POLICY BRIEF

SHOULD TURKMENISTAN USE THE CASPIAN SEA TO QUENCH ITS THIRST?

A Feasibility Assessment of Building a Desalination Plant on the Caspian Shore

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Authors:

JAHAN TAGANOVA

Originally from Turkmenistan, Jahan Taganova is a water diplomat, One Young World Peace Ambassador, and scholar, working at the intersection of global development and public policy. Jahan graduated with a joint MS in Water Cooperation and Diplomacy between the world-renowned IHE Delft Institute for Water Education, UN Mandated University for Peace, and Oregon State University. Jahan's research interests include water governance, integrated water resources management, climate justice, critical development studies, and social justice, and provides work that bridges the gap between natural resources and at-risk populations.

ZAIDA AURORA CHOLICO SANTOYO

Zaida Aurora Cholico Santoyo holds a BS in Civil Engineering from ITESM's Guadalajara Campus in Mexico, and an M.Sc. in Water Management and Governance from IHE-Delft in the Netherlands, for which she received the IHE-Delft Rotary Scholarship for Water and Sanitation Professionals. She is currently working as a water quality and watershed management consultant. Zaida's research interests include integrated watershed planning and resources management, water governance, nature-based solutions, ecosystem services, and climate change.

RACHANA MATTUR

Rachana Mattur is a civil engineer with a master's degree in Water Management and Governance with a specialization in Water Conflict Management. Currently working as Program Assistant at Water Rising Institute. Rachana's research interests include transboundary water management, gender equality, and solution-focused climate research.

Authors:

JACLYN BEST

Jaclyn Best is a PhD student in Integrated Coastal Sciences at East Carolina University in North Carolina and holds a joint Master's degree in Water Cooperation and Diplomacy from IHE Delft Institute for Water Education, the University for Peace, and Oregon State University. In addition to studying the intersections of water, conflict, and gender, her research interests focus on how water governance and policy are influenced by marginalized groups and public participation.

ANNA SHABANOVA

Anna Shabanova is a recent graduate of a double degree master's program at the Higher School of Economics and the University of Trento. In her scholarly work, Anna deals with issues of Central Asian regionalism, transboundary water management, and European Union foreign policy, especially in the natural resources sector.

Contributing Editor:

CHRISTOPHER A. ELLISON

Christopher A. Ellison is the Editor at the Institute for European, Russian, and Eurasian Studies at The George Washington University. He received his BA, cum laude, in Political Science and Literature from the University of California at San Diego; his MALD from the Fletcher School of Law & Diplomacy at Tufts University; and his MA in Economic History from Rice University, where he also studied at the James A. Baker III Institute for Public Policy. He is a board member of the anticorruption nonprofit organization Fides Intl., and a former Fulbright Fellow.

Executive Summary

Turkmenistan's water supplies are decreasing, making the desalination of the Caspian Sea an attractive option to meet the country's current water needs. While desalination is an attractive option to address water scarcity and increase freshwater supply, it is not without its disadvantages: its high energy requirements will increase carbon emissions, its byproduct brine creates waste management problems, and over-extraction of Caspian waters threatens the Caspian Sea's unique ecosystems and even the Sea's survival. These potential consequences should serve as a warning not to consider addressing water supply only as a short-term solution at the expense of long-term implications and the needs of future generations. With freshwater reservoirs drying up and river runoff shrinking due to the nation's heretofore inadaptability to climate change, should Turkmenistan consider desalination to increase its water supply? This policy brief analyzes the pros and cons of Turkmenistan's potential[1] desalination plant and proposes eight alternatives to address water scarcity sustainably and equitably.

Introduction

In Central Asia, just like across the globe, water scarcity is being exacerbated by population growth, increased water consumption per capita, economic development, and diminishing water supplies due to climate change and contamination. With Turkmenistan's growing population[2] between the late 1990s and early 2020s, the annual water availability per capita has decreased by 50%, dropping from 8,000 to 4,000 cubic meters in 2004 (more recent data is unavailable). As a result, water has become the most important strategic resource for determining the country's economic opportunities, water security, and human safety.

In 2019, the World Resources Institute's Aqueduct Water Risk Atlas reported that Turkmenistan is on the brink of a water crisis, with severe shortages potentially looming in the coming years. Per capita, Turkmen citizens consume four times more water than US citizens, and 13 times more than Chinese citizens. The available freshwater resources in Turkmenistan are insufficient to meet these high demands. This, in essence, negates the UN recognition of water as a fundamental human right and the UN's Sustainable Development Goal (SDG) #6, which calls for ensuring the availability and sustainable management of water and sanitation for all.

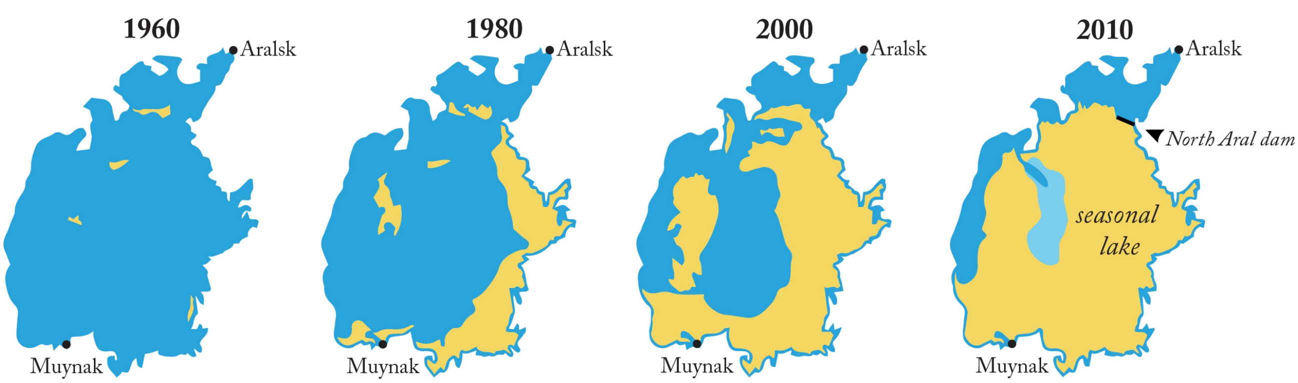
[1] On June 9, 2022, the Turkmen media outlet Orient.tm reported that President Serdar Berdimuhamedov instructed Deputy Prime Minister Annageldy Yazmyradov to study the possibilities of building desalination plants and supplying water from the Caspian Sea to Ashgabat.

[2] Population figures reported by the World Bank are based on data provided by the Turkmen authorities, which is highly contested. As reported by Radio Free Europe/Radio Liberty, Turkmenistan's population is experiencing an unprecedented decline, with only 2.8 million citizens living there in 2021.

Water scarcity in Turkmenistan, therefore, necessitates a *radical rethinking* of water resource planning, governance, and management that could include the exploration of unconventional water resources for sector water uses, livelihoods, ecosystems, climate change adaptation, and sustainable development. In recent decades, desalination has emerged as a techno-social fix to solve 21st-century water issues as a means to enhance water supplies for domestic and municipal use. To alleviate this problem, the government of Turkmenistan is currently considering desalinating water from the Caspian Sea.

