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Technologies for Desalinating Water from the Ocean and Sea Ice- A Review

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Abstract

Fresh water is required for life on our planet. Water scarcity affects around one-third of the world's population, or approximately 2.3 billion people, according to the WHO. According to the World Water Council, as the world population grows over the next fifty years, the water situation will worsen. Despite this, water covers over three-quarters of our world, with saltwater accounting for 97.5% of this total. As a result, addressing this dilemma requires a feasible and economically viable desalination technique. Several saltwater desalination methods have been developed in recent decades to supplement the supply of water in dry locations across the world. Many nations are unable to afford these technologies as a fresh water supply due to the restrictions of high desalination prices. However, the steadily expanding use of saltwater desalination has proved that seawater desalination is a viable water supply independent of rainfall changes. A seawater desalination method divides saline saltwater into two streams: a fresh water stream with low dissolved salt content and a concentrated brine stream. To desalinate, some sort of energy is required, and various different separation processes are used. The multi-stage flash (MSF) distillation and reverse osmosis (RO) processes are at the heart of two of the most economically important technologies. Although desalination technologies are mature enough to provide a stable source of fresh water from the sea, extensive research and development (R&D) has been conducted in order to continuously enhance the technologies and lower the cost of desalination.

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Keywords: *Sea Ice Desalination, Multi-Stage Flash, World Water Council*

INTRODUCTION

The world's water resources are primarily saline (97.5%) and fresh (2.5%). Salty water may be found in oceans, seas, and certain lakes, whereas fresh water is either stored underground (30%) or in the form of ice/snow covering hilly regions, Antarctica, and the Arctic (70%), but only 0.3% of it is useable by people. With a limited supply of usable fresh water, desalination provides a way to meet the growing demand for fresh water. Desalination methods are classified into three categories: I thermally activated (ii) pressure-activated systems, which force salty water through a membrane, leaving salts behind; and (iii) chemically-activated desalination methods.

Multi-stage flash distillation (MSF), multiple-effect distillation (MED), vapour compression distillation (MVC), humidification-dehumidification desalination (HDH), sun distillation (SD), and freezing are examples of thermally activated systems (Frz). Heat transfer is utilised in these systems to either boil or freeze the seawater or brackish water to convert it to vapour or ice, allowing the salts to be removed from the water. Permeable membranes are used in pressure-activated systems to generate two zones through which water can flow while leaving salt behind.

Reverse osmosis (RO), forward osmosis (FO), electro-dialysis (ED), and nanofiltration are among these technologies (NF). Ion-exchange desalination (I.Ex), liquid-liquid extraction (LLE), gas hydrate (G.Hyd), and other precipitation techniques are examples of chemically-activated desalination technologies. Adsorption technology (Ads) has recently been researched for desalination applications. To separate the water from the salts, an adsorbent material having a high affinity for water, such as silica gel, can be utilised in this approach. The purpose of this work is to objectively evaluate the performance of all existing desalination systems in terms of energy required, cost, feed and generated fresh water quality, and environmental effect.

Andreas N. Angelakis, NikolaosMamassis, Emmanuel G. Dialynas, and KonstantinosZotalis In Greece, I evaluated desalination technology. Data on desalination costs suggests a drop in the future, as does the possibility of water desalination in Greece.

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The paper outlines the existing situation in southern Greece (for example, the Aegean islands and Crete) and analyses the possibilities of producing desalinated water from brackish water.

Akili D. Khawajia, Ibrahim K. Kutubkhanaha, and Jong-MihnWieb examined the existing state, practises, advances, research and development efforts, and future possibilities of cutting-edge saltwater desalination technology. This analysis has focused on MSF distillation and RO technologies given their widespread usage as the two most economically viable processes.

P. G. Youssefa, R.K. AL-Dadaha, and S. M. Mahmouda compared the performance of contemporary desalination systems in terms of input and output water quality, amount of energy required, environmental effect, and cost. Adsorption desalination technology was discovered to be a potential approach for desalinating saltwater due to its cheap operating costs and minimal environmental impact due to the utilisation of waste energy resources.

Different desalination technologies, including sea ice solid-state desalination and sea ice melt-water desalination, were researched and compared by LixinXiea, JiaMaa, Fang Chengb, PingliLia, JieLiua, WeibinChenc, and ShichangWanga. One of the key regulating parameters in a centrifugal desalination experiment was rotation speed. The best salinity desalination result was found at a rotating speed of 2000 rpm for 2-3 minutes. When sea ice was desalinated by modest melting, temperature and time were the most important elements. The total dissolved solids of sea ice melt-water might be as high as 100 mg/L employing the reverse osmosis technique. The findings suggest that sea ice desalination technologies might reduce sea ice salinity from 3–8 to 0.2-2 at a reasonable cost.

