRM plans at the country-level involves understanding assumptions regarding water demand projections as well as favored water supply and wastewater treatment options. However, such preconditions might not be the optimal balance between infrastructure and other strategies available to water resources planners and decision makers to optimize the potential impacts of various water resources management levers on quality potable water service provision, maximization of water reuse, and reduction of the environmental impacts of water production and wastewater discharge. The tools developed for WRF support should be flexible and extensible, in the case of Bahrain allowing for the analysis of key uncertainties such as climate change and the costs of labor and energy inputs, as well as strategies such as artificial groundwater recharge, rainwater harvesting, and greywater reuse in new constructions.

Therefore, developing and implementing a comprehensive and flexible IWRM model that takes into account a variety of uncertainties, and both infrastructure and other strategies can be a constructive driver for identifying solutions that enhance the resilience of the country's water resources. The new WRM planning and analytical tools will be developed in an open data environment that can link water to energy, industry, health, environment and other sectors, and will include two allied Knowledge Platform elements, 1) a Decision Support System (DSS) based on the Water Evaluation and Planning (WEAP) model; and 2) a web-based Water and Climate Knowledge Platform (WCKP). Together, these will serve as quantitative modeling environments to assess water resource vulnerabilities and potential impacts of water management strategies.

3) Development of Water Information System for the Kingdom of Bahrain

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Abstract:

The creation of an effective water information system is essential for the formulation of sustainable water resources management, especially in countries where absolute water scarcity exists. This paper reflects on the experience of the Kingdom of Bahrain in developing the first part of its water information and management system – the Bahrain Water Resources Database (BWRDB). The prime objectives of the database are: (*i*) to provide a reliable, timely, up-to-date, standardized and internationally comparable water data and relevant information for knowledge sharing and dissemination; (*ii*) to support effective evidence-based decision and policy-making processes in water resources planning and management; and *(iii)* to provide water data and relevant information for tracking and reporting on progress against the sustainable development goal 6 targets and global indicators. The approach employed for the development of BWRDB is based on the globally accepted experiences in water information management and data quality standards. The developed methodology includes three complementary phases: assessing data and information needs; data collection and quality control; and integration with GIS visualization tools and web-portal facilities. The third phase of the database development is yet to be implemented and will therefore not be covered in this paper. In its current version, the water information system is a simple MS Excel spreadsheet platform comprising 13 components, 31 sub-components and more than 440 statistical topics or variables covering a wide range of data on water resources and uses. It is, however, viewed as a work-in-progress project with ongoing development and improvement in scope and functionality. Being already put in practice, the BWRDB has played a key role and proved to be a valuable tool and a solid information base for serving the previously mentioned objectives. The paper concludes with a series of important next step actions, first, strengthening the water data institutional framework by fostering inter-institutional coordination; second, constantly upgrading and improving the database as more water data become available and needs for further software applications and evaluation processes arise.

Keywords: Water Information System, Sustainable Water Management, Water Data Institutions, Water Data Monitoring System, Kingdom of Bahrain.

SPECIAL SESSION 4: INNOVATION IN DESALINATION

Coordinator:

Ahmed Al-Oraifi, *Saline Water Conversion Corporation (SWCC), KSA.*

Moderator:

Ahmed Al-Amoudi, *SWCC, KSA.*

Topic & Objectives:

This session presents recent advancements and innovations in the field of membrane desalination. The key themes of the webinar encompass advances in Reverse Osmosis membrane science and technology and practical innovations in the plant operations and brine mining.

Speakers and Panelists:

- **Seungwon Ihm,** *Senior Expert, Desalination Technology Research Institute, SWCC, KSA* "Multistage Nanofiltration System for Supplementing Drinking Water with Magnesium Extracted from Bine"
- **Byungsung Park,** *Desalination Technology Research Institute, SWCC, KSA* "Optimizing Pretreatment Performance"
- **Nikolay Voutchkov,** *Desalination Technology Research Institute, SWCC, KSA* "Brine Mining – the Path Forward"

POST CONFERENCE WORKSHOPS

Training Workshop 1: From Science to Analyses to Policymaking: Simplifying regional climate modelling outputs and their applications in the GCC and beyond

Organizer: ESCWA & WSTA

Duration: 1.5 hours

Description: Climate change impacts affect many sectors including water resources and agriculture. However, many studies either use climate modelling outputs incorrectly or use observed data to conduct trend analyses. In this workshop, we'll explore the advantage of using regional climate modelling outputs, why multiple models should be considered, and the advantages of using modelled data instead of observed data. We will also simplify access and usability of regional climate modelling outputs. Government officials and researchers working in the environmental, water, and agricultural sectors are encouraged to attend.

Trainer: Dr. Marlene Ann Tomaszkiewicz is currently working as climate data and geospatial analyst for the Economic and Social Commission for Western Asia (UN-ESCWA), Marlene has over 20 years of experience in hydrology and hydraulics, flood and drought studies, climate data analysis, GIS, and non-conventional water resources. She holds a Ph.D. in water resources and environmental engineering from the American University of Beirut (Lebanon), a M.S. in civil engineering from Louisiana State University (USA), and a B.S. in civil engineering from Illinois Institute of Technology (USA). She is a registered professional engineer (Washington, DC and USA) and a Project Management Professional.

