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Should Desalination Play a Role in Azerbaijan's Water Security Strategy?

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Azerbaijan's freshwater resources are limited with medium to high water stress index and huge dependency (70 percent) on upstream countries. Currently the country is in the process of rearranging its water resources management and reconsidering traditional approaches to ensure the sustainability of its freshwater resources. The establishment of a Water Commission (April 2020), the drafting of a Water Strategy (July 2020), and the recent consolidation of all water related institutions under one umbrella (March 2023), which was designed to avoid conflict of interests and ensure efficient management of the country's scarce resources, are the main recent developments in Azerbaijan's quest to improve its freshwater resources management. Following these developments, in April 2023 President Ilham Aliyev issued a decree on "Measures for the Implementation of a Pilot Project in the Field of Drinking Water Production Through Desalination of Sea Water" as a supporting action in advancing the country's water security, ensuring full access to drinking water, and applying innovative technologies to this entire set of public policy challenges.

Understanding Desalination

Desalination is a process of rendering saltwater suitable for consumption and it is regarded as a potential solution for water-scarce regions facing arid conditions. This method is applicable to both seawater and brackish groundwater, particularly in situations where alternative approaches are not feasible or appropriate. A report published by *Food & Water Watch* in 2009 indicates that desalination is viewed as a means of survival rather than a comprehensive solution to water scarcity given its high cost, substantial energy requirements, and significant environmental consequences.

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Nonetheless, due to escalating water stress driven by climate change and human activities, coupled with technological advancements, the desalination sector has experienced notable growth recently. Approximately 70 percent of desalinated water is presently generated in Middle Eastern countries, where the scarcity of water is intensified due to geographical and climatic factors. Israel, Saudi Arabia, and the United Arab Emirates heavily rely on desalination for a considerable portion of their freshwater supply. Moreover, countries like Kuwait and Qatar are entirely dependent on desalinated water sources. Australia, the U.S., and China also apply desalination technologies. Currently, desalinated water accounts for roughly 1 percent of the world's drinking water supply; however, predictions indicate that this is set to double by 2030. In concrete terms, this means that over 300 million individuals currently have access freshwater sourced from desalination processes.

While desalination appears to be a comprehensive solution to freshwater scarcity, given the rising demand for the limited resources, it presents challenges such as high costs, substantial energy consumption, and environmental repercussions. These consequences encompass emissions of greenhouse gases (GHGs) and the discharge of concentrated byproducts stemming from the desalination procedures themselves.

Overcoming a First Challenge: GHG Emissions

Energy input constitutes a substantial portion, ranging from one-third to over half, of the total expenses associated with desalination processes. Thus, the ongoing objective for all desalination methods is to minimize this energy consumption. Despite advancements and refinements achieved over recent decades, the production of freshwater from ocean sources continues to demand more energy than any alternative freshwater source.

Desalination technologies fall mainly into two categories: (1) membrane-based methods, primarily reverse osmosis (RO), and (2) thermal methods, including multi-effect distillation (MED) and multi-stage flash (MSF). While other innovative desalination approaches are still in their experimental phases, these three methods have gained widespread recognition and implementation. Among these methods, RO stands out as the most energy-efficient, boasting energy efficiency levels four to five times greater than its counterparts.

Various scientific articles in peer-reviewed journals show that RO remains approximately 8 to 10 times more energy-intensive when compared to traditional water treatment techniques applied to surface water sources. The assessments conducted in such studies pertain to ocean and sea waters with an average total dissolved solids (TDS) concentration of 35,000 parts per million (ppm). In contrast, the TDS of Caspian Sea water ranges from 13,500 to 16,000 ppm, enabling the utilization of low-pressure membranes and consequently reducing electricity consumption.

However, a hurdle emerges concerning the drinking water quality requirements. Notably, the boron levels in Caspian Sea water are incompatible with low-pressure membranes, which in high concentrations are harmful for humans and animals and can cause crop poisoning if used for irrigation. Boron concentrations are 4-5 ppm in the Caspian Sea and, according to international and national water quality standards, its permittable level is no greater than 2.4 ppm. Therefore, although low TDS seems like a positive aspect, with current available technology, it is not used to obtain energy efficiency.

Due to its higher energy demands compared to conventional water supply and treatment methods, desalination gives rise to concerns regarding its carbon emissions. Even when employing energy-efficient RO technology, the carbon footprint of seawater desalination is significant. The International Water Association estimates that the desalination of every 1000 m^3 of water using RO can potentially result in the release of 0.4 to 6.7 tons of carbon dioxide (CO_2), with the precise figure depending on factors such as total dissolved solids (TDS), plant size, and operational protocols. Notably, global CO_2 emissions stemming from desalination facilities that rely on fossil fuels were approximated to have reached 76 million tons in the year 2020.

