



Desalination in the Context of Water Scarcity Crisis: Dares & Perspectives

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Abstract

Throughout the world, providing drinking water via desalination engineering becomes a more and more adopted option. With quickly progressing desalination engineering and market maturation, desalination prices are fast dropping, and the ecological effects of desalination are steadily relieved. Even if desalination is probably to stay more costly in nearly all areas than conventional water provision solutions, it could turn into progressively a solution to satisfy inevitable deficiencies for particular markets. Consequently, desalination has to be employed strategically inside a combined water-planning program. This work discusses desalination as a practicable option to reduce a water provision-need vacuum and its techniques and features. Ecological duties should force a huge extension of used water gathering and handling; further, increasing water shortage and prices could render used water reuse growingly a profitable solution. Nontraditional solutions like wastewater reuse and desalination have to be considered jointly to deal with water shortage. Improving adopted technologies and increasing allocated funds to these future and indispensable nontraditional solutions remain unavoidable. Secured technologies like membrane processes should be largely applied throughout the world to secure potable water for all humankind.

Subject Areas

Chemical Engineering & Technology

Keywords

Desalination, Seawater (SW), Brackish Water (BW), Thermal Desalination, Membrane Desalination, Water Provision-Need Vacuum

1. Introduction

Around three-quarters of the worldwide inhabitants stay below water shortage [1] [2] [3]. In several regions, withdrawals really surpass the employable water, deteriorating the reservoir. In fact, a general “mining” of nonrenewable groundwater exists. Most of the earth’s aquifers become in danger [4]. Contaminating watercourses has damaged the quality and rendered them no longer available for use [1] [5].

As a matter of demand, demographic stresses and increasing degrees of usage worsen shortage [1]. In term of supply, pressures are as well getting larger with lower accessibility since precipitation patterns vary, moreover, warming augments evaporation and demand [6] [7] [8]. Lack of adequate water delivery seriously influences populous regions especially if water supply is limited [9] [10] [11].

In fact, many solutions, conventional and nontraditional, to decrease the water provision-need vacuum exist [1]. Such options deal with the sides of handling water for fair use and ecological preservation [12]. Those strategies precisely handle lack by means of improved performance and engineering (comprising usage of desalination) and via safeguard of the resource’s standard and volume [13] [14].

The simplest option remains to let performance ameliorations in cultivation and manufacture [15] [16] [17]. For several nations, the nearly all inexpensive options stay in cultivation [18] [19] [20]. Additional options are more and more suggested via integrating enhanced efficacy of water supply and utilization [1] [21] [22] [23] [24] [25].

Even with constant ameliorations in water treatment, at the actual speed of turn, many efforts remain to be accomplished. Several nations suffering water shortage have started applying procedures to handle supply and demand, and in some situations, have reached noteworthy positive result. Nevertheless, the proportion of advance generally remains comparatively lazy [1].

Solutions focusing on provision stay restricted; further solutions confront ascendant prices. Chances for exploiting the lasting natural waters that could be sustainably and economically developed remain restricted [26] [27]. Solutions concentrating on infrastructure ameliorations will reduce around 20% of the void separating provision and need [1]. Provision as well confronts dangers from global warming [28] [29]. Dropped precipitation and increasing temperatures could more decrease the reliable resource.

Under the present state, the water provision-need vacuum could not be reduced; further, water crisis coupled with ecological damage may aggravate [1].

Since stresses surpass, novel techniques will more and more add to the renewable resource [1]. Throughout the world, only around three-quarters of the freshwater taken away is consumed, and the remaining quarter is given back to nature in the form of used water. In fact, such used water constitutes a chance to augment water accessibility, especially if used water is well treated [30] [31] [32]. Ecological duties will progressively force a huge extension of gathering and pu-

rifying used water; moreover, increasing water shortage and prices could render used water reemployment growingly a profitable solution [33] [34] [35].

For particular markets and areas, desalination will stay the adopted technique [2] [13] [36]. With quickly progressing desalination engineering and market maturation, desalination prices are fast dropping, and the ecological effects of desalination are steadily relieved [14]. Even if there is more probability that desalination stays more costly than conventional water provision solutions, it can turn into progressively a solution to satisfy inevitable deficiencies for particular markets [14]. Consequently, desalination has to be employed strategically inside a combined water planning program [1] [14].

Combined water planning is obligatory to deal with such a water provision-need vacuum. What is learned from the worrying likelihood of an ever-increasing provision-need vacuum is that water stays a central section of a nation's strategy. In fact, organizing inside the water-employing sectors should be merged inside the total organization and the set of performance and supervision-amelioration actions needed must be supported and encouraged [1]. Otherwise, water quantities and prices must be taken into account for better organization.

Based mainly on the important solutions (desalination is one of them), upcoming water schemes could be suggested for a specific nation [1] [2] [13]. Employing an iterative process, nations could propose water scenarios from which to make a map of routes of development that equilibrate water provision and need. Such schemes can comprise the water need consequences. The water provision-need vacuum under each scheme could be determined. The solutions to reducing the void could therefore be defined and classified by price. At such a step, the range for nontraditional solutions like wastewater reuse and desalination will be estimated [2] [13] [14].

Planning procedures and the manner by which desalination is combined with them are well explained by researchers [1]. Such a type of combined organization is more than requested [2] [13] [14].

Desalination has to participate in decreasing the space between provision and need in the next decades [2] [13] [14]. Even if the plurality of the provision-need vacuum options stay arising from the conventional provision and need-side handling solutions mentioned above, researchers [1] focused on desalination as one of the workable choices. The cause for this is that deficiency is augmenting almost. Now, more than 150 nations are so soon employing desalination to satisfy specific parts of need [1].

The present work discusses desalination as a practicable choice to decrease a water provision-need vacuum and its techniques and features. Desalination costs are also reviewed. An outlook on the next trends is also given especially for technologies and prices. A comparison between desalination and water reuse is shortly presented. A brief discussion about some facts that nature comprises innate desalination engineering is briefly given. In the Middle East, thermal desalination plants are prevailing; however, such a situation is tending to be reversed in the benefit of membrane processes.

