



Is Desalination of Sea Water Cheaper than Constructing Dam in Coastal Areas for Irrigation?

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Authors' contributions

This work was carried out in collaboration among all authors. Author RB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author KM managed the analyses of the study. Author VSSG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The essence of global water scarcity is the geographic and temporal mismatch between fresh water demand and availability. The increasing world population, improving living standards, changing consumption patterns, and expansion of irrigated agriculture are the main driving forces for the rising global demand for water. Climate change, such as altered weather-patterns (including droughts or floods), deforestation, increased pollution, green house gases, and wasteful use of water can cause insufficient supply. At the global level and on an annual basis, enough freshwater is available to meet such demand, but spatial and temporal variations of water demand and availability are large, leading to (physical) water scarcity in several parts of the world during specific times of the year. Through these reasons there is a need to go for alternative measures to mitigate the water scarcity. Desalination may be the best alternative measure for drinking, irrigation and domestic purposes of the people. Desalination is the cheapest available technology and cost of production of one litre drinking water is varies between □ 0.04 to 0.15 compared to reservoir i.e. □ 2 to 2.75 for project efficiency of about 50years.

Keywords: Coastal areas; living standards; irrigation; agriculture.

1. INTRODUCTION

Water resources are natural resources of water that are potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. All living things require water to grow and reproduce. 97.5% of the water on the Earth is salt water and only 2.5% is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps [1]. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air [2].

Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia, South America and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. According to the World Business Council for Sustainable Development, it applies to situations where there is not enough water for all uses, whether agricultural, industrial or domestic. Defining thresholds for stress in terms of available water per capita is more complex, however, entailing assumptions about water use and its efficiency. Nevertheless, it has been proposed that when annual per capita renewable freshwater availability is less than 1,700 cubic meters, countries begin to experience periodic or regular water stress. Below 1,000 cubic meters, water scarcity begins to hamper economic development and human health and well-being.

1.1 Population Growth

In 2020, the world population was 7.8 billion. The UN estimates that by 2050 there will be an additional 3.5 billion people with most of the growth in developing countries that already suffer water stress. Thus, water demand will increase unless there are corresponding increases in water conservation and recycling of this vital resource. In building on the data presented here by the UN, the World Bank goes on to explain that access to water for producing food will be one of the main challenges in the decades to come. Access to water will need to be balanced with the importance of managing water itself in a sustainable way while taking into account the impact of climate change, and other environmental and social variables.

1.2 Expansion of Business Activity

Business activity ranging from industrialization to services such as tourism and entertainment

continues to expand rapidly. This expansion requires increased water services including both supply and sanitation, which can lead to more pressure on water resources and natural ecosystem.

1.3 Rapid Urbanization

The trend towards urbanization is accelerating. Small private wells and septic tanks that work well in low-density communities are not feasible within high-density urban areas. Urbanization requires significant investment in water infrastructure in order to deliver water to individuals and to process the concentrations of wastewater – both from individuals and from business. These polluted and contaminated waters must be treated or they pose unacceptable public health risks. In 60% of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished. Even if some water remains available, it costs increasingly more to capture it.

1.4 Climate Change

Climate change could have significant impacts on water resources around the world because of the close connections between the climate and hydrological cycle. Rising temperatures will increase evaporation and lead to increases in precipitation, though there will be regional variations in rainfall. Both droughts and floods may become more frequent in different regions at different times, and dramatic changes in snowfall and snow melt are expected in mountainous areas. Higher temperatures will also affect water quality in ways that are not well understood. Possible impacts include increased eutrophication. Climate change could also mean an increase in demand for farm irrigation, garden sprinklers, and perhaps even swimming pools. There is now ample evidence that increased hydrologic variability and change in climate has and will continue have a profound impact on the water sector through the hydrologic cycle, water availability, water demand, and water allocation at the global, regional, basin, and local levels.

1.5 Depletion of Aquifers

Due to the expanding human population, competition for water is growing such that many of the world's major aquifers are becoming depleted. This is due both for direct human

consumption as well as agricultural irrigation by groundwater. Millions of pumps of all sizes are currently extracting groundwater throughout the world. Irrigation in dry areas such as northern China, Nepal and India is supplied by groundwater, and is being extracted at an unsustainable rate.

1.6 Water Levels in Dams Dip to “Critical Level”

With water storage in dams dropping to a "critical" level, the Centre has issued a "drought advisory" to Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Telangana and Tamil Nadu, asking them to use water judiciously. The drought advisory is issued to states when the water level in reservoirs is 20 per cent less than the average of live water storage figures of the past 10 years. water storage in 123 reservoirs in India was 68.04 billion cubic metre (BCM) as on 6 May 2020, as per the Central Water Commission’s weekly bulletin.

1.7 How to Increase Water Supply?

The only methods to increase water supply beyond what is available from the hydrological cycle are desalination and water [3]. Of these, seawater desalination offers a seemingly unlimited, steady supply of high-quality water, without impairing natural freshwater ecosystems.

