POTENTIAL USE OF SMALL-SCALE DESALINATION UNITS IN REMOTE ARID LOCALITIES

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ABSTRACT
Water and energy are the two most fundamental ingredients of modern civilization. As the world's population grows in number and affluence, the demands for both resources are increasing faster than ever. According to the World Health Organization, approximately 2.4 billion people live in highly water-stressed areas. Reports on the availability of potable water in Africa have listed Algeria among 17 African countries affected by water shortage. In theory, the current water availability per capita in Algeria is 500 m^3, down from 1, 500 m^3 in 1962. It is projected that it will further reduce to 450 m^3 in 2020. Algeria abounds with natural resources such as oil and gas. However, Algeria is lacking in one very essential resource: water. The lack of fresh water in different remote parts of Algeria hinders the development of the communities in these areas. Fortunately, the solar potential of Algeria ranks among the highest in the world. The annual sunshine duration reaches 2000 hrs all over the territory and 3900 hrs in the Sahara. The received energy is 1700 kWh/ m^2/year in the north, 1900 kWh// m^2/year in high plains and 3000 kWh// m^2/year in the Sahara. This makes solar distillation a feasible solution to the problem in these areas. Several techniques for sea water (brackish water) desalination are now in use. But solar distillation remains the most economic and effective technique for plants with small capacities, having low investment and operation costs. Considerable attention has recently been given to the use of solar energy in sea and brackish water distillation. The work described below falls within an area of international interest as it deals with the optimum use of renewable energies. This work provides studies dealing with small scale distillation for low-density population areas using solar energy.

KEYWORDS: Solar desalination; Solar energy; Arid zones; Desert climatic conditions; Water shortage.

1. Introduction

In the past century, global water consumption levels increased almost tenfold, reaching or exceeding the limits of renewable water resources in some areas, such as in the Middle East and North Africa. The earth's existing freshwater resources are under heavy threat from overexploitation, pollution and global warming. Climate change is expected to account for about 20% of the global increase in water scarcity this century. According to recent reports, 50% of the world population will be in need for fresh water by the year 2030 [1].

The number of people without access to clean, reliable and affordable water needs to be reduced significantly in order to achieve the Millennium Development Goals.

The current global capacity of more than 15,000 desalination plants with a total capacity of 32 million m^3 is sufficient to supply about 160 million people with drinking water at a gross water use of 200 L/capita/d, this is equivalent to only 7% of the word's coastal population

In the last years, the drought phenomenon in almost all the southern Mediterranean parts has resulted in an intensive exploitation of ground water, which has dramatically diminished the fresh water potential. Thus, the water availability has become a crucial obstacle to the social and economical development of these countries [2].

Rainfall is the most important parameter in the water potential evaluation of these areas. It varies from over 2000 mm/y on the heights near the Mediterranean coast to less than 100 mm/y in the northern Sahara and much less than that in the deep Sahara. Fortunately, underneath this Saharan region lies a huge reservoir of underground brackish water. Its water is characterized by high temperatures which can reach 60°C and over, corrosive aspect due to the presence of H_2S and CO_2

and a salinity of 1-2 g/L, reaching 5 g/L in certain places. The depth of these waters varies from 100-1000 m. Furthermore, this region of the world disposes of a great amount of saline water along the long seacoast of the Mediterranean. The use of water desalination for domestic use has therefore become inevitable [3].

The southern arid and semi-arid zones benefit from an important solar renewable energy potential that could be used for small capacity needs, especially because the population is scattered in sparse communities. This possibility is illustrated by some experimental studies of small desalination units operated by solar energy undertaken in real sites in the remote lands. A homogeneously adequate and rational strategy must be put into action by taking into account the potentialities and compromises of nature.

2. Physical water scarcity worldwide

The physical evidence of water scarcity can be found in increasing magnitude around the world, affecting rich and poor countries alike. Today, nearly 40% of the world's population live in water scarce conditions, and this situation could worsen if current growth trends continue. The manifestations of pervasive water poverty include millions of deaths every year due to water-related diseases, political conflicts over scarce water resources and degradation of aquatic ecosystems especially in the third world nations. Nearly, 50% of all wetlands have already been lost and dams have seriously altered the flow of about 60% of the world's major river basins [4].

Water scarcity is not simply a factor of absolute quantity; it is rather, a relative concept comparing the availability of water to actual use. However, scarcity may exist in water-abundant areas if there is a heavy demand.

