# Actual Practice on Solar Water Distillation Technology and Clean Water Access Crisis in North Shoa-Ethiopia: A Detailed Review

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**Abstract:** ***Current practice to get to drinking water to the individuals these days narrowing everywhere throughout the world. Same as in Ethiopia absence of safe water get to is one of big issue where rural communities confronted, 61% of the population has access to safe water. The vast majority of the diseases are brought by water related; looseness of the bowels is the subsequent driving reason for death for youngsters, kids dies at regular interval. Rural communities mostly obtained water from shallow, wells, stream and rivers, however this water might be possibly filled with destructive substances and microbes therefore, dangerous for consumption. To take out the pollution of water, customary desalination activities like multi stage streak, fume pressure, different impact, iron exchange, reverse osmosis and electro dialysis are utilized. But very expensive for small quantity of water production, additionally utilizing of ordinary energy sources negatively affects nature. Ecofriendly water refinement is need, sun powered distillation is one of demonstrated, generally appealing and straight forward method utilizing free and sustainable energy from the sun for water distillation among alternatives. It is appropriate for little to huge plants at areas where solar energy is extensive. Ethiopia is one of a tropical nation favored with abundant sunshine. Every day normal solar radiation is somewhere in the range of 5.68 and 6.6 kWh/m$^2$/d for various places. It has a normal of 250 to 300 clear sunny days of the year. In this manner, it gets a solar irradiation of 5000 to 7000 Wh/m$^2$ per year, and in this way has extraordinary potential for the utilization of solar energy and meeting the energy requirements. Present article comprises of an overall detailed review and technical evaluation of solar distillation recent technologies, then construct experimental setup to observe its productivity at North Shoa-Ethiopia condition. The review incorporates prologue to the solar distillation and clean water crisis in Ethiopia, clarify the fundamental principles of solar distillation, current status and modifications (advancement) led for execution improvement of solar still for distillation process.***

**Keywords:** Heat Storing Elements (Black Basalt), K-Type Thermocouple, Reflector, Solar Distillation Review, Double Slope Solar Still

## 1. Introduction

Water is one of the valuable blessing from nature and the crucial assets. As It describes in figure 1, 71% of earth's surface by water, on earth 97% of all water is found in sea from this 3% is fresh water. 79% of freshwater is ice caps and ice sheets and 20% is groundwater, consequently from this 3.5% is open freshwater.

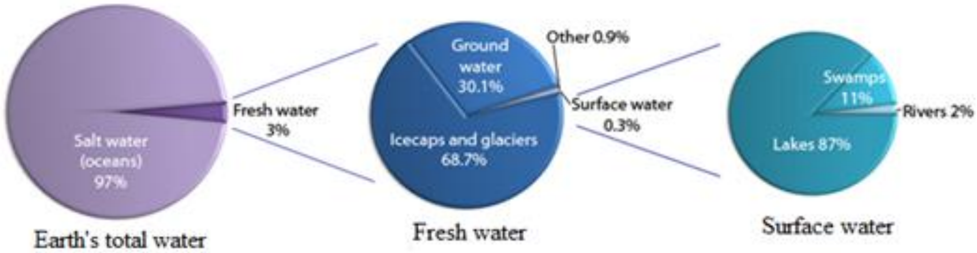



**Figure 1:** Distribution of water in the world

In addition, Ethiopia is one of favored country with plentiful water resources. However, as to many African nations, in Ethiopia parts of the population residing in rural regions are suffering because of shortage of clean water, they have got no longer clean and fresh water access for domestic use, even in cities 3 in 5 human beings do now not have access to clean water near their home, lack of sustainable technology and politics are the main reasons. A study performed and stated that 61% of the Ethiopian population has access to clean water supply [24]. In rural regions these facts drop even lower, ensuing not enough water, cause to infections and sickness in kids, water borne illnesses, including cholera or diarrhea. A ministry of water, irrigation and power of Ethiopia indicates the governments set goals in Ethiopia's growth and transformation plan II (GTP II) 2016–2020 to increase clean drinkable water supply as much as 75%. In Ethiopia clean water transport to the community is the duty of the government and seeking to invest excessive capital to remedy lack of drinkable water especially to cities like Addis Ababa, Bahir Dar, Mekelle, Hawassa and so on. The main water sources are from ponds, wells, streams and lakes. This circumstance is not unusual in rural areas of Amhara, Tigray, Oromia and southern region, they have got their water demand from openly available streams, ponds, lakes, rivers, sea, and so on. Those water source cannot healthy for direct intake because it consists of parasites or sicknesses, therefore is has significant health threat. Women and girls are responsible for gathering water to provide the family by walking lengthy distances and spend their time each single day (see the actual life population in figure 2), this leads girls absent from school and lady's exhaustion.