2. DESALINATION

Desalination process helps to remove salt minerals from sea water to make it consumable. Currently 18,426 desalination plants operated worldwide, producing 86.8 million cubic meters per day, providing water for 300 million people [4]. The largest desalination plant is Ras Al-Khair in Saudi Arabia, which produced 1.4 million cubic meters water per day. (www.google.com/amp/s/mobile.reuters.com/article/amp/idUSKBN26Y1HD).

2.1 Need for Desalination in India

Total water production is estimated to rise but water production per household is expected to decrease. Ground water extraction accounts for nearly 37% of the total water production. Still, around 225million people in India do not have access to safe drinking water. The widening gap between growing water needs of population and scarcity in supply in major coastal cities in India is giving rise to alternative water sources.

Despite India being a peninsula region, desalination technology is not seen as a natural fit, mainly because of the costs involved. The technology of separating brine from sea water to make it potable for daily use is expensive and energy-intensive.

Apart from the cost, for every 100 MLD of sea water treated, only 40 MLD is made potable and the remaining 60 MLD of concentrated saline water has to be discharged back into the sea. However, increasing population, industrialization and demand for fresh water has derived India’s desalination market over the past few years.

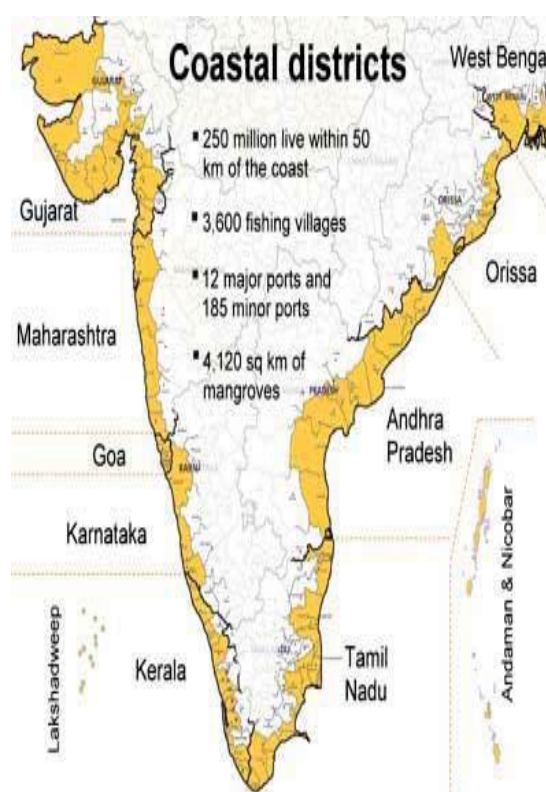


Fig. 1. Study map showing coastal districts

A number of coastal regions are turning to desalination and reverse osmosis treatments. At present, Indian desalination market with coastline of 7,517 km is at approximately US\$660 Mn. Desalination water technology is widely used in water scarce states such as Gujarat, Tamil Nadu, and Rajasthan. Many big Industries such as Nirma, Gujarat Heavy Chemicals Ltd, Indian Rayon are exploring the option of using sea water for their industries. As of 2013, India has 182 desalination plants operating majorly in western and southern parts and is expected to increase to 500+ by 2017.

