International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

Water Desalination Using Renewable Solar Energy

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Abstract: ***Water is one of the earth's most abundant resources, covering about three- quarters of the planet's surface. Plenty of water sources are available on the earth but only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69%resides in gla1ciers, 30% underground and less than 1% is located in lakes, rivers and swamps. Looked at another way, only 1% of the water on the surface is usable by humans and 99% of usable quantity is situated underground. Only 1% of the water is in a fresh, liquid state and nearly all of this is polluted by both pathogens and toxic chemicals. Tackling the water scarcity problem must involve better and more economic ways of desalinating seawater. This article presents a comprehensive review of water desalination systems, whether operated conventional energy or renewable energy, to convert saline water into fresh water. These systems comprise the thermal phase change and membrane processes, in addition to some alternative processes. Thermal processes include the multistage flash, multiple effects boiling and vapors compression, cogeneration and solar distillation, while the membrane processes include reverse osmosis, electro dialysis and membrane distillation. It also covers the integration into desalination systems of potential renewable energy resources, including solar energy etc. Such systems are increasingly attractive in such areas suffering of fresh water but where solar energy is plentiful.***

Keywords: Fresh Water, Sea Water, Desalination, Solar Energy

1.Introduction

Water is the essential component for all living beings. The United Nations (UN) Environment Programme stated that one –third of the world's population lives in countries with insufficient freshwater to support the population. Consequently, drinking water of acceptable quantity has become a scarce commodity. The total global water reserves are ~1.4 billion km cubes, of which around 97.5% is in the oceans and the remaining 2.5% is fresh water presents in the atmosphere, Ice Mountains and ground water. Of the total, only ~0.014% is directly available for human being and other organisms. Thus, tremendous efforts are now required to make available new water resources in order to reduce the water deficit in countries which have shortages.

The availability of good quality water is on the decline and water demand is on the rise. Various industrial and developmental activities in recent times have resulted in increasing the population level and deteriorating the water quality. Water shortage and unreliable water quality are considered major obstacles to achieve sustainable development and improvement in the quality of life. Water shortage and unreliable water quality are considered major obstacles to achieve sustainable development and improvement in the quality of life. The water demand in the country is increasing fast due to progressive increase in the demand of water for irrigation, rapid industrialization and population growth and improving life standards. The existing water resources are diminishing (1) Due to unequal distribution of rain water and occasional drought (2) excessive exploitation of ground water sources and its industrial effluents without adequate treatment. This is resulting into water stress/scarcity. In addition, a large number of villages in different parts of countries are known to be suffering from excess salinity, fluoride, iron, arsenic and microbial contaminations of ground water. Desalination is a process that extracts mineral components from saline water. More generally, desalination refers to the removal of salts and minerals from target substances, as in soil desalination, which is an issue for agriculture. Salt water is desalinated to produce water suitable for human consumption or irrigation. One by product of desalination is salt.

There are more than 7500 desalination plants in operation worldwide producing several billion gallons of water per day. Fifty seven per cent are in the middle east where large scale conventional heat and power plants are among the region's most important commercial processes, they play a crucial role in providing fresh water for many communal and industrial sectors, especially in areas with a high density of population. This article aims to present a review of the published literature on the various desalination technologies and their advantages and disadvantages in addition to their economics. These systems are meant for a basic need of drinking water and fresh water supply.

2.Overview of Desalination Processes

Various desalination processes have been developed, some of which are currently under research and development. The most widely applied and commercially proven technologies can be divided into two types: phase change thermal process and membrane processes and as shown in fig1, both encompass a number of different processes. In addition, there are alternative technologies of freezing and ion exchange which are not widely used. All are operated by either a conventional energy or renewable energy to produce fresh water.

