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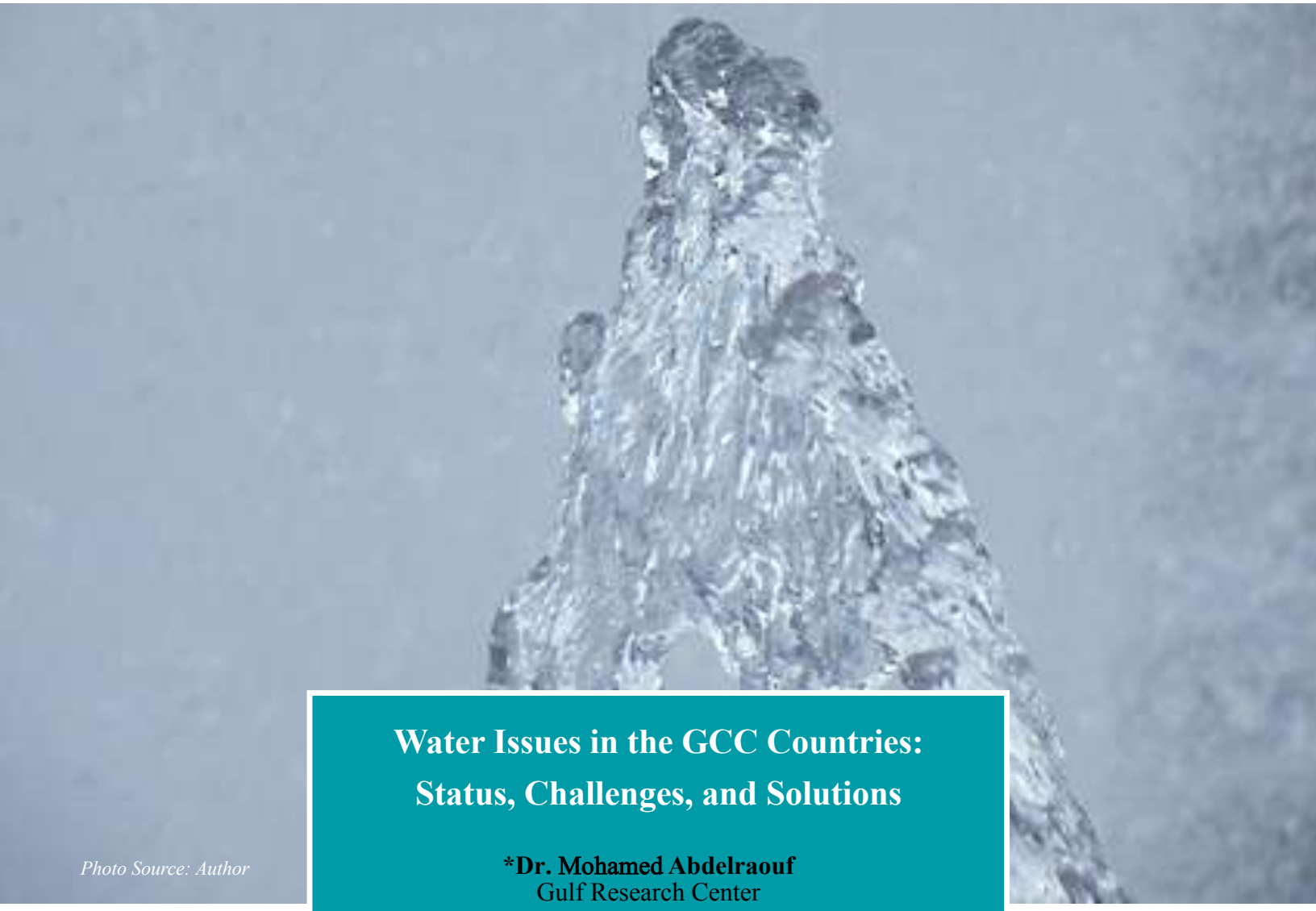

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Water Issues in the GCC Countries: Status, Challenges, and Solutions

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Introduction

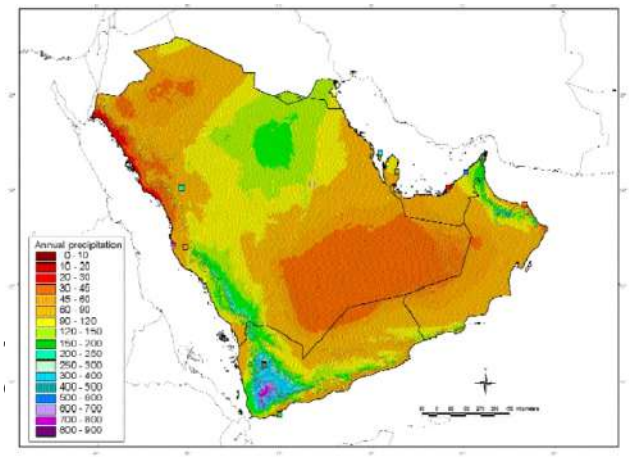
Water is essential for all forms of life. Besides its importance for maintaining healthy ecosystems, it is a fundamental resource for human survival and socio-economic development. The water issue is an integral part of the United Nation's 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) and 169 targets, aiming at nothing less than "transforming our world" into one that is more sustainable.

The SDGs cover a wide range of drivers across the three pillars of sustainable development and include a dedicated goal on water and sanitation (SDG 6) that sets out to "ensure availability and sustainable management of water and sanitation for all." SDG 6 focuses on the entire water cycle, including the management of water, wastewater, and ecosystem resources. Realizing SDG 6 would in fact go a long way towards achieving much of the 2030 Agenda.