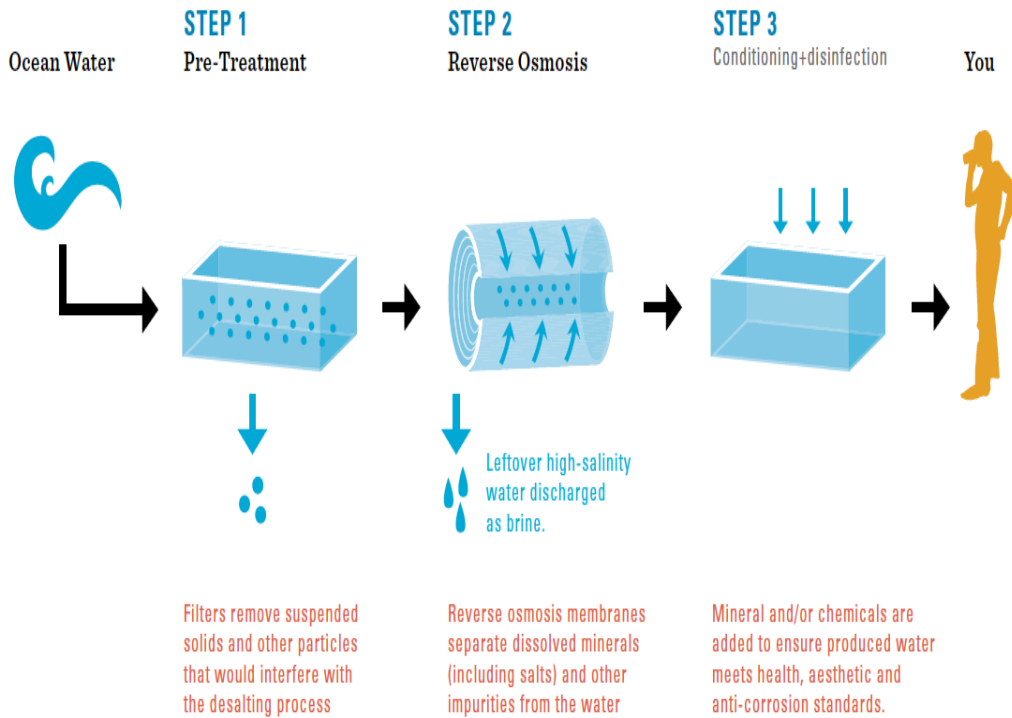


Fig. 2. Desalination process

3. DESALINATION PROCESS

3.1 Various Processes Available for Desalination

- Reverse Osmosis
- Distillation
- Multi-stage Flash
- Multi-Effect Distillation
- Electro Dialysis

Reverse osmosis is comparatively newer method of treating water and purifying it but has emerged to be one of the best.

Reverse osmosis (RO) is a water purification technology that uses a semi-permeable membrane to remove ions, unwanted molecules, and larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property that is driven by chemical potential differences of the solvent, a thermodynamic parameter. Reverse osmosis can remove many types of dissolved and suspended species from water, including bacteria, and is used in both industrial processes and the production of

potable water. Reverse osmosis or hyper filtration is actually a way of filtering water to reduce particles to a molecular level. It significantly decreases the salts and other potential impurities in the water, resulting in a high quality and great tasting product.

3.2 Steps Involved in Reverse Osmosis

1st Step - Removal of sediments from the water. In this step all the sediments like clay, silt and stones are removed from the water. For this, a 5-micron filter is used. The sediments are filtered in order to make sure that no damage is done to the membrane. The micron filter does not let these particles pass by and thus they are suspended.

2nd Step - The Reverse osmosis treatment is the usage of carbon filter. The carbon filter is used to remove the chlorine and other harmful chemicals that enter the water sources. The chemicals can be harmful to human health and thus it is necessary to remove them.

3rd Step - Reverse osmosis treatment generally focuses on passing the water from a dense and compacted carbon filter. The water that we get

may have some unpleasant characteristics and this third step helps in the removal of all such characteristics. All the contaminants left in the water are removed at this stage and water becomes almost clean.

4th Step - Water passes through the membrane and all the heavy metals present in the water are removed. Along with the metals, radioactive metals too are removed. In this step, the impurities are drained out of the reverse osmosis system and clean water is separated.

5th Step - The whole process of reverse osmosis is post filtration. This may be the last step but is the most important of all. In this last stage, the bacteria, chlorine, and bad odour are removed from water. After water passes from this stage, it comes out of the faucet and is perfect for consumption.

4. LIMITATIONS OF R.O. PROCESS

- Because of low back pressure in household systems; about 85% of the water entering the plant is not recovered as clean.
- Due to the selectively permeable membrane in use, the water is mostly *demineralised*, i.e., the water is devoid of important minerals.
- Depending upon the desired product, either the solvent or solute stream of reverse osmosis will be waste.

5. ADVANTAGES OF DESALINATION OF SEA WATER

- **Its method is proven and effective.**

Reverse osmosis, a method of removing salt from seawater has been proven effective in creating fresh sources of drinking water that can deliver the health benefits people need. When properly designed, desalination plants can then create drinkable water that is of high quality.

- **Its method is highly understood.**

Such a method of desalination is backed up by scientific data and is highly understood. The technology used is also reliable that it allows for high-quality water, which means that using such method should allow for great results and could help eliminate water shortage crisis that the world might face in the future.

- **It would preserve current freshwater supplies.**

As the planet's freshwater supply is rather limited, it just makes sense that we should preserve it as much as possible. This would secure more resources to be used where conservation efforts are currently placed, as there is scarcity of water that is available these days.

- **It has the massive amount of ocean water as source.**

Even if all water is produced through desalination, sea water would provide an almost inexhaustible supply, which means that even in times of drought; people would have sufficient access to fresh water supply needed for growing crops, for daily living and for a lot of other needs. Simply put, it brings an end to water crisis.

- **It is not dependent on changing factors.**

One huge problem with many proposed solutions to the ever-increasing water demand is that they heavily rely on uncontrollable factors. For example, more water reservoirs would presuppose that they need rain or snowfall to be filled up. However, desalination does not rely on anything aside from the ocean. With concerns surrounding the melting of the polar ice caps and the rise of the sea levels, nobody would be worried about the ocean disappearing anytime soon.

- **Its plants are safely located.**

Desalination plants are located away from large residential areas. Though there are large facilities, they are located in industrial zones, so they would not put residential areas at risk. People just have to put a plan in place for the location of desalination plants to make such a technology safer in the long term. What's more, just a single desalination plant will be able to supply more than 500 million litres of water that would be drinkable. With this incredible amount of water, we could change the way we get water.