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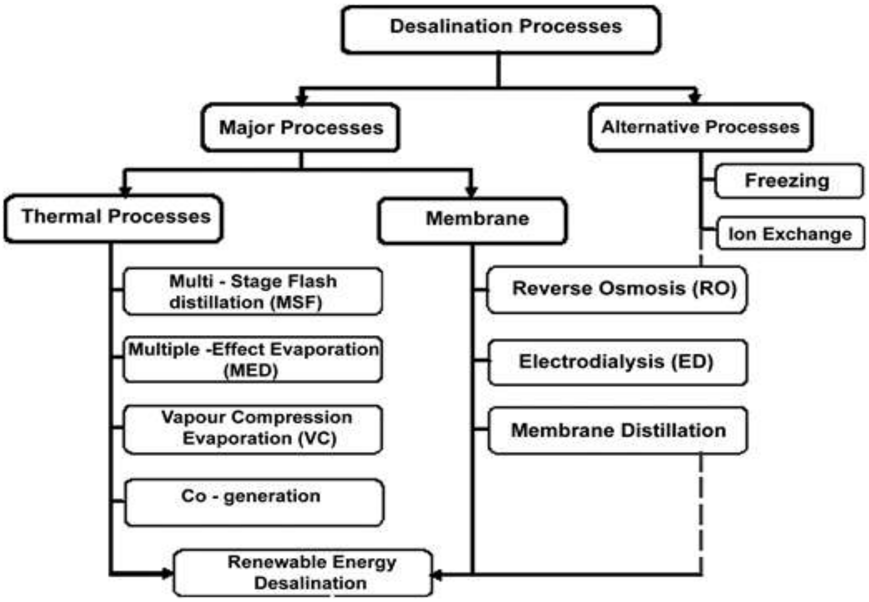


Figure 1

3.Thermal Desalination Process

Thermal desalination, often called distillation, is one of the most ancient ways of treating seawater and brackish water to convert them into portable water. It is based on the principle of boiling or evaporation and condensation. Water is heated until it reaches the evaporation state. The salt is left behind while the vapors are condensed to produce fresh water. In modern times, the required thermal energy is produced in steam generators, waste heat boilers or by the extraction of back pressure steam from turbines in power stations. The most common thermal desalination processes are:

- Multi Stage Flash Distillation(MSF)
- Multiple Effect Distillation (MED)
- Vapor Compression Evaporation(VC)
- Cogeneration
- Solar Water Desalination

Multi Stage Flash Distillation

Water distillation in a vessel operating at a reduced pressure and thus providing a lower boiling point for water, has been used for well over a century. In the 1950's, Weirs of Cataract in Scotland used this concept to invent the MSF process and it had significant development and wide application throughout the 1960's due to both of its economical scale and its ability to operate on low grade steam. MSF is currently producing around 64% of the total world production of desalinated water. Most of the MSF plants are located in Arab region.

Although MSF is the most reliable source for the production of fresh water from seawater, it is considered as an energy intensive process, which requires both thermal and mechanical energy. In the MSF process, illustrated in Figure 2, feed water (saline water)is heated in a vessel called the brine heater until it reaches a temperature below the saturation boiling temperature. The heated seawater flows through a series of vessels, in sequence, where the lower ambient pressure causes the water to boil rapidly and vaporize. This sudden introduction of heated water into the reduced pressure chamber is referred to as the 'flashing effect' because the water almost flashes into steam.

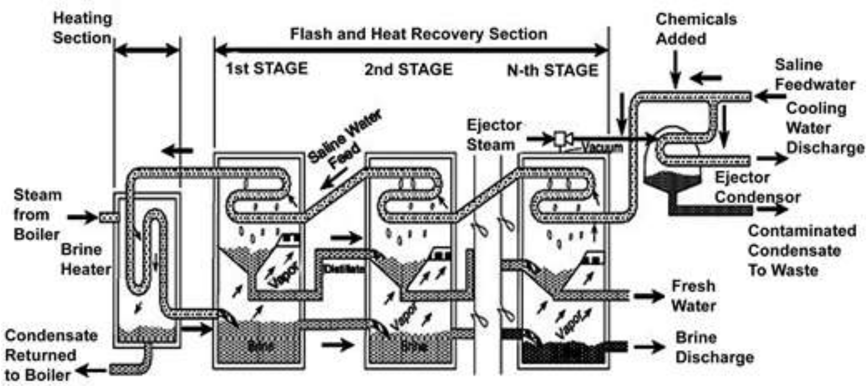


Figure 2

A small percentage of this water is converted into water vapor, the percentage is mainly dependent on the pressure inside the stage, since boiling continues until the water cools and vaporization stops. The vapor steam generated by flashing is converted to fresh water by being condensed on the tubes of heat exchangers that run through each stage. The incoming feed water going to the brine heater cools the tubes. This, in turn, heats up the feed water and increases the thermal efficiency by reducing the amount of thermal energy required in the brine heater to raise the temperature of the seawater.

