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MINING BRINE AND WATER:

DESALINATION IN THE CONTEXT

OF THE WEST ASIA – NORTH AFRICA (WANA) WATER REGIME

By

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Statement of Authorship

I, the undersigned Mohammad Abu Hawash hereby declare that I am the sole author of this thesis. To the best of my knowledge this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted as part of the requirements of any other academic degree or non-degree program, in English or in any other language. This is a true copy of the thesis, including final revisions.

Date: June 10th, 2021

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Abstract

"Evidently, the world water crises of the future are already here in the Arab countries." This is what the President of the Arab Water Council chose to say in his foreword to the third *Arab State of the Water* report. Water scarcity pervades into every issue in the region. Between the 1960s and 2011, Arab countries on average lost 72.68% of their per capita renewable water resources. As a result, desalination is proliferating across West Asia and North Africa (WANA). Desalinated seawater helps WANA cope with ensuing water scarcity, but it also has several drawbacks. Desalination is energy intensive, desalination plants are vulnerable, and they produce a salty byproduct called (ocean) brine / seawater concentrate. The volume of brine produced everyday can be higher than that of potable water at some desalination plants, so each plant must have a way of disposing of this byproduct safely. This paper investigates whether the WANA region could use brine as a public good. The findings of this study (which was based in qualitative analysis and expert interviews) suggest that more investments in brine concentrate mining makes sense for the Gulf Cooperation Council (GCC) sub-region of WANA. As for the rest of WANA, municipal & industrial wastewater management and a reckoning with the colonial impact on the distribution of water resources will yield better returns.

Acknowledgements

This policy research paper was the product of approximately one year of desk research and several months of interviews and outreach to stakeholders. It was no easy feat, and many people made contributions to make this project a reality. Special thanks goes out to Thilo Bodenstein, Zoltan Iles, and Alexio Antypas for helping me lay the foundation of this paper through many discussions, which were mostly on video call (Zoom, Microsoft Teams, and Skype) and via e-mail due to the COVID-19 pandemic. I also want to thank my parents, Jumana and Sami, for encouraging me to go on with this project despite many challenges. I want to thank my friend Saria Samakie and his partner Galina, with whom I spent many late nights in the Spring of 2021 working on this Thesis. They accommodated my excitement about this research topic and offered a listening ear when I needed to express my anxieties about this research project. Finally, I want to acknowledge Larisa Abulghanam, Hazim El-naser, Christopher Fellows, Barik Mhadeen, Mazin Qumsiyeh, and Tarek Zureikat for speaking with me at length about the various themes of this research project. Their input is an integral part of my findings. I would also like to thank Khaldon Khashman and Waleed Khalil Al Zubari for providing me with important snippets of information in our correspondence. Finally, special thanks goes out to my colleagues at the Jordanian Embassy in Washington DC, Dana Zureikat and Sammy Abdulrahim. I deeply appreciate their kindness and patience throughout the grueling process of writing a Master's thesis while also holding a full-time job.

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List of Abbreviations

Absorption Desalination (AD)

Aqaba-Amman Water Desalination and Conveyance Project (AAWDC)

Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD)

Arab Countries' Water Utilities Association (ACWUA)

Arab Water Council (AWC)

Arab Water Week (AWW)

Bahrain Electricity and Water Authority (EWA)

Desalination Technologies Research Institute (DTRI – also known as WTRI)

Environmental Agency- Abu Dhabi (EAD)

Egypt Water Regulatory Authority (EWRA)

European Desalination Society (EDS)

European Union (EU)

Gulf Cooperation Council (GCC)

International Desalination Association (IDA)

Jordan Ministry of Water and Irrigation (MWI)

Kingdom of Saudi Arabia (KSA)

King Abdulaziz University of Science and Technology (KAUST)

Kuwait Institute for Scientific Research (KISR)

Kuwaiti Ministry of Electricity and Water (MEW)

League of Arab States / Arab League (LAS/AL)

Middle East Water Forum (MEWF)

North African Minister's Council on Water (N-AMCoW)

Oman Public Authority for Water (DIAM)

Qatar Sustainable Water and Energy Utilization Initiative (QWE)

Qatar General Electricity and Water Corporation (KAHRAMAA)

Red Sea – Dead Sea Water Conveyance Project (Red-Dead)

Saline Water Conversion Corporation (SWCC)

Saudi Water and Electricity Regulatory Authority (ECRA)

Sea Water Reverse Osmosis (SWRO / RO)

Surface Discharge of brine (SD)

Table Salt / Sodium Chloride (NaCl)

Total Dissolved Solids (TDS)

Valuable Mineral Recovery (VMR)

Water Sciences and Technology Association (WSTA)

West Asia – North Africa (WANA)

Zero Liquid Discharge (ZLD)

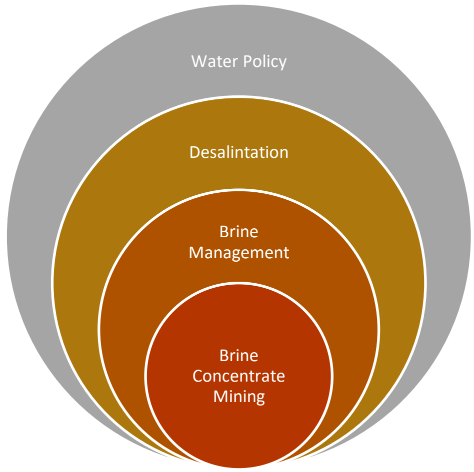
Introduction

This paper consists of five parts. The first part outlines the method of analysis. The second part presents the data around brine mining in the context of WANA's water regime. The third part investigates the available options for brine mining. The fourth part is a case study of Jordan derived from interviews and desk research, coupled with a brief analysis of some of Jordan's peers in WANA. The fifth part discusses the institutional framework for brine, desalination, and water policymaking in WANA then presents a set of policy solutions and action items.

Like the plastics industry, desalination created an incomplete cycle by creating a byproduct that is difficult to reuse. An incomplete cycle causes an increase in waste. For desalination to avoid this, the industry must continue investing in brine mining and knowledge-based economies that continuously improve on existing technologies. Humanity knew for ages that the sea contains many valuable elements and minerals. If West Asian & North African (WANA) countries employ more efficient desalination techniques, they can meet future demand for water more easily and possibly generate revenues from desalination through brine mining. A knowledge-based economy can gradually take WANA towards that goal.

Some regional experts, such as Vice President of the Water Sciences and Technologies Association (WSTA) Waleed Khalil Al-Zubari, envision a 'Water-Energy-Food Nexus' where the systems of obtaining and distributing water, food, and energy are interconnected to conserve resources. Others describe the improvements in desalination technology as potentially leading to an 'Integrated Water Resource Management.' WANA is in dire need for a different approach to water. Still, desalination is not for everyone. It is extremely energy-intensive and not every WANA country has the expertise and/or capacity to dispose of the brine safely.

Illustration 1: The Context of Brine Concentrate Mining



There is an astonishingly wide range in the social, economic, and political experiences of the people of WANA, which sometimes is referred to as the 'Arab world,' or the 'Middle East & North Africa (MENA).' Some of the poorest and richest, least and most educated, and least and most productive regions of the world are in WANA. Some of the world's oldest and newest cities and countries are also here, leading to the cohabitation of a vast array of perspectives on desalination and its byproduct. Yet the people of the region also share many things. Most people speak Arabic. The major religions of the region all trace their roots to the Bronze Age civilizations (the Abrahamic faiths), creating a coherent cultural background for most residents. Nonetheless, the socioeconomic inequalities of WANA shape who can and cannot invest in brine concentrate mining. Some experts have argued that these socioeconomic inequalities created "Three Arab Worlds" where the quality of life varies greatly (Rauch & Kostyshak, 2009). Thus, it is difficult to use WANA as an accurate aggregate in socioeconomic studies.

Due to the divergence in socioeconomic and political contexts in WANA, brine concentrate mining should not apply uniformly across the region. Nonetheless, the linguistic, cultural, topographical, and environmental similarities warrant close cooperation in the water sector. There is much work to be done to achieve collaborative water policy in WANA.

WANA is brought together under the umbrella of the League of Arab States (LAS). Eight of the eleven most water-scarce countries in the world are members of the LAS. This makes water scarcity a major social and policy challenge for this organization, which characterizes itself as a political and economic union. Unfortunately, the LAS has not created any institutions to address water scarcity since 1968- when it created *The Arab Center for the Studies of Arid Zones and Dry Lands* (ACSAD). This research center, headquartered in Damascus, is tasked with "unifying national efforts to develop scientific agricultural researches in the arid and semi-arid areas and exchanging information and expertise in a way that ensures benefiting from scientific advancements and transferring, developing and localizing modern agricultural techniques in order to increase agricultural production in these areas."[1] The Syrian civil war severely curtained ACSAD's work. The research center focuses mostly on projects in Syria until diplomatic relations with Syria return to normal.

As a result of the vacuum left by the LAS, other regional organizations have emerged to lead the way in regional policymaking. Some of these include the Arab Water Council (AWC), the Middle East Water Forum (MEWF), the North African Ministers Council on Water (N-AMCoW), and the Water Sciences and Technologies Association (WSTA).

Also connected to the issue of desalination is the construction of dams. The WANA region invested heavily in the construction of dams, which led to a shared soil-erosion and sediment build-up problem (among other consequences). More recently, WANA's neighbors have also invested in

[1] Acsd.org *About the Center*. Accessed April, 2021. Link: https://acsad.org/%d9%84%d9%85%d8%ad%d8%a9-%d8%b9%d9%86-%d8%a7%d9%84%d9%85%d8%b1%d9%83%d8%b2/?lang=en

dam construction. Today, Turkey and Ethiopia control the flow of water for hundreds of millions of WANA's citizens due to upstream dam construction. WANA's citizens are also very young overall and across the board. Therefore, similar demographic and generational dynamics affect the water challenge throughout the region. More recently, the region began to embrace a common solution to water scarcity – desalination. If combined with efficient infrastructure, responsible consumption, and agricultural reform, desalination can ease the immense pressure on the water supply in WANA. The 'reject brine' from desalination requires a constantly evolving methodical waste management process.

Through a combination of desk research and expert interviews, this thesis showcases the potential uses for the byproduct of brine and the possibility of implementing brine mining on a commercial scale. As a subset of the waste management industry, brine mining requires unique conditions to succeed. Since the contents of ocean brine (table salt/NaCl, magnesium, bromine, etc…) are not as concentrated as in mines and inland seas, desalination must be available at a large scale to make brine mining cost-effective. If environmental regulations end exploitative magnesium and bromine mining practices worldwide, the price of these elements might rise to a level high enough that makes brine mining not only cost-effective but also profitable. However, most of the WANA countries do not produce enough ocean brine to warrant investments in brine mining by themselves. As a collaborative effort, however, the WANA region could pool its resources to revolutionize both brine mining and wastewater management. Currently, the only region capable of investing in profitable brine mining is the GCC. The rest of WANA has a comparative advantage in municipal & industrial wastewater management, and should direct is resources towards that sector. Depending on the performance of the GCC in ocean brine mining, the rest of WANA could join the GCC's efforts.

The GCC countries adopted desalination as the main source of municipal drinking / potable water decades ago. They have accumulated an immense wealth of knowledge and expertise in this field. Saudi Arabia is utilizing new knowledge and technology to construct new plants in Shoaiba and Jubail that are more efficient at utilizing seawater than most other desalination plants in the world. The anticipated utilization rate at the new Jubail 2 and Shoaiba desalination plants is expected to increase from around 40% to nearly 80%. This will make profitable brine mining a real possibility for Saudi Arabia. Publicly, Saudi Arabia announced that it will share the know-how with the rest of the world.

For the rest of WANA, desalination and brine mining are not as promising as they are for the GCC. Furthermore, the GCC has not been as affected by colonialism as the rest of WANA. Indeed, water scarcity has been exacerbated by post-colonial boundaries. These boundaries are why two-thirds of the region's surface water flows in from outside the region – namely from Turkey and Ethiopia. Both Turkey and Ethiopia are redirecting the flow of water into WANA to serve their interests. This has made desalination and brine mining a more realistic options for countries like Syria, Iraq, and Egypt who all once had an abundance of fresh water. Sudan, which lies in between Ethiopia and Egypt, will enjoy a more regulated flow of the Nile thanks to the Renaissance dam. This will reduce the incidents of flooding in many of Sudan's urban centers. However, Sudan's agricultural sector may also lose out on water supplies due to the Renaissance dam. The next few years will show the real environmental consequences of this dam on Sudan, which is currently being filled. Coastal communities in Sudan have already invested in desalination, with some successful models of solar desalination successfully tested in the republic.

Like Ethiopia and Turkey, Israel is another country that considers itself to be outside of the region's governance framework. As such, it has redirected the flow of water away from its neighbors in much the same way as Turkey and Ethiopia. A similar case from outside the region is Singapore and Malaysia, who were also separated by post-colonial boundaries. Singapore invested heavily in filtration technology to support its wastewater reuse projects. These investments enabled the creation of a new, non-conventional source of potable water – municipal wastewater. Saudi Arabia and its peers in the desalination world built further on Singapore's achievements in wastewater filtration, since these systems are similar to those found in desalination plants. It will become apparent throughout this paper that desalination and brine mining are intricately connected to colonial boundaries across the world.

Before Turkey, Iraq, and Syria were divided by colonial powers into separate nations, the Tigris and Euphrates were a shared resource. No one controlled the flow of these rivers. Even if desalination and brine mining continue to proliferate across the region, WANA countries should still find a way to collaborate in the governance of their water basins.