The limited availability of fresh water in the Gulf Cooperation Council (GCC) countries - comprised of Saudi Arabia, Oman, UAE, Kuwait, Bahrain, and Qatar - has for decades presented a major challenge to the people and governments of the region. Scarce rainfall and population growth, together with high rates of water evaporation and consumption, as well as urbanisation, have led to deficits in the countries' so-called 'water budgets.'[1] The GCC countries have extremely dry climates with rare rainfall, high evaporation rates, and limited non-renewable groundwater resources. Conventionally available water supplies on a renewable basis in these countries are simply insufficient to meet the increasing water demands of the present modes of economic activities and resource exploitation.

The scarcity of water resources and the increasing gaps between demand and available supply in the GCC is a major challenge facing the development sectors. This coupled with a lack of defined policies and strategies geared toward optimizing and managing the scarce water supplies within the region, have contributed to wasteful and uneconomic practices, as well as to the inefficient extraction of non-renewable supplies.

The GCC countries have low and irregular rainfall, typically less than 100 mm/yr and as low as 50 mm/yr in the northern and central parts of the region. This region is arid, and its countries already fall well below the water scarcity line as defined by the World Health Organization (WHO) (having renewable water resources less than 1000 m^3/yr/capita).



[1] According to UN ESCWA, Water Budget is an estimate of the size of future water resources in an aquifer, catchment area, or geographical region, which involves an evaluation of all the sources of supply or recharge in comparison with all known discharges or extractions in other words a summation of inputs, outputs, and net changes to a particular water resource system over a fixed period.

[2] Mohamed Dawoud, Water Scarcity in GCC countries: Challenges and Opportunities, December 2007, Gulf Research Center

changes in lifestyle, industrialization, urbanization and climate change, and has led to water scarcity and increased competition for water between agriculture, industry, and rapidly growing cities. Taken together, this places tremendous pressure on the available water resources in GCC countries which historically have always faced an extreme shortage of reliable and renewable water supply.

Over the last quarter of a century, there have been three and four-fold increases in the size of the population and total water use respectively. The position of all GCC countries, except Oman (583m³/cap/yr), has fallen in the critical water scarcity category, meaning approximately 500 m³ renewable water/cap/yr. Moreover, total water demand is expected to increase 36 percent further over the next decade. One result is that groundwater is abstracted at a faster rate than the renewable aquifer system can be naturally recharged. This has resulted in falling water tables, saline water intrusion into fresh aquifer systems, water quality deterioration, and the mining of the non-renewable aquifers. As it stands, 71.3% percent of the combined total water demand is abstracted from ground and surface water, 23.9% percent by desalination of ground and seawater, and the remaining 4.8% from treated wastewater (GCC Water Statistics Book, 2022).

Although arable land in GCC countries is less than 5%, average agricultural water use accounts for 70-80% of the region's renewable water resources. Agricultural water demand is primarily met through the massive exploitation of groundwater, causing a significant lowering of groundwater levels. All GCC countries are becoming increasingly dependent on the non-sustainable mining of local groundwater aquifers that are presently threatened by pollution and depletion (2024).[3]

To be sure, GCC countries have made substantial progress in their respective campaigns for water resource management over the last two decades, especially in the area of development of non-conventional water resources. In order to see where the key challenges and demands for policy adjustments lie, this paper looks at water resources in the Gulf region with respect to:

- A diagnosis of the current situation of the water sector
- Identifying issues and challenges in the water resources sector of GCC countries
- Providing potential solutions for overcoming the water problems in the region
- Making recommendations for future actions

Water Status in GCC Countries

Water resources in GCC countries can be classified into two main categories: Conventional and Non-Conventional, as shown in table 1 below. A detailed explanation will follow in the next sections for each type of water source.

Table 1: Water Resources in GCC countries

1- Conventional	2- Non- Conventional
Surface (incl. aflaj, springs, and dams)	Desalinated water
Ground water (shallow and deep aquifers)	Treated wastewater
	Other resources such as cloud seeding

Source: Author

[3] Raha Hakimdavar. (January 2024). "Water is the New Oil in the Gulf." Time Newsletter. https://time.com/6556469/water-new-oil-gulf/ Accessed on July 30, 2024.

Surface Water and Groundwater

The surface water in the UAE is negligible and it includes floodwater, water retained in dams, some very small streams, ponds, spring water, and aflaj (traditional water Canals system). These are either confined or flowing when there is a land slope and are re-supplied by rainfall or groundwater. The average annual rainfall ranges from 70 to 130 mm, except in the mountain ranges of south-western Saudi Arabia, and southern Oman, where rainfall may reach more than 500 mm (2023)[4] (Table 2).

Table 2: Rainfall in the GCC Countries (2024)

Countries	Area (km^2)	Population (millions)	Variation in annual average rainfall (mm)
Bahrain	652	1.7	80
Kuwait	17,818	4.3	110
Oman	212,460	5.1	50–300
Qatar	11,610	2.9	75
Saudi Arabia	2,149,690	34.8	70–500
UAE	83,600	9.9	90

Source: Basant Helal and others, 2024[5]

The annual renewable surface water, desalinated capacity, and wastewater treatment capacity in the GCC countries are estimated at 4.14, 26.4, and 10.07 billion m3 respectively. The average per capita water consumption is around 550 l/d (2023) as shown in Table 3. The GCC countries have high water footprints.[6]

Table 3: Annual Renewable Freshwater Resources in GCC Countries (2023)

Country	Volume in hm3
Bahrain	116
Kuwait	20
Oman	1,400
Qatar	58
Saudi Arabia	2,400
UAE	150
Total	**4,144**

Source: Basant Helal and others, 2024

In the Gulf region, shallow groundwater aquifers located along the main wadi channels and the floodplains of drainage basins, are the only renewable water resource. Large deep aquifers are present in the region, which contain non-renewable supplies of fossil water, but these have a finite life and quality limitations. Only Saudi Arabia possesses substantial amounts of non-renewable groundwater in deep aquifers. However, even these are rapidly depleting.