Typically a MSF plant contains between 15 and 25 stages and a series of stages set at increasingly lower atmospheric pressure was developed so that the feed water which was passed from one stage to another was boiled repeatedly without adding more heat.

Distillation processes produce ~50% of the worldwide desalination capacity and 84% of this is produced by MSF technology.

Multi Effect Distillation

The MED process is the oldest large scale distillation method used for seawater desalination. At present ~3.5% of the world's desalted water is produced by MED plants. High distilled water quality, high unit capacity and high heat efficiency are its most obvious characteristics. In addition, MED has traditionally been used in the industrial distillation sector for the evaporation of juice from sugarcane in the production of sugar and in the production of salt using the evaporative process.

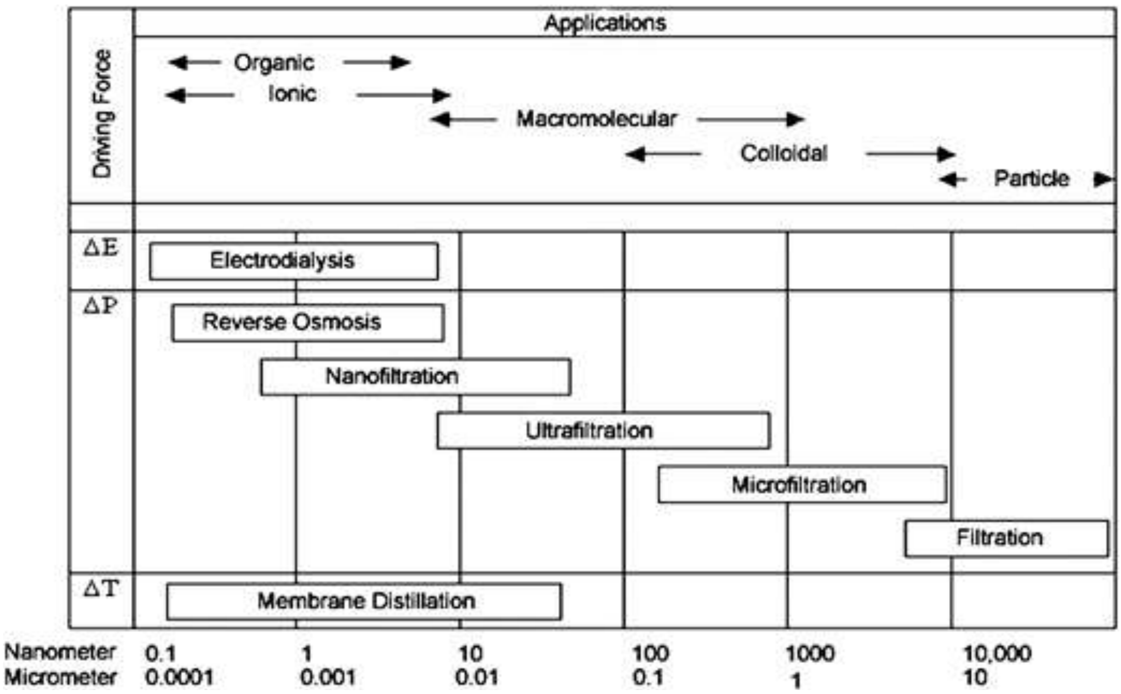
Vapor Compression Evaporation

The vapor compression distillation process is used in combination with other process like MED and single effect vapor compression. In this process, the heat for evaporating the seawater comes from the compression of vapor. VC plants take advantages of the principle of reducing the boiling point temperature by reducing the pressure. Two devices, a mechanical compressor and a steam jet are used to condense the water vapor to produce sufficient heat to evaporate incoming seawater.

Membrane Processes

Synthetic membranes were first introduced in separation processes in 1960's, but they began to play an increasingly crucial role in water desalination in the 1980's. These processes are also useful in municipal water treatment; RO and electro dialysis (ED) are replacing phase change desalting technologies for supplying water to coastal and island communities all over the world.

Figure 3 shows effective range of membrane processes and applications:



This section looks at the following process:

- Reverse osmosis
- Electro dialysis
- Membrane Distillation(MD)

Renewable Energy Water Desalination

The potential use of renewable energy as a clean friendly source of energy to operate small scale desalination units in remote communities has received increasing attention in recent years. The coupling of renewable energy sources and desalination such as solar, wind and geothermal energy with desalination systems holds great promise for tackling water shortage and is a potential for variable solution of climate change and water scarcity.

