جمعية علوم وتقنية المياه
Water Sciences and Technology Association

KAHRAMAA كهرماء
المؤسسة العامة القطرية للكهرباء والماء
Qatar General Electricity & Water Corporation

Under the Patronage of H.E. Eng. Saad bin Sharida Al Kaabi Minister of State for Energy Affairs

WSTA 15th

GULF WATER CONFERENCE

Water in the GCC: Embracing Technological Progress

28-30 APRIL 2024

Sheraton Grand Doha Resort & Convention Center

Doha Qatar

Scientific Program and Abstracts

مؤتمر الخليج الخامس عشر للمياه

The 15th Gulf Water Conference

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سعادة وزير الدولة لشـــؤون الطاقة

المهندس سعد بن شريده الكعبي

Under the patronage of

H.E. Eng. Saad bin Sharida Al Kaabi

The Minister of State for Energy Affairs

الخامس عشر	**مؤتمر الخليج للمياه** "المياه في دول مجلس التعاون: مواكبة تكنولوجيا العصر"
15th	**Gulf Water Conference** "Water in the GCC: Embracing Technological Progress"

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Introduction

Over the past five decades, the GCC countries have witnessed an unprecedented and sustained economic and social transformation, which has been associated with one of the world's highest population and urbanization growth rates, coupled with rapidly changing lifestyles and consumption patterns. Such transformation has been associated with a rapid increase in sectoral water requirements that goes beyond their limited available freshwater resources.

Although the GCC countries are situated in one of the most water-scarce regions of the world with an extremely poor endowment of freshwater resources, they have done well in the provision of water supply to their populations primarily by relying on desalination technology, which is made possible by their strong economies and substantial financial and energy resources. Currently, a safe, affordable, and stable domestic water supply has been established in each country covering 100% of its population. However, municipal water supply systems are associated with substantial financial, economic, and environmental costs.

On the other hand, agricultural water demands, representing about 80% of the total water requirements in the GCC countries, have been met mainly by heavy groundwater abstraction, and to a lesser extent by treated municipal wastewater. However, a major concern is that the majority of these groundwater resources are non-renewable, are being extensively mined, and are rapidly depleting, while the remaining limited and renewable groundwater resources are being over-exploited beyond their replenishment rates, leading to their quality degradation due to saltwater intrusion.

In the past decades, to address the water sector challenges the GCC countries have been focusing on a supply-side management approach to meet the ever-increasing demands for water, manifested by the construction of desalination plants, dams, systems for groundwater abstraction, and reuse of treated wastewater. Recently, the countries have complemented this traditional approach by a demand-side management approach utilizing structural, sociopolitical, and economic policy tools to influence demand and achieve water use efficiency in the various consuming sectors.

Within the GCC countries' efforts to achieve effective water resources management, technology can play a major part as an enabler for both supply-side engineering measures and demand-side management and efficiency measures. The implementation of technology in the GCC countries' water management system has been more focused on the supply-side engineering measures and operation, and less on the demand and efficiency measures. Examples of these are technologies used to produce fresh and clean water (e.g., desalination and wastewater treatment technologies), and mathematical models that facilitate decision-making in the planning, management and optimal operation of water resources systems (e.g., simulation models for groundwater and surface water systems). The supply and demand systems can be better considered holistically both for longer-term planning and real-time operations facilitated by technology.

Recently, new generation of technologies, driven by the developments in information and communication technologies (ICTs), have been emerging providing powerful enabling tools for effective water management. Examples of these are smart water management technologies relying on ICTs to provide real-time, automated data to resolve water challenges, as well as for planning and operational purposes; e.g., SCADA in water supply, modern in-situ sensors and earth observation, improved metering and billing systems, or creation of "digital twins" of facilities/systems. Other examples include smart agriculture using sensors for data acquisition, transmission and presentation, and hydroinformatic systems which integrate numerical modeling and data science methods in a digital environment (typically GIS and cloud computing to facilitate data management, analytics, and visualization) that facilitate the conversion of data into information, subsequently into knowledge, and eventually management decisions.

As we stand on the brink of a technological revolution, i.e., the fourth industrial revolution, which will fundamentally alter and transform entire systems of production, management, and governance, it is expected that technology will have an impact on the entire water sector and its management-related activities. The current plethora of data coming from all types of devices together with the escalating increase in computer capacity is revolutionizing almost all sectors. The water sector system will not be an exception. For example, in the municipal water supply sector, combining the power of big data analytics, including Artificial Intelligence, with existing and future urban water infrastructure represents a significant untapped opportunity for the operation, maintenance, and rehabilitation of urban water infrastructure to achieve economic and environmental sustainability. Similarly, in agricultural water management, adopting smart water management systems, where sensors measure soil moisture in real-time and automatically irrigate the field without human intervention provide a major opportunity to enhance irrigation efficiency and optimize water use.

There will be a need for stocktaking of these modern innovations, explore their current adoption in the GCC countries, and explore policy, institutional, and technical facilitation of these technologies to improve overall water management and sustainability in the region.

The **WSTA Fifteenth Gulf Water Conference** advocates harnessing the potential of technologies in both the supply-side and demand-side management areas to achieve effective water management in the GCC countries. It promotes the exchange of experiences and discussion on the benefits, costs, risks, required human capacities, and barriers faced in their implementation.

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

Conference Objectives

- REVIEWING current and emerging technologies used in the various water sectors, improve their awareness, and identify their advantages, challenges, and limitations.
- SHOWING how the different technological means of implementation can promote the necessary transformative change in the water sectors.
- PRESENTING technological solutions implemented in the region and internationally to address water sector challenges.
- DISCUSSING and highlighting the central role of investment in R&D in localizing and producing water sector technologies in the GCC countries to skate away from being just a market.
- IDENTIFYING the main barriers to the implementation of emerging technologies in the management of the water sector.
- CONNECTING water professionals to exchange experiences and best practice case studies in the GCC countries and other countries in the region on the use of technology in the water sector.

Conference Sessions & Training Workshops

Regular Sessions:

Day 1: Technical Session 1: Water Innovation and Technology (Keynote Speakers)

Day 2:

1) Technical Session 2A & 2B: Desalination Management
2) Technical Session 3A & 3B & 3C: Surface Water & Groundwater Management
3) Technical Session 4: Integrated Water Management

Day 3:

4) Technical Session 5A & 5B: Agricultural Water Management
5) Technical Session 6A & 6B: Wastewater Management

Special Sessions:

Day 1:

1) SS1: Water MIS for Efficient Integrated Water Resource Management; UNESCO Doha Office
2) SS2: Using Technology to Bridge the Data Gap for Efficient Management of Agricultural water; FAO-RNE
3) SS3: De-carbonization Pathways in the Water Sector in the GCC Countries (GCC reps); GCC-SG

Day 2:

4) SS4: Effective Management of the Municipal Water Sector; ACUWA
5) SS5: Frontiers in Water Science and Technology Research: UNESCO and the International Decade of Science for Sustainable Development; UNESCO Cairo Office

Day 3:

6) SS6: Privatization and Regulatory aspects of water utilities; ACWUA and WSTA

Training Workshops: (Attendance by registration)

Day 1: Wastewater Treatment and Reuse in the GCC countries: How to unlock the power of data?; provided by IWMI

Day 2: WHO's Sanitation Safety Plan (SSP) Tool; provided by WHO

Day 3: Session 7: Conference Conclusion and Recommendations

Conference Program

Day 1: 28 April 2024

08:00-09:00	**Registration**
Opening Ceremony	
09:00-10:00	**H.E. Eng. Essa Bin Hilal Al- Kuwari, President, Qatar General Electricity and Water Corporation (KAHRAMAA)**
	Eng. Abdelrahaman Mohamed Almahmoud, Chairperson of Board of Directors, Water Sciences and Technology Association (WSTA)
	H.E. Dr. Mahmoud Abu-Zeid, President, Arab Water Council (AWC)
	Eng. Khaldon Khashman, General Secretary, ACUWA
	Dr. Hammou Laamrani, United Nations Economic & Social Commission for Western Asia (ESCWA)
10:00-10:10	**Short Break**
Technical Session 1: Water Innovation and Technology	
10:10-10:20	**Conference Welcome and Introductory Remarks: Potential of Artificial Intelligence for Sustainable Water Management: Waleed Al-Zubari, Chairman, Scientific Committee, WSTA**
10:20-10:40	**Keynote Speaker: Digitalization in Water: Key to Security in the Realm of Risk of Cyber Insecurity; Hammou Laamrani, ESCWA**
10:40-11:00	**Keynote Speaker: Deep Neural Networks Application in Environmental and Water Resources Simulations; Mohammad Mahdi Rajabi, University of Luxembourg**
11:00-11:20	**Keynote Speaker: Navigating Water Scarcity and Supporting Food Security: Market-based Development of Sustainable Irrigation; Youssef Brouziyne, IWMI**
11:20-11:40	**Keynote Speaker: Updated WHO Guidelines and Tools on Water and Sanitation; Rola Al-Emam, WHO**
11:40-12:00	**Keynote Speaker: Addressing Climate Change Risks on Water and Food Security in the Arab Region, Vinay Nangia; ICARDA**
12:00-12:30	**Prayer and Refreshments Break**
Special Sessions	
12:30-13:30	***SS1: Water MIS for Efficient Integrated Water Resource Management; UNESCO Doha Office*** ***(Donia Abdelwahid: Patrice Moix (UNESCO-Paris), Helmi Ana'am (Yemen), Ayisha Al-Khatri (Oman))***
13:30-14:30	***SS2: Using Technology to Bridge the Data Gap for Efficient Management of Agricultural water; FAO-RNE (Bert Coerver (FAO-ROME), Abdullah Barhy (FAO-Rome), Mohamed Abdallah (FAO-Cairo))***
14:30-15:30	***SS3: De-carbonization Pathways in the Water Sector in the GCC Countries (GCC reps); GCC-SG*** ***(Mohamed AlRashidi: Hind Al-Ali (Ministry of Energy, UAE), Mousa AlHajri (SWCC, KSA), Mohammed AlAali (EWA, Bahrain))***
15:30-	**Lunch**
Training Workshop (Attendance by registration)	
16:00-18:30	***Wastewater Treatment and Reuse in the GCC countries: How to unlock the power of data?; IWMI: (Youssef Brouziyne (IWMI), Khaldon Khashman (ACUWA), Muhammad Khalifa (IWMI))***

Day 2: 29 April, 2024

	Technical Session 2A: Desalination Management	**Technical Session 3A: Surface Water & Groundwater Management**
	Chairpersons: Abdulmajeed Al-Awadhi	**Chairpersons:** Abdulaziz Al-Turbak & Mohammed Swar
08:00-08:20	**Keynote Speaker: Revolutionizing Desalination: KISR's Breakthrough Projects Addressing Water Crisis Challenges; Mansour Ahmed, KISR, Kuwait**	**Keynote Speaker: Airborne VHF Sounding Radar for Desert Subsurface Exploration of Shallow Aquifers: DESERT-SEA; Essam Heggy, QEERI, Qatar**
08:20-08:35	Fuel Allocation in Water and Power Cogeneration Desalination Plant; Ibrahim Al-Mutaz, Saudi Arabia	Flood Hazard Maps Generation caused by hypothetical failure of the Tabaqa Dam by use of HEC-RAS 2D model; Sadeq Sulaiman, Iraq

Note: Virtual presentations are in "Green"

08:35-08:50	Prospective Brine Management Strategies for Sustainable Desalination in the GCC Countries; Syed Javaid Zaidi, Qatar	Assessing the hydrological and hydraulic behaviour of an arid catchment which determines flood impacts in Dhofar governorate, Oman; Manal Al-Balushi; Oman
08:50-09: 05	Solar-driven Desalination in Saudi Arabia for Sustainable Energy Future: A Thermodynamic Approach for Universal Energy Efficiency with a Standard Solar Energy Platform; Raid Alrowais, Saudi Arabia	Development of Flood Risk Mapping and Mitigation Strategies for Al-Qassim Region, Saudi Arabia; Atef Kawara, Saudi Arabia
09:05-09:20	Advanced GC-MS-SIM Method for Simultaneous Determination of Bisphenol-A and Phthalic Acid Esters in Seawater; Mohammed Akkbik, Qatar	Hydrological Assessment of the weather state "Madar 22": Implications for Water Resources Management" in the Kingdom of Saudi Arabia; Yousry E. Mattar, KSA
09:20-09:35		Atmospheric Water Generation in Qatar: A Sustainable Approach for Extracting Water from Air Powered by Solar Energy; Aiyad Gannan, Qatar
09:35-09:45	**Discussion**	**Discussion**
09:45-10:00	**Short Break**	
	Technical Session 2B: Desalination Management	**Technical Session 3B: Surface Water & Groundwater Management**
	Chairpersons: Hamad Al-Hatmi & Ali Redha Hussain	**Chairpersons:** Ali Al-Maktoumi & Abrar Habib
10:00-10:25	**Keynote Speaker: Oil Spill Management to Prevent Catastrophic Shutdown of Desalination Plants; Zhaoyang Liu, QEERI, Qatar**	**Keynote Speaker: New Developments in Mathematical Modeling of Groundwater Systems; Abdelkader Larabi, Université Mohammed V, Morocco**
10:25-10:40	Oxide Activated Carbon for Seawater Desalination Using Solar Energy; Wafa Al Rawahi, Oman	Assessment of Groundwater Quality and its Implications for Drinking Purposes in Najran Southern Saudi Arabia; Abdulnoor Ghanim, Saudi Arabia
10:40-11:05	An Innovative Approach to Desalination and Cooling Using Forward Osmosis with Thermal Recovery and Vapor Absorption Cycle; Mansour Ahmed, Kuwait	Using MODFLOW to Evaluate Technical Feasibility of Operating Small RO Units with Shallow Groundwater Wells in Kuwait; Amjad Aliewi, Kuwait
11:05-11:20		Assessment of groundwater suitability for drinking and irrigation purposes using physicochemical parameters at Al-Jouf Area, Saudi Arabia; Raid Alrowais, KSA
11:20-11:30	**Discussion**	**Discussion**
11:30-13:00	**Prayer and Lunch**	
Special Sessions		
13:00-14:00	***SS4: Effective Management of the Municipal Water Sector, ACUWA (Khaldon Khashman, Muna Hindiyeh, Adel Alobeiaat)***	***SS5: Frontiers in Water Science & Technology Research: UNESCO and the International Decade of Science for Sustainable Development, UNESCO Cairo Office (Abdelaziz Zaki, Waleed Zubari, Mohamed AlRashid, Ali Al-Maktoumi, Dalal AlShamsi, Syed Zaidi, Mahmoud AbuZeid)***
	Technical Session 4: Integrated Water Management	**Technical Session 3C: Surface Water & Groundwater Management**
	Chairpersons: Mohammed Al-Rashid & Hamad Bawazeer	**Chairpersons:** Abdelkader Al-Arabi & Dalal Al-Shamsi
14:00-14:20	Water Demand Forecast using Machine Learning; Waleed Eldamaty, UAE	**Keynote Speaker: Artificial Intelligence Application in Hydrogeology and Groundwater Management; Khalid ElHaj, UAE University**
14:20-14:35	System Dynamics Model to Study the Effect of Different Policies on Bahrain Hydrological Processes; Abrar Habib, Bahrain	**Keynote Speaker: Mainstreaming the Outcome of the UN Groundwater Summit within the Arab Strategy for Water Security; Bisher Imam, UNESCO**
14:35-14:50	Assessment of the Sustainability of Water Management System in the Sultanate of Oman, A Case Study of Al-Batha Basin; Yaser Alsaadi, Oman	Feasibility and Site Investigation Study for Aquifer Storage and Recovery (ASR) Application for Water Supply in Arid Areas, Oman; Ali Al-Maktoumi, Oman
14:50-15:05	Status of IWRM in GCC Countries According to UN-SDGs; Mohamed Shamrukh, Qatar	Civil Society Participation in Constructing Small Storage Dams, The Experience of the Sultanate of Oman; Ali Al-Hamdi, Oman

15: 05-15:20	Water Reuse Strategies: Qatar's Successful Implementation of recycled water in District Cooling Plants, Hamad Bawazir, Qatar	Groundwater aquifers susceptibility index of Waterborne Diseases Outbreaks (ASIWD) in Nile Delta, Egypt; Osama Sallam, UAE
15:20-15:35	**Discussion**	**Discussion**
***Training Workshop** (Attendance by registration)*		
16:00-19:00	***WHO's Sanitation Safety Plan (SSP) Tool; WHO:** (Rola Al-Emam, Sohaib AbuHamoor, Khaled Al-Louzi, and Case studies: Ghada Kassab (Jordan), Raya (Nama-Oman), Dana Al-Abdulla (Ashghal-Qatar), Dan (Australia))*	

Day 3: 30 April, 2024		
Special Sessions		
08:00-09:00	***SS6: Privatization and Regulatory aspects of water utilities, ACWUA and WSTA** (Khaldon Khashman, Ahmad Alazzam (Jordan), Saud AlShithani (Oman))*	
	Technical Session 5A: Agricultural Water Management	**Technical Session 6A: Wastewater Management**
	Chairperson: Abdulrasoul Al-Omran	**Chairperson:** Youssef Brouziyne
09:00-09:20	**Keynote Speaker: Climate Change and Water Scarcity: Strategies for Sustainable Agricultural Water Use; Kamel Mustafa Alsayed, AOAD**	**Keynote Speaker: Electricity Generation and Industrial Wastewater Treatment Using Microbial Fuel Cell; Abdullah Al-Matouq, KISR, Kuwait**
09:20-09:40	**Keynote Speaker: Economics of Water under Climate Change in Arab Countries: A Policy Perspective; Mohamed Abdrabo, Egypt**	**Keynote Speaker: Advanced Wastewater Treatment using Functionalized Membranes; Mohammed Al-Abri, SQU, Sultanate of Oman**
09:40-10:00	**Keynote Speaker: Biosaline Agriculture in the GCC; Rachyd Zaabol, ICBA, UAE**	**Keynote Speaker: Business Model for Small-Scale Decentralized Wastewater Treatment and Sludge Management, Case Study Jordan; Emad Karabliah**
10:00-10:15	**Discussion**	**Discussion**
10:15-10:30	**Short Break**	
	Technical Session 5B: Agricultural Water Management	**Technical Session 6B: Wastewater Management**
	Chairpersons: Ali Al-Jaloud & Khalid Al-Ruwis	**Chairpersons:** Mohammed Al-Abri & Najib Al-Nasher
10:30-10:45	Developing a Sensor-based Agricultural Water Management System for Irrigation Scheduling, Automation, and Optimization; Farhat Abbas, Qatar	Wastewater Industrial Database for Total Nitrogen in Shuaiba Area in Kuwait; Adel Alhaddad, Kuwait
10:45-11:00	The Role of Information Technology in Treating Soil Logging and Salinization in Diyala Governorate; Mohamed Hachim, Iraq	Towards a Novel Wastewater Treatment Process: A Submerged Membrane Elector-Bioreactor (SMEBR)-Simultaneous Biodegradation, Electrocoagulation & Membrane Filtration; Khalid Bani-Melhem, Qatar
11:00-11:15	Treated Wastewater Application in Urban Agriculture; Ahmed Al-Busaidi; Oman	Farmers' Attitude Towards the Use of Treated Wastewater in Irrigation, the case of Saudi Arabia; Abdulrahman Alablan, Saudi Arabia
11:15-11:30	Towards Sustainable Water Management: Leveraging Soil Moisture Sensors for Smart Irrigation in the GCC; Hassan Ali, Qatar	Ecofriendly and Low-cost Adsorbent for Efficient Removal of Heavy Metals from Aqueous Solution; Sharifa Bakhit Ali, Oman
11:30-11:45	Strategic Water Management for Improved Tomato Yield and Quality in Greenhouse Environments with Different Water Quality; Akram Alshami, Saudi Arabia	Comparative Wastewater Quality Indicators and Multivariate Analysis of Riyadh Sewage Treatment Plants and its Impact on Irrigation of Riyadh District, Saudi Arabia; Ahmed Elfeky, Saudi Arabia
11:45-12:00		Green Synthesis of Zinc Oxide Nanoparticles for Wastewater Treatment; Amal Al-Rahbi, Oman
	Discussion	**Discussion**
12:15-12:30	**Short Break**	
12:30-13:00	***Session 7: Conference Conclusion and Recommendations***	
	***Chairperson**: Waleed Al-Zubari*	

Keynote Speaker

1) Introductory Remarks: Potential of Artificial Intelligence (AI) for Sustainable Water Management

Waleed Al-Zubari

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Overview:

An **introduction** to the conference theme, objectives, and sessions will be first given, followed by an **overview** of the various applications of artificial intelligence (AI) in the water resources management, through highlighting its importance of considering both water supply and demand side-oriented practices for effective water management, emphasizing the potential of AI in improving water resources management by enhancing efficiency, optimizing resource allocation, predicting and preventing failures, and ensuring water quality and sustainability, and addressing the benefits and challenges of implementing AI in water resources management. Finally, discussing the stages of AI adoption in the water sector and the need for further research and collaboration to enhance the use of AI in water resources management.

Keynote Speaker

2) Digitalization in Water: Key to Security in the Realm of Cyber Insecurity Risk in the Arab region

Hammou Laamrani

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Abstract:

Over the last decade, The GCC countries and to a lesser extent, the rest of the Arab region has experienced a profound digital transformation, bringing the online population from 28.8 % in 2012 to 70.3 % in 2022, and the number of internet users to 327 million.

The transition to digital economies as reflected in countries' visions, and the growing trend in planning and building smart cities is reshaping all economic sectors in GCC. Indeed, AI alone is projected to impact the region's economies to the tune of $320 billion within the next decade.

This trend is promoting the growth of a digital economy by fostering innovation, entrepreneurship, and digital skills development. Initiatives such as startup accelerators, innovation hubs, and investment funds support the development of technology-driven industries and digital startups. However, this transition is not advancing equally across sectors. and digitalization in the water sector, though steadily growing remains relatively slower compared to its potential.

From a water security perspective, digitalization is rapidly adopted in urban water management and planning (smart metering and monitoring, data analytics and predictive maintenance, remote monitoring and control systems, integrated management systems, cloud computing and IoT integration ...). However, the transition to digitalization in agriculture that is the larger consumer of water resources and that constitutes a threat to non-renewable groundwater resources in GCC countries and in the Arab region in general is far slower. This is partly due to the existing digital divide and digital literacy between rural and urban contexts.

Many challenges are still facing the digitalization in water sector in the GCC and the region, require adequate policies and programmes:

1. Digital Divide: While urban centers in GCC countries are rapidly digitalizing, rural and remote areas may face challenges in accessing digital infrastructure and services. Addressing the digital divide requires targeted investments in expanding broadband connectivity, digital literacy programs, and inclusive digital development policies.
2. Skills Mismatch: Despite efforts to develop a digitally skilled workforce, there may still be a gap between the skills demanded by the digital economy and those possessed by the workforce. Continuous investment in education, training, and lifelong learning programs is essential to bridge this gap and ensure the workforce remains competitive in the digital age.

3. Integration and Interoperability: Achieving seamless integration and interoperability among digital systems and platforms remains a challenge, particularly in sectors with complex ecosystems such as healthcare, transportation, and finance. Standardization efforts and interoperability frameworks are needed to facilitate data exchange, collaboration, and innovation across sectors.
4. Limited engagement of research and innovation: A search online shows that both RD and peer reviewed publications on digital tools and technologies in the water sector is limited and requires dedicated investments both by the public and private sectors. PPP investments could be a way to accelerate the innovation capacity for a grounded and secure digitalization in the water sector.

Besides the many remarkable opportunities digitalization implies in enhancing water sector resilience, sustainable management of water resources and water security, expanding the use of digital tools (AI, Blockchain, cloud computing and IoT integration IoT, Remote sensing and satellite imaging …) comes with new emerging cyber security threats to water infrastructure and service delivery systems requiring a whole new approach to water security.

The rapid development in the cyber threat landscape has put GCC countries in front of a growing threat from potential cyberattacks, including ransomware, phishing, and malware attacks, targeting government institutions, critical infrastructure, businesses, and individuals. Governments in the GCC region have established national cybersecurity strategies and agencies tasked with enhancing cybersecurity capabilities, raising awareness, and coordinating responses to cyber threats.

Regulatory frameworks related to cybersecurity are being developed and strengthened to ensure the protection of critical infrastructure, personal data, and digital assets. Compliance requirements and cybersecurity standards are enforced to mitigate cyber risks. Collaboration between government agencies, private sector organizations, and academic institutions is essential for sharing threat intelligence, best practices, and resources to combat cyber threats effectively. Moreover, investments in cybersecurity education, training, and workforce development are crucial for building a skilled cybersecurity workforce capable of defending against evolving cyber threats and vulnerabilities. Investment in cybersecurity technologies such as intrusion detection systems, endpoint security solutions, encryption, and threat intelligence platforms to detect, prevent, and respond to cyberattacks are increasing in the GCC countries.