Many semi-arid and arid regions in the world suffer from serious structural water shortages, which impose constraints on economic, social and human development. This is especially true in the Middle East and North Africa, where most of the countries of the region are facing a chronic water shortage. This is partially due to a rather low efficiency of water distribution and use, which in many cases does not reach present state of the art. It is also due to the continuous growth of population and economy, which requires more water for more people and for new cultural, economic and industrial activities.

In Algeria for example, the demand for fresh water is growing at 4 to 5% per annum. Water scarcity is aggravated by high population growth. With an annual growth rate of 1.7%; by the year 2020, the population is expected to reach 46 million. Clearly by then, the country will face serious water shortages [2, 5, 6]. As displayed in Figure 1. Algeria is well classified amongst dry countries.

According to some reports, slum dwellers, for example, typically pay 5-10 times more per unit of water than do people with piped water, and in rural households, women and children may spend the majority of their day fetching water from distant, and often unsafe, sources [1]. Numerous low-density population areas lack not only fresh water availability, but in most cases, electrical power grid connections as well.

Furthermore, severe ecosystem damage may be caused if water abstraction rates exceed natural renewal rates, leading to a depletion or salinization of water stocks and land desertification.

Although this region have an abundance of year-round solar radiation, most desalination plants currently use conventional non-renewable energy sources with associated carbon dioxide emissions contributing to global climate change.

During the last few years, political support for renewable energies has been growing steadily and continuously both at the national and international levels. One hundred and fifty-five countries, have signed the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro on June 1992. Countries which signed the UNFCCC in 1997 agreed on the Kyoto Protocol and committed themselves to reduce emissions of GHG to at least 5% below their average 1990 levels by 2012 [7].

According to some estimates, each cubic meter of water generated in a RO plant, using fossil fuel (oil), about 3 kg of CO_2 is produced. Efforts are being made to reduce the per capita generation of carbon. The Kyoto protocol requires the global carbon emissions to drop to 0.2–0.7 ton C/cap/yr.

The current values are 0.3 in developing countries, 5.5 from USA and 2.5 from Western Europe [8]. To reduce the CO_2 production, renewable energy sources, such as solar-generated power, could be used. Solar energy is available when demand for water is high (day time during summer), which is advantageous. This could be important for remote lands where it is not economical to extend an electrical grid.

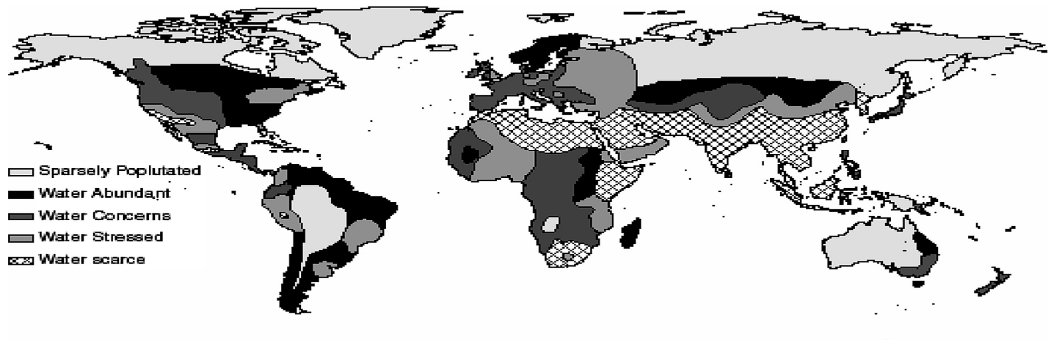

Figure 1: Projected worldwide water scarcity through 2020

3. Process selection

Desalination of brackish and seawater is a means by which modem technology can offer life to those regions where lack of fresh water hinders development. For instance, in some arid regions it was found more economical to install solar stills in locations farther away than 80 km from the fresh water source, than to supply it by transport means.

The economic limits for desalination compared with transport of drinkable water by piping from long distances must also be taken into consideration. When the demand for fresh water is small, (up to 40 m^3/d) as in desert remote lands, it is highly uneconomical to install long pipelines to supply fresh water to the region. By employing solar distillation techniques water could be supplied at less than half of the cost by piping [9].