2. Desalination as a Workable Solution to Reduce a Water Provision-Need Vacuum

2.1. Desalination Elucidated

From salty water fountains, mostly seawater (SW) or brackish water (BW), desalination (also named “desalinization”) forms freshwater [1]. Nature provides numerous illustrations of desalination.

BW sources possess mostly local capacity; however, the prime raw material, SW, is relatively boundless. Desalinated water is generated from BW (salinity more than 500 mg/L and less than 30,000 mg/L) or from SW (salinity more than 30,000 mg/L and less than 44,000 mg/L). Desalination of BW provides chances to generate lower-cost water than SW desalination. Even if BW’s sources may be locally considerable, its capacity is restricted by obtainable amounts (the global volume of BW is less than 1% of the Earth’s water). Moreover, the oceans hold around 97% of the Earth’s water reservoirs and so give a boundless raw material [1].

2.2. Secured Water Provision Solution: Desalination

Comparatively to different water provision technologies, desalination remains more expensive. Further, it requires a judicious application. Such technique could generate high-quality drinking water that equips the demands of huge cities [1] [37].

Pushed by increasing need and engineering progresses, desalination price dropped quickly during the last twenty years. However, the direction toward bigger plants has brought very important economies of scale. Consequently, desalination prices have downed from a usual domain of US\$ 2.50/m³ to US\$ 4.00/m³ in the 1980s to prices that presently average less than US\$ 1.50/m³ [1].

Consequently, desalination is beginning to be a more and more reasonably priced solution for over 150 countries that employ this technique to generate freshwater. Two years ago, around 20,000 desalination facilities were working worldwide, generating 90 million cubic meters per day of treated water each day (for around 300 million people). In fact, water treated by desalination actually constitutes almost 1% of the globe’s potable water [1] [38].

In spite of that, prices remain generally bigger than alternatives; this is why desalination in most cases stays a strategic solution. Even if the prices of desalination have decreased speedily (**Figure 1**), they stay nearly constantly bigger relatively to the prices of treating surface water or groundwater [1]. **Figure 1** shows an acute decrease in price of desalination since the 1960s. Such technology may be adopted as a feasible choice to close the water provision-need vacuum.

3. Desalination Techniques and Their Features

As a rule, in terms of engineering classes, desalination may be realized via thermal process or membrane process for removing salts from water [1]. In fact,

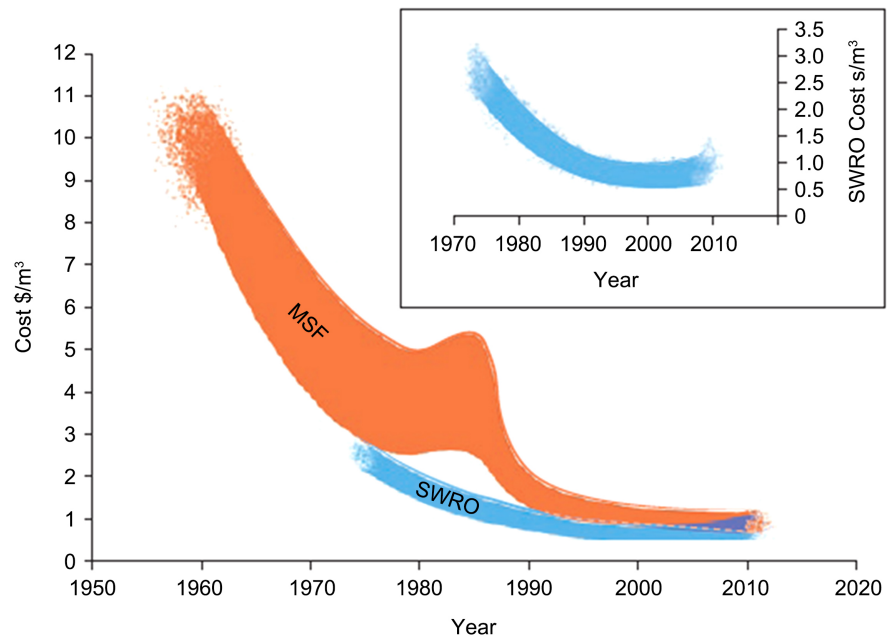


Figure 1. Price tendencies for Seawater Reverse Osmosis (SWRO) and Multistage Flash Distillation (MSF) techniques [37].

numerous desalination techniques are below investigation and numerous methods are in the expansion phase (however, the only two that are presently commercially applicable and largely employed remain evaporation and membrane separation processes). Before twenty years, water was mostly desalinated throughout the world by thermal evaporation. Nonetheless, lately, engineering's ameliorations in RO desalination reached a fast elevation in the number of factories employing membrane method. Indeed, membrane technology represents 65% of the desalination capacity through the globe, while thermal technology attracts the remaining part (additional techniques like electrodialysis reversal (EDR) and vapor-compression (VC) distillation drive a low fraction of the market) [1].

3.1. Desalination via Thermal Heating

Desalination employing heating (boiling, evaporating, and condensing) is the earliest technique utilized for removing salts from water on an industrial scale. In terms of fundamental idea, it concerns exerting heat to form vapor from water. Such vapor is condensed into clean water, salts and pollutants are removed. In matter of thermal processes configurations, Multistage Flash Distillation (MSF) and Multiple Effect Distillation (MED) remain the most frequently utilized thermal techniques [1] [13].

3.1.1. Multistage Flash Distillation (MSF)

Among desalination techniques, MSF remains the most durable. In addition, it stays the most efficient and dealing with huge production capabilities. MSF method comprises a set of steps or cells kept at reducing pressures starting from the

first step (hot) to the last one (cold). As shown in **Figure 2**, SW flows in on the right side via tubes in the upper part of the chambers where it is warmed by the water vapor formed in each stage.

More details that are technical may be found elsewhere [1].

3.1.2. Multiple Effect Distillation (MED)

Identically to MSF, MED functions like a phenomenon founded on evaporation. The saline water passes via a set of chambers. Each successive chamber runs at a gradually lower pressure. During the MED method, the vapor produced in one chamber condenses in the following chamber with the heat-liberated working as a heating source. Further, feed water is generally sprayed over the tube bundle at the top of each chamber (the dark blue track in **Figure 3**).

