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Environmental impacts of desalination technologies

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The purpose of this thesis was to illustrate how seawater desalination processes work in the production of potable water and how these processes affect the environment. In addition, the project deals with improving awareness by social media.

Water is essential for life. There is a lack of clean drinking water all over the world. The reasons for that are, for example, disregarded political, economic, social and environmental decisions.

Due to the global water crisis, they are continuously developing new solutions to produce more potable water. The problems of most technologies in-use compared to traditional methods are higher energy consumption and negative environmental impacts.

However, there are already methods in-use which are capable of making clean drinking water energy efficiently from seawater without an environmentally significant consumption. This is not the only solution fighting against the water crisis, but the awareness of importance, finiteness and consumption of fresh water should be improved. This attempt to improve awareness is made by social media.

Keywords	water crisis, desalination, environment, social media

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Tämän opinnäytetyön tarkoituksena oli havainnollistaa, kuinka suolanpoistomenetelmät toimivat merivedestä juomakelpoisen veden valmistuksessa ja kuinka kyseiset menetelmät vaikuttavat ympäristöön. Lisäksi työssä käsiteltiin tietoisuuden lisäämistä sosiaalisen median avulla.

Vesi on välttämätöntä elämän kannalta. Puhtaasta juomavedestä on pulaa ympäri maailman. Tähän ovat syinä muun muassa poliittiset, ekonomiset, sosiaaliset sekä ympäristöä koskevat piittaamattomat päätökset.

Maailmanlaajuisen vesikriisin vuoksi kehitetään jatkuvasti uusia ratkaisuja valmistaa enemmän juomakelpoista vettä. Useimpien käytössä olevien tekniikoiden ongelmia ovat perinteisiä menetelmiä suurempi energian kulutus sekä ympäristöhaitat.

Käyttöön on jo kuitenkin otettu sellaisia metodeja, joilla pystytään tekemään energiatehokkaasti merivedestä puhdasta juomavettä ilman, että se merkittävästi rasittaa luontoa. Tämä ei ole kuitenkaan ainoa ratkaisu taistelussa vesikriisiä vastaan, vaan myös tietoisuutta puhtaan veden tärkeydestä, rajallisuudesta ja kulutuksesta tulisi lisätä. Tätä tietoisuutta yritetään parantaa sosiaalisen median avulla.

Avainsanat	vesikriisi, suolanpoisto, ympäristö, sosiaalinen media

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Table of contents

Abbreviations

FAO	Food and Agriculture Organization of the United Nations
TDS	Total dissolved solids
RO	Reverse osmosis
EPA	Environmental Protecting Agency
MSF	Multi-stage flashing
MED	Multi effect desalination
VS	Vapor compression
ED	Electrodialysis
EDR	Electrodialysis reversal
CA	Cellulose acetate
PA	Aromatic polyamide
NF	Nanofiltration
MD	Membrane distillation
FO	Forward osmosis
HDH	Humidification-dehumidification
MEH	Multiple effect humidification
BSQ	Think big, act small, move quick. A goal planning strategy.

1 Introduction

Environmental impacts are unfortunately often part of the desalination technologies. These impacts are not sufficiently understood or cared about, so more research and awareness is needed.

This thesis has been commissioned by Mora Water Systems and the main purpose of it is to clarify how desalination techniques work, how they affect environment and how they optimize awareness in social media.

There is a lot of water in the world, but only a fraction of it is fresh and there is already a shortage of pure drinkable water. The awareness of the water crisis is at very low level, but the crisis is reality and keeps getting worse all the time. The lack of fresh water is one of the main reasons for many diseases and epidemics, especially in developing countries. This is why big international companies along with municipalities and governments try to find new and energy efficient ways to produce fresh, drinkable water.

Luckily, there are some methods to avoid or to reduce the effects of the water crisis, and those methods are based on making fresh water from seawater. These desalination technologies are already in use all around the world, but most of them are still slightly in their infancy from technical perspective. Those non-updated techniques do reach the purpose (produce potable water from the oceans), but they do it with side effects. Those side effects contain, for example, pollution and destruction of marine ecosystems.

However, a small portion of the operating desalination plants already use and develop techniques which are energy efficient and have less environmental impacts. At the moment, these modern and advanced desalination plants are not enough to solve all the fresh water problems.

2 Water crisis facts and figures

The water we drink and use these days has been here in one form or another ever since the earth was born, very long time ago. The population has exploded while the amount of freshwater on the planet has stayed about the same — continuously recycled through the atmosphere. It means that competition of necessary clean and safe water for cooking, bathing, drinking and sustaining life increases all the time. Water scarcity is a cruel reality for many but still an unknown concept for some. It has become from the sum of many environmental, political, economic and social disregard decisions. (3, 26)

Because of climate, geography, engineering, regulation and competition of resources, some people face drought and debilitating pollution, while others use freshwater way over their needs. In many of the developing countries, clean water is either difficult to find or obtaining it requires a significant currency or laborious work. (26)

No matter where or who they are, water is necessary for people to survive. Human body contains 60 percent of water, but that is not all. It is also a must have resource for producing food, clothing, paper, phones and almost everything else. Water is also cleaning the streets, moving our waste stream and helping people and the environment to stay healthy. (26)

Unfortunately, people do not use water very efficiently. The average hamburger takes about 2,400 liters of water to produce, and at the same time many of the water-intensive crops, such as cotton, are grown in arid areas. According to the United Nations, water use has grown on average (per capita) more than twice the rate of population increase in the last century. The challenge we have now is how to effectively save up, treat and distribute the fresh water we have. (26)

The world is quickly approaching a situation where water is the most competed resource for survival and development. The World Economic Forum announced in January 2015 that the biggest global risk based on impact to society (as a measure of devastation) is water crisis. There are about 663 million people around the world who suffer from the lack of access to safe and clean water (approximately 1 of every 10 people). About 2.4 billion people lack access to a water closet (approximately one third of the people in global population). It means that people have more mobile phones than water closets. Also one third of all healthcare facilities lack a source of clean water in poor and middle-income countries. Globally, a third of all schools suffer from a lack of clean water and a sufficient sanitation. (1, 8)

People have no other possibilities than to drink water directly from the natural flows in many developing countries. This water has no guarantied quality, and many of those streams cause many deaths through different deceases. Water shortages and contaminated water also causes big problems in sanitation. Cleaning in many places has to be performed with a very small amount of water. This exposes the health of the people and staff who use these places continually. Diarrhea caused by insufficient water for sanitation, drinking and hygiene causes globally about 842 000 human deaths per year. (49)

According to UNICEF, long-term exposure to low concentrations of arsenic in drinking-water cause painful skin keratosis (hardened lesions) and can result in cancers of the skin, lungs, bladder and kidney. Millions of people live in surroundings where all their water sources are mainly from nature and are contaminated with arsenic. These people might be in danger of arsenic poisoning because they do not have alternative sources or they are unaware of the risks. (49)

By promoting access to clean water, it is possible to reduce significantly many other diseases like cholera, Guinea worm disease, fluorosis, HIV/AIDS, malaria, intestinal worms, schistosomiasis, trachoma, typhoid. For example, about 500 000 (438 000 in 2015) deaths are caused by malaria mosquitos. Their population is massive in certain areas as they breed in still dirty water, which is caused, for instance, by low level of water in sewage system or uncovered water tanks. (48, 49)

Lack of clean water also takes part of people’s possibilities of education. A lion’s share of children (and teenage girls) in areas of water scarcity have to get up at dawn and walk for several miles every day to collect water. Because of that, they get tired and some of them are not able to go to school. In some communities, school attendance is forbidden to girls and women completely because of water and other family needs. These factors take a lot of time from people education, which may prevent a change in the next generations. (47)

