SOLAR DISTILLATION

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Contents

Summary

This chapter describes the state of the art in solar distillation system, including water sources, water demand, and availability of potable water, purification methods and historical background. The internal and external heat and mass transfer relations; performance evaluation and analysis of solar distillation system are discussed in detail. This chapter also presents the various designs of passive, active and hybrid solar stills along with economic viability of passive solar stills. It is concluded that the double slope FRP solar still is most economical for domestic applications mainly for drinking and cooking purposes while the active solar still is more suitable for commercial applications.

1. Importance of Water

Water is the most abundant and important substance in nature. It is the principal component of life, health and sanitation. It is absolutely essential for life and vegetation. Though the freshwater availability in the land areas of the earth is more than adequate to meet the current water needs, it is becoming scarce with time, leading to severe water crisis in many parts of the world. This is attributed mainly to uneven distribution of water resources and steep rise in population from rural to the urban areas. Table 1 shows the per capita water availability in 1990 and projected per capita water availability in 2025. It is clear from the table that availability of water decreases to less than half for most of the countries and for some countries, like Tanzania, per capita water availability would decrease to one third of the water available in 1990.

Many organizations like United Nations Development Programme (UNDP), World Health Organization (WHO) and the World Bank are actively involved in promoting projects related to supply of freshwater. The Government of India has accorded a top priority to drinking water supply and in order to meet the challenge, has set up a technology mission, known as Rajiv Gandhi National Drinking Water Mission (RGNDWM).

The mission functioning under Department of Rural Development is responsible for water management and its scientific application. In India, large part of national resources is spent annually for providing basic infrastructure at the village level. However, due to non-scientific approach, these infrastructures are often deteriorated and fail to provide the desired services. RGNDWN has developed technologies suitable for water resources development. A widespread knowledge of scientific practices among the common people, in particular village level functionaries, helps in preventing wastage of water. Vital benefits such as sustained supply of potable water have been realized in drought prone areas adopting a scientific approach. The approach makes it possible to: (i) optimize the water use so that it can be made available in desired time and space, (ii) avoid wastage and (iii) make it economically viable.

In the developing countries, poverty, malnutrition, unsafe drinking water and an unsanitary environment are largely responsible for epidemic and deadly diseases. Diseases related to water and sanitation, have far reaching social and economic consequences. In India, water-borne diseases alone are said to claim 73 million workdays every year. The cost in terms of medical treatment and lost production is around Rs. 24,000 million (US $ 600 million) per year. More than 70 percent of Indian population lives in rural and sub-rural areas. India has nearly 559,553 villages out of which about 28% are reported to have no adequate potable water supply either due to chemical or biological contamination. The inhabitants in these areas face several problems, among which the lack of potable water being pre-eminent, as it is directly and indirectly responsible for health and economic problems.

A majority of Indian villages depend on unsafe water resources such as wells, ponds, lakes, rivers, unprotected springs and rainwater collections, which are prone to contamination and pollution. In certain places (desert and coastal areas) where only saline water is available, potable water has to be carried from distant places. There are many scattered small communities in the rural areas, which lack both safe drinking water and a reliable power source. Thus, they are forced either to use saline water or fetch the freshwater from several kilometers. Women and children often spend the whole day in fetching water from a distant source and as a consequence, children do not go to school and women lose their valuable time that could be devoted to economic activities. In many parts of India, level of salinity is as high as 5000 ppm or even more in the form of total dissolved solids. The excess salinity is prevalent in 12 states, namely Andhra Pradesh, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajathan, Tamil Nadu and West Bengal and three Union Territories; Pondicherry, Andaman and Nicobar Islands and Lakshadweep. Excess brackishness causes the problem of taste and laxative effects. One of the control measures includes supply of water with total dissolved solids within permissible limits (1500 ppm).

Country	**Per capita water availability (cubic meters per person per year)**	
	1990	2025 (Projected)
Algeria	705	380
Barbados	170	170
Burundi	660	280
Cape Verde	500	220
Comoros	2040	790
Cyprus	1290	1000
Djibouti	750	270
Egypt	1070	620
Ethiopia	2360	980
Haiti	1690	960
Iran	2080	960
Israel	470	310
Jordan	260	80
Kenya	590	190
Kuwait	10	10
Lebanon	1600	960
Lesotho	2220	930
Libya	160	60
Malta	80	80

Morocco	1200	680
Nigeria	2660	1000
Oman	470	470
Peru	1790	980
Qatar	50	20
Rwanda	880	350
Saudi Arabia	160	50
Singapore	220	190
Somalia	1510	610
South Africa	1420	790
Tanzania	2780	900
United Arab Emirates	190	110
Yemen	240	80

Table 1: Per Capita water availability in 1990 and projected per capita water availability 2025 (cubic meters / person / year)
Source: Anon (1995)

This is accomplished by several desalination methods like reverse osmosis, electrodialysis, vapor compression, multistage flash distillation and solar distillation, which are used for purification of water. Among these, the solar stills can be used as desalinators for such remote settlements where salty water is the only type of moisture available, power is scarce and demand is less than 200 m^3/day. On the other hand, settings of water pipelines for such areas are uneconomical and delivery by truck is unreliable and expensive. Since other desalination plants are uneconomical for low-capacity fresh water demand, under these situations, solar stills are viewed as a means to attain self-reliance and ensure regular supply of water.