In general the most important considerations for selecting any desalting process for remote small communities are:

- the socio-cultural setting of the community,
- the lack of nearby water resources and water conservation facilities,
- the lack of appropriate technical skills in the community,
- the cost of supplying fresh water by other methods,
- the quantity of fresh water required,
- the impact of increasing fuel prices which becomes very serious for small communities,
- the availability of electric power close to the site,
- the availability and cost of maintenance facilities and labor at the site, as well as
- the availability of waste heat which is also an important factor for a proper selection.

4. Desalination

Since about a decade, the exploitation of freshwater in MENA region has surpassed the available renewable surface and groundwater sources, and the deficit is poorly covered by over-exploiting the groundwater resources. Desalination has become an imperative and inevitable solution to overcome its current shortage of potable water.

Most directly concerned countries are now considering desalination of seawater or brackish water as an important source of water. Desalination of seawater is the technology predominantly used for easing the problem of water scarcity in coastal regions. It accounts for a worldwide production capacity of 24.5 million m^3 /day. Brackish water presently, accounts for 22% and seawater for 58% of the water produced by desalination technologies [10].

5. Desalination and energy

Desalination plants require significant amounts of thermal and/or electrical energy depending on the process. About 0.7 kWh/m^3 is theoretically the minimum energy required to obtain fresh water from seawater. In reality, energy use for seawater desalination is in the range of 3-15 kWh/m^3 with the older distillation plants at the top end of this. For one cubic meter of water produced, 12 kWh of thermal energy and 3.5 kWh of electrical energy are required in MSF plants, which have a maximum operation temperature of 120 °C. These figures are lower for MED plants, which operate at lower temperatures (<70 °C) and require 6 kWh of thermal and 1.5 kWh of electrical energy per cubic meter. The RO process requires between 4 and 7 kWh/m^3 depending on the size of the plant and energy recovery systems installed. For example, more than 30% of unit production cost of RO desalinated water is attributed to energy costs [11, 12]. Therefore, a small change in energy prices can seriously affect the unit production costs.

Consequently, desalination has been seen as a very energy intensive and expensive process. A number of countries, mainly in the Arabian Gulf, using desalination have significant domestic fossil energy sources. These countries usually ***subsidize*** the provision of natural gas to power plants and thus subsidize indirectly the cost of electricity and steam used for desalination. This is also the case in Algeria and Libya. Energy subsidies distort the choice of desalination processes in favor of energy-inefficient technologies. Desalination using renewable energy is still at an early stage of development.

6. Desalination technologies

Table 1 shows some of the available desalination technologies. Thermal technologies have higher total energy consumption than membrane technologies for desalination 13 kWh/m^3 compared with 5 kWh/m^3). However, thermal desalination plants can make use of the waste heat of power stations, which can reduce their energy demand. Another advantage of thermal desalination is that its performance is unaffected by feed water salinity. For high-salinity feed water, membrane technologies have a lower recovery rate and hence higher specific energy consumption. Another aspect in favour of thermal desalination is that large-scale RO plants can cause pollution due to chemicals added to the brine rejects (hydrochloric or sulphuric acid, anti-scablands, etc.) that are disposed into the sea, whereas this is not the case for thermal desalination processes [13, 14].

Table 1: Thermal desalination technologies

Thermal desalination	Membrane
Multistage flash (MSF)	Reverse osmosis (RO)
Multiple effect distillation (MED)	Electro-dialysis reversal (EDR)
Vapor compression (VC)	

7. Environmental and health aspects of large scale desalination plants

Although desalination of seawater offers a range of human health and socio-economic benefits by providing a constant supply of somewhat high quality drinking water, ***serious concerns are raised*** due to potential negative impacts, in particular during the operating phase of the plants. These are mainly attributed to:

- the concentrate and chemical discharges, which may impair coastal water quality and affect marine life, and
- air pollutant emissions attributed to the intense energy demand of the processes.

Other impacts of usually more limited nature include: noise, visual disturbance, interference with public access and recreation, possible impacts from seawater intakes, as well as various environmental impacts during the construction phase and potential impacts from accidental spills.

Within the desalination plant, the feed water will be subjected to various processes, which lead to changes in its physical and chemical properties [15-17].
For instance, the use of different chemicals and additives will change the chemical composition of the water. As a result, the desalination plants discharges are not only the concentrated brine, but also other aqueous effluents such as washing waters and pretreatment chemicals (Figure.2).