Transportation of drinking water in remote areas and investment on conventional purification technologies like multiple effect, multi-level flash, iron alternate, vapor compression, electro dialysis and reverse osmosis methods are economically very high priced for the production of small quantity of clean water to rural scarcely populated areas. This practice is tough for government to solve clean water crisis; therefore, involvement of private stakeholders is essential to purify water without problems with low cost by way of introducing renewable and energy technologies. Solar energy is considerable on the planet and promising to purify water then it will be less expensive.

**Figure 2:** Images to describe how rural communities get access water for domestic use in Ethiopia

Ethiopia is one of a tropical country blessed with abundant sunshine. Daily average solar radiation is between 5.68 and 6.6 kWh/m$^2$/d for different parts of the country (figure 3 indicates solar irradiation SWERA map). It has an average of 250 to 300 clear sunny days per year. Thus, it receives a solar irradiation of 5000 to 7000 Wh/m² in a year, and thus has great potential for the use of solar energy and meeting the energy requirements.

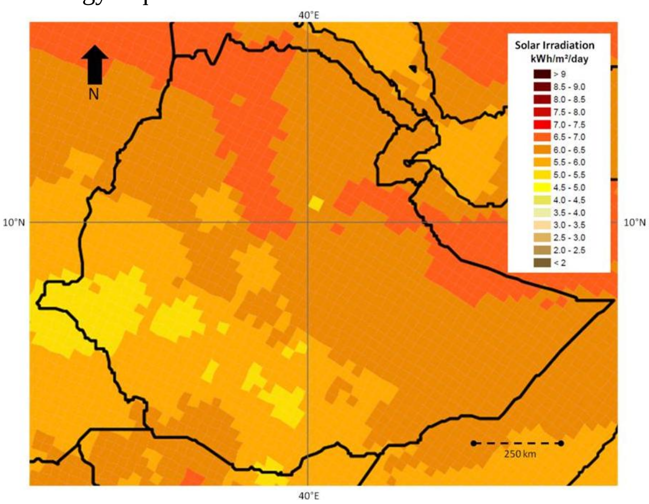



**Figure 3:** Solar irradiation in Ethiopia in kWh/m2/day, (SWERA 2018)

This paper comprises of an overall detailed review and technical evaluation of recent solar distillation technologies, then construct experimental setup to observe the productivity at North Showa, Ethiopia weather condition. The review incorporates prologue to the solar distillation and clean water crisis in North Shoa, clarify the fundamental principles, current status and modifications (advancement) led for execution improvement of solar still for distillation process.

## 2. Background

Distillation has been taken into consideration a way of producing brackish, salty and dirty water drinkable with a phenomenon of replicates the way of nature made rain. Early 4th century B. C., Aristotle described a way to evaporate infected water after which accumulate through condensing it. Arabian scientist where the earliest regarded people to use sun distillation to supply drinkable water in the 16$^{th}$ century. Although, the first documented conceptual stage layout became made in 1742 by Nicolo Ghezzi in Italy, while he has not actually built it. Captain Israel Williams in 1797 describe that he improvised a manner to distill water. The primary updated solar still was turned into constructed in Las Salinas, Chile, in 1872, by Charles Wilson, it consisted of water basins total area of 4459 m$^2$ made from blackened wooden with sloping glass covers, the reason was to supply 20,000 L/day of water to mining site animal consumption, and it is in operation these days to 1912 [18]. In the course of the 1950s, solar distillation technology interest becomes better, in California, big centralized distillation plant changed into developed with the objectives of producing 1 million gallons (3775 m$^3$/day) of water. However, research on it within 10 years concluded that large solar distillation plants were very expensive whilst in comparison with fuel combustion technology. Consequently, in 1960s and 1970s researcher shifted to smaller plant for small users, because interest in small residential still is growing. Nowadays solar energy can't compete with fuel energies both in cost as well ecofriendly, due to the fact now the price of oil is ten times what it became in 1960s, hence solar energy will virtually feasible to be a possible energy source in the coming years.