Descriptions that are more technical may be found elsewhere [1].

3.1.3. Multiple Effect Distillation (MED) with Thermal Vapor Compressor (TVC)

Increasing Multiple Effect Distillation (MED) performance could be elevated by introducing a vapor compressor. Indeed, a Thermal Vapor Compressor (TVC) could be combined with a MED setup to extract part of the steam produced in the final chamber for reuse. The extracted steam will be combined with the external steam for compression below high pressure, which then functions as a heating source in the first chamber. Since such amelioration could lead to considerable energy cost savings, MED-TVC appears as the most broadly utilized MED technique contemporarily [1].

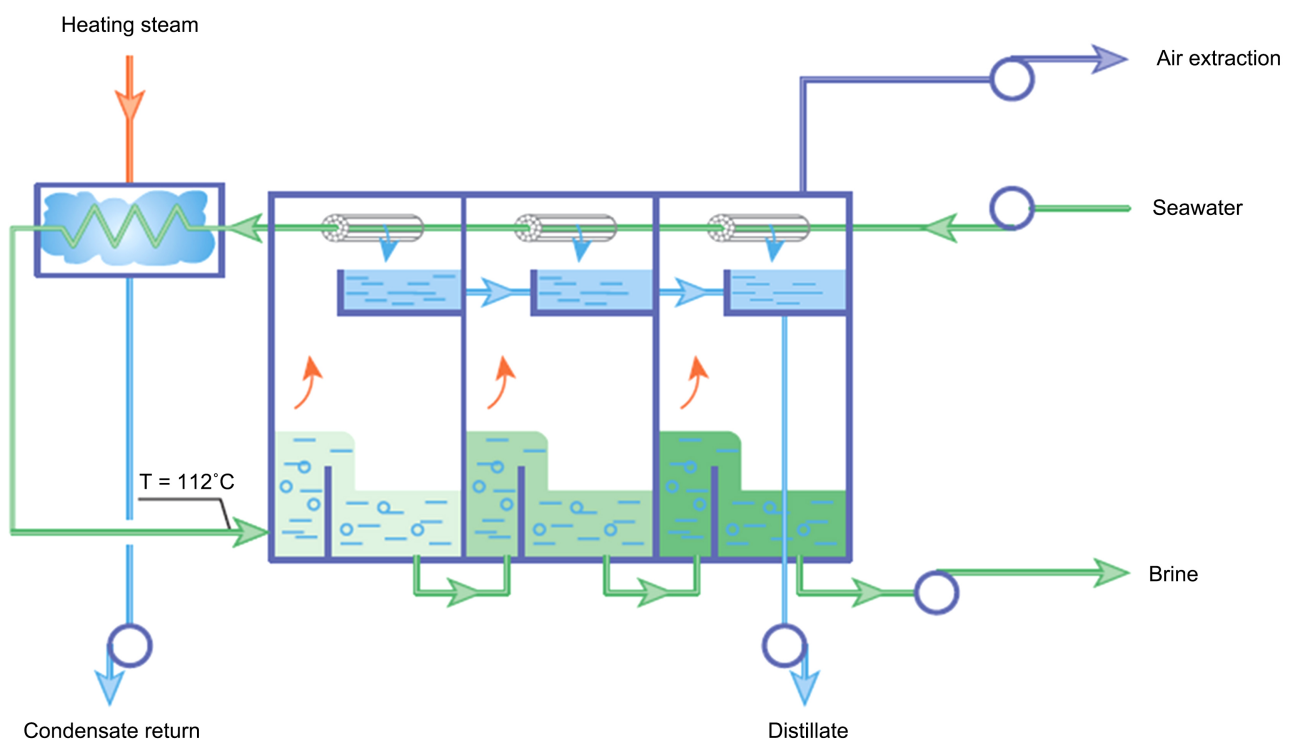


Figure 2. Global scheme of a Multistage Flash Distillation (MSF) facility [1].