It is claimed that by 2025 we will have approximately billion more people to feed world-wide, and agriculture will use globally about trillion cubic meters more water per year. The United Nations' FAO states that by 2025, two thirds of the people in the world might have their habitats in water-stressed circumstances and 1.9 billion people will be living in areas under absolute water shortage. According to the Falkenmark and Lindh (cited in 54), when water supplies per year are on average less than 1700m^3 per capita, a country or region is said to live in “water stress. When annual water supplies drop to less than 1000m^3 per person, the country is said to be in "water scarcity". Limited periodic lack of water is expected when annual average levels are between 1700m^3/person and 1000m^3/person. (54)

If the view of the future holds true, by 2030 we are living in the world where almost half of the people in the world are living in highly water-stressed areas; that includes from 70 to 250 million Africans (Figure 1). In addition, from 24 to 700 million people who are now living in some of the arid and semi-arid areas will be displaced. (2, 55)

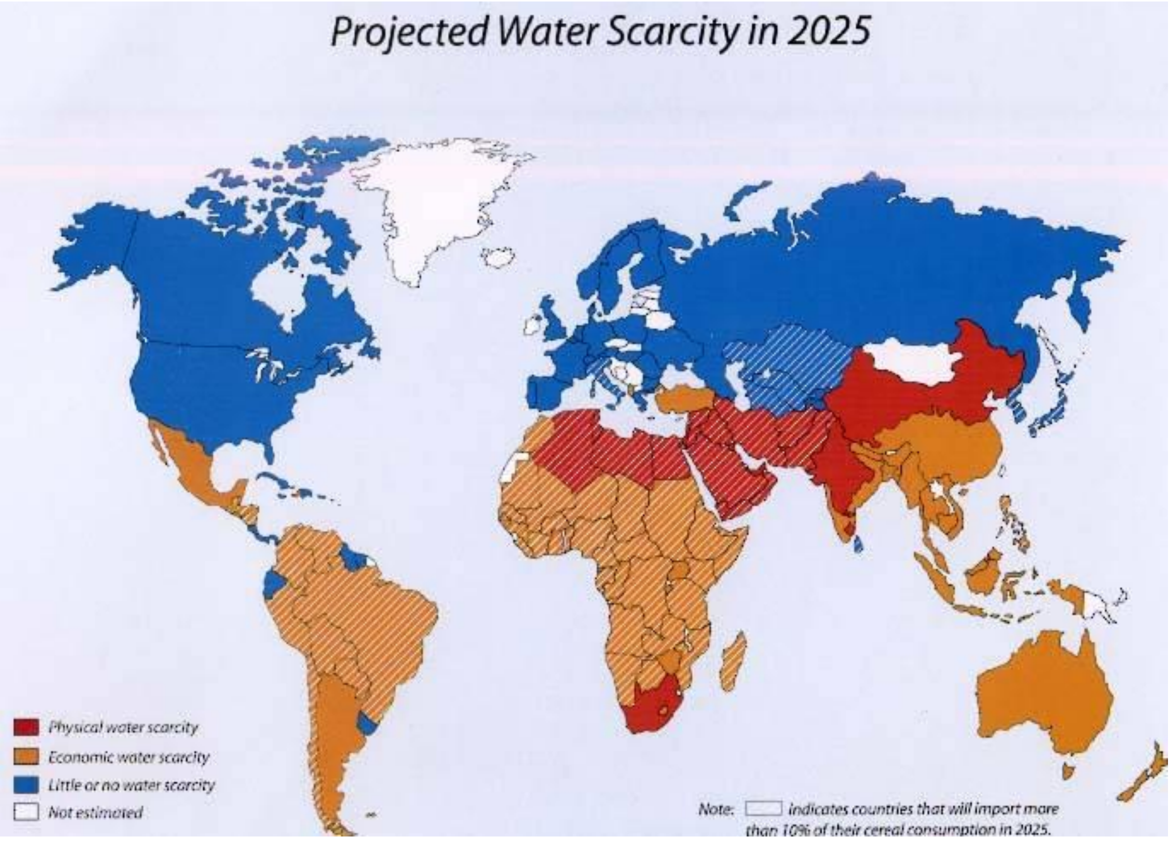

Figure 1. Projected water scarcity in 2025 (2).

3 Environmental risks

3.1 Depletion of fresh water

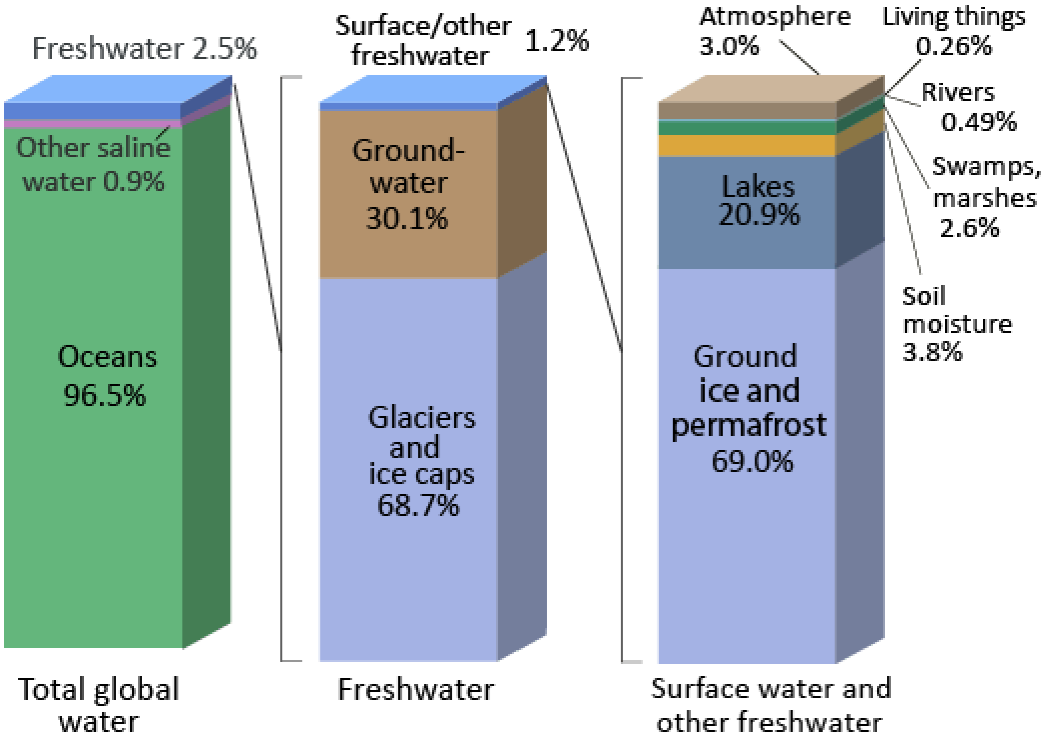

Figure 2. Earth’s water resources (4).

Freshwater is only a small portion of all water on our blue colored planet. Only 2.5% of our nearly 70 percent water-covered world is fresh water. The rest of the water is ocean or saline-based water. Even then, most of the freshwater is trapped in polar caps or glaciers, and just 1 percent of it is easily accessible. As a matter of fact, only 0.007 percent of the planet's water is available and usable to fuel its 6.8 billion people. (4, 26, 50)

From the 2.5% of freshwater available for supporting human life and most forms of all non-ocean life, 68.6% is stored in snowfields and glaciers. Another 30.1% of all fresh-water is groundwater, which means the water stored in underground aquifers – deep beneath the Earth's surface. Thus there is only 1.3% of the total freshwater on Earth in surface water sources such as rivers, streams and lakes. (4, 26, 50)

Only about 1% of the world's fresh water is easily accessible to humans. This 1% includes lakes, rivers, reservoirs and those underground sources that are shallow enough so that they can be used at a reasonable cost. (51)

3.2 Pollution of lakes and rivers

A primary reason for lakes and rivers being contaminated is that industrial, agricultural and domestic activities, which are the largest pollution sources, are usually positioned near the rivers. (5)