Brine concentrate mining is only one of many fields of the water sector where WANA countries can collaborate. Wastewater management and environmental policy are two other major fields where further collaboration can unleash the region's potential. In terms of wastewater management, WANA countries can share the cost burden of new research on wastewater systems. In environmental policy, WANA countries can work together to end the exploitation of shared resources like the Dead Sea, which would also greatly benefit the brine concentrate mining industry by making the extraction of bromine from the ocean (instead of the Dead Sea) more cost-effective.

Part 1- Desalination in the Context of WANA's Water Regime: Project Methodology

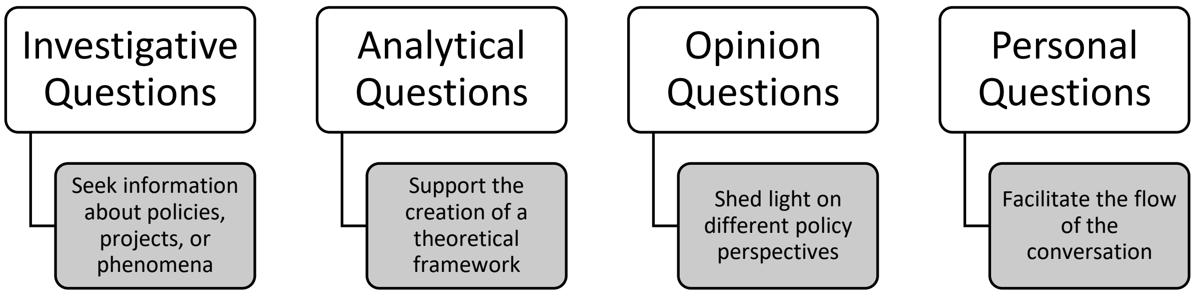
In his article titled "Water Resources in Arab Countries," Gabi El-Khoury sheds light on a sobering reality in the League of Arab States (LAS). With 10% of the world's area, Arab countries only receive 2.1% of the world's average annual precipitation (El-Khoury, 2014). This part of the world also has few rivers and lakes and over-exploited underground water. Despite this shared challenge, the approach taken towards water policy in WANA differs greatly from country to country. Any study of WANA's brine mining industry requires an acknowledgment of this divergence.

This paper utilizes expert interviews to help explain the divergence in water policies and contextualize the issue of brine management in WANA's water regime. In total, eight experts provided their input on this project. There were in-depth interviews with six experts and email correspondence with two more. The selection process of the interviewees integrates the educational, professional, and political background of each interviewee and the information their background endows upon them. In turn, the information gained from these interviews shaped the analytical framework of this project. For example, Dr. Mazin Qumsiyeh – Founder of the Palestine Museum of Natural History –introduced the colonial context into the framework of this project.

Profile of the Interview Questions

The interview questions build on a review of the literature on the issue, outlined in part 2 of this paper. The interviews included four types of questions. They are outlined below:

Illustration 2: Types of Interview Questions



The interviews took place over two rounds. Each interviewee's list of questions caters to their background and qualifications, enables a holistic conversation to take place, and gauges out information about brine mining or its context in WANA. Based on the information obtained from the first round of interviews, the second round of interviews included modified questions. The types of questions remained the same, and the objective of the interviews in both rounds remained the same – which is to understand whether it is possible to use ocean brine as an environmental public good in WANA (or not). The questions were either investigative, analytical, opinionated, or personal. Examples of investigative questions include:

Illustration 3: Examples of Investigative Questions

Examples of Investigative Questions	Has Palestine ever considered desalination as a way to source water and minerals? Why/why not?
	What are some pressing issues being discussed at the moment at the Middle East Water Forum?
	Soon, Saudi Arabia will pioneer filtration technology that will enable it to utilize seawater at a rate of 79.9% - over 30 percentage points higher than current rates. What enabled these developments, and what comes next?

The investigative questions served to augment the desk research of this thesis project. They also gave interviewees the chance to speak about policy issues that matter to them. However, analytical questions composed the bulk of the interview questions. Therefore, these questions and the responses they received charted the course of the interviews. Examples of analytical questions include:

Illustration 4: Examples of Analytical Questions

Examples of Analytical Questions	How will recent improvements in brine concentrate mining transform the desalination industry?
	There is persistent inequality in the West Asia / North Africa (WANA) region, including in terms of water resources. Can desalination help mitigate these inequalities?
	How has violence over the past 10 years affected water governance in West Asia?

The answers to the analytical questions improved this paper's theoretical framework. With every interview, they introduced new perspectives and concepts, such as the impact of post-colonial boundaries on water governance and the role of terrorism in shaping the water regimes of Syria, Iraq, Yemen, and Libya over the past decade. The analytical questions also helped distinguish brine concentrate mining from the rest of the mining industry. For example, the correspondence with Christopher Fellows, a senior expert at DTRI, helped clarify the distinction between brine mining from desalination and Zero Liquid Discharge (ZLD) from underground mining. To put it shortly, the mining industry needs ZLD due to the toxicity of its wastewater. This is not an issue for most desalination plants. In previous decades, brine produced from desalination plants contained potentially harmful anti-scalants and other chemical compounds. Today, most additives introduced into desalination are designed in a way that minimizes their impact on the toxicity of the brine.

In addition to the analytical questions, opinion questions served to bring the interviewee's voice into the conversation. Examples of opinion questions include:

Illustration 5: Examples of Opinion Questions:

Examples of Opinion Questions	By enabling wasteful water habits, has desalination done more harm than good to the GCC?
	What role do you think regional organizations can play in addressing water scarcity in WANA?
	Do you think the adverse effects of profitable brine concentrate mining in the Dead Sea are worth the risk?

Opinion questions seek to identify the interviewee's vantage point based on their experience and knowledge. They enable the interviewees to share their perspectives. On some occasions, interviewees supported their claims with anecdotes and experiences from their professional careers. These anecdotes are an added reward to the inclusion of opinion questions.

The final category of questions is the personal questions. These questions usually came at the beginning and end of the interviews. They are biographical in nature, inquiring into lessons learned from past professional, academic, or other kinds of experiences. The personal questions also helped the interviews flow more smoothly. On a few occasions, personal questions also introduced new concepts and ideas into the interview. Interviewees were encouraged to explore these concepts and ideas further. To prevent these explorations from divulging too far away from the scope of the interview, personal questions revolved around how water scarcity affected the interviewees' lived experience. Examples of personal questions include:

Illustration 6: Examples of Personal Questions

Examples of Personal Questions	What is it like to be a policymaker/scientist/entrepreneur/engineer/etc. in a water scarce country?
	How has the colonial legacy in the region affected your work as a scientist?
	Could you speak about your experience in working with any regional/international water governance organizations?

These questions prevented the interviews from becoming a dull affair, and acknowledged the lived experience of the interviewee. They also provided context for the answers to the analytical and opinion questions.

Qualitative Analysis: Understanding Parts 2 & 3

Research on parts 2 and 3 of this paper began months before the interview process. It continued throughout the interviews. The interviews in turn shaped the choice of new literature and data included in part 2. Owing to brine concentrate mining being an industry derived from desalination, it is important to situate any study of brine concentrate mining in the context of the water policy governing the country / region under study. This paper relied on the extensive literature on WANA's water regime and desalination industry. Reports and events by the AWC, WSTA, IDA, MEWF, ACWUA, LAS, World Bank, the Islamic Development Bank, the UNDP, the GCC, and many more institutions and organizations provided the bedrock for this paper's data analysis.

In addition, this this paper triangulates the findings of the region's water governance bodies with the developments in the global brine mining industry. The IDA's online repository of manuscripts and seminars play a significant role here, along with the knowledge production of international academic journals focused on desalination, mining, water, and wastewater management. The GCC region is better at collecting data about its desalination industry than the rest of WANA. Thanks to the GCC statistics book, deeper insights are available about the GCC's desalination sector than the rest of WANA. These elements combined produce part 2 of this paper.

Profile of the Interviewees: Understanding Part 4

Out of the eight experts who provided input on this project, five of them are Jordanian. They are Larisa Abulghanam, Tarek Zureikat, Hazim El-Naser, Khaldon Khashman, and Barik Mhadeen. The overrepresentation of Jordanians among the interviewees is not by design. The two interview rounds included experts from over ten countries. All experts had the chance to provide their input on this project in correspondence or via video call. As the author of this paper, I speculate that the greater success in obtaining responses with Jordanians might be because of my Jordanian citizenship and Jordan being at the center of my personal and professional networks.

Because of the inadvertent overrepresentation of Jordanians among the interviewees list, this project incorporates an abundance of information and insights about Jordan in comparison to the rest of WANA. This warranted the creation of a unique case study section on Jordan to highlight this project's in-depth study of the country. This is the origin of part 4 of this paper.

Profile of the Institutions: Understanding Part 5

Part 5 begins with a survey of the active regional and international organizations involved in the governance of WANA's water regime. There is a significant overlap between parts 2, 3, and 5.

This is because part 5 of this thesis was borne out of the findings of parts 2 & 3. This section outlines the role played by the key players in WANA's water regime and a brief analysis of their potential contributions for the future of WANA's brine mining industry in particular and WANA's water governance in general. Following that, this section delves into policy solutions and action items for the WANA region's water sector.

Part 2 - Mining the WANA Seas: The Numbers

Saudi Arabia alone produces 20% of the world's desalinated water (Al-Abdul Karim/SWCC, 2021). If we 'zoom out' of Saudi Arabia to include its neighbors in the Gulf Cooperation Council (GCC), we would be looking at the source of 43% of the world's desalination. If we zoom out even further, we would be including all of WANA - the most water scarce region in the world. Desalination found a foothold here, largely due to the pervasive water scarcity. WANA is home to approximately 77% of the world's desalination plants, making it the epicenter of the desalination industry (Ciocanea et. al, 2013).

Using the "Knowledge-Based Development" framework (Coates Ulrichsen, 2012), one can identify several policy solutions for the WANA seawater desalination challenges. These challenges revolve around the energy costs of desalination, the efficiency of its filtration systems that create brine after extracting potable water, and the possible ways to utilize that brine. Brine usually refers to any saline solution. However, the minerals, pollutants, and other chemical compounds that exist in sea / ocean water varies between different water bodies (Manasrah, Abu Hilal & Rasheed, 2019).

Brine concentrate mining is not a standalone industry. It is a derivative industry completely dependent on the desalination industry and the water governance regime that regulates desalination. Brine mining is a subset of brine management, which is built around the byproduct of desalination. It differs from the 'regular' mining industry because it also is a sector of the waste management industry.

Brine mining also serves the mining industry. Mines use large amounts of water, and they can benefit from improvements in filtration systems and technology that are often funded by the desalination industry. These improvements enable efficient water reuse in mines. The IDA facilitates the exchange of knowledge and information between researchers in mining and desalination. This creates new international business ties, such as the links between the GCC's desalination sector and the South American mining sector.

The main water bodies in WANA are the Mediterranean, the Red Sea, the Gulf of Aden, the Arabian Sea, and the Arabian-Persian Gulf. Each of these water bodies has slightly different physical and chemical properties that warrant a different approach towards *brine management*. For example, the Red Sea tends to get 'saltier' the deeper down one goes due to the presence of thermal springs in the sea's deep basins (Manasrah, Abu Hilal, & Rasheed, 2019). This is not the case in the Arabian-Persian Gulf, which is generally a shallow water body where salinity increases the closer one gets to the shore. These slight yet vital nuances of each water body create a divergence in the kinds of risks associated with desalination that depends on region.

Despite the differing characteristics of each water body in WANA, the challenges posed by the increasing use of seawater desalination on the main water bodies are largely similar. Perhaps the most alarming challenge is the severe decline in per capita water resources in WANA. Due to a combination of increasing population, rising per capita water demand, and overexploitation of water resources, the share of per capita water resources plummeted in the region. According to the UNDP Arab Human Development Report, most Arabs believe that the lack of public investment is the primary cause for the worsening water and sanitation situation (UNDP, 2020).

For some parts of WANA – namely the GCC – this is not a significant development. The GCC's water resources were meagre in the first place. The GCC governments anticipated this challenge and invested heavily in desalination as far back as the 1970s. By the turn of the century, the GCC had become the world's leader in desalination. The GCC's decision makers responded to the environmental consequences of the depletion of renewable water resources more recently by investing in water reuse, but the region is yet to take action on the use of non-renewable groundwater (aka: fossil water).

Illustration 7: Why are per capita water resources declining in WANA?

