ABSTRACT

Three essential commodities for human beings to live are shelter, clothing and food. Out of these three commodities, items one and two are for external use while the third is for internal consumption by people and animals orally. Water is a vital item in every day’s life, which may not be considered to be a major food. It is used in many ways like preparation / cook food, many snacks, dilution of thick/strong liquid food, drink to quench thirst and to clean the utensils etc., prime importance is given to water and its clean or non-infecting nature.

This paper is a review on the possible use of alternate energy sources to produce potable water is presented. It concentrates on the supply of drinking water, especially with respect to the remote / rural arid places. In the case of remote villages in developing countries, there is a need for systems, which can produce clean potable water and development of effective methods to use energy.

In the review, most common processes that can be used to produce water are discussed. Humidification and De-Humidification (H & DH) appears to be very popular to produce water in small quantities. The literature reviews cover different H & DH techniques in which air is used as a medium to carry water in the form of vapor. In this paper, appropriate techniques reviewed include the usage of passive and active systems, which are operated with or without the support of solar energy. Fog harvesting, use of thermo-electric modules and solar chimney are also discussed in brief. A concept of producing water from a SWRO plant with wind power is also discussed.

Keywords: Essential Commodities, Water Harvesting, Alternate Energy, Humidification, De-humidification, Clean Portable Water.
INTRODUCTION

Claire [1] indicates, in accordance to one of the surveys of World Health Organization (WHO), that 97.5 percent of water on the earth is salty and the remaining 2.5 percent is fresh water. He also indicated that 70 percent of the fresh water is frozen in the polar icecaps and the other 30 percent is either as soil moisture or in underground aquifers. This leads to an estimate of less than 1 percent of the world’s fresh water (or about 0.007 percent of all water on earth) is readily accessible for direct human use. Naturally, scarcity of good water is not a new problem.

Contaminated drinking water is dangerous to health. A recent study by Lorna of WHO [2] indicates that every eight second a child dies from a water related disease and that each year more than 5 million people die from illnesses linked to unsafe drinking water or inadequate sanitation. Household water filters can’t remove all the parasites, viruses, bacteria and heavy metals. These factors indicate the need of developing or identifying appropriate techniques suitable for an arid place especially situated at remote villages in developing countries in order to (1) produce good clean potable drinking water, and (2) to conserve water and energy.

Literature reviews and identifies all the different types of experimental procedures with solar energy and test rigs that were used to produce water. Numerous technical papers can be sited in the literature in the fields of small and large-scale desalination of water. So, only a few papers, specifically to identify the techniques are presented here.

1. WATER PRODUCTION

1.1. Solar Stills and Humidification & De-Humidification

Widely found small-scale desalination units are solar stills with single or multiple effects arrangement. Arshad [3] reviewed the status of the solar distillers in brief. Solar stills operate with the principles of green house effect. Water is allowed to evaporate first and then the vapor is cooled to condense over an inclined surface. Water thus condensed would be collected in a trough as the product water. In most of the reports, it is found that the water production was in the order of 5 and 16 lit/m2/d. The major limitations of solar stills are their small capacities, presence of non-condensing gases, entrapped volatile gases, limited evaporation / condensing areas and use of glass. Schematic diagram is provided in the fig.1.

To overcome the above-mentioned limitations of solar stills, rugged pilot plants operating with the principles of H & DH of air, with / without the support of solar heaters, were designed and tested. Few reports are identified here and they are due to Dai et al., [4], Said et al., [5], Sousa et al., [6] and Naser et al., [7]. The maximum water production capacity was in the order of 1300 l/d.

1.2. H & DH Units with Special Designs

Böhner, [8] tested a set of solar powered desalination units. Area of the collector surface was 800 m². The two special flow arrangements used were open water cycle with closed air cycle and open & air cycle. Closed loop with a seawater spray was used.
for humidification. Water producing capacity of the plant was in the range of 2 to 20 \(m^3/\text{day}\). Figure 2 shows a schematic diagram of this arrangement.

Madani and Zaki [9] used a pair of heat pipes to produce water in the dehumidification column to produce water. The water production was in the range of 630 ml/h to 1250 ml/h. They performed tests on solar distillation also.

Gandhidasan and Abualhamayel [10] constructed a solar distiller, which makes use of a liquid desiccant to extract fresh water from the humid atmosphere. The experiments with solar stills gave raise to a yield of about 1.92 kg/m\(^3\). They also explained a system suitable for any arid place, called ‘Earth-Water Collector’. It was constructed on the ground and moist sand little below the surface was used to humidify air inside the distiller. Moisture in the humid air was then made to condense at the bottom of the glazed roof. It was reported that the yield in the arid areas was about 1.0 l/m\(^3\). Figure 3 is a schematic diagram explaining the principle of earth-water collector arrangement.