Desalination of sea water is cheaper than the constructing dams in the coastal areas. From the below figure, to irrigate one hectare of agricultural land it cost as maximum as 20.4 lakhs in Maharashtra followed by Madhya

Pradesh (14.1 lakhs /ha) and Andhra Pradesh (12.0 Lakhs /ha). Least cost to irrigate the one hectare of agricultural land is Chhattisgarh (0.8 Lakhs) followed by Bihar (1.1 Lakhs/ha).

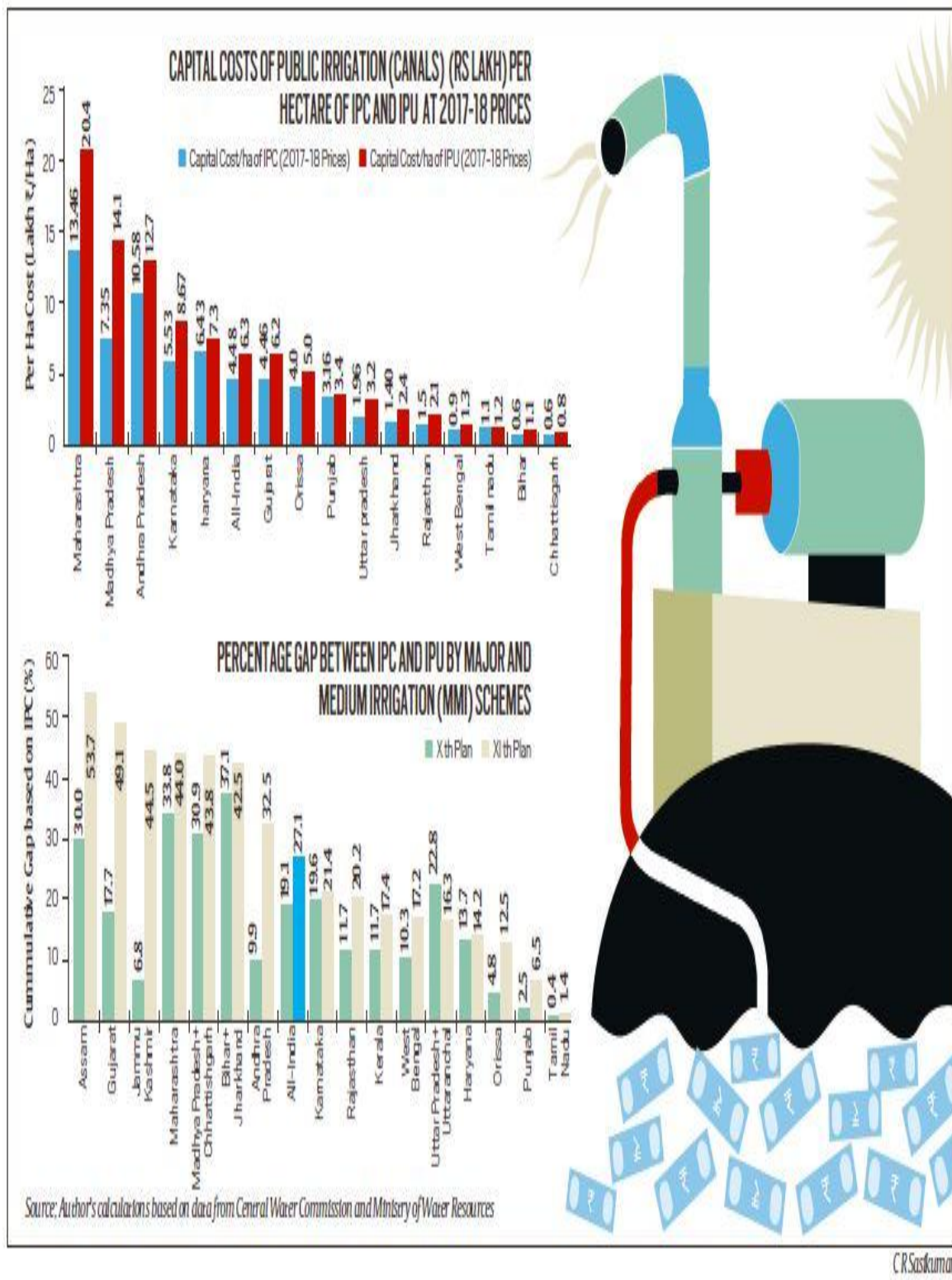


Fig. 3. Capital costs of public irrigation

Table 1. Water desalination plant and its capital investment

| Water Desalination Plant –Capacity 100 MLD | | |
|---|-------------------|--|
| Equipment's/Components | Units | Total Price (INR) |
| Seawater RO membranes | 8,500 | Approximate cost for all the equipment/ study is estimated to be around INR2bn |
| Pressure vessels | 248 | |
| Pressure exchanges | 23 | |
| High pressure pumps | 5 | |
| Pressure filter vessels | 16 | |
| Civil and Electrical works, automation and control systems | NA | |
| Environment Impact Assessment study, Environment Management plan, DPR, Obtaining mandatory clearances etc | | |
| Cost for Intake and Brine disposal system | | |
| Total Capital Investment | | |
| Description | Total Price (INR) | |
| Equipment Cost/ Engineering cost | 2,00,00,00,000 | |
| Land lease rent & development (242811 sq.m x 36.00x100) | 87,41,19,600 | |
| Working capital (O&M, Cost of consumables and chemicals) for next 5 years | 100,00,00,000 | |
| | Total | 3,87,41,19,600 |