In conclusion, digitalization offers clear opportunities to GCC countries and the region efforts to make water sector sustainable, resilient and ensure water security, but effective cybersecurity measures are essential to mitigate cyber risks and safeguard the integrity, confidentiality, and availability of digital assets and critical infrastructure. Continual investment in cybersecurity capabilities, awareness, and collaboration is necessary to address the evolving cyber threat landscape effectively. This opens new avenues for GCC countries' cooperation, yet to be explored and research has a critical role to play in the multiple transitions needed for a more water secure future.

Keynote Speaker

3) Deep Neural Networks Application in Environmental and Water Resources Simulations

Mohammad Mahdi Rajabi

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Extended Abstract:

Traditionally, environmental and water resources simulations (EWRS) have relied on physics-based analytical and numerical models. These models employ parameters that characterize the environmental systems, system state variables, and external forces as input into mathematical equations to predict future conditions of environmental systems and water resources. The effectiveness of these models is frequently limited due to the considerable computational resources and lengthy simulation times required for large-scale or repetitive simulations, and the partial comprehension or flawed mathematical representation of the physical processes that result in a mismatch between the predicted outcomes of the models and real-world observations at the field scale (Rajabi et al., 2023).

To address these challenges, there has been a shift towards employing data-driven models that incorporate machine learning (ML) techniques. Compared to traditional physics-based models, ML models are typically faster, simpler to develop, and require less detail information. Historically, a range of ML tools have been applied to develop data-driven models for EWRS, including random forests, support vector machines, polynomial chaos expansion, and tree-based regression models. Nevertheless, conventional ML methods often face difficulties when encountering infrequent, black swan cases within the dataset, struggle to adapt to new scenarios not included in their training data, may not effectively manage large volumes of data, and fall short in identifying the deep relationships and complex patterns among the parameters that affect outcomes. Deep neural networks (DNNs), a newer segment of ML, provide more flexibility and have shown to offer higher accuracy in predictions, particularly with extensive datasets (Samek et al., 2021). Their advanced learning capacities make DNNs a highly researched tool for EWRS, demonstrating significant promise over classical ML techniques.

Neural networks are computational models inspired by the human brain's structure, consisting of layers of interconnected nodes that process information using weighted connections and activation functions. They refine and optimize their internal parameters through a technique called backpropagation. DNNs build upon this foundation by incorporating multiple hidden layers between the input and output, enabling the extraction of progressively more abstract features from the data (Shen, 2018). In the context of EWRS, DNNs have found applications across various areas, including but not limited to flood prediction (Kao et al., 2020), hydrological modeling (Li et al., 2023), sediment transport modeling, water quality forecasting (Liu et al., 2019), weather prediction (Ren et al., 2021), groundwater modeling (Wang et al., 2022), water demand projection (Gil-Gamboa et al., 2024), and modeling changes in land use and land cover (Stoian et al., 2019), among others. DNNs have become increasingly popular in tasks requiring iterative simulations, such as Monte Carlo-based uncertainty analysis and combined simulation-optimization, as well as near real-time forecasting.

DNNs come in various architectures, each optimized for specific data types and applications. **Table 1** summarizes some prevalent DNN architectures along with their applications in EWRS. In recent years, the adoption of DNNs in EWRS has transitioned from primarily using deep feedforward neural networks to increasingly favoring convolutional neural networks (CNNs) and recurrent neural networks (RNNs), including long short-term memory

(LSTM) networks, for their enhanced ability to model spatial and temporal patterns. Although graph neural networks (GNNs) and generative adversarial networks (GANs) are not as commonly employed, their adoption is on the rise. GNNs offer a valuable approach for analyzing unstructured data, whereas GANs are increasingly recognized for their ability to generate synthetic data. This progression underscores a wider movement towards adopting increasingly sophisticated DNN architectures to model the dynamics of EWRS. Concurrently, the utilization of DNNs in EWRS has undergone substantial development, transitioning from basic vector regression tasks to more sophisticated predictive modeling, including time series forecasting and both image-to-value and image-to-image regression. This advancement has been facilitated using CNNs and their combinations with RNNs, such as CNN-LSTMs, allowing for the efficient analysis of spatial and temporal data. More recently, attention has expanded to include processing point clouds collected via light detection and ranging (LiDAR) or similar technologies, employing advanced DNN architectures such as PointNet and various GNNs (Fang et al., 2024).

DNNs are commonly trained utilizing data obtained from physics-based simulations, positioning them not as replacements but as supplementary surrogates to conventional physics-based models (Rajabi et al., 2022). However, there is a gradual shift towards training DNNs with field data sourced from sensors or aerial imagery, expanding their applicability to phenomena that are inadequately understood and challenging to simulate using physics-based models. A relatively recent concept involves integrating residuals of physical equations into the loss function of DNNs. This approach, known as physics-informed or physics-constrained DNNs, utilizes physics-based losses either as a component of the objective function in backpropagation or as constraints. these physics-informed neural networks (PINNs) learn from both observational data and established physics principles, often creating a balance between the two to generate solutions that align with observations while remaining physically plausible. Compared to data-driven DNNs, PINNs also offer the advantage of requiring less data for training, as they leverage an additional source of information (Wang et al., 2022). The development of PINNs for EWRS represents an active area of research, as there is still much exploration to be done in various applications and issues such as convergence, computational efficiency, and determining the optimal balance between data-driven and physics-based components require further investigation.

Table 1. Examples of DNN Architectures Commonly used in Environmental and Water Resources Simulations.

DNN architecture	Key features	Application examples
Feedforward Neural Networks (FFNNs)	Employs a straightforward architecture with layers connected in a feedforward manner. Commonly used for vector data.	Water demand forecasting (Gil-Gamboa et al., 2024).
Convolutional Neural Networks (CNNs)	Leverages convolutional layers for spatial hierarchy feature extraction. Go to option for image data and related tasks, such as image-to-image regression, image segmentation and image classification.	Forecasting contaminant and temperature distribution maps based on maps of material properties (Rajabi et al., 2022), Land cover prediction (Stoian et al., 2019).
Recurrent Neural Networks (RNNs)	Utilizes memory elements to process sequences and temporal dependencies.	Flood forecasting (Kao et al., 2020).
Hybrid CNN- Long short-term memory (LSTM)	Developed for spatiotemporal data analysis.	Flowrate prediction in a watershed (Li et al., 2023).
Graph Neural Networks (GNNs)	Uses graph-based data representations for node and edge analysis. Compatible with point cloud and mesh-based data.	Groundwater level forecasting (Bai and Tahmasebi, 2023).
Generative Adversarial Networks (GANs)	Involves a dueling setup where one network generates data, and another evaluates it.	Generating synthetic weather data (Ji et al., 2024), Leak detection in water distribution networks (Rajabi et al., 2023).

Additional areas for future research encompass: (1) addressing the prevalent perception of DNNs as opaque black box tools by developing methodologies to improve their interpretability, thereby aiding stakeholders in understanding model predictions. (2) Developing DNNs capable of effectively capturing multi-scale interactions within environmental systems, enabling more comprehensive simulations of complex phenomena. (3) Addressing the scalability challenges associated with handling large-scale environmental datasets, including the exploration of scalable architectures and algorithms that can efficiently process and analyze vast amounts of data. (4) Investigating transfer learning approaches to leverage knowledge from related domains or datasets to enhance the performance of DNNs in environmental and water resource applications. (5) Exploring the integration of DNN-based predictive models into decision support systems for environmental management and planning, enabling stakeholders to make informed decisions based on the insights provided by DNNs.

Keywords: Data-Driven Models, Machine Learning, Neural Networks, Environmental Simulations, Water Resources Modeling.

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Keynote Speaker

4) Navigating Water Scarcity and Supporting Food Security: Market-based Development of Sustainable Irrigation

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Abstract:
Water scarcity in the Middle East and North Africa (MENA) region is a complex issue influenced by various factors such as climate change, population growth, urbanization, inefficient water management practices, and geopolitical tensions. This situation has significant implications for the irrigation sector in the MENA region, impacting agricultural productivity, food security, and socio-economic development. some key implications are: (1) Decreased Agricultural Productivity: Water scarcity limits the availability of irrigation water for agriculture, leading to decreased crop yields and reduced agricultural productivity. Farmers may struggle to maintain their crops adequately irrigated, resulting in stunted growth, decreased fruit or grain production, and overall lower yields. (2) Crop Losses and Economic Impact: Insufficient irrigation water availability can result in crop losses, economic losses, and decreased income for farmers. Crop failures due to water scarcity can have severe consequences for rural livelihoods, exacerbating poverty and food insecurity in affected areas. (3) Increased Water Stress: Water scarcity exacerbates water stress in the irrigation sector, as farmers compete for limited water resources to irrigate their crops. This competition can lead to conflicts over water allocation, particularly in regions where water resources are shared among multiple users or countries. (4) Salinization and Soil Degradation: Water scarcity can exacerbate soil salinization and degradation in irrigated areas, particularly in arid and semi-arid regions. Limited water availability may result in improper irrigation practices, such as excessive groundwater pumping, leading to the accumulation of salts in the soil and reduced soil fertility. (5) Shift in Irrigation Practices: Water scarcity may necessitate a shift towards more water-efficient irrigation practices and technologies, such as drip irrigation, sprinkler irrigation, and precision agriculture. However, the adoption of these technologies may require significant investments in infrastructure and farmer training, which could pose challenges, particularly for small-scale farmers. (6) Impact on Agricultural Diversity: Water scarcity can influence the types of crops grown in irrigated areas, as farmers may prioritize crops that require less water or are more drought-resistant. This shift in crop choices can impact agricultural diversity and may have implications for food security and nutrition in the region. (7) Dependency on Non-renewable Water Sources: In some cases, water scarcity in the irrigation sector may lead to increased reliance on non-renewable water sources, such as fossil groundwater reserves or desalinated water. However, the extraction and use of these non-renewable water sources can have environmental consequences, including groundwater depletion and energy consumption.

Interventions in the irrigation market ecosystem and innovations are crucial for empowering irrigation as an effective adaptation tool in the MENA region. By promoting water-use efficiency, sustainable resource management, resilience to climate change, economic development, environmental sustainability, and adaptation and mitigation, policymakers can help ensure the long-term viability of agriculture in water-stressed environments.

The International Water Management institute (IWMI) and its various partners worked with farmers and other stakeholders in the agricultural water value chain to mainstream inclusive irrigation innovation in the global south, including in MENA.

Case 1: Modernizing irrigation systems in the Nile Delta

In the Nile Delta of Egypt, irrigation systems have historically been crucial for supporting agricultural production in one of the most fertile regions of the country. The Nile River, with its annual inundation, has long served as the lifeblood of Egyptian agriculture, providing water for irrigation and replenishing soil nutrients. Traditional irrigation methods, such as basin irrigation and flood irrigation, have been practiced for centuries, harnessing the natural flow of the river to water crops. In recent decades, modern irrigation infrastructure, including canals, pumps, and water distribution networks, has been developed to enhance water management and increase agricultural productivity. Despite these advancements, challenges such as water scarcity, soil salinity, and the impact of climate change present ongoing concerns for irrigation systems in the Nile Delta, necessitating continued investment in sustainable water management practices and technological innovations to ensure the region's agricultural sustainability.

In 2019, the Government of Egypt started to implement a Nationwide Irrigation Modernization Program, which seeks to convert about 6 million feddans (2.4 million ha) of irrigated land from traditional surface to modern pressurized irrigation systems. Roughly, farm-level investments alone can easily amount to US$3-4.5 billion. These investments are expected to offer significant opportunities for improving the productivity and competitiveness of the agricultural sector. So far, the areas that use modern irrigation systems in Egypt account for 4.6 million feddans. The program is also expected to reduce farm-level water allocations, which could then be reallocated to other sectors including industries, domestic, and the environment. Within this context the International Water Management Institute (IWMI) provided the activity entitled “Egypt-Supporting MALR strategic objective to Modernize the On-Farm Irrigation Systems in Delta (EMFI)” under the Nile Delta Water Management Programme (NDWM), which is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Under the NDWM, pilots of modern irrigation systems shall be installed in the two demonstration areas to contribute to improving the range of advice and services for smallholder farms on water-saving cultivation practices, initiating innovative measures and digital applications for efficient water use by smallholder farms, and strengthening the participation of civil society and women's groups in water use efficiency.

The project highlighted that Solar-Powered Irrigation Systems (SPIS) shall be engineered with multifaceted capabilities, incorporating photovoltaic panels for the capture of solar energy, inverters for the transformation of direct current to alternating current, and grid-tied controllers to facilitate interaction with the public electrical grid (feed in and usage). It also showed that a specialized adaptation shall be undertaken to manage both source water pumps and booster pumps, optimizing flow rates and hydraulic pressure to meet diverse irrigation requirements. To further extend its utility in agricultural settings, the system shall include smart controllers for both irrigation and fertigation, enabling precise, data-driven control over water and nutrient application rates. Accordingly, the business model is featured as a highly customized architecture that not only improves the system's operational efficiency but also offers an integrated solution for sustainable agriculture.

Based on these initial findings, the proposed customization of the market system is shown with all of its elements in the below figure (1):

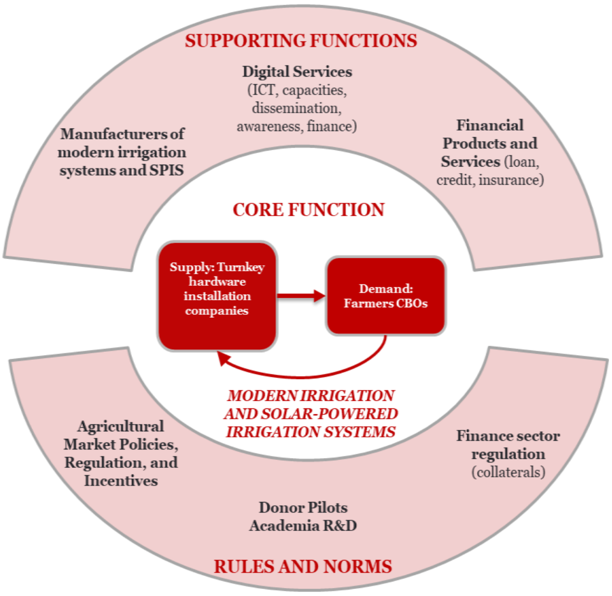

Fig.1: Modern Irrigation Systems and Solar-Powered Irrigation systems market diagram of core and supporting functions, and rules and norms that are key for the effective functioning of the market system for water/nutrient. Pesticides saving in agriculture.

Case 2: Taking drip irrigation to the next level in Jordan

In Jordan, irrigation systems play a critical role in sustaining agricultural production in a water-scarce environment. The country faces significant challenges due to its limited freshwater resources and increasing water demand. Traditional irrigation methods, such as flood irrigation, have been common historically but are gradually being replaced by more water-efficient technologies like drip and sprinkler irrigation. These modern irrigation systems help optimize water use by delivering water directly to the roots of plants, minimizing evaporation and runoff. Additionally, Jordan has implemented policies to promote sustainable irrigation practices, including water pricing mechanisms and subsidies for water-saving technologies. Despite these efforts, water scarcity remains a pressing issue, and ongoing investments in irrigation infrastructure and management are essential to ensure the resilience and viability of agriculture in Jordan.

Jordan is an exceptional context for policy-makers and development agents to innovate and learn about water management policies and strategies. According to experts, with so few new options for fresh water, the country "will be center stage in showing how a semi-arid region deals with the devastating impacts of a warmer and drier regional climate.

Under the Water Innovation and Technologies (WIT) Program, The goal of the Market System Development (MSD) approach is to contribute to sustainable poverty reduction at scale. This is done through interventions that facilitate sustained changes in the behavior of market actors, and the functions and structures that shape the performance of market systems that matter to people living in poverty.

The WIT program is a five-year initiative implemented between March 2017 and July 2022 in Jordan. It was funded by the United States Agency for International Development (USAID). during the life of the program, the combined efforts of WIT partners, early adopters and farmers led to savings of approximately 24 MCM (in agriculture alone), exceeding the program's target for agriculture by more than 5 MCM. These savings were generated by approximately 200 farmers who optimized around 1,300 hectares of farmland (Fig 2).

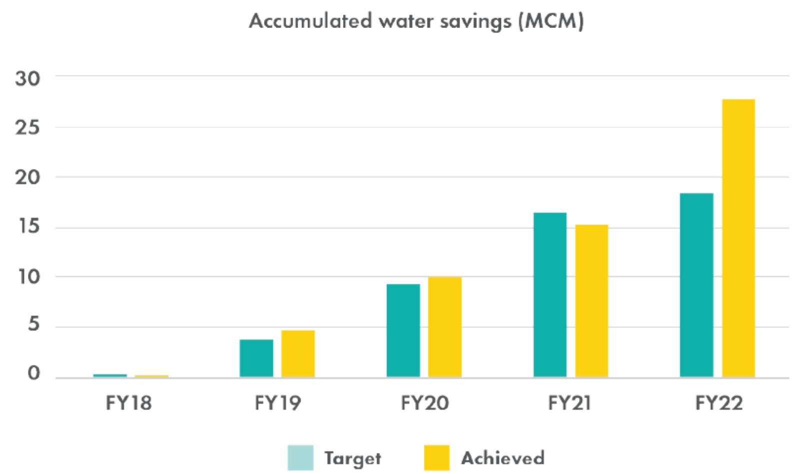

Fig. 2: *Accumulated water savings in MCM per fiscal year, including both the agriculture and household components (24 and 4 MCM respectively)*

To achieve these results, the WIT program explored how water-saving practices and technologies spread, which farmers adopt water-saving technologies and why, as well as technology adoption on farms as well as by different suppliers. Overall, the project identified the water saving market movement.

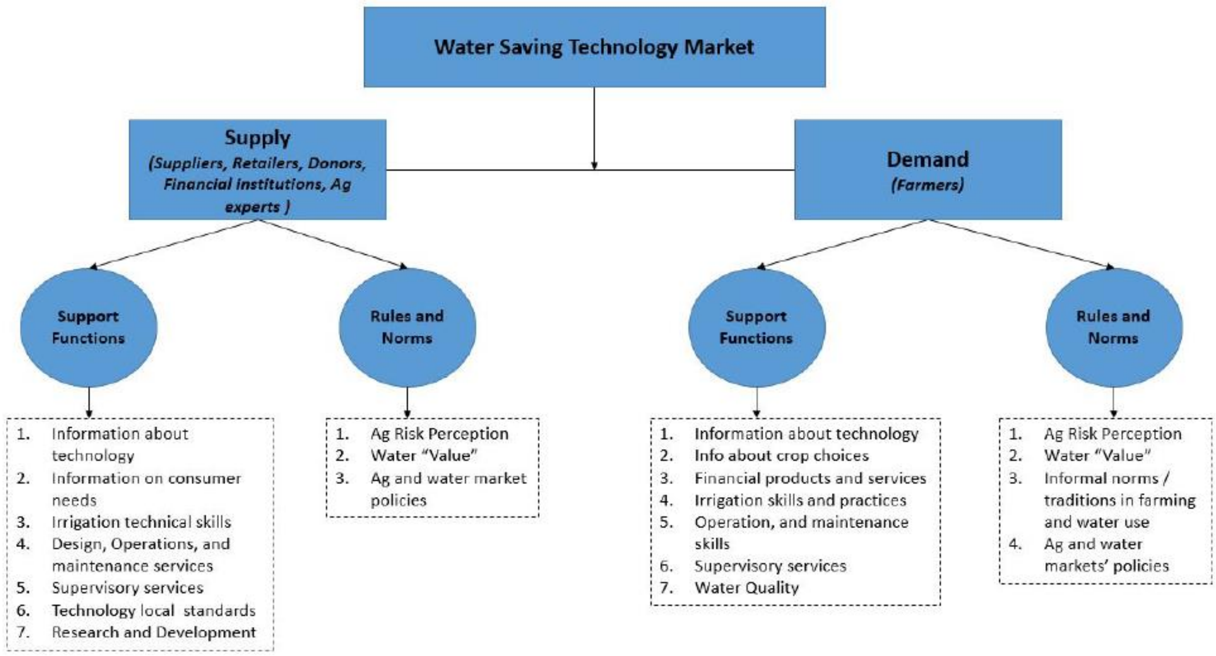

Fig.3: *Water Saving Technologies Market Components Addressed in WIT*

Overall, market-based development plays a critical role in driving irrigation innovation by enabling the incentivization of investment, promoting efficiency, enabling tailored solutions, facilitating scaling up, and ensuring sustainability. By harnessing market forces, policymakers, businesses, and entrepreneurs can unlock the full potential of irrigation innovation to address water scarcity, enhance agricultural productivity, and contribute to sustainable development.

Keynote Speaker

5) The Role of the World Health Organization in Drinking Water, Sanitation and Hygiene and Updated Publications

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Abstract:

Safe drinking water, sanitation and hygiene (WASH) are crucial to human health and wellbeing. Safe WASH is not only a prerequisite to health, but contributes to livelihoods, school attendance and dignity and helps to create resilient communities living in healthy environments.

Historically, the World Health Organization (WHO) work has included WASH components since the inception of the Organization in 1948. WHO has played a longstanding and significant role in promoting WASH as an objective and respected source of international guidelines, standards and normative information. The WHO vision for WASH is:

'TO SUBSTANTIALLY IMPROVE HEALTH THROUGH THE SAFE MANAGEMENT OF WATER, SANITATION AND HYGIENE SERVICES IN ALL SETTINGS."

WASH is enshrined in the WHO constitution. WHO takes on board the need for progressive realization of the human rights to safe drinking water and sanitation, adopted by the UN General Assembly in July 2010. It has consistently issued health-based guidelines and good practice publications on WASH, which are designed to assist countries in developing national standards, informing regulations and establishing effective surveillance systems. For decades, WHO has monitored global and country access to water and sanitation. While the Organization has had various flagship priorities over the years, technical work on WASH issues has been a constant and is often included in broader initiatives.

WHO assists countries in improving policy, governance and monitoring towards the achievement of Sustainable Development Goals (SDG) beyond the WASH-focused SDG 6, e.g. SDG 3 on health and SDG 13 on climate change, which cannot be met without meaningful progress on Goal 6.

The WHO WASH 2018-2025 Strategy is underpinned by the following principles:

- Prioritize actions with the highest public health benefit;
- Strengthen health sector capacities in promoting safe WASH and taking up its public health oversight role in WASH, including effective outbreak response systems;
- Align with the SDGs, specifically targets relating to WASH, health, climate change and nutrition, as well as human rights principles;
- Employ the highest quality science including through collection, review and use of evidence about WASH impacts on health and a full range of practical experiences when developing norms and good practice procedures;
- Promote a contextual, incremental improvement approach when supporting countries to set national WASH standards and ambitious but achievable national targets;
- Capitalize on existing regional policy frameworks that promote WASH and stipulate national target setting;

- Stimulate sustainable change by strengthening government institutions and systems charged with implementation, oversight and regulation of WASH service delivery; and
- Engage with partners and positively influence partnerships to ensure health issues are considered and addressed by the WASH sector and to also ensure that WASH issues, notably in health care facilities, are addressed by the health sector as prerequisites to providing quality care.

Key WHO partners and stakeholders for WASH include Member States, practitioners, institutions for research and development, WASH partners, etc.

Some of WHO's priority intervention areas and recent publications are as follows:

- **Drinking-water quality and safety:** Guidelines for drinking-water quality (2022), Guidelines for drinking water quality: small water supplies and the Sanitary inspection packages (2024), the WHO/IWA updated Water Safety Plan manual (2023), Lead in drinking-water: Health risks, monitoring and corrective actions (2022), State of the world's drinking water: An urgent call to action to accelerate progress on ensuring safe drinking water for all (2022), Toxic cyanobacteria in water - Second edition (2021), Guidelines on recreational water quality: Volume 1 Coastal and fresh waters (2021), Domestic water quantity, service level and health (2020), Microplastics in drinking-water (2019), A guide to equitable water safety planning: Ensuring no one is left behind (2019), Management of radioactivity in drinking-water (2018)
- **Improving safety of sanitation and wastewater management:** WASH and health working together: a 'how-to' guide for neglected tropical disease programmes, second edition (2023), Sanitation safety planning - Second edition (2022), Global research agenda for improving the health safety and dignity of sanitation workers (2022), State of the world's sanitation: An urgent call to transform sanitation for better health, environments, economies and societies (2021), Guidelines on sanitation and health (2018), Guidelines for the safe use of wastewater, excreta and greywater - Volume 1 (2013). WHO is a member of the Climate Resilient Sanitation Coalition.
- **WASH in health care facilities (including healthcare waste management):** Progress on WASH in health care facilities 2000-2021: Special focus on WASH and infection prevention and control (2023), Water, sanitation, hygiene, waste and electricity services in health care facilities: progress on the fundamentals (2023), Energizing health: accelerating electricity access in healthcare facilities (2023), WASH FIT: A practical guide for improving quality of care through water, sanitation and hygiene in health care facilities. Second edition (2022), Global analysis of health care waste in the context of COVID-19 (2022), Overview of technologies for the treatment of infectious and sharp waste from health care facilities (2019), Safe management of wastes from health-care activities (2014) and the summary (2017).
- **Monitoring via the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS), WHO/UNICEF Joint Monitoring Programme (JMP) and Burden of Disease:** Burden of disease attributable to unsafe drinking water, sanitation and hygiene: 2019 update (2023), Progress on household drinking-water, sanitation and hygiene 2000-2022: Special focus on gender (2023), Strong systems and sound investments: Evidence on and key insights into accelerating progress on sanitation, drinking-water and hygiene: GLAAS 2022 report, Progress on drinking-water, sanitation and hygiene in schools: 2000-2021 Data update (2022).
- **Integration of WASH with health and other programmes** such as AMR, cholera, climate change and emergencies: Technical brief on water, sanitation, hygiene (WASH) and wastewater management to prevent infections and reduce the spread of antimicrobial resistance (AMR) (2020), Safer water, better health (2019).