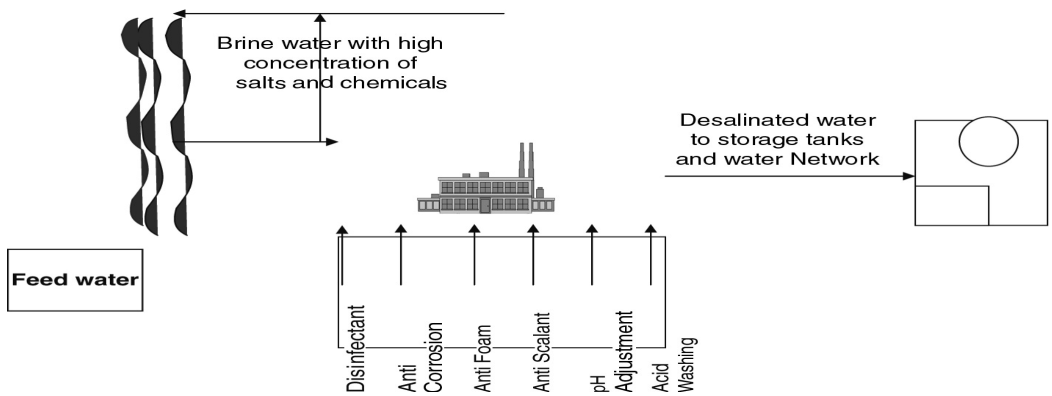

Figure 2: Schematic representation of inputs and outputs of desalination plants.

8. Renewable energy as energy source for desalination

Green energy is typically defined as energy produced and used in ways that have minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention in recent years. A great amount of renewable energy potential, environmental interest, as well as economic consideration of fossil fuel consumption and high emphasis of sustainable development for the future will be needed. Nearly 20% of all global power is generated by renewable energy sources.

More than 50% of world's area is classified as arid, representing the rural and desert part. Most inhabitants of such areas do not have access to grid electricity and are in need of drinking water and water for livestock or irrigation. They obtain fresh water from borehole wells traditionally or by means of water pumps, which are usually driven by diesel engines. Given the abundance of solar and other renewable resources, these rural needs represent a potential market for renewable energy technologies.
A growing number of people in these remote areas are starting to use renewable energy technology to obtain potable water, irrigate their land and light their houses, thus improve their living conditions. The renewable energy projects are tools for the management of reserves and sustainable development of desert communities.
Large parts of the Middle East and North Africa (MENA) region are characterized by arid and semiarid environments and face severe shortage in water. Many countries in this region relied almost 100% on desalination technology such as Qatar and Kuwait. Desalination is an energy intensive process and energy requirements are huge since desalination plants are high tonnage plants. Presently, these energy requirements are met with very expensive fossil fuels which continue to increase in price and greatly contribute to global warming. It is therefore, an essential obligation in the very near future to look for alternative energy sources to meet the growing demand for desalination in these countries. Renewable energy looks the most obvious choice especially solar energy since it is abundantly available in this region [17, 18, 19].

9. Desalination with solar energy

The availability of data on solar radiation is a critical problem. Even in developed countries, very few weather stations have been recording detailed solar radiation data for a period of time long enough to have statistical significance. Reliable radiation information is needed to provide input

data in modelling solar energy devices and a good database is required in the work of energy planners, engineers, and scientists.
In general, it is not always easy to design solar energy conversion systems when they have to be installed in remote locations.

- Firstly, in most cases, solar radiation measurements are not available for these sites.
- Secondly, the radiation nature of solar radiation makes difficult the computation of the size of such systems.

While solar energy data are recognised as very important, their acquisition is by no means straightforward. The measurement of solar radiation requires the use of costly equipment and manpower. Consequently, adequate facilities are often not available in developing countries to mount viable monitoring programmes.
Owing to rapidly rising oil prices and greenhouse gases, clean and renewable energy sources, such as solar energy, are receiving greater attention in many fields such as heating, cooling and ***desalination applications*** in developing and developed countries alike.

Solar energy is the most abundant natural resource in most Mediterranean and Middle East regions. The insolation time over the quasi-totality of the southern Mediterranean zone exceeds 2000 h annually and may reach 3900 h (Sahara). The daily obtained energy on a horizontal surface in these areas is about 1700 kWh/(m^2.y) and could reach 3000 kWh/(m^2.y) in the Sahara regions.
Many coastal regions and all inland areas in the Mediterranean countries lack adequate fresh water supply. The logical answer to the problem is solar desalination of available seawater or brackish water [20, 18, 8]. Cheap fossil fuels and the tolerated level of CO_2 accumulation in the atmosphere hindered the competitiveness of solar desalination. Today, both fuel prices and CO_2 emissions are on the rise.
The integration of renewable resources such as solar in desalination and water purification seems to be attractive and alternative way for supplying small communities in remote areas with water, this is because these technologies have low operating and maintenance costs.