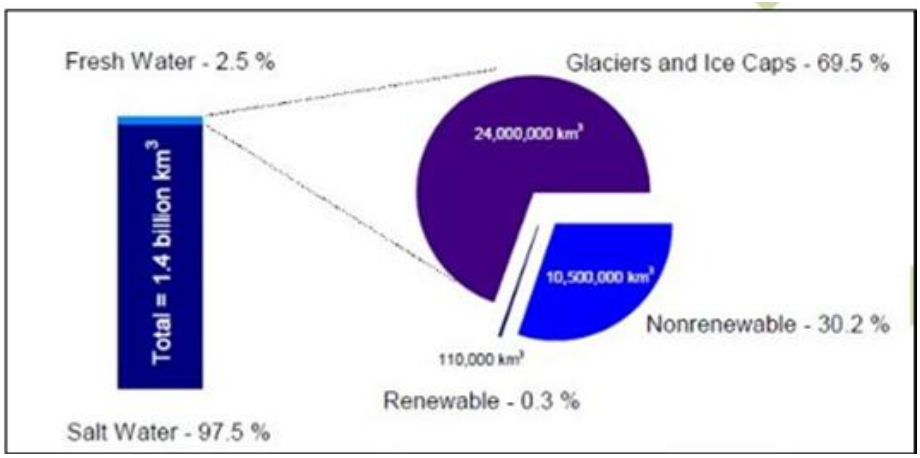
UmerShafique, Jamil Anwar b, Munawar Ali Munawar ,Waheed-uzZaman ,RabiaRehman b, Amara Dar a, Muhammad Salman b, Maria Saleem b,NaeemaShahid b, MehwishAkram b, AroojNaseer a, and Nadia Jamil c investigated the chemistry of ice: migration of ions and gases by directed freezing of water and discovered that anions and cations redistribution generates an electrical imbalance in ice generated from electrolyte solutions. The movement of acidic and basic ions in cooling solutions can significantly alter the pH of both frozen and unfrozen sections of the system. The amount of pH change caused

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by freezing is dependent on the concentration of solutes and the amount of cooling. The redistribution of hydrogen, hydroxyl, carbonate, and bicarbonate ions under directed freezing in batch aqueous systems was investigated in this study. In acidic and basic liquids, controlled freezing was used both vertically and radially. In each case, the ions moved significantly along with the shifting freezing front. The migrating ions were monitored using conductometry and pH-metry.

The global capacity of desalination plants, including renewable desalination, is expected to grow at an annual rate of more than 9% between 2010 and 2016. The market is set to grow in both developed and emerging countries such as the United States, China, Saudi Arabia (SA) and the United Arab Emirates (UAE). A very significant potential also exists in rural and remote areas, as well as in islands (Figure 2, rest of world (ROW)), where grid electricity or fossil fuels to generate energy may not be available at affordable costs. About 54% of the global growth is expected to occur in the Middle East and North Africa (MENA) region, where the 21 million m3/d of desalinated water in 2007 is expected to reach 110 million m3/d by 2030, of which 70% is in SA, the UAE, Kuwait, Algeria and Libya

There is an almost unfathomable amount of water on earth: about 1.4 billion km3 (330 million cubic miles) [3]. Of this total, less than 3% is fresh water (about 35,000,000 km3), much of which (about 24,000,000 km3) is inaccessible due to the fact that it is frozen in ice caps and glaciers (Figure 1). It is estimated that just 0.77% (about 11,000,000 km3) of all the earth's water is held as groundwater, surface water (in lakes, swamps, rivers, etc.) and in plants and the atmosphere.



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Sea Ice Desalination Technology

Ice forms when the temperature falls below freezing, but most salt ionic species in saltwater are so large that they are difficult to combine into the ice crystal lattice. As a result, the salts in saltwater are transported to the underlying ocean, with just a portion of them remaining in the volume of freshly formed ice in the form of a brine pocket. Desalination may develop further when sea ice accumulates and melts, reducing salinity to a lower level [9]. In contrast to fresh water ice, sea ice is made up of ice crystals, brine pockets, air pockets, and a few solid contaminants.The salt from sea ice resides mostly in the brine pocket; the salinity of sea ice is typically between 3 and 8, which is significantly lower than that of saltwater (approximately 3.5%). It can be observed that the process of sea ice creation is a natural desalination process, which may save a lot of money and cut costs when sea ice is utilised as a desalination material.Sea ice desalination, which encompasses both solid-state and liquid-state desalination, has been thoroughly explored at various scales. Centrifugal and slight-melting desalination are the most common solid-state desalination technologies, whereas RO is the most common liquid-state desalination method.