Despite the extensive technical support provided by WHO, populations are facing several challenges globally and in the Eastern Mediterranean Region. Emergencies are increasingly becoming more complex and affecting more populations than ever before. Climate change, natural disasters, and conflict are some of the few hurdles faced. Whether a natural disaster, a conflict, migration/refugee-related or a disease outbreak, and in many cases a combination of the above, WASH is an important element in both the provision of health care and reducing health risks during an emergency and in the future preparedness planning.

The keynote will mention some of the above WHO publications and will refer to the training session on Sanitation Safety Planning on Day 2 of the conference.

Keynote Speaker

6) Addressing Climate Change Risks on Water and Food Security in the Arab Region

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Abstract:

Water scarcity is increasing, especially in dry environments, such as in the Arab Region, with climate change and degradation of natural resources. About 41% of the Earth's land area is classified as dryland; wherein the farming system is characterized by low annual rainfall with much of it falling in the winter and spring. Agriculture, especially in the Middle East and North Africa (MENA) Region, is required to produce more food and welfare for rapidly increasing populations but with less freshwater resources. Conventional responses to this situation focus on increasing yields, improving irrigation efficiency, and managing demand. Here, it is argued that those strategies are either not working under current conditions or not anymore sufficient to cope with the daunting demand for more food in water scarce dryland regions. A paradigm shift in how we manage water is needed going into the future. The debate on how better to handle agricultural water allocation and use with increasing scarcity is being intensified over the last decade and is producing new transformative solutions. Climate-smart agricultural practices that require less water, can sustain climatic stresses, produce food with high nutritive values but require less water and energy to produce are the needs of the hour. ICARDA success stories from the Arab Region in these regards will be presented.

SS1) Water MIS for Efficient Integrated Water Resource Management

UNESCO - Doha Office

Patrice Moix, *Chief of Unit of Groundwater and Water Cooperation at HQ*
Helmi Ana'am, *Representative from Ministry of Water and Environment, Yemen*
Ayisha Alkhatri, *Ministry of Agricultural and Fisheries Resources and Water Resources, Sultanate of Oman*

Background:

Water is a critical resource essential for sustaining life, supporting ecosystems, and driving socio-economic development. Effective management of water resources is imperative to ensure their sustainable use, particularly in the face of growing global population and growing demands, climate change, and increasing water-related challenges. In this context, the deployment of Water Management Information Systems (MIS) has emerged as a pivotal tool to enhance the understanding, monitoring, and decision-making processes associated with water resources.

A Water MIS is a comprehensive framework that integrates data, information, and technologies to collect, process, analyze, and disseminate information related to water quantity, quality, usage, and availability. These systems leverage advancements in technology, including remote sensing, Geographic Information Systems (GIS), and real-time monitoring, to provide decision-makers with accurate and timely insights into water-related parameters.

The primary goal of a Water MIS is to facilitate informed decision-making at various levels, from local communities to national governments. By consolidating data from diverse sources, such as meteorological stations, river gauging stations, and satellite imagery, these systems enable a holistic view of water resources. Decision-makers can use this information to develop sustainable water policies, plan infrastructure projects, respond to emergencies, and address water-related challenges, including droughts, floods, and water pollution.

Water MIS not only enhances the technical aspects of water management but also contributes to the participatory and inclusive governance of water resources. Stakeholders, including communities, researchers, policymakers, and water resource managers, can access relevant and reliable information through user-friendly interfaces, fostering transparency and collaboration.

UNESCO, along with its extended water family network of Intergovernmental Hydrological Program, Category 2 Centers and UNESCO Chairs, recognizes the importance of Water MIS in achieving water security and sustainable development goals. Capacity building, knowledge exchange, and the promotion of best practices in implementing MIS are integral components with the strategic plan of the 9th phase of UNESCO intergovernmental Hydrological Programme (IHP-IX, 2022-2029: Science for Water Secured Word in a Changing Environment) to address water challenges. As the world grapples with the increasing complexities of water management, the continued development and utilization of Water MIS stand out as essential tools for navigating towards a water-secure and resilient future.

Objective:

UNESCO aims to bring together experts from around the world to discuss and advance the understanding and implementation of robust water management information systems.

The primary objectives include:

- Facilitate the exchange of experiences, best practices, and innovations in water management information systems among participating countries and organizations.
- Foster a dialogue among policymakers, researchers, and practitioners to develop and enhance policies that promote the integration of technology in water management for better decision-making.
- Provide a platform for showcasing technological innovations, tools, and methodologies that contribute to improved water data collection, analysis, and dissemination.

Coordinator:

- **Donia Abdelwahid, UNESCO - Doha Office**

Session Speakers:

- **Patrice Moix,** Chief of Unit of Groundwater and Water Cooperation at HQ,
- **Helmi Ana'am,** Representative from Ministry of Water and Environment, Yemen**,**
- **Ayisha Alkhatri,** Ministry of Agricultural and Fisheries Resources and Water Resources, Oman

SPECIAL SESSION 2:

SS2) Using Technology to Bridge the Data Gap for Efficient Management of Agricultural Water

FAO- Regional Office for Near East and North Africa (RNE)

Background:

Water scarcity represents a significant challenge to agricultural productivity and food security, particularly in the Near East and North Africa (NENA) region. Exacerbated by its arid and semi-arid climates, coupled with population growth, and changing climatic conditions, the demand for water in agriculture continues to rise despite the growing demands of other sectors, while water resources are becoming increasingly limited. In this context, data technologies, including Remote Sensing, Geographic Information Systems, Cloud Computing, Artificial Intelligence, among others, offer promising avenues for addressing water scarcity and agriculture-related issues.

Innovative solutions leveraging these technologies have emerged as crucial tools that provide valuable data and insights that contribute to monitoring of water use, assessment of crop yield and productivity, water requirements, and optimizing irrigation practices, and providing early warning, thereby enhancing water use efficiency and productivity in agriculture while considering the need of water in other sectors.

Overview and Scope:

Showcasing Analysis-Ready Remote Sensing Data and Geospatial Portals Utilization:

The first segment of this session aims to showcase some FAO data resources and practical applications of remote sensing analysis-ready data, with a focus on cloud-based geospatial portals. By demonstrating how this data can be leveraged for a better understanding of land cover and land use, crop yield and productivity, water management and use, and land resources and evaluation, attendees will gain a deeper understanding of the potential of geospatial technology in addressing limited water resources availability and agriculture-related issues. The presentations will cover the following:

- **FAO Water Productivity Open Access Portal Presentation:** This presentation will showcase the FAO's Water Productivity Open Access Database (WaPOR), offering insights into remotely sensed derived Water Productivity data. The audience will be introduced to the portal's open-access data on water productivity in agriculture across various countries and regions. The portal gives access to a database that provides crucial geospatial information and analytics on water usage and productivity, facilitating assessments of water use efficiency, identification of water stress areas, and the formulation of strategies for sustainable agricultural water management. The FAO WaPOR database emerges as a pivotal resource for tackling water-related agricultural challenges and promoting sustainable water management practices.
- **Land Cover and Land Use / Land Evaluation and Suitability Presentation:** This presentation will showcase the efforts of the FAO in the assessment and mapping of land cover, cropland dynamics, and the utilization of the System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL) platform. This includes demonstrating the capabilities of SEPAL in enhancing the understanding of land cover changes, crop monitoring, and land degradation assessment, as well as presenting the development of the Land Cover Legend Registry (LCLR) and Land Characterization System Software (LCHS) in collaboration with international partners, adhering to international standards. Additionally, the presentation will demonstrate the Global Agro-Ecological Zones (AEZ) database and modeling framework developed in collaboration between the FAO and the International Institute for Applied Systems Analysis (IIASA), highlighting how the GAEZ database supports sustainable

agricultural development decision-making by outlining the suitability and production potentials of various crop types under specific input and management conditions.

- **Cloud-based Geospatial Tools for Water and Agriculture Analyses Presentation:** The final presentation aims to highlight the transformative potential of geospatial technology, cloud computing, and analysis-ready remote sensing datasets in addressing data gaps within the water and agriculture sectors. Attendees will explore how platforms, like google earth engine (GEE), integrating geospatial data and cloud computing infrastructure can efficiently process vast amounts of information, overcoming data scarcity and accessibility issues. Such platforms enable insights into agricultural water consumption, rainfall trends, crop health, and crop patterns, facilitating more informed decision-making and sustainable practices.

Panel Discussion: Following the presentations, the technical session will facilitate a panel discussion and audience questions aimed at a deeper understanding of the explored themes and facilitate dialogue between experts and attendees. Leading the panel will be experts from FAO, offering diverse perspectives on harnessing remote sensing and geospatial technologies, alongside capacity development for sustainable agriculture and water management.

Expected Outcomes:

- *Enhanced understanding of FAO WaPOR data platform and capabilities:* Participants will gain deeper insights into the significance of FAO's Water Productivity Open Access Database (WaPOR) data and platform capabilities for addressing agricultural water productivity issues.
- *Increased awareness of FAO tools for land cover assessment and characterization:* Attendees will have an increased awareness of tools like the Land Cover Legend Registry (LCLR) and Land Characterization System Software (LCHS) supporting land cover assessment and characterization.
- *Advanced understanding of the use of SEPAL platform:* Participants will gain deeper knowledge of how SEPAL is utilized for assessing changes in land cover, monitoring crops, and evaluating land degradation.
- *Enhanced knowledge of the Global Agro-Ecological Zones (AEZ) database and platform:* Participants will gain a deeper understanding of how the GAEZ database supports sustainable agricultural development decision-making by illustrating the suitability and production potentials of different crop types under specific input and management conditions.
- *Increased familiarity with the use of cloud-based geospatial portals for water and agriculture related analyses:* Attendees will develop a deeper understanding of how geospatial platforms and analysis-ready data can be used to address challenges associated with water scarcity in agriculture.
- *Enriched Discussion and Knowledge Exchange:* Attendees and presenters will engage in a discussion that deepens their understanding of the topics presented.

Session Speakers:

- **FAO Water Productivity Open Access Database and Portal**
  Bert Coerver, *International Expert on Remote Sensing, FAO WaPOR Project, Land and Water Division, FAO Headquarters*
- **Land Cover and Land Use / Land Evaluation and Suitability**
  Abdullah Barhy, *Geospatial Expert, Geospatial Unit, Land and Water Division, FAO Headquarters*
- **Cloud-based Geospatial Tools for Water and Agriculture Analyses**
  Mohamed Abdallah, *Programme Implementation Support Expert, Water Scarcity Initiative, FAO Regional Office for the Near East and North Africa*

SS3) De-carbonization Pathways in the Water Sector in the GCC Countries (GCC reps)

Secretariat General of the Gulf Cooperation Council (GCC-SG) and WSTA

Background:

A special session in which national working papers from the GCC countries are presented to present their national vision, efforts, and experiences to reduce carbon emissions in the water sector to contribute to achieving carbon neutrality within the framework of the Paris Climate Change Agreement.

Coordinator:

- **Mohamed AlRashidi, Secretariat General of the GCC**

Session Speakers:

GCC Countries Water Sector Representatives:

1. **Hind Al-Ali (Ministry of Energy, UAE),**
2. **Mousa AlHajri (SWCC, KSA),**
3. **Mohammed AlAali (EWA, Bahrain)**

TRAINING WORKSHOP 1: (Attendance by registration)

Wastewater Treatment and Reuse in the GCC Countries: How to Unlock the Power of Data?

Convener: International Water Management Institute (IWMI)

Dr. Yousef Brouziyne

Regional Representative & CGIAR Water System Lead in MENA, IWMI

Duration: 2.5 hours

Description:

The Middle East and North Africa (MENA) region, characterized by its arid and semi-arid climate, is home to 11 of the world's 17 most water-stressed countries. Despite accommodating 6 percent of the global population, the region has access to less than 2 percent of the world's freshwater resources. As the effects of climate change worsen and populations and GDP grow, water resources are increasingly strained, impacting livelihoods, economies, and food security.

To meet growing water demand, many Arab countries have expanded their water resource base to include unconventional sources such as seawater desalination and groundwater extraction in addition to more conventional rainfall and surface water abstraction methods.

In MENA, including in the GCC countries, wastewater reuse is rapidly gaining traction as a promising unconventional water source. Appropriate treatment allows wastewater discharged from households, industries, and agricultural sectors to be transformed into a consistent, nutrient-rich resource throughout the year.

To unleash the full potential of wastewater reuse, several barriers that currently hinder the uptake of this technology must be addressed. The limited availability, accessibility, and comparability of data on wastewater generation, treatment, and reuse across the MENA region is one of the main barriers to broader technology adoption, along with scarce regulations and human and institutional capacities at the country level.

This workshop aims at unleashing the collective intelligence of various stakeholders to reflect and share experiences on effective approaches and interventions to overcome data issues including the use of data science and cutting-edge technologies.

Agenda

16:00 – 16:15	*Welcoming participants & Agenda presentation*
16:15 – 16:30	*Interaction with participants – Part 1*
16:30 – 17:00	*Opening remarks by the chair of the session - Khaldon Khashman, ACWUA:* *"Wastewater Monitoring and Data Management in the Arab Region"*
17:00 – 17:15	*Presentation 1 – Youssef Brouziyne, IWMI:* *"Wastewater Treatment & Reuse in MENA: Data-related Challenges and breakthroughs"*
17:15 – 17:30	*Presentation 2 - Muhammad Khalifa, IWMI:* *"Water Accounting Plus to empower reclaimed water in sustainable water balance"*
17:30 – 18:00	*Presentation 3 - Naga Velpuri, IWMI:* *"Leveraging Artificial Intelligence to inform reclaimed water projects"*
18:00 – 18:20	*Interaction with participants – Part 2*
18:00 – 18:20	*Closing*

Trainer: Dr. Yousef Brouziyne is the Regional Representative of International Water Management Institute's (IWMI)- Middle East and North Africa region. He brings significative experience in sustainability stewardship and resilience building across the water and agricultural value chains in North Africa, West Africa, and Southern Europe with multinational agribusiness corporations. He was previously a professor and researcher at the Mohammed VI Polytechnic University (UM6P) in Morocco from 2019 to 2022, where he managed and contributed to a portfolio of research and innovation projects around climate change impacts on agro-hydrological systems, climate-smart water and crops systems, as well as social and digital innovations for resilient and sustainable water and crops systems. Currently, Dr Youssef Brouziyne is IWMI's representative in Egypt and the MENA region. Together with a highly skilled team in the MENA office and a diversified panel of partners, he strives to help stakeholders in the region move towards growth and sustainable development through innovative science-based water and climate solutions.

Keynote Speaker

1) Revolutionizing Desalination: KISR's Breakthrough Projects Addressing Water Crisis Challenges

Mansour Ahmed

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Abstract:

Desalination, a vital solution to the rapidly increasing global water crisis, faces persistent challenges in efficiency, sustainability, and economic viability. This article presents a comprehensive overview of innovative research activities of Water Desalination Technologies (WDT) program at the Water Research Center (WRC) of Kuwait Institute for Scientific Research (KISR) aimed at revolutionizing desalination technologies to combat these challenges. The article explores into a multidimensional approach, showcasing WRC's intensive efforts in exploring innovative processes and cutting-edge technologies. This paper highlights an array of innovative projects conducted at laboratory and pilot scales and covers diverse solution areas. From exploring forward osmosis processes to pioneering hybrid membrane systems and zero liquid discharge treatment for oil produced water, the WRC's initiatives cover a broad spectrum of technological advancements. Notably, the research also explores into mineral extraction technologies and cutting-edge developments in membranes, showcasing a holistic approach to addressing desalination challenges. The article emphasizes KISR's commitment to innovation by spotlighting the institute's intellectual property developments in the desalination and water treatment domains. These initiatives collectively underscore a dedicated effort to overcome hurdles in desalination, offering promising pathways toward heightened efficiency, sustainability, and the realization of a water-secure future. By presenting a detailed overview of WRC's pioneering research, this article contributes valuable insights into the evolution of desalination technologies, paving the way for impactful advancements in the field.

Keywords: Desalination, Cutting edge technologies, hybrid membrane systems, zero liquid discharge, mineral.

2) Fuel Allocation in Water and Power Cogeneration Desalination Plant

Ibrahim S. Al-Mutaz*, Meshari S. Aldalbahi

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Abstract:

Most large thermal desalination plants are combined with power generation, making use of energy which would otherwise be rejected to the environment. Energy is usually one of the largest operating costs and can vary appreciably with fuel value as well as with the plant configuration and operating mode. In independent or privatized power and desalination plants, the Power and Water Purchase Agreement (PWPA) will contain the method for allocating energy and other operating and capital costs between power and water. The method used will be a key factor in the payment structure for the project. In this work, three methods were applied to calculate the fuel allocation. The most appropriate method was selected on the basis of a number of general criteria which match closely the operating conditions of the plants. The recommended method has been applied in one of the Saline Water Conversion Corporation (SWCC) water and power cogeneration desalination plant for better identifying of the fuel distribution between water and power production. The design operating conditions were used to identify the appropriate methodology among power to distillate ratio (PDR), heat value for potable water and exergy. The accuracy of each methodology was determined and compared by applying it to a standardized plant and then implementing the appropriate methodology on one of the water and power cogeneration desalination plant.

3) Prospective Brine Management Strategies for Sustainable Desalination in the GCC Countries

Syed Javaid Zaidi*, Haleema Saleem

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Abstract:

The dependence on desalinated water has been progressively increasing because of the rise in population as well as the over-use of naturally available freshwater resources. The Arabian Gulf is surrounded by desalination plants with approximately 50% of global capacity for desalinating seawater. The main technologies used in Gulf Cooperation Council (GCC) based commercial-scale desalination plants are mainly categorized into two groups- thermal (mainly multi-stage flash distillation) and membranes (mainly reverse osmosis) based. Currently, all the GCC countries are in a process of modifying their existing desalination plant partially or entirely by reverse osmosis process technology. Majority of these desalination plants dispose the brine, the hypersaline effluent, through surface as well as nearshore outfall into the Gulf. Brine, also termed as concentrate, is the main seawater pollutant, and has an adversarial effect on the surroundings because of its higher salinity. In the desalination technologies, 40.0 % percent of the feed water will be drinkable water and the remaining 60.0 % percent will be the discharge brine. The disposal of brine and wastewater is significant for the Arabian Gulf. In addition to its higher salinity, the brine might contain hazardous pretreatment chemicals, heavy metals, and organics. Hence, it is extremely important to have economical as well as viable brine management systems for reducing environmental pollution. In this study, several emerging technologies for brine treatment, such as greenhouse desalination, pressure retarded osmosis system, different hybrid systems have been analyzed. Moreover, the study presents the desalination scenario in the GCC as a whole, with respect to the desalination capacity, their reliance on desalinated water, the related economic costs, the environmental impacts of the reject brine as well as energy costs, the different desalination policies, and puts forward the emerging technologies, which are promising considering the environment, associated costs etc. The renewable energy use in the desalination sector is an inspiring concept for reducing the enormous energy costs related. In greenhouse desalination, it is probable to decrease the brine volumes using the evaporative coolers in seawater greenhouses, therefore facilitating the high-value crop cultivation and sea salt production [1]. Correspondingly, pressure retarded osmosis can generate energy from the salinity gradient arising from the salt concentration differences between the two different water solutions [2]. The application of pressure-retarded osmosis to the seawater reverse osmosis desalination plant can simultaneously solve the issue of higher energy use and the high-salinity brine production of these plants. Subsequent to the pressure retarded osmosis process, the brine is diluted and thereby the environmental impact of the brine could be reduced. Furthermore, hybrid systems also support in reducing the energy consumption and minimizing the environmental effect of the reverse osmosis brine. The two important influential factors in the production of brine are the feed water type used and the purification technology used in the desalination facilities. Thus, our study demonstrated that the new strategies examined here are suitable and beneficial for energy consumption decrease as well as environmental sustainability of desalination plant. In the current situation, as crude oil is a limited energy source, the thermal desalination methods will not be practical for the future of the GCC nations. More studies must be focused towards using the most available renewable energy

in the GCC region, like solar energy, wind energy etc., and for methods which cause minimal impact on the environment. Generally, the emergent technologies discussed in this study are very promising for the brine volume reduction, effluent volume, on the other hand, majority are just on a lab/pilot scale and it very hard to examine their applicability on a commercial scale. Additional studies are essential on a larger scale for assessing the efficiency and sustainability of these technologies. Various issues must be properly addressed for the practical application of the high salinity pressure retarded osmosis technique for the seawater reverse osmosis desalination facility. In the water sector, for ensuring that the desalination processes are effectively implemented, and performed in a promising manner, it is needed to have a proper organized system governing by laws and objectives. The GCC countries along with their resemblances in geography, and condition of water requirements could be the world leaders in bringing up state-of-the-art methods in the desalination field.

Keywords: Desalination; Brine Management; Pressure Retarded Osmosis; Greenhouse Desalination.

References:

1) Douani, M., Tahri, T., Abdul-Wahab, S.A., Bettahar, A., Al-Hinai, H. and Al-Mulla, Y., 2011. Modeling heat exchange in the condenser of a seawater greenhouse in Oman. Chemical Engineering Communications, 198(12), pp.1579-1593.

2) Sarp, S. and Hilal, N., 2018. Membrane Modules for Large-Scale Salinity Gradient Process Applications. In Membrane-Based Salinity Gradient Processes for Water Treatment and Power Generation (pp. 223-242). Elsevier.

4) Solar-driven Desalination in Saudi Arabia for Sustainable Energy Future: A Thermodynamic Approach for Universal Energy Efficiency with a Standard Solar Energy Platform

Raid Alrowais[1], D. Ybyraiymkul[2], Kim Choon. Ng[2]

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Abstract:

All primary (fossil) energy sources available on planet Earth emanates from the Sun, namely its s photosphere (at 5700K) where useful solar irradiance is acquired either directly or indirectly on a receiver surface. The maximum potential of solar irradiance is chiefly gauged by its direct normal irradiance (DNI).For the production of green electricity, the literature has widely reported three types of photo-voltaic (PV) and power systems form the production of green electricity, namely (i) the stationary PV, (ii) the concentrated PV or CPV in short and (iii) the CSP combined with thermal energy storage systems powering the conventional power plants. Thus, depending on the PV materials and receiver designs, the solar PV systems could operate over a wide range of solar irradiance, ranging from 1 sun (no concentration) to concentrations up to 1000 suns or more. In reality, the variety of PV receivers used hitherto, the solar irradiance or work potential could differ amongst the PV systems, caused by the dissimilar energy quantity and quality being utilized to avoid any thermodynamic misconception, this study introduces a standard solar energy (SSE) framework operating over the Long Term Electricity Rating (LTER). Standard Solar Energy (SSE) methodology is consistent with the classical heat engines, producing the maximum work or Carnot work that could be achieved under a finite heat transfer with associated source and ambient temperatures. Consequently, the SSE approach facilitates an accurate and thermodynamically rigorous comparison of the efficacy of PV systems. In the study of totally green desalination, all methods utilizing assorted PV and seawater desalination methods could be examined for their respective efficacy. Novel specific energy consumption can be presented such as the SSE needed per cubic meter of distillate produced, for example, stationary Photovoltaic (PV), concentrated Photovoltaic (CPV), and concentrated Solar Power (CSP) systems were shown to consume 6.49, 2.36, and 2.99 respectively. Despite the superior efficiency of CPV, yet the current investment trend seems to favor a less efficient method which defies common sense. Hopefully, this SSE methodology for PV systems could give the designers a more energy efficient choice that the existing "illogical" deployment approaches that were adopted hitherto.

Keywords: Green desalination methods; Standard Solar Energy (SSE); Solar energy.