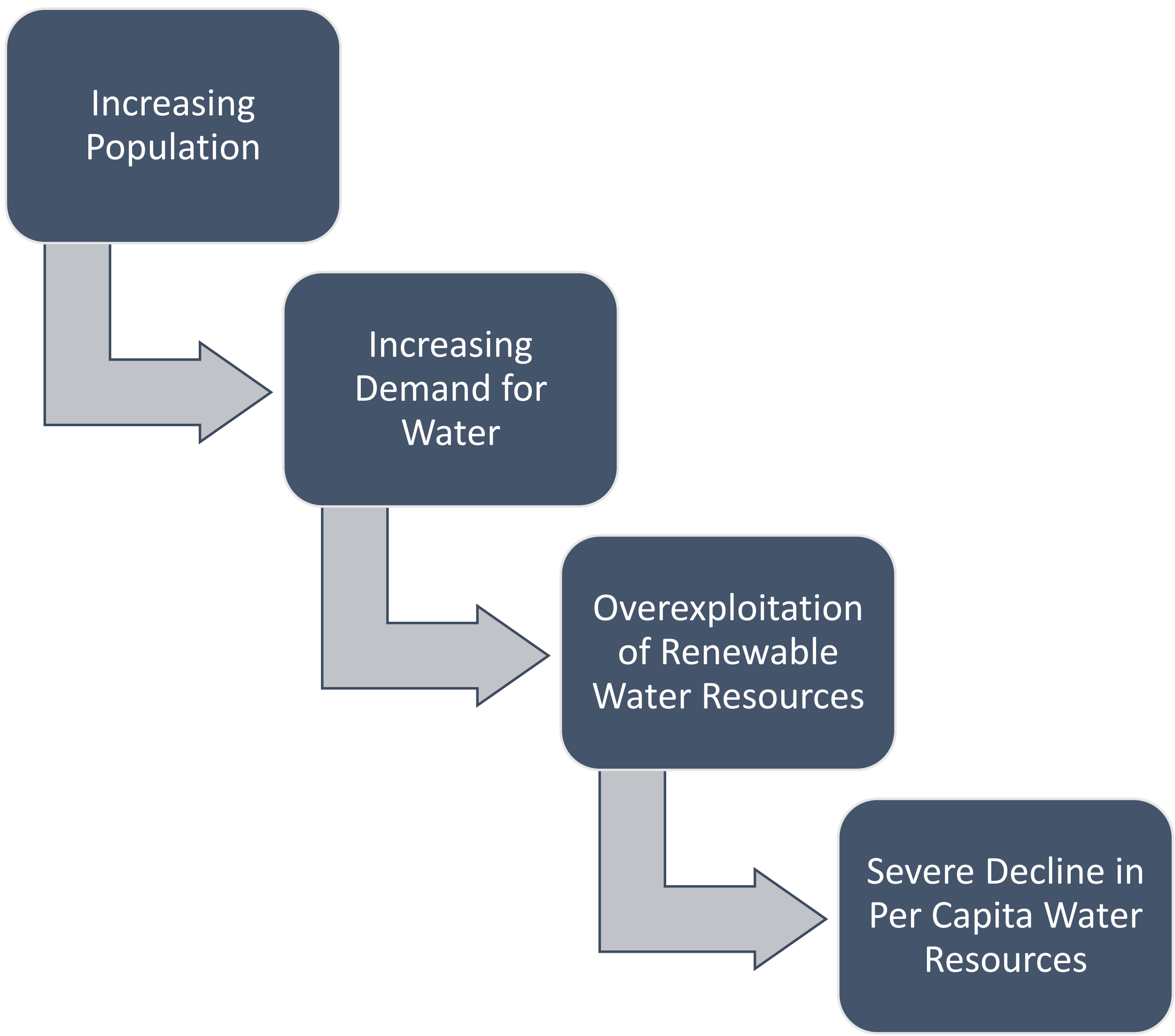


Table 1: Rate of decline in per capita renewable water resources in the League of Arab States, (1962-2011). Source: UNDP Water Governance in the Arab Region Report.

State	Percentage of decline in per capita renewable water resources (1962 – 2011) (%)
Algeria	68.9
Bahrain	87
Comoros	73.5
Djibouti	89.5
Egypt	64.4
Iraq	76.3
Jordan	84.7
Kuwait	No decline
Lebanon	52.4
Libya	77.4
Mauritania	74.5
Morocco	62
Oman	79.5
Qatar	97
Saudi Arabia	84.8
Somalia	69.2
Sudan & South Sudan	72.9
Syria	76.4
Tunisia	58.7
United Arab Emirates	98.7
Yemen	78.5
Average rate of decline (excluding Kuwait)	**72.68%**

Table 2: Total population of the League of Arab States' constituents in millions, (1992 – 2017). Source: UNFAO - AQUASTAT.

Year	Population
1992	283,142,430
1997	316,149,122
2002	348,052,070
2007	385,604,882
2012	428,690,018
2017	471,814,759

Algeria has four large desalination plants, creating a problem with brine discharge on its Mediterranean coastline. Algeria uses ‘diffusers’ to solve this issue (Amitouche et. Al, 2017). As their name suggests, diffusers distribute the brine discharge across a wide area to ease the diffusion of the minerals into the sea and prevent a rise in salinity near the desalination plants. Egypt is currently investing in the construction of more desalination plants, and is quickly outmatching Algeria. The GCC also relies on diffusers in many desalination plants. Although diffusers do not generate revenues for desalination, they can mitigate the harmful environmental impact of desalination.

Figure 1: A picture of marine life thriving in vicinity of the Perth desalination plant outfall in Australia. This plant utilizes diffusers. Source: Eng. Nikolay Voutchkov

Figure 2: A seahorse moving around in the area of the Perth desalination plant’s brine outfall. Seahorses are known to be saline-sensitive. Source: Eng. Nikolay Votchkov

Table 3: Per capita renewable water resources worldwide in cubic meters per person per year (2015). Source: Our World in Data.

Region	Year	Per capita renewable resources
Africa	2015	3319
Americas	2015	19725
Asia	2015	2697
Central America and Caribbean	2015	8397
Central Asia	2015	2420
East Asia	2015	2115
Eastern Europe	2015	21383
Europe	2015	8895
West Asia	**2015**	**1444**
North America	2015	12537
Northern Africa	**2015**	**256**
Oceania	2015	29225
South America	2015	30428
South Asia	2015	1131
Sub-Saharan Africa	2015	3879
Western & Central Europe	2015	4006
World	2015	5829

Table 4: Arab public opinion on the main reasons for worsening water and sanitation services (2020). Source: UNDP Arab Human Development Report.

Reason Given	Percentage of respondents who checked-off this option (%)
Lack of public investment	61.8
Lack of private investment	27.2
Depletion of infrastructure as a result of armed conflict	47.9
Depletion of infrastructure as a result of refugee influx	14.5
Other	7.1

Over time, the disposal of highly saline brine solution from desalination plants will increase the salinity of some shorelines and semi-enclosed water bodies, even with the use of diffusers (Ciocanea, Badescu, Cathcart, & Finkl, 2013). This is because of the continue proliferation in desalination across the semi-enclosed seas of the WANA region. Already there is a radius of dangerously saline seawater around some desalination plants in the WANA region. If our desalination practices do not change, we risk expanding these radii further. The real environmental consequences are yet unknown, but it is better not to wait until the situation deteriorates further.

Figure 3: Freshwater Withdrawals as a Share of Internal Sources (2014). Source: Our World in Data.

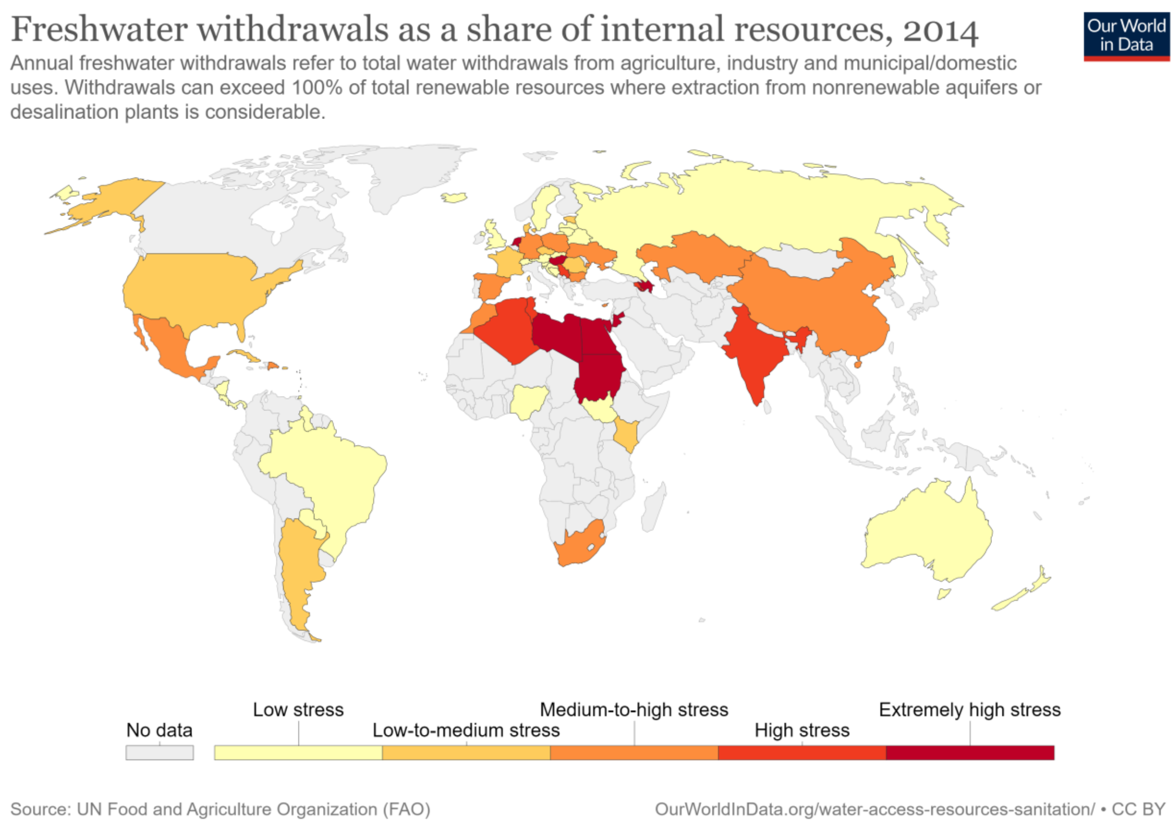
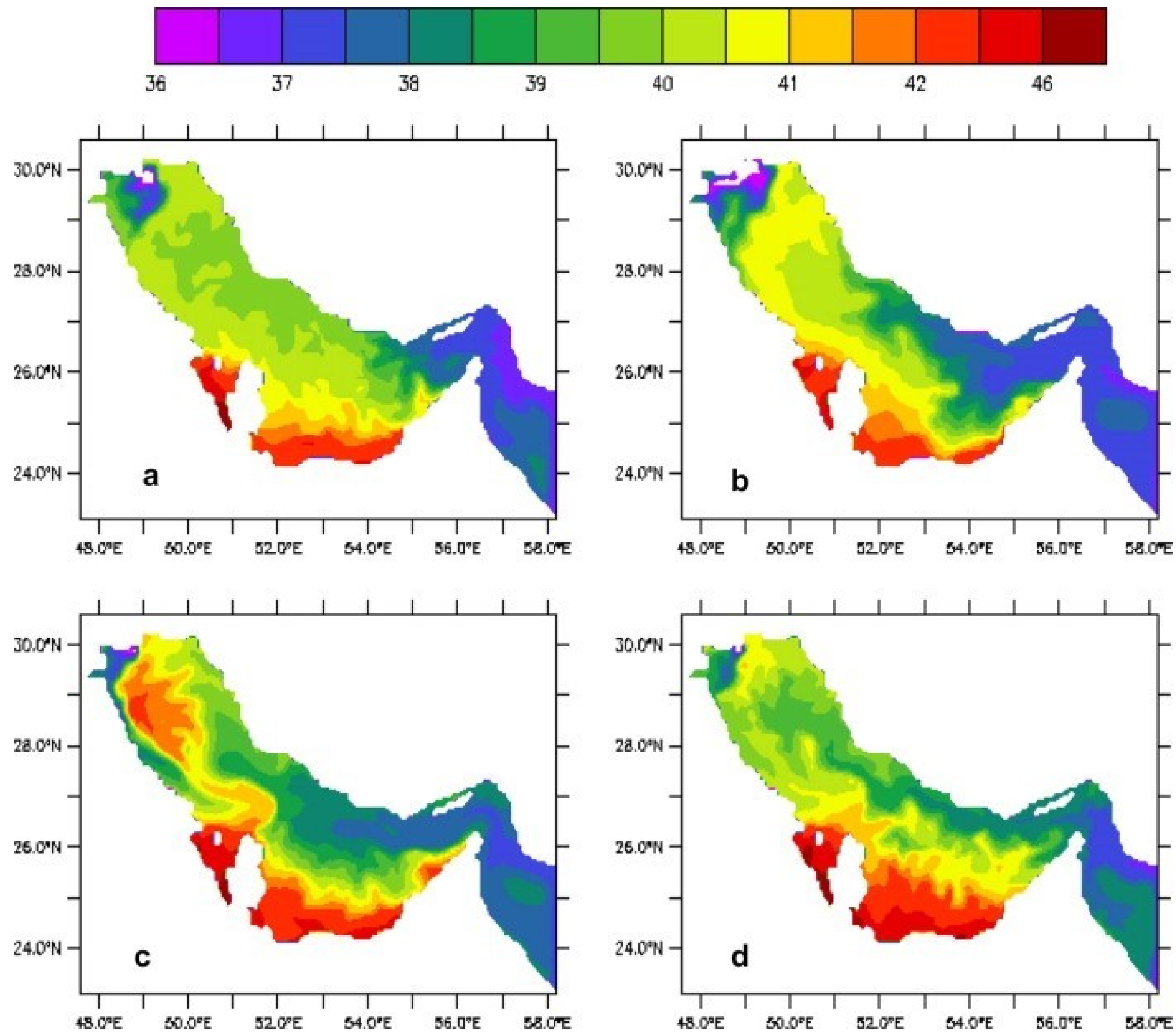


Table 5: Quantity of reused water in the GCC (2012-2018), in millions of cubic meters. Source: GCC Statistics Book.