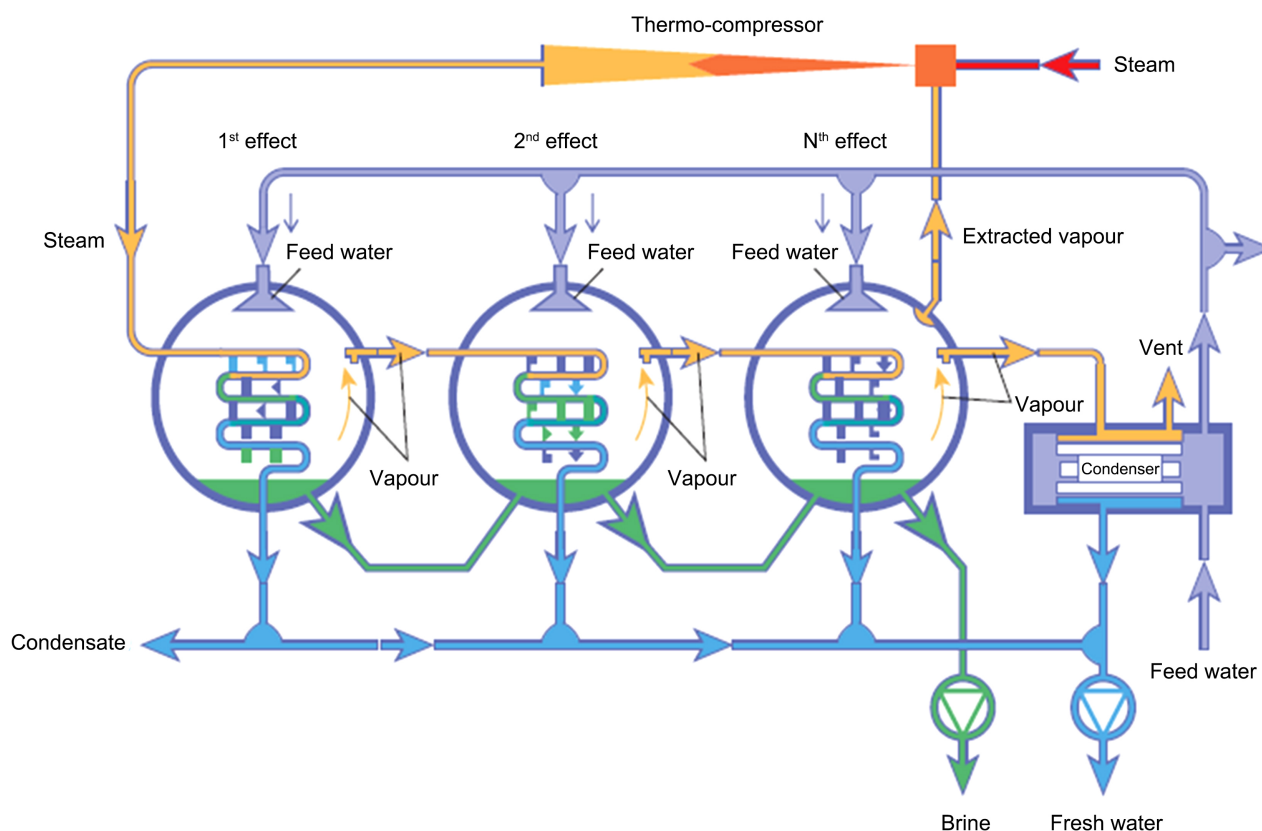


Figure 3. Illustration of Multiple Effect Distillation (MED) desalination technique [1].

3.2. Membrane Desalination

Membrane techniques adopt the natural phenomenon of osmosis. In fact, membranes have a crucial contribution in separating salts in natural phenomena like osmosis and dialysis. Such a concept has been adopted for industrial usage in water treatment via developing membranes that selectively let or block salts diffusion. Industrially obtainable membrane methods comprise reverse osmosis (RO), nanofiltration (NF), electrodialysis (ED), and EDR. RO is presently the only membrane technique utilized. The remaining membrane techniques are not widely applied at the industrial level. In fact, NF and RO use pressure; however, ED and EDR employ electrical current for removing salt [1].

RO remains a frequently employed technique for treating water. It uses a semipermeable membrane to eliminate mainly ions, molecules, and bigger particles [39]. During RO passage, an implemented pressure is utilized to beat osmotic pressure, which is due to chemical potential dissimilarities of water [40]. As an example, in the case of SW (*i.e.*, salinity of 35,000 mg/L) on one part of the membrane and potable water (*i.e.*, salinity of 500 mg/L) on the remaining part of the membrane, the osmotic pressure formed on the membrane is around 24 bars [1].

RO could retain several sorts of solubilized and suspended chemical substances as well as biological ones (mostly microbe) from water [39] [40]. This is

why it is utilized in desalinating and treatment water fields. The solute is kept on the pressurized part of the membrane and the pure water is left to go to the other part. Such membrane must not permit big molecules to pass across the pores; however, it has to authorize smaller water molecules to go readily [1].

As illustrated in **Figure 4**, the feed water is pumped below great pressure across a semipermeable membrane to retain concentrate (or brine [41]) from purified water [1] [39] [40].

Since its name implicates, the RO process is adverse to what takes place in osmosis. A pressure bigger than the osmotic pressure is implemented to saline water. As a result, freshwater flows over the membranes and salts are retained. An elevated-pressure pump pushes saline water at around 65 - 75 times the atmospheric pressure towards semipermeable membranes. The membranes are developed to authorize H_2O molecules to go across them whilst keeping solubilized salts. The RO technique could be utilized both for Seawater Reverse Osmosis (SWRO) desalination and for desalination of BW (brackish water reverse osmosis, BWRO). Usually, 40% - 60% of the SW introduced into a membrane process is recuperated as purified water. For BW desalination, water recuperation could fluctuate from 50% to 90% [1] [39] [40].

Seeing that RO membranes could be blocked readily by dispersed matters and mineral scaling substances, RO devices need particular equipment not employed in thermal desalination devices to prepare the source SW [21] [41] [42]. Further, purified water after that goes through additional stage (known as post-treatment, mostly composed of pH adjustment and disinfection [43] [44] [45]), to render it appropriate for human consumption [1] [40] [46].

Membrane techniques may as well be utilized for treating wastewater [1] [47] [48]. Indeed, membrane processes could be employed not only for removing salts from BW or SW supplies but also for dealing with used water thanks to their potential to as well retain pollutants other than salts (e.g., organic pollutants [49] [50] [51], microalgae [52] [53] [54], bacteria [55] [56] [57], and viruses [58] [59] [60]).

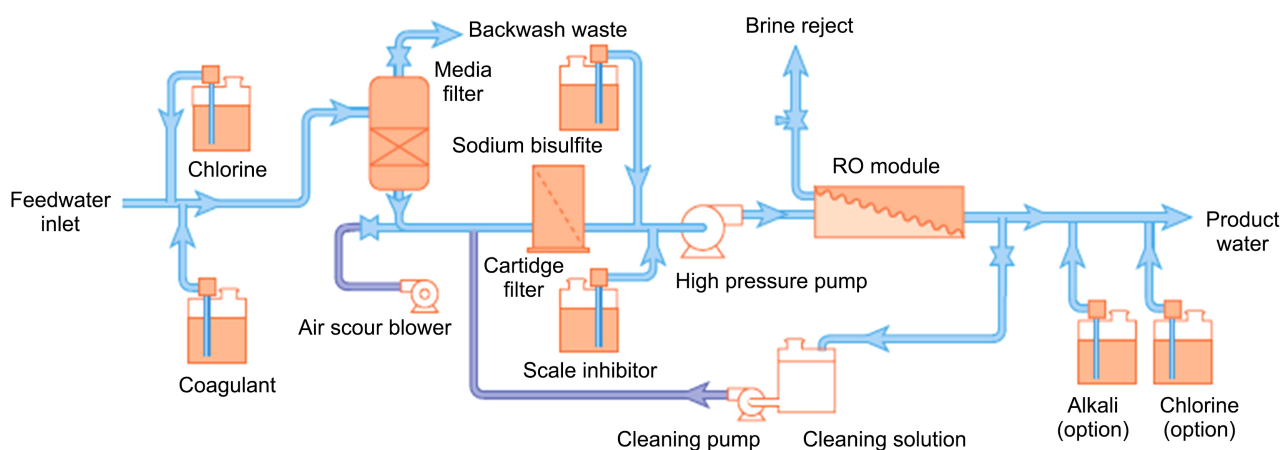


Figure 4. Illustration of the Reverse Osmosis (RO) desalination technique [1].

