

The Contribution of Water Technology to Enhancing Water Security: International Experiences

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Abstract:

This study aimed to highlight the fundamental role that water technology plays in enhancing water security by improving water resource management and meeting the increasing demand. This technology includes smart systems for monitoring and analyzing water consumption, developing desalination and purification techniques, improving agricultural irrigation methods, and reusing water through wastewater treatment. The findings indicate that these innovations help reduce waste, improve efficiency, and provide sustainable solutions to address challenges related to water scarcity. This, in turn, contributes to achieving sustainable development and ensuring the avail.

Keywords: water technology, water security, Smart Irrigation.

Jel Classification Codes: Q53, Q25, Q56.

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1. INTRODUCTION:

Water is one of the essential natural resources that form the foundation for the continuity of life and economic growth. With the continuous increase in population and climate changes that directly impact water availability and quality, it has become necessary to explore innovative solutions to ensure the sustainability of this vital resource. Among these solutions is the introduction of technological methods and techniques that enhance the efficiency of water resource usage and increase their capacity to meet growing demand. This technology encompasses a wide range of applications, from systems for monitoring water quality and reuse to the development of desalination and purification techniques. These systems help identify water leaks and address them promptly while optimizing water distribution based on need without wastage. Furthermore, this technology also contributes to the development of the agricultural sector by improving irrigation techniques through smart irrigation methods that reduce water loss and enhance agricultural productivity.

The use of water technology contributes to maintaining water security across various economic sectors by providing advanced alternatives to acquire new sources of water suitable for multiple uses, instead of relying on traditional sources. This is achieved through desalination techniques that convert seawater into potable water, as well as wastewater treatment technologies that allow for its reuse across different sectors at minimal cost.

The adoption and development of water technology significantly contribute to achieving water security, thereby providing the necessary foundation to support sustainable development and environmental protection. This technology remains a critical factor in addressing future challenges related to water and ensuring its availability for future generations.

1.1. Study Problem:

Based on the above, the main research question can be formulated as follows: **What is the role of water technology in maintaining water security?**

-The following sub-questions can also be posed:

-What is water technology?

-What do we mean by water security?

-What is the current state of water technology application in different countries?

1.2. Study Hypotheses:

To answer the main research question, the following hypotheses are proposed:

-Water technology comprises a set of modern techniques used to improve water quality.

-Water security means providing the necessary water needs for every individual worldwide.

-Water technology plays a significant role in maintaining water security.

-The use of modern technologies in managing water resources is essential.

1.3. Study Objectives:

This study aims to achieve the following:

- To understand water technology.
- To understand water security.
- To highlight the role of water technology in facilitating the management of water resources.
- To emphasize the important role of water technology and its techniques in maintaining water security.

1.4. Study Methodology:

To address the main research problem and to test the validity of the hypotheses, a descriptive approach was employed to describe the various dimensions and concepts of the study's elements.

1.5. Review of the Literature:

-Imed, T. (2024, June): The study aimed to analyze the critical role played by water security policies in strengthening food security in Algeria. The researcher employed a descriptive-analytical approach, evaluating the current policies related to water and agricultural security in Algeria. The study focused on analyzing official data and statistics concerning water consumption and agricultural production. It also involved a comparison of food and water security indicators over different time periods to identify the direct impacts of these policies. The results revealed a strong correlation between improved water resource management and higher levels of food.

-Boussag, E., & Mohamed, M. (2022): The study aimed to analyze the evolution of the concept of water security over time and determine its importance in political and legal contexts. The results showed that the concept of water security has evolved to include economic and social dimensions, making it essential to adopt comprehensive water strategies to ensure the sustainability of water resources and achieve political and economic stability. The study emphasized that effective water policies are key factors influencing the well-being of societies.

-Sara Ben Ghida, Saida Harakat (December 2020): This study aims to explore the role of modern technologies in enhancing water resource security, by analyzing how technologies such as remote sensing, geographic information systems (GIS), and artificial intelligence are used in water management. Successful international experiences in applying these technologies to ensure water sustainability in the face of climate and environmental challenges were reviewed. The results of the study showed that these technologies are effective in improving the efficiency of water resource management, despite challenges related to cost and training. The study recommended the adoption of these technologies in developing countries and the enhancement of international cooperation in this field.