There are two major aquifers: the Kuwait group (upper layer) and the Dammam group (lower layer). Bahrain receives groundwater by lateral under-flow from the Dammam aquifer, which forms a part of the extensive regional aquifer system, called the Eastern Arabian Aquifer. This aquifer extends from central Saudi Arabia, where its main recharge area is located at about 300 meters above sea level, to eastern Saudi Arabia and Bahrain, which are considered the discharge areas.

[4] Mohsen Sherif et al. (2023) "Water Availability, Sustainability and Challenges in the GCC Countries: An overview." https://www.sciencedirect.com/science/article/pii/S2405844023077514#:~:text=The%20average%20annual%20rainfall%20varies,may%20reach%20500%20mm%2Fyear Accessed on August 5, 2024.

[5] Basant Helal et al. (June 2024). "The Impact of Land Use on Water Resources in the Gulf Cooperation Council Region." https://www.mdpi.com/2073-445X/13/7/925 Accessed on August 10, 2024.

[6] Mohsen Sherif et al, 2023. Accessed on August 8, 2024.

Table 4: Shared Groundwater Aquifer Systems in the West Asia Region

Shared Groundwater Aquifer System	Shared Countries	Storage (Size)
Saq-Ram Aquifer System (West)	Jordan, Saudi Arabia	*~750 BCM*
Wajid Aquifer System	Saudi Arabia, Yemen	*34-231 BCM*
Wasia–Biyadh-Aruma Aquifer System (South)	Saudi Arabia, Yemen	~500 BCM
Wasia–Biyadh-Aruma Aquifer System (North): Sakaka-Rutba	Iraq, Saudi Arabia	-
Umm er Radhuma-Dammam Aquifer System (South)	Oman, Saudi Arabia, UAE, Yemen	180-1,100 MCM
Umm er Radhuma-Dammam Aquifer System (Centre)	Bahrain, Qatar, Saudi Arabia	~238 BCM
Umm er Radhuma-Dammam Aquifer System (North)	Iraq, Kuwait, Saudi Arabia	-
Tawil-Quaternary Aquifer System	Jordan, Saudi Arabia	22 BCM
Ga'ara Aquifer System	Iraq, Jordan, Saudi Arabia, Syria	-
Neogene Aquifer System (South-East)	Iraq, Kuwait, Saudi Arabia	~1.26 BCM

Key: ~ Approximately - Data not available
Source: UN-ESCWA. 2013. Inventory of Shared Water Resources in Western Asia.

Ground water was and still is one of the main water sources in the GCC countries but due to rapid expansion mainly in agriculture areas, several environmental problems have occurred:

- Over abstraction of ground water for agriculture has caused a sharp drop in water levels in freshwater aquifers.
- Saltwater intrusion from the sea in coastal areas, lateral movement of saline water from nearby Sabkha (marshes) dominated areas, or upwelling of saline water from deep aquifers into shallow freshwater aquifers.

The Traditional Water System (Aflaj)

Aflaj is the plural for falaj. The term "falaj" represents an irrigation system that includes economic, social, cultural, and managerial characteristics. The aflaj system still operates in some parts of the UAE and Oman and offers many economic and environmental benefits. A falaj is a channel that may be open or partially or completely covered. The channel collects groundwater through natural infiltration conditions and conveys it to the ground surface by gravity. The falaj system suits the social and cultural conditions of rural areas in arid and semi-arid zones. The continuous water flow from many aflaj overtime is proof of their efficiency, suitability, and sustainability to the hydrologic environment in the Arab region. A summary of pros and cons of the aflaj is shown in Table 5.

Table 5: Pros and Cons of the Aflaj

Advantages	Disadvantages
It is one of the most successful known traditional methods for utilizing the renewable aquifers in the region.	Falaj discharges depend upon groundwater fluctuations and may result in a negative effect on agriculture and other uses.
No energy needed as the water flows from the water feed area to the water use area by gravity.	The water is liable to high loss rates as the falaj discharges cannot be controlled and may exceed water needs during some months.
Easily maintained by locally available materials.	Water is vulnerable to pollution as it flows near to the ground surface.
Since ground water utilization is done within the framework of water balance, it does not lead to exploitation of limited water resources.	
Achieves a fair water distribution among users.	

Sources: Author

The disadvantages listed above can easily be overcome through the development of technology which can develop and manage the aflaj systems more efficiently. This includes improving the sources of water recharge through the use of artificial recharge technology and development of the methods of water collection and conveyance, resulting in the reduction of water losses through the introduction of modern and suitable technologies.

Falaj in UAE

Photo Source: "All About World Heritage." available at https://allaboutworldheritage.com/category/united-arab-emirates/

Falaj in Oman

Photo Source: "Omani Aflaj." available at https://www.watermuseums.net/campaigns/valuing-ancient-water-cultures/omanic-aflaj/

Non-conventional water resources:

- **Desalination**

The GCC states are considered world leaders when it comes to using non-conventional sources of water. Desalination, particularly in Saudi Arabia and Kuwait, began as early as 1938 (UNSPD, 2002). The bulk of the total installed capacity of all desalination plants in the world is in the Gulf region. GCC countries account for some 60 percent of global water desalination capacity, producing around 40 percent of the total desalinated water in the world using over 400 desalination plants across the region (2023).[7] In fact, Saudi Arabia is ranked first worldwide, followed by the UAE.

