CHAPTER 1

INTRODUCTION

1.1 ESSENTIALS OF WATER

Fresh water is one of the Earth’s most valuable renewable resources. It is the essence of life and is a basic human requirement for domestic, industrial and agricultural purposes. Sufficient drinking water resources are necessary for the development of any country. Water is not only indispensable to industrial development, to economic growth, to social wellbeing, but it is also indispensable for the preservation of natural resources. For a country, a region, a civilization, securing an adequate water supply has always been one of the essential prerequisites, not only to its development; but frankly, to its survival.

1.2 AVAILABILITY OF WATER

Nature, a very large - scale process of solar distillation, provides most of the required fresh water, through hydrological cycle. The important of supplying potable water can hardly be overstressed. More than two-third of the earth’s surface is covered with water. Most of the available water is either present as seawater or icebergs in the Polar Regions. As shown in Table 1.1, more than 97% of the earth’s water is salty; rest around 2% is frozen in glaciers and polar ice caps. Less than 1% fresh water is within human reach (Tiwari 2003). Even this small fraction is believed to be adequate to support life and vegetation on earth.
Table 1.1 Availability of water

<table>
<thead>
<tr>
<th>Water Source</th>
<th>Water volume in ml³</th>
<th>Percent of total water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>317,000,000</td>
<td>97.24</td>
</tr>
<tr>
<td>Icecaps, Glaciers</td>
<td>7,000,000</td>
<td>2.14</td>
</tr>
<tr>
<td>Ground water</td>
<td>2,000,000</td>
<td>0.61</td>
</tr>
<tr>
<td>Fresh-water lakes</td>
<td>30,000</td>
<td>0.009</td>
</tr>
<tr>
<td>Inland seas</td>
<td>25,000</td>
<td>0.008</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>16,000</td>
<td>0.005</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>3,100</td>
<td>0.0010</td>
</tr>
<tr>
<td>Rivers</td>
<td>300</td>
<td>0.0001</td>
</tr>
<tr>
<td>Total Water Volume</td>
<td>326,000,000</td>
<td>100</td>
</tr>
</tbody>
</table>

Large areas of our planet suffer from lack of or pollution of fresh water. These include traditionally dry regions such as deserts and modern industrial areas. The same problem also exists in remote areas and islands where in many cases fresh water supply by means of transport is expensive. One study of water scarcity trends estimates that approximately 6.3 billion people live on Earth, 400 million people now live in water scarce areas and the number of living in water stressed areas could grow to 4 billion by mid-century. The demand for potable water increased six-fold while the world’s population increased three-fold.

As the available fresh water is fixed on earth and its demand is increasing day by day due to increasing population and rapidly increasing of
industry, there is an essential and earnest need to get fresh water from the saline or brackish water present on or inside the earth. The worldwide problem is providing an adequate water supply for an increasing population and intensified agriculture and industry.

### 1.3 WATER POLLUTION

Man has been dependent on rivers, lakes and underground water reservoirs for fresh water requirements, but the use of water from such sources is not always possible or desirable on account of the presence of contamination and harmful organisms. The consumption of water is unfit for drinking, due to pathogens and salinity and is a major health hazard worldwide.

The need for water disinfection in the developing world is indisputable. Water-borne diseases cause about five million deaths per year, at least half of which are children. The average child experiences more than two episodes of diarrhea each year; frequent episodes of diarrhea leave victims weakened and malnourished, resulting in greater susceptibility to other diseases.

Water pathogens, water turbidity, local population density, availability, existing water disinfection, community structure, infrastructure issues, sanitation practices, hygiene practices, income and awareness of diseases are some of the reasons for water pollution, which have decreased the total amount of fresh water available for human consumption.

The major pathogens of concern, their sizes and associated diseases are listed in Table 1.2. Water turbidity also impacts the choice of water disinfection methods. Turbidity is a measure of the amount of solid particles suspended in water, commonly determined by light scattering and measured
in “Nephelometric Turbidity Units” (NTU). The turbidity of the well water is quite low (<10NTU), while the turbidity of dirty water and lake water varies widely (10-2000NTU). The turbidity is caused by suspended material such as small particles (eg. Bits of organic matter), fecal matter, or colloids (micron sized clay particles). These particles can reflect or absorb ultraviolet (UV) radiation, decreasing the effectiveness of UV disinfection.