Since Turkmenistan is nestled alongside the Caspian Sea, desalination–the process that removes salt, other minerals, and impurities from seawater through various technologies–might seem a viable option, especially considering that Turkmenistan has already built a desalination plant in the town of Ekerem, which is situated on the eastern shore of the Caspian Sea, with a capacity of 5,000 m^3 per day to secure the drinking water supply for approximately 20,000 inhabitants in a total area of approximately 3,000 km^2. President Serdar Berdimuhamedov has charged Deputy Prime Minister Annageldy Yazmyradov with the task of possibly constructing desalination plants to supply water to Ashgabat, which is experiencing severe water shortages. However, realizing the potential of desalinated water remains a challenge due to relatively high economic costs, environmental concerns, and brine management issues. Therefore, a detailed evaluation of the benefits and challenges of the desalination process in the context of Turkmenistan is paramount to avoiding sentencing the Caspian Sea to the same fate as its late neighbor, the Aral Sea (see Figure 1).

FIGURE 1. A series of images showing the shrinking of the Aral Sea between 1960 and 2010.



Source: Zoï Environment Network

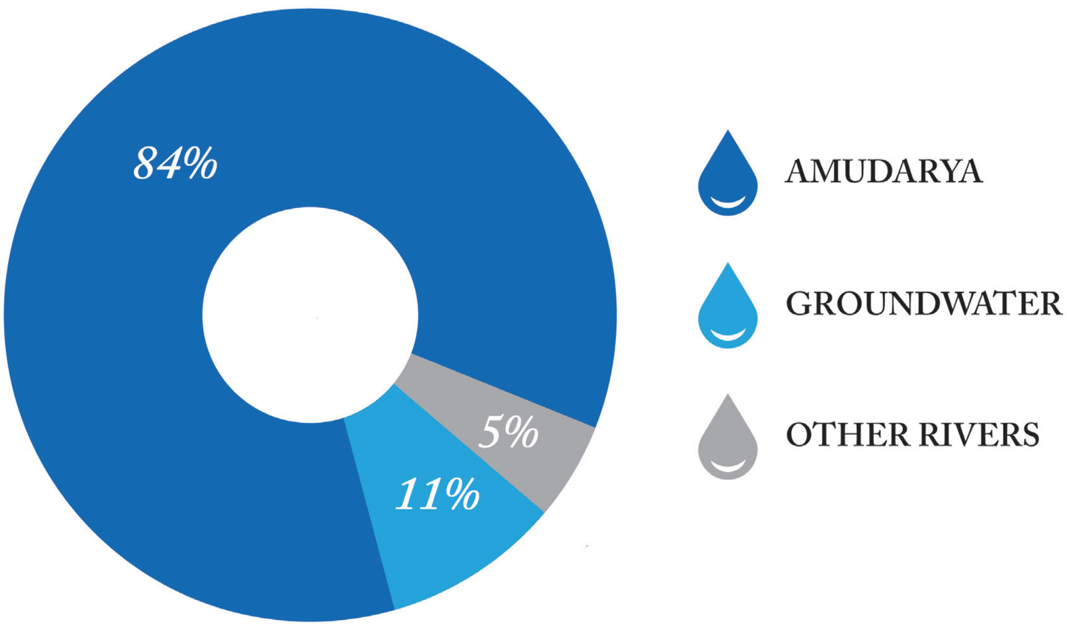
Despite the regional nature of the demand for irrigation and industrial use, the interconnected water and energy systems in Central Asia are poorly coordinated, which, in combination with the looming climate change threats, creates challenges for the region's water-energy nexus. Difficulties in the political realm, although partly resolved since the change of power in Uzbekistan in 2016, are still key to understanding the dynamics of water management in the basin. With the countries still relying on aging Soviet infrastructure leading to tremendous amounts of water leaking out of water supply pipes—with loss rates exceeding 30%—and being dependent on a not-so-feasible barter system between water and energy, Central Asian states are part of a vicious cycle of nationally-driven water and energy priorities confronting the needs to consider regional demands and environmental threats. In this regard, there are two points to be made here.

Central Asia is under growing environmental pressure, with global warming having a significant impact on the hydrology of the region. The Amu Darya River is entirely supplied by icecap runoff. Due to climate change, the icecaps of Central Asia that feed the Amu Darya and Syr Darya rivers are melting rapidly. Experts are predicting permafrost melt, causing a 7%-15% flow reduction by 2050. According to the University of Geneva, 0.1%–0.8% of the surface of the glaciers in the Tien Shan Mountains melts away every year, leaving only 2/3 of the glaciers intact compared to a century ago. Consequently, the Asian Development Bank estimates that the annual unmet water demand in the basin will increase from the current 8.8% to between 31.6% and 39.7% in 2050.

How Does Turkmenistan Get Its Water?

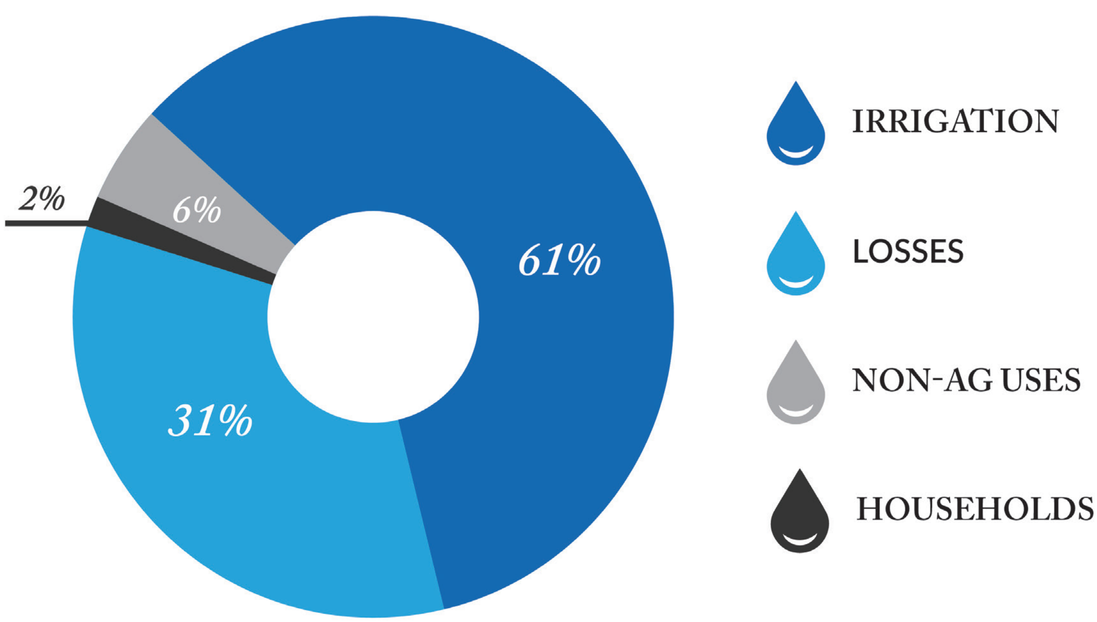
In Turkmenistan, the Amu Darya River, which flows from the Pamir Mountains and Tien-Shan Mountains to the Aral Sea Basin, serves as the main water source for the country. It is a transboundary river shared by Afghanistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. While the international agreements covering the use of the Amu Darya allocate 36% of its annual flow to Turkmenistan, only 1% of the Amu Darya's flow is formed on the territory of the country (see Figures 2 and 3). At the same time, Turkmenistan is extremely dependent on water resources for agricultural and economic development purposes. To satisfy Turkmenistan's water demand, intake from the Amu Darya is supplemented by surface runoff from the Murgap, Tedjen, and Atrek rivers, as well as other small springs. Groundwater also makes up a marginal part of Turkmenistan's water resources. In total, there are 3.4 km^3 of groundwater reserves, of which only 1.3 km^3 are usable due to high levels of salinity, effectively making it suitable neither for humans nor for livestock. The amount that is actually used today is between 0.4 and 0.5 km^3. A recent decision by the Turkmen president to explore desalination as an alternative water supply option is reasonable given the incompatibility between the country's hydrological supply and demand. However, the larger regional water dynamics in the Amu Darya Basin need to be considered as well.