2. Water Technology.

2.1. Definition of Water Technology:

Water technology is defined as "the integration of hardware, software, and analytics to automate, collect data, and analyze information, assisting water and wastewater utilities in addressing various challenges. This technology relies on effective techniques that aid in leak detection, energy conservation, and water quality improvement, making water technology a framework for enhancing water management" (superfy)

It is also defined as "technological innovation and the introduction of advanced technologies that drive economic growth through efficient water use and reduction of waste. It involves ongoing research and development across various technologies and aims to promote their wider adoption" (Qiao, Ai Yue, Hongyu Guan, Lan Mu, & Yuxiu Ding, 2022, p. 03)

2.2. Water Technology Classifications:

Water technology can be classified based on the methods and techniques used for water treatment as follows (O'Callaghan, 2020, p. 13):

-Biological Treatment: This relies on biological techniques for treatment, such as biological nutrient removal and biological catalysts.

-Physical Treatment: This uses physical techniques for treatment, such as non-membrane filtration, mechanical vapor compression, and membrane filtration (MF, UF, NF, RO, FO).

-Chemical Treatment: This involves techniques and tools for chemical treatment, such as photochemical treatment, advanced oxidation, disinfection and biocides, absorbents, ion exchange, and scale inhibitors.

-Electrochemical Treatment: This treatment uses electrochemical methods, such as ion removal by electricity, ion removal using capacitors, electrolysis, and electrochemical oxidation.

-Physical-Chemical Treatment: This combines physical and chemical techniques, such as dissolved air flotation, micro and nano bubbles, wet air oxidation, multi-effect distillation, multi-stage evaporation, and hydrothermal degradation.

-Sensors and Control Systems: This includes various devices and technologies used in water technology for managing water resources, such as artificial intelligence and decision support tools, smart metering, inline sensors, and data management systems.

2.3. Benefits of Water Technology:

The integration of various technologies and innovations in water management offers several benefits, including (superfy):

-Effective Water Management: Water wastage can cost industries billions annually. Water technology helps institutions detect volume fluctuations in real-time, allowing them to address issues immediately.

-Real-Time Water Usage and Analytics: Smart water meters provide end-users with real-time insights into their water consumption, with remote control capabilities for consumer convenience.

-Property Protection: These technologies act as 24/7 alarms against plumbing leaks, offering remote shut-off capabilities to protect assets and conserve water.

-Environmental and Social Governance: As water scarcity increases, companies are increasingly committed to managing water resources responsibly. This technology helps reduce carbon footprints by minimizing water wastage and energy consumption, thus aiding environmental preservation and ensuring water availability for future generations.

3. Water Security.

3.1. Definition of Water Security:

Water security can be defined as "the ability to obtain sufficient quantities of clean and safe water to maintain adequate levels of food, productive capacity, sanitation, and health. Water security as a concept is fundamentally based on adequacy and assurance across time and space". (Boussag & Mohamed, 2022, p. 1130).

According to the Global Water Council document, water security is defined as "ensuring that every individual in a community has access to enough clean and safe water at a sufficient cost to lead a healthy and productive life without compromising the sustainability of the natural environment" (Benkelouche. N, & Zineb. B, 2022, p. 03)

Figure.1. Water consumption by country.



Source: (irrigreen)

From Fig.1., we observe a disparity in freshwater consumption among countries. Notably, the countries with the lowest consumption are Canada, with an average consumption of 36.23 billion cubic meters, and Argentina, with 37.78 billion cubic meters. Conversely, the countries with the highest consumption are India, China, and the United States, with average consumptions of 761 billion cubic meters, 581.29 billion cubic meters, and 444.29 billion cubic meters, respectively.

3.2. Dimensions of Water Security:

Water security encompasses five dimensions that every community must address (Imed, 2024, p. 398):

-Environmental Water Security: This dimension represents the ecosystems such as rivers, lakes, reservoirs, and aquifers that must be preserved by every community.

-Economic Water Security: This refers to providing adequate supplies to support various economic activities, such as agriculture, industry, and energy production.

-Domestic Water Security: Ensuring that all individuals in the community have access to sufficient water and reliable, safe sanitation services.

