**Introduction:**

Approximately 97.5 percent of the water on our planet is located in the oceans and classified as seawater. Of the planet’s freshwater, approximately 70 percentage is in the form of ice and snow and 30 percent is groundwater river and lake water, and air moisture. So even though the volume of the earth’s water is vast, less than 35 million km3 of the 1386 million km3 of water on the planet is of low salinity and is suitable for use after applying conventional water treatment only [1]. Desalination provides a means for tapping the world’s main water resource from the Ocean.

Over the past 30 years, desalination has made great strides in many arid regions of the world, such as the Middle East and the Mediterranean. Technological advances and the associated decrease in water production costs over the past decade have expanded its use in areas traditionally supplied with freshwater resources.

At present, desalination plants operate in more than 183 countries worldwide; some desert states, such as Saudi Arabia and the United Arab Emirates, rely on desalinated water for over 70 percentage of their water supply. According to the IDA desalination yearbook [2], by the end of 2019 worldwide there were approximately 18,214 desalination plants, with a total installed production capacity of 88.9 million m3/day (23,485 million gal/day).

Over 50 percent of the world’s population lives in urban centers bordering the ocean [3], and in many arid parts of the world, such as the Middle East, Australia, North Africa, and Southern California, the population concentration along the coast exceeds 75 percent. Usually coastal zones are also the highest population growth hot spots. Therefore, sea water desalination provides the logical solution for the sustainable, long-term management of the growing water demand pressures in costal area. Brackish desalination is also expected to increase in capacity, especially in inland area with still untapped brackish water aquifers.

A clear recent trend in seawater desalination is the construction of larger-capacity plants, which deliver an increasingly greater portion of the fresh water supply of coastal city around the global.

The mineral or salt content of water is usually measured by the water quality parameter called **total dissolved solids** (TDS), the concentration of which is expressed in milligrams per liter (mg/L) or part per million (ppm). The world health Organization, as well as the United states Environment Protection agency (US EPA) under the safe drinking water act, have established a maximum TDS concentration of 500 mg/L (500 ppm) as a potable (Fresh) water. Typical water with a TDS concentration higher than 500 mg/L and not higher than 15,000 mg/L is classified as brackish. Natural water source such as sea, bay, and ocean water that have TDS concentrations higher than 15,000 mg/L are generally classified as seawater. For example, Pacific Ocean seawater has an average TDS concentration 35,000 mg/l.

**Desalination Technologies:**

Sea and Brackish water are typically desalinated using two general types of water treatment technologies: **thermal evaporation** (**distillation**) and **reverse osmosis** (**RO**) membrane separation.

In thermal distillation, freshwater is separated from the saline source by evaporation. In reverse osmosis desalination, freshwater is produced from saline source water by pressure-driven transport through semipermeable membranes. The main driving force in RO desalination is pressure, which is needed to overcome the naturally occurring osmotic pressure that in turn is proportional to the source water’s salinity.

Beside thermal distillation and RO membrane separation, two other mainstream desalination technologies widely applied at present are **electrodialysis (ED)** and **ion exchange (IX).** Electrodialysis is electrically driven desalination in which salt ions are removed out of the source water through exposure to direct electric current. The main driving force for the ED separation is electric current, which is proportional to the salinity of the source water.

IX is the selective removal of salt ions from water by adsorption onto ion-selective resin media. The driving force in this desalination process is the ion charge of the IX resin, which can selectively attract and retain ions of the opposite charge contained in the saline source water.

Table1 [3] provides a general indication of the range of source water salinity for which distillation can be applied cost effectively. For processes with overlapping salinity ranges, a life-cycle cost analysis for the site-specific conditions of a given desalination project is typically applied to determine the most suitable desalination technology for the project.

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| --- | --- |
| Separation Process | Range of Source water TDS concentration for cost effective Application, mg/L |
| Thermal process | 20,000 - 100,000 |
| RO separation | 50 – 46,000 |
| Electrodialysis | 200 – 3,000 |
| Ion Exchange | 1 - 800 |

Table1 [3] Desalination Process Applicability

In 2016, approximately 65 percent of the world’s desalination system are Ro membrane separation plants and 28 percent are thermal desalination facilities fig1 [4]. The percentage of RO desalination installation has been increasing steadily over the past 10 years due to remarkable advance in membrane separation and energy recovery technologies.

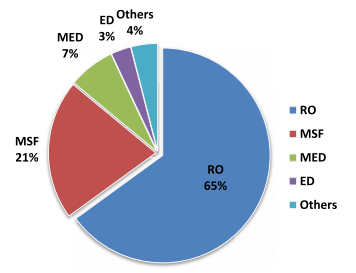


Figure 1, Desalination process contribution globally.

**Thermal Desalination:**

All thermal desalination technologies are based on heating the source water to product water vapor, which is then condense into low-salinity water. Since the energy for water evaporation is practically not dependent on the source water salinity concentration, thermal evaporation is very suitable for desalination of high-salinity waters. This is one of the reasons that thermal desalination has been widely adopted by Middle Eastern countries such as Saudi Arabia, Oman, The United Arab Emirate and Kuwait, which use some of the most saline water bodies on the plant for water Supply namely, the Red Sea, Arabian Gulf and Gulf of Oman. In 2012, approximately 75 present of the world’s thermal desalination plants are located in the Arabian Peninsula, half of those in Saudi Arabia.