Farms and ranches are producing us food, cotton and other merchandises that we need. When the fertilizers they use are washed into lakes and rivers, algal blooms are increasing. Algal blooms can cause health problems as well as taste and odor problems in water. Usually these fertilizers include nitrogen, which might cause damage to fish and other animals. (5)

In many cases, when forests are cleared away, people do not think about the effects of the erosion that flows into waters. Forests, grasslands, wetlands and floodplains are helping us to keep erosion and other impurities out of lakes, rivers, for example. They are also stabilizing rainwater flow by slowing their way into rivers, lakes and groundwater. (5)

All industries use water to make their products. For example, it takes 24 gallons of water to make one pound of plastic. Industries also produce emissions (such as Sulphur) and cause acid rains, which harm aquatic life. A number of industrial plants are washing their waste straight into rivers lakes and seas. (52)

3.3 Global access to drinking water

Access to drinking water can be defined as follows:

> The source is less than 1 kilometer away from its place of use and that it is possible to reliably obtain at least 20 litres per member of a household per day. (7)

> Safe drinking water is water with microbial, chemical and physical characteristics that meet World Health Organization guidelines or national standards on drinking water quality. (7)

> Access to safe drinking water is the proportion of people using improved drinking water sources: household connection, public standpipe, borehole; protected dug well, protected spring, rainwater. (7)

The Earth contains over a billion trillion liters of water, but just a small part of it is drinkable (under 3%). Over 65% from all of the safe drinkable water requires hard work to reach because it is hidden or locked into glaciers and ice caps. About 95% from the rest of the water is located in underground aquifers, which also require some effort to reach it. Only a very small portion of all the water on Earth is easily available for us to use. And drinking is not the only purpose for which we need water. Pretty much everything in our life is in some sort of relationship with water. (53)

4 Desalination technology overview

Desalination is a process that removes minerals from saline water. More generally, desalination may also refer to the removal of salts and minerals. (11)

Water desalination processes produce fresh water by separating salts and other unwanted minerals from the water. Seawater and wastewater are the most common feedwater sources for desalination. The main interest in desalination technology is concentrated on developing inexpensive and energy-efficient ways to make drinkable water and salt as a by-product. With recycled waste water, this is one of the rare ways of producing fresh water which is not dependent on the amount of rainfall. At the moment it is cheaper to produce fresh water from rivers, lakes, for example. but engineers are continually researching ways to reduce energy consumption and to improve the efficiency of desalination technology. (12)

According to the International Desalination Association, in June 2015, 18 426 desalination plants operated worldwide, producing 86.8 million cubic meters per day, (providing water for 300 million people). Produced water amount have been increased by 57% from June 2010. (11)

The biggest desalination plant in the world is called Ras Al Khair project, which is located in Saudi Arabia. In 2014 they produced 1025000 cubic meters per day on average by using membrane and thermal technology. (13)

The largest non-thermal membrane-based desalination plant is Sorek, which is in Tel Aviv, Israel. This reverse osmosis plant was started in 2013. It has a capacity of 624 000 cubic meters per day, and they are planning to increase the capacity. They are part of the desalination master plan launched by the Water Desalination Administration (WDA), an Israeli Governmental Agency, in 2000. The plan is to produce about 650 million cubic meters of fresh water per year in 2020. The agency has already built 3 plants, which have a total capacity of 290M m^3/a. (14)

Vacuum distillation is the traditional way for these operations (Figure 3). It can be used with or without heating. The principle is that the pressure above the liquid mixture to be distilled is less than its vapor pressure causing evaporation for the most volatile liquid. Usually these operations are made at a less than atmospheric pressure and because of that at a much lower temperature than normal. That way “waste” heat from electrical power generation or industrial processes can be minimized.

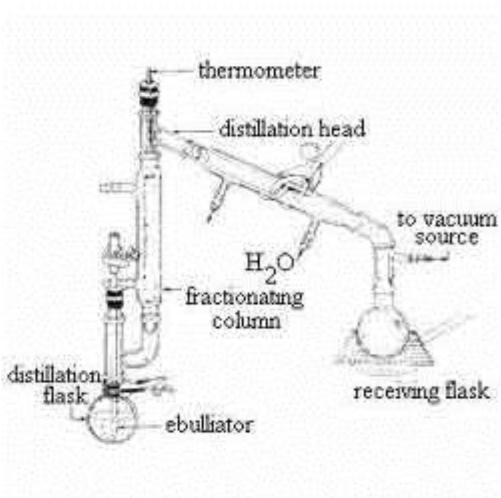

Figure 3. Basic model of vacuum distillation unit. (15)

Competing processes desalinate mainly with membranes with reverse osmosis technology (Figure 4). The principle of these processes is to separate salts from water with pressure and semipermeable membranes. These membranes prevent larger molecules and allow smaller components of the solution to pass freely. Reverse osmosis typically uses less energy than thermal distillation, which reduces the overall desalination costs.

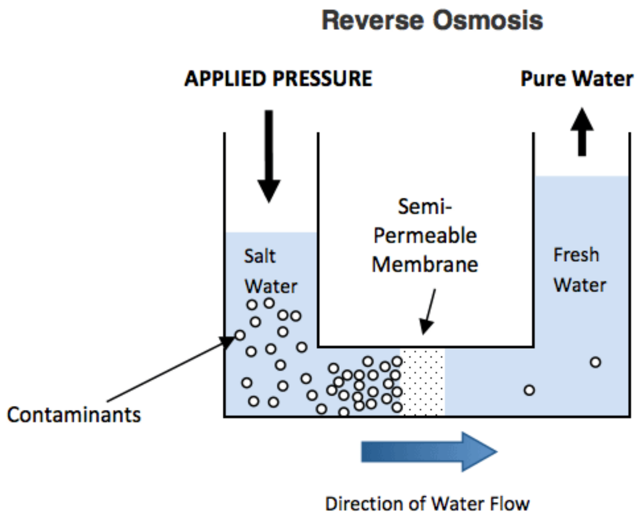

Figure 4. Reverse osmosis unit. (16)

Comparing distillation to the most chosen alternative, reverse osmosis (RO), distillation offers better distillate numbers in the purity range with only 2-10 ppm TDS (total dissolved solids). The reason why distillation is less sensitive to raw water quality is that variations in salinity and content of suspended solids and harmful elements affect more to RO performance. Reverse osmosis system is more sensitive to fouling and scaling than a distillation system.

4.1 Desalination critisism

4.1.1 Energy consumption

Including prefiltering and additionals, energy consumption of seawater desalination can be as low as 3 kWh/m^3. According to present knowledge the minimum energy consumption for seawater desalination is around 1 kWh/m^3 excluding prefiltering and pumping. With the existing RO technology researchers have reached a little under 2 kWh/m^3, but comparing that to local fresh water supplies, which uses only 0,2 kWh/m^3 or even less, it is clear why desalinated seawater is not as common yet.

Desalination plants use a lot of energy and they release a lot of greenhouse emissions from the fossil fuels. The most used desalination method RO makes carbon footprint 0,4 – 6,7 kg CO_2eq per cubic meter of produced clean water. Emissions could be reduced for example by water reuse systems (which range from 0,1 to 2,4 kg CO_2eq/m^3)

or by renewable energy. The main problem is that renewable techniques are more expensive than the conventional ways. (17)

The relationship between desalination and climate change is very complicated. While desalination can remove the world's water scarcity problem, it also increases the climate change in a large scale. Climate and energy policies are trying hard to reduce energy use and greenhouse emissions while the process of desalinization burns many times more fossil fuels than the same amount of fresh water from fresh water bodies. (17)

4.1.2 Marine ecosystems

Desalination plants' intakes and outflows can cause devastation to commercial fisheries and marine ecosystems. Many of these plants use outdated water intake and outflow structures causing significant environmental impacts.

