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An extensive review on different design and climatic parameters to increase distillate output of solar still

Hitesh N. Panchal[a,*], Sanjay Patel[b]

[a] Mechanical Engineering Department, Government Engineering college, Patan, India
[b] Mechanical engineering department, Government Polytechnic, Ahmedabad, India

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ABSTRACT

Most of the part of the land is covered by saline water where fresh water is available in less proportion and also the demand of fresh water for drinking use is increasing rapidly day after day due to increase in the population. Hence, solar desalination is a feasible alternative to sweep over this massive difficulty. The process by which impure water is converted into clean water is called soar desalination and instrument which is used for it is known as solar still. A lot of investigation has been done by various researchers to inspect the parameters which affect the efficiency of solar still and thereby to improve its performance. In this review paper different design and climate parameters are reviewed which affects the yield of a solar still.

1. Introduction

Water is essential for all life forms on earth-plants, animals and human etc. For fresh water requirements humanity is dependent on fresh water resources like rivers, ponds, lakes and underground water reservoirs. The available fresh water on the earth is fixed. But the demand of fresh water increases, due to population growth and rapid industrialization. Industrial waste and sewage dischargers are mostly mixed in the rivers, so the available fresh water is reduced. The provision of fresh water is gradually becoming a more important issue in many areas of the world. The ocean is the only available source for an abundant amount of water. But the ocean water contains high salinity, so it needs to desaline the water [1].

Desalination is one of humankind's most primitive forms of water treatment, and it is still a popular treatment solution throughout the world today. In nature, solar desalination produces rain when solar radiation is absorbed by the sea and causes water to evapourate. The evapourated water rises above the earth's surface and is moved by the wind. Once this vapour cools down to its dew point temperature, condensation occurs, and the fresh-water comes down as rain. This basic process is responsible for the hydrologic cycle. This same principle is used in all man-made distillation systems using alternative sources of heating and cooling [2].

Major desalination techniques like vapour compression distillation, reverse osmosis and electrolysis used electricity as input energy. Nevertheless, in recent years, most of the countries in the world have been significantly affected by the energy crisis because of heavy dependency on conventional energy sources (coal power plants, fossil fuels, etc.). Hence, the environment and economic growth of these countries is affected significantly. However, these technologies are not appropriate for remote villages and small islands. To provide fresh-water for these places, solar stills may be potentially applicable.

Researchers from all around the world have developed different solar still for increment in distillate output. Many researchers analyzed the works carried out on the solar still and reviewed. Malik et al. [1] have reviewed the work on passive solar distillation. Tiwari et al. [2] have carried out a study on the present status of research work on both passive and active solar distillation systems. They recommended that double slope passive solar stills can be economical to provide drinkable water for rural area. For better distillate output, multi-effect solar still is better hence; the productivity of multi-effect solar still has been studied by Rajaseenivasan et al. [3] and found that, higher distillate output is obtained from the multi-effect solar still as compared with conventional. They also compared different parameters affecting the rate of evapouration and condensation on multi-effect solar still with conventional solar still. Muthu Manokar et al. [4] made an analysis of different types of solar still based on heat and mass transfer analysis.

In this regard this paper aims to review the different designs, climatic and operational parameters used for the efficient design of solar still.

2. Various desalination technologies

Desalination can be achieved using a number of techniques. Industrial desalination technologies either use phase change or involve semipermeable membranes to separate the solvent or some solutes.

* Corresponding author.

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Therefore, desalination techniques may be classified into the following categories: phase change or thermal processes and membrane or single-phase processes.

2.1. Phase change processes

In the phase change or thermal processes, the distillation of seawater is achieved by utilizing a thermal energy source. The thermal energy may be obtained from a conventional fossil fuel source, nuclear energy, or a non-conventional solar energy source or geothermal energy. These processes involve heating of saline water and collecting the condensed vapour (distillate) to produce pure water.

2.1.1. Multi-stage flash desalination

The MSF process is composed of a series of elements, called stages. In each stage, condensing steam is used to pre-heat the seawater feed. By fractionating the overall temperature differential between the warm source and seawater into a large number of stages, the system approaches ideal total latent heat recovery. Operation of this system requires pressure gradients in the plant.