5) Advanced GC-MS-SIM Method for Simultaneous Determination of Bisphenol-A and Phthalic Acid Esters in Seawater

Mohammed Akkbik*, Ahmad Ali Ahmadi and Noora Al-Qahtani

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Abstract:

In response to environmental concerns and the need for precise analytical methods, a highly sophisticated gas chromatography-mass spectrometric (GC-MS) technique was developed for the simultaneous quantification of bisphenol-A (BPA) and three common phthalic acid esters (PAEs) in seawater samples. This novel method was meticulously designed to ascertain the total concentration of PAEs present in collected seawater samples, thus addressing environmental and health-related concerns in Qatar which is the main source of domestic water supply. The development of the extraction method for the determination of BPA, dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), and bis (2-ethylhexyl) phthalate (DEHP) involved a comprehensive optimization process. Four crucial parameters, including the selection of the solvent, manipulation of physical conditions, and precise determination of the volume of acid, were meticulously refined. The extraction process was achieved through liquid-liquid extraction employing dichloromethane as the solvent. A 50 mL of seawater was previously adjusted to pH 4.0 with 50 μL of HCl (36-37%), then the mixture was manually shaken for 1 min with 2 mL of DCM. To further enhance precision, an ultrasonic water bath shaker was utilized for a precisely timed 30 minutes extraction period, all conducted at room temperature. Analytes, namely DBP, BPA, BBP, and DEHP, exhibited distinct and well-defined retention times of 10.2, 11.2, 11.9, and 12.7 minutes, respectively, within the chromatographic system. Our method demonstrates remarkable sensitivity, with instrument detection limits established at 0.09, 0.43, 0.33, and 0.93 μg/L for DBP, BPA, BBP, and DEHP, respectively. Furthermore, the calibration curve working ranges were thoughtfully determined to span from 2.5 μg/L to 250 μg/L for each of the target compounds. In assessing the precision of our method, relative standard deviation (RSD), indicating precision, consistently fell within the range of 0.87% to 11.10% for DBP, BPA, BBP, and DEHP. Additionally, recovery values spanning from 80.9% to 103.7% demonstrated the robustness and accuracy of our method across a range of sample matrices. In our comprehensive analysis of seawater samples, it was evident that the concentration levels of DBP, BPA, BBP, and DEHP remained well below the stringent standards established by the Environmental Protection Agency (EPA) for DEHP (6 μg/L) and the United States Environmental Protection Agency (USEPA) for PAEs (3.0 μg/L) in raw water. These results underscore the effectiveness and reliability of our advanced GC-MS method, which holds significant promise for environmental monitoring and health-related research.

Keywords: BPA; PAEs; seawater; GC-MS-SIM.

Keynote Speaker

1) Airborne VHF Sounding Radar for Desert Subsurface Exploration of Shallow Aquifers: DESERT-SEA

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Abstract:

Shallow fossil aquifers are the largest freshwater bodies in the North African Sahara and the Arabian Peninsula. Their groundwater dynamics and response to climatic variability and anthropogenic discharge remain largely unquantified due to the absence of large-scale monitoring methods. Currently, the assessment of groundwater dynamics in these aquifer systems is made primarily from sporadic well logs that barely cover a few percent of the geographical extent of these water bodies. To address this deficiency, we develop the use of an Ultra-Wide Band (UWB) Very High Frequency (VHF) interferometric airborne sounding radar, under a Space Act Agreement between NASA and the Qatar Foundation, to characterize the depth and geometry of the shallowest water table in large hyper-arid hydrological basins in North Africa and the Arabian Peninsula. We describe herein the science objectives, measurement requirements, instrument design, expected performance, flight implementation scenarios, primary targets for investigation, and the first technology demonstration of the concept. Our performance analyses suggest that an airborne, nadir-looking sounding radar system operating at 70-MHz center frequency with a linearly polarized folded-dipole antenna array—enabling a bandwidth of 50 MHz—and a surface SNR of 85 dB flying at an altitude of 500-2000 m, can map the uppermost water table depths of aquifer systems spanning tens of kilometers at a vertical resolution of 3 m in desiccated terrains to an average penetration depth of 50 m, with a spatial resolution of 200 m. For the first time, this airborne concept will allow time-coherent high-resolution mapping of the uppermost water tables of major aquifer systems in hyper-arid areas, providing unique insights into their dynamics and responses to increasing climatic and anthropogenic stressors, which remain largely uncharacterized. The above significantly surpasses the existing capabilities for mapping shallow aquifers in these harsh and remote environments, which today rely on data collected on different time scales from sparse well logs that do not cover their geographic extents.

Keywords: Airborne sounding radar, VHF radar, Synthetic aperture radar, Desert hydrology, Subsurface imaging, Groundwater and aquifers.

2) Flood Hazard Maps Generation Caused by Hypothetical Failure of the Tabaqa Dam by Use of HEC-RAS 2D Model

Sadeq Sulaiman

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Abstract:

One of the most devastating natural calamities is flooding. Time of occurrence, mode of spread, and magnitude are all crucial pieces of information to have. Catchments and regions are frequently reported to have been flooded, with tragic results including loss of life, destruction of property, suspension of traffic, loss of power, and suspension of community activities. The spatial and temporal propagation of flow in a river or river network is an intricate topic. Construction and settlement along rivers necessitate precise estimates of water levels and flow rates, driving the development of intricate flow routing models. The height of infrastructure like bridges and levees is based in part on the predicted flood water level, thus its calculation is essential. The failure of dams occurs from several factors, including what is natural, such as heavy rains in excess of the capacity of dam reservoir, violent earthquakes that strike dam area, or a result of human action, such as explosions resulting from wars, and defective maintenance of the dam's facilities. This leads to flooding on neighboring properties when water flows out of its channel. Decision-makers can use flood analysis to better foresee and prepare for floods. The challenge that arises from this is tracking the wave's progress and noting changes in its height or magnitude. Unsteady flow is a challenge for rivers in nature because of the significant changes in hydraulic resistance and cross-sectional geometry between the river channel and floodplain. Instead of taking the lengthier journey via meandering channel, some of the flow will take the more direct route along the floodplain, further complicating an already unstable situation. This means that the canal and floodplain have distinct wave attenuation and travel time characteristics. This is because water moves in a distinct way via the channel and floodplain. Engineers now have access to extremely accurate hydraulic modeling tools that generate graphical two- and three-dimensional visuals for analysis thanks to advancements in fully dynamic, unstable models. Incorporating time-series data within a geographic interface, such as the Geographic Information System (GIS), is crucial for dynamic visualizations in dynamic modeling. In a case study, a numerical model was constructed for Euphrates River to predict how flood waves would flow via the river's channel and floodplains. It is based on a slightly altered version of the full Saint-Venant equations of unsteady flow. Flows in the winding river channel, the left overbank floodplain, and the right overbank floodplain are distinguished using these revised equations. All three sections of the valley cross-section are considered, as are the variations in hydraulic and geometric features and flow-path distances that exist between them. The effect of a hypothetical failure of Tabaqa Dam on Euphrates River's peak discharge, peak water level, lag time of peak discharge, and lag time of peak water level along the river reach under study was investigated using the numerical model for various values of the Manning roughness coefficient of the floodplain. The study area spanned 538 km from Tabaqa Dam to Haditha Dam along the Euphrates River. The HEC-RAS 6.4 model was applied to the study area to simulate and produce maps showing latitudinal spread of water, inundation areas, and wave arrival time over most of the major cities along the Euphrates River in the study area. The ability of Haditha Dam to drain flood wave reaching the dam lake was also simulated.

3) Assessing the Hydrology and Hydraulic Behavior of Catchments for Determining Flood Impacts in the Dhofar Governorate, Oman

Manal A Al Balushi[1], Joseph Holden[1], and Mark A Trigg[2]

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Abstract:

Oman has experienced several major recent flood events, most of them considered as deadly flash floods. The Dhofar governorate has been at the brunt of such floods, most recently in 2018 and 2020. This study seeks to identify appropriate flood risk mitigation measures by understanding the hydrological processes operating in catchments in the region. Hydrological and hydraulic models were used to simulate previous floods events in 2002, 2018 and 2020. Multiple evidence sources are used to validate the models. Different scenarios of catchment management are tested to understand their impact on flood reduction for a range of storm event sizes, including changes to grazing regimes and sets of small storage dams. The outcomes are presented based on a coupled hydrological and hydraulic model showing key areas of the landscape that could be modified to reduce flood risk downstream.

4) Development of Flood Risk Mapping and Mitigation Strategies for Al-Qassim Region, Saudi Arabia

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Abstract:

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 produce a comprehensive map of flood risk in the Al-Qassim region. Flooding has become a pressing issue in this region, and this initiative aims to apply fundamental scientific principles to advance our understanding of flood risks, ultimately resulting in the development of innovative mitigation strategies. Flood risk mapping is vital in watershed management and planning, especially in reducing flood damage. In this study, a flood risk map will be developed for AL-Qassim by combining geographic information system techniques with a multi-criteria decision-making method known as the Analytical Hierarchy Process (AHP). Several factors will be investigated in the study, including elevation, slope, topographic wetness index, drainage density, rainfall, soil and land use, and land cover. The watershed will be divided into five regions: very high, high, moderate, low, and very low flooding danger areas. The obtained results will provide helpful knowledge for the policy and decision-makers to make the right decisions regarding the effectiveness of the protective structures of the study area against the risk of flash flooding in the future.

Keywords: Flooding, Al-Qassim, Hydrological Modeling, AHP, HEC-RAS, GIS.

5) Hydrological Assessment of the weather state "Madar 22": Implications for Water Resources Management" in the Kingdom of Saudi Arabia

Yousry E. Mattar[1], Raied S. Al Harbi[2], Ahemed A. Al Ghamdi[3]

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[2] *Assistant Professor, King Saud University, Riyadh, KSA, Email: rsalharbi@ksu.edu.sa*
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Abstract:

Rare summer weather state has affected the Arabian Gulf countries, Yemen, and western Iran in the months of July and August 2022. Wide geographical areas of the Kingdom of Saudi Arabia including major cities such as Riyadh, Jeddah, Qassim, Dharan, Najran, Asir, Jazan and Al Baha have been affected with this tropical weather state. The Committee of Naming of Distinctive Weather States in Saudi Arabia has documented the name "Madar 22" to this summer weather state. "Madar 22" is considered as a tropical weather state arising from the tropical depression, and unusual seasonal activity of wind movement in the Indian Ocean and the Arabian Sea towards the south of the Arabian Peninsula. "Madar 22" has lasted as 30 days beginning from 23 July 2022 to 21 August 2022, resulted in medium to very heavy daily precipitation. "Madar 22", is considered as rare and distinctive historical summer weather state in terms of its spatial distribution and intensity resulting in flooding in many areas in Saudi Arabia and Arabian Gulf countries. The precipitation rates during "Madar 22" are considered unprecedented in months of July and August within the last 30 recorded years in the Arabian Gulf countries. Significant amounts of precipitation were recorded within this summer weather state, for example (300) mm in Oman, (222) mm in Al Fujairah port which is considered as the highest precipitation during July in the last (27) years in United Arab Emirates. The present study aims at the assessment of the hydrological implications of "Madar 22" for the water resources management in Saudi Arabia. The daily and hourly records of the hydrologic network's stations including rain, weather stations and the monitoring wells, have been used to utilize the spatial distribution maps of "Madar 22" and compared with the "Rahw" summer weather state, which has affected the southwestern Saudi Arabia regions in July and August 2020 and lased in 18 days from 24 July 2020 to 10 August. The maximum daily precipitation during "Madar 22" has recorded in Asir region attaining (78.8) mm, whereas the weighted precipitation all over the kingdom of Saudi Arabia regions during "Madar 22" was calculated as (29) mm using ARC GIS spatial interpolation techniques. On the other hand, "Madar 22" resulted in considerable amounts of runoff causing great damage to the infrastructure in parts of some Arabian Gulf countries. Large quantities of runoff estimated at (251.3) million cubic meters were harvested in the reservoirs of (189) surface dams out of a total number of (574) dams in all regions in the kingdom of Saudi Arabia, including (56) dams in the Asir region, (31) dams in Al-Baha, (24) dams in Makkah Al-Mukarramah, (23) dams in Al-Madinah Al-Munwarah, (22) dams in the Najran, (16) dams in Riyadh, (8) dams in Jazan, (7) dams in Hail and (2) dams in Tabuk region. The maximum floods volumes have been received in dam reservoir during this rainy state was in Baysh dam in Jazan region with (64.2) million cubic meters, followed by (51) million cubic meters in Najran surface dam. The harvested runoff water in dam reservoirs during "Madar 22" contributes to enhancing both renewable surface and groundwater water resources in Saudi Arabia in summer days, where (113.5) million cubic meters of water were drained from dams to the downstream of wadies to enhance the groundwater levels and to contribute to the agricultural seasons. The shallow groundwater levels are arising between (2-5) m at the alluvial indicating considerable indirect recharge.

Keywords: Hydrology, Hydrometeorology, Weather states, Runoff, Rainwater harvesting, Dams.

6) Atmospheric Water Generation in Qatar: A Sustainable Approach for Extracting Water from Air Powered by Solar Energy

Aiyad Gannan

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Abstract:

In alignment with Qatar Vision 2030's commitment to sustainable energy and a clean environment, this research focuses on developing an Atmospheric Water Generating (AWG) system utilizing hygroscopic materials to address water scarcity and the system will be powered by solar energy. This study is conducted to investigate and review a different type of sustainable water harvesting methods from the atmospheric humidity, fogs and dew. In this research study, the water collection performance of various fog/dew collectors will be demonstrated. Furthermore, feasibility study to review the technical aspects of fog collector and the efficiency improvements. Fog harvesting technology is obviously limited by global fog occurrence. In contrast, dew water harvester is available everywhere but requires a cooled condensing surface. In this research also, the dew water collection systems will be studied. The key target in all these approaches is the development of an atmospheric water collector that can produce water regardless of the humidity level, geographical location, low in cost and can be made using local materials. This project aims to adapt Atmospheric Water Generating (AWG) system design and material to ensure excellent performance and reliability of AWG in harsh conditions such as in Qatar. It will be particularly focused on the development of passive system. High efficiency solar cell technologies are proposed here as selected candidates for desert AWG development. Furthermore, a comprehensive Technoeconomic Environmental Risk Analysis (TERA) study will be conducted to investigate the cost-effectiveness of the proposed solar-powered AWG, compared to the desalination power plant and assess the environmental footprint of the solar-powered AWG system, considering water usage, carbon-based emissions, and other relevant factors.

Keynote Speaker

1) Oil Spill Management to Prevent Catastrophic Shutdown of Desalination Plants

Zhaoyang Liu
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Abstract:
The combination of a growing global population and climate change has raised global concerns about the availability and safety of drinkable water. Seawater desalination is emerging as a low-cost, high-efficiency solution to coastal water constraint [1,2]. There are around 16,000 desalination plants in operation worldwide, spread over 177 countries, producing approximately 95 million m^3/day of fresh water. Nowadays, saltwater desalination technology is divided into two types: distillation and reverse osmosis [3]. Distillation desalination uses distillation units to convert seawater to steam and then condense it. Reverse osmosis desalination entails pressing new water via membranes. High-quality feed water is required for the efficient functioning of desalination units [4]. Pollutants that bypass the saltwater intake and pretreatment processes and enter the downstream desalination operations diminish heat transfer efficiency in thermal desalination facilities while fouling and destroying membranes in reverse osmosis desalination plants. As a result, the quality of the produced water deteriorates [5]. Intensive flushing and equipment cleaning frequently need a substantial plant closure [6,7].

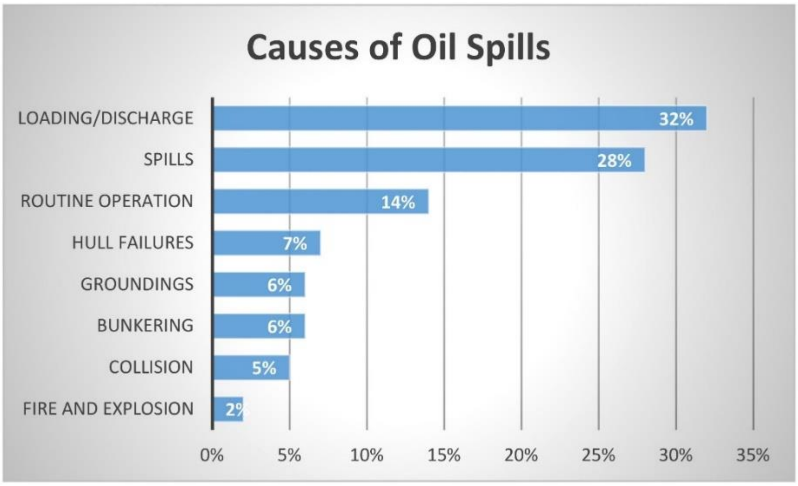

Fig. 1. Various causes of oil spills [8].

The world's principal energy sources are oil and natural gas. Oil spills have emerged as one of the most important environmental concerns in recent years [9]. As seen in Figure 1, there are various reasons of oil leaks. The majority of oil spills are caused by human error, but they can also be caused by fatigue loading, which occurs when fractures form in aging pipes as oil leaks. Furthermore, military actions related to regional wars and disputes have resulted in comparable instances [10]. Oil spills in the marine environment undergo a range of processes, including evaporation, dissolution, degradation, and emulsification [11]. Many types of oil can coexist in water, complicating oil spill cleanup [12]. Furthermore, waves and tides can exacerbate the problem by producing additional unanticipated oil motions. Seawater intake portals are often found in shallow water, which is heavily influenced by wave and tide activity. Currently, most oil spill response tactics focus on limiting marine environment damage rather than desalination shutdown [13]. Desalination facilities usually use open surface seawater intake and conventional pretreatment, but these methods cannot handle significant seawater quality deterioration induced by accidental or planned oil spills [14]. For example, in 2001, more than 1300 t of fuel oil leaked from a sunk ship, forcing the closure of two desalination plants in the United Arab Emirates and causing water shortages [15]. In 2017, an aging pipe in Israel released approximately 100 cubic meters of oil into the sea, resulting in an oil disaster that forced the closure of three desalination plants for three days [7].

Table 1. Threat of oil spills to desalination plants in the Middle East

Countries	Causes	Consequences	Impact on Human life
United Arab Emirates (UAE)	Diesel spilled from a damaged tanker (1997) A spreading oil slick from a sunken barge (1998) An oil slick reached the emirate's beaches from the sunken tanker Zainab. (2001) Oil spill in the Arabian Gulf off the west coast of UAE reached the Al-Fujairah coast (March 2017). Oil spill after attacks on 4 oil tankers in UAE waters (2019) UAE oil spill causes 2km of damage Thick layer of oil affected a major desalination plant at Fujairah (2013)	Shut down a water desalination plant and left Sharjah emirate without water for a day. Forced Emirates of Sharjah and Ajman to close two desalination plants, Al Liyya Water Desalination Plant was temporarily shut down to protect the inlets of the plant. Fujairah oil spills caused by tankers illegally cleaning their holds. Bunker spill from one of the four vessels attacked near Fujairah emirate. It affected a major desalination plant at Qidfa.	SEVERE
Saudi Arabia	Oil spilled during Persian Gulf War (1991) Oil spills brought under control at Yanbu Port. (2022)	Shut down a desalination plant that provides drinking water to millions of people. Authorities shut the desalting plant at Safaniya. Pollution caused by an oil leak in Jeddah.	SEVERE
Kuwait	Oil spilled from an offshore oilfield (2017)	Shut down the desalination plant for two days.	SEVERE
Egypt	Clean-up efforts in Egypt's Red Sea under way following oil spill (Aug 2022)	Jordan's official news agency Petra reported an oil spill at the berth of a container terminal in the port of Aqaba. Preliminary investigations determined that the spill had been caused by a docking ship in the area.	SEVERE
Yemen (2015 – 2022)	**Very near miss** The FSO Safer tanker had been rusting away off Yemen's coast since 2015. It threatened to release roughly four times the amount of crude oil spilled off Alaska in the Exxon Valdez disaster of 1989.		SEVERE

The operation of desalination plants is highly dependent on feed water quality, which is controlled by a variety of parameters such as raw seawater quality, saltwater intake processes, and onshore pretreatment methodology [16, 17]. Existing desalination facilities must be re-evaluated and redesigned with all of these aspects in mind in order to remove oil contaminants and ensure the quality of feed water during catastrophic oil spills. This is critical to preventing desalination shutdowns and ensuring a continuous water supply. This article examines various oil/water separation technologies from the viewpoints of offshore oil spill cleanup, seawater intake, and onshore pretreatment. The benefits and drawbacks of each technology are discussed, as well as their applicability in various contexts. Due to the variety of oil types found in water, no single technology can remove all kinds of oil pollutants. Furthermore, because most oil spills occur by mistake and no one can foresee how badly, where, or when they would occur, a strong management plan to prevent desalination shutdown must take all of the aforementioned factors into account.

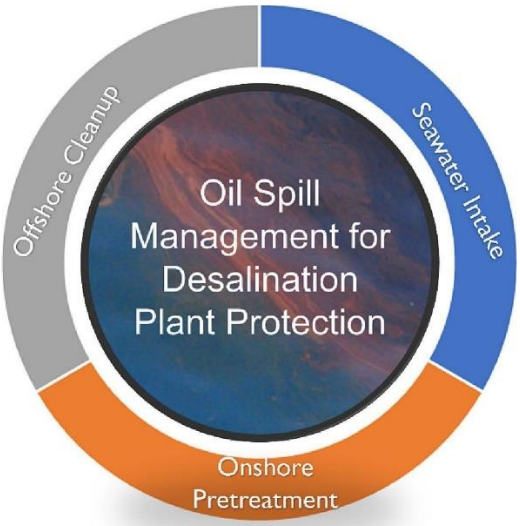

Figure 2. Seawater desalination is an important technology utilized to provide fresh water, but its safety is jeopardized by marine oil spill accidents. Historically, oil spills have caused entire shutdowns of desalination plants as well as serious disruptions in water supply. The functioning of desalination plants is sensitive to feed water quality, which is influenced by the following factors: (i) raw saltwater quality, (ii) seawater intake methods, and (iii) onshore pretreatment technology in desalination plants. As a result, this review paper thoroughly explores numerous oil-removal strategies from the perspectives of (1) offshore oil spill cleanup, (2) seawater intake, and (3) onshore pretreatment. A comprehensive strategy that incorporates all components is proposed to protect seawater quality and desalination facilities, with the goal of preventing desalination plant shutdown during oil spill situations [17].

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2) Oxide Activated Carbon for Seawater Desalination Using Solar Energy

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Abstract:

Desalination of seawater is an efficient process and a viable solution for water shortage problems. This process is consuming a large amount of energy. One of the latest possible solutions with less energy consumption is the use of activated carbon for the desalination process. Activated carbon can be produced using several materials including agricultural waste. In this work activated carbon was produced from palm tree trunks. The preparation of the activated carbon was done by two steps process. The first step was the pyrolysis for two hours at 700 °C under nitrogen gas flow of 150 ml/min. The next step was the physiochemical activation using potassium hydroxide (1:1) under nitrogen and carbon dioxide gas flow of 150 m/min for two hours. The prepared activated carbon was analyzed using Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray (EDX) to study the surface area, the porosity and the chemical composition. The application of the activated carbon in the desalination process was done by initially oxidizing the AC to use it for the reduction of the boiling point of the seawater followed by the desalination. This was supported with the use of a solar panel to provide the required energy for evaporation. The treated water was analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES). The prepared activated carbon in this study was used to produce fresh water by the desalination of seawater based on environmentally safe and lower energy cost method, which is a promising technique that can overcome the shortcomings of the current used technologies.

Keywords

Activated carbon, oxide- AC, desalination, solar energy.

3) An Innovative Approach to Desalination and Cooling Using Forward Osmosis with Thermal Recovery and Vapor Absorption Cycle

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Abstract:

The escalating need for freshwater, coupled with the restricted availability of natural water resources, has prompted Kuwait to increasingly depend on energy-intensive desalination techniques. Moreover, the prevailing hot and humid climate during summer necessitates the use of air-conditioning systems in most areas, resulting in a substantial surge in power usage. An innovative, dual-purpose system that integrates forward osmosis with thermal recovery and a vapor absorption cycle to address these concerns is presented in this work. This novel system, leveraging the author's patented technology US 11,407,659 B1, utilizes low-grade heat sources, such as solar energy or waste heat from power plants, to power a vapor absorption cooling cycle. The waste heat from this cycle is then harnessed to drive the forward osmosis with a thermal recovery desalination system. Using forward osmosis with thermal recovery addresses prevalent desalination issues, including scaling, fouling, and precipitation. This combination of processes offers a promising approach to efficiently and concurrently managing extreme weather conditions and water scarcity. The findings of this paper demonstrate the system's technical feasibility, efficacy, and operating conditions. The system's design, performance, and efficiency details are thoroughly evaluated, yielding a comprehensive data set for this innovative technology. The success of this system underscores the potential of efficient, dual-purpose solutions in addressing the global challenges of water scarcity and energy consumption.