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
GCC	657.45	689.14	863.56	869.97	-	-	-
UAE	308.65	376.8	431.25	451.73	470	493.9	513
Bahrain	12.8	13.1	15.1	15.1	14.8	16.1	31.6
KSA	194	183	256	229	216	254	302
Oman	16.2	-	27.3	31.9	33	46.1	58.25
Qatar	78.8	80.04	94.01	97.37	104.18	130.53	150.88
Kuwait	47	36.2	39.9	44.87	-	-	-

Figure 4: Salinity of the Persian Gulf (Hassanzadeh, S., Hosseinibalam, F., & Resai-Latifi, 2011). Figure shows simulated horizontal salinity (psu). (a) January 15, (b) April 15, (c), July 15, (d), October 15.



Ocean brine experts are building on innovations in mining and waste management/treatment. The salt industry is also a source of inspiration. After all, 75-90% of the 4.5-5% mineral content of seawater is composed of sodium (Na) and chloride (Cl). In mining, ocean brine (aka: seawater concentrate) experts are building on innovations in 'Zero Liquid Discharge' (ZLD) to improve the efficiency of brine mining. Saudi Arabia’s role is central to this process, especially since it is responsible for 20% of the world’s desalination. Both the desalination and the mining industries will benefit from improvements in filtration.

While the real consequences are unknown, there is a consensus among experts that enclosed regional seas like the Arabian-Persian Gulf and the Red Sea are at a higher risk of being harmed by excessive brine disposal than open seas and oceans (Ciocanea et. al, 2013). 6.4 million Cubic meters of desalination brine was discharged every day into the Red Sea in the 1990s. In the 2000s, the figure rose to 6.8 million Cubic Meters (Ciocanea et. al, 2013). The main contributors of desalination brine discharge in the Red Sea are Saudi Arabia, Jordan, and Israel. Egypt is now another major contributor. In the 2010s, the volume of desalination brine discharge is even higher but exact estimates vary due to Egypt’s speedy and explosive entry into the desalination market.

The challenge posed by desalination is compounded by exponentially increasing demand for water in the WANA region. For example, Egypt recently opened the Al Galalah desalination plant (Metito Group, 2019). Al Galala desalination plant (located on the Red Sea’s northern shores) is projected to service 1,000,000 citizens and will produce 150,000 Cubic meters of water per day. However, this does not come close to meeting Egypt’s increasing water demand, so president Sisi announced yet another desalination plant (Takouleu, 2020). This new plant will be located at El Arich on the Mediterranean. It will have double the capacity of al Galalah, at 300,000 Cubic meters of water per day. This makes the plant at El Arich the largest desalination enterprise in Africa and one of the largest in the world. For Egypt, desalination became a matter of national security especially because of Ethiopia’s renaissance hydroelectric dam. The renaissance dam is located upstream on the Nile. It will give Ethiopia control over the flow of water to Egypt. Iraq suffers from similar issues with its counterparts Syria and Turkey, who built many dams on the Tigris and

Euphrates rivers. As such, Iraq is interested in enlarging its seawater desalination capacity for the benefit of its water (and national) security. As more countries begin to engage in desalination as a reliable method of supplying clean drinkable water, the time horizon for fixing our brine management problem shrinks. In other words, disposing more and more brine using current methods will only hasten the coming of disaster.

Like Egypt, Jordan is also increasingly reliant on desalination. While it currently sources much of its water from the Disi underground reservoir that it shares with Saudi Arabia, Jordan also launched its first RO desalination plant in 2017 (desalination.biz). AquaTreat, a Jordanian company that provided desalination and brine management services to oil companies in the GCC, built the plant. Unlike its peers, Jordan's experiment with desalination is focused on the industrial sector and not on supplying households. This plant is rather small, producing 15,000 Cubic meters per day. Thirty percent of the production will go to the Arab Fertilizers & Chemicals Industries (KEMAPCO), a company that uses locally sourced phosphates to produce fertilizers for export (desalination.biz). The city of Aqaba's Aqaba Water Company purchases the remaining seventy percent. Through the Aqaba-Amman Water Conveyance and Desalination Project (AAWDC), Jordan will expand its desalination capacity in the coming decade as the non-renewable Disi reservoir runs dry. Part 5 of this paper discusses AAWDC in detail. On another note, Jordan also receives several million Cubic meters of water every year from Israel in accordance with Wadi Araba peace agreement (Elmusa, 1995). Massive population growth since then has reduces the importance of this provision in the agreement, though it remains an important commitment that ensures peace between the two countries. A significant portion of the water delivered to Jordan by Israel comes from seawater desalination plants.

Compared to its desalination capacity, Jordan's wastewater management is far superior. This fits Jordan's needs, since its population centers are far from the shoreline. Nevertheless, Jordan is considering the construction of a new pipeline that transports desalinated water from Aqaba to Amman.

The largest consumer of desalinated water and hence the largest producer of seawater brine in the world is the Gulf Cooperation Council region (GCC). The GCC is composed of Kuwait, Bahrain, Saudi Arabia, Qatar, the UAE, and Oman. These countries have minimal freshwater resources (Sezer, Evis,& Koc, 2017). Kuwait, Saudi Arabia, Qatar, and Bahrain do not have any permanent rivers (except for a few small rivers and stream in the Hejaz region). Qatar obtains 99.9% of its potable water through desalination (Sezer et. al, 2017).

Table 6: Quantity of Desalinated Water in the GCC (2000-2018) in millions of cubic meters. Source: GCC Statistics Book

	2000	**2005**	**2010**	**2014**	**2015**	**2016**	**2017**	**2018**
GCC	-	-	-	5,459.56	5,767.67	6,063.12	6,327.99	-
UAE	701.9	1,241.3	1,679.6	1,949	2,004.7	2,004.9	1,979.24	2,20.53
Bahrain	61	95.7	188.2	219.2	241.6	241.9	239.2	-
KSA	797.2	1,025	1,485	1,912	2,050	2,241	2,458	2,541
Oman	-	-	-	244.1	261.4	306	326.1	340.4
Qatar	147	195	374	482.2	533	557	602	637
Kuwait	374.9	471.62	593.69	653.08	676.97	712.36	723.45	721.89

In the GCC, for every cubic meter of water produced there is as much as two cubic meters of brine discharged into the water body of origin (Sezer et. al. 2017). This is a highly inefficient ratio, yet it is relatively efficient for the standards of the contemporary desalination industry. Unfortunately, the ratio is becoming higher due to "intensive desalination processes constantly decreas(ing) the quality of seawater for desalination and continuously impact(ing) the marine life" (Sezer et. al, 2017). This is the result of decades of reliance on desalination to source water in the GCC.

Thankfully, new improvements in filtration technology is offsetting the decreasing quality of seawater.

Figure 5: Ras Laffan desalination plant, located in northern Qatar. This plant produces 450,000 m^3 of water per day. It also produces 30% of Qatar's electricity. The heat discharge from the electricity generation is used in the desalination process. Source: https://www.wsp.com/en-US/projects/ras-laffan-c-iwpp

Despite being the poorest region in the world in terms of freshwater reserves, the GCC has some of the highest water consumption rates in the world. This is the result of rentierism. Rentierism is a political economic system whereby the governing coalition legitimizes its authority through the provision of services to its electorate (Kamrava, 2012). Desalination is one of the primary components of the GCC's rentierism. The rest of WANA has much lower per capita water consumption rates in comparison to the GCC. In the GCC, running water is free for citizens and subsidized for residents (recently, the UAE removed some of these subsidies). This is despite desalination being one of the most expensive methods of obtaining fresh water. Kamrava describes the rentier state as a common theme across the GCC (Kamrava, 2012). Free/cheap access to water for citizens and residents in the GCC helped create a wasteful water consumption culture. Qatar, for example, once had the highest water consumption rate per capita. It remains among the highest in the world (Mohammad & Darwish, 2017).

Part 3- Mining the WANA Seas: The Options

The primary method of brine disposal across WANA is 'surface discharge (SD),' or simply redepositing the brine into the sea (Sezer et. al., 2017). This method wastes the potential revenues from brine mining, contributes to rising salinity of the seas in the (very) long term, and reduces the quality of future feed water for desalination. Other methods under consideration include:

1. Deep well injection
2. Evaporation ponds
3. Irrigation of saline-tolerant plants
4. Valuable mineral recovery
5. Zero-liquid discharge
6. Sodium bicarbonate production
7. Utilization of brine to develop coral reefs
8. Solar Crystallization (e.g.: using photo thermal pillars/columns)

There is also a lot of overlap between these methods. For example, some brine management methods are classified as both a solar crystallization and ZLD method.

Each of these methods has its advantages and disadvantages. For example, deep well injection is relatively affordable and requires little to no processing of brine before injection. However, it is a temporary solution at best. Evaporation ponds are a cheap method for large countries, but they do not work well for small countries like Qatar that lack sufficient land resources. Additionally, the beds of the evaporation ponds must be lined with expensive special materials to avoid dangerous contamination of underground resources and soil degradation (Sezer et. al, 2017). The irrigation of saline-tolerant plants is another promising option. Wastewater facilities such as As-Samra plant in Jordan uses the brine discharge from its treatment process to feed a bio saline species (Tarek Zureikat, video call, 2021). This shows how waste management and brine mining overlap. While few plants that produce fruits or vegetables can tolerate saline water, there are halophytes that are used to produce biofuels (Eshel et. al, 2010). These halophytes can tolerate highly saline water, and biofuels are experiencing a surge in demand today (Gul et. al, 2013). For most other methods of brine management, new improvements in filtration technology is necessary. Valuable Mineral Recovery is one example.

Valuable Mineral Recovery (VMR) is a highly promising method of brine management. It involves the filtration of brine discharge to extract valuable minerals. Some of these minerals include bromine, fluoride, calcium, magnesium and (of course) sodium & chloride (Sezer et. al, 2017). This method has been in use since the 1980s, but is usually restricted to the filtration of a single mineral/molecule/compound per process. Salt is the most logical choice at face value, but other elements have been extracted at scale too. Saudi Arabia has extracted magnesium from its brine for decades (Al Mutaz & Wagialia, 1990). Israel successfully produced commercially viable sodium chloride, but its production of brine is too small to warrant exports (Ravisky & Nadav, 2007). Bromine extraction from the sea was popular in the previous century, but competition with the Dead Sea and other natural bromine deposits largely ended this (Fellow, 2021).

Currently, the GCC region is a net importer of salt. However, if its brine is utilized it could be a major global exporter of salt (NaCl) and other minerals recovered from seawater brine. In fact, the brine produced from desalination in the GCC every year contains far more NaCl than humanity currently consumes on an annual basis (Fellows, C., video call, 2021). This means that it is not necessary to extract 100% of all the NaCl in the brine. Instead, each country can extract what it needs and store or redeposit the rest.

Zero Liquid Discharge (ZLD) is another method of brine management. For the context of desalination, ZLD could serve as an intermediary between desalination and VMR (Gorjian et. al, 2019). In the conventional mining industry, ZLD reduces the toxicity of briny solutions produced during the mining process. ZLD incorporates the crystallization or concentration of brine such that all hydrogen dioxide (ware) is removed from the solution. This allows for the recovery of valuable minerals and –in cases where recovery has no commercial uses- safe storage of the crystalized/concentrated brine. ZLD brine can also be safely deposited in landfills without contamination risk (Sezer et. al, 2017).

Efforts to Improve Brine Management in WANA

Due to its leading role in the desalination industry, most studies on the improvements of brine mining in the WANA region start in the GCC. For example, Qatar initiated the *Sustainable Water and Energy Utilization Initiative* (QWE) with the engineering faculty at the Texas A&M University - Qatar campus (QWE, 2020). QWE is part of Qatar's 'Knowledge-based Development' campaign, hoping to create domestic solutions to the country's challenges. In the past, Qatar and the GCC contracted foreign companies to solve such integral problems at extremely high costs. The hope of initiatives like QWE is to reduce the costs of fixing structural problems in Qatar's water and energy regimes. QWE also hopes to create frameworks for solutions to export abroad, hence creating new sources of revenue for Qatar.

Other countries in the GCC also developed their own innovations and solutions. In Saudi Arabia, the King Abdulaziz University of Science and Technology (KAUST) developed a hydrophilic silica-based substance that increases the efficiency of Multi-Stage Flash (MSF) thermal desalination. This substance solves the problem caused by overheating at Saudi Arabia's desalination plants that use the evaporation method (as opposed to RO). The silica-based substance produced at KAUST absorbs water at cooler temperatures and releases it at higher temperatures (KAUST Official Youtube, 2016). This process is called 'Absorption Desalination' (AD) and it is a scientific triumph for Saudi Arabia. This innovation relies on oil-based products, which Saudi Arabia has in abundance. Saudi Arabia can export this silica-based substance to other countries for profit. However, one cannot construct an entire desalination plant relying solely on AD. Instead, AD complements the fossil-fuel intensive ‘evaporation/thermal desalination’ method. This is possibly by design, since Saudi Arabia also profits from the growth of thermal desalination method worldwide through the sale of Saudi oil and gas. It is possible to invest more resources into researching ways to improve the absorption method, possibly through a WANA-wide cooperation in order to reduce the burden on individual countries. Another brine management solution supported by KAUST is solar crystallization. Solar crystallization is an offshoot of ZLD. KAUST supported the design of large photo thermal pillars that are theoretically capable of crystallizing huge amounts of brine in the same way that small photo thermal disks crystallize brine on a small scale in labs (Zhang, C. et al, 2021). Peng Wang, a professor at KAUST and Hong Kong Polytechnic, introduced this ‘next generation’ solar crystallization method for brine treatment in April of 2021 at a joint webinar of Saline Water Conversion Corporation (SWCC) and IDA. The key to the upscaling from photo thermal disks to large photo thermal pillars/columns is the addition of nitrilotriacetic acid (NTA), which prevents the crystals from attaching to the photo thermal surfaces and preventing more crystallization. The important thing about this new method is that it has a low energy burden. Wang highlighted that Saudi Arabia produces 2 billion cubic meters of brine from desalination every year. This large quantity of brine will require huge amounts of energy input to be mined. As such, Wang attempted to reduce the energy cost by relying on solar energy to power his new solar crystallization method.

