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ALTERNATIVE METHODS OF DESALINATION: PERSPECTIVES ON INTEGRATING AI AND UTILIZING SCADA SYSTEMS

Abstract

The challenge of desalinating seawater into potable water has become increasingly critical in today's world. The growing global population, coupled with food shortages and inadequate access to clean drinking water, is pushing humanity to the brink of a major crisis. This article explores modern desalination methods proposed by various countries and companies. It aims to provide valuable insights for nations currently facing water scarcity or those with scientific forecasts predicting such crises.

Keywords: seawater desalination, modern methods, AI in potable water production.

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Intradaction

The topic of seawater desalination is widely discussed in scientific publications around the world, with numerous articles available today. On the one hand, it is encouraging to see so many innovative ideas and a promising outlook for addressing the global water crisis. However, a deeper analysis reveals the need to evaluate which of these solutions are truly reasonable, cost-effective, and economically viable. This evaluation is particularly challenging given the diverse geographical, economic, technological, and even cultural or religious contexts of different countries. Finding a universal solution is no simple task. Let us explore some of these methods and assess their practical applicability.

Water desalination using synthetic membranes is among the latest advancements developed by Egyptian scientists. Researchers from the University of Alexandria have introduced a novel desalination technique called **pervaporation**, which efficiently removes excess salts from seawater, converting it into potable water. These scientists assert that their technology surpasses the efficiency of the widely used reverse osmosis method [2].

Mean

While synthetic membranes are not new—having been utilized in various industries since the mid-20th century—their application in desalination represents an innovative development. Synthetic membranes are employed in diverse separation processes such as dialysis, electrodialysis, hemodialysis, hemofiltration, ultrafiltration, hyperfiltration, and pervaporation. These processes are typically defined by the driving force applied, such as concentration gradients, which enhance separation efficiency.

Synthetic membranes feature multichannel elements that enable conductivity. Ceramic membranes, a specific type of synthetic membrane, are fabricated from inorganic materials such as aluminum oxide, titanium oxide, zirconium oxide, recrystallized silicon carbide, or certain glassy substances. Unlike polymer membranes, ceramic membranes are resistant to aggressive media such as acids and strong solvents. Their excellent thermal stability also makes them suitable for high-temperature operations.

The performance of ceramic membranes can be quantified using the formula:

$$\mathbf{Q = P \times A \times \Delta P},$$

Where:

- **Q** = water flow rate (liters per hour),
- **P** = permeability (LMH/bar),
- **A** = membrane area (m^2),

- **ΔP** = applied pressure (bar).

For example, using the following parameters:

- Permeability (**P**) = 5 LMH/bar,
- Applied Pressure (**ΔP**) = 6 bar,
- Membrane Area (**A**) = 0.2 m^2,
- Recovery Rate (**R**) = 50%,

The water flow rate can be calculated as:

Q = 5 × 0.2 × 6 = 6 liters per hour.

After adjusting for the recovery rate (**R**):

Q potable = 6 × 0.5 = 3 liters per hour of potable water.

This calculation highlights the potential of ceramic membranes in desalination processes, demonstrating both their efficiency and practicality.

There are several other innovative technologies for seawater desalination, one of which is electrodialysis. This method uses an electric current to move salt ions through ion-exchange membranes, effectively separating salt from water. Electrodialysis not only extracts fresh water but also manages brine in an efficient manner. It is considered an environmentally friendly and cost-effective technology, having been first introduced in the 1960s.

The principle of electrodialysis is based on the movement of positively and negatively charged ions toward electrodes under the influence of an electric current. The simplest electrodialysis unit consists of a three-section flow tank with electrodes in the outer chambers. This tank is divided by two ion-exchange membranes: one that allows negatively charged ions (anions) to pass and another that permits positively charged ions (cations) to pass. Together, these membranes facilitate the separation of salt from water, making electrodialysis a viable method for desalination.

Under the influence of an electric field, cations and anions in the section between the membranes of an electrodialysis unit migrate into the outer chambers near the electrodes. This process results in the accumulation of alkali and acid solutions near the electrodes, while desalinated water remains in the intermembrane space. In practice, multi-chamber electrodialysis units are commonly used, where the tank is divided by multiple alternating anion- and cation-selective membranes.

