CHAPTER I

INTRODUCTION

1.1 GENERAL

All over the world, the availability of clean water is going to become one of the most pressing resource issues. Fresh water is one of the prime elements responsible for life on earth. The origin and continuation of mankind is based on water. There is severe shortage of fresh water in the world today. In developing countries, lack of safe and unreliable drinking water constitutes a major problem. Drought and desertification are expected to increase the shortage of drinking water further. Drinking water consumption has been increasing with an ever increasing population. About 25% of the world does not have access to good quality and quantity of fresh water. The increasing population together with the increasing industrial and agriculture activities contributes to the depletion and pollution of fresh water resources. Hence, there is an essential and earnest need to get fresh water from the saline/brackish water in the earth. Nowadays pollution in rivers and lakes by industrial effluents and sewage disposal has resulted in scarcity of fresh water in many big cities described by Omar O. Badran and Mazen M. Abu-khader [1]. In this research work an attempt has been made to develop a solar thermal water distillation system with galvanised iron and black coated copper sheets using some accessories.

At the current trend of growth, it is predicted that the global population will reach 8 billion by 2025. Along with depletion and pollution of the existing water supplies, the growing world population leads to the assumption that two thirds of the population will lack sufficient fresh water by the year 2025. The average amount of fresh water per capita may still be enough to meet human needs, if it is properly distributed. But equitable distribution is not possible mainly for two reasons. The first is, two third of the global population lives in areas receiving only one fourth of the global annual rainfall and the second is, there is no systematic rainfall throughout the seasons or from year to year described by Bhanu Pratap Singh [2].
Water is a gift of nature and it plays a key role in the development of an economy and in turn for the welfare of a nation. Non-availability of drinking water is one of the major problems faced by both the underdeveloped and developing countries. Water is an abundant natural resource that covers three quarters of the earth’s surface. Although water covers approximately 70% of the earth's surface, supplies of potable water are rapidly disappearing. However, over most of earth’s water (around 97%) is found in oceans as salt water, contains too much of salt and cannot be used for drinking or growing crops or for most industrial uses.

The remaining 3% of all the earth’s water sources is fresh water and found in surface water bodies such as rivers, streams, lakes, ponds and underground. Less than 1% of fresh water is available within human reach and even this small fraction (lakes and rivers and water underground) is believed to be adequate to support life, vegetation on the earth and the rest is permanent snow cover, ice and permafrost in the polar region. A very small fraction, about 0.3% of the available water resources is available as fresh water narrated by Kargar Sharif Abad et al. [3].

1.2 WATER DESALINATION TECHNIQUES

The widely used desalination techniques are generally classified into thermal and membrane processes. Thermal processes require a source of heat and electricity, while membrane processes require a driving power (electricity) to maintain the high pressure needed.

In thermal desalination, salts are removed from water by evaporation-condensation processes. Membrane based techniques employ a membrane through which water diffuses with a high proportion of the salts being retained. However, these techniques require a large input of energy and are not cost effective for low demands of clean water demonstrated by Tiwari et al. [4] and Kalidasa Murugavel et al. [5].

Nowadays, various methods of desalination have been developed namely Multi-Stage Flash (MSF), Multi-Effect Distillation (MED) and Vapour Compression Distillation (VCD) while the latter class comprises Reverse Osmosis (RO), Nano Filtration (NF), Electro Dialysis (ED), Reverse Osmosis (RO), Multi-Stage Flash (MSF), Multi-Effect Distillation (MED) and Electro Dialysis (ED). These desalination units require fossil/electric energy sources.
Desalination is the oldest technology used by people for water purification. The desalination techniques like vapor compression distillation, reverse osmosis and electrolysis utilize electric power, which is not economic and also it has an indirect adverse effect on the environment due to the pollutants generated during power plant operations. Various technologies were invented for desalination from time to time and it has been accepted by people without knowing future environmental consequences. Conventional water purification using solar energy has become more popular because of its eco-friendly nature and low cost.

### 1.3 SOLAR STILL

![Sea Water](image1)  ![Solar Distillation](image2)  ![Drinking Water](image3)

*Figure 1.1 Concept of solar distillation*

The utilization of renewable energy has a flourishing future and plays an important role in the domain of brackish and seawater desalination in developing countries. Among that, the solar distillation is the most economical way to accomplish this objective. Figure 1.1 shows the concept of solar distillation. Solar stills are used to produce fresh water from brackish water by directly utilizing the sunshine. Solar energy is available in abundance in most of the rural areas and hence solar distillation is the best solution for rural areas and has many advantages of using freely available solar energy. It is a simple technology and more economical than the other available methods. The abundance of solar energy coupled with limited conventional water and
energy resources, makes solar desalination even more attractive. Desalination uses a large amount of energy to remove a portion of pure water from a salt water source. The solar still is a most favorable process for small compact water desalting. Different still designs have been used in different regions globally. Salt water (feed water) is fed into the process and the result is one output stream of pure water and another of waste water with a high salt concentration described by Kabeel and El-Agouz [6] and Bouchekima et al. [7].