CRYODESALINATION

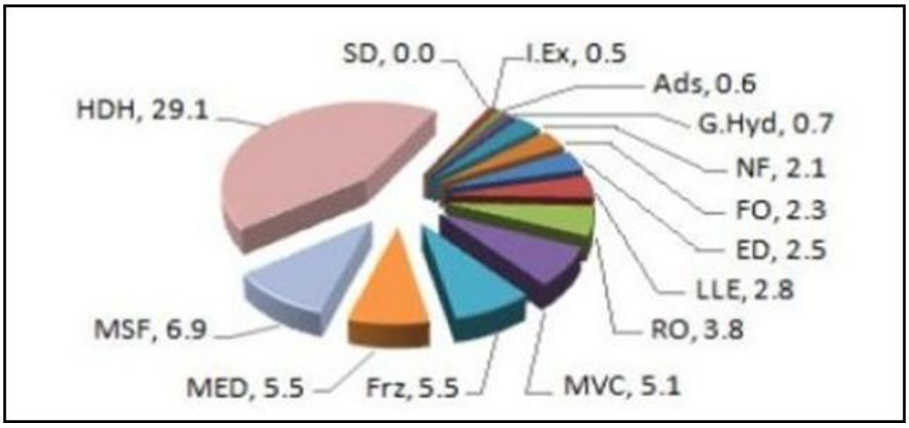
Norbert Buschbaum created a trial unit for seawater desalination using a new approach known as cryodesalination. Desalination by freezing procedures is based on the fact that ice crystals created are composed of basically pure water when the temperature of saline water is reduced to its freezing point and further heat is removed, leaving behind brine solution. When these crystals come into contact with a liquid, they turn into slush. Brin sticks to the crystals and gets stuck. It is difficult to completely remove salinity from slush. As a result, when the ice melts and turns into water, the leftover brine in the slush salts the water. This is why freeze desalination has failed in the past.
Flotation, a technology never before employed in freeze desalination, is used to separate ice from brine.

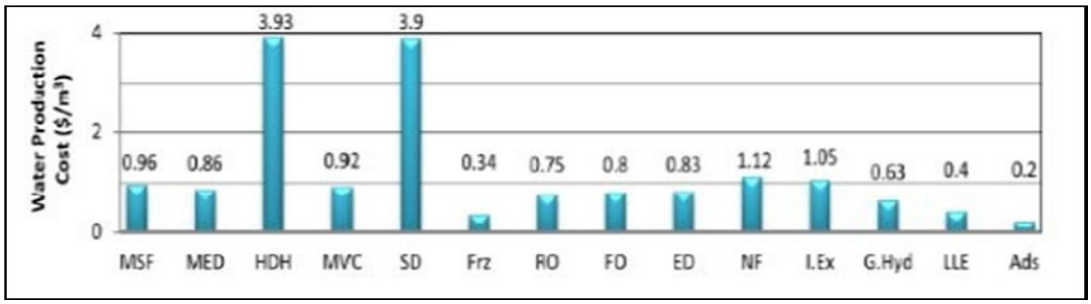
Simply put, the approach works like this: ice floats on water. Many fluids float in water as well. We can efficiently separate the ice from the brine by using a fluid that floats between the ice and the brine. Fresh water is produced by harvesting this separated ice.This challenge is solved by interacting oil, brine, and ice in a separation column, which results in effective ice-brine separation. Cryo desalination uses very little energy.