Most of the desalination in GCC countries is done by thermal processes referred to as multistage flash and multi-effect distillation (MSF and MED). Thermal processes have been used due to the low cost of energy in these countries and the problems faced by membrane processes in dealing with the Arabian Gulf water, such as fouling and scaling problems.

Yet desalination is not without its pitfalls. Desalination plants consume high amounts of energy, and the capital costs and space requirements are relatively large. There are other adverse effects on land use since their plants are located near the shoreline. Thus sites that could be used for recreation or to attract tourism are instead dotted with industrial plants and intrusive pumping stations.

Then there is the impact on the aquifer especially if a desalination plant is constructed inland as any leakage from the pipes may result in the penetration of salt water and therefore presents a danger to the aquifer. In addition, there is the impact on the marine environment as a result of reject brine and the rise in temperature. Any chemicals added to the desalination process for scale prevention, corrosion reduction, or corrosion products might be discharged to those water bodies together. Likewise, inland brackish water desalination plants can also face major challenges in disposing of brine discharges in a safe manner and incur heavy treatment costs.

- **Wastewater Recycling**

Every drop of water on Earth is infinitely recycled and reused through purification systems linked to the natural water cycle. In modern societies, humans use mechanical, physical, and biological processes to treat wastewater to make it usable for various development activities. Wastewater reuse is therefore an important conservation measure for non-potable uses such as irrigation and horticulture. This source has future potential if proper irrigation practices are applied. Other forms of non-conventional water sources, such as rainwater harvesting, weather modification, etc. are still in the research stage.

Treated wastewater represents one of the main alternatives that can be used to meet some of the present water requirements and lessen the long-term supply/demand imbalance. At present, the GCC is operating modern treatment facilities with tertiary and advanced treatment capabilities. Treated water is used mainly for urban purposes including irrigating gardens, green spaces, reforestation, fodder crop irrigation, and highway landscaping etc.

The obstacles that face the use of treated water are the lack of transmission and distribution networks to supply clientele (which are mainly national parks and private companies such as golf resorts) and cultural aspects, as it is still difficult to convince consumers such as farmers to use recycled water. In this context, a

[7] Achref Chibani. (June 20240. "The Costs and Benefits of Water Desalination in the Gulf", https://arabcenterdc.org/resource/the-costs-and-benefits-of-water-desalination-in-the-gulf/#:~:text=GCC%20countries%20account%20for%20some,plants%20for%20their%20water%20needs Accessed on August 13, 2024.

continuous awareness campaign to influence people's attitudes towards recycled water usage is needed including highlighting that in almost all cases, treated wastewater may have better quality for many uses than surface or even groundwater.

Wastewater treatment in the Gulf region constitutes an increasing water source driven by escalating water consumption in urban areas. The total wastewater treated and reused in 2015 and plan for 2025 in the GCC countries is shown in Table 6.

Table 6: Treated Wastewater Production and Use in GCC Countries (2022)

Country	Treated Wastewater Production (mcm)		Treated Wastewater Use (mcm) 2015
	2015	Plan 2025	
Bahrain	102	150	31
Kuwait	290	420	189
Oman	84	125	67
Qatar	160	230	64
Saudi Arabia	812	1,200	487
UAE	587	900	264
Total	**2,034**	**3,025**	**1,101**

Source: Anders Jägerskog and Shawki Barghouti, World Bank (2022)[8]

- **Cloud Seeding**

The GCC countries, especially Saudi Arabia and the UAE are two pioneer countries in terms of cloud seeding and artificial rainmaking where they have conducted some artificial rainmaking experiments in mid-summer. What makes conditions right for cloud seeding in the Gulf region is that it is a very humid part of the world, meaning that there is a lot of water vapor already in the atmosphere. However, cloud seeding is a very costly option and it is still relatively understudied.

Saudi Arabia has focused its cloud-seeding efforts along its Red Sea coast, where natural conditions lend themselves better to rainfall enhancement. In general, cloud seeding in the Kingdom has a much bigger land area to capture rainfall. However, investments will be required to build dams and other infrastructure to utilize the increase in rainfall to its full potential, as well as construction of the necessary precautions for possible flooding events. While such a technique has proven its success in increasing the amount of precipitation, there is nevertheless the need for more detailed cost-benefit analyses to make sure it is a viable source compared to investing in other options, such as desalination or even water conservation campaigns.

Drivers Affecting Water Resource Availability in the Region

The dependence on water for rapidly growing development sectors in arid and semi-arid regions holds a special place in the water scarcity and management debate. The increased pressure on water resources is due to (1) population growth - demanding not only more water for food, but also inducing changes in the hydrological cycle, (2) changes in lifestyle and urbanization and (3) climate change, which has led to water scarcity and increased competition for water between agriculture, industry, and the rapidly growing cities.

- **Climate Change**

According to the Intergovernmental Panel on Climate Change (IPCC), water scarcity in the Gulf region is expected to increase due to the impact of climate change. Predictions indicate that in the next 50 years rainfall may decrease by 15–20% leading to decreases in water availability, decreases in groundwater recharge, greater frequency of flash floods and drought

[8] Anders Jägerskog and Shawki Barghouti. (2022). "Advancing knowledge of the Water Energy nexus in the GCC countries." World Bank. https://documents1.worldbank.org/curated/en/099355009132215715/pdf/P1768640ebe4770180b3970bccc84ae2926.pdf Accessed on August 4, 2024.

events, in addition to losses of productivity in rain-fed areas.