FIGURE 2. Structure of Turkmenistan's water resources



Total water resources 26.273 billion m^3 (long-term average).

FIGURE 3. Structure of water uses (2004)



Total water intake 28 billion m^3.

Source: Adapted from Ivan Stanchin and Zvi Lerman, "Water in Turkmenistan," Discussion Paper no. 888–2016–65088 (Jerusalem: Hebrew University, 2007).

Water Dynamics in Central Asia

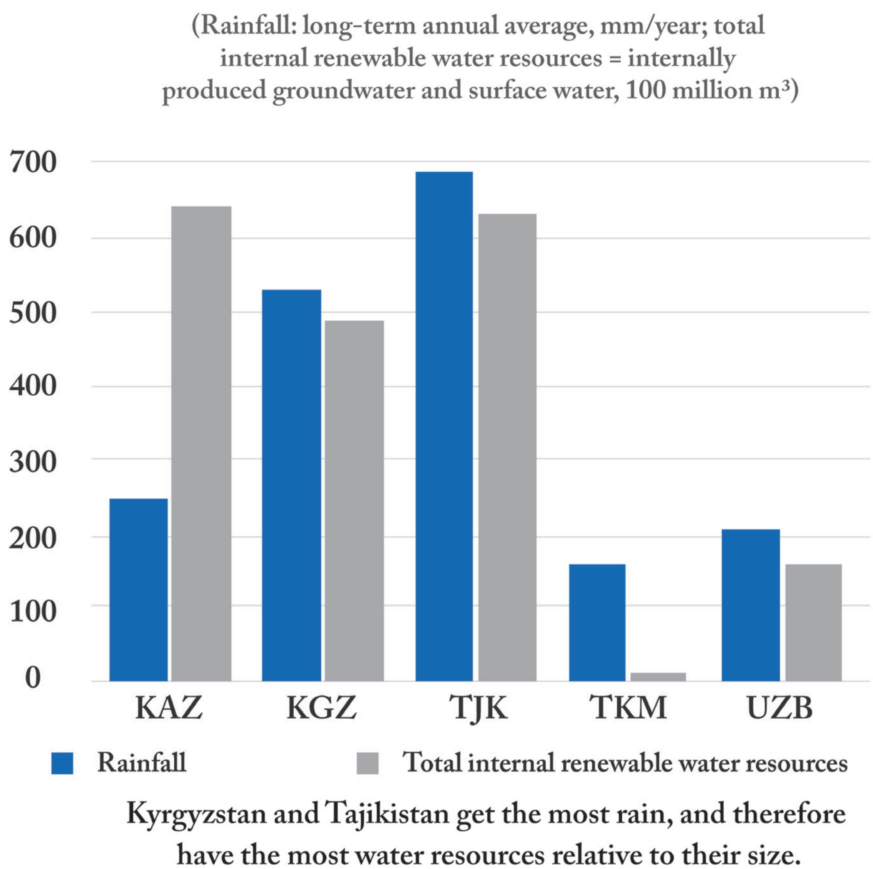
During the Soviet era, water security was ensured through a water-energy exchange between the upstream and the downstream states, where upstream water-abundant countries (Tajikistan and Kyrgyzstan) provided water for irrigation in summer to downstream states (Turkmenistan, Uzbekistan, and Kazakhstan), while downstream countries supplied energy sources (gas, coal) to their upstream neighbors in winter to help with heating. However, after the demise of the USSR, the former Soviet Socialist Republics gained their independence in 1991, and the centrally-planned water and energy management systems established during the Soviet era had to be reshaped towards market-oriented approaches. Consequently, the previously domestic watercourses became transboundary, and their use had to be negotiated at the international level. At the same time, the former Soviet republics became players in a zero-sum nation-building game wherein natural resources turned into valuable commodities that could not be as easily traded due to the price difference between upstream hydro-energy and downstream fuel-produced energy. While energy resources such as oil, gas, and coal have a relatively high market price, water (especially since it is a transboundary resource) is considered to be exempt from market dynamics and is deemed to belong to the state wherein the particular part of a body of water is located. As a result, the ownership of water by upstream Central Asian states is often contested by their downstream neighbors and, consequently, leads to conflicts, disputes, and even threats of potential water wars.

While there are currently sufficient water resources in the region in terms of volume to quench thirst, due to water delivery system mismanagement (such as not fixing leaking pipes), there is currently an 8.8% shortfall between demand and supply, which the Asian Development Bank warns will grow to between 31.6% and 39.7% by 2050 if these issues are not properly addressed.

Increasing temperatures are coupled with the prospective changes in rainfall patterns that will affect the snow and glacier melt. Currently responsible for up to 65% and 46% of flow contribution to the Amu Darya and Syr Darya, respectively, snow and glacier melt is expected to decrease by 26%–35% and 22%–28% for these rivers, respectively, by 2050. At the same time, water consumption may increase by 4%–5% in the Amu Darya Basin and by 3%–4% in the Syr Darya Basin, significantly straining the water regime in the region and putting communities at risk of imminent drought in the future.

Within the entire Aral Sea Basin, Turkmenistan has less than 1% of the total internal renewable water resources (that is, excluding rainfall), at around 194.5 billion m^3 (see Figure 4). Turkmenistan also has the second-highest rate of freshwater withdrawals in the region (after Uzbekistan), effectively making Turkmenistan subject to severe water stress, exacerbated by its dependency on upstream countries. By the year 2100, 50%–90% of the glaciers that feed Central Asian rivers are forecast to disappear, significantly reducing the flow of water in the summer, which is crucial to the agricultural sector of downstream states in the basin. Consequently, the decision of the Turkmen president to seek the development of water resources elsewhere (namely from the Caspian Sea, to which it has direct usage rights) should not come as a surprise.

FIGURE 4. Water resources in Central Asia.



Source: Adapted from EU Parliament Briefing.

Second, Central Asia's governments have historically utilized antiquated laws and regulations that have promoted unsustainable development projects and failed to resolve water disputes. Central Asian governments often see water as a nation-building tool, leading to exorbitant use of it. Turkmenistan in particular is known for its poor water governance projects such as building elaborate fountains in the capital city, which have made their way into the Guinness Book of World Records; building the Golden Age Lake in the middle of the Karakum Desert; and declaring plans to grow particularly water-thirsty crops such as walnuts, almonds, dates, and even bananas. While the residents of Ashgabat and other parts of Turkmenistan experience periodic water unavailability and are forced to fetch water manually, the government has been rolling out large-scale greening campaigns, such as the "grand greening action"—planting more than three million trees that need large quantities of water.