-Climate Change-Related Water Security: This dimension is crucial because it significantly impacts global water security. It is unpredictable, with potential increases in water availability due to flooding or decreases due to drought, which can have severe consequences for countries worldwide.

3.3. Sources of Water Security:

Water security sources include both traditional and non-traditional sources (Kheira, 2016, pp. 105-107-108-111-112):

-Traditional Sources:

-Rainwater: Refers to the precipitation that falls throughout the year, varying from one country to another.

-Groundwater: This includes water formed over the years found at great depths below the Earth's surface, reaching depths of about 2,000 meters.

-Surface Water: Encompasses all water present on the Earth's surface, which may be stored in reservoirs, dams, or flowing through rivers.

-Non-Traditional Sources:

-Desalination of Seawater: Achieved through various methods, including distillation techniques such as flash evaporation and multi-effect distillation, as well as more modern methods like membrane desalination.

-Recycling of Used Water: Involves the treatment of wastewater, utilizing various technologies and methods. For example, countries like Mexico, Argentina, and other Latin American nations have used treated wastewater for agricultural irrigation around major cities, while China has employed it for industrial uses surrounding Beijing

3.4. Strategies for Achieving Water Security:

The key strategies for achieving water security include (Fatima, B. Ben Zidane, F. Z, & Ziani, Z. 2019, p. 113):

-Developing a Comprehensive Information System: Due to recent climate changes, it has become challenging to manage information about natural water resources. To effectively manage these resources, it is essential to utilize technological advancements for collecting and storing necessary geographical data. This information aids in decision-making processes for efficient water resource management.

-Advancing Scientific Research and Adopting Modern Technology: This involves creating and implementing new technological methods that facilitate coordination among various research centers focusing on water resources, agriculture, drinking water, wastewater, and energy. It also involves encouraging further research and finding solutions to water sector challenges, aiming to improve management within a holistic and sustainable framework.

-Addressing Climate Change: This strategy includes developing policies and strategies that adapt to the ongoing changes and mitigate potential impacts. It involves using and promoting scientific research and development in this area to address climate-related challenges.

-Building Human Capacity: This includes training and education to adapt to different conditions and enhance the ability to make informed decisions for optimal water resource management.

4. International Experiences on the Role of Water Technology in Maintaining Water Security:

-Singapore's Experience with Smart Meters:

The Public Utilities Board (PUB) in Singapore has implemented a smart water network by installing smart water meters. These meters collect detailed data on household water consumption, creating customer consumption profiles to identify patterns and trends. The data is then analyzed and provided to customers, allowing them to manage their water use more effectively, reduce waste, and strive for greater conservation in the future (AQUINO & D ROBERT C, June 2021, p. 4)

-Germany's Experience with Electric Sea Water Desalination Technology:

German scientists have developed an innovative technology for desalinating seawater using electric currents to remove salt particles from the water. This electric desalination technique is more energy-efficient compared to reverse osmosis, which consumes a lot of energy. The technology works by separating the components of seawater salt, which include positively charged sodium ions and negatively charged chloride ions. By applying an electric current, the signal is reversed, allowing the desalination of seawater to achieve up to 95% purity, making it suitable for drinking. (Manna, 2022)

- Saudi Arabia's Experience with Smart Irrigation System:

The Smart Irrigation System project was implemented by Lumo, a company specializing in water management technologies to address the global challenge of water scarcity. This project tackles the shortcomings of traditional irrigation methods by developing a smart valve integrated with flow sensors and units. This setup ensures that only the necessary amount of water is used—no more, no less. As a result, labor costs are reduced by 90%, water usage is decreased by 20%, and environmental sustainability is enhanced. (Ministry of Environment, March 2024, p. 18)

Figure.2. Smart Irrigation System in Saudi Arabia.