## 3. Working Principle

Distillation of water the usage of solar power is easy innovation to turn seawater, brackish even contaminated dirty water into clean drinkable water. It is natural evaporation and condensation method, which equal the manner nature makes rainwater process. Simple schematic as shown in figure 4; the cavity covered by means of glass to trap enough solar energy within the basin surface then water evaporates, as a result water vapor rises. Temperature distinction among water vapor and glass cover leads this vapor condensate on the glass surface for collection.

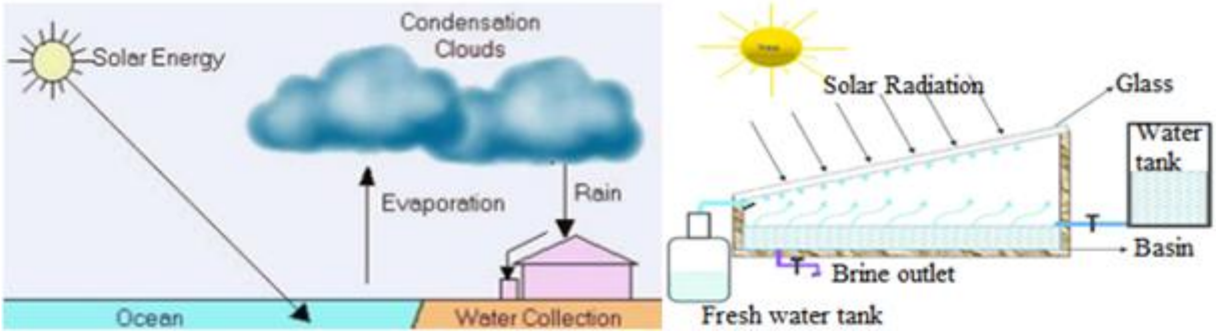



**Figure 4:** (a) How nature makes rainwater (b) How solar still works

This technique may be used to effectively remove many impurities consisting of salts, heavy metals as well as removes microbiological organisms.

## 4. Literature Survey

Various approach and methods of solar distillation have reviewed and studied to recognize the present-day fashion of efficient and inexpensive Design of solar still. Sumit S. Naygaonkar et al. (2018), [3] of their work at they build an experimental setup of solar distill made up of 0.54 $m^2$ basin area GI sheet metal with tray setting at a distance of 10cm, a length of 90 cm and 60 cm width with 30 cm height. The basin covered with airtight 3.5mm galvanized glass with inclination of 22º. The solar distill insulated using glass mohair to prevent heat dissipation. They conclude that using of double slope glass cover and coating the absorber can rise the production rate of water. Mehul Agrawal and Lt Piyush Nema, (2016), [2] conducted experimental test on single-slope solar still included with an evacuated tube collector. From the study observed that the productivity of distillated water without EGT at water depth 1, 2, 3, and with EGT at water depth 1, 2, 3cm were 20, 19, 15, and 41, 45 and 35% respectively. Therefore 2 cm water depth offers more distilled water and attain higher efficiency.

Abdullah et.al, (2015), [13], on this study the traditional single slope solar still is changed to encompass solar preheating device, to preheat dirty water preheat before moving into the solar distill (see figure 5). The reason is because of improve hourly/daily production of clean water, then thermal performance is examined experimentally. Addition of the solar water preheater to the system drastically increases the inlet basin saline/dirty water temperature to almost saturated temperature and saline water within the distill need small warmness to be vaporized. Subsequently will increase the production rate of fresh water. The experiment carried out considering the effect of several quantities of water and considers flat, finned and corrugated sorts of distill basin surface. Consequently, saline/dirty water depth of 1 cm and with finned basin surface offers clean water production stepped upward by 20%.