![Diagram of the process of solar distillation]

**Figure 1.2 Process of solar distillation**

One of the techniques used by people for water purification is solar distillation. Safe drinking water from available water should be made using the technologies with limited financial resources and practices that minimize ecological disturbances. Many options are available to distillate the brackish/saline water. Among the non-conventional methods to purify the polluted water, the most prominent method is the “Solar Distillation”. Figure 1.2 shows the process of solar distillation and it explains the process of converting saline water into potable water by using solar energy. The heat energy obtained from solar radiation heats the water, water evaporates and then condenses as distilled water. This is the oldest method to get the potable water from
brackish or saline water by utilizing solar energy which is the most abundant natural resource in the world.

A study was performed by Ghassan A. Al-hassan and Algarni [8] to compare different types of solar systems for various applications in Jordan, according to their benefits and costs. Results showed that solar desalination was found to be a promising option and should be given priority in terms of research and development.

### 1.3.1 Principle of Solar Distillation

Distillation is one of many processes that can be used for water purification. This requires an energy input, as heat, solar radiation can be the source of energy. Solar stills use exactly the same process which in nature generates rainfall, namely evaporation and condensation. Nature itself provides most of the required fresh water through hydrological cycle. The essential features of hydrological cycle are summarized as the production of vapors above the surface of the liquids, then transport of vapors by winds, the cooling of air vapor mixture, condensation and precipitation. The basic principle of solar water distillation is same as the way nature makes rain. The principle of solar distillation is shown in the Figure 1.3.

![Figure 1.3 Principle of solar distillation](image-url)
The sun's energy heats water and the evaporated water, rises above the surface and is moved by the wind. Once this vapor cools down to its dew point, condensation occurs and the fresh water comes down as rain. This natural process is copied on a small scale in basin type solar still. Solar energy can directly or indirectly be harnessed for desalination. The solar stills are simple and have no moving parts. Solar distillation is one of the most important methods of getting potable water from brackish and sea water by using free energy supply from the sun. The use of solar energy is more economical than the use of fossil fuel in remote areas having low population densities, low rain fall and abundant available solar energy. To augment the productivity of the simple solar still, several research works are being carried out.

![Solar still diagram](image)

**Figure 1.4 Schematic of solar still setup**

Figure 1.4 shows the schematic of solar still setup. The solar still consists of an air tight chamber in which evaporation and condensation of water takes place simultaneously. It is constructed using concrete/cement, fibre reinforced plastic (FRP), glass reinforced plastic (GRP) or mild steel (MS) sheet or galvanised iron (GI) sheet with a top cover made of transparent material like glass or plastic etc. The inner surface of the rectangular base is blackened to absorb incident solar radiation more effectively. The top of the basin is covered with glass tilted and fixed so as to allow maximum transmission of solar radiation. The glass cover per
length solar radiation to enter into the solar still and absorbed by the blackened surface and further converted to water mass and enable condensed vapor to trickle down into troughs. The provision is made at the lower end of the glass cover to collect the distillate output.

The brackish or saline water is fed into the basin of the solar still for purification. The still is filled with the brackish water in a thin layer. The bottom and sides of the still are insulated properly to minimize the thermal losses to the atmosphere. The edges of the glass are sealed with tar tape so as to make the basin airtight. The entire assembly is placed on a stand structure made up of mild steel angles. The outlet is connected to a storage container through a pipe.

The distilled water from a solar still does not acquire the "flat" taste of commercially distilled water since the water is not boiled (which lowers pH). This allows for natural pH buffering that produces excellent taste as compared to steam distillation.

1.3.2 Single Basin Passive Solar Still

![Figure 1.5 Schematic of single basin passive solar still](image)

Figure 1.5 shows the schematic of single basin passive solar still. Solar stills can easily provide enough water in houses for drinking and cooking needs. The solar stills are simple and have no moving parts. The black coated absorbing plate contains the brackish water which is directly exposed to the solar energy.
conventional basin type solar still, the still consists of a shallow airtight basin lined with a black, impervious material, which contains brackish or saline water. Brackish or saline water is filled in the still basin which is painted black at the bottom. The brackish water is completely enclosed in an air-tight condition inside the transparent glass cover. The incident solar radiation passes through the transparent glass cover and is absorbed by the black painted galvanised iron sheet or aluminium sheet. The absorbed heat is then transferred to the water with no significant energy loss. The brackish water starts heating and evaporating, the formed vapor on the water surface starts moving in an upward direction as due to the created driving force (convective currents) due to the temperature difference between the water and glass cover ($T_w-T_g$).