4.1.2.1 Intake

According to EPA, most of the desalination water intake structures are harmful for environment because they pull fish and shellfish into their industrial system and there the organisms may be killed or injured by chemicals, heat or physical stress. Some intake types like beach wells would avoid such problems, but they might limit the production together with higher energy requirements and higher costs. (41)

4.1.2.2 Outflow

All desalination processes produce a lot of concentrated brine, which may contain residues of pretreatment and cleaning chemicals. Large amounts of that by-product can cause disappearance of some organisms. The ocean floor is most at risk because the brine is twice as saline as the sea and thicker than seawater; thus, it sinks and remains there long enough to damage the ecosystem.

Outflow brine includes manganese, lead, iodine, chlorine, ferric chloride, copper, sulfuric acid and biocides.

To minimize the environmental impact of outflow, it is possible to weaken the brine due another stream of water (for example outfall from wastewater treatment or power plant), mixing the brine with a diffuser or divide the outflow into many branches and release it piece by piece.

5 Desalination methods

5.1 Distillation

In seawater desalination, distillation means separating salt from seawater with evaporation and condensation. These basic techniques are widely used in many seawater desalination projects. The most used distillation methods are called Multi-stage flashing (MSF) and multi-effect desalination (MED).

5.1.1 Multi-stage flashing (MSF)

MSF is a thermal desalination method (Figure 5). The goal is to vaporize feed (seawater) and condense it back to product (freshwater). The most energy efficient way to do it is to use feed water as a condenser and heat it after that. In MSF, seawater is led through multiple “flash chambers” to heating section. After heating under high pressure, feedwater goes to the first chamber where pressure is released critically to cause rapid boiling, which results flashing (sudden evaporation). Flashed water vapor rises up where cooler feedwater pipes forces vapor to condense in its liquid form resulting fresh potable water. Only a small portion of water is evaporated and condensed in the first chamber, and the rest of the water (that has not evaporated) continues to next chamber where flashing continues because the pressure is lower than in the previous chamber. To make this method as effective as possible, flashing is processed in multiple chambers where each of them has lower pressure than the previous one.

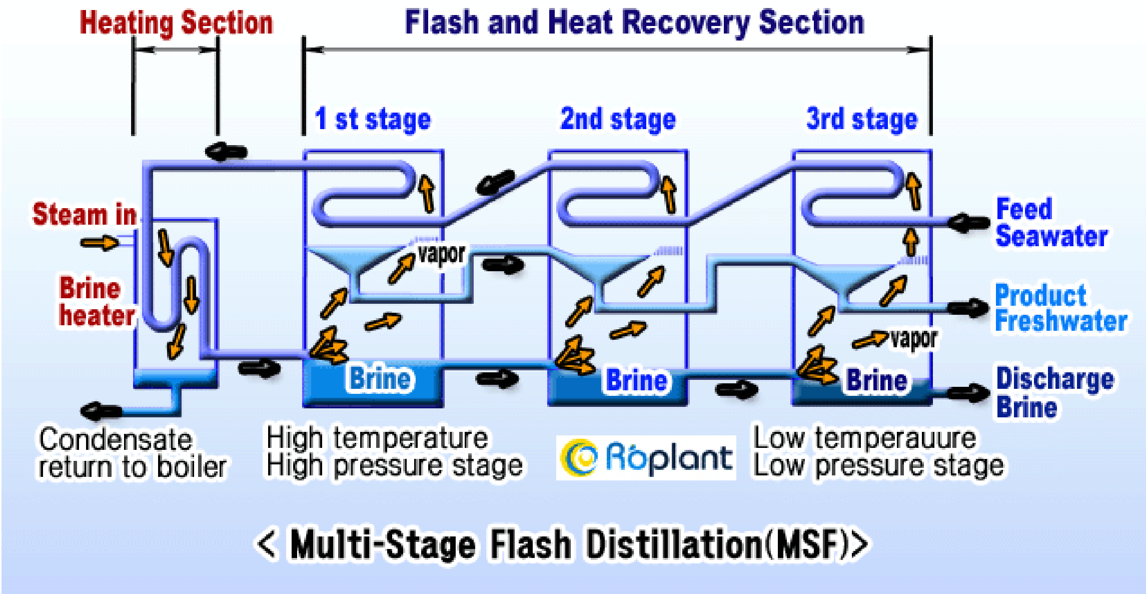

Figure 5. Multi-stage flash distillation (MSF) unit. (18)

The first MSF plants were built in the late of 1950s. MSF plants might have 15-25 stages in the system, but generally it does not have the capacity larger than 15 MGD (millions gallons per day). Multi-stage flashing plants provide about 42% of all desalination capacity worldwide and most of the plants are located in Middle East because of the costs and resources. (18, 35)

The process can be assembled so that the feedwater passes through the process only once (and then disposed) or the feedwater can be recycled for cooling. Both of these methods can have a “long tube” design, where the tubes are placed parallel to the flow, or a “cross tube” design where the tubes are placed perpendicular to the flow. (18, 35)

5.1.2 Multi-effect distillation (MED)

Much like the MSF distillation, Multi-effect distillation (MED) is a thermal method and it is based on distillation in multiple chambers. The difference is that MSF uses pressure and heat to evaporate feedwater and MED uses evaporated water as a heating source for evaporating. Seawater feed is led to the first chamber, where hot tubed steam evaporates part of it into hot steam. Hot steam rises to the top of the chamber where it is led into tubes towards the next stage. Rest of the feed water (which has not evaporated) drains to the bottom of the chamber from where it is routed to the next chamber. Evaporation is generated at progressively lower pressures (lower pressure needs lower temperature for evaporation – pV = nRT) and multiple stages to get the most efficient results. It is also possible to use vacuum for increased vapor speeds. (34)

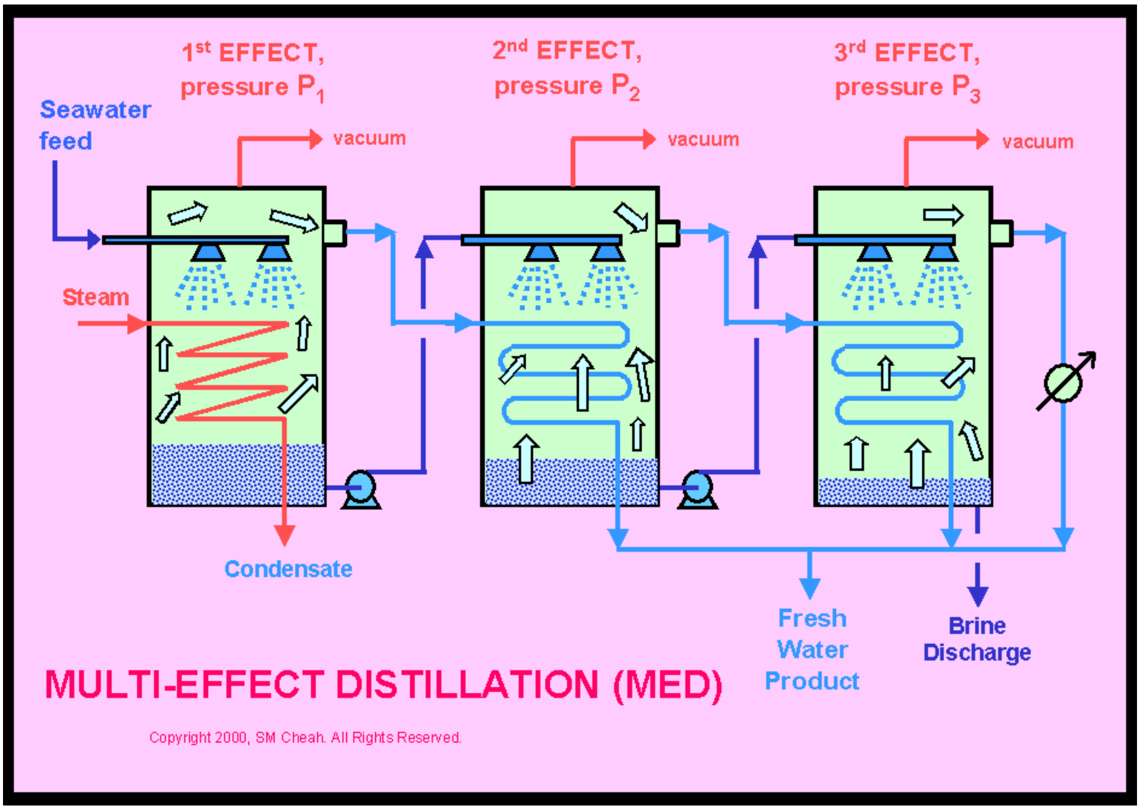

Figure 6. Multi-effect Distillation (MED) unit. (19)