Nevertheless, the progress made in technological advancements and equipment innovation over the past two decades has yielded a remarkable 80 percent reduction in energy requisites, signifying a pivotal supportive element for desalination. When considering the renewable energy potential of the Absheron Peninsula and the promising trajectory of clean energy sources, the shift towards the desalination era might not be as financially burdensome or environmentally detrimental as perceived. The availability of wind and solar energy, complemented by their adaptable integration with desalination methods, holds significant promise for environmental and societal gains, ultimately fostering sustainability within the intricate interplay of water and energy.

Solar energy, being the most well-tested and mature among renewable options, not only aligns exquisitely with desalination needs but is also extensively accessible, particularly in regions with water scarcity. Notably, countries with extensive desalination practices have already embarked on an energy transition within the desalination sector. A prime example is Saudi Arabia, which has not only set an ambitious goal of generating 9.5 gigawatts (GW) of renewable energy by 2030 but also aspires to transition its desalination operations from fossil fuels to green energy within its Vision 2030 (2016). In a parallel, Australia has made a commitment that any new desalination plants established in Western Australia must be powered by renewable energy sources. China, also, seems to have committed to prioritize renewable energy-based seawater desalination.

These and other concerted endeavors have led to a noteworthy surge in the adoption of renewable energy for operating small- to medium-sized desalination facilities—an approach that has gained further traction as these facilities grow in scale and capacity over time.

Overcoming a Second Challenge: Toxic Waste

Another significant challenge associated with desalination pertains to the production of toxic waste arising from the desalination process itself. The residue, consisting of salt and chemicals present in the brine left over after desalination, has the potential to pose a threat to local marine ecosystems. The implications of desalination activities on these ecosystems remain an area that lacks comprehensive exploration, and viewpoints on the impact of brine discharge on marine water salinity differ. Over time, the discharge of brine can engender adverse effects on the habitats of marine organisms. For example, there is evidence that the waste byproducts from desalination processes contribute to a reduction in the oxygen content of water, hinder the proliferation of aquatic life forms, and subsequently diminish biodiversity. This cascading effect also extends to the production of a negative impact on the performance of the desalination facility itself.

Furthermore, the recurrent discharge of brine leads to a rise in the salinity of the surrounding water. This, in turn, escalates subsequent energy requirements for the desalination process itself, which makes it even more financially burdensome. Although there is no shortage of seawater in the world, this is not the case with the Caspian Sea; being the largest inland water body, the Caspian Sea's water volume can be negatively affected by an intensification of desalination activities. Even in the absence of such activities, over the past 15 years, there has been a noticeable decrease in water levels—a trend that has yet to be explained. The main fluvial tributaries of the Caspian Sea are the Volga (80 percent of inflow), the Kura-Aras (6.3 percent), the Ural (3 percent) and the Terek (2.5 percent) rivers. Unfortunately, water levels in all these rivers have dropped substantially, due to various climatic factors and anthropogenic activities.

Way Forward

Water-scarce countries need to radically reconsider their water resources' planning and management. In the case of Azerbaijan, *it is imperative to initiate an assessment of the current water resources*. The figures being cited today are rooted in data from the 1970s and no longer accurately represent the current state of water resources of the country.

Moreover, greater focus needs to be placed on

- decreasing water losses and increasing invest in the improvement of water infrastructure, i.e., identifying loses and preventing them;
- metering all water users and dividing the water network into technical and household;
- identifying obstacles in implementing water efficient practices and technologies, and promoting them;
- enforcing the usage of water collecting and treatment facilities in newly-built settlements and buildings, by making this part of the building code;

- emphasizing the role of historically proven water systems like *kahriz* that expose groundwater to the surface through special underground channels; and
- raising awareness at all levels of society on the importance of water saving and investing in water efficient options.

Considering the increasing tendency of using desalination worldwide, it is crucial for Azerbaijan to conduct science-based *pilot* projects to assess its potential effects and benefits. In this regard, it is critical to specifically focus on energy efficient technologies; if possible, building this technology on green energy would contribute to global desalination research and development.

Additionally, as the impact of brine on marine ecosystem is understudied, it is highly recommended to establish an environmentally-safe brine discharging scheme that would involve a regular monitoring and evaluation component. This activity is not only important for saving the marine habitat, but also to understand the impact of desalination plants on the living organisms that inhabit the Caspian Sea itself.