Mattheus et al., [11] used a greenhouse with an area of 10,000m\(^2\) and seawater spray of 0.1m\(^3/\text{s}\) for humidification. With seawater as the cooling fluid in a condenser (dehumidifier), product water obtained per day was in the range of 57.8 to 125.5 m\(^3\). Figure 4 shows a schematic diagram of this arrangement.

**1.3. New Concepts of Water Production**

In Gulf Countries, during the months of June to August, the environmental air is found to be very humid and foggy. Based on the environmental data from the year 1971 to 1980, [12], the range of atmospheric temperature and relative humidity, have been published by the Ministry of Agriculture and Water. Data published covered different seasons, especially during the summer (June, July & August) and winter (December, January and February) months. Three different regions in the survey are the Arabian Gulf, Inland Stations and Red Sea. Maximum and minimum values of the reported humidity and temperature are in the ranges of 13 to 78 percent RH and 4.5 to 36.8°C. The mean air velocity in the mountainous area is reported to be 12 to 15 km/hrs and in the escarpment mountainous area it is in the range of 7 to 13 km/hrs. Based on the above-mentioned facts on fog and wind speed, following concepts of obtaining water are presented.

a) At Chile, Philip [13] used an ingenious water-supply ‘fog harvesting’ system. Fifty ‘fog catchers’ were installed. At the top of a hill, huge nets were installed with the support of 12 eucalyptus pillars. Water containers were placed at the bottom. Water collected was in the order of about 1,900 gallons per day. It was reported that the water from the small-scale system to be clean, cheap and it was also said that the supply was steady. In the ‘Source Book on Alternate Techniques (OUS)’ [14] a report has been identified that water droplets in fog are collected in the net and run off into a conveyance system that carries the water to storage area. Technique is said to be the most effective of all water augmentation technologies for arid and mountainous areas. It was said that 30 percent of the mist contained in fog could be harvested. System is
under developmental stage. The cost of water produced by this method is estimated to be $ 3 / 1000 lit.

b) Ravindran [15] proposed the use of thermoelectric module, which is a solid-state device used to transfer heat primarily through the use of dissimilar semiconductor materials. Thermoelectric cooler is a heat pump. The cold junction becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another. A heat sink discharges the accumulated heat energy from the system. A DC power source pumps the electrons from one semiconductor to another. T.E. module and its heat sink can be used to dehumidify the humid air. The concept of using thermoelectric module as a producer of water cum heater / cooler, in a remote place, is depicted in the fig.5.

c). Another concept by Ravindran [15], which is suitable and ideal for the arid environment, is to make use of the wind power. A standalone wind mill can supply electrical energy sufficient enough to operate a standalone SWRO plant. Concept of standalone wind mill and SWRO is depicted in fig.6.

d). Another concept by Ravindran [15], which is suitable and ideal for the milk and juice manufacturing industry make use of heat to obtain the concentrates of the raw materials. The raw materials are milk or juice and certain preservatives; which vary depending on the manufacturing process. There are many by-products like skinned milk, butter, ghee, curd, buttermilk, cheese, milk powder, pulp, essence etc. In the process large quantities of water, nearly 30 to 60 percent of the raw material by weight would be evaporated and driven away into the environment. By having a heat exchanger in the exhaust, water can be recovered. A conceptual diagram is provided in the fig.7.

2. CONSERVATION OF WATER

2.1 Domestic Water Conservation

It is well known that ‘Water saved is water produced’. Trees and rainfall are somehow connected by nature. In order to improve the number of trees and plantations, another slogan, which gains popularity in India, is ‘One Family - One Tree’. Drinking water conservation by rainwater accumulation is becoming popular at various parts of India. Collected rainwater can be used for irrigation thereby the requirement on good water is reduced. Drip irrigation is suggested for the purpose. To store rainwater, tanks are suggested. A schematic arrangement to accumulate is shown in the fig.8. To improve the ground water level, soak pit type of arrangements are suggested in order to allow water to percolate in to the ground. Plastic bags thrown in open, over a long period of few decades, would form an impermeable layer in sand or soil. Damages caused by the layer would be totally non-recoverable. As plastics are not biodegradable, use of bags made of biodegradable materials like paper or cloth is encouraged.

One of the main rural needs is preservation of vegetables. To preserve vegetables in their good conditions many methods are being used in the rural places. They are drying (with hot air, fire or solar),
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pickling (in salt or sugar) and refrigeration [16]. By adopting the first two methods, taste of the commodities would suffer slight loss of aroma and taste. To use refrigeration systems, electricity is essential, which possibly may not be available in abundant at rural sites.

2.2 Conservation of Water in Existing Industries

Ismail and Matrawy [17] performed experiments with an air washer to conserve water. Recovery of water was from a dehumidifier placed in a duct. They used heat exchangers of finned type. Yield of the dehumidifier was found to be in the order of 10 kg/hr.