In general, climate change impacts on West Asian countries are predicted to range from highly vulnerable to significant to extreme. The expected increases in temperature due to climate change will increase water requirements for all uses, but especially in the irrigation sector. Large parts of the region are prone to sea-level rise, which threatens significant areas through seawater intrusion that in turn negatively affects coastal underground aquifers. Notwithstanding this, the negative impacts of climate change on water in the region could be a driver for joint bilateral and/or regional cooperation over shared underground water resources, and could take the form of, for example, joint research efforts and projects to better understand climate change impacts, common protection measures or policies, and integrated water management plans.[9]

- **Water Consumption by Sector**

Population growth and rapid development in the agriculture and industrial sectors in GCC countries are major issues affecting all sustainable socio-economic developments. The high population growth rate in the region by far exceeds the rate of water resource development. Consequently, the annual per capita share of water resources is rapidly decreasing. In addition, this rapid development in the industrial sector increases pressure on water resources. On average, agriculture sector water consumption accounts for around 77%, the industrial sectors accounts 18%, and households account for 5% of the consumption of available GCC water resources.[10]

One of the primary reasons for the unsustainable exploitation of groundwater resources has been the provision of direct and indirect subsidies to well excavation, pumps, fuel, and other inputs as well as price support programs and trade protection in some GCC countries for achieving food security. This has resulted in distorted costs and revenues as well as misallocation of resources by artificially attracting investment to the sector thus obscuring the high opportunity cost of groundwater for municipal and industrial uses, creating a disincentive for the rational use of this resource. While the governments intend to redistribute oil revenues for citizens, given that most of the employment in the agriculture sector is provided by expatriates, employment generation is not an objective of agricultural policy in the GCC countries.

Table 7: Average Water Use by Agriculture Sector in GCC Countries (2022)

Country	Water Use (mcm) (% of total available water)	Added Value to GDP (%)
Bahrain	45	0.3
Kuwait	54	0.4
Oman	89	1.3
Qatar	59	0.1
Saudi Arabia	88	1.9
UAE	83	0.7
Total	**70**	**0.8**

Source: Basant Helal and others, 2024

The increase in water use for irrigation of low-value agricultural crops in GCC countries, especially costly desalinated water, raises the question of the sustainability and future of the

9 Mohamed Abdelraouf. (October 20180. "West Asia Regional Cooperation on Water and Sustainable Development Goal 6." Emirates Diplomatic Academy. https://www.agda.ac.ae/docs/default-source/Publications/eda-insight_wa-water-diplomacy_en_final.pdf?sfvrsn=4

10 Waleed K Al-Zubari. (2017). "An Overview of the GCC Unified Water Strategy, 2016-2035." 12th Gulf Water Conference, Bahrain. https://wstagcc.org/WSTA-12th-Gulf-Water-Conference/waleed_zubari.pdf Accessed on August 6, 2024.

agriculture sector in GCC countries and whether the resulting wastage of both non-renewable and renewable resources would be better reserved for present or future high value uses. Only limited attempts have been made to control groundwater demand through the use of water charges, restrictions on groundwater pumping, limitations on groundwater development, and the introduction of advanced irrigation systems.

The above makes clear that water usage in the GCC countries is on an unsustainable and devastating path. In addition, there are key water management issues facing the GCC countries that need to be discussed. These key issues include: the lack of water demand management; institutional and legal constraints; lack of private sector participation; pollution of water resources; as well as the overall lack of information.

- **Institutional and Legal Constraints**

In many of the GCC countries, responsibility for the administration, regulation, and development of water supplies is fragmented between many government entities. This frequently results in conflicting policies, political competition between agencies, and the lack of a comprehensive and coordinated policy for the allocation, management, and use of water supplies. Much greater coordination between water planning and regulatory functions, and the user-oriented institutions, should be mandated. While the solutions vary with each country, there should be a strong effort to clearly define the roles of each institution involved in the water sector and to effect coordination between these entities.

The lack of GCC-wide water resources monitoring networks and programs has led to a lack of available information about the real present status of water resources. In many published papers and research, conflicting figures as to groundwater recharge and abstraction abound. Furthermore, there is no central authoritative body empowered to manage water resources in an efficient and responsible manner or to publish reliable water statistics. Some exceptions can be found in Saudi Arabia, Abu Dhabi, and Oman.

- **Lack of Private Sector Participation**

The role of the private sector in investment in the water industry in GCC states is insignificant although there has recently been a shift toward the privatization of utilities in line with economic diversification plans. For example, the Dubai Electricity & Water Authority held an initial public offering in April 2022 and Saudi Arabia has increased private sector involvement in water desalination and power generation projects. Moreover, Bahrain recently transformed its governmental water and energy authority into a governmental company, an initial stride toward privatization. In 2023, Kuwait conducted a feasibility study on privatizing some of the country's power and water facilities.[11] Still, the journey ahead for GCC countries for a wider role for private sector participation in the water sector remains long. There is a need for enacting policies and incentives that can attract the private sector with government authorities taking on more of a monitoring role.

- **Pollution of Water Resources**

The over-extraction of groundwater beyond safe yield levels has resulted in the pollution of the existing groundwater aquifers due to intrusion of saline seawater and the upcoming of brackish and saline water supplies from lower aquifers. Over-abstraction from groundwater aquifers along the coast has resulted in a rapid deterioration of water quality. This is particularly serious in Oman, Bahrain, and Qatar where major deterioration of groundwater quality can be observed through

[11] Naser Alsayed. (May 2024). "Privatizing the Gulf Utility Sector." The Arab Gulf States Institute in Washington, https://agsiw.org/privatizing-the-gulf-utility-sector/ Accessed on August 2, 2024.

examination of iso-chlor and iso-salinity maps over time.