10. Coupling photovoltaic cells with small RO plants:

Small capacity desalination units utilizing the Reverse osmosis (RO) technology and powered by photovoltaic (PV) cells, may represent a good answer for providing freshwater to small communities in isolated arid areas with high solar irradiation and having access to the sea or brackish water. The use of photovoltaic cells as a source of power is a promising choice under such circumstances due to [13, 17, 19]:

- Modularity: this feature avails system enlargement whenever needed,
- Reduced operation and maintenance cost, especially in the case of battery-less systems,
- Low noise level: as a power generating system, solar panels have no rotating parts. The only noise would be from the pump. Without batteries, the system would only run in daytime and would not disturb people at night.
- Long life: currently, solar panels are guaranteed to stay in service up to 20 years, and could withstand harsh environments.
- Desalinated water from small plants can be distributed through tankers or stand posts, thus limiting the use of this valuable commodity to drinking and cooking, while brackish water can be used for other purposes.
- Environmentally friendly: CO_2 emissions normally accompanying burning of fossil fuels in conventional power plants do not exist.

Nevertheless, the main limitations of the small RO plants are:

- The huge ground area normally required for solar panels, especially when the power demand is high, represents a limiting factor which negatively affects their widespread use.
- An important consideration in using solar panels in hot environments is the performance deterioration of crystalline silicon solar cells with increasing temperature where panel performance drops by about 0.4% per °C.
- A more serious problem usually encountered when using solar panels for powering desalination units in remote areas is the need for a backup system to enable powering the desalination unit by night and during blackout hours (cloudy conditions may continue for days).
- However, some small plants could occasionally face breakdowns because of limited community capacity to maintain them and the frequent absence of technicians on the site.
- The choice of an appropriate, low-maintenance technology such as electro-dialysis is therefore necessary for these plants.
- One difficult problem with any inland desalination is the disposal of brine, which can constitute a significant additional cost.

11. Portable small-scale solar distillation units

Most of the locations in many geographic remote areas are isolated and are thinly populated. These sites often use unfit brackish groundwater or surface water where freshwater is unavailable or its supply varies seasonally.

It is generally observed in these lands that one or more members of the family, in addition to bringing firewood needed for cooking, are always kept engaged in fetching water from distant, and often unsafe sources; spending much human energy which otherwise could be used for some productive purpose.

The lack of providing potable water to these small isolated communities is seriously menacing their very existence. Urgent solutions should be found to avoid massive unplanned immigration waves of these communities to the already densely populated big cities.

Small-scale brackish water distillation can make a considerable contribution to secure freshwater supplies for these rural communities.

Nomads, for example, are constantly on the move following the graze for their flocks. Solar distillation stills are characterized by their small size. Probably their greatest advantage is that, they can be easily transported by the moving nomads.

11.1 Earlier work on solar distillation

The dream of transforming unsuitable water into freshwater for man's use recurs throughout history. The first recorded instance of this was by Arab Alchemists in the sixteenth century who may have actually succeeded in producing small quantities of solar distillate. The French chemist Lavoisier used a concentrator of solar energy for the distillation of the contents of a flask. The modern history of solar distillation began in the second half of the nineteenth century probably due to the industrial production of glass sheets.

The first major solar distillation project was built and operated for the purpose of supplying drinking water for the mules used in transporting ore and supplies to and from the nitrate mines in Las Salinas, Chile 1872. The basin had a total area of 4,767 m^2 and was covered with glass. Brackish water was used as feed. The plant was in operation for about 40 years and yielded more than 4.9 kg of distilled water per m^2 of the still surface on a typical summer day.

11.2 Principles of a solar still

Solar still is a device to desalinate impure water like brackish or saline water. It is a simple device to get potable/fresh distilled water from impure water, using solar energy as fuel, for its various applications in domestic and industrial sectors. The basic concept of using solar energy to obtain drinkable fresh water from salty, brackish or contaminated water is quite simple. Water left in an open container will evaporate into the air. The purpose of a solar still is to capture this evaporated (distilled) water by condensing it onto a cool surface.