The Caspian Sea is unique in its salinity levels and history. With an age of approximately 6 million years, the Caspian Sea was once part of the ancient Tethys Ocean. Unlike typical oceans, its salinity is highly uneven. The southeastern regions of the Caspian have salinity levels as high as 11–13 ppm, while near the mouth of the Volga River, salinity drops to as low as 0.05 ppm. This stark contrast is due to the fact that several major rivers, such as the Volga, Samur, Terek, and Sulak, flow into the Caspian Sea, bringing fresh, non-saline water. Despite this inflow, the Caspian Sea remains saline because of its historical connection to the Tethys Ocean and its status as a closed water body with no significant outlet for salt removal.

While electrodialysis is a proven desalination technology, it is not well-suited for the Caspian Sea. This method is more effective in environments with higher salinity densities, such as oceans, and its efficiency diminishes in water with low salinity levels like those found in the Caspian. Therefore, other desalination methods may be more appropriate for addressing water scarcity in this region.

There is also a biological method in which microalgae play an important role. Additionally, deionization methods use electrodes to remove salt ions from water through electrostatic processes. The use of algae is a current hot topic, as they are actively employed in wastewater treatment and as biofuels. Recent developments suggest that algae, along with specific microorganisms, can also be used in the distillation of saltwater into freshwater. While this method is promising and worthy of research, it is essential to consider that the water in the Caspian Basin is unique. Therefore, microorganisms must be thoroughly studied to avoid harming the fauna of this special sea. Nuclear energy also holds significant potential for seawater desalination. As technology continues to develop, particularly with the advancement of artificial intelligence, the pace of innovation in this field will only accelerate. Water desalination will remain a critical issue, as water is and will continue to be the essential resource for all life on Earth. However, one fact remains clear: any new technologies must ultimately be used for the benefit and prosperity of life on our planet.

Microalgae - come in different types: *Diatomeae, Chrisophyta, Cryptophyceae, Chlorophyta, Haptophyta, Cyanophyta and others could be utilized as a fuel.* The primary challenge lies in the slow growth of microalgae species with the highest oil content, coupled with limited research into their biology and genetics. This gap hinders efforts to achieve genetic improvements in these microalgae. Additionally, there is a lack of comprehensive understanding regarding the kinetics of oil and starch production in microalgae and how these processes depend on factors such as water, light, and nutrients. This insufficiency makes it difficult to conduct a thorough analysis of the feasibility of industrial biofuel production from microalgae. Moreover, the design and cost of photobioreactors still require significant advancements. Further challenges may emerge as algal technologies scale up for biofuel production. For instance, nitrogen and phosphorus, essential for algal growth, will be required in large quantities, similar to their use in traditional agriculture. However, producing nitrogen fertilizers alone currently consumes up to 50% of the energy expended in modern agricultural practices, adding another layer of complexity to the viability of algal biofuel technologies [3].

In the field of water supply, a key area of infrastructure development in Azerbaijan, significant progress has been made. Melioration and water management facilities have been constructed, and major repair works have been carried out. These measures have accelerated the development of the water management system, significantly improving and modernizing the continuous supply of drinking water to Azerbaijan's population—limited by scarce freshwater resources—and enhancing the irrigation system.

However, several challenges persist. The country's limited freshwater resources, global climate change, rising average temperatures, and a notable reduction in surface water resources, river water levels, and precipitation (much of which originates from neighboring countries) have exacerbated water scarcity. Additionally, rapid population growth, improved living standards, economic expansion, and the development of agriculture have increased water demand. The expansion of agricultural lands, irrigation networks, and drinking water supply systems further underscores the urgent need for measures to ensure water security. Compounding this issue is the inefficiency in water usage; 73.5% of irrigation canals are underground, leading to significant water losses, with irrigation usage accounting for up to 30% of available water.