6. VIBRANT GUJARAT, CONNECTING INDIA TO THE WORLD, 8TH GLOBAL SUMMIT, 2017. GOVT. OF GUJARAT [9]

From the above figure, to produce 100 MLD it cost about 387 crores.

To produce 1 litre of water from desalination of sea water it costs only 2.58 paisa. This compares the cost of production of 1 litre between the desalination and irrigation from the projects. From this it concluded that sea water desalination is cheaper than the constructing dams for irrigation.

Information regarding setting up of desalination plants in Israel given in above figure. Which indicates to produce 1 litre desalinated water is cheaper than from other conventional water resources.

1. The **Ashkelon plant** in southern coast city Ashkelon was built at an estimated cost of 1479crores with an annual production capacity of 115 million cu m. The water price for the Ashkelon plant was 4.0 paisa per liter.
2. The **Hadera plant** in the northern coastal city of Hadera, Ashkelon was built at an estimated cost of 2630crores with an annual production capacity of 127 million cu m. The water price of Hadera plant was 4.5 paisa per liter.
3. The **Sorek plant** is located in the Tel Aviv District was built at an estimated cost of 2630crores with an annual production capacity of 150 million cu m. The water price for the Sorek plant was 3.6 paisa per liter.
4. The **Ashdod plant** is the newest desalination facility in Israel, was built at an estimated cost of 2933 crores with an annual production capacity of 100 million cu m. The water price for the Ashdod plant was 4.7 paisa per liter.

Table 2. Fact sheet

| Name of the desalination plant | Cost of Installation (Rs.) | Capacity (Million Litres/Annum) | Cost/Lit (Rs.) |
|--------------------------------|----------------------------|---------------------------------|----------------|
| Ashkelon Plant | 1479 crores | 115000 | 0.040 |
| Hadera Plant | 2630 crores | 127000 | 0.045 |
| Sorek Plant | 2790 crores | 150000 | 0.036 |
| Ashdod Plant | 2933 crores | 100000 | 0.047 |

Fact sheet seawater desalination in Israel. FSC19/16-17

7. IRRIGATION WATER MANAGEMENT STRATEGIES IN ISRAEL AND SPAIN

In most of the Israeli plants, DSW is planned to be pumped directly into the distribution system, without being first mixed with other water sources. On the contrary, in SE Spain DSW is usually blended with other water sources. Therefore, irrigation with DSW might occur under two major scenarios: when it is expected to constitute the only or the principal water source, and when it is going to be blended with other local water sources. The first scenario, which

could happen in water-lacking agricultural areas adjacent to desalination plants, implies farmers will receive low-mineral content water continuously and thus agronomical problems might appear. The second scenario, where DSW represents a complementary water source for agricultural areas with a structural water deficit, concerns an irregular water quality supply according to the seasonal availability of other natural resources and the resulting blending rates. Under both scenarios, technical means may mitigate the adverse effects on agricultural production.