Source: (Ministry of Environment, March 2024, p. 18)

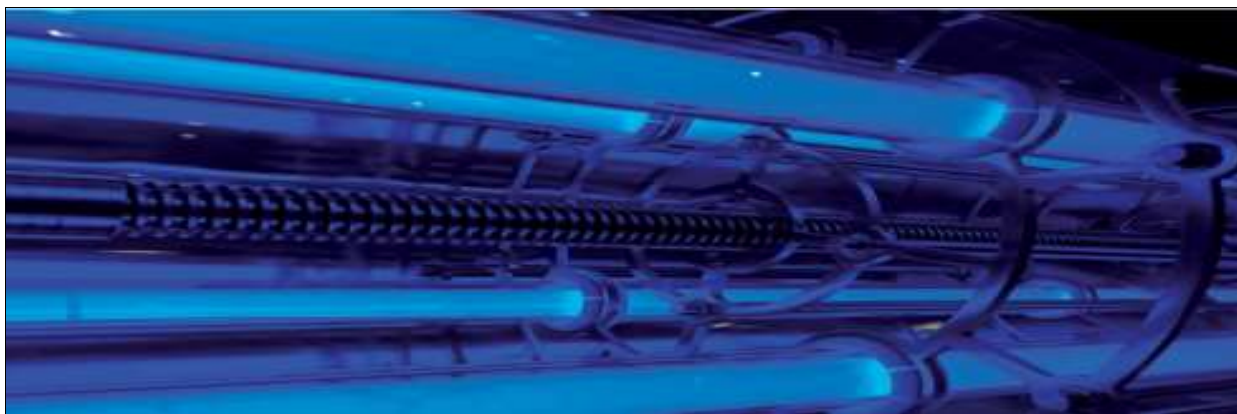
-England's Experience with Optical Fiber for Leak Detection:

Anglian Water conducted an experiment using optical fiber cables to detect leaks in its water pipeline network. These cables enhance the efficiency of water pipe installation engineers and reduce leaks by employing virtual sensors along monitored pipeline sections. These sensors provide rapid information about the location of leaks, allowing for swift resolution. (AQUINO & D ROBERT C, June 2021, p. 4)

-Ireland's Experience with UV Water Disinfection Technology:

A water treatment plant in Ireland implemented ultraviolet (UV) water disinfection technology. This technique uses ultraviolet waves to reliably and significantly improve water purification. The adoption of this technology resulted in reduced overall operational costs compared to traditional methods. (O'Callaghan, 2020, p. 11).

Figure.3. UV Water Disinfection System at the Water Treatment Plant in Ireland.



Source: (O'Callaghan, 2020, p. 14)

-Tunisia's Experience with Aquatic Plant Technology:

The International Center for Environmental Technology in Tunisia, in coordination with local authorities, established a biological wastewater treatment plant in the village of Júcar in the Zaghouan governorate. This project utilizes aquatic plant technology, which relies on the natural ability of plants—through bacteria and microorganisms in their root systems—to remove pollutants from liquid waste. This method has proven effective in treating such wastewater and is cost-effective compared to other technologies. The center was awarded patent number 19161 in 2007 for this technology and received the Best Innovation Award for Institutions in 2005. (Technology)

Figure.4. Use of Aquatic Plant Technology in Tunisia.



Source: (Technology)

-Japan's Experience with the Water-Saving Bubble90 Nozzle:

One of the recent successful products is the Bubble90 nozzle, manufactured by DG Takano Co., Ltd in Higashi-Osaka. This nozzle achieves significant water efficiency without compromising washing power and quality. It does so by generating a pulsating flow that continuously releases water droplets containing air into the semiconductor components used in washing machines. (Takano, 2017)

Figure.5. Water-Saving Bubble90 Nozzle Technology in Japan.



Source: (Takano, 2017)

-America's Experience with Shade Balls Technology to Prevent Water Evaporation:

Los Angeles faced a significant challenge with water evaporation, so it implemented shade balls technology to address this issue. Approximately 96 million black plastic balls were deployed in the Van Norman Drinking Water Reservoir in Sylmar. These balls created a thick layer covering the reservoir to prevent water evaporation. To secure the balls in place, they were filled with water to add weight, covering every inch of the reservoir's 175-acre area. The shade balls protect the water from contamination by dust, rain, birds, wildlife, and chemical reactions caused by sunlight. The technology is cost-effective, with the entire project costing around \$35 million, compared to an estimated \$300 million for traditional methods. The shade balls have a lifespan of about 10 years and can be recycled and reused. This technique began in 2008, and Los Angeles has since applied the shade balls technology to four drinking water reservoirs. (Khaddash, 2015)

Figure.6. Shade Balls Technology Used in Los Angeles, USA.