The three most commonly used types of thermal desalination technologies are multistage flash distillation (MSF), multi-effect distillation (MED), and vapor compression (VC). Each of these classes have evolved over the past 40 years toward improvements in efficiency and productivity. These types manly differ by the temperature and pressure at which the source water is boiled to generate freshwater vapor, for example MSF boils water at near atmospheric pressure and temperature close to 100 C and required a large quantity of steam.

MED and VC are newer thermal desalination technologies, whose improved efficiency stems from the fact that water can boiled at a lower temperature if the boiling process occurs at pressure lower than the atmosphere pressure which allows the use of less and lower quality steam for production of the same volume of water.

All thermal desalination technologies generate vary low salinity water (TDS in a range of 5 to 25 mg/L), and very low content of pathogens and other contaminants of concerns. This technology is most popular in the Middle East, where seawater desalination is typically combined with power generation that provides low cost steam for the distillation process.

**Membrane Desalination:**

Membrane desalination is the process of separating minerals from the source water using semipermeable membranes. Two general types of technologies currently used for membrane desalination are electrodialysis (ED) and RO, in ED systems, salts are separated from the source water through the application of direct current, this current drive the mineral ions and other ions with strong electric charge that are contained in the source water through ion-selective membrane to a pair of electrodes of opposite charges (fig2) [5].

The TDS removal efficiency of Electrodialysis ED desalination systems is not affected by non-ionized compounds or objects with a weak ion charge (i.e., solids particles, organics, and microorganisms). Therefore, the TDS removal efficiency of ED systems is typically lower than that of Reverse Osmosis systems (15.0 to 90.0 percent versus 99.0 to 99.8 percent), which is one of the key reasons why they have found practical use mainly for brackish water desalination

**Reverse Osmosis:**

Reverse osmosis (RO) is a process where water containing inorganic salts (minerals), suspended solids, soluble and insoluble organics, aquatic microorganisms, and dissolved gases is forced under pressure through a semipermeable membrane. Semipermeable refer to a membrane that selectively allows water to pass through it at much higher rate than the transfer rate of any constituents contained in the water.

Depending on their size and electric charge, most water constituents are rejected on the feed side of the RO membrane while the purified water (permeate) pass through the membrane. Figure3 [3] illustrates the sizes and types of solids removed by RO membranes as compared to other commonly used filtration technologies.

RO membranes can reject particulate and dissolved solids of practically any size. However, they do not reject well gases, because of their small molecular size. In terms of physical size, RO membranes can reject well solids larger than 1 (Angstrom) Å. This means that they can remove practically all suspended solids, protozoa, bacteria, viruses, and other human pathogens contained in the source water. While RO membranes can retain both particulate and dissolved solids, they are designed to primarily reject soluble compounds (mineral ions).  the solid particulates would accumulate and quickly plug (foul) the surface of the RO membranes, not allowing the membranes to maintain a continuous steady-state desalination pro cess. Therefore, the suspended solids (particulates) contained in source water used for desalination have to be removed before they reach the RO membranes.

Over the past 20 years, RO membrane separation has evolved more rapidly than any other desalination technology, mainly because of its competitive energy consumption and water production costs

**Renewable Energy:**

In the recent years, renewable energy alternatives became the best solutions for the global warming and greenhouse effects resulted from the continuous use of the conventional energy resources like coal and oil and cost-effective solution for the remote areas and for the depletion of conventional energy resource.

The most promising renewable energy resources are solar and wind. Solar is rapidly becoming one of the most important sources of renewable energy based on merits such as: it is free of cost, it is abundant, it is easily available and it is environment-friendly since it produces zero atmospheric pollutants or emissions. Solar energy can be converted to either electrical or thermal energy. A photovoltaic (PV) cell, more commonly known as a solar cell is an electrical device which directly converts sunlight into electrical energy by photovoltaic.

PV modules, which are a collection of PV cells, are emission-free, require little maintenance and do not burden the consumer with fuel costs, and becoming rapidly common at both domestic and industrial level as a source of electrical energy and they are the topic of focus in this study.

**Photovoltaic Thermal (PVT) Collector:**

The most widely available PV modules are made of crystalline silicon and can only convert a small portion (4-17%) of incident solar energy to electrical energy. So more than 80 % of the incident energy remains unconverted and serves only to heat up the PV module. Thus, exposing PV modules to sunlight together with high ambient temperatures and low wind speeds results in extreme rises in solar cell working temperature (sometimes as much as 50˚C) above the ambient temperature.

Increasing solar cell temperatures result in a loss of electrical performance and can even lead to permanent structural damage if thermal stresses remain in the module for a prolonged period. A PV module can be cooled by attaching it to the top of a solar thermal collector. The fluid circulating through the collector will remove the excess heat from the PV module and the collector which would bring the cell temperature down. Such a combined device is called a photovoltaic thermal (PVT) collector and it supplies both electricity and heat in the form of hot fluid. A PVT collector has higher energy yield per unit area than either PV or solar collector as the electrical efficiency of the PV panel increases as it cools down. Since a PVT system can provide both electrical and thermal energy simultaneously it can fulfill part of the electricity and hot water requirements of buildings, such as hospitals, schools, hotels, and houses.