Solar stills consist of an airtight space, in which salt water evaporation and vapor condensation are performed simultaneously. Solar energy penetrates through a tilted transparent cover and is partially absorbed by salt water in a basin below the air space. Thus the water is heated to a temperature higher than that of the transparent cover, but lower than the water's boiling point. Accordingly, the air-vapor mixture at the surface of the salt water has a higher temperature and lower density than the air-vapor mixture immediately beneath the cover. Convection currents are formed between the water surface and the cover. Gliding over the salt water surface, the air-vapor mixture is saturated with water vapors, moves upwards, is cooled by contact with the cover and its vapors are partially condensed. Then the cooled air-vapor mixture moves back to the water surface again. The distillate is collected in gutters along the lower sides of the transparent cover.
This process takes place in narrow layers on top of the water surface and beneath the cover surface. The bulk of the air mass does not participate in the process. Therefore, it is advantageous to keep the distance between the water surface and the cover, and at the same time the angle between the cover and the horizontal, as small as possible. The larger the temperature difference between water surface and cover, the more intense becomes the circulation.

Heat losses occur at several places, e.g. solar radiation is partly reflected from the outside and inside surfaces of the cover, as well as from the water surface and bottom. Also, some radiation is absorbed by the cover. The remaining radiation is absorbed mainly by the salt water and partly by the lining. Most of the latter heat is transferred to the overlying water and only a small part is lost by conduction to the ground underlying the basin. The heat loss by the cover to the outside air is necessary to keep the cover cool and thus maintain operation.

Mass flow balances for solar stills involve the quantity of feed water introduced into the still and the amounts of water leaving the still in form of distillate collected, blow-down, brine leakage, distillate leakage and water vapor loss from eventually not tight places. Figure.3 combines all these components in a simple solar still design.

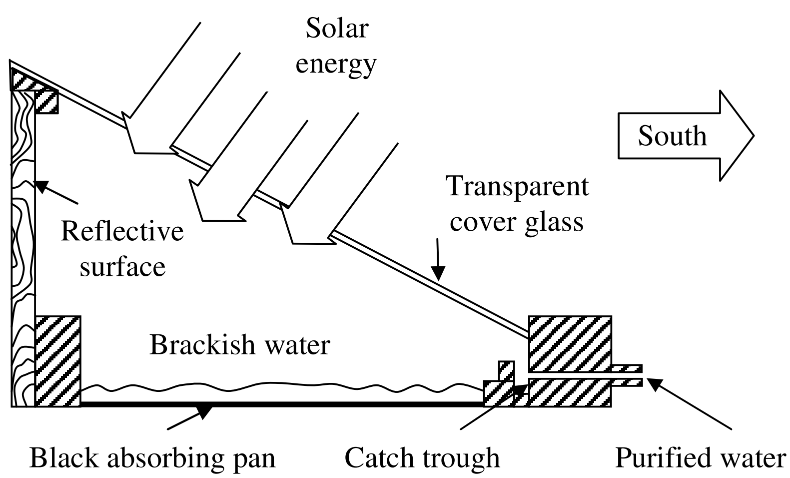

Figure 3: A simple solar still design

The overall efficiency of a solar desalting unit is often determined by, the ratio of product condensate to the theoretical amount of salt water expected to vaporize, i.e., the ratio of the heat of evaporation of the distillate to the solar heat reaching the apparatus.

The productivity of a solar still expresses the amount of distillate produced per unit area of the water surface. It is a function of the brine-surface temperature and the Δt between the brine surface and the cover. In order to evaporate 1 kg of water at a temperature of 30°C about 2.4×10^6 J is required, assuming an isolation of 250 W/m^2, averaged over 24 h and this energy could evaporate a maximum of 9 L/m^2/d. In practice heat losses will occur and the average daily yield might be 4-5 L/m^2/d, which gives an efficiency of 45-55 % [18].

Solar desalination schemes are widely considered all over the world. Some of them are still at laboratory development levels and others are field tested. But when considering the use of solar energy, it is necessary to know the energy falling on that unit area of the earth's surface per year and also the seasonal and other variations due to atmospheric conditions.