In addition to the research at KAUST, Saudi Arabia’s SWCC funded research on improved filtration systems that radically improve the country’s seawater utilization rate (Seungwohn Ihm, 2020). This will enable new achievements in brine mining. Saudi is not alone in funding the improvement of filtration systems. In Kuwait, the Kuwait Institute for Scientific Research (KISR) doubled the water recovery rates in some experimental plants from 30% to 60% by altering a previous design of a pressure-driven RO membrane system (Ahmad, 2021). Once implemented on a commercial scale, Kuwait will be able to significantly reduce the energy costs of desalination. Kuwait is also seriously considering brine concentrate mining, and not only for NaCl. Kuwait's Shuwaikh Desalination plant alone extracts $464 million worth of magnesium every year. At the moment, this magnesium is redeposited in the sea. Other WANA countries have taken action to avoid losing the valuable brine. To avoid the loss of brine's financial potential, Abu Dhabi constructed a massive underground cistern to store its brine while it figures a way to maximize its utilization of this resource.

In Oman, the Nanotechnology Research Center at Sultan Qaboos University devised a membrane that rejects liquids and solids, but takes in vapor (Al-Abri, 2021). This membrane can significantly increase the efficiency of Oman's desalination plants. Membrane distillation is a niche of the desalination sector, and Oman is rapidly developing a comparative advantage there. This could allow Oman to corner the market for membrane distillation in the future, bringing in alternative revenues to fossil fuel exports. Since membrane distillation can also be used with wastewater and brackish water, there is a significant potential for improving this technology.

WANA-Wide Cooperation in Desalination and Brine Management

If a WANA-wide cooperation is not possible due to current outstanding conflicts, one could begin with a GCC-wide cooperation and expand outwards to WANA as the geopolitical situation stabilizes. The GCC has successfully coordinated the development of steel, fiberglass, and glass-reinforced polyester industries in the GCC (Lawson, 2012). Desalination could be the GCC's next frontier of innovation and coordination. In light of the recent rapprochement between Saudi and Qatar, this possibility is all the more relevant.

Table 7: Number of Desalination Plants in the GCC (2000-2018). Source: GCC Statistics Book.

	2000	2005	2010	2013	2014	2015	2016	2017	2018
GCC	69	91	131	143	151	160	169	174	-
UAE	27	36	44	46	48	48	50	44	-
Bahrain	4	5	5	5	5	5	5	5	-
KSA	12	13	19	35	37	40	43	45	44
Oman	18	28	40	42	45	50	52	60	65
Qatar	3	4	7	7	7	8	9	10	-
Kuwait	5	5	6	8	9	9	10	10	-

Table 8: Composition of Seawater per kilogram. Source: Christopher Fellows, Desalination Technologies Research Institute (2021)

Element	Percentage per kg (%)	Amount in grams (g)
Chloride	2.3	23
Sodium	1.85	18.5
Sulfate (bromine)	0.32	3.2
Magnesium	0.177	1.77
Calcium	0.05	0.5
Potassium	0.046	0.46
Other Minor Constituents	0.022	0.22

While Table 8 showcases the quantities of the elements that are available in a sample of seawater, the “minor constituents” section fails to capture the diversity of elements that can be found in seawater. If we only look at the per-kg content, it will also be difficult to illustrate the diversity of constituents in the brine. Therefore, it might be better to use per-million m^3 as an alternative metric. In every million cubic meters of seawater, there is (on average) 0.3-20 grams of gold, 3 kg of Uranium, 100 kg of lithium, and 100 kg of rubidium. These elements are far too diffused in the ocean to warrant commercial extraction at the moment. Compared to these rare elements, a million cubic meters of seawater contains 35,000 tons of NaCl, 80 tons of bromine, 2000 tons of Magnesium, and 500 tons of potassium (Fellows, C., 2021). Any of these elements and compounds can be extracted from seawater on a commercial scale, with the exception of Magnesium (which is often extracted from seawater for military or strategic purposes).

The GCC is projected to have a shortfall of 2.5 tons per annum of NaCl by 2030 (Fellows, C., 2021). Brine mining is an ideal way to cover the shortfall. In anticipation of this, Saudi Arabia has commissioned the Jubail 2 and Shoaiba projects (Ihm, S., 2020). These projects will feature new nanofiltration systems and a dual brine concentrator. The concentrator will further reduce the liquid content of brine, making its mining more cost-effective. The new plants will produce NaCl at 99.7% purity, and it will serve the Chlor-Alkali industry of the GCC. These developments are the product of international collaboration in the desalination industry, involving Arab, US, Japanese, and other companies. Some of these include Sabic Petrokemya, Pacific Water Solutions, Hydranautics, Toyobo, Khair Inorganic Chemical Industries, FEDCO, and Fluid Technology Solutions.

The new desalination and brine mining plant at Jubail will be the host of an international conference on brine mining co-organized by SWCC and the IDA in October 2021. IDA and SWCC are leaders in sponsoring knowledge production and scholarly collaboration across borders in the field of brine concentrate mining. This is due to the mandate of IDA, and SWCC's control of ~20% of the world's brine production. Through WSTA, SWCC works with the GCC. IDA's academic branch – *IDA Academy* – also works to improve knowledge production in the fields of desalination and brine concentrate mining. In July of 2021, the Dean of IDA Academy John H. Lienhard V and governor of SWCC Abdullah Al-Abdul Kareem spoke at a joint webinar where they praised the developments in brine concentrate mining at the upcoming Jubail 2 and Shoaiba desalination plants. The President of IDA's board of directors, Carlos Cosin, also spoke at the event, where he acknowledged the dream of "starting to produce a value product from the brine" (Cosin, C., 2020). SWCC's Desalination Technologies Research Institute (DTRI) general director, Ahmad Al-Amoudi, added that "the cost-effective extraction of valuable minerals from brine is the key to affordable desalination" (IDA-SWCC Webinar, 2020). In these remarks, the leaders of IDA and SWCC laid the groundwork for further collaboration in brine concentrate mining.

Sodium bicarbonate production is another method of brine management that involves placing one of several kinds of reject brine (not necessarily seawater brine) in a chemical reaction with carbon dioxide and ammonia (El-Naas, 2011). This method is called the 'Solvay process' in reference to Ernest Solvay who apparently first developed this method in 1881 (Sezer et. al, 2017). Sodium bicarbonate production is not a major solution for brine management in the WANA region since it is not commercially viable on a regional scale. Some of the brine could be reused through this method, but it would have to complement a more efficient and commercially viable method of reusing and recycling brine (and possibly reducing per capita water consumption in high consumption areas like the GCC).

In recent years, the UAE developed a method for using brine to develop coral reefs. While brine has been shown to hurt preexisting coral reefs if diffusers are not utilized to distribute the brine discharge (Petersen et. al, 2018), the UAE is showing that processed brine can be utilized to artificially grow corals in controlled environments. This is a very new development and its promise is yet to materialize. Theoretically, some contents of ocean brine can serve as nutrients to support coral reefs. Finally, solar applications for brine disposal is an umbrella term for different methods of obtaining ZLD brine and also VMR (Gorjian et. al, 2019). Solar crystallization features earlier in this section as an example. There is extensive literature about how to efficiently reuse or recycle brine using solar applications- perhaps the cheapest application of brine management.

Part 4- Jordan: A Case Study for Brine Management

Data analysis on a regional scale helps identify common issues and generalizations. However, it misses the nuances that shape local water governance. To illustrate how the local context impacts WANA's water regime, this section incorporates a case study of one WANA country – Jordan – and brief analysis of other regions in WANA. While Jordan shares many of the same water scarcity and brine management challenges of its WANA peers, its topography, post-colonial boundaries, and other unique characteristics make the Jordanian experience different from the rest of its peers in the region.

Jordan controls half of the Dead Sea's coastline. Due to the Dead Sea's immense mineral wealth, Jordan possesses great international influence on the brine mining industry. The export of extracts from the Dead Sea brine are the primary reason why bromine extraction from seawater is not cost-effective.

Few countries are well suited for desalination. Even fewer countries are in a position to engage in brine/seawater concentrate mining. What criteria must a country meet to be able to desalinate? What about those countries that are in a position to invest in concentrate mining? This section delves into the case of Jordan, a country for whom desalination is far from being the most suitable source of potable water. Despite that, Jordan will soon lay a new pipeline from its southern shores to its northern cities to transport desalinated water. After briefly touching on Jordan's peers in WANA, this section will explore Jordan's experience with desalination.

GCC

The Arabian-Persian Gulf is where a plurality of the world's desalination takes place. Desalination plants in the GCC are the primary source of water for the area. This is unlike anywhere else in the world. The gulf is experiencing a rise in salinity partially due to the extraction of potable water from its waters. The other major cause is the declining flow of water into the gulf from the Tigris and Euphrates (Fellows, C., video call, 2021). In addition to the extraction of potable water and the declining inflow from upstream, the redepositing of seawater concentrate from desalination plants into the gulf also has a marginal effect on its salinity. The impact of rising salinity is most felt in the semi-enclosed portion of the Gulf between Qatar, Bahrain, and Saudi Arabia. On the Red Sea, Saudi Arabia constructed tens of desalination plants. Some are active year-round to serve the communities of the region, while others accelerate their production around the time of the Hajj. The rest of the Red Sea basin also benefits from desalination.

Due to its heavy reliance on desalination, the GCC should begin mining brine today before tomorrow. A large country like Saudi Arabia can easily extract minerals from brine for commercial purposes now. A smaller country with high desalination capacity like Qatar is also well suited to invest in brine concentrate mining, but only for military/strategic purposes or to serve some local manufacturing facilities. Qatar's desalination output is significant, but it does not match Saudi Arabia. The only reason Qatar is in a position to invest in brine concentrate mining is thanks to existing industrial infrastructure at locations such as Mesaieed and Ras Laffan. The presence of much of the needed infrastructure means that new investments to prepare for brine concentrate mining will be minimal. To enable a commercial brine management enterprise for the GCC's smaller members, the union as a whole must launch a joint effort. Due to the truly massive amounts of brine produced in the GCC every day, the union can achieve complete self-sufficiency for a number of elements and become an exporter for others. If this succeeds, the GCC can collaborate with WANA to implement this model for the entire region.

Egypt and Sudan

Egypt has recently become more interested in desalination due to the construction of the Renaissance dam on the Nile in Ethiopia. This upstream dam will reduce the flow of freshwater into Egypt. In response, Egypt is investing in massive desalination projects as discussed previously. Compared to Egypt's water demand, however, the amount of water produced from these projects is the equivalent of a drop in a vast ocean. Next-door Sudan is also facing a similar situation, and its government invested in solar-powered desalination to meet rising demand. Like Egypt, Sudan will not be able to rely on desalination to provide the bulk of its water supply.

Desalination will never be enough to meet Egypt and Sudan's water demands, nor will it need to. Instead, it can solve some localized problems in both countries. For example, El Sokhna desalination plant will feed the water needs of the coastal vacation spots on the Red Sea and El-Arish desalination plant will feed the water scarce regions of Sinai. Desalination plants can become mandatory for touristic destinations, such as beach resorts and golf courses (Taylor, A., 2019). Feasibility studies into the potential of brine concentrate mining at these desalination plants should be done before making a decision on to establish a concentrate mining industry. Egypt and Sudan have other mining industries that produce massive amounts of wastewater. The Egyptian and Sudanese governments would benefit from looking into ZLD to manage the waste produced from its mines before looking into brine concentrate mining. Egypt could bring its brine management program under the umbrella of its already comprehensive wastewater management system. Funds and expertise from nearby GCC countries is easily accessible, which could accelerate Egypt and Sudan's progress.

Algeria and the Maghreb Union

Unlike Egypt and Sudan, Algeria does not suffer from geopolitical pressures on its water sources. The country's population centers are spread across a vast coastline, and its rear is protected by a vast desert. No central waterway extends into the Algerian desert. All of Algeria's rivers are relatively short, flowing from the highlands of the northern regions into the nearby Mediterranean coast. Algeria's four desalination plants are spread out across the northern regions. Much like the GCC, Algeria could collaborate with its peers in the Maghreb Union to launch a joint effort in brine mining. However, this project would be of a smaller caliber than the GCC's. The Maghreb Union enjoys the benefit of a large watershed in the Atlas mountains, which extend from Morocco to Algeria. Tunisia has several rivers and other surface water sources that support its population. While dams and overexploitation of the Maghreb Union's watershed are affecting the region's renewable water resources, the situation is still redeemable. The only country in this union that could urgently benefit from desalination is Libya, which has suffered terribly under civil war and desertification. Currently, the brine discharge from the Maghreb Union's plants is deposited into the Mediterranean Sea with the help of diffusers. This minimizes the environmental impact on the sea. Instead of investing in new brine mining methods, the Maghreb Union would benefit more from investments in wastewater management. This is because the volume of wastewater produced by the Maghreb Union far exceeds its desalinated water production. Treated wastewater could also help reduce the amount of water retrieved from the Atlas Mountains and the region's rivers and lakes.