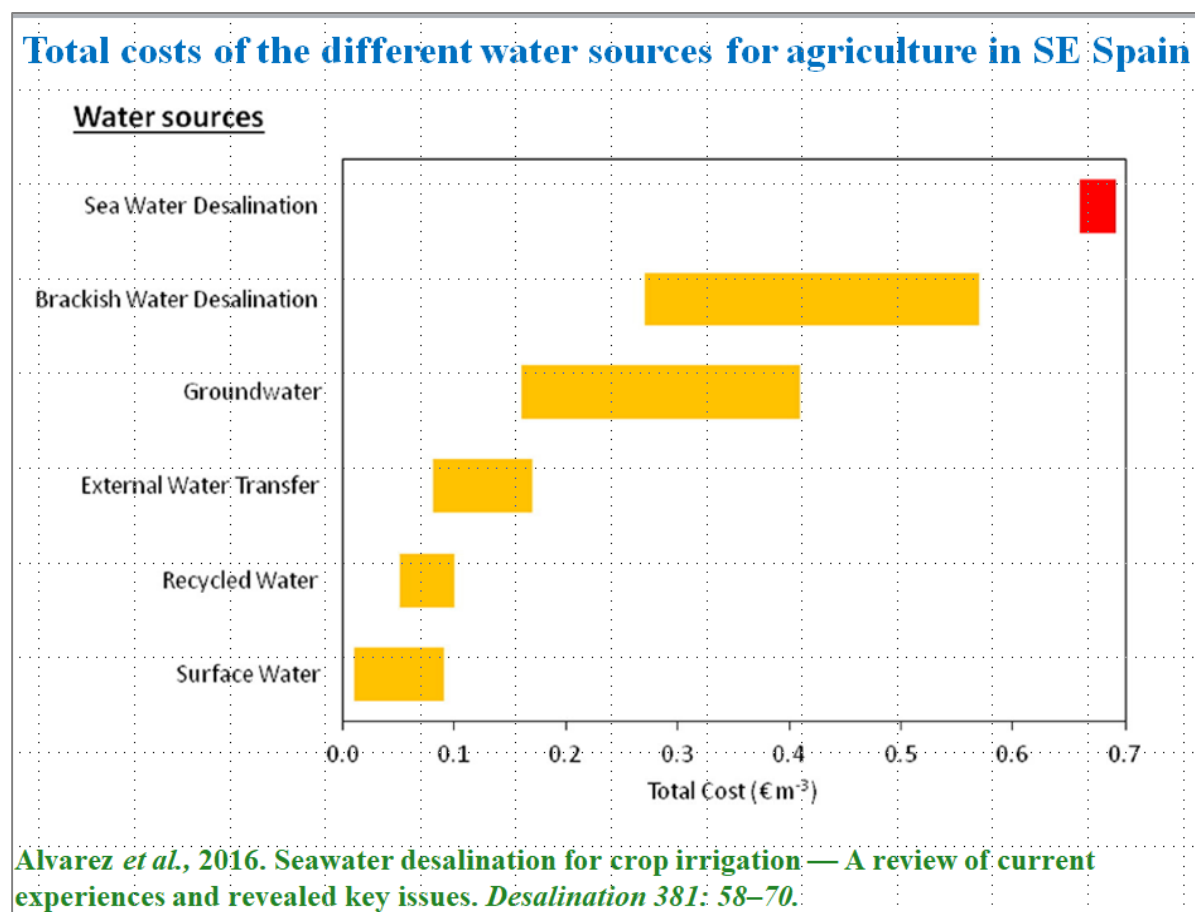


Fig. 4. Total costs of the different water sources

When DSW is the main or the only water source for agricultural irrigation, it is recommended to expand water-quality in desalination post treatment. The constant addition of adequate Ca²⁺, Mg²⁺ and SO₄²⁻ concentrations at SWDP may circumvent the need for dosing them through on-farm fertilisation. If those minerals are not added by further post-treatment, the farmers should take on the increased operational costs of fertilising. When DSW is blended with other water sources in collective water supply infrastructure, the water actually delivered to farmers is variable and the risk of low mineralisation and alkalinity still exists. In this case broad and quick variations in the mineral content could occur, and the lack of accurate information by farmers about that could cause incorrect remineralisation of their final irrigation water, leading even to the addition of excess minerals in the event that the water mineral content is assumed to be low when it is in fact

sufficient. Therefore farmers will need sophisticated, independent control systems to tackle such fluctuations. These systems can involve farm-scale water storage facilities, water-quality monitoring equipment, and fertiliser-pumping facilities capable of quickly reacting to input water quality. The on-farm capital costs of such equipment have been estimated to be about \$10,000 per irrigation head. For that reason it is recommended that the mineral content of the DSW approaches the content of the other available local water sources, even if it is going to be blended, to minimise fluctuations in the quality of the final supplied water.

In Fig. 5 clearly showed that as improvement in the technology with passing time, there is drastic reduction to produce the desalinated water for drinking as well as irrigation purpose when compare to conventional water production systems.