Solar energy in most purposes is divided into two components, direct radiation which is received directly from the sun and diffuse radiation which has been scattered by clouds and dust and arrives from all directions. The relative proportions of direct to diffuse radiation will depend on the site, season and time of the day. The diffuse radiation will be around 10-20 % of the total radiation (diffuse + direct) on a clear day, but will rise to 100% of a much smaller total radiation on a cloudy day. In order to extract the maximum possible of solar radiation, the collector device surface should be arranged to be at right angle to the sun's direct radiation and as direction changes with the sun's apparent motion a tracking mechanism must be used.

The combination of solar energy with desalination processes can be classified into two major types: 100% solar driven desalination plant in which all thermal energy is supplied by solar means. The second type is the partial solar powered desalination plant, in which there are two alternative sources of heat, a conventional fuel-fired boiler and solar collectors. In such type the solar collector system does not include thermal storage system. Such system will be designed to operate at constant output and the boiler provides all the energy required when there is no isolation and make up when there is shortage during the day.

11.3 Water quality of solar still distillers

In principle, the water from a solar still should be pure. The slow distillation process allows only pure water to evaporate from the pan and collect on the cover, leaving all particulate impurities behind. Since a clean glass cover plate and storage vessel should produce no contaminants, the catch basin, or trough, remains as the potential source of direct impurities (pollutants).

The catch trough should be made of material unlikely to degrade water flowing through it, even at the moderately high temperatures, which might be encountered. PVC (polyvinyl chloride) plastic plumbing pipe is commonly available at relatively low cost. Since vinyl chloride has been identified as a potentially harmful carcinogen, one should be extra vigilant about using this material in a drinking water system.

Secondary potential sources of contamination include materials present in the air inside the distiller, and in the lining or coating of the evaporating pan, which might somehow find their way into the water condensing on the underside of the cover glass.

With care in design and operation, the solar still should, therefore, be able of producing good quality drinking water free of harmful substances. When the minerals common to drinking water are removed, taste goes, too. One flavor recommendation is to add small amounts of minerals or salts to the distilled water, since the minerals found in water may be healthful. Another way is to mix a larger amount of brackish water to the distilled water (X-to-one, depending on the salinity of the local water).

Small-scale low-cost solar distillation for use in developing countries has been widely investigated. Studies have shown that solar energy is more applicable to low-temperature desalinating systems than to high-temperatures. Therefore, great efforts have been made to adapt solar energy to low-temperature desalinating systems.

Small-scale solar distillation pilot units have been set up in many research centres to demonstrate the performance of solar desalination. Boukar and Harmim presented performance evaluation of one-sided vertical solar still tested under desert climatic conditions of Algeria, in summer and autumn seasons. The study showed that still yield varies from 0.275 to 1.31 L/(m^2d) for a corresponding energy varying from 8.42 to 14.71 MJ. They also investigated the effect of desert climatic conditions on the performance of a simple basin solar still and a similar one coupled to a flat plate solar collector. Tests were conducted at the solar station of Adrar, an Algeria Saharan site. They resolved that the daily still productivity in summer period varied from 4.01 to 4.34 L/(m^2d) for simple basin solar still and from 8.02 to 8.07 L/(m^2d) for the coupled one [21, 22]. Bouchekima et al. presented the results of experiments carried out with a capillary film distiller installed in the south of Algeria, in a village near Touggourt where the temperature of the groundwater was about 65°C at the source, for groundwater distillation using solar energy and the capillary. It was found that the efficiency of this distiller increased with increasing the temperature of the brackish water at the inlet and also with increasing the intensity of the solar radiation and it depended besides on the heat loss and fabric used [22, 3]. Figures 4a and 4b illustrate respectively, a one and three stages of a capillary film distiller.