Keywords: Combined Cooling and Desalination; Forward Osmosis with Thermal Recovery; Vapor Absorption Cycle; Low-Grade Heat Utilization.

Keynote Speaker

1) New Developments in Mathematical Modeling of Groundwater Systems

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Extended Abstract:

The numerical modeling of groundwater flow in unconfined aquifers is much more involved than in confined aquifers. This is because the governing equation (i.e., Richard's equation) is highly nonlinear and is subject to nonlinear boundary conditions as well. This nonlinearity is related to the dependence of the relative permeability and the water retention in the unsaturated zone on the pressure head. Moreover, fully saturated models are typically associated with boundary conditions such as constant head, pumping/injection flow rates, and leakage flux through a semi-confining bed. These are essentially linear and do not pose additional challenges to standard numerical solution techniques. This is not the case for unconfined flow models where some boundary conditions are nonlinear and therefore are unknowns a priori; thus, they are an integral part of the numerical solution. A typical example is the free and moving water table boundary. Another complication in modeling unconfined groundwater flow is to locate the position of seepage faces when the water table reaches the land surface. The seepage boundary faces are not known prior to the numerical solution and are, therefore, not fixed as typically done with other boundary conditions. Additionally, wells pumping groundwater from unconfined aquifers might become dry as the water table drops below the well screens, and natural or artificial drains may stop draining groundwater as the levels drop below predefined elevations. These are typical examples that necessitate additional bookkeeping procedures during the nonlinear iterative solution process when solving for an unconfined groundwater flow model. Furthermore, natural groundwater flow occurs mostly in highly heterogeneous and anisotropic materials, thus increasing the nonlinearity of the resulting discrete algebraic systems of the equations. Hence, robust and advanced numerical methods are needed in this context.

Modeling unconfined groundwater flow subject to free and moving boundaries is performed using two broad classes of methods. The first category assumes a fixed mesh. Within this class, an algorithm should determine the spatial and temporal distribution of three types of cells: wet, dry, and partially wet cells (i.e., crossed by the water table). The second category considers a moving mesh that adapts to the dynamics of the water table boundary. Hence, unlike for a fixed mesh method, the dry zone (i.e., approximate unsaturated zone) is not part of the computational domain. The main advantage of an adaptive mesh technique is to solve a saturated groundwater flow equation, hence a linear system of algebraic equations, during each iteration of the mesh adaption process. Meanwhile, more elaborate algorithms are needed for mesh adaption and the interpolation of hydraulic properties between moving cells.

The fixed mesh approach is probably the most widespread owing to the availability of many computer implementations such as MODFLOW developed by the USGS at the United States of America. Legacy versions of MODFLOW were criticized for an unphysical representation of unconfined groundwater flow dynamics, leading to a numerical instability for highly nonlinear problems. This was due, in part, to the heuristics upon which the

decision to rewet a previously dry cell are based. Second, Picard iteration for some highly nonlinear problems may converge at a very slow rate or not at all. The latest releases include, however, a new Newton–Raphson-based formulation that substantially improves the computational stability. Another known difficulty within the fixed mesh approach derives from the way to artificially hide the flow patterns in the dry cells. Because this is not possible as the mesh is fixed, different approaches have been developed to tackle this problem. Desai (1988) developed a two-dimensional finite element model that linearizes the relative permeability function and recast it as a function of hydraulic head. The same approach was used by scientists in the framework of three-dimensional finite element models. Other authors used a sharp representation of this function; that is, the hydraulic conductivity in all dry cells is multiplied by a small residual factor (i.e., ~10–2–10–3). New developments presented the numerical solution of 3D unconfined seepage problems with the smoothed finite element method borrowed from solid mechanics (Kazemzadeh-Parsi, 2013). A limitation of the fixed mesh approach is that the exact position and shape of the water table could only be determined by post-processing computed groundwater heads. Hence, it is expected that a moving mesh technique will always lead to a more accurate position and a smooth shape of the phreatic surface when compared with a fixed mesh approach using the same resolution.

The second class of methods solve a series of linear equations on a deforming mesh. The mesh is adapted iteratively to fit the water table position. Here, again, many sub-approaches have been developed that could be categorized as rigorous or simplified. As described in standard textbooks of Bear (1972), the phreatic surface does not only fulfill the zero-pressure condition, but it is a kinematic boundary condition too. In other words, it is an interface through which the effects of unconfined storage, net recharge, and nonlinear effects related to the changing shape of the surface geometry are balanced. To the best of our knowledge, the only published numerical model taking into account both conditions was presented by Knupp (1996); such kinematic boundary condition, even under steady-state conditions, cannot be neglected.

Solving unconfined groundwater flow with a moving mesh technique using a finite difference method has some limitations. These problems do not exist when using a conforming (i.e., nodal-based) finite element technique such as the Galerkin weighted residual approach. However, while the groundwater head and the water table shape obtained by the conforming FEM using a moving mesh method might be accurate, it is well known that this is not the case for the specific discharge field. Moreover, the conforming FEM is not exactly mass conservative, which is problematic for nodes sharing elements with a high contrast of hydraulic conductivities. Post-processing techniques were introduced to derive continuous nodal-specific discharge fields, but it was reported that this procedure has a high computational cost. Mixed finite element methods were introduced to simultaneously approximate a scalar variable and its first-order derivative fields. Promising results highlighting a higher accuracy of this approximation technique when compared with alternative techniques were obtained for flow problems. The mixed finite element method leads, however, to an indefinite system of algebraic equations which is difficult to solve with direct or iterative methods. A hybridization technique avoids this problem by reformulating the mixed problem with primary unknowns on the faces of the mesh and using local algebraic relationships to recover the cell-centered heads and the normal specific discharge components. This gives rise to a method formally known as the mixed hybrid finite element method (MHFEM). Previous works established the outstanding behavior of this method to tackle groundwater flow problems in highly heterogeneous and anisotropic formations. While the MHFEM approximation was used for many classes of groundwater flow problems such as unsaturated flow and two-phase flow, to the best of the authors' knowledge, this is the first time that it has been used in combination with a deforming mesh approach to solve an unconfined flow in phreatic aquifers.

The objective of this paper is to introduce a new state-of-the-art three-dimensional MHFEM numerical model for confined–unconfined groundwater flow in complex aquifer systems characterized by irregular geometries, heterogeneous and anisotropic materials, and nonlinear boundary conditions of a practical relevance. These include, in particular, the nonlinear kinematic and seepage face boundary conditions generally ignored or weakly dealt with in previous studies. The work also deals with the model formulation and numerical discretization on layered unstructured grids.

In summary, determining the water table shape and position in unconfined aquifers is fundamental to many groundwater flow assessment studies. The commonly used industry standard fixed mesh models, contrary to popular belief, do not provide an accurate description of the phreatic surface. When using such models, the water table position is post-processed from the simulated groundwater heads, leading to an approximation error. This error becomes larger for coarse vertical grids. This paper introduces a novel moving mesh technique to simulate the groundwater table in three-dimensional unconfined aquifers under steady-state or transient conditions. We adopt the face-based mixed-hybrid finite element discretization approach in space, leading to a more accurate approximation of the specific discharge field. The model uses an adaptive unstructured but layered mesh which is iteratively adjusted until its top fits the phreatic surface. The developed algorithm accounts for a linearized form of the kinematic boundary condition prescribed on the moving boundary and also supports usual boundary conditions as well. The model was compared to the existing analytical, fixed mesh, and previously published solutions. The obtained results show that the developed model is superior in terms of its numerical stability, convergence behavior, and accuracy. Furthermore, the simulated phreatic surface is free from a cellwise interpolation error and independent of the vertical grid size as used in fixed mesh methods. We also found that the ro-bustness of the moving mesh method cannot be surpassed by a fixed mesh alternative. The model's efficiency is supported by an almost quadratic rate of convergence of the outer iteration loop. Several theoretical and realistic examples are provided to demonstrate the model's accuracy, efficiency, and capability to successfully simulate unconfined groundwater flow with this novel moving mesh technique.

2) Assessment of Groundwater Quality and its Implications for Drinking Purposes in Najran Southern Saudi Arabia

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Abstract:

In arid and semi-arid regions of Saudi Arabia, where water scarcity is an issue, monitoring groundwater quality is crucial. The main goal of this study is to assess the quality of groundwater and investigate the characteristics of water wells in Najran City, Saudi Arabia. A total of 10 groundwater wells in the study area were analyzed for physical, chemical, and bacterial properties. The physical tests were conducted on-site for each well, while the chemical and bacterial tests were carried out in the central laboratory for water and sanitation in Najran province. The results showed that the physical and bacterial properties of all 10 wells were within the recommended limits. However, the chemical analysis results varied among the wells, with some showing high levels of nitrate, chloride, sulfate, and hardness, making the water unsuitable for drinking. This situation could potentially cause harm to the ecological habitat in the region. The study suggested that groundwater wells should be monitored and treated regularly to ensure safe drinking water in Najran City.

Keywords: Groundwater wells, Groundwater quality, Drinking water standard, Heavy metal, Najran.

3) Using MODFLOW to Evaluate Technical Feasibility of Operating Small RO Units with Shallow Groundwater Wells in Kuwait

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Abstract:

The efficient operation of small Reverse Osmosis units in community centers in Kuwait necessitates a minimal supply of brackish groundwater with suitable water quality standards. Specific requirements were established for a public center in Al-Salmeyeh, Kuwait, demanding a brackish groundwater supply of 250 m3/h with suitable quality parameters (TDS less than 15,000 mg/l and free from contamination). This volume should be extracted without inducing significant drawdowns. The methodology employed combined pumping tests and numerical modeling to evaluate the impact of pumping activities on water levels. Analysis of pumping tests revealed an average transmissivity of 292 m2/d and a specific yield of 12%, indicating promising replenishment potential. However, due to formation damage around the wellbores, the total pumping rate achievable from the six wells (without well development) amounted to 215 m3/h, falling short of the required 250 m3/h. Nonetheless, the maximum drawdown observed after 5 days of continuous pumping stood at 8.04 meters, well within the acceptable effective drawdown limit of 14 meters, suggesting favorable hydraulic conditions in the project area. Numerical models were constructed using MODFLOW software to simulate long-term drawdown under simultaneous operation of all wells. It was determined that by operating the pumping rate per well at 50 m3/h, the necessary water production of 250 m3/h could be achieved without inducing undesirable drawdowns, with no anticipated significant deterioration in groundwater quality. Salinity analysis indicated levels ranging between 8,000 and 10,000 mg/l, with water classified as Na-SO4-Cl type.

Keywords: MODFLOW, small scale RO units, pumping tests, community centers, Kuwait.

4) Assessment of groundwater suitability for drinking and irrigation purposes using physicochemical parameters at Al-Jouf Area, Saudi Arabia

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Abstract:

Al-Jouf region is one of the most agriculture areas in Saudi Arabia. Due to the increase of drinking and irrigation water requirements in this region, there is an urgent interest in studying groundwater quality. Thus, the main aim of this study is to analyze physicochemical parameters of groundwater in Al-Jouf region for irrigation and drinking purposes. Thus, this study has been investigated some parameters include total dissolved solids (TDS), pH, electric conductivity (EC), hardness, and various anions and cations were compared with national and international standards. Ground water quality index (WQI) was estimated to evaluate the suitability of groundwater for drinking purposes. The electric conductivity (EC), sodium percentage (Na^+ %), magnesium hazard (MH), sodium adsorption ratio (SAR), potential salinity (PS) and Kelley's ratio (KR) were assessed to evaluate suitability of groundwater for irrigation. The results of water quality analysis showed the suitability of ground water in most parts of the studied area for drinking and irrigation use except that of Al Qaryat region. Moreover, the groundwater is dominated by alkali metals and controlled by rock–water interaction domain, and the ionic abundance ranking was $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ for cations, and $Cl^- > SO_4^{2-} > NO_3^-$ for anions.

SS4): Effective Management of the Municipal Water Sector

Organized by ACUWA

Khaldon Khashman, Muna Hindiyeh, Adel Obaiat

Overview:

The session is organized by **ACWUA** and will address the topic of effectively managed utilities (EMU) in the water sector. In this session the speakers will present the tools that ACWUA has developed or implemented in Jordan and other Arab Countries. **Eng. Khaldon Khashman** will present the best practices ACWUA has developed such as NRW, Energy Efficiency in Water facilities, TSM, TAP public awareness and capacity building and certification programs.

Dr. Muna Hindiyeh will be talking about the institutionalization integrated Water and Wastewater safety plans (IWSSP) project based on the WHO manuals that ACWUA is implementing in the Ministry of Water and Irrigation (MWI) with the support of UNICEF Jordan. The aim of the project is to enhance the IWSSP within the departments in the MWI, Water Authority of Jordan (WAJ) and the Jordanian public utilities. The project includes defining the mandate of every stakeholder within the ministry and other entities and building capacity within the entities.

Eng. Adel Obaiat and **Eng. Khaldon Khashman** will present Institutionalization in WDM in Municipal, Agriculture and Industry within the WEC financed by USAID Jordan. The aim of the project is to develop manuals in the three sectors by introducing the best practices and new innovations, water safety tools worldwide in these manuals. Revising all legislations, bylaws, regulations and standards, the manual will be endorsed through the legal governmental procedures (WAJ and Jordan Cabinet). By that, implementation of all the best practices and innovations in this manual is a mandatory by all the stakeholders in the three manuals.

The Water Demand Management unit and the regulatory body in the sector will be responsible for monitoring and supervising the performance of all the stakeholders in implementing all these manuals. It is expected to make saving near about 70 MCM of water.

Session Speakers:

- **Eng. Khaldon Khashman**- ACWUA best practices tools in managing utilities.
- **Dr. Muna Hindiyeh**- Institutionalization Water and Wastewater safety plans in MWI and Jordanian Utilities.
- **Eng. Adel Obaiat** and **Eng. Khaldon**- Institutionalization in WDM in Municipal, Agriculture and Industry in MWI.

1) Water Demand Forecast using Machine Learning

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Abstract:

Water scarcity is one of the main challenges that GCC countries have been facing for multiple decades. The challenge grows bigger as the region is experiencing a huge social and economic transformation leading to an increase in water demands. Out of the various solutions that were implemented to face the challenge, the demand and supply side management was heavily investigated. The balance between water supply and demand requires efficient water management system techniques, which are highly dependent on the use of accurate forecasting concepts and tools. Accurate demand forecast is a necessary input to many water processes such as determining the required water reserve precisely as well as develop optimum operational plans for pumping stations and water production plants. There is no global single optimum method used to forecast the water demand. It is more of a case-by-case approach depending on the network complexity, operational limitations, available data, forecast horizon, intuitiveness of the tool, accepted percentage of deviation between actual and forecasted demand. The purpose of this paper is to achieve the global sustainability goal by addressing the gap that is currently present between water supply and demand. This is done by presenting an innovative accurate methodology to forecast the water demand using machine learning (ML). The results for Abu Dhabi Emirate showed that the mean absolute percentage error (MAPE) between the actual and forecasted demand was reduced from 5.42% for the conventional forecasting method to 2.72% for the proposed ML forecasting method. Similarly, the root mean square error (RMSE) was reduced from 11.14 (MIGD) for the conventional forecasting method to 5.91 (MIGD) for the proposed ML forecasting method. Additionally, the total difference per year between the actual and forecasted demand was reduced from 2682 (MIG) for the conventional forecasting method to 913 (MIG) for the proposed ML forecasting method. This shows that by having an accurate demand forecast, the gap between the actual and forecasted demand can be reduced, which will improve the overall efficiency and performance of the water management system.

2) System Dynamics Model to Study the Effect of Different Policies on Bahrain Hydrological Processes

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Abstract:

System Dynamics (SD) Modeling is a helpful tool for modelling complex interconnected and dynamic systems by representing them with blocks and feedback loops defined mathematically. SD modelling greatly helps decision-makers study the effect of different policies on a variable in concern. It was first introduced by Professor Jay Forrester in the 1950s (Forrester, 1958) and was later adopted in different fields including the water sector (Huang et al., 2011; Simonovic, 2008; Winz, Brierley & Trowsdale, 2009; Zomorodian et al., 2018). In the water sector, common applications of SD are modelling socio-hydrological and hydro-economical models (Balali & Viaggi, 2015; Bekchanov & Lamers, 2016; Mirchi, Watkins Jr. & Madani, 2010; Wei et al., 2012). This aligns with the concepts of Integrated Water Resources Management and Water-Energy Nexus which involve accounting for the big picture. Nevertheless, building confidence in SD models remains a challenge due to the association of some qualitative behavior (such as social behavior) and factors for which data are not available (such as future changes or policies that have intangible or unmonitored effects) (Mirchi et al., 2012). In this work, we aim to perform a holistic analysis of Bahrain's hydrological system and study the effects of different policies in the relevant sectors – such as economic, environmental, agricultural, etc. – on the hydrological sector. To do this we start by developing an SD model that represents the main hydrological variables and validating it against a reliable hydrological model. The SD model includes rainfall, evaporation, land surface permeability and infiltration, all lumped for the study area which is Bahrain. The hydrological model is a semi-distributed model that calculates the water budget using a series of non-linear reservoirs for each catchment at every 30-minute time-step for the simulation period 2016 – 2021. The hydrological model is validated using regionalization techniques; hence, its results are considered the 'correct' values against which the SD model will be validated. To test the SD model, we implement the following different scenarios:

- Impact of urbanization, i.e., change of land surface permeability in SD model. We will experiment with different spatial configurations of changes to land surface in hydrological model and how well SD model can be calibrated to represent these changes. Insights into this process will be presented since SD models do not include spatial representation.
- Response to prolonged low-intensity rain and short high-intensity rainfall.
- Response of the SD model with different antecedent conditions (dry conditions followed by rain and wet conditions followed by rain).

Once the hydrological processes in the SD model are represented accurately, the second stage of this work is to expand the SD model to include environmental, agricultural, economic, and other elements from relevant sectors. The challenge in the second stage is to accurately represent the system of systems and to build confidence in the model. This is achieved by validating the model using data whenever possible, and in cases when data are not available, uncertainty bounds will be determined using mathematical models. This helps decision-makers avoid making wrong decisions by keeping their options open and revisiting the SD model whenever new data are available.

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3) Assessment of the Sustainability of Water Management System in the Sultanate of Oman, A Case Study of Al-Batha Basin

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Abstract:

The natural resources sector in the Sultanate of Oman is one of the sectors that face many challenges due to the various comprehensive development requirements. There is an imbalance between supply and demand, and thus the Sultanate of Oman is working on building many desalination plants to cover the water deficit and building many dams in the valleys. Wastewater treatment also contributes little to meeting the water deficit. However, the approach that the Sultanate of Oman is currently working on has not helped reduce the water deficit, which is estimated at 316 Mm^3. Seawater desalination is considered very expensive for the government and has environmental impacts over time. This study aims to evaluate the water resources management system in the Sultanate of Oman by using one of the water basins, which is the Al-Batha Basin as a case study, and through this basin, the most important challenges facing the management of water resources in this basin were identified, and suggested what are the possible solutions and future scenarios that It can contribute to reducing the water deficit in the Al-Batha basin, which is estimated at 54.6 Mm^3. The WEAP program was used to build a dynamic mathematical model that simulates the water management system in the Al-Batha basin during the period from 2020-2040, the period of implementation of the Oman 2040 vision. The results showed that if the leakage in the network was reduced by 10%, the sewage collection rate was increased, and the irrigation efficiency was raised to 70%, this would have a significant impact in reducing the amount of water to a large extent. In 2040 the total municipal water demands are calculated at 294 Mm^3 compared to about 317 Mm^3 under the reference scenario. The amount of collected wastewater in 2040 will be about 318,744 m^3, compared to the reference scenario where the amount is about 316,866 m^3, an increase of 1,878 m^3. If irrigation efficiency measures are implemented in the agricultural sector it can be reduced from 236.6 Mm^3 in the reference scenario to 118.3 Mm^3 by 2040. This study recommended the necessity of reducing leakages in the network, increasing the collection of wastewater, and raising the efficiency of irrigation.

Keywords: WEAP, Integrated Management of Water Resources, Aflaj, Water Supply, Water Demand.

4) Status of Integrated Water Resources Management (IWRM) in GCC Countries According to UN-SDGs

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Abstract:

The Gulf Cooperation Council (GCC) Countries are located in arid region with rare natural freshwater resources and increasing amounts of treated wastewater for reuse or recycling. Therefore, integrated water resources management (IWRM) is essential for water security in the GCC countries. Globally, IWRM is one of the UN Sustainable Development Goals; and UN-Water is the primary international authority for monitoring the IWRM strategic development goal indicators, including indictor No 6.5.1. This indicator tracks the degree of IWRM implementation by assessing the four key components of IWRM: 1) enabling environment, 2) institutions and participation, 3) management instruments, and 4) financing. In this work, the current status for IWRM implementation in the GCC countries according to UN-Water indicators are presented and analysed in order to assess the level of IWRM implementation in the region. Also, lessons learned from the results of these analyses with respect to implementing the United Nations Strategic Development Goals (UN-SDGs) for IWRM are discussed for each of the GCC countries. Kuwait, Qatar, Oman, and the UAE falls within the very high to high implementation categories. Sustaining momentum and fostering cooperation among the GCC nations could lead them to meet the global target. The findings of this work can contribute to augmenting current efforts towards achieving efficient and sustainable IWRM in the GCC counties.

Keywords: Integrated water resources management, IWRM, GCC, SDGs, water management.

SS5): Frontiers in Water Science and Technology Research: UNESCO and the International Decade of Science for Sustainable Development

UNESCO Regional Office in Cairo, Hydrology Program

Overview:

The United Nations General Assembly has now proclaimed 2024 to 2033 as the "International Decade of Sciences for Sustainable Development (IDSSD)"- acknowledging the imperative to bridge across scientific disciplines and knowledge forms in order to address the complex and intricate challenges of our time.

The Intergovernmental Hydrological Programme is devoted to advancing water research and management, and the related education and capacity development efforts considered essential to foster sustainable and integrated water resources management. UNESCO-IHP offers a scientific and education platform related to water involving key water research institutions to share knowledge and integrate different points of view. IHP promotes partnerships and cooperation among the UN water family institutions at global, regional and sub-regional levels to advance the results of scientific research and innovation into practical uses and to promote knowledge sharing at all levels.

Water Scarcity is a major challenge in the GCC countries. the available water resources are inadequate to meet domestic, economic development and environmental needs, especially when taking into consideration the changing and uncertain future climate, and a rapidly growing population that is driving increased social and economic development, globalization, and urbanization. Current and future water solutions to address water challenges require innovation in science, technology and practice within the strategic visions of water scientific and research institutions.

Accordingly, UNESCO Regional Office in Cairo, in coordination with our Offices in the Region, organizes a round table discussion during the WSTA 15th Conference within the theme “The Role of R&D in localizing and producing water sector technologies in the GCC countries”. The panel will focus on “Frontiers in Water Science and Technology Research: UNESCO and the International Decade of Science for Sustainable Development”. The Session will feature leaders of key water research institutions in the GCC and to share their institutional vision of short and mid-range R&D priorities, especially with respect to localization of technologies and the sharing of knowledge. The outcome of the session will be a shared statement on key water science research priorities, opportunities for cooperation, and their expectation from the IDSSD as well. The output will be shared with UNESCO Science Sector as input to UNESCO planning of future IHP actions in the region within the Decade.

Session Speakers:

- **What is the Future of the Water Science and Research for Sustainable Development: IDSSD perspectives**, Dr. Abdelaziz Zaki, UNESCO Regional Office in Cairo
- **Water Research and Development Priorities in the GCC Unified Water Strategy 2035,** Prof. Waleed Zubari, Arabian Gulf University (AGU)
- **GCC institutional vision of R&D priorities for localization of technologies and the sharing of knowledge**:
    - **Prof. Mohammed Al-Rashid,** Kuwait Institute for Scientific Research (KISR)
    - **Dr. Ali Al-Maktoumi**, Water Research Center, Sultan Qaboos University (SQU)
    - **Dr. Dalal Al-Shamsi,** Water and Energy Center, UAE University
    - **Prof. Syed Zaidi,** UNESCO Chair in Water Technology, Qatar University (QU)
    - **Prof. Mahmoud Abu-Zeid,** The Arab Water Academy, Arab Water Council

Keynote Speaker

1) Artificial Intelligence Application in Hydrogeology and Groundwater Management

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Abstract:

Groundwater management involves overseeing groundwater resources to ensure their ideal utilization and long-term sustainability. More than two billions of the world population depend on groundwater resources as their main water source (Famiglietti, 2014), as result, managing such an important resources would be of paramount importance to governments. This would be even more important for countries like UAE where groundwater provides about 51% of the total water budget (Al Rashed et al., 2023; Ministry of Environment & Water, 2014). Managing groundwater resources involves many aspects, including observing its usage and predicting its future utilization, evaluating the scenarios affecting its utilization and any kind of adverse effects it can have on public health. In addition to aquifer delineation, pollution indicators, and any kind of relation the different aquifers may maintain with each other.