Water insecurity in Turkmenistan is, thus, a socio-ecological issue, and to a large extent a result of man-made problems related to the Soviet legacy of water resources management combined with nation-building processes of the post-independence period.

The Caspian Sea and Climate Change: What's at Stake?

Located between Europe and Asia, the Caspian Sea (see Figure 5) stretches from southern Russia to the Iranian Plateau in Southwest Asia, just west of the broad steppe of Central Asia, dividing Central Asia from the Caucasus. The Caspian Sea is a vast body of landlocked saltwater about the size of Norway and is shared by five littoral states: Iran, Azerbaijan, Russia, Kazakhstan, and Turkmenistan. The Volga River, the longest in Europe, is the source of 80% of the Caspian's freshwater inflow. The Caspian Sea does not have an outlet to the world's oceans, which effectively makes it a lake, but it is sea-like in its size, stretching nearly 1,200 km. from north to south, with an average width of 320 km. It has a salinity of approximately 1/3 that of average seawater, about 13.5 parts per thousand (ppt), but this figure conceals a variation from a mere 1 ppt near the Volga outlet to a high of 200 ppt in the Kara-Bogaz-Gol lagoon, the large inlet located in northwest Turkmenistan.

FIGURE 5. Map of the Caspian Sea and its neighboring countries.

Source: Wikimedia Commons.

The Impact of Climate Change

In recent years, heightened attention has been paid to water management and security in Central Asia due to climate change. Warmer temperatures and more volatile weather patterns correlated with climate change disrupt ecosystems and increase the frequency of extreme droughts, floods, mudflows, heatwaves, and forest fires. Annual average temperatures in Turkmenistan between 1990 and 2020 were at least 5°C higher than they were between 1960 and 1979, resulting in drier summers and more winter rainfall (with an attendant decreasing amount of snow). According to the World Bank, the average annual temperature in the region is expected to rise by at least 1.3°C and even as much as 5.1°C by the mid-2090s, depending on emissions pathway projections. Climate change will increase evaporation over the Caspian Sea, which will not be balanced by river discharge or precipitation, making it the leading driver of changes in the Caspian Sea Level (CSL).

The Caspian Sea is already experiencing a devastating decline in its water level due to climate change, mismanagement of the rivers whose courses naturally flow into it, and the damming of the Volga River. Additionally, in 2021, Iran introduced an ambitious seawater desalination and transfer plan from the Caspian Sea to fight unprecedented levels of drought. Meanwhile, Kazakhstan, with its desalination plant, and Azerbaijan are already desalinating Caspian seawater as a response to their own water shortages. With numerous desalination projects both existing and planned, water extraction from the Caspian Sea would only accelerate its depletion. It is estimated that the *northern portion* of the Caspian Sea, in which water depths are less than 5 meters, may disappear in 75 years if CSL continues to decrease at 7 cm/yr, representing a major threat to fragile ecosystems and wreaking havoc on the region's climate.

Furthermore, as a result of climatic variations and human activity, desertification (the persistent degradation of dryland ecosystems) is spreading rapidly, threatening sensitive Caspian shore wetlands such as the Volga Delta and the area around the city of Ramsar in Iran. According to the Desert Institute of Turkmenistan, 66.5% of the country's territory is affected by desertification. Overall, the falling Caspian Sea water levels will be compounded by global climate change and cause devastating effects in Central Asia, including threats to the fishing industry and water infrastructure of the Caspian, as well as food and energy security for littoral states.

Is Seawater Desalination a Sustainable Technological Solution for Turkmenistan?

Mismanagement of Turkmenistan's water resources and the effects of climate change have put a strain on its freshwater supply, so desalination is an alternative solution worth considering. Desalination is regarded by techno-optimists as the "magic bullet"[3] that could help overcome the 21st century's water

[3] Melanie Lidman, "Desalination Isn't the Magic Bullet, Water Authority Warns Israelis," *Times of Israel,* June 5, 2018, www.timesofisrael.com/desalination-isnt-the-magic-bullet-water-authority-warns-israelis; Andrew Tarantola, "Seawater Desalination Will Quench the Thirst of a Parched Planet," Engadget, October 27, 2017, https://www.engadget.com/2017-10-27-seawater-desalination-quench-parched-planet.html.

challenges, including threats to the water cycle posed by climate change. But desalination has major social, political, and environmental implications if done without assessing the Caspian Sea's current state and conducting a cost-benefit and multi-criteria decision analysis of the process.

The potential impact of desalination on transboundary hydropolitics in the Amu Darya Basin

As a result of Soviet-era policies, Turkmenistan and Uzbekistan benefited from water allocations in Central Asia. Upstream Afghanistan's water resource issues were deprioritized, and Tajikistan became a water regulator, mainly through dam construction. When administrative Soviet Union boundaries became international boundaries in 1991, Central Asian states faced inequitable water allocation limits and interdependencies among their water provision structures. Following independence from the USSR, Uzbekistan's military power contributed to the perception that it would become the hydro-hegemon: a hegemony at the river-basin level, achieved through water-resource control strategies (military power, resource capture, integration, and containment) in the region. However, Turkmenistan's control over the Amu Darya's lower and middle infrastructure such as the Tuyamuyun Reservoir, which provides water to the Khorezm and Karakalpakstan regions of Uzbekistan; and the pumping stations, which pump water to Bukhara and Kashkadarya provinces; have positioned Turkmenistan as a hydro-hegemon relative to Uzbekistan. At the same time, large-scale infrastructure projects such as the Rogun Dam in Tajikistan can alter water control and shift regional hydro-political interactions through resource capture and increase of reservoir capacity. Specifically, by building the Rogun Dam, Tajikistan would be able to produce more hydropower and pressure downstream riparian states to pay for water releases supporting agricultural production. On the other hand, the construction of the new desalination plant in Turkmenistan could also be a "game-changer in transboundary hydropolitics." First, desalination removes some quantitative restrictions on freshwater supply and its unpredictable nature, giving states more stability, flexibility, and predictability with respect to their water resources. Second, desalination facilities allow for some freedom in terms of their location, such that states no longer have to rely as heavily on freshwater resources and may consequently change the distribution of power in a basin. This may significantly alter major factors in transboundary water interactions between the Amu Darya Basin states. Although there is disputed evidence that water scarcity alone will lead to conflict on a transboundary scale, desalination, by providing additional water to a basin, might then be assumed to reduce the potential cause for conflict. Conversely, however, by reducing the reliance on transboundary freshwater resources, desalination could also decrease the incentives for states to cooperate with one another, given their newfound hydrological independence.