When the water vapor comes in contact with the condensing surface (glass cover which is externally cooled) in order to improve the condensation rate, the vapor will condense at different small-size droplets of fresh water, then the condensate starts moving down along the inclined glass cover due to the gravitational force. Condensed water vapor trickles down into the trough and from there it is collected in the storage container. Finally, the condensate will be collected from the collecting channel which is connected to the collecting vessel.

The working of the solar still is based on the simple scientific principle of evaporation and condensation. The sun’s energy heats water to the point of evaporation. As the water evaporates, water vapour rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals and also eliminates microbiological organisms. When water evaporates, water vapor rises leaving the impurities (salts and microbes left behind) and condenses on the underside of the glass cover which is relatively cold. Condensed water vapor trickles down into the trough and from there it is collected in the storage container. The end result is water cleaner than the purest rainwater. The solar distiller only needs sunshine to operate. There are no moving parts to wear out. The water from the oceans evaporates, only to cool, condense and return to earth as rain. Solar stills mimic this natural process. Fortunately, the regions in most need of additional fresh water are those with the most intense solar radiation. Aayush Kaushal and Varun [9] reviewed the work on passive solar still and suggested that solar still is the best option for supply of drinking water in remote communities.
1.4 ADVANTAGES OF SOLAR STILL

The following are the various advantages of the solar still than the other methods available for water purification described by Singh and Tiwari [10]. The solar still can improve health standards by removing impurities from saline water supplies. Distillation also kills bacteria present in the water.

- The solar still is used to produce potable water from saline/brackish water sources containing dissolved chemicals.
- The solar still is an attractive alternative because of its simple technology, economical, low maintenance and low energy input.
- The solar still does not require any skilled workers.
- The solar still does not require electricity/fossil fuel.
- The solar energy used in this system is cost free and environment friendly.
- More than 90% of feed water recovery.
- It is more usable in coastal areas and particularly for anglers during fishing.
- It can indirectly help to reduce the investment in health plans for rural people in developing countries. Solar distillation is a cost-effective means of providing clean water for direct and indirect human consumption [four basic human needs (i.e. drinking, cooking, washing, bathing), industrial uses and green house cultivation].
- Where sea water is available, it can reduce the dependence on rainfall.
- Solar stills, operating on sea or brackish water, shall ensure supplies of water during the time of drought.
- Solar distillation generally uses less energy to purify water than the other methods.
- Solar distillation will permit settlement in sparsely-populated locations, thus relieving population pressures in urban areas.
1.5 OBJECTIVES

The main objectives of this research work are as follows.

- Design and development of an experimental setup for
  1. Passive solar still with galvanised iron sheet (PSS - GI).
  3. Modifying the passive single basin solar still with black coated copper sheet using pebbles, fins and vacuum pump (PSS - Cu, B, S, F, V).

- To study the performance characteristics of the above solar stills.

- To develop a thermal model for the above solar stills.

- Comparison and interpretation of experimental and theoretical results.

- Comparison and validation of experimental and theoretical results.

- Life cycle cost analysis of all the above models.

1.6 ORGANIZATION OF THE THESIS

All the works were carried out, results obtained and discussions described in five (5) chapters as mentioned below.

In Chapter I, the importance of water and current status of water issues in India have been highlighted. Also, various water desalination techniques, advantages of the solar still and its principle of working are discussed. The problem identification and objectives of this research work are also discussed.

In Chapter II, a review of literature is presented. Special attention is given to the passive solar distillation system made up of black coated copper sheet and modifying the passive single basin solar still with black coated copper sheet using pebbles, fins and vacuum pump (PSS - Cu, B, S, F, V). A summary of literature review has also been included in this chapter.

The description of experimental setup and details of different instruments used for data collection are discussed in Chapter III. The experimental procedure and
experimental uncertainties are also discussed. Thermal modelling of passive single basin solar still with black coated copper sheet using pebbles, fins and vacuum pump (PSS - Cu, B, S, F, V) has been discussed in detail. The life cycle cost analyses of various solar stills developed in this work are also discussed.

Chapter IV analyses the detailed results and discussion of this research work. All the solar stills developed during this work are compared daily, seasonally and annually and the result findings are discussed. The validation of thermal modeling of solar stills with the experimental results is also discussed. The life cycle cost analysis of all the solar stills by considering the maintenance cost, salvage cost, interest rate and life of solar still are discussed.

The research findings and conclusion derived from this research work are discussed in Chapter V.