An effective integration of these technologies will allow countries to address water shortage problems with a domestic energy source that does not produced air pollution or contribute to the global problem of climate change due to lower conventional energy consumption and lower gas emissions. Meanwhile, the cost of desalination and renewable energy systems are steadily decreasing, while fossil fuel prices are rising and its supplies are steadily decreasing, while fossil fuel prices are rising and its supplies are depleting.

The desalination units powered by renewable energy systems are uniquely suited to provide water and electricity in remote areas where water and electricity infrastructures are currently lacking. The rapid increase in demand for energy is making the world focus on alternative sustainable sources. In 2008, 10% of generated electricity worldwide was produced by renewable energy sources (hydropower, biomass, biofuels and wind, geothermal and solar). A recent assessment conducted by the US energy information administration forecast that by 2035, consumption of renewable energy will be ~14% of total world energy consumption, which shows strongest growth in global electric generating capacity as in Figure 4

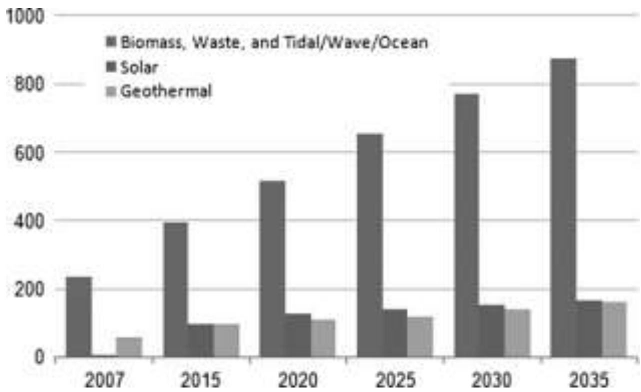


Figure 4

The majority of desalination systems that use a renewable energy source can be divided into three categories: Wind, Solar photo voltaic (PVs) or Solar Collector and those that use geothermal energy.

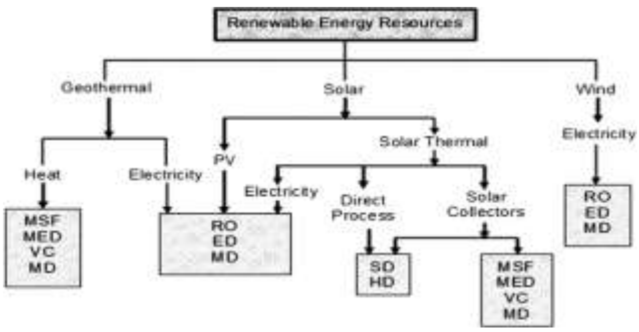
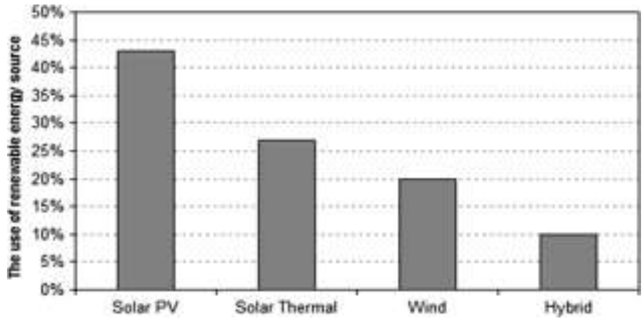


Figure 5

It has become obvious that the solar energy is the most widely used among other renewable energies as in Figure 6



Solar Powered Water Desalination

Introduction to Solar Energy

The sun was adored by many ancient civilizations as a powerful god and solar energy is the oldest energy source used by human beings. The first known practical application was in drying for food preservation .Scientists have long looked at solar radiation as a source of energy, trying to convert it into a useful form for direct utilization. Solar energy is used to heat and cool buildings, to heat water for domestic and industrial uses, to heat swimming pools, to power refrigerators, to operate engines and pumps, to desaline water for drinking purposes, to generate electricity, in chemistry applications and many more functions.

Water Desalination Using Solar Energy

Solar powered desalination processes are generally divided into two categories, direct and indirect systems.