The first multi-effect distillation plants have been built in in the late 1950s. The MED process can have a vertical design, a horizontal design or a vertically stacked design. (18)

5.1.3 Vapor compression (VC)

The vapor compression (VC) by itself has a very limited use in industry (Figure 7). VC is usually used in a combination with other processes such as MED. Vapor compression units have been made in many different setups, which are usually based on a mechanical compressor. These processes work the required heat from the compression of water, so it does not need any external heat source like a boiler. Vapor compression units are often used at hotels, resorts, remote areas and in industrial applications as they are generally small in capacity. (20)

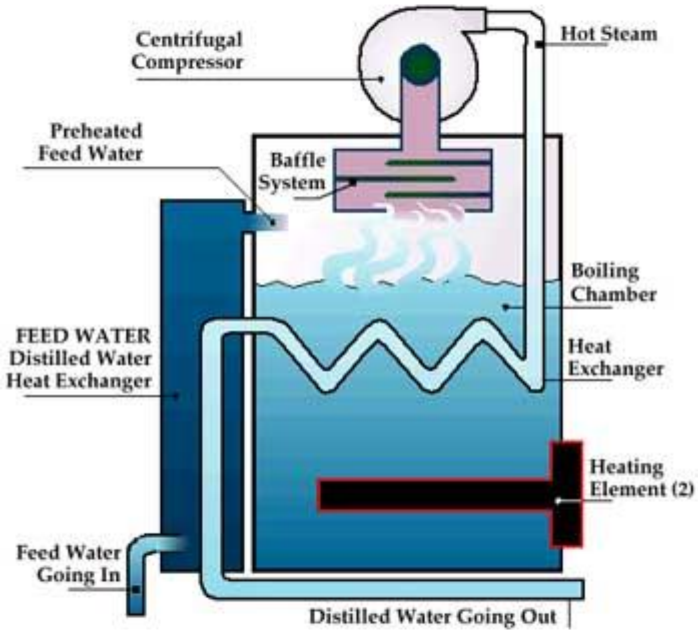

Figure 7. Vapor compression distiller unit. (21)

In Figure 7 above, heating element is used to start the process. When the boiling begins the centrifugal compressor starts pressuring the steam which raises its temperature before it is routed to the heat exchanger. This superheated hot steam works as a boiler for the process, and the heating element turns off. While the steam is giving up its latent heat, the steam will condense to fresh water. At this stage, the condensed water is still very hot (just a little bit under boiling temperature) and it is used as a preheater to incoming feedwater to get the maximum efficiency from the VC system. If needed, the heating element will cycle on and off periodically to provide the system operating at optimum temperature. (21)

5.2 Ion Exchange

Ion-exchange technologies applied to desalination are rather complex, and these operations are often used for water softening among other applications. Ion Exchange process utilizes either grainy or powdery components which are usually resins. These resins can be made using naturally-occurring inorganic materials (such as zeolites) or synthetic materials. They can capture to their surface cations (cation exchanger) or anions (anion exchanger) from the surrounding water.

Chemical resins (solid phase) are designed to exchange their ions with liquid phase (feedwater) ions, which purify the water. Salty seawater (feedwater) is passing through resins where seawaters salt ions are replaced to other ions.

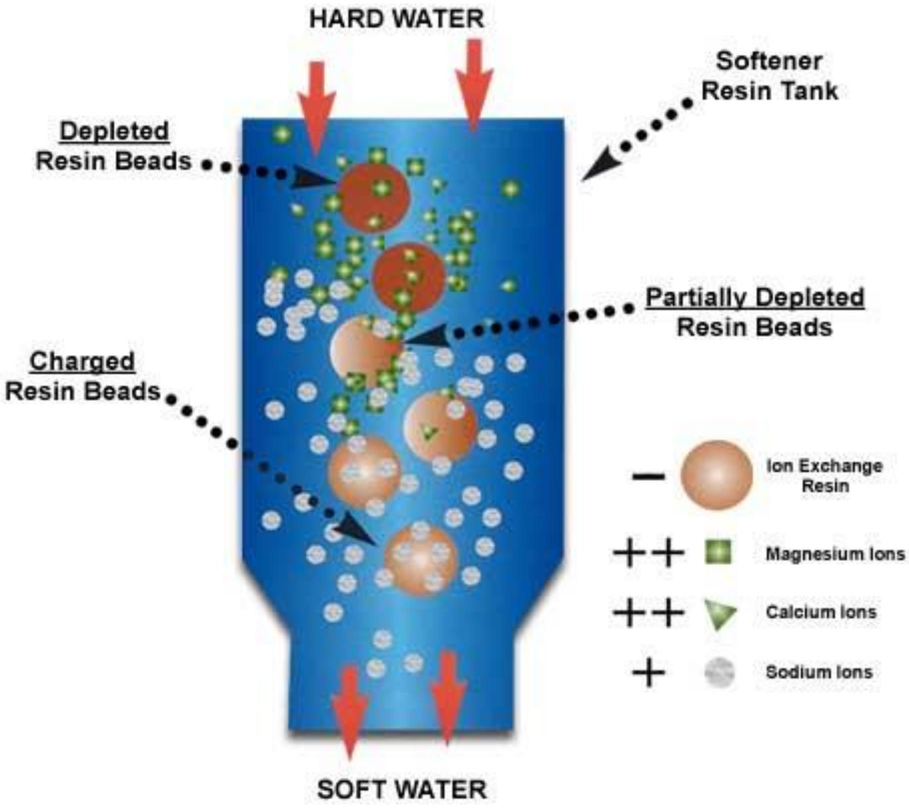

Figure 8. Ion exchange unit. (22)

When the ion-exchanger cannot exchange ions anymore, it needs to be regenerated. Regeneration is generally processed by threatening the resins with a strong solution. Resins get their original exchange capacity when they change their ions with the solutions similarly charged ions. Regeneration solution for cation exchanger is usually hydrochloric acid, sulfuric acid or nitric acid. Recovery solution for anion exchanger is usually sodium hydroxide. (23, 24)

5.3 Membrane processes

In the last decades, membrane technologies have taken a remarkable part in desalination technologies because membranes are scalable and they can transfer specific components selectively and energy efficiently due the reasonable temperatures. (36)

5.3.1 Electrodialysis (ED) and Electrodialysis reversal (EDR)

Salt is basically anions (negatively charged ion) and cations (positively charged ions), which is why it is possible to separate them from water by using electricity. Electrodialysis (ED) is based on the technology that uses continuous DC power and a series of membranes, which are waterproof, but permeable to either positively or negatively charged ions.