To address these concerns, the President of the Republic of Azerbaijan issued Decree No. 2178 on July 27, 2020, titled "Measures to Ensure the Efficient Use of Water Resources for 2020–2022." This decree includes the approval of an action plan to optimize water resource management. Clause 1.2 of the Action Plan specifies the "installation, operation, and monitoring of measurement systems based on modern technologies for assessing water resources at major water and management facilities in the country, as well as the integration of relevant data into the 'Electronic Water Management' online information system."

As part of this initiative, the Action Plan for 2020–2022 also includes the installation of water meters at key facilities managed by the OJSC, funded through the allocation of resources for these projects, as per the President's Decree No. 2522 dated February 26, 2021.

In addition to new technologies, ultrasonic flowmeters are also widely used. These devices measure the velocity of a fluid (liquid or gas) flowing through a pipe by utilizing ultrasound principles. Ultrasonic flowmeters are non-invasive, meaning they can often measure flow without disrupting the fluid or cutting into the pipe. Below is an overview of how they work and their applications [1]:

Additionally, SCADA systems are extensively used in various regions of Azerbaijan, where accurate water flow measurement and data storage are critical concerns.

Here are some key specifications currently employed in major projects, which also could be useful in our project:

Scada Technical Specifications

1. The Scada system is to be managed from a single center and include licensed copies of the software.
2. PLC products are to be European-made and possess the necessary conformity certificates.
3. The Scada system will be installed in a "Hot Redundant" structure with a "2 Servers and 2 Clients" architecture.
4. A storage unit with a data storage capacity of 20 TB is required for Scada data management.
5. All Scada data is to be stored in memory for a minimum of 3 years.
6. The Scada system is to include an internal network and 20 user licenses.
7. Scada is to provide monitoring of reports for up to 20 users over the Secured Internet network and internal network, along with a visual display of information about the status of connected equipment (active/passive).
8. Scada is to be accessible for monitoring by up to 20 users through Android or Apple phone applications.
9. Scada should feature a three-level geographic coordinate system, displaying all points (point cloud) on the map.
10. Scada is to communicate with PLCs over Ethernet without requiring an external protocol.
11. All Scada licenses are to be original and transferred to the organization at the end of the project.
12. The system should allow for new additions and corrections.
13. All Scada information is to be monitored as a Trend.
14. The Scada software should include reporting and archiving capabilities and maintain archived user data.
15. Scada software and its interface should support three languages: Azerbaijani, Russian, and English.

PC Features

1. Scada computers are to be Rack-Type Workstations with the following minimum specifications:
   - **Processor**: Intel Core i5, CPU 2.9 GHz
   - **RAM**: 32GB DDR4-2400 (2x8GB) registered RAM
   - **Disk**: HP 1000GB SATA 7200 1st HDD
   - **Media Card Reader**: 15-in-1 Media Card Reader
   - **Operating System**: Windows 10 Pro 64-bit
   - **Keyboard & Mouse**: HP USB Keyboard and HP USB 1000dpi Laser Mouse
   - **Power Supply**: 700W 90% efficient chassis
   - **Screen Size**: 27 inches

Flow Meter PLC Technical Specifications

- **Job Program Memory**: Integrated 2 MB
- **Job Program Data**: Integrated 8 MB
- **Memory Loading**: Plug-in with SIMATIC memory card
- **Screen Size**: 6.1 cm
- **Command Execution Times**:
  - Bit Processing: 0.002 µs
  - Word Processing: 0.003 µs
  - Fixed-Point Processing: 0.003 µs
  - Floating-Point Processing: 0.012 µs
- **Bit Memories, Timers, Counters**:
  - Counters/Regulators: 2048 each
  - Bit Memories: 16 KB
- **I/O Addressing**:
  - Inputs: 32 KB (all inputs stored as processes)
  - Outputs: 32 KB (all outputs stored as processes)
- **Motion**: Up to 96 axes supported
- **Communication Features**:
  - PtP: Supported (via CM)
  - PROFINET: 1x PN (and via CM), 1x PN IO IRT (2-port switch)
  - PROFIBUS: 1x DP (via CM)
  - Web Server: Supported

Battery Controller Features

1. Excellent EMC design
2. High-speed 32-bit MCU
3. High-efficiency series PWM battery
4. Compatible with four battery types: Dry, Gel, Water, and User-defined (9-17V) batteries
5. Intelligent lighting and timer control for solar lighting systems