**Figure 5:** Solar irradiation in Ethiopia in kWh/m2/day, (SWERA 2018)

Imad A1-Hayek et. al, (2004), [14] in this study measured two type of solar distills, and then factors which have impressions on the efficiency of solar distills are studied. From the experimental analysis it shows that water production rate of asymmetrical greenhouse (ASGHT) type distills having glass on its inside walls changed into that of the symmetric greenhouse (SGHT) type distill and it results more efficient. Water distillation rate of the ASGHT type distill was higher than that of SGHT type distiller by 20%. Performance of the two distills confirmed that the temperature at the water surface is closely related to the incident solar radiation, and the productivity & the distills can be raised with decreasing water depth using extra dye. Anirudh Biswas (2012), [1]; this study aims to design cheap, portable and solar driven water distillation system in order to purify nearly available water. Conventional single basin solar still become designed by the aid of integrating with a parabolic solar trough as shown in figure 6. Results, 30 liters of water distillated each day using 0.266$m^2$ basin area. They conclude effective geometries of the distiller and trough concentration system will maximize production rate and additionally able to decrease waste thermal losses.

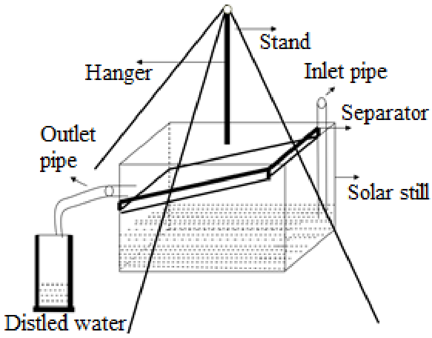



**Figure 6:** systematic view of working, Anirudh B. 2012, [1]

Tiwari and Dwivedi (2009), [17] in their experimental investigation they have evaluated the heat transfer coefficient of single and double slope solar distill in summer season and winter climatic situations for 3 different water depth conditions of (0. 01, 0. 02, 0. 03 m) by varying the design models. The experimental validation of distillation yield as compared with theoretical values of hourly yield and observed that Dunkel's version offers better agreement among theoretical and experimental results. In addition, Dunkel's model has been used to assess the inner heat transfer coefficient for each single and double slope solar distills. When the water depth increases from 0. 01 m to 0. 03 m convective heat transfer coefficients value was varying. The annual output of a single slope solar distill become higher (499.41l/m2) in comparison with a double slope solar distill (464. 68 l/m2). Hikmet S. Aybar, Fuat Egeliofglu, U. Atikol, (2005), [5] on this research inclined solar water distillation system was proposed and measurement is taking with the situation: using of bare plate, black-cloth wick, and black-fleece wick as described in figure 7. From the experimental result concluded that, the wick improved the water production quantity than conventional or using of a bare plate. The advantage of this project was same time it can produce hot water with enough temperature for domestic use.

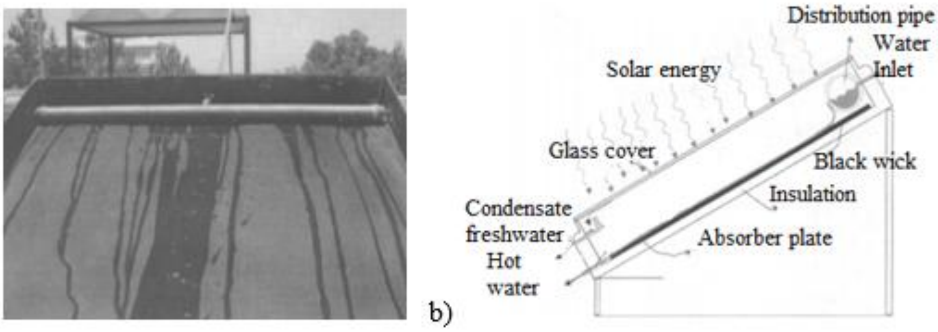
a)  b)


**Figure 7:** (a). Inclined solar water distillation system without glass cover and black wick, (b). Schematic diagram of the inclined solar water distillation system, Hikmet S 2005, [5]

P. Valsaraj, (2002). [10] an experimental study carried out in a single-slope solar distill after introducing a modification of adding folded aluminum sheet over the surface of the basin as indicated in figure 8, which absorbs greater solar heat and forestalls the whole water mass from getting heated up and permits evaporated water from the protected segments to escape out into the air gap through the holes on it. From the result concludes that the distillation performance considerably advanced especially when amount of water increases. The study additional indicated future modification amendment capabilities also would improve the output.