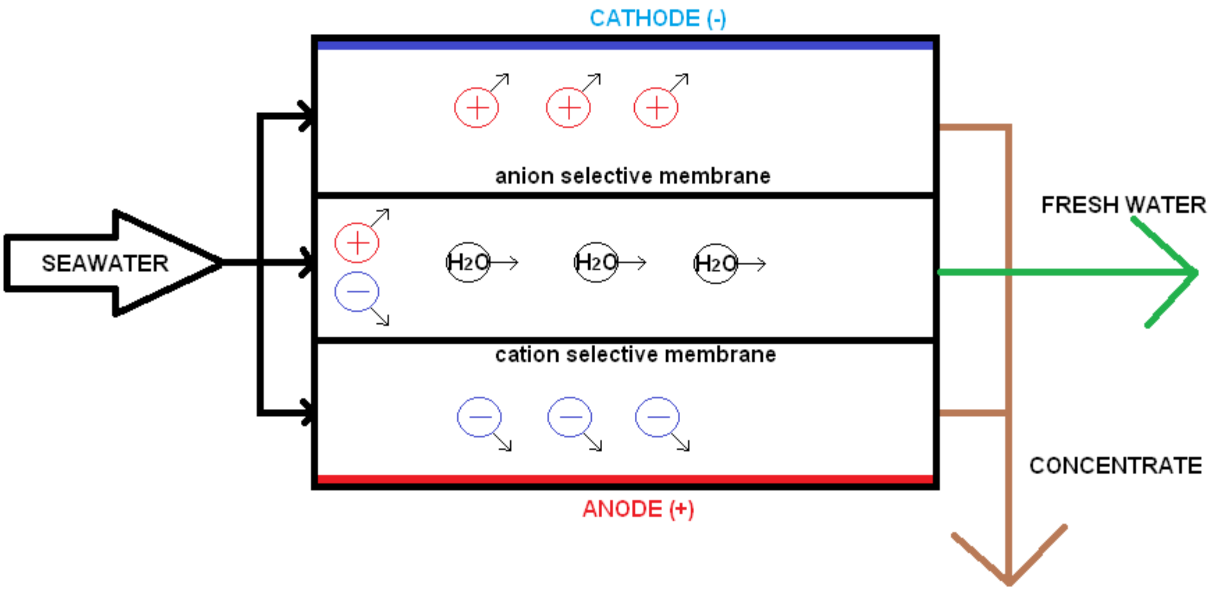

Figure 9. Electrodialysis process.

Seawater is supplied to tank which includes waterproof membranes (permeable for salt ions) on each side, and behind these membranes there is a cathode (negatively charged) on the other end and an anode (positively charged) on the other. The cathode pulls positively charged ions, (through the waterproof membrane) towards it, and the anode pulls negatively charged salt ions (through another waterproof membrane) towards it.

The complete assembly of cell pairs and electrodes is called the membrane stack. The number of cells within a stack varies depending on the system. The ED process requires a pressure between 4,8 and 6,2 Bar (Brunner 1990). It has a high recovery rate and can remove from 75% to 98% of total dissolved solids from feedwater. (25)

ED is the same kind of process than EDR (Electrodialysis reversal). The difference is that in EDR the electrodes reverse to routinely alternate current flow. Charged electrodes are reversed about four times per hour. That decreases fouling of the membrane and creates a kind of cleaning mechanism for the system. The variant polarity and feedwater circulation within the system creates a bit higher recovery rate to EDR than RD. (25)

Both of the electrodialysis methods are not very sensitive to pH or hardness levels in feedwater. These processes do not need a lot of manpower and the costs of the maintenance aren’t very high. They are also adaptive for different functional variations. (25)

In economic terms, the electrodialysis is not the best solution for higher than 4000 mg/l TDS concentrations because the costs are strongly related with the feedwaters total dissolved solids concentration. (25)

5.3.2 Reverse osmosis (RO)

The first RO processes for industrial use have been built in the 1970s. Reverse osmosis is a simple and effective process to TDS (total dissolved solids) concentrations of up to 45 g/l.

Reverse osmosis uses pressure, and the amount of pressure required relates directly to the TDS concentration of the feedwater. Most of the membrane materials are sensitive to fouling and chemicals (such as chlorine). Almost every RO process is essential to have a proper pretreatment of feedwater for protecting the membrane, reducing energy consumption and increasing salt retention. The feedwater should be free of large particles, organic matter, bacteria, oil and grease.

Membranes used in RO for desalination are categorized in Cellulose Acetate (CA) membranes or Non-CA membranes. The CA membrane has a relatively smooth surface, which is resistant to fouling. Non-CA membranes (“thin-film composite membranes”) include aromatic polyamide (PA) membranes and composite membranes using common organic materials like polysulfone. Non-CA membranes are more sensitive to fouling than CA-membranes, but they are more stable for pH variations, have higher flux rate and compared to CA membranes, allow passage of lower salt concentrations.

RO processes may also need a post-treatment depending on the intended use of the product water.

5.3.3 Nanofiltration (NF)

Nanofiltration is a membrane filtration based method that uses membrane with nanometer sized cylindrical through-pores, which is similar to reverse osmosis membrane, but it has larger pore size (0,05 - 0,001um). It means that Nanofiltration needs less pressure than reverse osmosis, but the separation is not as pure.

Nanofiltration is often used to partially soften water and is successful at removing solids, as well as dissolved organic carbon. For low TDS (=total dissolved solids) waters, NF can be used alone for removing salts.

5.3.4 Membrane distillation (MD)

Membrane distillation is a thermally driven process, in which water is vaporized and filtered through a nonwetted porous hydrophobic membrane. In seawater desalination, the basic principle is to heat seawater into steam, transport it through a membrane (which prevents impurities) and condense filtered water vapor to clean water. (36)

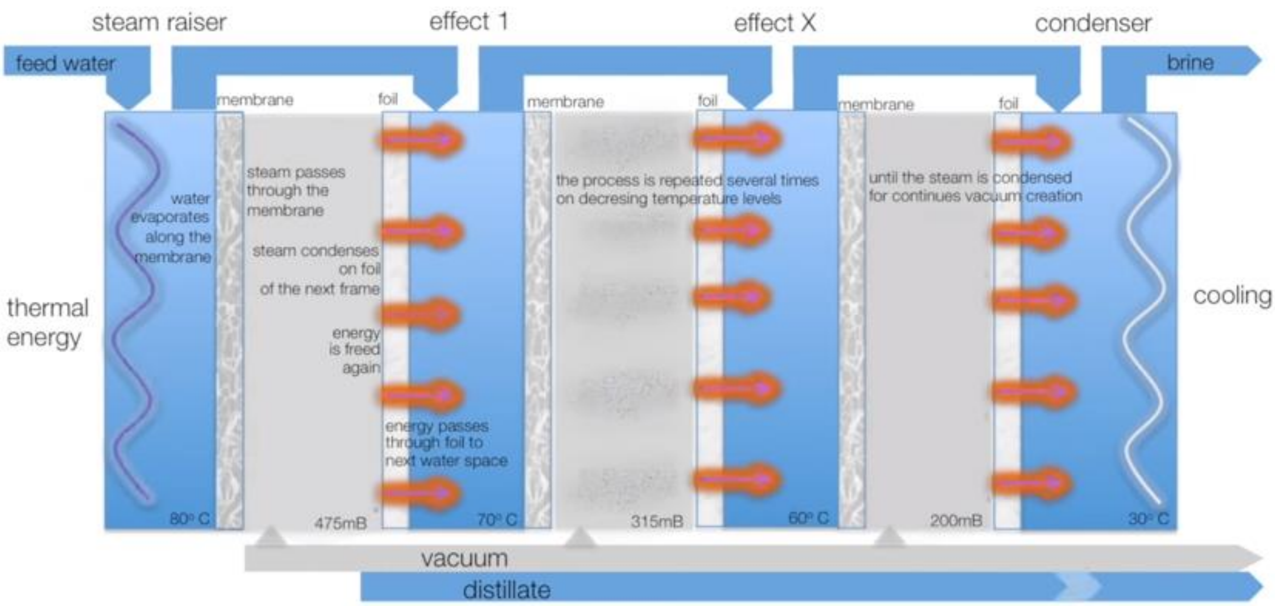

Figure 10. Membrane distillation (MD) unit. (27)

The above example (Figure 10) is a tank which is divided in parts by membranes (which prevents all the liquids and is permeable only to water vapor) and foils. The membrane is hydrophobic, and it remains separate from the liquid stream by surface tension, while higher vapor pressure drives steam molecules across the membrane. The foil is chosen as a spacer because of its heat transferring features. Salty seawater is pumped to the first chamber, where it is heated; thus, that a portion of the water evaporates and moves through the membrane to the other side in which the opposite "wall" (foil) emits cooler temperature. Because of the cooler temperature the water vapor condenses back to water and drains to the bottom of the tank. The permeate side is provided with vacuum to intensify the results. The unvaporized seawater continues to the next chamber (other side of the foil - where it acts as a cooling power for the first chambers). The process is repeated several times on decreasing temperature levels.