Case Study: Jordan

Jordan has two major water conveyance projects related to its desalination and brine management systems. The first is the decade-old Red Sea – Dead Sea Water Conveyance project, and the second is the newly devised Aqaba-Amman Water Desalination and Conveyance project. The former has been plagued with delays. On May 29, 2021, the World Bank removed the Red Sea – Dead Sea Water Conveyance project from its list of funded projects. As a matter of national importance, this was immediately reported by Jordan's *Roya News*. The next day, Omar Salamah - spokesperson of the Jordanian Ministry of Water - spoke to the *Jordan Times* and reassured the public. "The Amman-Aqaba Water Desalination and Conveyance National Project (AAWDC), which was launched in February 2020, will move forward unaffected," said Salamah before addressing the issue of the Red-Dead canal (Batool Ghaith, 2021). Other regional players, namely Saudi Arabia, have been watching this issue unfold with great interest. Saudi Arabia is investing large sums into brine concentrate mining, and the potential of these investments depends on the survival of the Dead Sea. This small body of water possesses high concentrations of many minerals. Saudi Arabia hopes to extract these minerals from the Red Sea and the Gulf instead, but this would not be commercially viable so long as the mining of the Dead Sea continues. For most Jordanians, the Red-Dead Water Conveyance project (also referred to as the Red-Dead canal or simply Red-Dead) is important for very different reasons. Omar Salamah's statement redirected Jordanians' attention away from the Red-Dead canal and towards the newly devised AAWDC.

Currently, Jordan's renewable freshwater resources can sustain a population of two million people (El-naser, video call, 2021), making Jordan one of the poorest countries in the world in terms of per capital water resources. Combined with a short coastline and inland population centers, desalination alone will not sustain Jordan's population. Prior to its colonization, communities in what is today Jordan shared the same water sources as their neighbors. Post-colonial boundaries gave Jordan's northern and western neighbors influence over the flow of surface water into Jordan, thus severely curtailing Jordan's ability to create a sustainable water governance system. This led

Jordan to invest heavily in municipal wastewater treatment as a more logical non-conventional water resource, especially for inland communities. Jordan's coastal city of Aqaba and the nearby province of Ma'an benefit from a desalination plant in Aqaba.

Since its upstream water resources are controlled by Israel and Syria, Jordan has also been working for decades on finding a way to bring desalinated water from the Red Sea to its northern cities. Jordan's great interest in this project brought the Red-Dead canal into the World Bank's radar.

In recent years, water has become a sensitive issue in Jordan largely due to the severe decline in per capita renewable water resources in the country. The AAWDC is an attempt to 'patch-up' the water system. Jordan is waiting for its neighbors to the west and north to stabilize their political & social environments for long enough to collaborate towards a holistic solution to the region's water scarcity. Jordan's AAWDC project follows in the example of Jordan's southern neighbors, Saudi Arabia and the Gulf Cooperation Council (GCC), who embraced desalination back in the 1970s. Egypt, Algeria, Jordan, and other countries in the region and beyond are following suit. Nearly every country in West Asia and North Africa is considering/investing in desalination as a remedy for water scarcity.

The Red-Dead Conveyance project was first thought of as a way to revive the depleting Dead Sea. After a series of public consultations and extensive studies, the project was augmented with a planned desalination plant that would produce potable water for Jordanian, Palestinian, and Israeli civilians and businesses. Seawater concentrate (brine), the byproduct of desalination, would be deposited into the Dead Sea in hopes of preventing further depletion. The Dead Sea area is a treasure trove in many ways. Besides being an ecologically valuable area, The Dead Sea and its underground aquifers contain a billion tons of bromine (futuremarketinsights.com, 2020). The Dead Sea makes Jordan the second largest exporter of bromine in the world. Every year, the Dead

Sea loses 0.8 to 1.2 meters of its depth (Al-Ghazawy, 2013). Half of this is due to the diversion of water from the Jordan River that would otherwise feed into the Dead Sea, which is supposed to replace the water that evaporates. The other half is due to the extraction of valuable minerals and commodities from the Dead Sea by Israel (the largest exporter of bromine in the world) and Jordan. Perhaps the most well-known of these exports is bromine and Dead Sea mud. The exploitation of the Dead Sea is institutionalized by Jordan and Israel, and it shows no sign of slowing. Even though both governments realize that this must change, they have not been able to collaborate to end their exploitative practices. Neither side wants to 'lose out' on the profits before ocean brine concentrate mining replaces the Dead Sea as a major source of bromine. Palestine's delayed statehood has prevented it from being an effective actor on the Dead Sea and other water-related issues.

Soon, the bromine mining industry of the Dead Sea will end and cause a rise in the price of bromine, enabling new developments in the economic utilization of seawater concentrate (brine). There are two possible scenarios leading to the end of bromine mining in the Dead Sea. The first scenario involves the Dead Sea basin communities 'waking up,' ending the exploitation of the Dead Sea, and bringing back the flow of freshwater to the Jordan and Yarmouk rivers. Unlike the first scenario, the second scenario is bleak and dystopian. It involves an Aral sea-type disaster where human exploitation destroys the Dead Sea habitat. At the moment, The Dead Sea is racing towards the second scenario. It lost almost 100 meters since the mid-20th century.

The Red-Dead canal is imagined as a way to save the Dead Sea from depletion. Unfortunately, this project would not save the area's bromine mining industry, whose profits are to pay for the $10+ billion price tag of the canal. The Red Sea's water won't replenish the finite bromine reserves of the Dead Sea. Without the bromine money, it would make more sense to reuse the naturally existing canals that once fed and replenished the Dead Sea (i.e: the Jordan river, Yarmouk river, and their tributaries) instead of digging a new canal from the Read Sea and spending billions to build a desalination plant along the canal. Saving the Dead Sea would require Israel and Syria to release the dammed water upstream. Jordan would also need to change its water governance regime as well, but the impetus lies on Syria and Israel due to the control of water rewarded to them by post-colonial boundaries and political systems.

Regardless of which scenario manifests into reality, the bromine mining industry will eventually turn to the open seas and oceans. Once that happens, the world's leading countries in desalination will be able to extract bromine from seawater concentrate (brine) for commercial purposes. This will allow the diversification of profitable seawater concentrate mining beyond Sodium Chloride – NaCl - (aka table salt).

Desalination is not the only non-conventional source of potable water for Jordan. As far back as 1982, Jordan's water strategy has centered on another non-conventional source- wastewater. With a short coastline that is far away from many of its population centers, Jordan's post-colonial boundaries make desalination less attractive as a non-conventional water resource. Since its construction in 1982, As-Samra enjoyed many expansion projects. The United States Agency for International Development (USAID) financed an expansion in the plant's capacity to 365,000 cubic meters per day (Arab Water Council et. al, 2011). Like desalination plants, wastewater treatment plants (usually) produce potable water and some byproducts. The wastewater 'brine' from As-Samra was Municipal wastewater is indeed a better option than desalination for many countries in WANA. Water reuse can take place near population centers, which may be better for inland communities.

The treated wastewater from As-Samra feeds the municipal water supplies of Zarqa and Amman. Some of the water was initially sold to a tissue factory on a 7-year contract, and the brine from the water treatment process was used to feed a bio-saline plant that resembles grass (Tarek Zureikat, video call, 2021). This wastewater ecosystem was designed by Engicon O&M, whose CEO (Tarek Zureikat,) was interviewed as part of this research project. Engicon O&M was a consultant on the As-Samra expansion project.

As-Samra provides an alternative model to desalination for the region. Still, Jordan is far from achieving its full wastewater treatment potential. According to Zureikat, roughly 40% of the water circulating in Jordan's pipelines is lost. Another interviewee, Larisa Abulghanam, confirmed this (Abulghanam, video call, 2021). Indeed, Jordan loses a significant amount of its water resources to leaks, theft, and irresponsible use. Investments into these issues would yield greater financial and economic returns to Jordan than desalination.

Part 5- The Institutional and Policy Framework for Brine Mining

In April 2021, the governor of the Saline Water Conversion Corporation (SWCC) of Saudi Arabia announced that it will soon implement ZLD on a commercial scale. His exact words were:

> "We have very robust opportunities in using engineering developments that the desalination industry witnessed in recent years (in terms of brine management)."

Abdullah bin Ibrahim Al-Abdul Karim (Governor of SWCC), 8th of April 2021 at the "Investment Opportunities in Brine Water" Virtual Seminar

The governor went on to say:

> "We believe that soon we will be able to apply the Zero Discharge technique on a commercial scale."

Exactly what he meant by "soon" is unclear. By looking at the numbers, "soon" could mean years, or possibly even decades. If Saudi Arabia's new plants at Jubail and Shoaiba succeed, they would bring Saudi's seawater utilization rate to 79.9%. This does not amount to ZLD, however. Furthermore, ZLD is one of many methods to extract minerals from seawater. Some ocean brine experts prefer to describe these new developments as 'creating value' from brine, especially since ZLD maximizes utility in mining but not desalination. Nonetheless, this was a monumental announcement. Most desalination plants barely cross 40% utilization through their systems today. The governor's announcement suggests that new efficient systems are making desalination more cost-effective. Perhaps an achievement like this is not only impressive but also necessary for Saudi Arabia, considering its massive daily output of desalination – 5.9 million cubic meters of water per day. The reduction in the energy costs at Jubail and Shoaiba will be significant.

Review of Relevant Institutions

The West Asia – North Africa (WANA) region has a complex and decentralized water governance regime. The water governance regime is also fragmented, with several organizations playing the role of a regional transnational water governance body for the whole or part of the WANA region.

The region that best tracks its desalination industry is the GCC, but the rest of WANA is following suit.

With the exception of WSTA, WANA's water governance organizations do not center desalination as a primary source of drinkable water. Therefore, WSTA is the only regional water governance organization that is heavily invested in brine concentrate mining. WSTA's mandate is confined to the GCC region.

The Arab Countries Water Utilities Association (ACWUA) is another regional water governance organization with a wider mandate that WSTA. It has 100 members from 18 Arab countries. ACWUA is more focused on managing the distribution of water as a public utility than it is focused on desalination.

Table 9: List of Regional Water Governance Organizations in WANA and Their Mandate

Entity	**Mandate**
Arab Water Council	League of Arab States region / all of WANA
Arab Countries Water Utilities Association	Most of WANA, with a few exceptions
Center for Environment and Development for the Arab Region and Europe	Mediterranean basin, North Africa, and the European Union
Middle East Water Forum	Most of WANA, with many outside members
North African Ministers Council on Water	North African portion of WANA
The Arab Center for the Studies of Arid Zones and Dry Lands	League of Arab States, with a focus on Syria
United Nations Development Program	Worldwide, with a special department for WANA water issues

The Arab Water Council (AWC), the largest water governance organization in WANA by membership, is showing more interest in desalination and brine mining. However, the AWC's mandate covers the entire WANA region, which translates into the AWC giving more attention to wastewater management than desalination because wastewater management is a crosscutting issue with huge potential across the entire region, unlike desalination. A seminal 2011 report by AWC highlights the potential consequences of the huge amounts of untreated wastewater on the flora and fauna of WANA and its water bodies (Arab Water Council, 2011). The report states that in 2011, 40% of the region's wastewater was untreated. This is equivalent to 4.36 cubic kilometers of water. While the share of untreated water has declined since this, it remains dangerously high. This is much more urgent environmental issue than brine discharge into the sea.

Along with the Arab Water Council, the Middle East Water Forum (MEWF) has recently emerged as a popular space for water experts of the region to congregate. Founded by former Jordanian Minister of Water and Irrigation Hazim El-Naser in 2018, MEWF has grown to include 2000 or so members. In absolute numbers, this makes MEWF larger than AWC. However, MEWF's position as a relative newcomer to the region's water governance system curtails its influence.

In North Africa, the North African Ministers Council on Water (N-AMCoW) brings the region together to address its water issues. Directed by Khaled Abuzeid, this council has come to gain more importance on the North African level than the AWC. This is partially because the AWC has a wider mandate, meaning that it cannot provide as much attention to North Africa as N-AMCoW can. The Libyan civil war, division of Sudan, multiple revolutions, and instability in the Sahara regions south of Morocco have curtailed N-AMCoW's work but did not prevent it from moving forward. By the sheer force of its existence as a common policy making space, N-AMCoW maintains some degree of cooperation and collaboration in the North African water sector. On the other hand, the absence of a similar body in the Levant partially caused the breakdown in collaboration on water issue.

Approximately 14% of the global population will live in water-scarce regions by 2050 (Gorjian et. al, 2019). This would be a major increase from today, where several hundred million people live in water-scarce areas. These areas are mostly in WANA. How WANA deals with its water challenge will shape the future of water and brine management on this planet. A successful WANA water and brine management regime can set a positive example for the rest of the world as it begins to experience what WANA has experienced for the past decades. At the same time, the WANA region has its own unique challenges that are not found in other regions around the world. For example, the 45 desalination plants at the Ramanathapuram district on India did not yield dangerously saline coasts due to India's access to a large ocean where it can discharge its brine (Manivanan, 2015). Despite the high concentration of desalination plants in the area, the seawater salinity near the plants is approximately 63 ppt, slightly higher than the average of 35 ppt on the coast of the Tamil Nadu region of India (Manivanan, 2015). Still, if India does not learn from the WANA experience, it will eventually find itself with Arabian-Persian gulf levels of salinity.