**Figure 8:** The modified distill with folded, perforated and black coated sheet floating over the water surface (shown with the glass cover removed), P. Valsaraj, 2002, [10]

The research conducted by Koilraj et al. (2013), [4] a single basin solar distillation performance compression between whilst the distill is manufactured from copper and galvanized iron sheet materials. From the experimental test they observed that, when a basin made up of GI sheet offers 1360 ml/day and 30 % performance, and Coper Sheet solar distill raised the productivity to 2490 ml/day and 80 % efficiency due to the higher thermal conductivity property of the copper. Moses Koilraj et. al. (2013), [6] designed a new modified single basin Nano-Still. The experiment was aimed to analyze and compare the device for both with and without nanofluid conditions (see figure 9). When they conclude their work that aluminum has higher thermal conductivity which will increases the heat transfer in order that yields extra output of 6 L/day, the performance of the system is improved greater 20% through providing insulation to reduces heat loss, extra 15% by painting the absorber to absorb excessive heat, by blending nanofluids with water to increases heat transfer rate by 40% which in flip will increases water temperature and thus increasing the evaporation rate and increases the performance by way of 60%. Further to this the studies demonstrates that clean water production rate can range with the system design, properties of absorbing materials, depth of water and water dilution (concentrations).

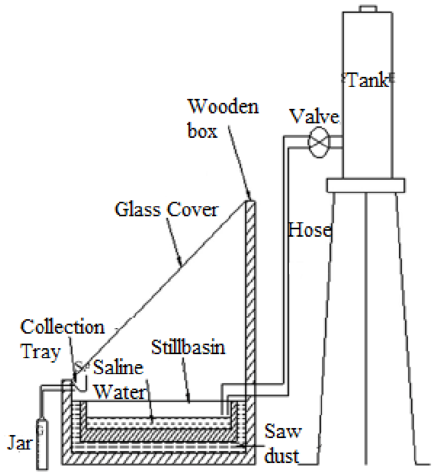



**Figure 9:** Experimental setup of Nano-Still, Moses 2013, [6]

In the study conducted with the objective to design an economical and modest single basin solar distillation system by Ali Samee et al. [7] which is indicated in figure 10. Then data taking for 8-days and yields average daily distilled water output was 1.7 liters using 0.54 $m^2$ basin surface area, the inclination of glass cover to be 33.3°. Efficiency was calculated as 30.65% with a maximum hourly output of 0.339 L/hr. The property of available raw water was evaluated in lab before distillation process and the conductivity, total dissolved solids (TDS) and pH were measured and gives 370 ppm, 1.291 µS/cm and 6.72, and after distillation the quality becomes 30 ppm, 41 µS/cm and 6.5 respectively. They conclude their study that how TDS and pH agree with the WHO guidelines for drinking purpose.