5.3.5 Forward osmosis (FO)

The osmotic gradient is the difference between two concentration solutions at both sides of a semi permeable membrane. The osmotic gradient forces water to diffuse between the two solutions toward the higher concentration. Water continues to flow both ways, resulting equalized concentrations. The membrane between these two solutions prevents most of the dissolved solids.

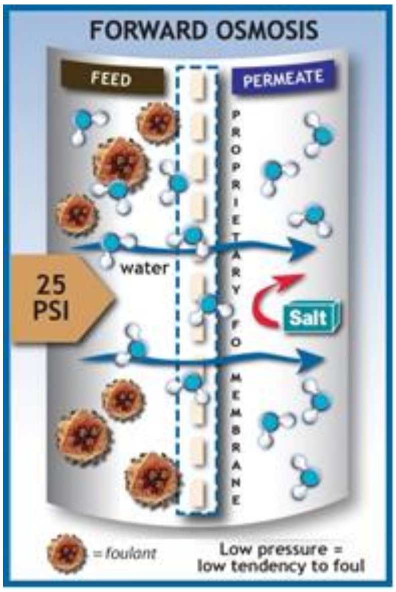

Figure 11. Forward osmosis process. (28)

In the example above, the permeate side of the membrane contains a salt solution which has a higher osmotic potential than the dirty feed water on the other side of membrane. Because of the higher concentration of the permeate side the water moves towards it (through the membrane) without dissolved solids. Forward osmosis operates at very low pressure (which lowers the tendency of fouling the membrane) leaving organics, minerals and other solids behind in the feed solution. (28, 29)

5.4 Freezing desalination

Desalination processes can be divided into two categories; processes that remove water from the salt and processes that removes salt from the water. The freezing method belongs to the first category. (30)

Freezing desalination is based on that salt waters have a certain critical temperature which is a function of its salinity. When salty water is reduced to this temperature a portion of it starts freezing which creates so called “ice crystals” into the water. These ice crystals are frozen fresh water and it is possible to mechanically separate them from the solution. Re-melting those separated “ice crystals” results fresh water. (30)

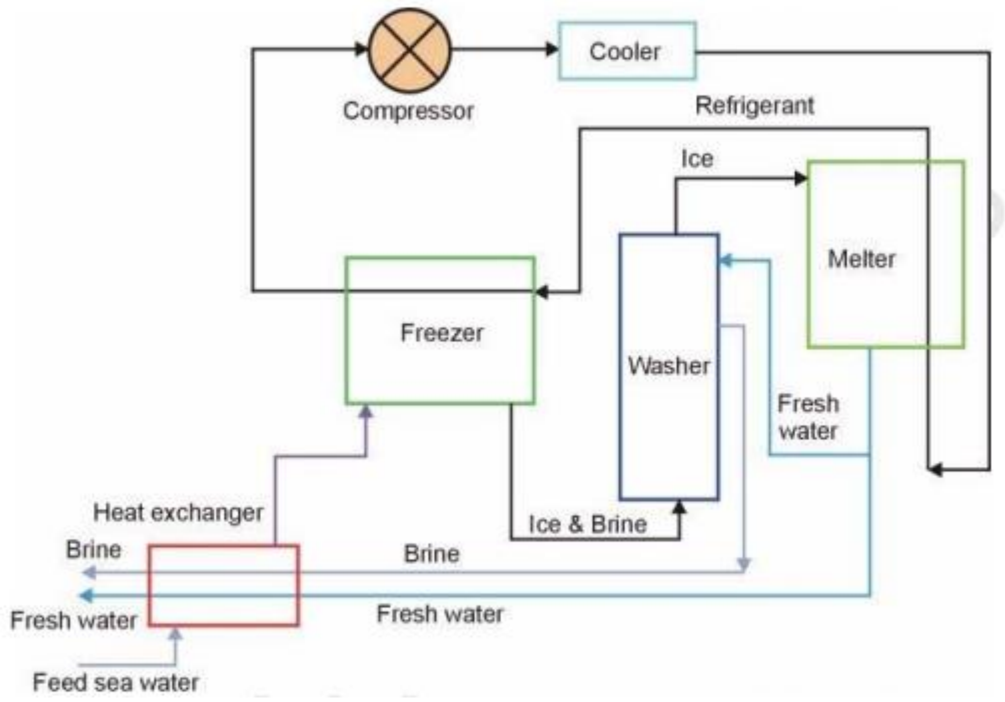

Figure 12. An Indirect freezing process (30)

In the indirect freezing process example above, the feedwater is pumped through a heat exchanger (reduces feed temperature) to freezer. In the freezer the feedwaters temperature is reduced to its critical temperature, where ice crystals composed of fresh water are formed. Crystalized water is routed to washer section, where salt water and ice crystals are separated mechanically. After the separation, ice crystals are led to the melter where the ice melted to fresh water. Melter uses the heat released from condensation of the compressed refrigerant. A small portion of Fresh water is led back to washer to wash the ice crystals. Rest of the fresh water and the saline water from washer are routed through the heat exchanger (and used as a pre-cooler for incoming feedwater) before discharging from the system. (30, 31)

In freezing desalination processes have a number of advantages. It is very energy efficient and needs almost no pretreatment. In theory, freezing 1kg of water requires about 80kcal and evaporation for the same amount of water requires approximately 600kcal. Scaling and corrosion are greatly reduced because of the low temperatures. Corrosion of steel pipes and removing the scale formed inside of the pipes requires costly maintenance. To prevent even more corrosion, lower temperatures also allow the use of plastics and protective coatings on the pipes. Freezing process is also very permissive to changes in the concentration or type of substances in feedwater. (30, 31)

Environmental impacts are the biggest issue to freezing desalination. It releases large quantities of highly concentrated brine water, as well as carbon and other gases to the environment. To reduce the environmental impact some of the brine water can be handled and returned to the sea (if the location is selected carefully). (31)

5.5 Renewable energy desalination

5.5.1 Geothermal desalination

The first usages of geothermal energy for electric power production have been made a century ago in Italy by a commercial power plant. (38)

Geothermal desalination method is still under developments, but it is claimed benefits are that it requires less maintenance than reverse osmosis membranes and main energy source (geothermal heat) creates an environmental advantage on CO_2 emissions by at least 50% compared to fossil fuel fired boilers. It is shown that in a certain places and a certain depths the temperature stays relatively constant through the year, which means there is no need for thermal storage. (37, 38)