Furthermore, the excessive use of fertilizers and pesticides, as well as the problems associated with untreated industrial waste, contribute to the pollution of groundwater aquifers through seepage. In Qatar, farmers use large quantities of low-quality water for washing salts and to avoid the wilting of plants and apply heavy chemical fertilizers for increasing the yield. Also, while the coverage rate of basic sanitation services appears to be quite high in all GCC countries, a fairly large portion of the area is covered by on-site sanitation facilities such as septic tanks and cesspits. These may not provide adequate water pollution control measures in high population areas. In fact, improperly constructed and poorly maintained septic tanks and cesspools have led to the percolation of effluent to shallow aquifer systems and the contamination of groundwater resources.

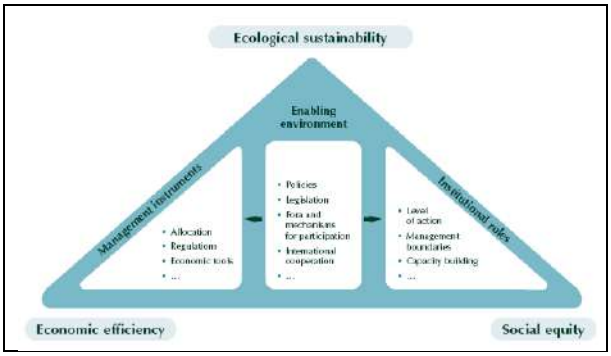
Moreover, the use of high saline and brackish groundwater in irrigation has resulted in soil salinization and salt accumulation in plant root zones, affecting the plants' growth and yield and in general a reduction in cultivated areas. The high evaporation rate due to high summer temperatures increases the process of salt accumulation. There are no groundwater protection policies and no national groundwater quality monitoring networks to detect the changes in groundwater levels and quality in all GCC countries.

Solutions:

- **Integrated Water Resources Management (IWRM)**

Integrated Water Resources Management has been defined as "a process which promotes the coordinated development and management of water, land, and related resources, in order to maximize the economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." Adopting an Integrated Water Resources Management (IWRM) is the best strategy to plan and manage available water resources and plan for sustainable water management for future generations. Understanding the technical, political, economic, social, and environmental issues and how they affect the development of any sustainable and integrated water resources policy is essential, as shown in Figure (3). New water management skills and institutional capacity building are also needed.

Figure 2: General Framework for Integrated Water Resources Management



Source: Anil Agawal and et al, Integrated Water Resources Management, 2000[12]

The GCC countries should also conserve their fresh groundwater resources as strategic reserves for emergency use and for future generations, rather than depleting them with wasteful irrigation practices. Artificial recharge using treated wastewater could enhance the level of potential groundwater reserves.

It worth mentioning that the environmental impact of the treated wastewater for recharging the aquifers should be studied carefully. The emirate of Abu Dhabi already has some good

[12] Anil Agawal and et al. (2000). Integrated Water Resources Management. https://www.researchgate.net/figure/General-framework-for-IWRM_fig2_42765751 Accessed on August 1, 2024.

experience in the field of artificial recharge using desalination. Moreover, the use of brackish groundwater for desalination feed and salt-tolerant crops could release valuable fresh groundwater resources for other purposes requiring high quality water sources. Based on the IWRM policies, GCC countries should then develop national and regional water master plans covering water demands of all sectors and all sources, including conventional and non-conventional sources in participation with all relevant agencies and stakeholders.

Furthermore, GCC countries should develop mid to long-term investment plans as well as their operational plans for each region, including water supply, sanitation, and reuse networks based on a comprehensive review of future water supply sources and demand projections. The economic and financial analysis of the water management system is crucial to helping manage and allocate water in a more efficient way depending on seasonal and yearly conditions, as well as the required energy sources and costs for water treatment, pumping, and transfer.

- **Effective Utilization of New Technology**

In recent years, the use of GIS, remote sensing, databases, and numerical models has grown rapidly in water resources assessment and management. A well-designed GIS-linked database can significantly reduce the time needed for water data preparation and presentation.

In groundwater management issues, flow, and quality models are the best tools to predict the response of groundwater aquifer systems under the proposed future management scenarios and can help in formulating a management strategy. Groundwater flow is mathematically approximated by partial differential equations, which are simultaneously solved to predict future water levels and fluxes. Mathematical groundwater model equations can be developed by creating either the finite difference or finite element grid covering the study area, and specifying boundary conditions, sources/sinks, soil properties, aquifer hydraulic properties, groundwater levels, and other model input parameters. More dependence on 5GIS tools can help to develop a conceptual model and display the input data over the modeled domain.

- **Enhancing Urban Water Demand Management**

Water resource management agencies in GCC countries have done an excellent job of providing adequate high-quality supplies of municipal and industrial water through investment in desalination plants, transmission and distribution networks, and through blending with groundwater. However, they have done little in the area of water demand management.

All GCC countries should place emphasis on water demand management. Demand management should include action plans towards saving water in the various water-use sectors. This could include controlling water wastage in irrigation and creating a combination of tariffs, financial incentives, regulations, and improved efficiency in municipal water use, in order to achieve conservation of scarce fresh-water resources and minimize water wastage.

- **Water Use Efficiency Improvement Measures**

Action is needed for improving water-use efficiency in both agriculture and domestic sectors. Still, agricultural policies do not encourage rational water use, although this sector contributes an insignificant proportion of GDP, which causes an inordinate share of the agriculture sector in the over-exploitation of this valuable resource. The main challenge for policy makers in the GCC countries is reducing the unsustainable rate of groundwater mining for use in agriculture, in addition to making agriculture more competitive.

Still, agricultural policies in GCC countries need to be revisited with the dual objectives of improving efficiency and competitiveness in the agricultural sector. This will help meet the challenges of integration within the global economy and water conservation to sustainable, or less unsustainable, levels. This requires an integrated approach to water resource management through the implementation of policies that will help achieve the common goal of optimizing the use of scarce water resources for highest value activities. This could be achieved through phasing out the subsidies and price support programs, increasing the integration with global marketing and using efficiency indicators for agricultural policy analysis.