In the WANA region, evaporation and reverse osmosis (RO) are the most common methods of desalination. While evaporation is conducted differently in each country, RO is conducted in a uniform method across the board. The public sector largely controls the seawater desalination industry. The major exceptions are Egypt and Israel, who have experimented with private desalination enterprises. Still, the Egyptian and Israeli governments enforce an extensive regulatory framework that governs their desalination regimes. Their regulatory frameworks also give these two governments expansive authorities over the private enterprises that own and/or operate desalination plants in Egypt and Israel. Egypt's massive Al Galalah desalination plant - located at Ain Sokhna- is the product of a corporate partnership between the UAE-based Metito Group and the Egyptian Orascom group (Metito Group, 2019). The Egyptian Water Regulatory Agency (EWRA) regulates the production of water and disposal of brine at Al Galala. Israel has a similar system to Egypt, as it allows for companies to compete for contracts through a contract tendering system. 13% of Israel's water comes from a single desalination plant at Askalan/Ashkelon, located right next to the Gaza Strip (water-technology.net). Like Al Galalah, the plant at Askalan is privately operated. It is regulated by the Israel Water Authority (IWA), which also has expansive power over colonized and occupied Palestinian populations.

Qatar's water production is largely done through public-private partnerships where the state owns the desalination plants and hires local and international companies on periodic contracts to operate the plant(s) on the state's behalf. This is how Qatar's plant at Ras Laffan is operated (wsp.com). Qatar relies on seawater desalination more than Egypt and Israel, so it cannot afford to bring high outside risk into its water regime. A similar situation can be observed in other GCC countries. Nonetheless, each country in the GCC has its own ministries and regulatory authorities that oversee the production of brine in a similar way to Egypt. These entities are:

1. Qatar: Kahramaa
2. UAE: each emirate has its own regulator, such as Abu Dhabi's EAD. All regulators follow the UAE's *Water Security Strategy 2036* that is enforced on the federal level
3. Oman: DIAM
4. Bahrain: EWA
5. Kuwait: MEW
6. Saudi Arabia: ECRA & SWCC

Policy Solutions

The 'disaster' scenario that must be avoided at all costs is a situation akin to that which the South African city of Cape Town found itself in this past decade. Due to severe droughts, the city of Cape Town was forced to ration water to the population and erect a number of makeshift desalination plants across South Africa's beaches to extract and obtain desalinated water swiftly (Halevi, 2020). This was necessary from a policy perspective, as a lack of water can cause societal collapse. However, the city of Cape Town's actions severely harmed South Africa's beaches and coastline. Brine was disposed onsite with virtually no treatment or processing like one would traditionally expect (Halevi, 2020). Even though surface discharge remains the most common method of brine management in the GCC, the brine is treated and processed at the desalination plant before discharge into the sea. Diffusers distribute the discharge of brine to reduce the harmful impact. This treatment prevents the harming of marine life.

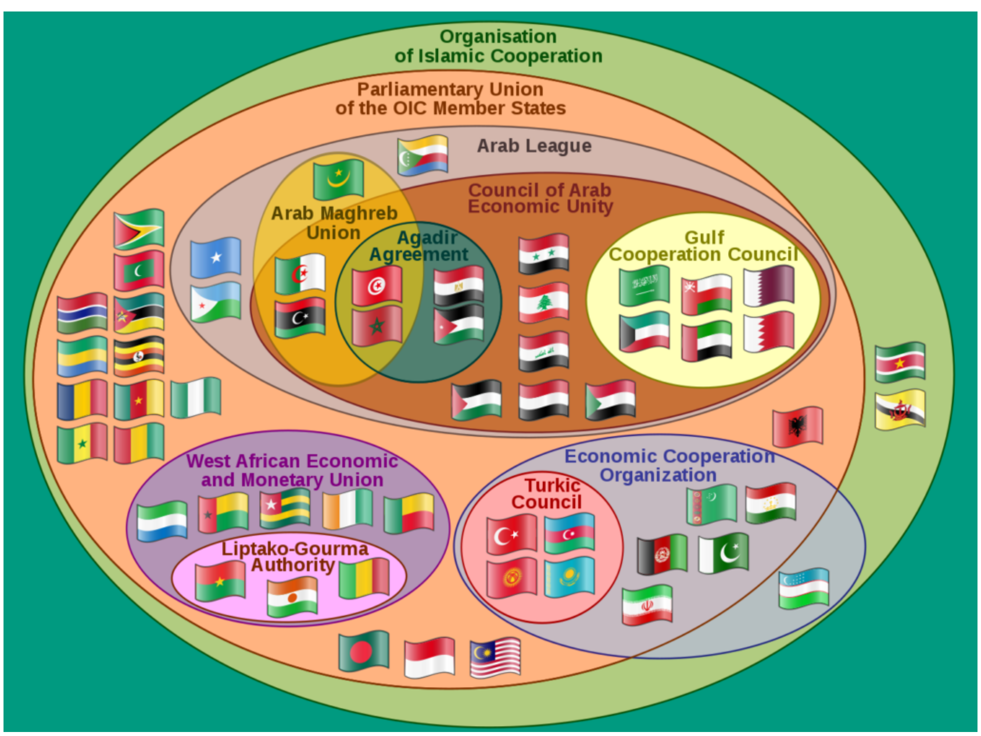
Thankfully, this disaster scenario occurs very rarely. It can be completely avoided by preparing for emergency situations and maintaining reserves of fresh water.

Seawater desalination in WANA is integral to the security and stability of the region. By creating a common policy space for the management of water production and brine disposal, WANA countries can work together to align their interests and avoid escalation of conflict over water interests. This is in line with the age-old logic that countries that trade in resources and knowledge are less likely to fight each other. This logic was the basis for post-WW2 European cooperation through the European Coal and Steel Community The same goes for the ASEAN region, which coordinates the affairs of approximately a billion people living in South East Asia, avoiding total war in the South China Sea over access to underwater resources in the South China Sea.

In the case of the WANA region, coal and steel will be replaced by water and brine. Jordan and Israel already found a way to coordinate their desalination practices in the Gulf of Aqaba- part of the Red Sea (Mohsen, 2007). A lot can be learned from their example, especially since these countries were at war for decades. Still, there is much room for improvement. Jordan and Israel need to cooperate with the Palestinian Authority to save the Dead Sea from drying up (Mohsen, 2007). Israel refuses to cooperate with Palestinians on this matter and does not treat Palestine as an equal partner in Dead Sea affairs.

A WANA-wide policy space for seawater brine management will need to be much more comprehensive than the Jordanian-Israeli cooperation. Additionally, the Jordanian-Israeli partnership is currently in jeopardy due to several disagreements between Jordan and Israel surrounding Israel's brutal policies in the Palestinian territories. Indeed, Palestinians do not benefit from seawater desalination. Palestinians receive a small fraction of the amount of water that Israelis receive (Gasteyer et. al, 2012). Unfair access to water is an aspect of Israel's apartheid regime that recently received attention. Seawater desalination can help fix this gross injustice through the introduction of seawater desalination to the Gaza Strip and providing the Palestinian Authority with access to the Red Sea and Mediterranean to source clean and drinkable water, both independently and through cooperation with Jordan and Israel. Israel must also end its colonial policies of land and water-grabbing in Palestinian territories to make way for cooperation between the two states.

Illustration 8: A depiction of the institutional framework of several AfroEurAsian International Organizations and the overlaps in membership between them. (Open Source)



Luckily, the WANA region already has an expansive institutional infrastructure for cooperation. The League of Arab States (LAS) is one of the oldest international organizations in the world, even older than the European Union (EU). The LAS can create a subsidiary organization composed of all the water regulators in the WANA region, where they could exchange knowledge and facilitate cooperation between LAS countries. Such a cooperation could invite the water regulatory authority from what is now Israel. Already Israel has the opportunity to establish relations with the Arab league through what is known as the 'Arab Peace Initiative,' a peace proposal submitted to the LAS by Saudi Arabia offering full normalization with Israel in return for a just and fair treatment of Palestinians.

Water can be used to facilitate peace in the Arab region (Hefny, 2011). If an LAS-wide cooperation cannot be obtained immediately, Arab countries could first go through the smaller councils that constitute the LAS. The six members of the GCC could begin within their own region by synchronizing their water regulatory frameworks and find joint solutions to their brine management challenges in the Arabian-Persian Gulf. The signatories to the Agadir agreement (Jordan, Tunisia, Morocco, and Egypt) could do the same and form a framework for brine management in the Red Sea and Mediterranean. The Arab Maghrib Union could create a framework specifically for the Mediterranean. Beyond that, the council of Arab economic unity could commission reports that look into the commercial potential of brine management. Brine could replace part of the revenues currently obtained from oil and gas sales in WANA. Furthermore, a joint brine management framework can provide opportunities for experts to be employed in the region- ending the brain drain.

On the local level, countries can follow the Qatari example of knowledge-based development. Through the creation of libraries, science parks, and provision of research funding, new innovations can emerge that transform the context of the problem (Gremm et. al, 2018). This long-term solution will not solve the immediate challenge on the ground. But it will provide foresight and reduce the reliance on knowledge production from other regions that perhaps do not understand the challenge as we understand it in the WANA region (Gremm et. al, 2018). Countries should also look into integrating their water, energy, and food governance. As the three pillars upholding social harmony, water, energy, and food can be governed more efficiently through institutional integration (Mohtar, 2016). Qatar has integrated its water, energy, and good governance frameworks while maintaining three independent entities for each 'pillar.' This integration acknowledges the interdependence of the energy, water, and good regulatory bodies on each other (Mohtar, 2016). Other Arab countries could benefit from doing the same, and so will the process of brine management- which permeates into water, energy, and food policy.

List of Action Items for WANA's Water Sector

1. Increase research funding for brine mining and management and involve all the major water governance organizations in this research.
    a. At the moment, the IDA and SWCC are the only active regional sponsors of this kind of research in WANA.

2. In the short term, encourage non-GCC WANA countries to invest in wastewater management as opposed to desalination plants.
    a. This is due to the massive quantities of untreated wastewater in WANA of over four billion cubic kilometers of untreated wastewater per year (Arab Water Council, 2011). Before generating new non-conventional water resources, WANA should maximize the utility of its currently available resources.

3. Involve WANA's water governance organizations in the GCC's push to advance brine management and brine concentrate mining. At the moment, WSTA is the only directly involved regional water governance organization in the new plants at Jubail and Shoaiba.
    a. This will facilitate information sharing and knowledge production across the whole WANA region.
    b. Some examples of organizations to involve include AWC, MEWF, ACWUA, and N-AMCoW

4. Advocate for ending exploitative mineral extraction from the Dead Sea (particularly bromine) to protect the areas habitat and enable profitable bromine extraction through seawater desalination.

Conclusion

Brine concentrate mining will become more attractive as WANA's desalination capacity continues to grow. Improvements in filtration technology and brine management systems will make it easier to scale-up the extraction of valuable minerals from the sea. The impetus lies on the communities and political leaders of WANA to make sure that our physical environment does not experience harm due to these transformations. Furthermore, investments in wastewater management should remain a priority for the non-GCC parts of WANA. While desalination is an attractive option that policymakers might be tempted to embrace, municipal and industrial wastewater treatment is often a better investment for WANA.

Despite that, the fact remains that WANA is the center of the world's desalination industry, and many sectors of the mining industry as well. This paper showcased how desalination and mining are interlinked. There is an opportunity there to ensure that finite resources, such as the mineral wealth of the Dead Sea, are not overexploited. Desalination can offset the reduction in the exploitation of such resources. It would usher in a new approach to the WANA mining industry. Brine concentrate mining is key to such a new approach. This transformation is inevitable. It is merely a matter of time. What is not inevitable, however, is the equitable distribution of benefits from this transformation. The governments of WANA should work towards ending the post-colonial legacy on the region's water (governance) regime.

A century ago, scientists and engineers dreamed of accessing the wealth of the oceans. In the 1970s, Singapore (which was dealt a bad hand in the post-colonial world – an island with barely any freshwater) pioneered new filtration technology to treat its wastewater, in hopes of creating an easily accessible non-conventional water resource that is not controlled by its neighbor - Malaysia.

Saudi Arabia built on Singapore's achievements. The Kingdom will soon pioneer filtration technology that will enable it to utilize seawater at a rate of 79.9% - over 30 percentage points higher than current rates.

In October of 2021, many of the world's leading experts on desalination and ocean brine will congregate in Jubail, Saudi Arabia for an international conference titled "Ocean Brine Mining for Desalination." The organizers released a call for papers in anticipation of this conference. A large sum of money has been set aside to fund the selected papers and support the realization of the ideas expressed in them. The awe-inspiring advancements in brine concentrate mining will continue, and more achievements are to come.

Appendix 1: List of Interviewees and Their Backgrounds.

Video Call & Correspondence:

1) **Hazim El-naser:** PhD in Water Resources Management; founder of Middle East Water Forum; President of General Assembly of the Arab Countries' Water Utilities Association (ACWUA); former Jordanian Minister of Water (2001-2005 & 2018-2019); former Jordanian Minister of Agriculture (2003-2004 & 2018-2019); Former member of the Jordanian Parliament.

Dr. Hazim El-Naser is one of the most recognized authorities on water issues in Jordan and the West Asia region. His expertise derives from a long academic and professional experience. Dr. El-Naser's experience in several executive positions (both government and non-governmental), combined with his legislative experience and many political initiatives (such as the Middle East Water Forum) endow him with expansive knowledge and insightful perspectives on the water sector in the region.