1.1 Water Sources

More than two-thirds of the earth's surface is covered with water. Most of the available water is either present as seawater or as icebergs in the Polar Regions. Relative proportions of various forms of water and distribution of freshwater in the hydrosphere are given in Table 2 and Table 3, respectively. More than 97 percent of the earth's water is salty; rest around 2.6 percent is fresh water. Less than 1 percent freshwater is within human reach. Even this small fraction is believed to be adequate to support life and vegetation on earth. Nature itself provides most of the required freshwater, through hydrological cycle.

Water form	Relative proportion (%)
Oceans	97.39
Polar ice caps, glaciers	2.01
Underground water, soil moisture	0.58
Lakes and rivers	0.02
Atmospheric water vapor	0.001
Total hydrosphere (of which, freshwater is 2.6)	100

Table 2: Relative proportions of the various forms of water in the hydrosphere
Source: Purohit and Saxena (1990)

Water form	Relative proportion (%)
Polar ice, glaciers, etc.	77.23
Underground water (800 m)	9.86
Underground water (0.8 to 4 km)	12.35
Soil moisture	0.17
Freshwater lakes	0.35
Rivers and other waterways	0.003
Hydrated minerals	0.001
Biomass	0.04
Total	100

Table 3: Distribution of fresh water in the hydrosphere
Source: Purohit and Saxena (1990)

A very large-scale process of solar distillation naturally produces freshwater. Solar radiation falling on the surface of rivers, lakes, marshes and oceans is absorbed as heat and causes evaporation of water from these heated surfaces.

The resulting vapors rise as humidity of the air above the surface and move along winds. When the air vapor mixture is cooled to the dew point temperature, condensation may occur; and the pure water may be precipitated as rain or snow.

The essential features of this process are thus summarized as the production of vapors above the surface of the liquids, the transport of vapors by winds the cooling of air-vapor mixture, condensation and precipitation. This natural process is copied on a small scale in basin type solar stills.

1.2 Water Demand

Water is essential for human life. Every activity of man involves some use of water. The most important uses of water are in three sectors, namely (i) domestic, (ii) agriculture and (iii) industrial.

Figure 1a gives the percentage of world water use by different sectors for the year 1970 and 2000. In India, major water demands come from the agricultural sector, as it is clear from Figure 1b.

Domestic sector alone demands 6 percent of the total demand for water. Solar stills are generally used to meet small-scale demands. Hence they are used for the domestic purposes.

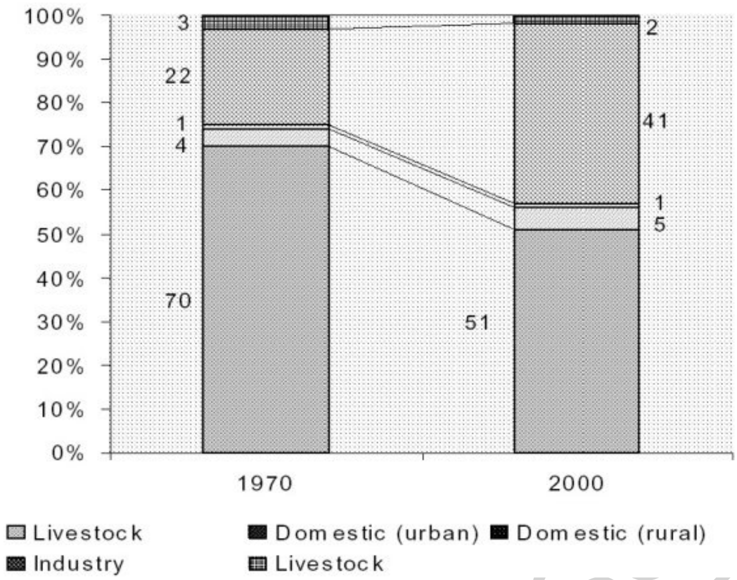

Figure 1a: World water use by different sectors for the year 1970 and 2000 [Speidel et al 1988]

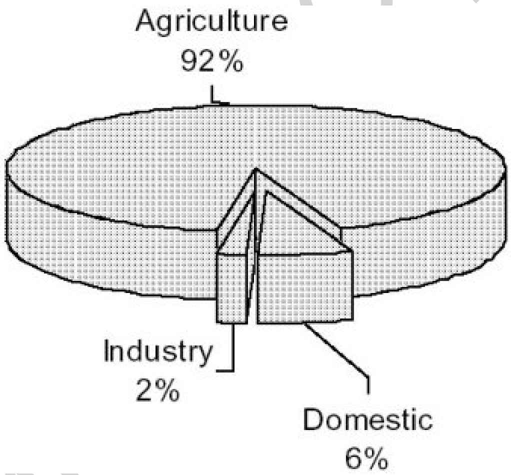

Figure 1b: Water distribution in various sectors in India

1.3 Drinking Water Quality

The quality of water required generally depends on the type of use. For instance, the public water supply should be free from pathogenic organisms, clear, pleasant to the taste, at reasonable temperature, neither corrosive nor scale forming and free from minerals which would otherwise produce undesirable physiological effects. In view of the wide range of variations in chemical composition of water available in different parts of India, it is hard to prescribe any rigid standards in Indian context. Taking the overall view, World Health Organization (WHO) has prescribed certain standards, which are given in Table 4.

WHO Test Standards	Permissive	Excessive
Physical turbidity (NTU)	5	25

Appearance		Clear
Chemical odor	Unobjectionable	Unobjectionable
pH	7 to 8.5	6.5 to 9.2
Total solids (ppm)	500	1500
Hardness (ppm)	300	600
Chloride (ppm)	200	400
Nitrate (ppm)	20	50
Iron (ppm)	0.3	1
Alkalinity	-	-

Table 4: WHO standards for physical and chemical quality of water

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