3.3. Combined Processes

Combined desalination plants mix thermal desalination facility (either MSF or MED) and an SWRO desalination setup. The merged thermal and SWRO plants are usually co-located with a power generation station; further, they share a joint intake and outfall. Hybrids are mostly adopted if there is a large change in power or water demand need diurnally or between seasons. This permits the combined plant to benefit from cheap energy when it is accessible; however, to satisfy needed degrees of water production via switching between SWRO and thermal technology following which system provides the cheapest product at the time. Since such a strategy needs accurate planning for the equilibrating of water and power supply and need at the least cost, it is commonly unsuitable for “retrofitting” onto present power production facilities. Frequently, hybrids constitute part of a novel build merged water and power generation complex expanded as an “independent water and power project” [1].

3.4. Expansion Patterns of the Frequently Employed Desalination Techniques

SWRO has surpassed thermal method. Now it constitutes two-thirds of used capacity throughout the world. Until 2000's, thermal technology (especially MSF) was the most frequently employed technique. Employing SWRO technology has speeded up during the ultimate twenty years thanks to its lower energy usage and progresses in applied techniques (especially membrane processes and pre-treatment method) [41] that have rendered it very ruthless, even in the highly saline SWs in which thermal technologies were previously more ruthless. Six years ago, the SWRO technique constituted almost 63% of the global desalination capacity (Figure 5), pursued by MSF (23%) and MED (8%). ED, hybrids, and other technologies took the remaining 6% desalination capacity [1] [61].

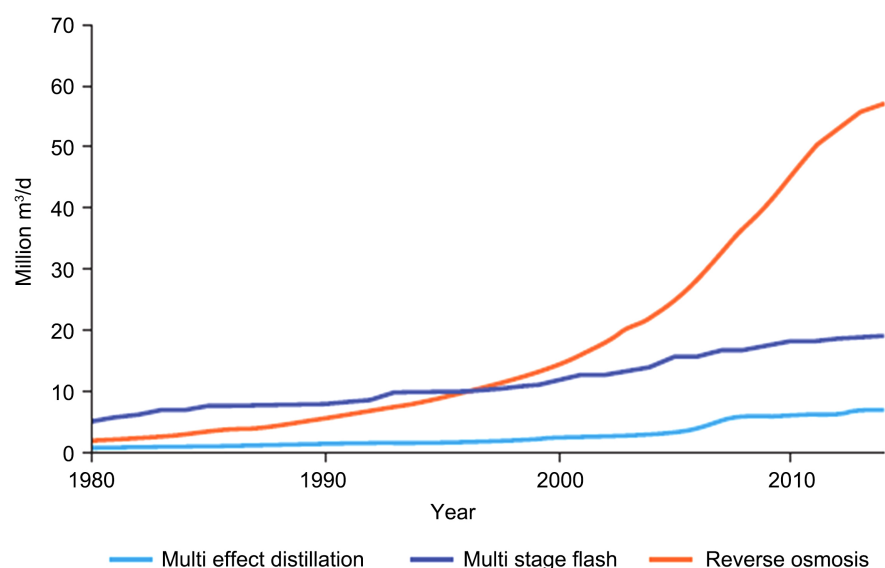


Figure 5. Global cumulative capacity of SW desalination by technology, 1980-2014 [1].

4. Desalination Prices

As a rule, overall costs have been quickly decreasing. Indeed, new usual prices of water treatment depict large decreases for MSF and MED, but in particular, for SWRO that is presently knowing costs around US\$ 0.64/m³. Researchers [1] formed a database including more than fifty desalination projects throughout the globe built during the previous twenty years (Table 1). As an illustration, Table 1 presents the real prices of desalination following method and feed water reservoir for SWRO factories [1].

5. Future Trends

5.1. Nature Includes Innate Desalination Engineering

As the main part of the water cycle, evaporating water over the oceans and seas stays the most evident natural phenomenon for removing salts from water (Figure 6) [1] [13] [62]. More details about the simulation of the open sky SW distillation may found elsewhere [13].

One more phenomenon remains the generation of sea ice. Such phenomenon forms ice with a little salt that is much lower than that in SW [1]. Desalination takes also place in the plant world (Figure 7) [63]. Indeed, mangrove trees grow in SW, liberating the salt in their roots and leaves. Further, willow trees and reeds absorb salt and additional pollutants, successfully removing salt from water. Such a natural desalination phenomenon is exploited in industrially constructed wetlands for dealing with urban used water [1].

Astonishingly, the animal world could as well desalinate. Seabirds like pelicans, petrels, albatrosses, gulls, and terns distill SW utilizing a gland that liberates highly concentrated brine near the nostrils above the beak. The bird then “sneezes” the brine out. This lets birds to drink salty water from the ocean while they are far from land [1].

Table 1. Summary of worldwide SW desalination prices (Costs are at 2016 estimates. MED-TVC = Multiple Effect Distillation with Thermal Vapor Compression; MLD = million liters per day; MSF = Multistage Flash Distillation; O&M = Operation and Maintenance; SWRO = Seawater Reverse Osmosis) [1].