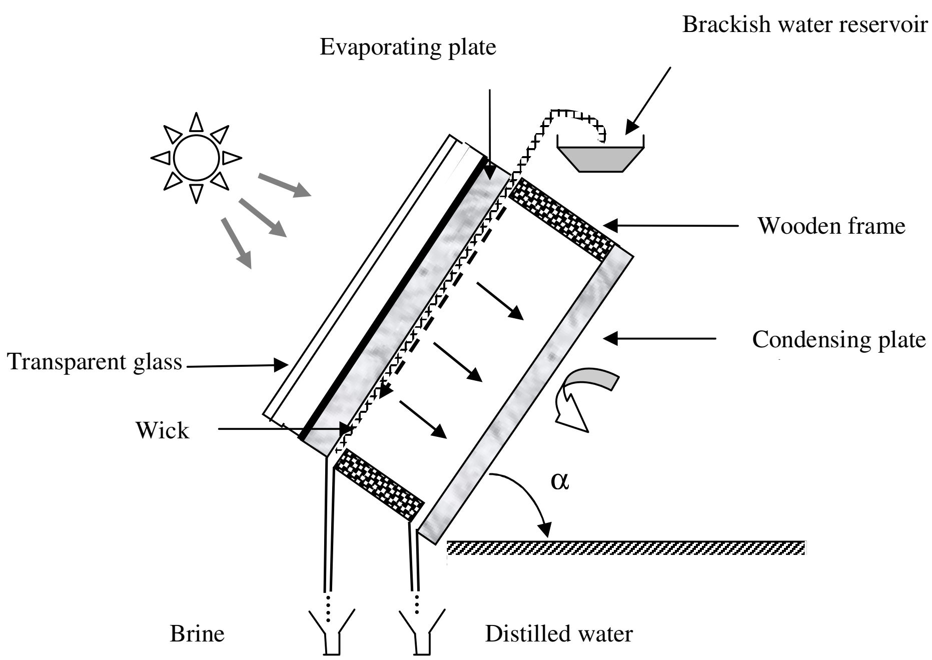

Figure 4.a: One stage- DIFICAP

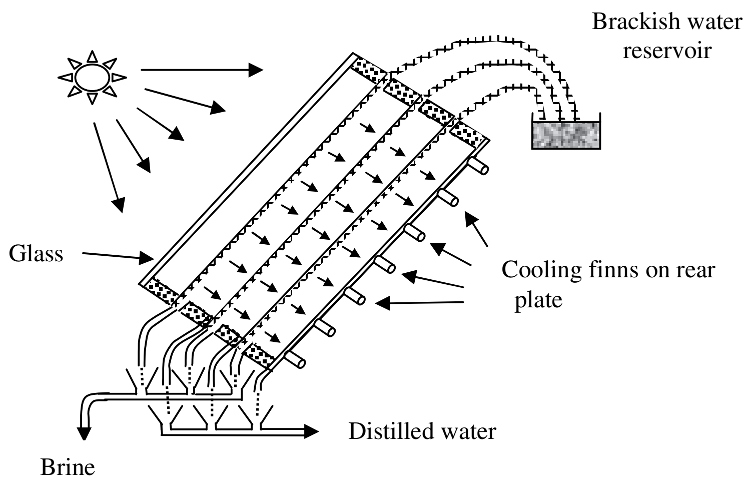

Figure 4.b: Three stages DIFICAP

Some of the important considerations with regard to the suitability of low-cost small-scale distillation techniques for rural isolated areas include:

- Relatively low initial capital costs,
- Simple and cheap technologies are used,
- Easy to construct and fabricate with locally available natural materials,
- Easy to operate with no complicated electronic/mechanical protocol,
- They do not require specialised manpower,
- Easy to maintain all parts and components,
- Simple replacement of parts during breakdowns,
- This type of desalination is usually more targeted towards poor communities than large-scale desalination.
- They are environmentally friendly,
- Contribute in social, economic and cultural prosperity of isolated communities,
- Help in keeping these communities in place, therefore, prevent/reduce massive unplanned immigration waves to the already densely populated large cities,
- Easy to transport,
- More importantly, they do not require any fuel.

12. General conclusions and recommendations

The following may be established as conclusions:

- Launching of public awareness campaigns among local investors particularly small scale entrepreneurs and end users of RET.
- Allocation of a specific percentage of soft loans and grants obtained by governments to augment budgets to manufacturing and commercialization of RET particularly desalination.
- To encourage the private sector to assemble, install, repair and manufacture non pollutant desalination devices via investment encouragement, more flexible licensing procedures.
- The laws should be flexible and allow for improvement in future.

- Availing of training opportunities to personnel at different levels in donor countries and other developing countries to make use of their wide experience in application and commercialization of RET particularly desalination.
- The undisputed importance of continued and increased capacity building in the water sector and particularly the desalination sector.
- There is a continued need for developing the skill and capabilities of people for desalination, by developing water policies, implementing new forms of contracts, and adjust the legal framework.
- Capacity building may very well include support to the private sector.
- Capacity building in research (creation of research projects on desalination).
- Introduction of higher taxes on CO_2 and other gas emissions.

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