Desalination technologies and their implications

Desalination is the process of removing salt, minerals, and contaminants from seawater to obtain fresh water. States in the Middle East such as Israel, Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates, and Oman have pioneered the use of desalination on a large scale for domestic and industrial use since as early as the mid-20th century. The world's desalination capacity has increased exponentially since then. Currently, reverse osmosis and thermal processes are used to desalinate seawater. Thermal processes include multistage flash distillation (MSF), multi-effect distillation (MED), mechanical vapor compression (MVC), and thermal vapor compression (TVC). Thermal desalination has been used widely in oil-rich but water-scarce Gulf countries since the early 2000s. In these processes, seawater is heated and the evaporated water is condensed to produce fresh water. In addition to consuming substantial amounts of electricity and thermal energy; which in Turkmenistan comes mostly from traditional energy sources such as coal, oil, or natural gas; thermal desalination also releases greenhouse gases.[4] A relatively newer technology being utilized in desalination is reverse osmosis (RO), which is based on a membrane system in which seawater is pressed against a semipermeable membrane that allows water to pass through, but not salts, viruses, or bacteria. In the last two decades, RO technology has significantly improved in its efficiency, surpassing that of thermal technologies. As of 2021, there were over 17,000 operating desalination plants worldwide, and approximately 50% of those used RO technologies. In the context of Turkmenistan, RO desalination can be an effective tool for alleviating water shortages; however, it is constrained by energy and monetary costs for treatment and brine management, as well as adverse environmental impacts.

1. *Carbon footprint*

Thermoelectric energy, the main power source for seawater desalination plants, results in the emission of carbon dioxide, nitrous oxide, nitrogen dioxide, and sulfur dioxide. To illustrate this, the current state-of-the-art seawater RO plants consume between 3 and 4 kWh/m^3 and emit between 1.4 and 1.8 kg of CO_2 per cubic meter of produced water. Turkmenistan is already one of the world's biggest emitters of methane, just behind Russia and the US. The carbon footprint generated by large-scale desalination plants can be substantial.

There are a number of recent technological innovations to reduce the carbon footprint of desalination. For instance, RO systems have the option to implement Energy Recovery Devices (ERDs) that are used in seawater desalination applications to recover the pressure energy of the concentrate. Hence, the use of ERDs results in a significant reduction in the specific energy consumption of RO plants. Furthermore, the concentration of brine from RO desalination plants by natural evaporation can reduce the energy consumption of the treatment and the associated costs. Additionally, the capital cost, energy consumption, and environmental impact of desalination would be eased by reducing or eliminating the pretreatment stage. And advances in membrane technology would diminish the requirement for post-treatment in seawater reverse osmosis plants, which would additionally improve energy efficiency and reduce capital costs. Despite these cost-saving and energy-reducing measures, the levels of greenhouse gas emissions from large-scale desalination processes remain a high concern.

Turkmenistan has very favorable conditions for developing wind energy to power desalination plants. Further research should additionally explore the option of using nuclear energy to power desalination. For nuclear

[4] Manoj Chandra Garg, "Renewable Energy-Powered Membrane Technology: Cost Analysis and Energy Consumption," in *Current Trends and Future Developments on (Bio-) Membranes: Renewable Energy Integrated with Membrane Operations* (Amsterdam: Elsevier, 2019): 85–110.

desalination, socioeconomic, safety, environmental, and other considerations have shown nuclear energy to be equivalent or better when compared to other energy sources powering desalination. However, this must come with careful consideration because Turkmenistan is considered to be an area of significant seismic activity. Additionally, the lack of a well-trained cadre of nuclear scientists and engineers who could operate and maintain nuclear power plants is another pitfall that needs to be addressed. Finally, given that Turkmenistan borders Afghanistan and Iran, the security of the nuclear power plants and the potential of terrorist attacks to sabotage the technology should be considered.

Turkmenistan ratified the Paris Climate Accords (also known as the Paris Agreement) in 2016, and adopted an Intended Nationally Determined Contribution (INDC), thus committing to reducing greenhouse gas emissions on a national scale by 2030. In accordance with its commitments under the Paris Agreement, Turkmenistan also approved its updated Nationally Determined Contributions (NDCs) in May 2022 for submission to the United Nations Framework Convention on Climate Change (UNFCCC). It is evident that Turkmenistan's government is motivated to join international efforts to mitigate climate change in the next decade. As Turkmenistan's authorities are presently exploring seawater desalination options, they should consider installing renewable energy (that is, wind and solar) plants to minimize greenhouse gas emissions resulting from the desalination process. However, because desalination requires constant energy flows, its potential for being powered by intermittent renewable energy sources such as wind and solar energy is currently limited. Some have proposed that renewable energy plants could power desalination plants through indirect compensation or offset measures; however, this has not yet been implemented on a large scale.

2. *Brine management*

The desalination process separates feed water into two different streams: a freshwater stream (product water), and wastewater with very high concentrations of salt and chemicals, known as *brine*. In the UN University's Institute for Water, Environment and Health-backed paper, experts estimate that global brine production is at 141.5 million m^3/day, totaling 51.7 billion m^3/year—roughly 50% greater than the total volume of desalinated water produced globally. Put simply: for every liter of freshwater output, desalination plants produce on average 1.5 liters of brine (though this value varies significantly, depending on the feed water salinity and the desalination technology used, as well as local conditions).

Desalination plants located near shorelines often discharge untreated brine directly into saline surface waters, which raises important environmental and ecological concerns. Currently, scholars from the Polytechnic University of Valencia suggest concentrating brine through RO up to the operational limit of the process (around 70 g/L of salinity) and crystalizing the concentrated liquid by evaporation until getting a solid waste from which salt and minerals (such as sodium, calcium, potassium, magnesium, lithium, strontium, bromine, boron, and uranium) can be recovered for commercial use. Other proposed measures to offset impacts from high-salinity desalination plant brines include dilution with other waste streams, disposal in less-sensitive marine ecosystems, and more effective pretreatment. Likewise, Stanford University researchers have developed a device that splits the components of brine into commercially valuable chemicals such as sodium hydroxide (used in the manufacturing of many products including soap, paper, aluminum, detergents, and explosives), hydrogen (used for industrial purposes such as fertilizer production, and energy storage and delivery), and hydrochloric acid (used in battery production, as a food additive, and even in leather processing), avoiding the need to dispose of potentially hazardous chemicals in local ecosystems. Agrobiotechnology researcher David Jiménez-Arias and his team have developed a process for producing mineral solutions from recycled brine and using them to grow hydroponic tomatoes. In Saudi Arabia, there are proposed plans to desalinate seawater using concentrated solar thermal energy (STE: a form of energy and a technology for harnessing solar energy to generate thermal energy for use in industry as well as in the residential and commercial sectors) and not dispose of the brine water in the sea, which is the typical form of brine disposal. However, this is still a proposed project and there are uncertainties as to where the brine would be disposed.

These new innovations in brine management were conducted in small pilot projects. More comprehensive studies on a large scale are necessary to properly identify all alternative options for brine repurposing and remedies to mitigate the impacts of brine discharge.