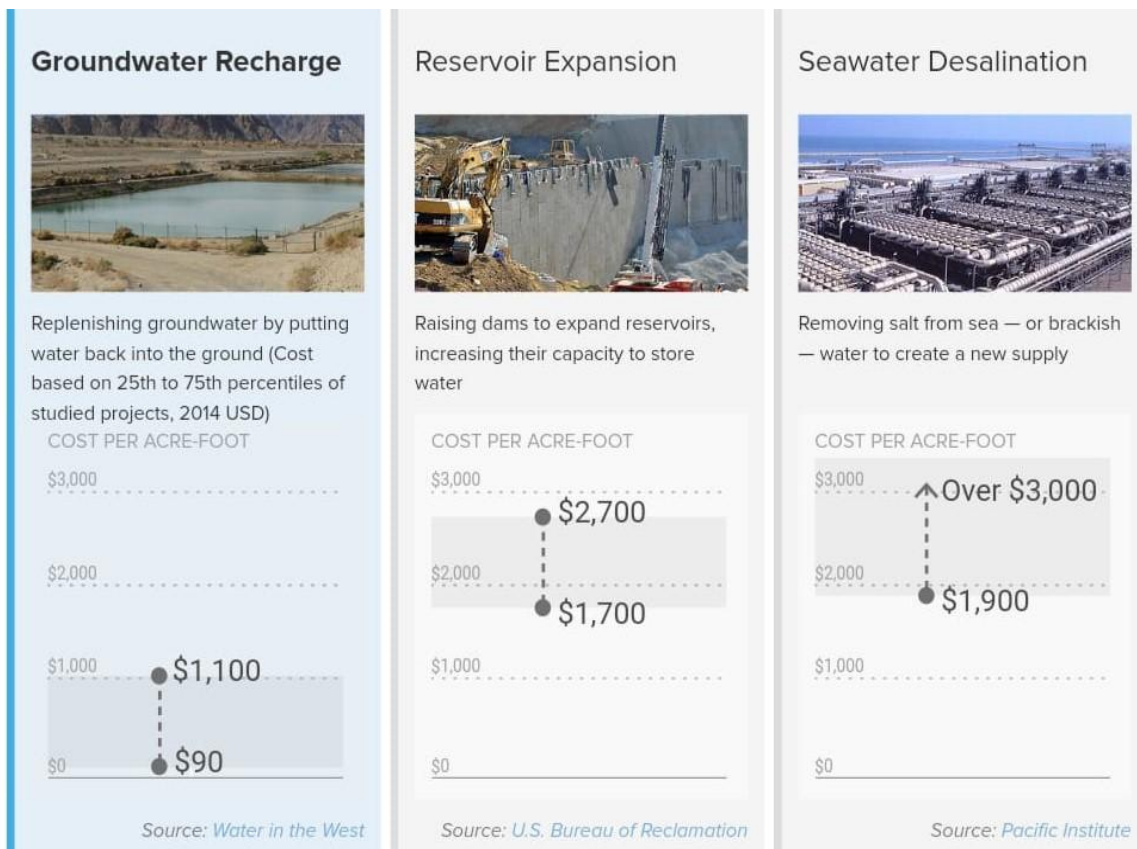
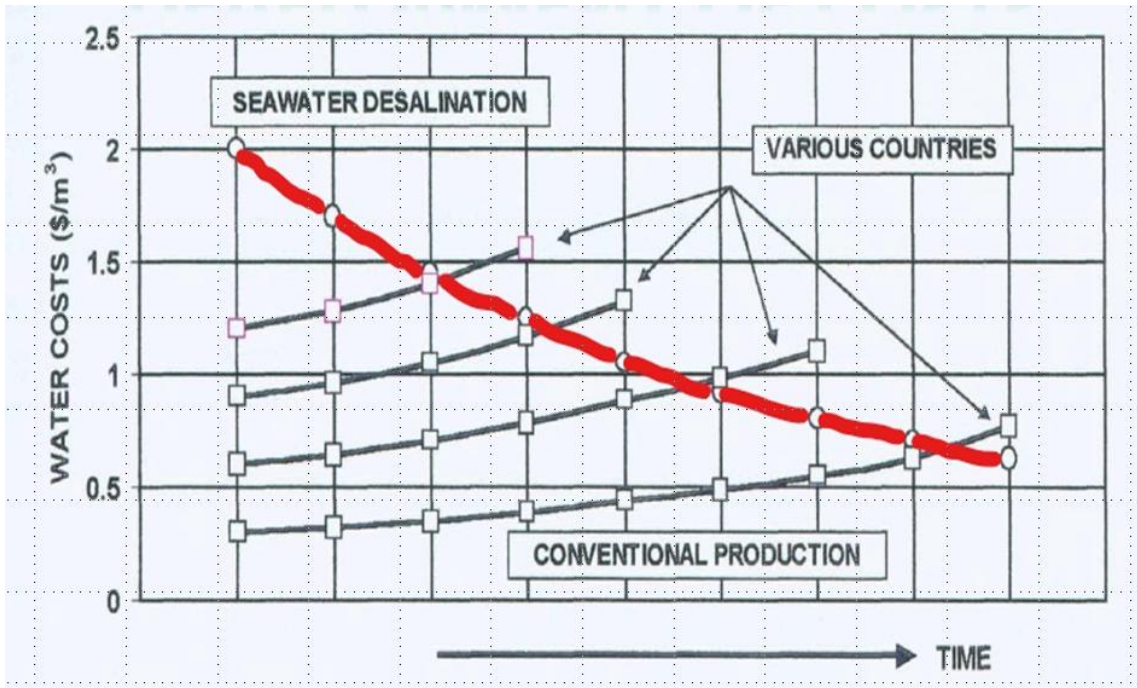
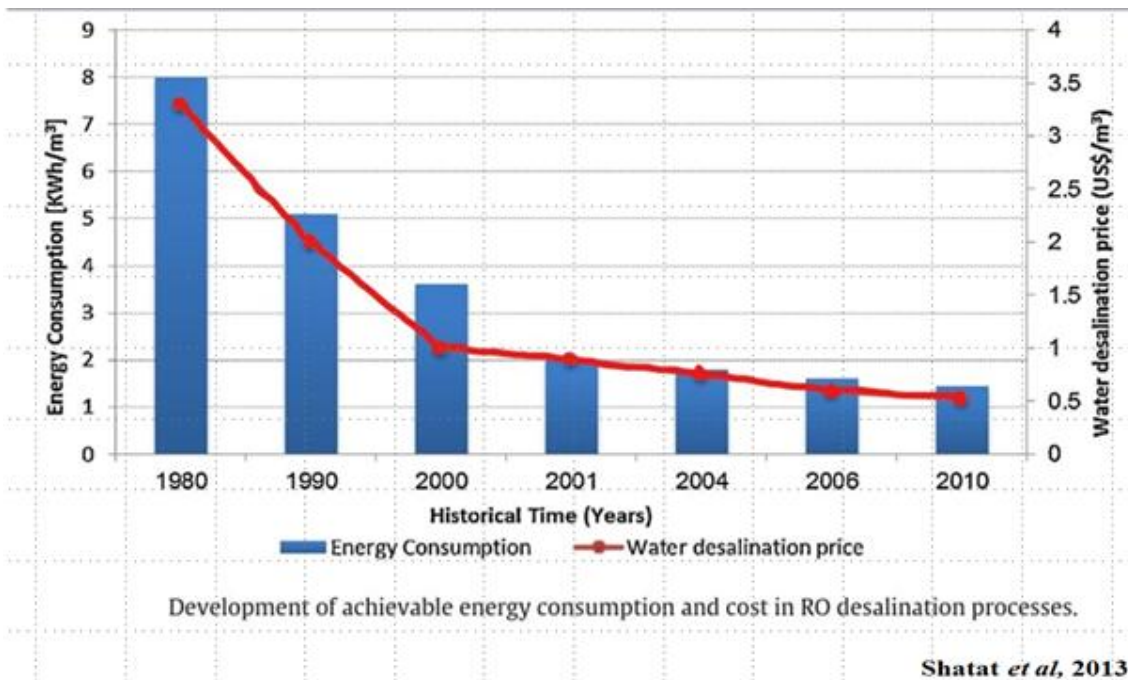