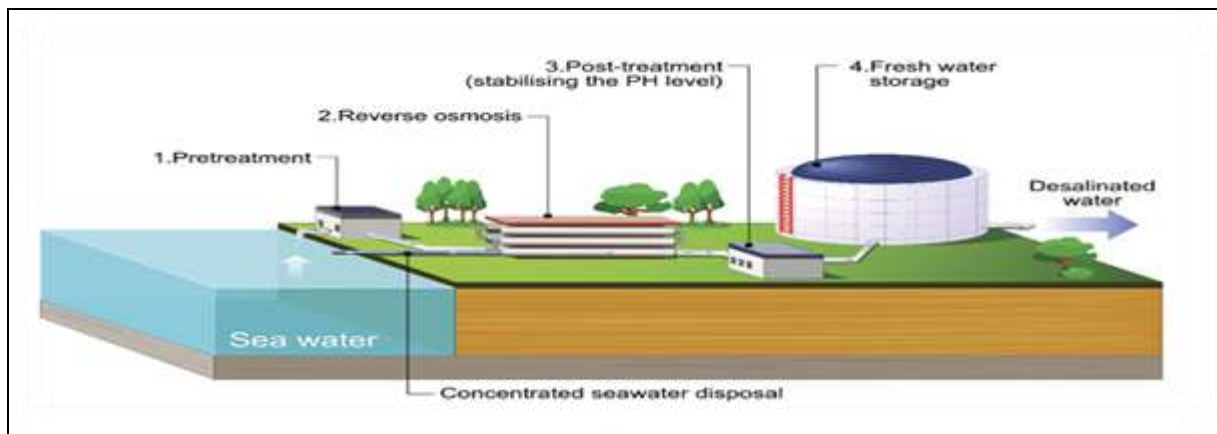


Source: (Khaddash, 2015)

-Saudi Arabia's Experience with Advanced Reverse Osmosis Systems:

The advanced reverse osmosis systems enhance the performance of desalination plants by using thin, semi-permeable membranes with narrow pores to filter pure water, while retaining larger particles such as dissolved salts and other impurities like bacteria. This pioneering technology in seawater desalination offers a cost-effective solution to meet the growing demand for water from both residential and industrial sectors. The technology has been widely adopted across Saudi Arabia due to its significant benefits. (Ministry of Environment, March 2024, p. 36)

Figure.7. Advanced Reverse Osmosis Systems in Saudi Arabia.



Source: (rusukh)

-Britain's Experience with the Magic Filter for Desalinating Seawater:

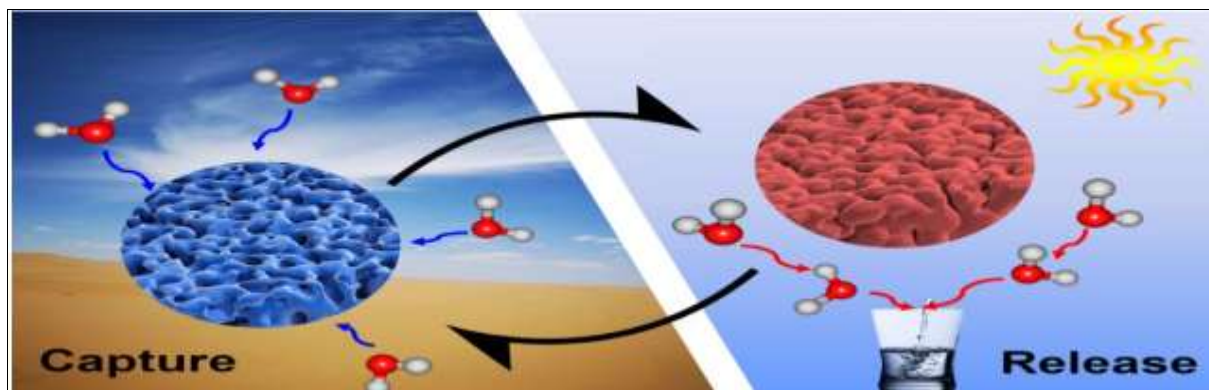
British scientists have developed a filter known as the "magic filter," made from graphene, the thinnest material in the world. Graphene, a form of carbon with a thickness of just one atom, is 200 times stronger than steel. This filter converts salty seawater into drinkable water using a novel method that allows precise control over the pore size in the graphene membrane, enhancing its ability to purify water and make it suitable for consumption. (Manna, 2022)