- **Cost Recovery**

Reform in demand management of municipal water through the introduction or increase in tariff rates is essential for water conservation and achieving financial sustainability in water resource management. The municipal water tariff structure of each GCC country should be subject to rigorous review and structural reform. It is recommended to raise water tariffs with a progressive block tariff structure in order to reduce the subsidy level. It is also recommended to increase sewerage service fees in a phased manner in order to promote efficient water use. It should be noted that part of the reduced subsidies can be used to provide targeted subsidies for those below a certain threshold income.

Tariff systems should be made transparent so that any subsidies established by government policy are clearly identified and funded. It is worth mentioning that a seasonal rate tariff can be applied in some cases or cities based on peak usage seasons such as summer or high tourist seasons.

- **Water Recycling**

In most GCC countries, sanitation coverage itself seems to be rather high--in the range of 80-90 percent although not much data is available on this. What is clear is that some urban areas and most rural areas are covered mainly by on-site sanitation facilities, such as septic tanks and cesspits, which may not provide adequate treatment for preventing water pollution discharge to aquifers, wadis and coastlines.

In some cases, wastewater effluent is not treated, leading to the pollution of local water bodies, even to the extent of causing hygiene problems among local population. Treated wastewater can be used for landscape irrigation, amenity purposes, irrigation of non-contact agricultural crops, and aquifer recharge. A water recycling and re-use master plan on a regional scale should be prepared based on the availability of treated wastewater in time and space and the identification of its potential uses. Treated wastewater can be used more efficiently as a precious water resource.

Under the recycling and re-use plan, the degree of treatment and associated monitoring requirements should be defined based on the specific purpose of treated wastewater re-use as well as the required safety level and acceptable health risks. The use of modern treatment technologies should be considered in order to attain high health standard security for more extended use of the treated wastewater resources, considering both the environmental/health risks, economic benefits, and costs.

Furthermore, using treated wastewater for groundwater aquifers recharge programs should be piloted more extensively along with rigorous risk control measures for the environment and health. Aquifer storage recovery (ASR) using treated wastewater as well as desalinated water in winter has been piloted for establishing strategic groundwater reserves and maximizing its use in Kuwait and Abu Dhabi.

- **Sustainable Aquifer Management**

All GCC countries over-abstract their non-renewable aquifer system. This causes severe depletion and pollution of these aquifers and there is an attitude that the eventual destruction of aquifers and the full reliance on desalinated water for meeting all water demands is inevitable. GCC countries should view aquifers as a strategic resource to sustain various water uses, conserve ecosystems, and provide emergency reserves in the case of disruption of desalinated water supply due to large-scale oil spills.

GCC countries should adopt the following measures, taking into consideration the local conditions of each country:

- Establish a comprehensive groundwater regulatory (well permits, drilling rigs control, etc.) and monitoring system.
- Register all wells and installation of flow meters in all large farms.
- Impose volumetric metering and charges (ideally on a progressive scale) to send price signals for all groundwater users.
- Accelerate the installment of efficient irrigation systems and grow more water-efficient and high value-added crops.
- Facilitate possible water transfer through tradable water rights along similar lines as the aflaj system in Oman.
- Conduct extensive education and public awareness programs at schools and local levels, as well as an extensive media campaign that emphasizes the scarcity and economic value of water resources and the need for their conservation and economic use.
- **Institutional Reform**

Most GCC countries suffer from the fragmentation of water policies and responsibilities between various agencies and institutions. Thus, the existing institutional arrangements for coordination of various water allocation and water-use issues are still weak.

To overcome this problem, the overall planning functions towards sustainable and integrated water resources management in GCC countries should be consolidated into one agency that is not an operating entity in any water sector. This agency must then be able to view the water resources of the country on a macro scale with a view towards the integration of water planning and management into the overall economic and developmental planning of the country. In this manner, the critical water resources needed to support overall national development can be integrated into planning and development.

Furthermore, each GCC country should discuss and formulate continuous performance review programs. It is critical to establish clear and realistic management targets and a reform timeframe, as well as monitor oversight procedures for water resource authorities and operational agencies.

- **Policy Mix**

Water laws and the regulatory framework should be examined to determine what modifications need to be made to discourage water wastage and to improve the efficient use of this resource. For instance, water laws should mandate the registration and regulation of all wells within each country, the monitoring of groundwater extractions, and the issuance of water-use rights that allow authorities to limit extractions within safe yields. These laws should establish a strong regulatory body with power to regulate the extraction of water and to establish water-use rights. These laws should also establish a legal framework for the adoption of regulations on all matters regarding the use of water, including well excavation criteria, water appliance efficiency, water transport, water tariffs and collection, water quality, wastewater collection, treatment and

discharge or reuse, water user participation, etc. Much of this type of framework is in existence but is not adequately administered or has not been adequately developed into workable regulatory forms.

However, in order to have successful Integrated Water Resource Management it is better to depend on a policy mix of water regulations, economic incentives, and continuous education and awareness programs targeted to specific sectors and consumers.

Public awareness is an essential component of water conservation programs. Therefore, the cooperation of everyone, including civil societies, consumers, service providers, and policymakers in designing and implementing conservation measures is essential. Both education and raising awareness are indispensable if attitudes are to be changed.

- **Water Information Management System**

In order to develop water master plans based on accurate and reliable data, a consolidated and accessible water information system is an absolute necessity. In some GCC countries, important data gaps exist, most notably the volume of extractable groundwater resources and benchmarking data for indicating utilities management efficiency. In many of these countries, this effort is fragmented, and data is not readily available in a transparent and usable manner.