3. *Ecosystem impacts*

Brine disposal onto the surface of water bodies can cause biochemical alterations, such as increased salinity and water temperature, and the accumulation of metals that can threaten ecosystems in the receiving water. Brine underflows also deplete oxygen from receiving waters, which in combination with high salinity can have a major negative impact on benthic organisms such as clams, worms, oysters, and mussels that live on the seafloor, which can translate into ecological effects observed throughout the food chain. The magnitude of environmental impacts on marine organisms caused by impingement and entrainment of seawater intakes varies from one project to another; however, policymakers should consider these effects when contemplating whether to build a desalination plant on the shores of the Caspian Sea. In order to protect sensitive habitats, like wetlands, water managers need to minimize brine disposal near these areas. Therefore, policymakers and water resource managers should conduct baseline ecological assessments, impact studies, and careful monitoring to assess the effects of impingement and entrainment should the desalination plant(s) be built. They should also consider building intake pipes outside of areas with high biological productivity to minimize impingement and entrapment.

4. *Contaminants and seawater quality*

Chemicals in brine deteriorate the quality of the receiving water when it is discharged into the marine environment. For example, a report from 21 desalination plants on the Red Sea coast estimated that 2,708 kg of chlorine, 36 kg of copper, and 9,478 kg of antiscalants are released each day into the sea from brine discharge. The result is substantial contamination of marine habitats around desalinization outfalls. In another study conducted in the upper Spencer Gulf, South Australia, brine discharge from seawater desalination threatened the growth, survival, and condition of giant Australian cuttlefish embryos.

The Caspian Sea has already been polluted due to oil and gas byproducts from crude oil extraction in the sea and coastal areas, and marine transportation of crude oil and its derived products. These discharges have high concentrations of salts and nutrients, which cause eutrophication. Major sources of pollution are oil production and underwater oil pipelines near the Apsheron Peninsula (Azerbaijan) and Mangyshlak Peninsula (Kazakhstan). A hazard assessment of Caspian water conducted on the Kazakhstan border of the Caspian Sea by Kazakhstani scholars found 11 of 19 priority pollutants. While this is of concern, this research concluded that the average daily intake value for the pollutants after treatment was below reference dose values, indicating there is no health hazard. The use of potentially contaminated seawater as the source of public water makes it essential for desalination plants to use highly effective seawater purification methods. As a new desalination plant is constructed, brine management will have to be seriously addressed in order to avoid further deterioration of the sea's environmental conditions, water quality, and biodiversity.

Alternative Solutions and Recommendations

Desalination is not a magic formula for increasing water supply—in Turkmenistan or elsewhere. The process needs to become more efficient and sustainable prior to adopting it on a large scale. Plants must convert from using fossil fuels to using renewable energy sources to curb greenhouse gas emissions, and sustainable brine management technologies must be developed.

Policy decisions aimed at addressing water shortage are often made without cross-sectoral coordination, targeting sector-specific optima (for example, desalination plants), which results in risks and uncertainties across sectors and scales. While desalination would be a viable option to increase the water supply in the region, it should be a last-resort, drought-proofing solution. To alleviate the stresses on water supply, address hydro-climatic risks, and provide sustainable water security for the country, Turkmenistan's government must consider other nature-based solutions and alternative adaptation pathways such as reducing water use and creating water efficiencies through recycling, conservation, infrastructure repair, and improved distribution systems.

Perhaps the most obvious sector in which to reduce water use and increase efficiency is that of irrigation. Here, a holistic approach is required to ensure efficient water supply to meet demand. Actions that only focus on one problem in isolation and on short-term gains often lead to maladaptation (Intergovernmental Panel on Climate Change: IPCC SP C.4.1).

Below are some recommendations for adaptation pathways—structured and dynamic approaches to planning that allow policies to change over time to ensure that they take into account system changes, new vulnerabilities, and new opportunities in order to avoid being locked in to a particular approach.

Recommendation 1: Using integrated irrigation management practices to improve water use efficiency

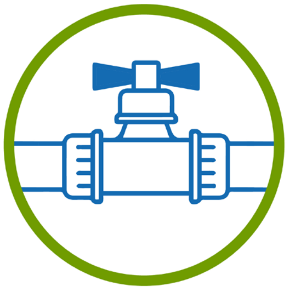
According to the World Bank, about 91% of the water withdrawn from the rivers in Turkmenistan is used for agricultural purposes, whereas industrial and domestic uses account for 7% and 2%, respectively. Water use efficiency is low, estimated at about 60%. Due to the state-owned nature of Turkmenistan's water and the lack of volume charges, farmers are only required to pay 3% of their gross income to state-controlled irrigation agencies as a contribution to the general and technical maintenance of water delivery systems. This approach, however, is not necessarily conducive to curbing water waste because using prices to manage water demand is more cost-effective than implementing non-price conservation programs. However, as in any policy context, political and economic considerations must be factored in.

Since water losses from irrigation are part of Turkmenistan's larger water security problem, mitigation should be part of the solution. Turkmenistan is already reusing drained water from irrigation. However, a water management program that integrates irrigation best management practices should be implemented around the country in order to improve efficiency, and thus, water availability. Techniques such as drip irrigation, irrigation scheduling, crop rotation, and cover crops are means farmers can implement to save water. Noting that one of Turkmenistan's 2012 National Climate Change Strategy's main objectives is to "develop and promote the use of modern irrigation systems," this might be a strong policy window opening to operationalize its commitments.

Recommendation 2: Adjustment of crop mix

As a result of Soviet Premier Nikita Khrushchev's "Virgin Lands" campaign of 1954–1963, Moscow expanded agricultural development in Central Asia by 88.6 million hectares on the basis of a concept called "cotton first." Thus, cotton cultivation became an important economic activity in Central Asia, including in Turkmenistan. In 2017, cotton represented 6.2% of Turkmenistan's total exports. Cotton is a water-intensive crop. Consequently, the intensive cotton cultivation in the region has forced significant amounts of water to be diverted from the Amu Darya and the Syr Darya, causing the Aral Sea to dry up, thus leading to one of the world's worst ecological catastrophes. Upon gaining independence from the USSR, Turkmenistan began to emphasize wheat production as a means of food self-sufficiency and security. As a result, the area under wheat cultivation increased from 15% of total sown hectares in 1990 to 50% in the early 2000s. Over the past decade, water use and intake have stabilized due to a shift from cotton monoculture to wheat-cotton agriculture; however, shifting to crop mixes that consume less water might also be a prudent decision in light of the recent food crisis in Turkmenistan. Taking action to effectively end cotton cultivation will not only alleviate water shortages but also bolster local food security and improve farmer and producer incomes.

Recommendation 3: Retrofitting and improving current water infrastructure



Retrofitting and improving water infrastructure is another way to boost efficiency in water supply operations. Turkmenistan's infrastructure quality, according to the World Bank's Logistics Performance Index infrastructure indicator, is weak, with a score of 2.23 out of 5. This puts it on par with the Kyrgyz Republic and only slightly higher than Tajikistan. Turkmenistan can improve this score by reducing water leakage, water contamination, and overuse of water by retrofitting and modernizing the existing water infrastructure, thereby also lowering the energy and gas consumption of the urban population. Improving water efficiency via retrofitting urban infrastructure can additionally lower energy and gas consumption.

Recommendation 4: Implementing nature-based solutions

While there is a dearth of accurate data, climate change extremes including droughts and heat spells increase Turkmen citizens' vulnerability to water insecurity. The Netherlands Delta Commission suggested in a 2008 report that natural systems could perform many critical infrastructure functions, reliably providing co-benefits with greater returns on investment. Turkmenistan, therefore, should consider adopting more nature-based solutions in order to address water shortages and climate change to sustainably manage and restore natural and modified ecosystems.