Aly [18] collected water from an absorption air-conditioning system, which operated with LiBr and H₂O. The absorption refrigeration unit was operating with generator temperature of 300°C. Waste heat from a nearby facility was used to run the system. The comfort air condition system produced a supply of fresh water of 29 l/d as a by-product. Vapor absorption units are nowadays available with capacities of 30 tons and the maximum capacity would be in the order of 1000 tons. Solar powered vapor absorption systems are readily available in the market. Schematic arrangement of solar powered unit is shown in the fig.9.

Tewari [19], reports on BARC’s low temperature evaporation (LTE) desalination plant, which uses waste heat. As the energy cost component is a major fraction of the desalinated water cost, utilization of waste heat as energy input for seawater desalination is an attractive option. It is one of the eco-friendly ways to produce desalinated water as it does not require chemical pre-treatment of feed seawater. Ocean thermal energy can also be utilised for sea water desalination. The desalination unit essentially consists of three portions i.e. heater, separator and condenser. In the heater shell, vertical tubes are used. Feed sea water enters the unit at the bottom of the tubes and partly evaporates by the time it comes out from the top. After water and vapour mixture come out of the tubes, the vapour rises through the vertical shell, enters the horizontal tube bundle kept at the top of the vertical shell and condenses around the tubes (which are cooled by sea water flowing inside) producing desalinated water. The product water is pumped out. Figure 10 shows the schematic diagram of LTE desal unit.

Solar PV based Water Treatment Systems BARC is engaged in developmental work on desalination systems based on solar energy. Small and community level RO and UF units are developed for producing safe drinking water. Figure 11 shows the schematic diagram of PV based small scale RO and UF units.

Community size RO plant water conservation becomes an issue when the natural recharge rate of the source is slow as in the case of ground water. For this reason, a significant fraction of the concentrate stream (which otherwise is rejected) is recycled back, so that fresh feed as well as discharge volumes can be minimized. In the case of low saline (1000 ppm) brackish water, the concentrate also can be used for non-potable purposes, if the product recovery is kept minimum. This would prevent wastage of water by way of reject disposal. Figure 12 shows the schematic diagram of Community level RO plant along with PV panels (250 LPH).
Dr. Irving Moch, Jr., [21] had developed a concept of ‘Solar Chimney’. Solar Chimney has a very large green house, to cover several acres of land, possibly in a circular shape. It has an inclined glass roof, and has a long chimney, which houses a wind turbine. As the hot air flows from the green house through the chimney the wind turbine shall produce power and runs an electrical generator. Seawater or the brackish water will be sprayed to the plants and also to evaporate the water to produce water vapour, which in turn shall condense over a heat exchanger, at the water inlet. Thus potable water will be produced. The final products of the plant will be (1) Electric power, (2) Potable water and (3) Vegetables.

CONCLUSION

As numerous technical papers can be sited in the literature, only a few literatures, specifically to identify the techniques are presented here.

Surveys of the appropriate techniques are reviewed in two categories, firstly to produce water and secondly the conservation of water. To be more relevant to the topic, only the experimental reports have been reported.

The techniques covered do cover many appropriate technologies developed at different parts of the world. They can be used according to the local conditions of the arid environment and needs.

It is worth mentioning that the technique of humidification and dehumidification will find its applications in the other fields like (i) Development of a small mobile water chiller / heater (ii) Off-road land-transport vehicles (iii) Land survey camps; (iv) Ships (v) Off Shore platforms, (vi) Emergency situations, (vii) Special military operations etc.

REFERENCE

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20. Dr. Irving Moch, Jr., one day Training Workshop on, ‘Membrane Desalination Technology in Practice’, training workshop organized by I. Moch & Associates, Inc., USA, Eng. Mohammad Amin Saad, Masar Inc., Tech., USA, , 28th October, 2002
APPENDIX

Fig. 1. Passive Solar Still Arshad [3]

Fig. 2. Humidification and De-humidification Unit, Böhner /8/
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Fig. 3. Principle of Earth-Water Collector
Gandhidasan [10]

Fig. 4. Active Green house, Mattheus et al., [11]
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Fig. 5. Concept of using TE System at a Remote Site
Ravindran [15]
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Fig. 6. Wind Mill & SWRO, Ravindran [15]

Fig. 7. Recovery of Water in a Process Industry, Ravindran [15]
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Fig. 8. Rainwater Accumulation

Fig. 9. Vapor Absorption System to Produce Water, Aly [18]
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Fig. 10. LTE Desalination using Waste Heat, Tewari [19]

Fig. 11. PV based small scale RO and UF units, Tewari [19]

Fig. 12. Community level RO plant along with PV panels (250 LPH)
Fig. 13. The concept of Solar Chimney