Our work involved exploring many of the key aspects of groundwater management. We utilized state-of-the-art Artificial Neural Networks to predict the fluctuations in Al Ain city groundwater levels. The algorithm utilized state-of-the-art Artificial Neural Networks that used the location, time and meteorologic conditions to predict the groundwater level in any location within Al Ain city. It achieved an accuracy of 0.952 in Coefficient of Determination (R^2). The trained model was used in conjunction with a geomodelling framework that utilized GIS to create variability maps to visually highlight the changes with time in a spatial form (ElHaj et al., 2023b)

We also investigated the critical issue of rising groundwater salinity using machine learning techniques. In a recent study submitted to COP28, we developed predictive models trained on historical total dissolved solids (TDS) data from multiple wells across Al Ain. The models were then used to forecast potential future changes in groundwater salinity under business-as-usual conditions. Additionally, we leveraged the trained models to simulate salinity responses under various climate scenarios, including substantial increases or decreases in precipitation and temperature. This provided actionable insights into how groundwater quality could evolve under different climate futures, enabling proactive management strategies to mitigate salinization risks. Overall, our integrated modeling approach generated data-driven projections to support evidence-based policies aimed at sustaining fresh groundwater resources in the face of environmental change.

We developed an integrated machine learning workflow to elucidate relationships between aquifers using their unique hydrogeochemical fingerprints. The approach involved first leveraging supervised learning techniques to train models on the available hydrochemical data. These models were then used to impute any missing values in the dataset - a crucial step enabling robust subsequent analysis. We next utilized unsupervised clustering algorithms to objectively group wells based solely on similarities in their hydrochemical makeup. This delineated distinct groundwater bodies in a completely data-driven manner. The clustered wells were then visualized spatially using our custom GeoZ library for visualizing clustering outputs, revealing meaningful spatial patterns aligning with the

hydrostratigraphy (ElHaj et al., 2023a). By integrating supervised learning for imputation with unsupervised clustering for classification, the workflow provided an automated means of elucidating connections between aquifers based on their hydrogeochemical signatures. The approach extracted new hydrogeological insights, including groundwater mixing, flow paths, recharge sources, and more. Overall, it demonstrated the power of artificial intelligence techniques to uncover meaningful patterns in complex and imperfect hydrochemical data.

Accurately delineating aquifer boundaries provides numerous critical benefits that support sustainable groundwater management and utilization. Well-mapped aquifers empower decision-makers to effectively monitor, regulate, and protect groundwater resources. Aquifer delineation further aids pollution prevention efforts, disaster preparedness planning, informed land use development, efficient infrastructure sitting, and environmental conservation. Additionally, clearly defined aquifer boundaries enable cooperative legal and transboundary management of aquifers spanning multiple jurisdictions. Aquifer mapping also facilitates economic development planning that accounts for available groundwater resources. It can even assist geothermal energy exploration by elucidating subsurface hydrogeological structures. Overall, precise aquifer delineation is an essential foundation that facilitates informed, integrated groundwater management from local to regional scales.

To address the need for accurate yet efficient aquifer delineation, we developed a novel data-driven methodology leveraging hierarchical clustering analysis of groundwater hydrographs. The approach depends solely on leveraging existing hydrograph data from monitoring wells to delineate aquifer boundaries, without requiring expensive and time-consuming geophysical surveys. A key novelty lies in the custom distance metric we formulated to specifically address unique aspects of hydrogeological time-series data. This custom function compares the hydrographs from different wells based on similarities in groundwater level fluctuations over time. Wells with similar hydrographs are grouped into clusters using agglomerative hierarchical clustering. We selected this algorithm for two main reasons; first, agglomerative hierarchical clustering had the most flexibility in tuning among all the clustering methods tested during the project first phase, this allowed us to customize it to work more efficiently with hydrogeological datasets. The second reason we chose agglomerative hierarchical clustering was due to its hierarchical nature when choosing the number of clusters. We utilized this characteristic to address the issue of aquifer heterogeneity.

The algorithm is embedded within an overarching optimization framework enabling systematic tuning of parameters for optimal performance. This allowed further flexibility in tuning the preprocessing aspect of the data pipeline in addition to manipulating the clustering algorithm parameters. Creating the method in this way allowed us to test numerus scenarios, different methods, and use different metrics to assess the model performance. Not to mention that this approach also made the model future proof, as introducing any new methods within the framework would be done with minimal effort and without any major change to the main codebase. The output of the clustering algorithm would be general clusters containing the most similar wells. We developed GeoZ to map these clusters into geographic maps and used these maps to delineate the aquifer boundaries based on the available data.

The last step of the project was to enclose the developed framework within an objective function and run it in an optimization algorithm to find the best parameters to achieve the highest accuracy in addition to find the limits of the requirement to operate the model on any area of interest. The optimization algorithm achieved 90% accuracy in aquifer delineation using a monthly average of synthetic observation data that spanned a minimum of 400 months (33 years and 4 months). Using the same observation period limit on real groundwater observation data obtained from Texas state aquifers resulted in 73% accuracy. Longer hydrograph records improve accuracy but reduce the number of usable wells. Striking an appropriate balance is key to maximizing delineation while utilizing the most data.

The method can be optimized in many ways, including new imputation methods, outlier detection, similarity calculations among others, and the framework approach would make implementing them much easier. Also, the method was tested on monthly average regional scale datasets. With the advancement of groundwater observations methods and the new continuous telemetric observation equipment introduced in the Gulf Cooperation Council (GCC) Countries, this approach might provide new insights with more granular data with local and regional scale aquifers in the middle east. The efficiency of the method has not yet been tested on local aquifers with more granular data such as local dataset with daily or hourly readings, so it could be a very good research opportunity to explore the feasibility of the method in this aspect.

Overall, the methodology provides an inexpensive and efficient means of extracting value from existing hydrograph data to map aquifer boundaries. Precisely delineated aquifers empower communities and governments to enact informed, sustainable groundwater management practices. The work highlights the power of machine learning to advance large-scale hydrogeological characterization from imperfect data sources.

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- Ministry of Environment & Water, 2014. HYDROATLAS UNITED ARAB EMIRATE.

Keynote Speaker

2) Mainstreaming the Outcome of the UN Summit on Groundwater in the Arab Strategy for Water Security

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Abstract:

The United Nations Summit on Groundwater was held at UNESCO headquarters in Paris, France, from 6 to 8 December 2022. This summit was the conclusion of a year in which the focus was on groundwater (the hidden resource). In parallel, with the summit, the United Nations Commission on Water also held an expanded meeting that resulted in the issuance of a joint letter and call to action from the United Nations Commission on Water Resources - Groundwater: The Hidden Resource for Sustainable Development. The message called on the countries of the world to enhance financing, data collection and exchange, human and institutional capacities, deployment of innovative technologies, and groundwater governance.

Following the summit, and at the request of the Arab Ministerial Water Council, UNESCO Cairo Office, jointly with other regional agencies and academics, organized a series of regional consultations on groundwater management in the Arab Region with the objective of mainstreaming the Summit's outcome in the implementation plan of the updated Arab Strategy for Water Security.

This presentation will provide and discuss the outcome of the UN Summit on Groundwater, as well as the outcome and recommendation of the Cairo Regional Ground Water Experts Meeting (October, 2023) on the mainstreaming of the summit's outcome in the Arab Strategy for Water Security along the following key priorities:

- Data and information
- Capacity development
- Innovation
- Finance
- Governance
- Groundwater in Africa; and
- Strengthening the science-policy Interface.

3) Feasibility of Aquifer Storage and Recovery for Management of Groundwater Supply in Arid Areas: Case Study from Oman

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Abstract:

Aquifer Storage and Recovery (ASR) using injection wells is considered one of the important measures to augment water resources in arid areas. It is viewed by NAMA Water Services (NWS), Oman, as a strategic option to augment aquifer storage using excess desalinated water during low-demand times. This paper presents a feasibility study for ASR at Alkhoud site in Oman. The study includes hydrogeological and geophysical field surveys, exploration drilling and pumping test, analysis of the water chemistry, evaluation of ASR operation modes using numerical modelling, etc. ASR capacity was found to be site-specific and its feasibility is governed by the groundwater developments in the vicinity of the ASR site. This paper presents the main findings for Al-Khoud site. Considering the AlKhoud site, the associated risks of ASR operation and hence feasibility were identified as follows: (1) Uncontrolled bubble drift due to changing groundwater gradients and directions, (2) High hydraulic gradient towards the sea when the recharge dam just upstream the ASR site is full after rain and flashfloods events, (3) Abstraction of stored water by private wells in the vicinity of the ASR site (loss of stored water), and (4) Upconing of saline groundwater from deeper groundwater layers in case of increased abstraction due to high ASR well density and highly permeable aquifer until a depth where brackish and saline water occur (Salinisation of wellfield). The study revealed that the feasibility of the ASR for sites does not only rely on the hydrological and technical features of the site but also on the scheme and extent to which the recharged aquifer is managed. This is crucial for managing the recovery of the stored water which requires rigorous groundwater governance to conserve both quality and quantity of groundwater systems under ASR practice.

Keywords: Aquifer Storage and Recovery, Aquifer, Arid region, Desalinated Seawater, Numerical Simulation.

4) Civil Society Participation in Constructing Small Storage Dams, the Experience of the Sultanate of Oman

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الملخص:

أوضحت وزارة الثروة الزراعية والسمكية وموارد المياه بالسلطنة في تصريح لها لوكالة الانباء العمانية في مارس 2022 " أن حجم الموارد المائية المتجددة السنوية بالسلطنة يقدر بحوالي 1318 مليون متر مكعب. ويستهلك ما يقارب 83 بالمائة منها للزراعة. ويبلغ العجز المائي في سلطنة عُمان بحوالي 316 مليون متر مكعب كل عام". "وتمثل المياه الجوفية ما نسبته 83 بالمائة من مصادر المياه في السلطنة، تليها مياه التحلية بنسبة 10 بالمائة في حين لا تشكل المياه السطحية إلا 5 بالمائة، أما مياه الصرف المعالجة فلا تمثل إلا ما نسبته 2 بالمائة". وتعد الأمطار المصدر الرئيسي لتغذية الموارد المتجددة. ولذلك شرعت الحكومة العمانية في انشاء 12 محطة للاستمطار الصناعي باستخدام تقنية الايونات والتي عززت من نسبة الهطول المطري بزيادة تتراوح ما بين 15 الى 18 ملم. كما أولت الحكومة العمانية اهتماما كبيرا بمشروعات السدود المختلفة: التخزينية بعدد 115 سد والحماية من الفيضانات بعدد خمسة سدود والتغذية الجوفية بعدد 67 سدا. وبمجموع سعات تخزينية لهذه السدود تقدر بـ 357949 متر مكعب سنويا. وتأتي مبادرة الشراكة المجتمعية في مشاريع السدود التخزينية في منظومة إنشاء السدود التخزينية، حيث حرصت الحكومة العمانية على إشراك المجتمع المدني أفرادا ومؤسسات في تجربة هي الأولى من نوعها على المستوى الإقليمي. وذلك من خلال تنفيذ السدود التخزينية الصغيرة بالشراكة ما بين الحكومة بنسبة 20% من تكلفة مشروع السد و80% من المجتمع المدني. وقد ساهمت هذه التجربة الفريدة من نوعها منذ انطلاقتها في 2017 الى زيادة تنفيذ هذه المشروعات لتصل الى 38 سدا متوزعة في ثلاث محافظات بالسلطنة. وبتكلفة تقدر بـ 2,559,183 ريال عماني أي ما يعادل 6,734,692 دولار امريكي، وبسعات تخزينية تقدر بـ 4,294,000 متر مكعب سنويا من مياه الامطار. وهذه التجربة الفريدة تتطلب مزيدا من الاهتمام والعناية على المستوى المحلي والإقليمي نظرا لأهميتها على الصعيدين الاقتصادي والاجتماعي. ومن أجل تفعيل هذا الاهتمام نوصي بالآتي: **1.** ضرورة إسهام المؤسسات الاكاديمية المتخصصة في قضايا المياه المختلفة في دراسة التأثيرات الإيجابية لهذه السدود في تعزيز المخزون الجوفي وتعزيز مصادر المياه السطحية في المواقع التي يتم انشاء هذه السدود فيها. وتأثيرها كذلك على الإنتاج الزراعي وتفعيل الدور السياحي لها حيث غدا بعضها مزارا سياحيا حيويا في مواسم هطول الامطار. **2.** زيادة نسبة المساهمة المجتمعية في توفير الأموال اللازمة لإنشاء هذه السدود من خلال اعتبارها رسميا من جنس العمل الخيري المستدام وتشجيع الافراد المؤسسات الربحية على دعمها ماليا. **3.** قيام الجمعيات المهنية كجمعية علوم وتنقية المياه الخليجية والجمعية العمانية للمياه بتبني هذه المشروعات والاعداد لصندوق تمويلي خاص بها محليا وخليجيا. **4.** تسهيل الإجراءات الكفيلة باعتبار بعض هذه السدود مزارا سياحيا وتشجيع الاستثمار فيها. **5.** الاهتمام بالإنتاج الزراعي في القرى التي تغذيها هذه السدود انتاجا وحصادا وتسويقا وتصنيعا ان أمكن. **6.** إيجاد بدائل أخرى في عمليات انشاء هذا النوع من السدود بما يسرع من عملية الانشاء ويمكن من القيام بعمليات التنظيف الدوري لتلك السدود والاستفادة من الطمي المتراكم فيها في تخصيب تربة القرى المحيطة. **7.** ربط مواقع إنشاء تلك السدود جغرافيا بالمستجمعات المائية التي تنتمي اليها حتى يسهل دراسة تأثيراتها الإيجابية على تدفق المياه السطحية المستدامة وعلى تعزيز المخزون الجوفي. **8.** استبدال طلبات انشاء آبار مساعدة للأفلاج التي تتعرض للجفاف بإنشاء سدود تخزين سطحي لها.

3) Groundwater aquifers susceptibility index of Waterborne Diseases Outbreaks (ASIWD) in Nile Delta, Egypt

Osama Sallam[1], Karim Soliman[2]

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Abstract:

The Corona pandemic and its significant economic and social effects, as well as the large spread of parasites, motivated us to conduct this research to develop a map of the sensitivity of groundwater pollution to waterborne pathogens. This study aims to create an index for evaluating groundwater aquifers' susceptibility to waterborne diseases outbreaks risks. During this study, groundwater Aquifer Susceptibility Index to Waterborne Disease outbreaks (ASIWD) was developed by appending a new attribute designated as waterborne diseases parameters such as urbanization, population density, water drains density, and existing sewage treatment systems. The study area covers eight governorates in Egypt, Menoufia, Beheira, Kafr El-Sheikh, Sharqia, Daqahlia, Qalyubia, Gharbia, and Damietta. By analyzing the ability of the aquifer to transmit infection for waterborne diseases, the main conclusions are: (i) In Qalyubia governorate, the percentage of the area is exposed to very high risks reaches more than 90% of the total area, while in Menoufia, Gharbia, Dakahlia, and Sharqia, it reaches 51%, 48%, 18%, and 17% respectively. (ii) the area is exposed to very high risks reaching 32%, 24%, 32%, and 32% of the total area in the governorates of Menoufia, Beheira, Gharbia, and Dakahlia, respectively. (iii) the area is exposed to medium risks representing 32%, 24%, 32%, and 32% of the area of Damietta, Sharkia, and Beheira governorates, respectively, and (iv) the area is exposed to Low to very low risks, reaches 98%, 55%, and 44% of the total area of Kafr El-Sheikh, Dakahlia and Beheira governorates respectively. ASIWD approved the importance of including anthropogenic parameters in susceptibility computations and its reliability as an effective tool for investigating groundwater aquifer susceptibility to waterborne disease outbreaks in Egypt's Nile Delta study area. Groundwater in the study is in hydraulic connection with surface water from Nile River branches, irrigation canals, and drainage networks; therefore, maintaining groundwater quality requires an integrated approach for both ground and surface water.so, it is recommended to improve the irrigation system and prevent the continuous drainage of sewage and wastewater to the canals and the drainage system. Sewage treatment services must be developed and concentrated in very high-risk governorates such as Qalyubia, Menoufia, and Gharbia. Also, it is highly recommended to make public awareness about the threats of pollution on groundwater resources, especially in susceptible areas.

Keywords: Nile Delta, Groundwater, Aquifers, Susceptibility Index, Waterborne Diseases.

TRAINING WORKSHOP 2: (Attendance by registration)

WHO's Sanitation Safety Plan (SSP) Tool: Step-By-Step Risk Management for Safely Managed Sanitation Systems

Organizer: WHO
Dr. Rola Al-Emam

Duration: 3 hours

Description:

In 2018, the World Health Organization (WHO) launched its first comprehensive guidelines on sanitation and health to promote safe sanitation systems and practices. The guidelines aim to provide evidence-informed recommendations and offer guidance to ensure international, national and local sanitation policies and programs effectively protect public health. One of its key recommendations is to ensure systems and services are selected to respond to the local context and that investment and system management are based on local risk assessments along the entire sanitation chain. Sanitation Safety Planning (SSP) is the WHO-recommended approach for local health risk assessment and management for sanitation systems. SSP identifies incremental improvements at each step of the sanitation service chain to allow progressive implementation towards sanitation targets and allows investments to be prioritized according to the highest health risks and thereby maximize gain. Furthermore, SSP can and should take into consideration current and future risks, including those posed by climate variability and climate change.

Session Speakers:

- Rola Al-Emam, WHO
- Sohaib Ammour, WHO
- Khalid Al-Lawzi, WHO

Case studies:

- Ghada Kassab (Jordan),
- Raya (Nama-Oman),
- Dana (Ashghal-Qatar),
- Dan (Australia)

Trainer: Dr. Rola Al-Emam is currently working as the WASH technical officer at the WHO Eastern Mediterranean Regional Office supporting 22 countries in the region. Rola has been working for more than 14 years on WASH, climate change, occupational health, and healthcare waste management. She holds an MPH from the Johns Hopkins Bloomberg School of Public Health (USA), an M.S. in Pharmaceutical Healthcare from Long Island University (USA), and a B.S. in Pharmacy from the University of Jordan (Jordan).

SPECIAL SESSION 6:

SS6): Privatization and Regulatory aspects of water utilities

Organized by ACWUA and WSTA

Khaldon Khashman, Ahmad Azzam, Issa Al-wer, Saud Al-Shidhani

Overview:

In this session the speakers will address the Private Sector Participation PPP and the regulatory experience for monitoring the performance of utilities as well as the private sector. **Eng. Khaldon Khashman** will be addressing ACWUA experience about Performance based contract project implemented by ACWUA and financed by GIZ in Yarmouk Water Company (YWC) by increasing the revenue from the wastewater running charges (wastewater treatment tariff). **Dr. Ahmad Azzam** will discuss the role UPMU in monitoring the performance of utilities, and **Eng. Issa Al-wer** represents the national carrier project (BOT Project) in Jordan. Eng. Issa will clarify to the audience the aim and the progress of the BOT project. **Eng. Saud Al-Shidhani** –will talk about the Regulation of the Water Sector in Oman.

Session Speakers:

- **Eng. Khaldon Khashman** - PPP, Performance based contract in improving the financial sustainability in utility.
- **Dr. Ahmad Azzam** - The role of UPMU in monitoring the performance of utilities.
- **Eng. Saud Al-Shidhani** - Regulation of the Water Sector in Oman.

Keynote Speaker

1) Climate Change and Water Scarcity: Strategies for Sustainable Agricultural Water Use in the Arab Region

Kamel Mustafa Amer

Water Resources Advisor, Arab Organization for Agricultural Development (AOAD)

Background:

Climate change represents a profound and ubiquitous challenge with particularly acute consequences in the Arab region. In this area, inhabitants confront escalating temperatures, shifting rainfall patterns, and increasingly frequent and intense meteorological phenomena. These alterations exacerbate the pre-existing critical issue of water scarcity. The arid climate, burgeoning populations, and brisk economic development intensify the pressure on water resources. The region's susceptibility to climatic shifts presents substantial hazards to the vital water supplies necessary for agriculture, potable use, and hygiene purposes. Studies indicate that the Arab region is warming at a rate surpassing the global average, jeopardizing the water security of over 360 million individuals. This predicament necessitates prompt action to alleviate the impacts and preserve water resources for future generations.

1. Current State of Water Resources

In the Arab region, the allocation and accessibility of water resources are markedly inconsistent and frequently subjected to intense pressure. Central challenges encompass significant groundwater depletion, pervasive contamination, and escalating salinization, all of which contribute to a fragile state of water security. Groundwater serves as a vital water source in over 11 Arab nations, yet it is being exhausted at rates significantly surpassing natural replenishment rates, with certain regions experiencing annual declines in groundwater levels exceeding two meters. Moreover, agricultural endeavors, which account for the highest water usage—often surpassing 85% in several countries—are hindered by inefficiencies that are compounded by antiquated irrigation techniques and suboptimal water management strategies, all further aggravated by the effects of climate change.

2. Agricultural Water Use

In the scope of agriculture, a pronounced divergence exists between the water requirements of crops and the water supplies available, fostering pervasive inefficiencies and unsustainable farming techniques. This discrepancy often arises from deficient water management strategies and reliance on outdated irrigation methods that fail to integrate contemporary water-conservation technologies. To mitigate these issues, it is crucial to implement a combination of more effective irrigation technologies, select crop varieties that demand less water, and embrace advanced water management approaches. These enhancements have the potential to boost water use efficiency by as much as 40% in certain regions, thus narrowing the existing chasm between water demand and availability. Furthermore, the selection of crop varieties that can withstand dry conditions and the adaptation of irrigation schedules to leverage real-time data can significantly advance the alignment of agricultural operations with the objectives of sustainable water management.

3. Challenges and Opportunities

The environmental predicaments facing the Arab region are intensifying, with escalating threats of drought, desertification, and the deterioration of soil quality. These complications are magnified by climatic shifts anticipated to heighten the frequency and severity of extreme weather conditions. The threat of desertification is notably severe, impacting specific zones with profound consequences for land utilization and agricultural productivity. Socioeconomic dynamics, including the swift population growth observed in numerous Arab nations and increasing urbanization, exacerbate the demand for water. In some areas of the Arab region, the pace of population expansion places immense pressure on existing water and agricultural infrastructures. Nonetheless, these difficulties also present significant prospects through the lens of technological progress. Cutting-edge developments in water management and agricultural methodologies provide viable strategies to boost water efficiency and promote environmental sustainability.

4. Innovative Water Management Strategies

Using innovative water management strategies is essential to reducing the grave problem of water scarcity, particularly in the agricultural sector—which uses a lot of water. Innovative irrigation techniques, including drip and precision irrigation systems, have demonstrated a critical role in increasing water use efficiency. These methodologies can engender considerable conservation of water, with research suggesting that smart irrigation could curtail water consumption by a considerable percentage. This is achieved by channeling water directly to the plant's root zone, thereby curtailing evaporation and runoff. Such a pinpointed modus operandi not only preserves water but also fosters more robust crop development by ensuring plants receive the precise volume of water at the requisite junctures. Water reclamation, which entails the reconditioning of wastewater for its subsequent employment in agricultural irrigation, represents another tactic that has demonstrated the potential to diminish dependence on unadulterated freshwater sources. Through the reuse of water, the agricultural domain can access a steady supply, a boon for regions where water scarcity is intensified by seasonal fluctuations. In certain scenarios, the implementation of water recycling has been capable of slashing the demand for freshwater by as much as 50%, contingent upon the sophistication of the treatment process and the variety of crops irrigated.

An auxiliary strategy, rainwater harvesting, involves the accumulation and storage of rainwater for future application. This technique can significantly bolster water conservation efforts, particularly in arid and semi-arid locales where precipitation is sporadic yet can be torrential when it does transpire. Rainwater harvesting apparatuses can range from diminutive rooftop contrivances to expansive infrastructural undertakings. In some cases, rainwater harvesting has been able to furnish up to 70% of the water requisites for crop irrigation throughout the parched season, thus markedly alleviating the burden on traditional water sources.

The amalgamation of these pioneering water management strategies can usher in a more sustainable and robust agricultural sector. By amalgamating smart irrigation with the strategic repurposing of water and the systematic collection of rainwater, it is feasible to engender a cumulative effect that amplifies water conservation and guarantees a more steadfast supply of water for agricultural purposes. For example, the integration of sophisticated sensors and meteorological prognostication in intelligent irrigation systems can be synchronized with the strategic reserve of recycled and harvested rainwater to fine-tune water usage across the calendar year.

5. Role of Technology and Research

The significance of technology and research in enhancing water management tactics cannot be overstated. Sophisticated monitoring frameworks and analytics-based decision-making processes enable more accurate allocation of water resources, optimizing utilization while reducing excess. Investigative pursuits into cutting-edge technologies, including the refinement of desalination methodologies or the integration of renewable energy for irrigation purposes, are pivotal in the progressive evolution of water management techniques. Moreover, cooperative initiatives, especially in the dominion of research and development, are vital for catalyzing innovation and deploying technological solutions tailored to the unique challenges of the Arab region.