According to World Health Organization (WHO), the permissible limit of salinity in water is 500ppm and for special cases up to 1000 ppm while most of the water available on earth has the salinity up to 10,000 ppm whereas the sea water normally has salinity in the range of 35,000 – 45,000 ppm in the form of total dissolved salts. Excess brackishness causes stomach problems and laxative effects. One of the control measures includes supply of water with total dissolved solids within permissible limits of 500ppm or less. One of the best methods for solving this water related problem is solar desalination.

Table 1.2 Water – borne diseases

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Pathogen class</th>
<th>Size of Pathogen</th>
<th>Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bacteria</td>
<td>0.5-2μm</td>
<td>Diarrhoea, cholera, enteric and typhoid fever, dysentery</td>
</tr>
<tr>
<td>2</td>
<td>Viruses</td>
<td>20-80nm</td>
<td>Hepatitis, polio, diarrhea, meningitis, lung diseases</td>
</tr>
<tr>
<td>3</td>
<td>Protozoa</td>
<td>4-20μm(cysts)</td>
<td>Giardiasis, amoebic dysentery, diarrhea</td>
</tr>
<tr>
<td>4</td>
<td>Helminths (worms)</td>
<td>0.03-2mm (eggs)</td>
<td>Round worm, guinea worm, schistosomiasis</td>
</tr>
</tbody>
</table>
1.4 DISPOSAL OF INDUSTRIAL EFFLUENT

The textile and tannery industries are facing lot of problems to dispose its effluents. Since these effluents are salty, treatment of such liquid is expensive. Usually they are disposing with a help of natural evaporation ponds. The land area required for such ponds are very high. Getting land nearby such industries are also very difficult. The population density is too high in an industrial area. The people living nearby such industries are facing lot of problems to get fresh water. So, it is planned to desalinate the industrial effluent water and salt water using solar desalination techniques to produce fresh water.

1.5 DESALINATION TECHNIQUES

Desalination can be achieved by using a number of techniques. Industrial desalination technologies use either phase change or involve semi-permeable membranes to separate the solvent or some solutes. Desalination methods may be classified into the following categories:

i) phase-change or thermal processes; and

ii) membrane or single-phase processes

All processes require a chemical pre-treatment of raw seawater to avoid scaling. Foaming, corrosion, biological growth and fouling and also require a chemical post-treatment. In Table1.3, the most important technologies in use are listed. In the phase-change or thermal processes, the distillation of sea water is achieved by utilizing a thermal energy source. The thermal energy may be obtained from a conventional fossil-fuel source, nuclear energy or from a non-conventional solar energy source or geothermal energy. In the membrane processes, electricity is used either for driving high-pressure pumps or for ionization of salts contained in the sea water.
### Table 1.3 Desalination processes

<table>
<thead>
<tr>
<th>Phase change processes</th>
<th>Membrane processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multi-stage flash (MSF)</td>
<td>1. Reverse osmosis (RO)</td>
</tr>
<tr>
<td>2. Multi effect boiling (MEB)</td>
<td>2. Electro dialysis (ED)</td>
</tr>
<tr>
<td>3. Vapour compression (VC)</td>
<td></td>
</tr>
<tr>
<td>4. Freezing</td>
<td></td>
</tr>
<tr>
<td>5. Humidification/dehumidification</td>
<td></td>
</tr>
<tr>
<td>6. Solar stills</td>
<td></td>
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</tbody>
</table>

Commercial desalination processes based on thermal energy are multi-stage flash (MSF) distillation, multiple effect boiling (MEB) and vapour compression (VC), which could be thermal vapour compression (TVC) or mechanical vapour compression (MVC). MSF and MEB processes consist of a set of stages at successively decreasing temperature and pressure. MSF process is based on the generation of vapour from sea water enters an evacuated chamber. The process is repeated stage by stage at successively decreasing pressure. This process requires an external steam supply, normally at a temperature around 100°C. The maximum temperature is limited by the salt concentration to avoid scaling and this limits the performance of the process. On MEB, vapours are generated due to the absorption of thermal energy by the seawater. The steam generated in one stage of effect is able to heat the salt solution at a lower temperature and pressure in the next stage. The performance of the MEB and MSF processes is proportional to the number of stages or effects. MEB plants normally use an external steam supply at a temperature of about 70°C. On TVC and MVC, after initial vapour is generated from the saline solution, this vapour is thermally or mechanically compressed to generate additional production.