Desalination technology	Capital costs (million US\$/MLD)		O&M costs (US\$/m³)		Cost of water production (US\$/m³)		
	Range	Average	Range	Average	Range	Average	
MSF	1.7 - 3.1	2.1	0.22 - 0.30	0.26	1.02 - 1.74	1.44	
MED-TVC	1.2 - 2.3	1.4	0.11 - 0.25	0.14	1.12 - 1.50	1.39	
SWRO (Mediterranean Sea)	0.8 - 2.2	1.2	0.25 - 0.74	0.35	0.64 - 1.62	0.98	
SWRO (Arabian Gulf)	1.2 - 1.8	1.5	0.36 - 1.01	0.64	0.96 - 1.92	1.35	
SWRO (Red Sea)	1.2 - 2.3	1.5	0.41 - 0.96	0.51	1.14 - 1.70	1.38	
SWRO (Atlantic and Pacific Oceans)	1.3 - 7.6	4.1	0.17 - 0.41	0.21	0.88 - 2.86	1.82	
Hybrid	MSF/MED	1.5 - 2.2	1.8	0.14 - 0.25	0.23	0.95 - 1.37	1.15
	SWRO	1.2 - 2.4	1.3	0.29 - 0.44	0.35	0.85 - 1.12	1.03

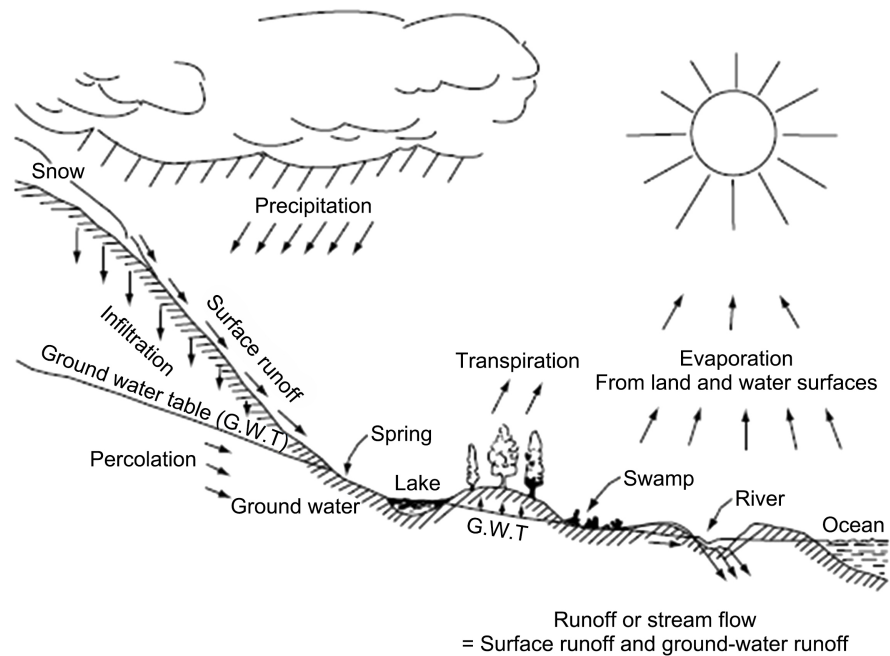


Figure 6. The hydrologic cycle [62].



Figure 7. Salt crystals on Black Mangrove [63].

5.2. Prevailing Thermal Desalination Plants in the Middle East: Towards Its Reversal in the Benefit of Membrane Processes

Thermal techniques are utilized everywhere in the Middle East [1]. It is possible that such technologies will persist to be famous in the area for numerous causes. The regional seas are highly saline and warm, and periodically have elevated levels of organic matter, which are hard conditions for membrane desalination engineering. Further, thermal techniques could employ low-temperature waste steam from power production turbines; consequently, colocation of desalination and power production for considerable efficiency savings, profiting from shared intake and discharge structures as well as increasing energy efficiencies (mostly

by 15%). Such causes, merged with the low-cost energy in the region, render thermal techniques a more interesting desalination technique in such a region than in most other areas. Moreover, membrane plants have only lately attained the huge generation capabilities requested in such an area.

However, such a tendency may be reversed towards membrane techniques due to global warming gases, as thermal desalination employs oils to get energy at least it will use solar energy [64] [65].

5.3. Outlooks for Technologies and Prices

Desalination engineering has ameliorated, and prices persist to down greatly [1]. From 1980 to 2005, the price of desalination dropped by more than half (**Figure 8**). Even if desalination stays costly juxtaposed to traditional water treatment techniques, more decreases in prices are possibly to close the space more in the next twenty years. Such progresses are most probably to be in desalination engineering, in pretreatment [66] [67] [68], in brine management [14] [46], and in energy efficiency and sourcing [2] [29] [36].

Additional huge price discounts are predictable, especially for SWRO, in which prices are awaited to more drop by up to two-thirds during the following twenty years thanks to technological ameliorations in membrane design and system integration [1].

5.3.1. Progresses in Traditional Desalination Methods

While only comparatively restricted additional amelioration in thermal techniques is anticipated, elevating performance in fundamental price elements will persist to render SWRO more competitive. Among such cost-decreasing ingredients has been the amelioration in membrane productivity that has doubled during the last two decades. Ameliorations are continuing apace, as freshly expanded membrane elements give flexibility and choice and allow trade-offs

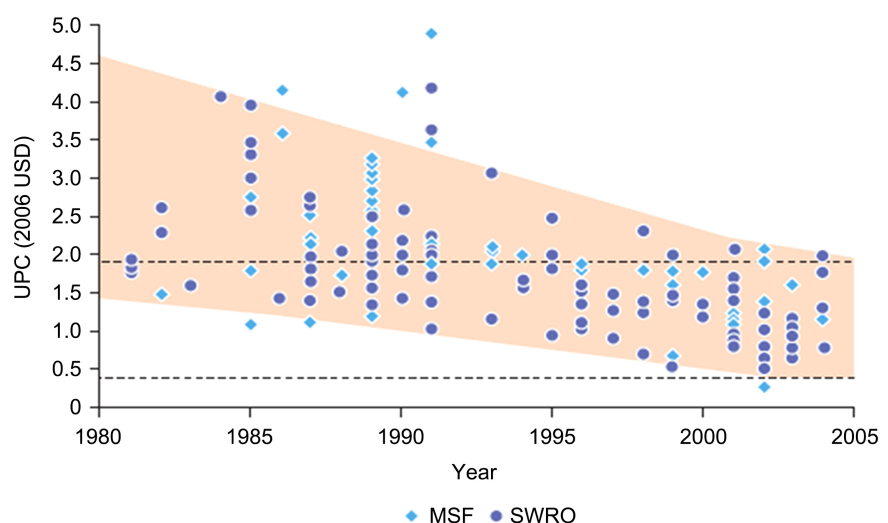


Figure 8. Trends in the cost of desalination of Multistage Flash (MSF) distillation and Seawater Reverse Osmosis (SWRO) plants [1].

among productivity and energy prices. In fact, such ameliorations in membrane performance rather than in energy recovery that are anticipated to support the position of SWRO as the most cost-competitive process in most circumstances [1].