6. Policy and Regulatory Framework

In the quest to address the dual challenges of water scarcity and climate change, the establishment of a comprehensive policy and regulatory framework is paramount. This framework must be conducive to the sustainable utilization of water resources. The enactment of well-conceived policy initiatives is indispensable for steering the integration and adoption of water-saving practices and technologies, thereby ensuring the prudent stewardship of water resources. The escalating pressures of burgeoning demand in the face of dwindling supplies underscore the imperative for pioneering policy interventions or substantial revisions to extant regulations. Such policies ought to extend beyond mere water conservation; they must weave climate change mitigation strategies into the fabric of water resource management planning to secure enduring resilience and sustainability.

To surmount the obstacles of water scarcity in the Arab region, a concerted approach is necessary—one that encompasses the augmentation of technological prowess, the introduction of progressive water governance frameworks, and the fortification of robust policy structures. These endeavors should be buttressed by persistent research and cooperative ventures, tailored to the dynamic environmental and socio-economic terrains.

7. Future Directions and Recommendations

In the Arab region, the formulation of strategic frameworks for water management is imperative, requiring the creation of comprehensive, long-term objectives and the integration of these plans with broad-based climate mitigation tactics. This strategic methodology should encompass measurable targets, such as reducing water usage by predetermined percentages or boosting the employment of recycled water in agricultural activities by a designated year. The critical importance of stakeholder involvement in this endeavor is paramount—it is essential for the effective execution of sustainable practices. Involving a varied array of stakeholders, including community groups, governmental bodies, and private sector actors, guarantees the incorporation of diverse insights and expertise into water management strategies. Furthermore, international collaboration is vital in this domain, offering a venue for the exchange of knowledge, resources, and exemplary practices across national boundaries. Such international engagement is essential for tackling the transboundary nature of water resources and the effects of climate change. Collaborative initiatives should strive to cultivate a sense of ownership and accountability among all parties involved, ensuring that water management efforts are comprehensive and successful. For example, international alliances could concentrate on advancing technology sharing and expertise, as well as procuring financial backing for water management endeavors, with the objective of enhancing water efficiency in the region by 30% by 2030.This strategy underscores the need for collective decision-making and the synchronization of governance norms across various societal and institutional strata. Employing participatory methods can fortify more robust and flexible water management systems, as they integrate local insights and preferences at the onset of the planning stage, thus potentially elevating the success rates of the policies and projects implemented.

8. Conclusion

A comprehensive strategy is necessary to effectively address the intertwined challenges of water scarcity and climate change in the Arab world. This plan should incorporate cutting-edge technology applications, sound policy frameworks, and global cooperation. Water sustainability will be advanced throughout the region and agricultural productivity will rise by giving priority to cutting-edge water management strategies and research-based solutions. It is imperative that an all-encompassing policy environment that promotes the adoption of sustainable practices and technologies underpins these strategies. Furthermore, accomplishing the primary objectives of increased water efficiency and climate resilience requires developing international partnerships and encouraging the sharing of expertise. By putting these measures into place, the area will ensure a prosperous and sustainable future by meeting present demands while also protecting water resources for future generations.

Keynote Speaker

2) Economics of Water Under Climate Change in Arab Countries: A Policy Perspective

Mohamed A. Abdrabo
Alexandria Research Center for Adaptation to Climate Change (ARCA), Alexandria University

Abstract:
The Arab region is one of the driest regions in terms of water availability, as the region is located in arid and sub-arid regions with low rainfall and high temperatures in summer, they are vulnerable to drought. and climate change is expected to heighten water stress in the region, with a reduction in precipitation and increased demand from competition users, particularly with rapid population growth and improving living standards. Water scarcity, particularly from an economic perspective, a very complex multidimensional issue due to the same resource may have different targets to attain including being a human right, socio-cultural, supporting ecosystems functioning, and being input to most economic activities. The diversity of uses as well as sources of water creates complex interlinked issues, especially when considering the energy, food, and environment, that need to be addressed simultaneously.

From a policy perspective, water scarcity is typically dealt with in Arab countries by attempts to augment water resources using traditional and non-traditional sources. Water demand management still lags with limited efforts, with the classical focus of potable water pricing, for instance, is cost recovery, meaning trying to cover the cost of the process of water treatment and pumping, which implicitly assumes that the economic value of water as a natural resource is zero.

The paper in hand intends to examine the implications of climate change on the economics of water security in Arab countries, attempting to identify potential management actions. It was found that there is a need to have a significant shift in policymaking concerning water management. Such a shift would require:

- Adopting a holistic integrative framework for sustainable development and water management.
- Incorporating economic valuation into water-related decision-making to resolve some of the resourcing and capacity issues challenges.
- Integrating various economic instruments, e.g., abstraction charges, water markets, tradable pollution permits, subsidies, and payments for environmental services, into water policies.

Such actions should be utilized to attain efficiency and equity among different water users including socio-cultural, economic, and environmental purposes.

Keynote Speaker

3) Biosaline Agriculture for Food Security in the Arid GCC

Rachyd Zaabol

International Center for Biosaline Agriculture, UAE

Extended Abstract:

Water scarcity is a prominent challenge threatening efforts to achieve food security in the GCC. A predominantly arid region characterized by scant and erratic rainfall combined with high potential evaporation rates exacerbates the profound and widespread impacts of accelerating water scarcity on local agricultural sustainability. The increasing demand for freshwater to meet the growing need for food to sustain the growing population remains a pressing concern amidst the constrained freshwater supply. Agriculture, consuming over 70 percent of the available water resources in the GCC, faces a forecasted 50 percent increase in water demand by 2050, intensifying competition with other essential water sectors.

Climate change's present and anticipated impacts on agriculture and water resources suggest a worsening situation for arid regions such as the GCC. Rising temperatures, variable rainfall, and increased occurrences of extreme droughts and floods are set to exacerbate water scarcity, jeopardizing vulnerable farming communities and food security. Global warming is expected to lead to higher temperatures across many regions, including the Middle East. Higher temperatures can intensify evaporation rates, potentially leading to increased water loss from soils, wadis, oasis, and reservoirs. North Africa is predicted to get drier, with an annual rainfall deficit reaching more than 50% by the end of this century under a high-emission scenario. The annual rainfall predictions for the GCC are more optimistic, with a potential increase in the annual rainfall reaching more than 50% by the end of this century under a high-emission scenario. However, this rainfall increase is insufficient to meet the growing demand for freshwater.

Soil and water salinization also present a growing concern in the MENA, the GCC region, and globally, posing a threat to some of the most productive lands currently utilized for irrigated agriculture. Rapid soil degradation due to salinization and soil sodicity has emerged as a significant challenge in recent decades, leading to substantial risks to global food security and environmental sustainability.

These mounting pressures severely undermine the region's capacity to ensure equitable access to water and food for all. The agr-innovative programs the International Center for Biosaline Agriculture implemented provided locally suited solutions for increasing food production in arid conditions with limited freshwater availability. This research for development programs focused on four main thematic areas of research. The first program is climate-smart crops that are heat, drought, and salt tolerant. These crops can grow under harsh, arid environments, where a range of crops that can tolerate different levels of salinity were provided to many farmers in these arid regions. For example, for low soil and water salinity levels ranging from 5 to 8 ds/m, Amaranth, Sorghum, Pearl millet, Mustard, and Sunflower produced a significant yield increase of 30% compared to conventional varieties or crops. Similarly, for higher salinity levels up to 30 ds/m, important forages, fruits, and crops such as Salicornia, Sporobolus virginicus, distichlis Spicata, date palm trees, and quinoa were grown. In addition to selecting and introducing these crops, ICBA provided a holistic solution through farms' best practices of inputs and fertigation, irrigation, and enhancing the value chain from the farm to the fork.

The second program is land and water, providing smart solutions for improving water use efficiency and agricultural water productivity. On-farm management practices utilizing water-saving and fertigation technologies have proven effective in conserving water and maximizing farmers' benefits per unit of water used. Scaling up these best practices through field extension projects and training initiatives can enhance the quantity and quality of food production, meeting market demands while minimizing environmental impact.

Watershed management using GIS and remote sensing techniques helped to manage the available water resources at the basin and sub-basin levels. Land use and land cover mapping were used to delineate the change in the agricultural areas needed to track and monitor agricultural production and productivity, and it also allowed the calculation of the actual water use of selected crops. In addition to brackish water, other non-conventional water resources such as treated wastewater, desalinated water, and its valuable by-product, the brine, were used in ICBA's research and development projects. These water resources are crucial in averting food crises and sustaining food production. ICBA promoted using non-conventional water resources in agricultural production because they are crucial for addressing water scarcity. Fortunately, many countries in the GCC region have incorporated non-conventional water resources into their national water balance and strategies, encompassing policies, institutional frameworks, regulations, and more.

Improving soil health through mixing with suitable soil amendments such as biochar helped to achieve a better crop yield, saved water up to 30%, and allowed for carbon sequestration. Adding the soil amendment improved the soil water retention near the crop roots. The rehabilitation of degraded soil due to salinity and sodicity showed significant improvement in agricultural production, bringing degraded lands to be productive again. Many farms are abandoned due to increasing soil salinity or degrading the water quality. Best practices to improve the soil health provided to the farmers through demonstration farms, farmers' field schools, and extension works improved the farms' yield and protected the environment from further degradation.

With the emergence of big data, the data-driven program succeeded in modeling the effect of climate change on agricultural production using several global and regional climate and emission scenarios, which helped the countries monitor and plan their water resources to adapt to or mitigate its effect. The Center built the staff capacity in four countries in the MENA region, Morocco, Tunisia, Jordan, and Lebanon, by developing decision support tools to allow them to monitor the drought events and make the right decision at the right time.

Remote sensing and satellite images integrated with in situ field sensors controlled by the Internet of Things (IoT) provided more precise estimates of crop water requirements and appropriate irrigation scheduling by irrigating the right volume of water at the right time. High-resolution satellite images were downscaled from global databases and used with less than 30 meters resolution. Several applications and tools were developed using machine learning and AI, and they benefited from these open-source images.

Significant innovative solutions were provided under the novel production program, which focused on improving Controlled Environment Agriculture (CEA) by developing desert-type CEA in collaboration with a Korean program. The research addressed significant issues of greenhouse cooling, new structural designs, growing media, and relevant materials. The water saved from irrigation and cooling was about 30% compared to the conventional CEA. Alternative water sources for cooling were tested at ICBA's farm, such as brackish water and treated wastewater. The results showed the potential to use these alternative water resources in cooling, but further research is still needed on their technical and financial feasibility.

The Integrated Agri-Aquaculture Approach showed realistic results and was considered a relevant agricultural solution for the arid environment. The approach incorporated circular economy concepts by using brine as a water source instead of considering it a waste. This provided additional benefits to the farmers by growing fish in the fish tanks using brine water, and sequentially, the aquawater is used to irrigate halophytic crops. The experiment's results showed a potential to scale out this approach for many farmers using small-scale RO units on their farms.

In conclusion, in the face of increasing water scarcity and the challenges posed by aridity, harnessing biosaline agriculture emerges as a promising strategy for securing food production in the arid GCC region. The extensive efforts of the International Center for Biosaline Agriculture underscore the potential of innovative agricultural practices tailored to thrive in harsh environments characterized by limited freshwater availability and high salinity levels.

ICBA's multifaceted approach, spanning climate-smart crops, efficient land and water management, and integrating non-conventional water resources, exemplifies a holistic strategy toward sustainable food production. Significant yield increases have been achieved by introducing heat, drought, and salt-tolerant crops suited to the region's conditions, offering a viable alternative to conventional varieties. Moreover, optimizing water use efficiency through on-farm management practices and adopting water-saving technologies contributes to conserving precious freshwater resources while maximizing agricultural productivity.

The utilization of non-conventional water sources such as treated wastewater and desalinated water, coupled with innovative irrigation techniques, not only mitigates water scarcity but also enhances the resilience of agricultural systems against climate variability. ICBA's emphasis on improving soil health through soil amendments and rehabilitation techniques boosts crop yields and rejuvenates degraded lands.

Moreover, ICBA's pioneering initiatives in harnessing big data, remote sensing, and IoT technologies enable precise monitoring of agricultural systems, facilitating informed decision-making amidst changing climatic conditions. By leveraging cutting-edge advancements in Controlled Environment Agriculture (CEA) and integrated agri-aquaculture approaches, ICBA pioneers sustainable farming practices that promote resource efficiency and circular economy principles.

As the GCC region navigates the complex interplay of climate change, water scarcity, and food security, the transformative potential of biosaline agriculture becomes increasingly evident. The GCC can unlock new pathways towards resilient, sustainable, and food-secure futures in the arid landscape by scaling up these innovative solutions and fostering collaboration between research institutions, governments, and farmers. Through concerted efforts and strategic investments in biosaline agriculture, the GCC can transcend the challenges of aridity, ensuring food security for generations to come.

Keynote Speaker

1) Electricity Generation and Industrial Wastewater Treatment Using Microbial Fuel Cell

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Abstract:
Due to the rapid increase in population and industry sectors, the consumption of energy from fossil fuels is increasing rapidly, as a result, carbon emissions have increased, which negatively affects the environment. Currently, the electrical energy plants in Kuwait serve around 70,085 million Kilowatts per hour (M. kWh) and this is expected to increase in the future, which will increase the strain on the budget of the Kuwaiti government [1]. Most of the energy consumption was concentrated in the water and electricity sector, oil sector, transportation sector, and household sector. Furthermore, the industrial sector is another important sector that consumes a significant amount of energy on a daily basis [2]. In Kuwait, there are now more than 18 industrial areas and most of these industries are located mainly in Shuaiba, Mina Abdullah and Mina Al-Ahmadi. Those areas mainly contain the following industries: refineries, dairy factories, detergents factories, and soft drinks factories.

Kuwait Environmental Protection Authority (KEPA) has divided industrial wastewater into two main categories: industrial wastewaters that meet KEPA's standards and can be treated off-site at municipal wastewater treatment plants, and industrial wastewaters that do not meet KEPA's standards and can be treated on-site or at special treatment plants. Thus, it is important to find an effective and sustainable way to treat industrial wastewater on-site and then transfer it to the treatment plant.

Generally, wastewater contains a huge amount of energy, approximately 3 to 10 times more energy than the energy required for treating wastewater [3]. Each gram (g) of chemical oxygen demand (COD) contains 14.7 kJ, which means that there is a massive amount of energy in wastewater [3]. Using conventional wastewater treatment processes are expensive and consume huge amounts of energy, especially with the restrictive regulations prior to discharge where most of the energy is used for aeration and recirculation. Microbial fuel cells (MFCs) are bio-electrochemical devices that utilize electrochemically active bacteria (The microorganisms that are capable of exocellular electron transfer) as catalysts to convert the chemical energy of organic substrate into electricity [4]. MFCs are able to recover energy by degrading organic and inorganic matter in wastewater and produce less sludge. MFC offers a promising wastewater treatment technology with great environmental friendly benefits, such as a source of energy, wastewater treatment process, biosensor system, and low carbon emission process [4]. MFCs have many advantages, such as being easy to handle, not being toxic, the ability to extract 90% of electrons from organic compounds, and self-sustaining systems. MFC produces around 0.5 to 0.8 V working voltage (0.02 – 0.07 kWh/kg-COD), which considers low for real applications but very efficient in wastewater treatment. The generated energy is a function of wastewater type, COD concentration, MFC design, and the selected design materials. In addition, the generated electricity can be promoted by connecting many individual MFCs in parallel, series, or hybrid stacks.

Methodology

Eight tubular MFCs (approximately 5 L each- dimensions: length 50 cm and diameter 12 cm) will be designed, installed and operated at Sulaibiya Research Plant (SRP). The MFCs will be divided into 4 groups. Each group contains two MFCs and will be operated individually using industrial wastewater from one of the industries (dairy, refinery, detergents, and soft drinks). The MFCs will be operated to assess the efficiency of MFCs to treat industrial wastewater and to generate electricity. The MFC contains a carbon brush anode and a carbon cloth cathode contained a platinum catalyst. The anode and cathode will be connected by titanium wires with an external resistance. The cathode electrode will be exposed to air on its outer surface, as well as being in contact with the membrane. A cation exchange membrane (Nafion 117#) will be wrapped around the tubular anodic chamber to separate the anodic and cathodic chambers, and then a layer of carbon cloth will be wrapped around the CEM to function as the cathode. The generated voltage across the external resistance of 1000 Ω was recorded every 10 min using an ADC-24 data logger system. Real activated sludge from Kabd Wastewater Treatment plant will be used to inoculate the anode chamber. The anode chamber will be inoculated with a 1:1 mixture of activated sludge and anolyte medium (containing in (g/L): Sodium acetate 3.28 + ammonium chloride 0.31 + potassium chloride 0.13 + sodium phosphate anhydrous monobasic 2.69 + disodium hydrogen phosphate 4.33 + 10 mL of vitamins solution + 10 mL of a trace element solution).

The following parameters will be analyzed at the inlet and outlet of the MFCs; temperature, pH, conductivity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total solid (TS), total suspended solids (TSS), and heavy metals such as, (Hg, Zn, Cu, Fe, Ni, Cr, Ag, Cd, Pb, Cn, As, B).

Results

All the MFCs were continuously operated for more than 90 days, and the generated electricity varied depending on the industry. The MFCs that operated with dairy wastewater achieved the highest maximum open voltage of 0.625 V, followed by detergent wastewater at 0.495 V, soft drinks at 0.468 V, and finally petrochemical wastewater at 0.165 V, which achieved a low electrical energy output of 0.165 V (Fig. 1). In addition, an extra MFC (control MFC) was operated simultaneously with the eight MFCs using domestic wastewater collected from the inlet stage at Kabd WWTP. The control MFC achieved a maximum open voltage of 0.5 V. All types of industrial wastewater have generated electricity; however, the amount of energy varies depending on the wastewater type. Generally, the MFCs that operated with dairy wastewater generated the highest current density (73 mA/m^3) throughout the study. The second industry that generated high electrical energy is the detergent industry (69 mA/m^3), followed by domestic wastewater (64 mA/m^3) and then soft drinks (62 mA/m^3).

Furthermore, the MFCs achieved a maximum CE of 2.9% using soft drink wastewater. The second greatest CE was for domestic wastewater, followed by detergent wastewater and then dairy wastewater. Finally, the CE in petrochemical wastewater was the lowest of all MFCs. The CEs in all MFCs in this study were low and similar results were obtained in different studies. The low CE in his study indicates that most of the released electrons in the oxidation reactions are not used in electricity generation; however, it has been consumed in other electron acceptors such as NO_3 and sulfate. In addition, the MFC design including reactor volume and catalyst layer leads to high electron losses. Also, the complex characterization of the used industrial wastewater leads to deterioration in the oxidation reactions.

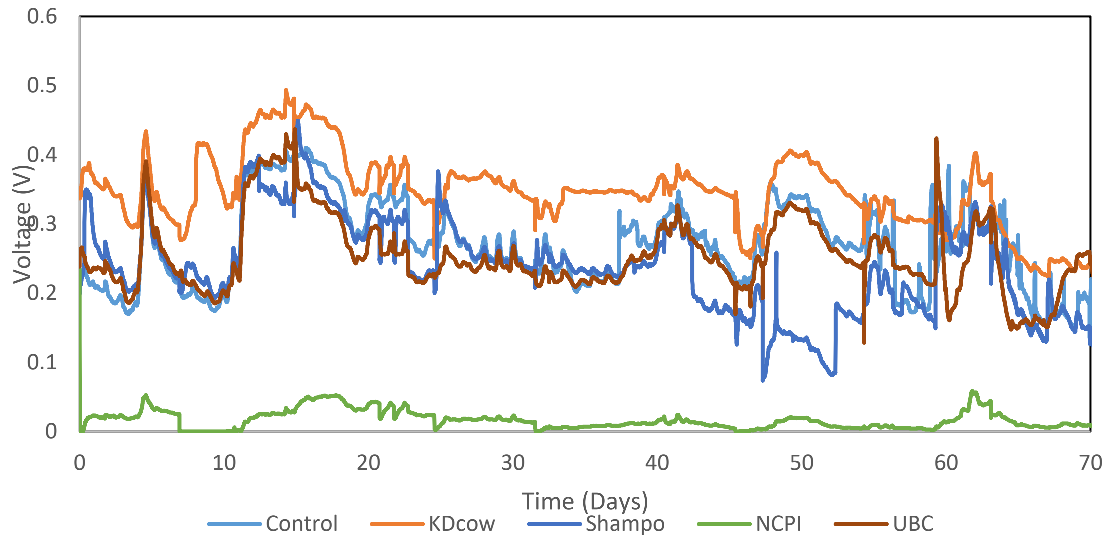

Figure 1. Change in output voltage over time in the MFCs units using wastewater from the selected factories.

In terms of treatment efficiency, all MFCs had COD removal efficiencies of >70% (Fig. 2), except detergents and petrochemical MFCs. Detergents and petrochemicals had the highest influent COD concentration, and it might require more HRT to improve the treatment efficiency. Therefore, the HRT dose has been increased to understand the effect of HRT on treatment efficiency. Increasing the HRT in detergents and petrochemical MFCs from 7 to 14 days increased the treatment efficiency from 44 to 62% and from 7 to 14%, respectively. Increasing the HRT led to an increase in the contact time between the substrate and the microbial community, which provides more time for the bacteria to degrade the organic matter. Generally, MFCs achieve high COD removal compared to many other treatment technologies, and the operational cost is low. MFCs can theoretically generate around 0.004 kWh/kg COD, which can be used to compensate for any energy consumed in the process. On the other hand, activated sludge, which is the main process in wastewater treatment, consumes around 0.6 kWh/kg COD, which is considered an expensive process. Besides the operational cost, MFCs can be used to recover multiple products, such as P, ammonia, and heavy metals, from wastewater. There was no significant correlation between the removed COD and the generated electricity (P>0.05), as low CE (<2%) was obtained in all MFCs. Most of the COD removed was not used in energy generation and was consumed by other microbial consortiums.

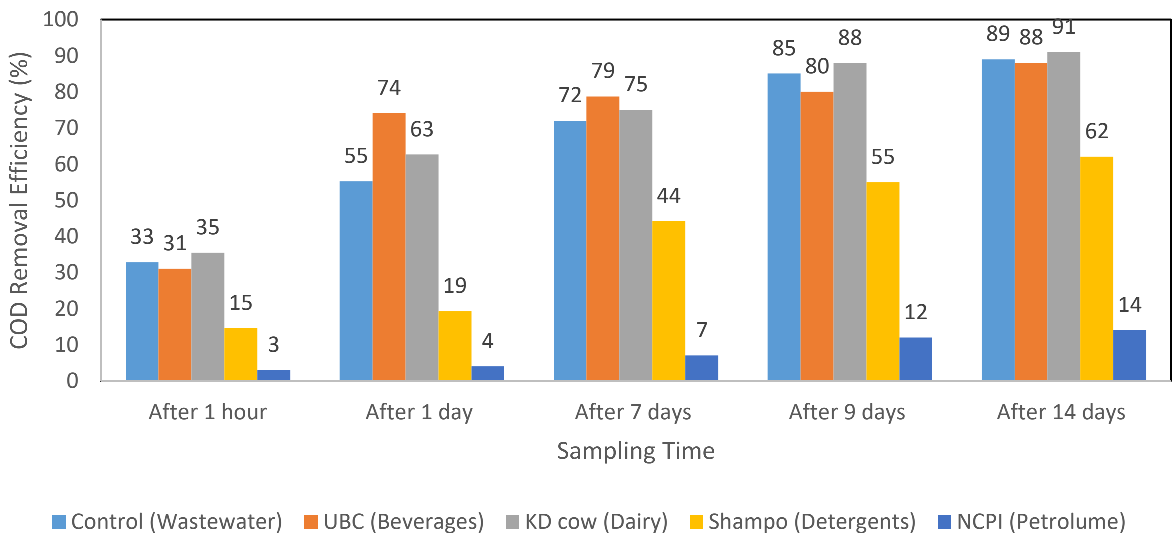

Figure 2. Comparison of COD removal efficiency over time using wastewater from all four selected factories.

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Keynote Speaker

2) Advanced Wastewater Treatment using Functionalized Membranes

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Abstract:

Membranes play a crucial role in water treatment and desalination, offering an essential solution to meet the increasing global demand for clean water. The versatility of polymeric membranes in terms of fabrication processes, membrane properties, and applications makes them incredibly well-suited for various wastewater treatment applications. Their adaptability allows for tailored designs and optimization to specific water treatment challenges. Moreover, the recent advancements in electrospun nanofiber polymeric membranes (ENMs) have revolutionized membrane technology, presenting exciting opportunities to enhance the performance of membranes in produced water treatment greatly. The development of ENMs has opened up new avenues for improved filtration efficiency, enhanced water permeability, and increased resistance to fouling, addressing the unique challenges posed by wastewater treatment. These innovative membranes hold significant promise in overcoming the limitations of conventional membrane technologies and advancing the field of water treatment.