6. High-precision sampling ensures 12-bit A/D accuracy
7. MOSFET used for electronic opening and closing
8. Fully adjustable and modifiable parameters
9. Browser interface suitable for daily operations
10. Temperature compensation
11. LCD display with a 4-key humanoid machine interface, integrated menu display, and operation
12. Energy statistics function
13. RS485 ports with MODBUS communication protocol
14. Optional PC monitoring with real-time monitoring and battery management parameter settings
15. Upgradable software

Ultrasonic Flowmeter Features:

1. The Doppler radar shall measure the permissible velocity with an accuracy of 0.001 m/s, while the integrated 81 GHz radar shall measure the continuous level with an accuracy of 0.5 mm.
2. The open channel flow shall be automatically calculated after processing the channel geometry in the transmitter interface.
3. The device shall measure water flow by assessing the flow rate in the bottom and surface layers of the channel and calculating the average velocity.
4. The non-contact radar technology shall enable quick and simple sensor installation on the water surface, minimizing maintenance and installation costs.
5. The integrated tilt sensor shall automatically measure the sensor's inclination angle and correct any errors due to the cosine factor of the mounting angle.
6. The device shall have an IP68 protection class, and the IP68 certificate shall be provided during the tender process.
7. The transmitter's analog 4-20 mA, digital RS232, RS485, and CAN Bus communication protocols for level, velocity, and flow rate data shall integrate easily with existing telemetry equipment and SCADA systems.
8. The device shall have an IP68 protection class, and the IP68 certificate shall be provided at the tender stage.
9. It shall have a velocity accuracy of 0.001 m/s and a level tolerance of 0.5 mm.
10. It shall support all 4-20 mA, digital RS232, RS485, and CAN Bus communication protocols.
11. It shall measure velocity from 0.02 m/s to 15 m/s.
12. Level measurement shall be possible up to 30 meters.
13. The device shall operate instantly, with a simple structure.
14. Graphical and 3D simulation data shall be visible.
15. The following standards and certifications shall be met: EN 50293: 2000, EN 61000-6-2, EN 61000-6-4: 2007.
16. The following standards and certifications shall be met: EN 61000-3-2: 2006 + A1: 2009 + A2: 2009, EN 61000-3-3: 2008, EN 300 440-1, EN 300 440-2, FCC Part 15 Subpart C. These must be submitted with the offer.
17. **Speed Sensor:**

- K-band 24.125 GHz Doppler radar, 21 dBm EIRP
- Speed Sensor Angle: 12°
- Speed Range: 0.02 to 15 m/s
- Radar Level Sensor: Microwave W-band 77-81 GHz FMCW radar
- Level Range: 0 to 30 meters
- Speed Resolution: 0.001 m/s
- Speed Accuracy: ±1% FS
- Level Resolution: 0.5 mm
- Level Accuracy: ±3 mm
- Protection Class: IP68
- Power Supply: 9 to 27 VDC
- Operating Temperature: -40°C to +85°C
- Interfaces: Modbus / RS-485 half duplex, RS-232 (two-wire interface)
- Baud Rate: 1200 bps to 115200 bps
- Analog Output: 1 or 2 x 4-20 mA
- Certifications: EN 50293: 2000, EN 61000-6-2, EN 61000-6-4: 2007, EN 61000-3-2: 2006 + A1: 2009 + A2: 2009, EN 61000-3-3: 2008, EN 300 440-1, EN 300 440-2, FCC Part 15 Subpart C

The use of AI programs is becoming increasingly integral across various aspects of our lives. AI-driven systems, often written in Java or Python, are powerful tools in diverse applications, including the desalination of seawater. Notably, AI can enhance the efficiency and effectiveness of these processes. It is also worth mentioning that there are innovative methods for extracting potable water from sources other than seawater. Technologies such as ***Atmospheric Water Generators (AWGs), solar-powered water collection, fog nets, dew collection, and moisture absorption by materials*** can extract water from the air, turning it into drinking water. These methods, alongside AI, present promising solutions for addressing water scarcity.