2) **Christopher Fellows:** Associate Professor, University of New England. Senior Expert, Desalination Technologies Research Institute (DTRI)

Christopher Fellows is a widely recognized authority in the desalination world. His research into the development of petrochemical polymers endows him with a deep understanding of the filtration systems used in the desalination process. He started his career in the sugar industry before transitioning to desalination. Professor Fellows also works closely with the Saudi Saline Water Conversion Corporation (SWCC) thanks to his position as Senior Expert at (DTRI). SWCC is responsible for approximately 20% of the world's desalination output. Professor Fellows often collaborates with other regional and international associations involved in desalination, namely the Water Sciences and Technologies Association (WSTA) and the International Desalination Association (IDA).

3) **Larisa Abulghanam:** Eng. CRDF Global; B.Eng. in Water and Environmental Engineering and Management, German Jordanian University.

Larisa works for the US-based CRDF Global, a non-profit organization registered by the United States (recognized by the FREEDOM Support Act and established in 1995 by the National Science Foundation.) with offices in Amman and Kyiv. Larisa is a Project Associate at CRDF's Amman office. Our conversation will revolve around the issue of water scarcity in the WANA region and possible remedies.

4) **Barik Mhadeen:** Senior Policy Researcher; MA, International Relations; BA, Political Science/International Relations.

Barik Mhadeen is a Jordanian researcher, thinker, and thought leader. He is a senior policy researcher at Generations for Peace, a Jordanian NGO. Prior to joining GfP, Mhadeen was part *of the West Asia / North Africa Institute's Human Security research division. Mhadeen was a member of the Mediterranean Discourse on Regional Security (MDRS), a network of academics centered on the Mediterranean sea.*

5) **Mazin Qumsiyeh:** founder, Palestine Museum of Natural History. Founder, Palestine Institute for Biodiversity and Sustainability. PhD, Zoology/Genetics.

Mazin Qumsiyeh is a renowned activist and educator in Palestine. With an illustrious career in education that includes Bethlehem University, Birzeit University, Yale University, Duke University, and the University of Tennessee, Qumsiyeh is a prolific and widely respected educator. He also founded two integral institutions in the Palestinian environmental sector- the Palestine Museum of Natural History and the Palestine Institute for Biodiversity and Sustainability. The approach of these two organizations tends to prefer a minimal human interference in the biosphere and the enabling of natural cycles to function unencumbered. This often makes Professor Qumsiyeh an opponent of seawater desalination as a solution for water scarcity.

6) **Tarek Zureikat:** CEO, Engicon.

Tarek Zureikat is the CEO of Engicon, a regional a regional Engineering Firm involved in several water projects. Engicon functions as a "multi-disciplinary consultancy," with specializations in the following areas:

- *Water and wastewater*
- *Roads and transportation*
- *Architecture*
- *Construction management and supervision*
- *Capacity building and institutional development*
- *Urban planning and infrastructure*
- *Environmental services*

Two of Engicon's major water-related projects include an industrial water-reuse project in Amman and a water supply-design project in Basra. Founded in 1988, Engicon has a team of 450 individuals. The company is based in Amman, Jordan but has a regional presence. It recently expanded to the United States.

Correspondence Only:

7) **Khaldon Khashman:** founder, Arab Countries Water Utilities Association (ACWUA); Bachelor of Engineering

Eng. Khaldon Khashman is a renowned water engineer and current secretary general of the Arab Countries' Water Utilities Association (ACUWA). Eng. Khashman is a member of the board of directors of the Jordan Water Authority. He is a recognized figure in the Jordanian Engineers' Association. Eng. Khashman is an outspoken advocate for the sharing of knowledge and experience in water engineering, which he actively pushes for as part of his position in ACWUA. Eng. Khashman has an unparalleled understanding of Jordan's recent water history, *having worked at the Jordan Drinking Water Corporation (now defunct) and later joined as a board member of the Jordan Water Company (Miyahuna)*

8) **Walid Khalil Al Zubari:** PhD. MSc. Ground Water Mathematical Modelling; Vice President, WSTA; Editor in Chief, Arab Gulf Journal of Scientific Research (2006-2010); President, Gulf Water Conference (2003-05 & 2013-15).

Prof. Al-Zubari is a professor of Water Resources Management at the Arabian Gulf University (AGU). He obtained his MSc. From Ohio University and PhD. From Colorado State University. He is one of the most respected voices in the world of Arab water, and especially the Gulf region. His credibility and knowledge are manifested in his long service to the water resource management sector of the Gulf. Prof. Al-Zubari has served on the scientific committees of seven Gulf Water Conferences, putting him at the center of the discussion on water in the region. He also initiates his own projects, and is a prolific author.

Appendix 2: List of Questions from Interviews

Investigative Questions

1. Has Palestine ever considered desalination as a way to source water and minerals? Why/why not?
2. As an expert in natural history, could you outline to me the main causes of water stress in the Levant?
3. Could you identify some organizations in Jordan and West Asia - North Africa (WANA) that you believe are making significant contributions to address water scarcity on a large scale?
4. To the best of your knowledge, is the non-governmental & non-profit sector in Jordan seriously considering desalination as a remedy for water scarcity? Why? Are they considering other solutions, if any?
5. What are the main components of a successful and effective water management regime?
6. Could you speak about the industrial water reuse project you worked on in Amman?
7. What role can the League of Arab States play in the GCC desalination industry? What about the Arab Water Council and the Arab Countries' Water Utilities Association?
8. Could you speak about your experience in working with any regional/international water governance organizations (WSTA, IDA, AWC, ACWUA, MEWF etc.)?
9. What will happen to the production of polymer-based nanofiltration systems after we deplete the Earth's petroleum resources? Do you think that we will be able to extract the rarer materials (gold, rubidium, uranium, etc.) before we run out of oil?
10. What are some pressing issues being discussed at the moment at the ACWUA and MEWF?
11. According to the "Water Reuse in the Arab World: From Principle to Practice" Report, Arab countries reuse 20% of their wastewater. Why do you think that is the case?
12. Where does the Wehda dam stand in the context of Jordan's long-term water resources?

Analytical Questions

1. In your opinion, is it better to invest in water reuse or desalination to address the water scarcity issue? If both, where should we start?
2. By enabling wasteful water habits, has desalination done more harm than good to the GCC?
3. How does the intersection of apartheid policy and water policy look like?
4. How have the economic dynamics of the agricultural sector in Palestine changed over the past century? How has that affected the water sector?
5. What role do you think regional organizations can play in addressing water scarcity in Palestine, the Levant, and the West Asia/North Africa region as a whole?
6. Where do you think investment should be targeted to catalyze the adoption of sustainable brine disposal/management?
7. Would you characterize Saudi Arabia as a desalination superpower?

8. How has violence in the past 10 years affected the water sector in the West Asia / North Africa region?
9. How would you compare the governance regime of the Arabian gulf to the governance regime of the Red Sea? And how do the Gulf and Red Sea compare to the Mediterranean sea? Similarities / Differences.
10. There is persistent inequality in the West Asia / North Africa (WANA) region, including in terms of water resources. Can desalination help mitigate these inequalities?
11. Despite the inequalities in the WANA region, everyone shares in the challenge of water scarcity. However, colonial boundaries have created artificial water scarcity as well. How has the colonial legacy in the region affected your work as a scientist?
12. Is desalination for everyone? Are there water-scarce countries for whom you would not advise desalination as a remedy for water-scarcity?
13. Recently, Eng. Abdullah bin Ibrahim Al-Abdul Karim (governor of Saudi Arabia's Saline Water Conversion Corporation) announced that Saudi Arabia will soon be able to apply the Zero Liquid Discharge technique on a commercial scale. Do you think Saudi Arabia is truly capable of doing this?
14. Do you agree that the construction of so many dams in Syria and Turkey exacerbated the water problem in Iraq & the whole region?
15. 48.9 kWh are used to transport 1 cubic meter of water from the Eastern shores of Saudi Arabia to the population centers of the province of Riyadh. How does this energy dynamic change the desalination industry in Saudi Arabia? How does this compare to other countries, such as Bahrain, Qatar, or the UAE?
16. How does brine disposal relate to the Water-Energy / Water-Energy-Food Nexus?
17. The Gulf region is a pioneer in water desalination. WSTA intends for the region to become a pioneer in sustainable water desalination, but do the residents of the region want that as well?
18. Do you think seawater desalination is an effective alternative water-sourcing method for the Jordanian agricultural industry?
19. Do you think the adverse effects of profitable brine concentrate mining in the Dead Sea is worth the risk? In what context could the Dead Sea industry be sustainable?
20. According to Nabih Bulous of the Los Angeles Times, Jordan's northern Wehda dam is performing far below its capacity. Where does the Wehda dam stand in the context of Jordan's long-term water resources?
21. How can the region's water governance regime improve?
22. The Aqaba-Amman desalination project will offset the losses in freshwater resources from the north of Jordan. How will this impact the water governance regime in Jordan?

Opinion Questions

1. The Aqaba-Amman desalination project will offset the losses in freshwater resources from the north of Jordan. How will this impact the water governance regime in Jordan?
2. To the best of your knowledge, is the non-governmental & non-profit sector in Jordan seriously considering desalination as a remedy for water scarcity? Why? Are they considering other solutions, if any?

3. What are your thoughts on the Dead-to-Red project? Are there better approaches/alternatives, and what are they?
4. Why do you think there is no single water governance body in the Arab region? Do you think there is a place for a centralized water governance body?
5. What, in your opinion, are some notable commercial consequences to water scarcity in West Asia and North Africa?

Personal Questions

1. Could you speak about your experience as a student of water engineering in a water-scarce country? Did that aspect affect your academic experience, and how?
2. What is like being a businessman and business administrator in a water-scarce country?
3. What is it like to be a water policymaker in a water-scarce country?
4. What is it like to be a scientist in a water-scarce region?
5. What is it like to be a policy researcher in a water-scarce region?
6. What motivated you to delve into and specialize in the field of water politics?
7. When did you realize how drastic the water scarcity problem is in Jordan?

Glossary

Antiscalants (organic & inorganic): Chemical Compounds that are used to prevent the clogging of filtration systems and pipelines.

Brine / Reject Brine: This is the salty discharge from desalination. When the intake/feed water is from the sea/ocean, the brine tends to contain 90% Sodium Chloride (NaCl), which is the compound that constitutes table salt.

Brine Concentrate Mining: The process of extracting valuable elements and compounds from the concentrated solution that is the byproduct of desalination. This solution consists mostly of Sodium and Chloride, but also contains other elements such as Bromine (Br), Magnesium (Mg), Lithium (Li), and other valuable elements.

Brine Concentrate / Saturated Brine: This is the byproduct of seawater desalination. Due to the prior extraction of freshwater, this liquid is much more concentrated than seawater.

Conventional Water Resources: Surface or ground water that is typically fresh and easily accessible.

Desalination/Seawater Desalination: This is the process of extracting freshwater (H_2O) from seawater. In cases where this water is used to supply a municipal water system, there is usually a process of remineralization to make the water suitable for human consumption, since distilled water lacks many of the minerals that humans usually get from drinking water.

Fossil Water: This is another term for non-renewable water resources. Fossil water usually refers to underground aquifers and reservoirs, such as the Disi aquifer shared by Jordan and Saudi Arabia.

Integrated Water Resource Management (IWRM): According to the Global Water Partnership (GWP), IWRM refers to the promotion of a coordinated development and management of water, land and related resources. The goal of IWRM is to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Multi-Stage Flash Desalination (MSF): This is a more complex method of thermal desalination, and it designed to conserve and reuse energy/heat throughout the thermal desalination process. MSF played a major role in enabling desalination on a large scale in the GCC.

Membrane Distillation: This is the process of extracting distilled water (H_2O) by using specially designed membranes that are water-permeable but keep out other elements and molecules.

Micro/Nano/Ultra filtration: This refers to the characteristics of a filtration system. The suffix (micro-, nano-, ultra-, etc.) describes the size of the pores in the membranes that are used in the filtration process.

Non-conventional Water Resources: Water resources that require processing before access, such as wastewater or desalination.

Reverse Osmosis (RO): This is one of the processes of desalination and water treatment more broadly. It has been developed and improved over decades. RO is made possible through developments in filtration technology. It consists of a complex network of pressurized water filtration using specially design membranes. To prevent clogging, some materials (known as antiscalants) are used during RO.

Seawater Intake / Feed water: The water that is introduced into the desalination process.

Solar Crystallization: This is the process of creating crystals from the solid elements in a solution using solar power. This process can utilize photothermal disks, among other technologies.

Thermal Desalination: This is the traditional method of seawater desalination. It consists of boiling seawater to separate solids from distilled water.

Veturi Diffuser / Diffuser: A tool used at desalination plants to distribute the redepositing of brine to prevent increasing the rise in salinity that results from depositing desalination brine in a single, concentrated location.

Water-Energy-Food Nexus: the inter-linking of water, food, and energy security.

Water Scarcity: A water scarce region typically has renewable freshwater resources of 500 m^3 per person per year.

Water Stress: A water stressed region typically has renewable freshwater resources of 1700 m^3 per person per year.

Zero Liquid Discharge (ZLD): This term is frequently used in the mining industry and refers to the process of extracting all liquid from the wastewater of the mining process. ZLD is important for the mining industry because its wastewater tends to contain toxic content that prevents it from being disposed of easily. ZLD enables the mining industry to reduce its consumption and reuse its water, as well as dispose of its waste safely in landfills.

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