2.1.2. Multi effect distillation

The multi effect distillation process is composed of a number of elements, which are called effects. The steam from one effect is used as heating fluid in another effect, which, while condensing, causes evapouration of a part of the salty solution. The produced steam goes through the following effect, where, while condensing, it makes some of the other solution evapourate, and so on. For this procedure to be possible, the heated effect must be kept at a pressure lower than that of the effect from which the heating steam originates. The solutions condensed by all effects are used to pre-heat the feed. In this process, vapour is produced by flashing and by boiling, but the majority of the distillate is produced by boiling. Unlike an MSF plant, the MED process usually operates as a once-through system without a large mass of brine recirculating around the plant. This design reduces both pumping requirements and scaling tendencies.

2.1.3. Vapour compression

Vapour compression desalination refers to a distillation process where the evapouration of sea or saline water is obtained by the application of heat delivered by compressed vapour. Since compression of the vapour increases both the pressure and temperature of the vapour, it is possible to use the latent heat rejected during condensation to generate additional vapour. The effect of compressing water vapour can be done by two methods. The first method utilizes an ejector system motivated by steam at manometric pressure from an external source in order to recycle vapour from the desalination process. The form is designated Ejecto or Thermo Compression. Using the second method, water vapour is compressed by means of a mechanical device, electrically driven in most cases. This form is designated mechanical vapour compression (MVC). The MVC process comprises two different versions: Vapour Compression (VC) and Vacuum Vapour Compression (VVC). VC designates those systems in which the evapouration effect takes place at manometric pressure, and VVC the systems in which evapouration takes place at sub-atmospheric pressures (under vacuum). The compression is mechanically powered by something such as a compression turbine. As vapour is generated, it is passed over to a heat exchanging condenser which returns the vapour to water. The resulting fresh water is moved to storage while the heat removed during condensation is transmitted to the remaining feedstock. The VVC process is the more efficient distillation process available in the market today in terms of energy consumption and water recovery ratio. As the system is electrically driven, it is considered a “clean” process, it is highly reliable and simple to operate and maintain.

2.1.4. Freezing

Freezing desalination has been proposed as a method for desalination for several decades, only demonstration projects have been built to date. The concept is appealing in theory because the minimum thermodynamic energy required for freezing is less than for evapouration since the latent heat of fusion of water is 6.01 kJ/mole while the latent heat of vapourization at 100 °C is 40.66 kJ/mole.

2.1.5. Humidification-dehumidification

The HD process is based on the fact that air can be mixed with important quantities of vapour. The amount of vapour able to be carried by air increases with the temperature; in fact, 1 kg of dry air can carry 0.5 kg of vapour and about 670 kcal when its temperature increases from 30 °C to 80 °C. When airflow is in contact with salt water, air extracts a certain quantity of vapour at the expense of sensitive heat of salt water, provoking cooling. On the other hand, the distilled water is recovered by maintaining humid air at contact with the cooling surface, causing the condensation of a part of vapour mixed with air. Generally the condensation occurs in another exchanger in which salt water is preheated by latent heat recovery.

2.2. Single phase processes

In the single-phase processes, electricity is used for either driving high-pressure pumps or ionization of salts contained in the seawater. In this method membranes with very fine holes in the order of microns are employed. When the water is passing through this membrane, it gets purified and desalinated.

2.2.1. Reverse osmosis

Reverse osmosis (RO) is a membrane technical filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side.

2.2.2. Electrodialysis

Electrodialysis is used to transport solutions from one solution through ion-exchange membranes to another solution under the influence of an applied electric potential difference. This is done in a configuration called an electrodialysis cell. The cell consists of a feed (dilute) compartment and a concentrate (brine) compartment formed by an anion exchange membrane and a cation exchange membrane placed between two electrodes. In almost all practical electrodialysis processes, multiple electrodialysis cells are arranged into a configuration called an electrodialysis stack, with alternating anion and cation exchange membranes forming the multiple electrodialysis cells. Electrodialysis processes are different compared to distillation techniques and other membrane based processes (such as reverse osmosis) in that dissolved species are moved away from the feed stream rather than the reverse. Because the quantity of dissolved species in the feed stream is far less than that of the fluid, electrodialysis offers the practical advantage of much higher feed recovery in many applications.

3. Basic operational principle of simple solar still

The principle of the solar still is based on nature’s hydrological cycle. In the natural desalination process solar radiation is incident on the seawater and causes water to evaporate and the evaporated water rises in the upward direction of the earth's surfaces due to low density and moved by the airstream. When this vapour is cooled down to its dew point temperature condensation Process start and clean water comes down as rainfall. The fundamental process is liable for the nature's hydrological cycle. This same theory Evaporation and Condensation are utilized for the refinement of pure water from impure