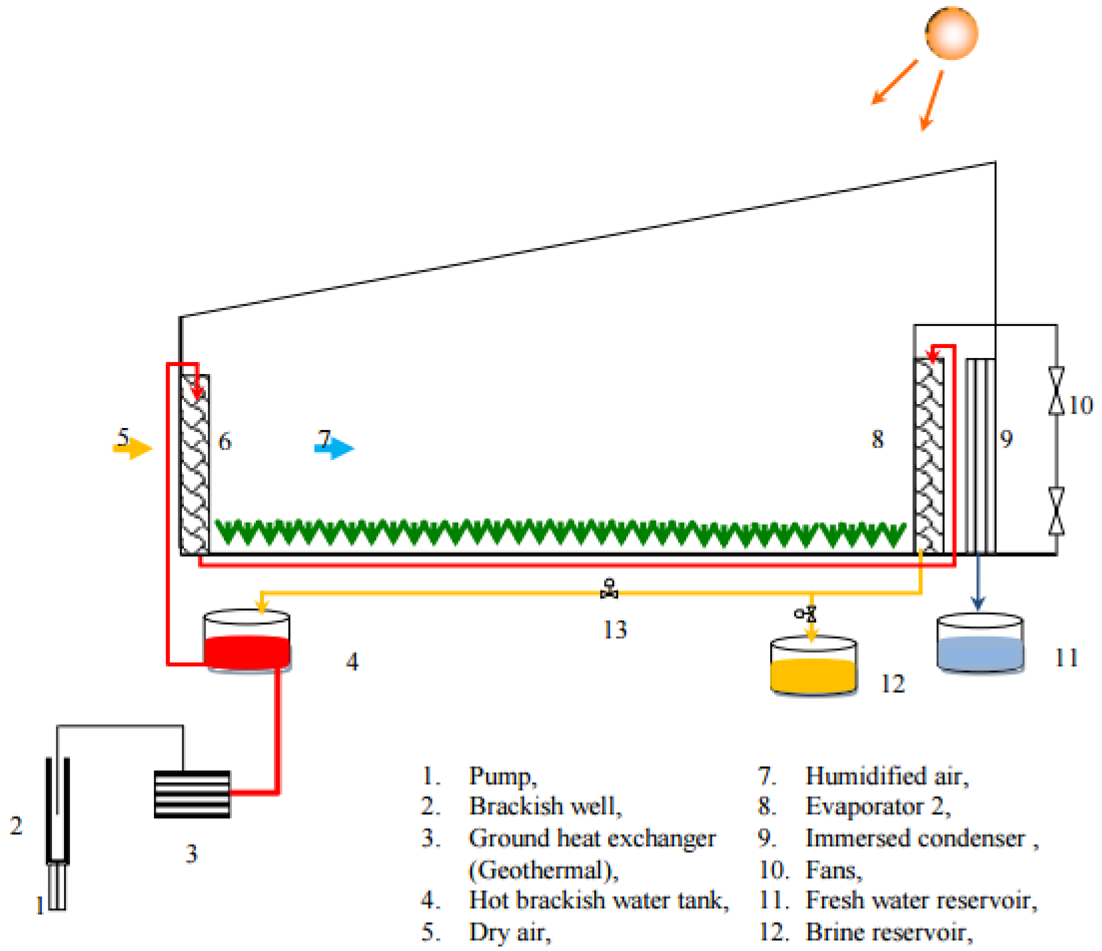

Figure 13. Process schematic of geothermal energy coupled to water greenhouse. (38)

The first this kind of seawater greenhouse was built and tested in 1992 (Tenerife). The results were promising, but it damaged and closed down due the excessive use of ground water. Other pilot processes have been built and they are still under research and development. (38)

5.6 Summary

Common factor to all desalination techniques is that they all aim to ensure that the produced water is pure and the most energy efficient.

Distillation is the oldest desalination method, and it is still one of the most commonly used techniques. The first land-based plant was built in 1928 (Curacao, Netherlands Antilles). Plant was processed by a multiple-effect distillation (60m^3/day). (39)

The most energy efficient techniques are made by using renewable energy sources, but those techniques are still more or less under research. That might be the reason why renewable energies have not already completely displaced the others. Nowadays the most commonly used desalination method is reverse osmosis; although, the multi-stage flashing produces the largest amount of desalinated water (about 42% of all desalinated water). (40)

6 Optimizing awareness by using social media

The internet has started a new era of technology that connects people to each other in short order. Due to the enormous size of the Internet it is very difficult to understand its potential completely.

Social media gives everyone – not only b2b companies – a great possibility to get people's attention and engage them in many different ways. Due to social media it is possible to earn attention by creating something interesting or valuable and publish it online for free. Social media is the one that allows everyone to communicate with everyone. There are many categories of social media, for example, forums and message boards, reviews and opinion sites, social networks, blogging, microblogging, bookmarking, media sharing. To make awareness as effective as possible, it is very important to choose which kind of categories to use. Success in social media is not found in how many people got your message; it is found how many people thought your message was remarkable. (6)

6.1 Targets and goals

It's very important to know your target groups and then choose which social media networks to focus on. Focusing is recommended to where your target groups are spending their time. If they are most likely everywhere, then all the top social networks (for example: Facebook, Twitter, Instagram, LinkedIn and YouTube) should be used. If your customers are using Facebook and you are using only Instagram, it is impossible to communicate with them. (6, 9)

We all have a limited time and if you do not have unlimited resources to keep up multiple social media accounts you may want to make sure that you are prioritizing in those social networks that really matters. It is important to have some sort of presence on every main network where your targets might be to at least give them a chance to get in touch with you. (6, 9)

When all the target groups and networks are decided, it is time to set goals. There is a lot of different goal setting strategies, but it is recommended to have something measurable and realistic. One of the most common goal strategies is called BSQ (think Big – act Small – move Quick). (10)

Table 1. Example of BSQ strategy (10)

Think Big	Act Small	Move Quick
Open a successful restaurant within one year	Develop business strategy	By June
	Decide on business name	By July
	Obtain financing	By August
	Finalize restaurant location and sign lease	By September
	Begin interior remodel and construction	By September
	Hire lead Chef	October
	Develop menu	By end of the year
	Hire and train staff	January– February
	Grand Opening	March 15 at 6 p.m.

6.2 Reaching people

When creating profiles to social networks it is important to choose username that is easily recognizable, uploading a recognizable photo (like a company logo), including clear and illustrative descriptions of you or your business. (9)

The best way to reach people is to make content shareable and worth of their attention. If people like the content and think it is remarkable, they might share it to their friends and in the best case it causes a snowball effect. To reach the same people again as easy as possible, it is important to engage them somehow - like following or subscribing a newsletter. The more followers you have, the more people you reach in the baseline. (6)

Toughest thing in social media is to create the best possible content. There are a lot of tips for that (pictures, writing styles, perspective, for example), but all the people are individuals, so it's nearly impossible to say what is the best way. (9)

To enhance the visibility it is important to know your best posting times. That means the time when most of your target audience is usually surfing in social media. Of course it is worth to support other times too to get as wide visibility as possible. (9)

6.3 Feedback

Reaching a large amount of people is not everything. Success in social media is more about people thoughts about your publication. For example, it is better if the message gets one reader who think it is truly remarkable than to have ten readers, but no one really cares about it. Feedback and to interact with people are key factors in all social media networks. (6, 32)

Listening feedback gives valuable information about your content, products, changes etc. It tells what should be done differently and what should be done the same way. (33)

7 Summary and outlook

Clean water is vital for people; thus, if no other new ways of producing are discovered, desalination is indispensable.

At the moment, the main problems in the current techniques are environmental impacts and expenses. The environmental impacts are mostly caused by energy production (fossil fuels) and from by-products which are released to the sea.

The operation expenses of different desalination techniques and a significant environmental impact from fossil fuels make the use of renewable energy sources universally interesting. Those renewable energy producing ways have already been developed and tested in a number of ways.

There are also some desalination techniques that do not release the by-products back to the ocean. Usually these ways are combinations of evaporation ponds, solar stills and condensation trap which does not use chemicals, any burning of fossil fuels, membranes or any components that include heavy metals.

Views are changing to have more green solutions by the governments and municipalities. A number of State governments have, therefore, proposed methods by which they plan to address the greenhouse implications of any desalination plants they build. (42)

A lot of helping projects around the world have been done and more is coming. Just to name a few, water.org supports people in 14 different countries around the world, for example, they helped more than 40 communities in Honduras to build their own safe water systems. USAID have brought safe water and sanitation to more than 50 million people, while assisting governments and private firms to plan, manage and distribute water more equitably and affordably. Watertrust.org has completed over 300 projects in Africa on building water sources, teaching mechanical skills and training sanitation and hygiene knowledge. (43, 44, 45, 46)

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