Training Workshop 2: Water Accounting concept and sharing experience

Organizer: IWMI & WSTA

Duration: 3 hours

Description: Water accounting provides comprehensive information related to hydrological processes and water consumption for better communication, policy, and decision-making in a geographical domain. The training workshop, offered by IWMI, will introduce state-of-the-art knowledge on Water Accounting (WA) concept and will discuss challenges in developing and implementing water accounting cycles (Rapid and Advanced). In addition, the workshop will highlight the need to apply water accounting for efficient water resources management at different geographical scales (from farm to catchment). The workshop will be interactive, include short exercises, and create awareness about the benefit of implementing WA systems and lessons learned from the international pilot projects.

Trainer: Eng. Marwa Ali is a Research officer of Water Resources Management and Accounting at the International Water Management Institute (IWMI) the Middle East and North Africa Office (MENA). Over 17 years of experience, she built her career in a variety of roles and activities, where she was not only a researcher but also a lecturer, workshops and training organizer. Eng. Ali implemented many national, regional, and international projects that dealt with water resources management, flash floods risk management, hydrological modeling, geo-heritage, climate change impacts on the water resources, and drought management. In addition, she supervised MSc theses and design curricula for post-graduate water resources courses. Eng. Ali's mission is to provide support to improve the management of water resources in the MENA region and to build capacity to improve the productive use of water in all related water sectors.

Training Workshop 3: Valuing Water

Organizer: UNESCO

Duration: this training will be conducted through 4 session each with 2 hours. The first and second sessions will be conducted on the 15-16 February 2022 (the third and fourth will be on 21-22 February 2022); the session will start at 10am.

Description: The activity is funded by Sultan bin Abdulaziz Al-Saud Foundation of the Kingdom of Saudi Arabia. The training is developed to improve participants' knowledge and understanding on methodologies and approaches to valuing water across different use sectors and how these tools have been applied to improve water management. The desired outcome is that the trainees would understand how valuation can potentially lead to better decision-making in terms of financing, governance, and knowledge and capacity-building and implement what they learned in their professional activities.

Trainer: Prof. Ali Karnib is working extensively on a wide range of areas in sustainable water resources management in the Arab region, such as studies on IWRM, Water-Energy-Food-Ecosystems Nexus and assessment of the impact of climate change on water resources and water use. His experience is a combination of strong academic credentials (Full Professor of Engineering at the Lebanese University and strong publications and scientific modeling record) as well as wide experience from projects and programs management and consultancy services both at policy level as well as from the field. Prof. Ali Karnib holds a PhD in Civil Engineering from Artois University, France. He has published over 60 scientific articles, international working papers, reports and technical manuals. He is member of the Editorial Board of the Water Resources Management Journal (Springer Editions) and member of the international scientific committee of the WORLD CONGRESS OF EWRA on Water Resources and Environment.

WATER SCIENCES AND TECHNOLOGY ASSOCIATION (WSTA)

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

1) 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". The 13th Conference was held in Kuwait during 12-14 March 2019 under the theme "Water in the GCC: Challenges and Innovative Solutions".

2) Symposiums & Workshops

The WSTA has organized many symposiums and training workshops. The followings are a list of these: "Symposium on Water Supply Fluoridation" 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", organized in co-operation with the European Desalination Society (EDS), 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. Training course on "Using Mathematical Dynamic Modelling for Integrated Water Resources Management Using the program WEAP 20 October 2014 in the Sultanate of Oman in cooperation with the Ministry of Regional Municipalities and Water Resources. WSTA conducted a Regional Training Course on "Water Footprint Assessment in the Gulf Cooperation Council" during April 20-22, 2015, in the Kingdom of Bahrain, in cooperation with AWARENET, AGU, MENA NWC, ESCWA and Cap-Net UNDP. Further, a training workshop on "Non-Revenue Water" was held during 15-19 November 2015 in the Kingdom of Bahrain, in cooperation with the Arab Countries Water Utilities Association (ACWUA). Moreover, WSTA conducted many training workshops, either during its conferences or separately. The Association 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. In addition to the workshops, WSTA had organized a Seminar on "Bottled Water Consumption in the GCC Countries", in collaboration with KISR and KFAS on 9th January 2020, followed by a virtual seminar on "The Experience of Artificial Recharge in the Countries of the Gulf Cooperation Council," organized in cooperation with KISR, 17 March 2021. In addition, a virtual seminar on "Investment Opportunities in Brine Water", was held on 8 April 2021. Recently, a webinar on "Produced Water Management, Challenges and Opportunities" was held on 25th October 2021, organized jointly with WSTA and Omani Water Society.

3) 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:

- **Prof. Abdulaziz S. Al-Turbak**, President, Kingdom of Saudi Arabia
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For further information, please visit the WSTA website at: https://wstagcc.org/

Previous Gulf Water Conferences