Direct System

The direct systems are those where the heat gaining and desalination processes take place naturally in the same device. The basin solar still represents its simplest application, the still working as a trap for solar radiation that passes through a transparent cover.

Solar Still

Solar still distillation represents a natural hydrological cycle on a small scale. The basic design of a solar still, which is similar to a greenhouse, is shown in Figure 7 Solar energy enters the device through a sloping transparent glass or plastic panel and heats a basin of salt water. The basin is generally black to absorb energy more efficiently.

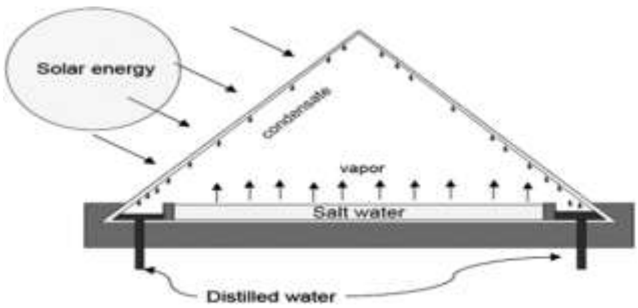


Figure 7

Indirect System

In these systems, the plant is separated into two subsystems, a solar collector and a desalination unit. The solar collector can be a flat plate, evacuated tube or solar concentrator and it can be coupled with any of the distillation unit types described previously which use the evaporation and condensation principle, such as MSF, VOC, MED and MD for possible combinations of thermal desalination with solar energy. Systems that use PV devices tend to generate electricity to operate RO and ED desalination processes. Figure 8 shows the worldwide use of the various desalination technologies using solar power sources.

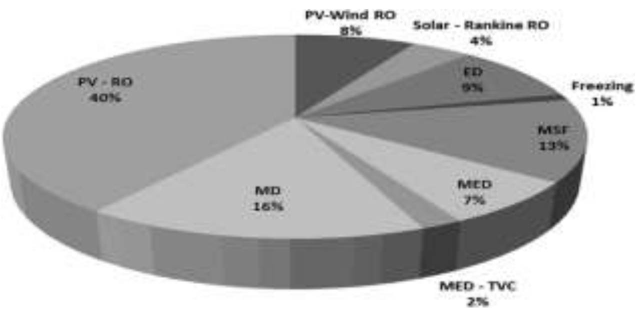


Figure 8

Summary of Water Desalination Economics

To sum up, the desalination systems can be operated by the use of conventional and renewable energy sources and the vast majority of desalination plants over the world are currently operated by fossil fuels instead of renewable energy due to technical and economic barriers. From the literature, it has been concluded that the cost of water produced from desalination systems using a conventional source of energy is much lower than those powered by renewable energy sources.

Health and Environmental Aspects

The number of desalination plants worldwide is growing rapidly and as the need for fresh water supplies grows more acute, desalination technologies improve and unit cost are reduced. Desalination processes should aim to be environmentally sustainable. Most drinking water applications use WHO drinking water guidelines as water quality specifications. ‘WHO Guideline for Drinking water Quality ‘covers a broad spectrum of contaminants, including inorganic and synthetic organic chemicals, disinfection by products, microbial indicators and radionuclides and is aimed at typical drinking water sources and technologies. The intake and pretreatment of sea water, as well as the discharge of the concentrate reject water produced; have to be adapted to the specific conditions at the site of each desalination plant. Hence, it is necessary to consider and evaluate the criteria that help to select the best available technology and the optimal solution for the intake and outfall system at each plant. These environmental aspects are just as important as the commercial details and must be considered in the design and construction phases and during plant operation.

Important elements regarding the environmental impact requirements that should be considered concentrate discharge standards and location:

- Waste water discharge standard
- Air pollution control requirements
- Noise control standards
- Land use
- Public services and utilities
- Aesthetics light and glare

4.Conclusion

The use of solar energy for water desalination in countries in Africa and the Middle East region which have plenty of solar energy is a promising issue for meeting water demand and would definitely contribute both towards solving water scarcity problems and reducing carbon dioxide emission by means of an environmentally friendly process. Moreover, the coupling of renewable energy and desalination systems has to be optimized and further technical research development of renewable energy augmented desalination technologies that require little maintenance and waste heat source are recommended which are uniquely suited to provide fresh water in remote areas where water and electricity infrastructure are currently lacking.

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