5.3.2. Arising Technical Progress with Elevated Desalination Price Lowering Possibility

In addition to the technical ameliorations previously anticipated under frequently utilized desalination techniques, several fresh methods or adaptations are arising, which could provide the potential for even bigger productivity and lower prices (**Table 2**).

Table 2. New techniques or readjustments apt for giving the possibility for bigger productivity and lower prices [1].

Fresh method or readjustment	Description
<i>Nanostructured membranes</i>	Such membranes possess until 20% bigger productivity than traditional ones, or they could function at the identical productivity but employ until 15% less energy.
<i>Carbon nanotubes</i>	If carbon nanotubes with much bigger productivity could be suggested, then this may slash desalination prices to the level of traditional water treatment techniques during ten years.
<i>Forward osmosis (FO)</i>	Such type of osmosis, presently utilized mostly for industrial wastewater treatment, is being expanded for drinking water, with the capacity to decrease energy use until one-third.
<i>Membrane distillation (MD)</i>	Such version of distillation technology can mainly double the recovery ratio from SW (from 45% - 50% to 80%).
<i>Dewvaporation</i>	<i>Dewvaporation</i> , a low-temperature, low-price evaporation technique at an early step of expansion, can diminish the prices of thermal evaporation until one-quarter, especially in hot, dry regions.
<i>Adsorption techniques</i>	Such methods could decrease scaling and corrosion in thermal plants, even if the techniques remain costly.
<i>Electrochemical desalination</i>	Electrochemical desalination can considerably decrease prices until 15% via more efficacious energy usage.
<i>Capacitive deionization (CDI)</i>	CDI can bring priced is counts until one-third if the numerous technique dares could be beat to render it a main stream solution.
<i>Biomimetic membranes with aquaporin structures</i>	These membranes, which are membranes modeled on those of living organisms, can furnish the ultimate breakthrough in low-energy desalination. Intensive research is undertaken; however, it stays in the early steps.

The possible influence of technology expansion is spectacular and can cut SWRO prices by half or more in the next decade. Present tendencies in the depression of the desalination price, and the augmenting prices of the alternatives, are possible to persist, and it is not unlikely that cost decreases of 20% during 5 years will be encountered for SWRO and 60% in 20 years [1] [70].

6. Desalination vs. Water Reuse

Researchers [69] confronted the cost of water reuse to the cost of SW desalination. With a view to treating water of equivalent quality, an RO stage was introduced to the process flow diagrams shown in **Figure 9** [16] [69]. In this situation, RO is required to eliminate dissolved organic carbon and residual nutrients like nitrate [16] [69]. For desalination, it was supposed that surface SW (TDS of 35,000 mg/L) was pretreated via coagulation and multi-media filtration before RO. The process flow diagrams are illustrated in **Figure 10** and the parameters employed for the two techniques are confronted in **Table 3**.