-China's Experience with Atmospheric Water Harvesting Technology:

Researchers from Shanghai Jiao Tong University have developed a promising new solar-powered atmospheric water harvesting technology. This method can provide sufficient drinking water in challenging dry regions. The technology uses a superabsorbent hydrogel made from plant derivatives and hygroscopic salts, capable of absorbing and retaining unprecedented amounts of water. One kilogram of dry hydrogel can absorb 1.18 kilograms of water in arid conditions and up to 6.4 kilograms in humid environments. The hydrogel is simple and cost-effective to prepare. The team created a prototype with adsorption and condensation chambers running in parallel and used a turbofan in the condensation chamber to increase water recovery to over 90% in an initial outdoor test.

The team plans to use renewable energy to enhance daily water productivity per unit mass of the adsorbents and improve system performance for practical water generation applications. Atmospheric water-harvesting materials could also play a significant role in future applications like moisture removal, agricultural irrigation, and thermal management of electronic devices. (ReviewsNews, 2023)

Figure.8. Schematic of Atmospheric Water Harvesting Cycle During the Day.



Source: (ReviewsNews, 2023).

-India's Experience with Nanotechnology for Water Purification:

Researchers at the Indian Institute of Technology, Madras, have developed a new type of portable water purification system based on nanofiltration technology for ultrafine particles. This nanofilter effectively removes ultrafine particles, heavy metals, and all biological contaminants such as algae, fungi, bacteria, and viruses from drinking water. The filter is cost-effective, does not require electricity for water treatment, and is the first device to combine microbial kill capability with the removal of chemical contaminants like lead and arsenic. The new system uses a two-stage filtration process, providing 10 liters of clean water within one hour. The first stage removes viruses, bacteria, and other harmful microorganisms, while the second stage absorbs heavy metals like lead and arsenic. The result is a low-cost, portable water purification device compared to similar portable filtration systems. (Kabil, 2016)

4. CONCLUSION:

Recently, there has been increasing pressure on water resources due to population growth and climate change. Utilizing water technologies has become essential for maintaining global water security. These technologies enhance water use efficiency, provide innovative solutions for desalination and purification, and promote sustainable water resource reuse. With growing challenges related to water scarcity, investing more in research and innovations in this field is crucial to meet the needs of current and future generations at lower costs.

Key findings include:

- ✓ The use of water technology plays a crucial role in maintaining water security, as demonstrated by international experiences in this study.
- ✓ Water scarcity requires more advanced solutions to ensure the availability of water in the future.

- ✓ Water technology helps reduce water waste by providing techniques for recycling and treating different types of water.
- ✓ Water technologies support water sustainability by offering innovations in desalination and creating alternative sources of fresh water.
- ✓ Modern irrigation technologies contribute to reducing water consumption in the agricultural sector.
- ✓ Advanced purification techniques help remove pollutants and impurities from water, improving its quality and ensuring its safety for human and industrial consumption.

Recommendations:

Water technology is crucial as it helps preserve the essential element of life: water. The following recommendations are proposed:

Enhance Research and Development in Water Technology: Support research and innovations in water technology to develop more effective and economical solutions for increasing water challenges.

-Invest in Water Infrastructure: It is essential to update and develop water infrastructure to incorporate smart technologies and advanced water resource management.

-Encourage International Collaboration in Water Management: Strengthening cooperation between countries and sharing innovative technologies and expertise can enhance the effectiveness of global water management strategies.

-Raise Awareness and Provide Training in Water Resource Management: Increasing awareness of the importance of water conservation and providing training programs for professionals and local communities can improve water resource management.

-Promote Sustainable Water Policies: Governments should adopt supportive policies for water technology, including incentives for investing in modern technologies, measures to reduce waste, and improvements in efficiency.

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