Countries should endeavor to establish a reliable network of data collection. They must subsequently integrate and archive this information with data collected from the private sector, regional and international organizations, and other sources. The data must be readily accessible by both the private and public sectors as needed and be compatible with its use in electronic modeling. It must be ensured that the provision of data with regard to quality, coverage, periodicity, timeliness, consistency, inter-agency coordination and staff training be clearly defined, programmed, and funded.

One such integrated structure could be the building of an integrated water resources information system which would link water information layers with those prepared by other government agencies (agriculture, industry, petroleum, etc.) that affect, or are affected by decisions taken by the appropriate water authorities.

- **Public-Private Partnership in the Water Sector**

The private sector can play an important role by partnering with the public sector to help improve the operational efficiency of utilities management and providing technical and management expertise and funds for major investments in water infrastructure. The provision of new technologies and operational strategies should be considered as one of the key elements for the development of comprehensive water supply and distribution as well as wastewater collection, treatment, and reuse programs.

The main rationale for private sector participation (PSP) in the water sector, in addition to attracting very large private investments needed for desalination and wastewater treatment infrastructure, is to improve operational efficiency, lower costs through the introduction of better technology and managerial capacity, and improved customer service.

- **GCC Coordination and Integration**

Water, whether surface or underground, by nature is a transboundary resource, and thus cooperation between GCC countries is a necessity. In an arid region like the Gulf, the lack of fresh-water resources and the competition over transboundary water resources could become a major source of conflict. To avoid this, these resources must be managed carefully to ensure the interests of the different stakeholders at different levels of

governance, including regional, national, and local, are protected.

The GCC issued regional guidelines for the conservation of water resources in member states. These guidelines outlined the proposed water conservation rules, executive procedures, and extensive groundwater registration, inventory, and regulation procedures. The GCC appears to provide a principal vehicle for the coordination of joint efforts to develop model integrated water resource management policies, procedures, and regulations that are adaptable to the Gulf region. The council can strengthen its role in harmonizing water legislation and policies among GCC countries by adopting a common water sector strategy and policy. This will help reduce excessive depletion of fresh groundwater, especially in aquifers shared by the GCC countries, and in water tariffs and cost recovery.

Under the umbrella of the Water Resources Committee of the General Secretariat of the GCC, many water-related projects have been undertaken. These include the GCC Water Grid whose main objective is to secure the national water systems in emergency conditions by interconnecting them, providing strategic and reliable water back up and diversifying seawater and fresh water sources, and the exploration of shared groundwater aquifers. Through this project a regional survey and exploration of the shared groundwater aquifers such as the Dammam Formation is undertaken allowing for evaluating and assessing the groundwater potentiality in terms of quantity and quality.

In addition, the GCC can initiate joint feasibility studies, and subsequent implementation and financing studies to establish their viability. These could include: (a) water importation from neighboring countries; (b) supporting research on more efficient desalination technology and the use of brackish water in agriculture; (c) establishing a regional hydro-meteorological information system for water resources; and (d) development of water databases.

Conclusions and Recommendations

In water thirsty countries like those in the Gulf region, water cooperation is a must to help achieve water security for the public, for development processes, and for environmental requirements. This simply means water security addresses environmental protection and seeks good governance for water resources. It also aims to end the fragmented responsibility for water between various authorities, municipalities, countries, regions etc. and integrate water policies across all sectors – finance, planning, agriculture, energy, tourism, industry, education, and health.

The water sector management challenge lies in addressing the following issues: balancing water supply-demand, enhancing water use efficiency, especially in the irrigation sectors, and optimizing allocation among competing sectors, effective and enforced institutional arrangements and legal frameworks, mandated coordination with other related policies, committing adequate financial and trained human resources, effective stakeholder participation, strengthening of water governance issues, forging partnerships with the private sector, and effective regional cooperation.

Priority should be given to shifting the water sector function to act as a regulator instead of provider of services in order to meet SDG 6 and the human water right, reducing water demand for agriculture, increasing the reuse of adequately treated wastewater, the gradual application of economic instruments and water saving technologies that account for the wellbeing of the poor, enhancing efficiency, and increasing productivity.

This research paper outlined the problems facing various water issues and the challenges confronting GCC countries with respect to the preservation of present water resources and the

means for its outgrowth. Based on the discussions in this study, the following are recommended:

- Revise and modernize water legislation and engage and strengthen the mechanisms for its implementation. Comprehensive institutional and legal reform programs are urgently needed to overcome the fragmentation of responsibilities in water sectors.
- Adopt a policy mix (legislations, incentives, and awareness programs) to encourage sustainable water production and consumption.
- Encourage the private sector role in constructing, operating, and maintaining various water projects and in supporting scientific research in the GCC states.
- Encourage the exchange of experience and knowledge, the expansion of the awareness program, and establish the capabilities in the areas of development and management of water resources in the GCC states.
- Use new technologies such as geographic information systems, remote detection systems, and other supporting systems for mathematical modeling in the field of planning and management of water resources.
- Transfer and develop the most recent desalination technologies and techniques to reduce the cost of desalinated water and to improve pre-treatment systems and materials employed in water desalination processes to reduce corrosion.
- Continuously assess progress to achieve ideal integrated and sustainable management of all available water resources through networks designed specifically for the monitoring of groundwater levels and quality.
- Advance the recycling of treated sewage wastewater for various applications in order to lessen the burden on the presently scarce natural water resources.

In conclusion, a GCC joint approach to cooperation around SDG 6 could also have a positive spill over impact on efforts to achieve other SDGs in the region, including in the areas of socio-economic development, food, energy, and migration among others.

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