In Turkmenistan, extreme rainfall events seem to be increasing as a result of climate change. Flash floods, mudflows, and heavy rainfall increased from 1986–1995. According to the World Bank, "As of 2010, assuming protection for up to a 1-in-25-year event, the population annually affected by flooding in Turkmenistan is estimated to be 14,000 people with an expected annual impact on GDP of $90 million (approximately 0.4%). Development and climate change are both likely to affect these figures." Cities that are nestled at the foot of the Kopetdag Mountain Range are especially vulnerable to mudflows. Prolonged rainstorms in 2018 and 2019 submerged several districts of the capital city of Ashgabat beneath mudflows. Similarly, in 2019, mudflows swept through Bereket and a dozen villages in the Balkan province along the Caspian Sea, washing away bridges and roads, and flooding building foundations. To contain floods, Turkmenistan could adopt the Chinese "sponge cities" nature-based solution, which uses the natural landscape to retain water at its source, slow its flow, and clean it along the way. This nature-based solution will not only mitigate flooding but also control water scarcity in urban spaces and provide an alternative solution for harvesting water for irrigation. Unlike gray infrastructure (which is used for stormwater management such as pipes, ditches, swales, culverts, and retention ponds), sponge cities use less concrete and energy, and expand green spaces along with natural waterways and permeable soils, which are employed in sponge city designs. They clean the water and reduce pollution. In addition to controlling floods, sponge cities can also address water shortages, and manage and restore natural and modified ecosystems sustainably.

Beyond adopting imported nature-based solutions, the Turkmen government could revive indigenous nature-based solutions. For example, the traditionally nomadic people in the desert regions of Turkmenistan have historically used indigenous nature-based water management technologies. One such technology is called *takyr*:[5] "flat or slightly sloping dense clay surfaces which act as natural catchment areas." The average total volume of runoff generated by takyrs in Turkmenistan has been estimated to be 350–450 million m^3 per year. Historically, takyr catchments were the cheapest and often also the only source of freshwater supply, which allowed the Turkmen people to support runoff farming and keep livestock. However, under the Soviet regime and in recent decades, these indigenous tribal technologies have been neglected, in part due to a booming water supply through large-scale irrigation development, and takyr surfaces have degraded. When compared to transporting water over long distances, the development of takyr technology is cost-effective. On the national level, a strategic use plan for takyr techniques could be integrated into the action plan for combating desertification and water shortages in Turkmenistan. To this end, nature-based solutions can address water security challenges effectively and adaptively, while also benefiting human well-being.

Recommendation 5: Stormwater harvesting during the wet season

January to April is the rainy season in Turkmenistan, and during this time, stormwater harvesting could provide another alternative option for meeting water demands. Stormwater harvesting consists of the collection, treatment, storage, and use of stormwater runoff from urban areas. These systems are designed with the source and beneficiary uses in mind. Sources typically determine water supply quality, as runoff would pick up pollutants. Beneficiary use would determine volume and treatment criteria. Uses for stormwater include sanitary sewer flushing, irrigation, vehicle washing, street cleaning, and dust control, among others. The uses of stormwater harvesting can be applied in different sectors and specifically aid the agricultural sector by diversifying supply. Additionally, women benefit most from water-harvesting initiatives, since these give more control to each individual household over its water supply, even if it is not for the entire year. Similar studies have shown that in rural areas where rain-harvesting infrastructure has been installed for domestic and agricultural use, women make up the overwhelming majority (70%) of rain-harvesting users, a sign of the benefits this technique provides for rural women.

Recommendation 6: Using recycled water

Recycled water is made from purifying wastewater, by passing it through multiple treatment processes making it safe for indirect consumptive uses such as agriculture, as well as watering city gardens and parks. Treatment for recycled water is determined by its end use. Depending on the level of treatment, recycled water should be paired with other irrigation best management practices, such as monitoring constituents of agronomic relevance such as salts, nitrogen, phosphorus, etc. Water efficiency provided by recycled water use can range up to 100% of the demand or

[5] Luuk Fleskens et al., "Desert Water Harvesting from Takyr Surfaces: Assessing the Potential of Traditional and Experimental Technologies in the Karakum," *Land Degradation & Development* 18.1 (2007): 17–39, https://onlinelibrary.wiley.com/doi/abs/10.1002/ldr.759?casa_token=1vuQ32AqyPAAAAAA:5V1o4W8KkVKQTuQDE4XJ5TwOTTtoKfSBZt2SGN7RYKchU1CQVgXKZRNT0CNzzvvj7fETT1GrGxSJbiQ.

could be supplemented with traditional sources of water to produce a blend with lower salinity than that of using recycled water alone. Singapore is an example of a country that has successfully adopted water recycling. Water obtained from recycled wastewater now meets 40% of Singapore's water demand, and is expected to reach 55% by 2060. Turkmenistan could combat its recent water shortage by adopting water recycling. In Ashgabat, which suffers from water shortages, recycled water could be used to supply water to fountains or water used for industrial purposes.

Recommendation 7: Enhancing regional collaboration and dialog

The shortage of water resources and their inefficient use in Central Asia are exacerbated by poor water governance frameworks and weak institutional capacity. A series of climate, water, and ecological crises is plaguing Turkmenistan, raising fundamental questions about regional cooperation with neighboring states, sustainability, water governance, and security. Turkmenistan's current situation underscores the importance of a joint intergovernmental effort—one that encourages national and regional agencies to collaborate and work as a unit to address the complex and interrelated challenges around water and energy. Turkmenistan and neighboring countries' joint response to the current inflection point will have profound consequences for citizens' well-being, health, livelihoods, regional water security, and hydro-geopolitics. If Turkmenistan holds off on desalination, the incentives and potential benefits of cooperation at the interstate level on existing transboundary resources increase. Unfortunately, relationships between Central Asian governments are not always cordial. In late July 2022 at a gathering of Central Asian presidents, Tajikistan and Turkmenistan refused to sign a treaty committing all countries to "friendship, good neighborliness and cooperation."

Water is inherently connected to and impacted by issues such as climate change, energy security, and food security. In the face of increasing uncertainty about the future of the water-energy-food nexus (WEF), governments across Central Asia are not able to effectively plan and allocate resources. In fact, the relations between Central Asian states are characterized by a lack of trust, which leads to a lack of information and data sharing. When negotiations and dialog do occur, they are dominated by single-sector interests (primarily water). To build resilience, however, the scope of regional cooperation needs to be broadened to include all relevant and overlapping aspects of the water, energy, and food sectors.

The water-energy-food nexus approach calls for an understanding that resources are closely interconnected, and that therefore the impacts of policy initiatives need to be considered across these overlapping factors, instead of just on a sector-by-sector basis. In this regard, the water-energy-food nexus allows for the identification of synergies and minimization of silos, as well as for optimizing among trade-offs in achieving water, energy, and food security in the region. Using a nexus approach in Central Asia can be particularly useful in balancing the competing interests of riparian countries where those located upstream (Tajikistan and Kyrgyzstan) want to utilize water for hydropower, and downstream countries (Turkmenistan, Kazakhstan, and Uzbekistan) want water for irrigation, industrial, and domestic uses. This would follow the growing trend of water governance around the world, which has shifted in many ways from state-led management to more decentralized systems, opening up seats at the decision-making table to actors in both the public and private sectors.