Fig. 5. Charges for irrigating agricultural land from different resources in USA



Banat, 2007

Fig. 6. Development of water costs



Development of achievable energy consumption and cost in RO desalination processes.

Shatat et al, 2013

Fig. 7. Development of achievable energy consumption

Recent developments in membrane materials, pumping and energy recovery systems have dramatically reduced the energy consumption in RO desalination processes, as shown in above

Fig. The cost of water desalination in membrane processes varies according to the type and composition of the feed water. Large scale RO plants can use brackish water containing total

dissolved solids (TDS) of from 2000 ppm to 10,000 ppm [5] but, as TDS concentrations increase, the unit cost of the desalinated water also increases, [6]. The cost of brackish water desalination in Middle East was 0.26 \$/m³ with a TDS concentration of 2300 ppm, whilst the cost for brackish water desalination in Florida was 0.27 \$/m³ with a concentration of 5000 ppm [7]. Whilst for seawater desalination the estimated water production cost for the world's largest RO seawater desalination plant in Ashkelon, Israel, was 0.52 US\$/m³ for a capacity of 320,000 m³/day, (SWRO, 2011) and the cost of an RO plant in Florida was \$0.56/m³ for a capacity of 94,600 m³/day [8].

8. CONCLUSIONS

1. Desalination of sea water is cheaper than constructing dam in coastal areas for irrigation.
2. As the appropriate technology is available, so that desalination of sea water used for agriculture is technically feasible.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. "Earth's water distribution". United States Geological Survey. Retrieved 2009-05-13.
2. "Scientific Facts on Water: State of the Resource". Green Facts Website. Retrieved 2008-01-31.
3. Shannon MA, Bohn PW, Elimelech M, Georgiadis JG, Mariñas BJ, Mayes AM. Science and technology for water purification in the coming decades. *Nature*. 2008;452:301–310.
4. Henthorne, Lisa. Desalination and water Purification technology roadmap: A report of the executive committee. *Desalination: Solutions and Roadmap for an Improved Water Supply*. 2012;87-179.
5. Delyianni E, Belessiotis B. Methods and desalination systems – Principles of the desalination process. Athens, Greece: NCSR "Demokritos"; 1995.
6. Liu C, Rainwater K, Song L. Energy analysis and efficiency reverse osmosis desalination process. *Desalination*. 2011;276:352–358.
7. Avlonitis SA. Operational water cost and productivity improvements -size RO desalination plants. *Desalination*. 2002;142(3):295–304.
8. Wilf M, Bartels C. Optimization of seawater RO systems design. *Desalination*. 2005;173(1):1–12.
9. Vibrant Gujarat, Connecting India to the World, 8th Global Summit, 2017. Govt. of Gujarat; 2017

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