Oil and gas-produced wastewater, or oilfield wastewater, is the wastewater generated during oil and natural gas extraction and production. It is a byproduct that emerges alongside the hydrocarbons during drilling, well stimulation, and production processes. Oil and gas-produced wastewater is a complex mixture that contains various contaminants, including hydrocarbons, heavy metals, salts, suspended solids, organic compounds, and naturally occurring radioactive materials (NORMs). The composition of produced water can vary depending on the characteristics of the oil or gas reservoir, the extraction methods used, and the geological formations in the area. Due to its composition and potential environmental impact, the treatment and disposal of oil and gas-produced wastewater present significant challenges for the oil and gas industry. Effective treatment methods must remove or reduce contaminants before safe disposal or potential water reuse.

Additionally, conventional water treatment infrastructure is confronted with a growing challenge stemming from higher living standards, an expanding pharmaceutical industry, and the proliferation of personal care products, micro and nano-plastics, and various human-made chemicals. These persistent contaminants pose a serious threat to water systems as they find their way into natural water bodies, necessitating advanced treatment strategies beyond the capabilities of conventional methods.

Nanotechnology, with its precision in manipulating matter at the atomic and molecular levels, emerges as a transformative force in overcoming these challenges. It offers modular and efficient solutions for general wastewater treatment. Nano-adsorption, photocatalysis, and functionalized membranes are key processes targeting diverse contaminants. This multifaceted approach ensures high wastewater treatment efficiency, modularity, and cost-effectiveness.

The utilization of nanofiber membranes incorporating nanomaterials for produced water treatment has gained considerable attention. Specific emphasis has been placed on nanofiber membranes with surface characteristics exhibiting superhydrophobic/superoleophilic or superhydrophilic/superoleophobic properties. Generally, nanoparticles such as iron oxide (Fe_3O_4), titanium dioxide (TiO_2), and silica (SiO_2) have been employed to improve the properties of ultrafiltration (UF) membranes. Incorporating nanoparticles can significantly enhance the hydrophilicity of the membrane surface, thereby improving water permeability and resistance against fouling when treating domestic or industrial wastewater. Nanomaterial-enhanced membranes possess not only superwetting properties but also exhibit photocatalytic capabilities. Commonly used metal oxide nanoparticles like TiO_2 and ZnO are photocatalysts for various water applications. Photocatalysis utilizes visible light or UV to degrade organic contaminants and disinfect bacteria through oxidation or reduction reactions.

Despite nanotechnology's promise, translating these advancements into large-scale industrial applications has encountered hurdles, primarily due to the complexity of system design. Bridging the gap between cutting-edge research and practical implementation is essential for the widespread adoption of nanotechnology in water treatment. This study provides valuable insights into the latest developments, challenges, and opportunities in nanotechnology-based approaches, paving the way for sustainable and responsible water management practices amid evolving environmental concerns.

Keywords: Membranes, Nanofibers, Functionalization, produced water, emerging contaminants, water treatment.

Keynote Speaker

3) Business Model for Small-Scale Decentralized Wastewater Treatment and Sludge Management in Jordan

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Abstract:

Wastewater treatment is often driven by government mandate. The dissemination of decentralized wastewater management as complementation to large-scale centralized wastewater treatment plants in areas that cannot be connected due technical engineering issues or cost-efficiently can play a decisive role to achieve the SDG6. This paper describes the necessary conditions for successful business model and identifies the most important barrier to implement decentralized wastewater and sludge management system in Jordan. The absence of sustainable business models for decentralized system represents probably the major institutional barrier to this improvement. Wastewater systems in small towns and villages are usually too small and fragmented to raise the revenues and gather the capacities needed to operate and maintain them. Decentralized management can be economically and technically efficient, and conductive to sustainable urban development in the application area according to site specifics. Private sector can be enhanced to create outsources to these services and to alleviate the pressure of the public budget. The market of decentralized system has to be regulated by public control to ensure that quality and due diligence are maintained. Effective and enforced legislation and standards for construction, operation, and reuse are required. Revising by-laws and regulations are needed to include private capital expenditures and O&M for services providers. Expanding the role of the private sector that involves the divestiture of assets from the public to the private sector (such as design-build-operate), and a variety of public-private partnerships such as service contracting. Privatization also cannot be implemented unless certain policy barriers are overcome. These include policies related to operation, revenue collection, grants, taxation, and procurement, as well as trading regulatory. The challenges and barrier to business in decentralized wastewater management are: uundefined institutional responsibility; unclear and fixed responsibility for O&M; lack of regulator and certification bodies, lack of education, training and capacity building of the administrative and operational staff; unclear tariff system, insufficient private sector involvement (design, construction, O&M); weak competitive market for O&M; lack of cost recovery mechanism and revenues collections, subsidy policy and low collection rate; and lack of implemented and innovative strategies. The decentralized model needs to be established based not only on the demand of services, but also on the vulnerability of surface and groundwater contamination, health issues and environmental pollutions. Full operational cost recovery can be attained from business operation, if the revenue generated can exceed the operational cost in addition to profit margin for the private sector.

Keywords: Decentralized Wastewater Treatment System, Business Model, Barriers and Challenges.

1) Developing a Sensor-based Agricultural Water Management System for Irrigation Scheduling, Automation, and Optimization

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Abstract:
The role of agriculture has been marked significantly in sustaining societies throughout the globe. Its relevance to dry arid regions like GCC (Gulf Cooperation Council) region countries is more particular in the wake of food security, sustainability, and climate change. Qatar's efforts in safeguarding food security have been witnessed greatly in recent years due to the country's increased food demands, caused by its rapid population growth and economic development. The blockade imposed on Qatar in 2017 also raised a serious concern for food security and self-sufficiency. This situation emphasizes the need to explore options for precision irrigation water management through climate-smart farming in Qatar to meet its food security and sustainability targets as a part of the National Food Security Program and Qatar's National Vision 2030 (QNV-2030). An automated irrigation system can assist in irrigation scheduling for precision water conservation and natural resource (water) optimization through enhancing irrigation water use efficiency. A scientific and smart-agriculture approach is being adopted as a work package of an applied research project, "*Development of Smart Agricultural Technologies to Optimize Resource Allocation to Ensure Food Security – A Pathway Towards Sustainable Vegetables and Date Palm Production in Qatar*" funded by the Qatar Research, Development and Innovation (QRDI) Council — Qatar. This novel approach involves developing and testing a sensor-based smart and sustainable irrigation system to irrigate date palm trees and agricultural fields cultivating vegetables in Qatar. As a first step, a laboratory experimental setup was developed consisting of A) a wireless SM-100 soil moisture sensor B) an irrigation solenoid valve controller, C) a single channel relay, D) a solenoid valve, E) a step-down transformer 240/24VAC (volts, alternating current), and F) soil state representations. The system was tested to mimic soil moisture conditions for wilting point and field capacity to respectively start and stop irrigation via controlling a solenoid valve of an irrigation system wirelessly connected with a soil moisture sensor. In its second step and after a successful laboratory trial, the system is prepared to be installed and tested in the field under real conditions of GCC region countries to irrigate date palm orchards and greenhouse crops. The system will operate with a soil water characteristics curve to be established as part of this step. With the successful use of artificial intelligence in various fields of system automation, the automation of irrigation systems can benefit from these modern approaches to system automation. The novel system thus developed will help ensure GCC region countries address challenges of food security, sustainability, and climate change.

Keywords: Irrigation scheduling, system automation, soil moisture monitoring, water characteristics, water management, precision irrigation, artificial intelligence.

2) The Role of Information Technology in Addressing Soil Logging and Salinization in Diyala Governorate

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الملخص:

التغدق والتملح هو انخفاض أو تدهور في قدرة الانتاج البيولوجي للتربة والذي يؤدي في النهاية إلى خلق أوضاع صحراوية. وهو أحد جوانب التدهور الشائع الذي تتعرض له النظم البيئية وبالتالي تدمير الامكانيات البيولوجية أي الانتاج النباتي والحيواني والأغراض الذين يؤيدون باستمرار لتحقيق التنمية السليمة. إن المشكلة الأساسية التي يعاني منها تطوير القطاع الزراعي في محافظة ديالى هو مشكلة تملح التربة وتغدقها والتي تشكل مساحات كبيرة في وسط وجنوب العراق، حيث تقدر مساحتها بـ 100 ألف دونم من الأراضي صالحة للزراعة سنويا. وتتباين المناطق الرطبة في محافظة ديالى والبرك المالحة والأراضي المتغدقة والتجمعات المائية الصغيرة الدائمة عند مصبات الأنهر في المحافظات، إلى الخزانات المائية التي يقوم الانسان بإنشائها ومحطات المياه القادمة. ويعتبر أي تجمع مائي في هذه المنطقة شبه الجافة ذو أهمية كبيرة لبقاء الطيور المائية والمهاجرة، وينظر إلى جميع المسطحات المائية على أنها مصدر للاستعمالات الحضرية والزراعية والصناعية، وقد تأثر عدد كبير من المسطحات المائية بزيادة الملوحة. وعلى ضوء ذلك يناقش هذا البحث مدى مشكلة التغدق والتملح في تربة محافظة ديالى، وهل لتكنلوجيا المعلومات مجال في حل هذه الاشكالات باستخدام الذكاء الاصطناعي ونظم المعلومات من خلال تقنين الري والتحكم بالمتغيرات المناخية. وتوصي الدراسة بالحاجة الى الدعم التكنولوجي والمادي لمكافحة التصحر واستصلاح الاراضي الجافة.

3) Treated Wastewater Application in Urban Agriculture

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Abstract:

Water deficit countries need to look for innovative and sustainable production of food using integrated circular approach (reduce, reuse, recycle) in urban agriculture such as hydroponic and aquaponics systems. Circulating water in a close hydroponic system with fish and vegetable production (aquaponics system) using treated wastewater will contribute to sustainable consumption and production (SCP) in the region. Therefore, the objective of the study was to evaluate the effect of treated wastewater on plant growth and production using hydroponic and aquaponics systems. This approach will enhance the saving of freshwater and used fertilizer in similar agriculture systems. Three types of leafy vegetables were planted in two groups, the first group using tertiary treated wastewater and the other using fresh water. Plants heights, chlorophyll content and weights were observed and recorded. Water samples used in both systems were tested and compared with the local and international standards. Water and plants samples were analyzed for metal contents using ICP machine. Results showed, a positive effect of treated wastewater on plant growth and all measured parameters. In addition, metals concentrations in plant samples were within the standards. For aquaponics system, nine tanks with dimensions of 80*40*40 cm were filled either with freshwater or a mixture of freshwater and treated wastewater at (50:50 & 75:25 % ratios). Each tank was stocked with 25 pieces of Tilapia with an initial body weight of 49 g. Each tank was connected with another tank of the same dimensions that was used to grow lettuce and bean crops on the top layer. Water was circulating between two tanks. No fertilizer was added to all treatments and all tanks got similar amounts of fish feed. It was found that tanks with treated wastewater got higher values of metal content due to minerals added from treated wastewater compared to fresh water alone. Therefore, lettuce and bean growth were much better and got higher values of chlorophyll content compared to control tanks. For heavy metal analysis, all waters got similar values with small increase in some elements found in treated wastewater. For the edible part, lettuce grown in treated wastewater got higher value of Fe and Ba compared to control. Similar concentrations were found with bean plants with higher values in treated wastewater compared to freshwater. However, low concentrations of heavy metals were found in the edible parts of all treatments, and it was within the international standards. Fish analyses showed that all tested heavy metals were within the safe limit. However, applying this technique in the farming system will help the environment by utilizing treated wastewater and reducing fertilizer applications. Moreover, farmer income will increase since both fish and crops will be produced with minimum resources.

Keywords: Hydroponics, aquaponics, fish, heavy metal, plant quality.

4) Towards Sustainable Water Management: Leveraging Soil Moisture Sensors for Smart Irrigation in the GCC

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Abstract:

Efficient water management in agriculture is paramount in the arid and semi-arid regions of the Gulf Cooperation Council (GCC) countries. Soil moisture sensors-based irrigation scheduling have emerged as crucial tools for optimizing irrigation practices, conserving water resources, and improving crop yields. This paper delves into the application of soil moisture sensors for smart irrigation scheduling in the GCC, discussing their types, benefits, challenges, and relevant research and development (R&D) efforts demonstrating their successful implementation in this region. The authors identify several key areas of concern and provide a roadmap for future research endeavors in maximizing the potential of soil moisture sensors for efficient water management and smart irrigation in the GCC region.

Keywords: Soil moisture sensors, soil moisture monitoring, irrigation scheduling, smart irrigation, precision agriculture, water management.

5) Strategic Water Management for Improved Tomato Yield and Quality in Greenhouse Environments with Different Water Quality

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Abstract:

The purpose of the study was to examine the impact of salinity stress and deficit irrigation on different growth stages of tomato plants cultivated in greenhouses. The experiment included 18 treatments with three types of water: freshwater (FW), saline water (SW), and a 1:1 mixture of fresh and saline water (MW). Six variations of treatment were used, including full irrigation at 100% potential tomato ETc (FI), deficit irrigation at 60% ETc (T2), and four deficit irrigation strategies at 60% ETc, excluding full irrigation during specific growth stages of initial, crop development, mid-season, and end-season (T3, T4, T5, and T6, respectively). The results showed that irrigation with saline water decreased the yield and water use efficiency (WUE) of tomatoes. The maximum yield under deficit irrigation was at T3, reaching 107.18, 101.04, and 78.97 tons per hectare under FW, MW, and SW, respectively. 3The best WUE was determined by T2, which had values of 23.41, 21.93, and 15.71 kg/munder FW, MW, and SW, respectively. When combined with salt stress, the adverse effects of deficit irrigation became stronger, resulting in yield reductions of T2 during MW and SW of 20.6% and 43.2%, respectively. The highest fruit vitamin C content value was seen when non-saline water was combined with deficit irrigation at 60% ETc during all growth phases (T2). However, the control treatment (FW-FI) showed the lowest vitamin C content (T1). Total soluble solids (TSS) and pH values were the highest when saline water was used combined with deficit irrigation at 60% ETc for all growth stages (T2), while the lowest values were at T1 treatment. The study provides valuable recommendations for improving tomato cultivation methods, particularly in greenhouses, where water quality and deficit irrigation can significantly affect productivity and fruit quality.

1) Wastewater Industrial Database for Total Nitrogen in Shuaiba Area in Kuwait

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Abstract:

A contract project was carried out to determine the quality and quantity of 17 petroleum industrial wastewater from different sources in Shuaiba area 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 Shuaiba industrial area in Kuwait. In this study, wastewater samples were collected and analyzed on a monthly and biweekly basis from 17 petroleum factories of Shuaiba industrial areas. This paper was targeting assessment of total nitrogen in the raw wastewater for factories of Shuaiba industrial area. The field wastewater data indicated presence slightly acid to alkaline (5.7-12.9), reduced to oxidized environment (-431 mv - 617 mv) and freshwater to brackish water (333µS/cm-33,090µS/cm). The laboratory results revealed that total nitrogen concentrations for wastewater of 17 factories ranged between 0.003 mg/l and 150 mg/l The mean values of total nitrogen concentrations for wastewater of 17 factories with exception Kuwait Lube Oil Company were meeting the maximum limit (65 mg/l) set by KEPA for irrigation water purposes. The mean value of quantities of wastewater generated from 17 factories was found to be 62.28 m^3/week. The large quantities of raw wastewater generated from these factories can be used safely as irrigation water with respect to total nitrogen concentrations.

Keywords: Wastewater, field survey, laboratory results, petroleum, nitrogen, sample collection.

2) Towards a Novel Wastewater Treatment Process: A Submerged Membrane Elector-Bioreactor (SMEBR)-Simultaneous Biodegradation, Electrocoagulation and Membrane Filtration

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Abstract:

The limited freshwater resources make the need for wastewater treatment and reuse a mandatory option in many countries around the world. Wastewater treatment and reuse is a particularly attractive option in arid and semi-arid regions like the Arab Gulf area due to severe water scarcity. Therefore, focusing on advanced wastewater treatment methods has become a hot issue in recent years. Membrane processes belong to this group and attract a high degree of attention from researchers in different academic institutions. In the last few decades, membrane bioreactor (MBR) technology, specifically the submerged membrane bioreactor (SMBR) which integrates membrane filtration with an activated sludge process (ASP) has exhibited promise as a very attractive method for various kinds of wastewater treatment. The SMBR has many advantages in comparison with ASP such as superior effluent quality, higher mixed liquor suspended solids (MLSS) and organic pollutant loading, independent control of hydraulic retention time (HRT), and sludge retention time (SRT). However, the phenomenon of membrane fouling is still considered one of the main obstacles to SMBR technology. Many methods have been developed and investigated to overcome this serious problem. Among the different proposed approaches, using the electrochemical methods by applying a direct current (DC) field on the activated sludge has been shown as a promising and novel approach. One of the early developed electrochemical methods with SMBR is called Submerged Membrane Electro-Bioreactor (SMEBR). The SMEBR integrates three processes in one reactor unit: biological treatment, membrane filtration, and electrocoagulation. The method was developed at Concordia University, Montreal-Canada in 2008 and later registered as a patent in the USA in 2010. The significant benefits of designing the SMEBR system are (i) a smaller footprint; (ii) no chemicals are required for coagulation; (iii) reducing the operating costs by reducing the requirements of aeration in conventional SMBR systems; and (iv) improving sludge dewatering conditions. The designed SMEBR system may find a direct application for 2 various types of wastewaters, including sewage, without extensive pretreatment. Such a solution is required by several small municipalities, mining areas, agriculture facilities, military bases, and different regions. Finally, such a compact hybrid system can easily be adapted to a mobile unit, and it can be driven by solar energy. This study presents a comprehensive review of the conducted studies on SMEBR and its application in wastewater treatment and the potential of reducing the membrane fouling phenomenon. The study summarizes the advantages of SMEBR in comparison with other treatment technologies and highlights the last applications of SMEBR.

3) Farmers' Attitude Towards the Use of Treated Wastewater in Irrigation, the case of Saudi Arabia

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Abstract:

Reuse of treated wastewater could provide a key solution to address water scarcity and provide sustainable water resources for agricultural use. However, the success of this practice depends on farmers' acceptance and involvement, which require careful assessment and evaluation. The purpose of this paper is to investigate the farmers' perception about the treated wastewater reuse from economic benefit, social acceptance, environmental and health risks. 391farmers in five regions (Al-Ahssa, Qatif, Riyadh, Taif and Medina) in KSA were interviewed using structured questionnaire through a systematic random sampling method to explore how they perceive the quality of treated wastewater. The sample size and distribution were determined according to the number of agricultural holdings, cultivated area and source of irrigation water. Descriptive statistics including cross tabulation is used as useful tool for evaluating the significance of anomalies between regions. The percentage of farms using treated wastewater was 65% in average of the total sample, however the highest treated wastewater reuse was in Al-Ahssa and Qatif with average ratio 77 % and 67% respectively. Water scarcity and the non-availability of alternative water resources were among the main reasons for accepting the use of treated wastewater. About 78% of farmers are satisfied with using treated wastewater for irrigation. Some farmers expressed their desire to use treated wastewater as a complementary source (43%) and (39%) as an alternative source. The highest positive impact of the use of treated wastewater in irrigation from the farmers' perspective was the impact on productivity, reduction of the cost of fertilizers and saving the cost of water abstraction. The highest perception of negative impact was pest prevalence on the farm, fear from consumer acceptance, health related aspects, soil contamination and not suitable for personal use. Only 57% of farmers indicate that they are receiving extension service on the use of treated wastewater. In conclusion, public awareness, farmers' capacity building and agricultural extensions program must be executed to change negative perceptions of farmers. Farmers are more likely to accept the use of treated water when there is awareness of water scarcity, suitable water quality and economic benefits exceed costs.

Keywords: Socioeconomic factors, farmer's perceptions, Reuse of treated wastewater Health impact of Reused Treated Water.

4) Ecofriendly and Low-cost Adsorbent for Efficient Removal of Heavy Metals from Aqueous Solution

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Abstract:

This study aims to investigate the removal of heavy metal from industrial waste water using a low-cost bio-adsorbent. Banana peels was treated chemically with phosphoric acid and methanol. The ability of treated banana peel to remove lead and nickel from wastewater was investigated. Adsorption experiments were performed to optimize the effect of process conditions such as adsorbent dose, pH and contact time on heavy metals removal. Banana peels treated with phosphoric acid was found to have a higher removal efficiency compared to the one treated with methanol. The maximum removal efficiency of lead and nickel was found to be 78 and 43% with the banana peels treated with phosphoric acid at pH 6 and with using 2 g of treated peels. The lead removal efficiency was found to increase from 27 to 95 % with the increase of adsorbent dosage from 0.5 to 4 g, respectively. The adsorption processes for lead and nickel were well described by Langmuir and Freundlich isotherm model, respectively. The experimental results suggest that the fabricated bio adsorbent is an alternate low-cost adsorbent for waste water treatment.

Keywords: banana peels; bio-adsorbent; water pollution; lead; nickel.

5) Comparative Wastewater Quality Indicators and Multivariate Analysis of Riyadh Sewage Treatment Plants and its Impact on Irrigation of Riyadh District, Saudi Arabia

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Abstract:

The ability of the communities to continue to live normally and grow is doubtful if such a large volume of water is allocated to irrigation for agriculture. As a result, we try to analyze a non-conventional source of non-potable water for irrigation. The investigation assessed wastewater treatment plants in Riyadh, Saudi Arabia, particularly emphasizing tertiary-treated wastewater used for irrigation and groundwater replenishment. The treated water quality parameters, Canadian water quality indices (CWQIs), and comprehensive water pollution (CPI) were implemented for irrigation purposes, while principal component (PC) analysis was used to determine dependable parameters. The present study aimed to evaluate the physicochemical quality of Riyadh wastewater treatment plant effluent for being used in agricultural irrigation. In this study, 10 physicochemical and 1 microbial parameter were collected during 2013-2016. The water quality parameters used were pH, EC, turbidity, TSS, DO, NH^{4+}, NH^{3-}, BOD_5, COD and E. coli. The CCWQI outcomes ranged from 73.75 to 95.26%. The variations during a four-year period. It was of acceptable and sufficient quality. The CPI results ranged from 0.16 to 1.61. However, it was found that the average CPI was 0.6, showing that there had been some light pollution throughout the entire time interval. The effluent from the Riyadh wastewater treatment plant is suitable for irrigation over the year. The dataset's variance was primarily attributed to PC1, which accounted for 63% of the total. This component represented dissolved oxygen parameter loading and can provide a dominant pattern of the data set for better understanding the characteristics of the effluent. Other components included 17% for electrical conductivity (EC), 6% for *E. coli*, 2.7% for Sodium Absorption Ratio, and 1.8% for chemical oxygen demand (COD). These factors provide a dominant pattern for understanding wastewater characteristics.

6) Green Synthesis of Zinc Oxide Nanoparticles for Wastewater Treatment

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Abstract

This study focuses on the use of a green synthetic strategy to synthesize zinc oxide nanoparticles using Albizia lebbeck pods extract. The synthesized nanoparticles were characterized using ultraviolet-visible spectroscopy, Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). The influence of nanoparticles preparation method was examined. XRD patterns confirmed the formation of hexagonal wurtzite structure and SEM results showed high agglomeration with irregular shape. The catalytic degradation of methyl orange and methylene blue dyes using the synthesized nanoparticles was examined. Results indicate that the removal efficiency of 87 and 82% was obtained for methyl orange and methyl blue within 60 min using nanoparticles dosage (0.02 g) and initial dye concentration (40 ppm). The experimental data were suitably fitted by Langmuir isotherm indicating a monolayer nature of the adsorption process. The obtained results demonstrate that the synthesized zinc oxide nanoparticles could be effectively utilized as adsorbents for the removal of methylene blue and methyl orange from aqueous solutions.

Keywords: Green synthesis, ZnO, Wastewater, Contaminants.

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 was 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". 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 in 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". The **14th** Conference was held in Riyadh, KSA, from 13-15 February 2022 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. In 2022, WSTA organized a Training workshop entitled "The Role of Media Professionals in Raising Community Awareness on Water Challenges in the Gulf Cooperation Council Countries" held in Muscat during 28-29 September 2022. This was followed by the 2nd Seminar on Bottled Water Consumption in the GCC Countries held in Doha, Qatar, during 30 April-1 May 2023, in cooperation with the Ministry of Environment and Climate Change. The Association also organized a symposium on "The Problem of Shallow Water Table Rise in the Urban Areas in the GCC Countries" in Doha, State of Qatar in collaboration with the Public Work Authority (ASHGHAL) on 17 September, 2023.

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.

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