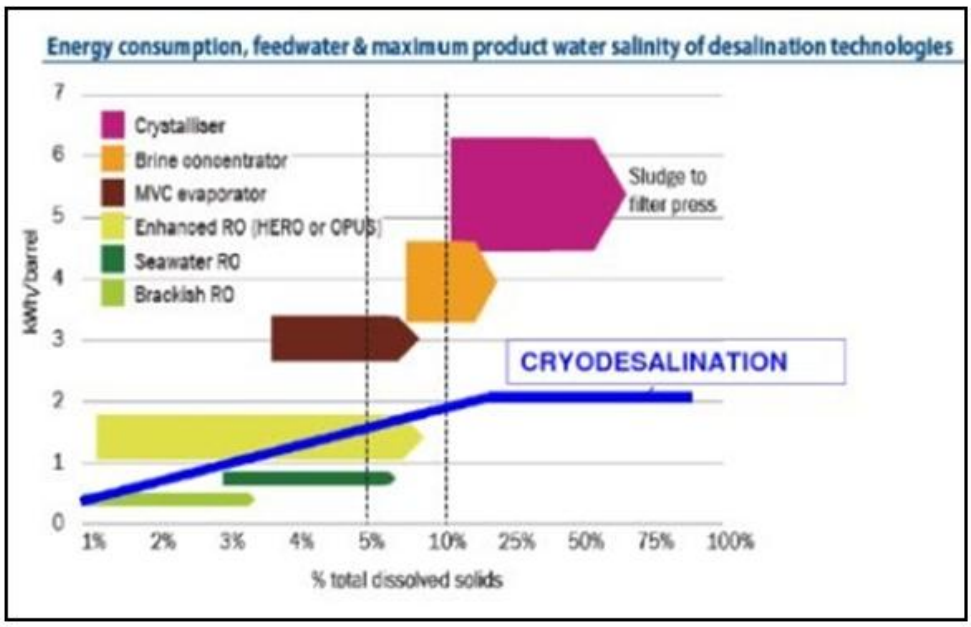
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Efficiency is getting close to the thermodynamic minimum. This efficiency is made possible by using the "cold energy" in the ice to condense the refrigerant vapours. This saves a lot of the energy that was used to make the ice.

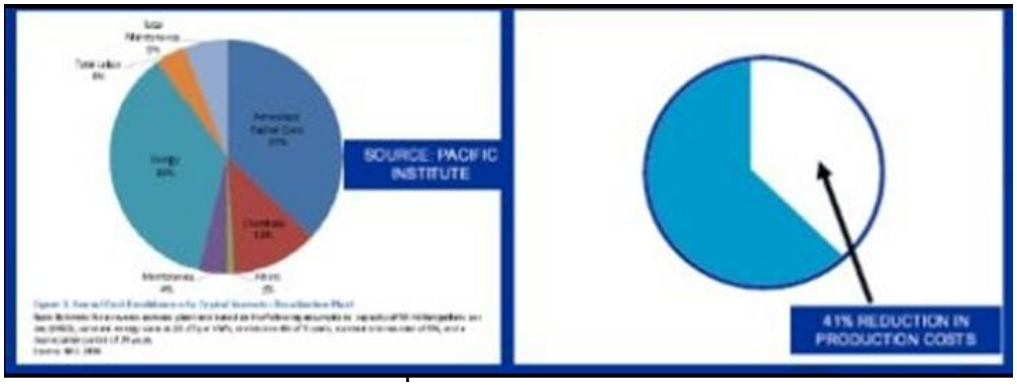
Comparison of Different Technologies







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Several factors influence the selection of desalination systems, including the quality of the salty water to be desalinated, the salinity of the generated potable water, the input energy, the environmental effect, and the cost. Water can be classified as brackish or seawater based on its salinity. Total dissolved solids (TDS) in brackish water are higher than in potable water but lower than in saltwater. TDS should be less than 1000 ppm (or mg/l) in potable water and between 1,000 and 25,000 ppm in brackish water, with saltwater having an average TDS concentration of 35,000 ppm. Figure 2 depicts the variance in feed water and generated water salinity for the methods indicated. This chart clearly shows that MSF and Ads desalination technologies can manage high salinity feed water and create low salinity water. Figure 3 depicts how much thermal and/or electrical energy each technique requires. This statistic clearly shows that SD, I.Ex, G.Hyd, and Ads use the least amount of energy (less than 2kW.hr/m3). Figure 4 depicts the environmental effect of each technology in terms of CO2 emissions, with all calculations based on an emission factor for natural gas combustion of 6.42x10-5 tCO2/MJ (thermal energy) and an emission factor for electricity production of 0.4612 tCO2/MWh [1]. This picture clearly shows that SD, I.Ex, Ads, and G.Hyd create the least amount of CO2 below 0.7 kg/m3. Figure 5 depicts the operating costs of the mentioned technologies, with Ads, Frz, and LLE having the lowest costs of less than 0.5$/m3.

CONCLUSION

All the techniques which are available have their own advantages & disadvantages, Cryodesalination is better when implemented in large scales & when used for sea ice desalination rather than sea water desalination, this cost reduction is the result of eliminating the costs of chemicals, membranes, and filters (17%) plus lowering by one half the capital, labor,

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and maintenance costs of RO (½*(10%+37%)). Their sum represents a 41% reduction in total cost of production when using CryoDesalination rather than Reverse Osmosis. Adsorption technology is also proving to be competent, because of its lower environmental impact, less energy consumption, less CO2 emissions, Slight-melting desalination has own special advantages; for example, no complex equipment, easy to be realized, lower cost, easy operation, etc. Therefore, it is suited for situations which do not require very high water quality but do need lower investment.

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