In addition to the information mentioned above, we would like to draw your attention to a project we are currently developing. The innovative methods and technologies discussed earlier in the context of land reclamation and irrigation systems can also be effectively applied to seawater distillation, converting saline water into potable water. While our project is currently conceptual and has only been developed to the level of a master's thesis, it holds significant potential for future implementation, as supported by insights gathered from numerous consultations with experts.

The project envisions the development of self-floating barges, controlled by advanced artificial intelligence programs, specifically designed for seawater distillation. Each barge will be equipped with 16 solar panels and 4 wind batteries, ensuring a sustainable and renewable energy source for continuous operation. As a pilot experiment, a water distillation company would deploy 21 such barges into the Caspian Sea basin.

Based on the design specifications, each barge will be capable of producing 10 liters of distilled water per hour. To enhance the quality of the water, essential vitamins and minerals will be added on-site, making the water suitable for consumption. Operating 24 hours a day, a single barge will produce 240 liters of drinking water daily, resulting in a collective output of 5,040 liters per day from the 21 barges.

This project leverages state-of-the-art technological and engineering advancements, including ultrasonic flowmeters, SCADA systems, artificial intelligence, solar panels, wind energy storage systems, and advanced navigational tools. These innovations ensure the project's efficiency, sustainability, and economic viability, paving the way for a reliable solution to meet the growing demand for clean drinking water.

Conclusion

In conclusion, based on the remarkable research by scientists in the field of distillation and water purification, it is clear that the search for new methods will ultimately be judged by future generations. Naturally, not all solutions will be applicable in every environment. Each water body—whether a reservoir, sea, river, or ocean—has its own unique characteristics, including scale, flow intensity, and chemical composition. Therefore, it is crucial to consider the specific structure of these water sources.

The decreasing water levels of the Caspian Sea, as well as other seas and lakes, present new challenges for scientists. They must not only identify the causes but also address these issues while ensuring the needs of the population for drinking and technical water are met, without compromising the environment. In tackling these complex challenges, technical advancements such as artificial intelligence, solar power, wind energy, and biofuels can serve as valuable tools to assist scientists in their efforts.

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АЛЬТЕРНАТИВНЫЕ МЕТОДЫ ОПРЕСНЕНИЯ: ПЕРСПЕКТИВЫ ИНТЕГРАЦИИ ИИ И ИСПОЛЬЗОВАНИЯ SCADA-СИСТЕМ

Резюме

Проблема превращения морской воды в питьевую становится всё более актуальной в современном мире. Растущее население планеты, наряду с нехваткой продовольствия и ограниченным доступом к чистой питьевой воде, подталкивает человечество к грани серьёзного кризиса. В этой статье рассматриваются современные методы опреснения, предлагаемые различными странами и компаниями. Цель статьи — предоставить полезные сведения для стран, сталкивающихся с нехваткой воды, или для тех, у кого научные прогнозы предсказывают подобные кризисы.

Ключевые слова: опреснение морской воды, современные методы, ИИ в производстве питьевой воды.

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ALTERNATIV DUZSUZLAŞDIRMA METODLARI: SÜNI İNTELLEKTIN İNTEQRASIYASI VƏ SCADA SISTEMLƏRINDƏN İSTIFADƏ PERSPEKTIVLƏRI

Abstract

Dəniz suyunun içməli suya çevrilməsi problemi bu günün dünyasında getdikcə daha da aktuallaşır. Dünyada əhali artımı, qida çatışmazlığı və təmiz içməli suya məhdud çıxış insanlığı ciddi bir böhrana sürükləyir. Bu məqalədə müxtəlif ölkələr və şirkətlər tərəfindən təklif olunan müasir duzsuzlaşdırma metodları araşdırılır. Məqalənin məqsədi, su çatışmazlığı ilə üzləşən ölkələrə və ya elmi proqnozlara əsasən belə böhranların baş verəcəyi ehtimal olunan ölkələrə faydalı məlumat təqdim etməkdir.

Açar sözlər: dəniz suyunun duzsuzlaşdırılması, müasir metodlar, içməli su istehsalında süni intellekt.