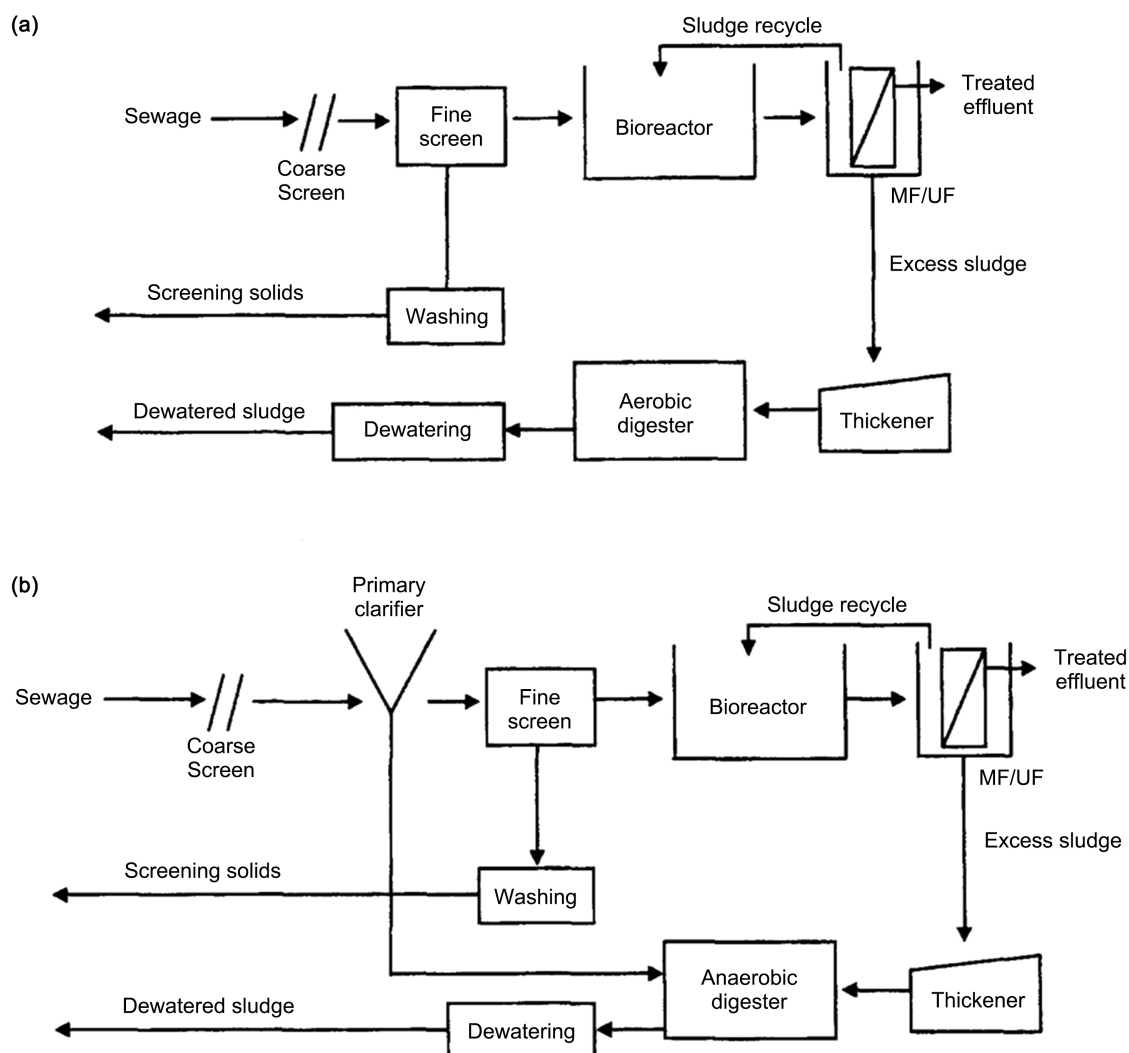


Figure 9. Process flow diagram for the membrane bioreactor option (MBR): (a) small plants; (b) large plants [69].

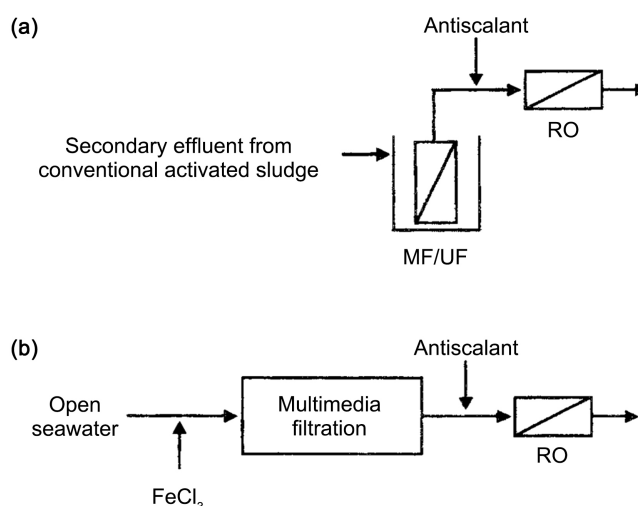


Figure 10. Process flow diagrams for comparison of water reuse and SW desalination: (a) water reuse; (b) SW desalination [69].

Table 3. Design process parameters for the RO facilities (MBR = Membrane Bioreactor, CAS-TF effluent = Conventional Activated Sludge + Tertiary Membrane Filtration) [69].

Unit process	Parameter	Water reuse (WR)	Desalination
Coagulation	FeCl ₃ dose, mg/L	No	5
Pretreatment		MBR or CAS-TF effluent	Multimedia filtration
Reverse osmosis (RO)	Anti-scalant addition		
	Dose, mg/L	2	5
	Stages, number	2	2
	Recovery, %	75	50
	Flux, L/m ² /h	20	13
	Feed pressure, bar (psi)	13.6 (200)	68 (1000)

The total costs evaluated for treating RO water from secondary effluent and from SW are confronted in **Table 4** for 38,000 m³/d facilities. The costs in column A do not comprise the cost linked to conventional activated sludge (CAS) since it was supposed that sewage would be treated to that degree for discharge; for simplicity, the cost for tertiary filtration assessed previously were employed as pretreatment cost for RO. It was hypothesized that the concentrate from both plants may be disposed of at no cost [16] [69].

The capital costs for a factory treating water from SW are around 50% more elevated than the costs of a factory reusing secondary sewage. Both the pretreatment costs and RO costs are more elevated. In the situation of pretreatment, this is attributed to the void in recuperation (75% for secondary effluent; 50% for SW), which conducts to a bigger SW setup. The capital cost for the SWRO process is bigger than for the secondary effluent RO since it is working at a much more important pressure, lower permeate flux, lower recovery, and should be constituted of materials that resist corrosion in SW [69].

Table 4. Costs of treating water from secondary effluent and from SW for a 38,000 m³/d factory [69].

Component	A: from CAS effluent	B: from SW	Ratio (B/A)
Capital costs, \$/m ³ /d			
Pretreatment	161	238	1.48
Reverse osmosis (RO)	321	492	1.53
Total	482	730	1.51
Total life cycle costs, \$/m ³			
Capital	0.07	0.10	1.51
Operation and maintenance (O&M)	0.21	0.60	2.86
Total	0.28	0.70	2.50

In the same way, the O&M costs for treating RO water from SW are around 3 times bigger than the cost of reusing secondary sewage. The bigger pretreatment costs are linked to chemicals, the continuous dosage of a coagulant and more important dosage of antiscalant. The bigger RO costs are linked mainly to energy (the working pressure is five times bigger and the feed flow is 1.5 times more important), but also to membrane replacement [69].

The total life cycle costs for treating RO water from secondary effluent and SW are 0.285/m³ and 0.705/m³, respectively, a ratio of 2.55 [69].

7. Conclusions

This work discussed desalination as a practicable solution to close a water provision-need vacuum and its techniques and features. Desalination costs are also reviewed. An outlook on the next trends is also given. A comparison between desalination and water reuse is shortly presented. From this review, the following conclusions arise:

Ecological duties should force a huge extension of wastewater collection and treatment, and increasing water shortage and prices will render wastewater reuse growingly an economic solution; it so far is in so water-short nations. Even if desalination is probably to stay more costly in most areas than conventional water supply solutions, it will turn into progressively a solution to satisfy inevitable deficiencies for particular markets. Nontraditional solutions like wastewater reuse and desalination have to be considered jointly to deal with water shortage. Improving adopted technologies and increasing allocated funds to these future and indispensable nontraditional solutions remain unavoidable. Secured technologies like membrane processes should be largely applied throughout the world to secure potable water for all humankind.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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