Freezing and humidification/dehumidification processes also involve phase change. The conversion of saline water to fresh water by
freezing has always existed in nature and has been known to man for thousands of years. It is a separation process related to the solid-liquid phase change phenomenon. When the temperature of saline water is reduced to its freezing point, which is a function of salinity, ice crystals of pure water are formed within the salt solution. These ice crystals can be mechanically separated from the concentrated solution. Basic energy input for this method is the refrigeration system.

Humidification or dehumidification method also uses a refrigeration system but the principle of operation is different. The humidification or dehumidification process is based on the fact that air can be mixed with large quantities of water vapour. Additionally, the vapour carrying capability of air increases with temperature. In this process, sea water is added into an air stream to increase its humidity. Then this humid air is directed to a cooling coil on the surface of which water vapour contained in the air is condensed and collected as fresh water.

The other category of industrial desalination processes does not involve phase change but membranes. These are the reverse osmosis (RO) and electro dialysis (ED). The first one requires electricity or shaft power to drive the pump that increases the pressure of the saline solution to that required.

Among the non-conventional methods to disinfect the polluted water, the most prominent method is the ‘solar distillation’. It seems to be a promising method and alternative way for supplying small communities in remote areas and islands with water. In fact, it has been reported that for such places, solar distillation could be the most favorable way for water supply. Comparatively solar distillation method requires simple technology as no skilled workers needed and low maintenance due to which it can be used anywhere with lesser number of problems. Solar distillation is one of the
thermal desalination methods that attracted researcher’s attention due to its potential application in remote locations far from electricity grid.

Solar energy can be used for sea water desalination either by producing the thermal energy required to drive the phase-change processes or by producing electricity required to drive the membrane processes. Solar desalination systems are thus classified into two categories, that is direct and indirect collection systems. As their name implies, direct collection systems use solar energy to produce distillate directly in the solar collector, whereas in indirect collection system, two sub systems are employed (one for solar energy collection and one for desalination). Conventional desalination systems are similar to solar systems since the same type of equipment is applied. The prime difference is that in the former, either a conventional boiler is used to provide the required heat or electricity is used to provide the required electric power, whereas in the latter, solar energy is applied. The most promising and applicable renewable energy systems (RES) desalination combinations are shown in Table 1.4.

<table>
<thead>
<tr>
<th><strong>RES technology</strong></th>
<th><strong>Desalination technology</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar thermal</td>
<td>Multiple effect boiling, multi stage flash</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>Reverse osmosis, Electrodiagnosis</td>
</tr>
<tr>
<td>Wind energy</td>
<td>Reverse osmosis, Mechanical vapour compression</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Multiple effect boiling</td>
</tr>
</tbody>
</table>

### 1.6 SOLAR STILLS

As early as in the fourth century B.C., Aristotle described a method to evaporate impure water and then condense it for potable use. However, historically the earliest documented work on solar distillation was by Arab
alchemists in the 16th century. The first water-distillation plant constructed was a system built as Las Salinas, Chile, in 1872 (Soteris 2005).

Construction and operation of a single basin solar still is very simple. A black painted basin contains brackish or sea water. This is enclosed in a completely air tight surface formed by a transparent cover. Incident solar irradiance passes through the transparent cover and is absorbed by the black basin plate. Consequently, water contained in the basin heated up and evaporates in the saturated conditions inside the still. Water vapors rises until they come in contact with the inner surface of the cover. There they condense into pure water, run down along the cover bottom surface due to gravity and is collected by using glass stopper. The construction of this type of still can easily be performed by local people using locally available materials. The operation is simpler and requires no skilled person. No hard maintenance and require almost no operation and maintenance cost.

Moreover, people living in remote areas or islands, where fresh water supply by means of transport is expensive, face the problem of water shortage every day. Solar still presents some specific advantages for their use in these areas due to its easier construction using locally available materials, minimum operation and maintenance requirements and friendliness to the environment. It is really very fortunate that in times of high water demand, solar radiation is also intense. It is therefore beneficial to exploit solar energy directly by installing solar stills. Two major advantages that favour the use of solar stills are: clean and free energy, and friendly to the environment. Their main disadvantage, however, is the lower output of distilled water in comparison with other desalination systems. The production capacity of a simple type still is in the range of 2 to 5 l/m²/day only. This makes the system highly uneconomical.