Recommendation 8: Changing public perceptions of water and individual water stewardship

Public access to key information regarding government policy, environmental regulations, and the state of the environment is limited in Turkmenistan. For instance, when the government publishes legislation on its website, it does not provide a search function or classification system that would help the public find relevant laws and regulations easily. The government could establish accessible, user-friendly platforms whereby the public could access the relevant information. In order to make water governance more transparent, accessible, and responsive to public concerns and needs, there must be a better understanding of how to collaborate with the media, water operators, local authorities, NGOs, UN agencies, and other development organizations. Collaborations like this have triple dividends because they create partnerships, provide legitimacy to social instruments in water management, and increase capacity and ownership. Evidently, developing an effective interface with a wider audience is critical to water governance success. Therefore, the Turkmen government needs to explore innovative communicative tools and social networks for public buy-in, discussion, participation, and ownership. After all, successful water governance systems call for both bottom-up input as well as top-down initiatives.

Given that there is overall low public awareness of ecological issues, it is imperative to promote such awareness, raise public interest, and build commitment in responding to the environmental and water challenges facing the country. This can start in the public schools: beginning as early as kindergarten, explaining to students how treasured water is, especially in Central Asia, and providing them with tools for water stewardship. An educated and empowered population will help to ensure that the needs of the people and ecosystems relying on this critical resource are met effectively without compromising the rights of future generations.

Conclusion

In Turkmenistan, as in other parts of the world, high human population growth, improved living standards, and a rapidly changing climate threaten the resiliency required in order to sustainably manage water resources. With the exponential growth of desalination as a method for augmenting existing freshwater resources, it is understandable that Turkmenistan would consider desalination on the Caspian Sea shore. Despite this potential, however, there are a number of socio-ecological and political considerations and trade-offs that come with desalination, namely the negative environmental and ecological consequences having to do with brine wastewater, the high energy demand that would likely be met by burning more fossil fuels, and the potential shifts in transboundary hydro-politics among neighboring Central Asian countries.

On the surface of it, desalinating water from the Caspian Sea would increase water security for Turkmenistan, specifically for residents of the capital city, Ashgabat. This would further help towards achieving the UN's Sustainable Development Goal #6, which calls for ensuring the availability and sustainable management of water and sanitation for all. Turkmen farmers and other water-intensive industries could also be spared the impacts of current and future water shortages associated with water-intensive crops, aging water infrastructure, and dwindling upstream freshwater resources due to climate change and the overuse of existing water resources. In the hydro-diplomatic sphere, desalinating water in a transboundary setting has also been hypothesized to ease the strain on other freshwater resources, which in the Central Asian context could result in increased cooperation between Amu Darya Basin states.

The current proposal to construct desalination plants on the Caspian Sea to supply Ashgabat would require freshwater to be transported to the capital city, 570 kilometers from the Turkmenbashi Gulf. In order to do so, a substantial amount of infrastructure investment will be required, which could translate into a higher cost for freshwater and could become a drain on the already shrinking public budget. In light of Turkmenistan's worst economic crisis in 30 years, which has led to hyperinflation and widespread food shortages, ordinary residents of Ashgabat may not be able to afford higher water bills. Increased water prices could exacerbate the unequal distribution of water resources, becoming an impediment to the fundamental human right to water.

Further, as has been outlined in this brief, large-scale desalination of the Caspian Sea would result in high emissions of greenhouse gasses in order to provide reliable energy for the proposed plants. Renewable and alternative energy operations do exist, such as wind, solar, and nuclear, but are not currently as commonplace. Desalination also has widespread environmental consequences, such as those from brine disposal, which can severely alter coastal and marine ecosystems and contaminate the surrounding seawater.

We argue that before Turkmenistan spends time, labor, and energy investing in desalination, it should first address the shortcomings of its existing water resources and the governance and management thereof. The recommendations in this brief advocate for moving the focus of Turkmen policymakers beyond desalination and for identifying alternative, holistic water governance mechanisms for macro (that is, relating to the broader Amu Darya River Basin) and micro (that is, local actions) coherence; alternative directions such as nature-based solutions and the water-energy-food nexus, which could mitigate adverse consequences of desalination; and the more efficient and sustainable use of existing freshwater resources. Within Turkmenistan, there has been a lack of coordination in terms of governance over the water sector with overlapping sectors, such as irrigation, agriculture, and energy. While desalination might lead to greater water security within Turkmenistan, we strongly urge for an intersectoral, holistic nexus approach that will address these considerations.

Water supply issues in Turkmenistan can be addressed with existing water resources by rethinking how these are managed. Here, we have suggested an integrated water resources management approach, which can be applied using best management practices and simple water-saving techniques. Other supply-side recommendations include crop rotations, improving existing water infrastructure, stormwater harvesting, reusing wastewater, and implementing innovative yet inexpensive nature-based solutions. These recommendations can be implemented at multiple scales, adopt indigenous practices of water management, and reduce reliance on a centrally-organized, top-down governance structure. On the socio-political front, we additionally suggest that an increased focus on interstate cooperation between Central Asian states should be made a high priority and can be used to build regional and basin-wide resilience to current and future droughts and other water-related impacts of climate change. We also implore Turkmenistan and its neighboring countries to adopt an intersectoral approach to water governance and management, namely the water-energy-food nexus, to increase interconnectivity and create mutual gains through trading between and within these sectors. Finally, changing public perceptions of water resources can help with collaborations with nongovernmental organizations and lead the way toward sustainable water stewardship.

If desalination is rashly implemented on the basis of its short-term solutions without sufficient awareness of the context in which it is to be implemented, there is a risk of causing a major ecocide: the widespread or long-term destruction of ecosystems, with irreparable harm to nature. Putting the right policy response in place means going beyond just short-term solutions to cope with the crisis at hand. Therefore, a comprehensive analysis of all options, including conservation and efficiency, should be conducted by water planners, water agencies, and policymakers in order to pursue less expensive, less environmentally damaging alternatives first. Rather than pursuing policy analysis and pathways based on a world that is known now, planners and policymakers should use estimates of future, not present, climate and Caspian Sea ecological conditions while remaining adaptable to future uncertain conditions. Ultimately, the benefits of supplying fresh, desalinated water to Ashgabat come at both high ecological and economic costs, and in the long run, desalination could become a maladaptive strategy to cope with the effects of climate change on water resources.

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3. **Alexander Mauroner** is an environmental professional working on issues surrounding climate change adaptation and resilient water resources management. He is the Chief Operating Officer at the Alliance for Global Water Adaptation (AGWA) and holds a Professional Science Master's degree in Environmental Science from Oregon State University.

4. **Henry Amorocho-Daza** is a Ph.D. candidate at the IHE Delft Institute for Water Education and Delft University of Technology. His research interests include applying quantitative methods for improving decision and policy making in complex environment-related settings. Henry holds a B.Sc. in Industrial and Environmental Engineering from the Universidad de los Andes, in Colombia, and an M.Sc. (Hons) in Water Management and Governance from IHE Delft.

POLICY BRIEF

CENTRAL ASIA PROGRAM

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