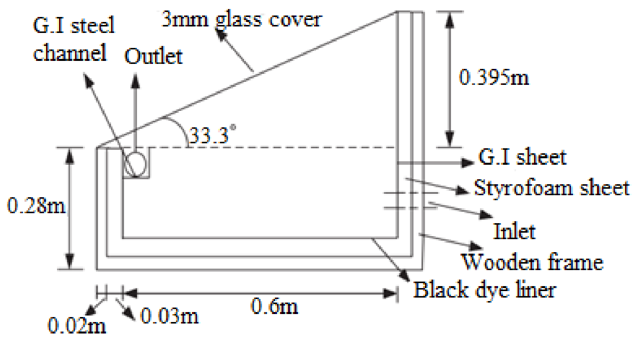



**Figure 10:** Schematic diagram of single basin solar still, Muhammad Ali Samee et al. (207), [7]

O.O. Badran, (2007), [12] conducted performance investigation of a single slope solar still, different operational parameters were studied by constructing experiment. The distillation system productiveness elevated with by 51%, this is because of while asphalt is carried out in the basin surface layer resulted in a significant improvement of production rate by 29%, and sprinkler blended with the asphalt becomes extra effectiveness than the use of asphalt alone by way of further 22%. When there is no solar radiation during night the system contributed 16% of the daily production of distillated water. It is able to concluded that wind and temperature have an instantaneous impact on the productiveness, additionally it's obvious from the end result that because the depth of water decreases the daily still output is extended. K. Voropoulos et al, (2003), [8] designed kind of a greenhouse solar still integrated with a hot water storage tank for continuous heat transfer from the hot water tank to the saline water, this change make sure water production rate within the system is sort of constant day and night, and having higher water temperature within the storage tank for domestic use. From the test it is validated that the thermal characteristics of solar still storage tank system has been determined that performance boost regarding to production quantity. S.K.Shukla, et. al. (2005), [16] in their research single and double slope multi-wick solar still integrated with a wet piece of jute cloth was constructed, which helps for rapid evaporation of water. The wet blackened jute cloth separated by way of polythene sheets; one end is in the water reservoir as the same time the opposite end kept over the absorber basin. Sets of experiment had been carried out in summer and wintry weather for individual still. It becomes concluded that despite the fact that daily distillate was higher in summer however overall thermal performance of both the stills changed into low because of increasing losses. However, percentage increase in the distillate of double slope multi-wick in winter become 1.3 times more than that from the single slope multi-wick. Experimental and theoretical outcomes had been found to be agreement each other.

S.Nafey et al (2001), [9] the studies develops a method to enhance the productiveness of single basin solar still using of black rubber/gravel as a storage medium as indicated in figure 11. In this experiment the impact of various thickness of absorber has studied underneath equal working situations in 4 units of the system, subsequently the end confirmed that 10 mm thick black rubber improve the productiveness by means of 20% on the situation of saline water 60 L/$m^2$, glass cover angel 15°. The gravel size of 20 – 30 mm improves the productiveness by 19% at the condition saline water 20 L/$m^2$ at same inclination angel.

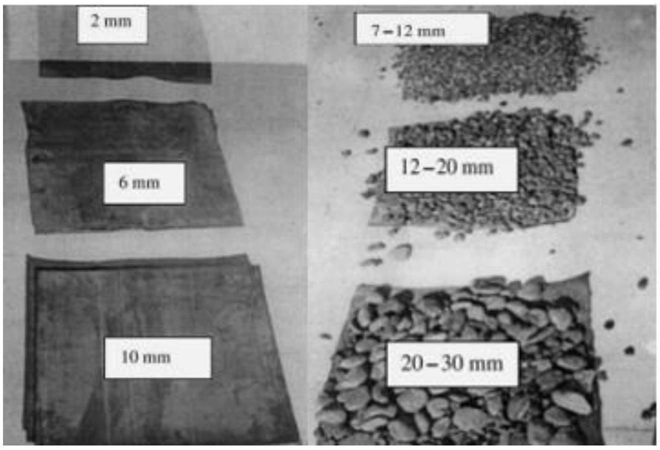



**Figure 11:** Different gravel thickness photograph, A.S.Nafey et al. (2001), [9]

S. Nijmeh, (2004), [11] in this paper offers experimental and theoretical research on solar still to be able to improve the performance by with the aid of adding various absorbing materials. The system is built with same angle of double sloped glass covers and effective basin area of 3 $m^2$. Charcoal was the absorbing materials selected to enhance the absorptivity of water for solar radiation, violet dye and dissolved salts i.e., potassium permanganate ($KMnO_4$) and potassium dichromate ($K_2Cr_2O_7$). The addition of the dissolved salts is a novel approach in improving the performance of solar stills. The design produced enormous development in the system distillation productiveness and performance. As an instance, the addition of 70 mg/l of $K_2Cr_2O_7$ and 50 mg/l of $KMnO_4$ improve the efficiency by 17% and 26%, respectively. Addition of charcoal while it covers 50% of basin surface area produce optimum efficiency and productivity as much as 17.3% and 5.290L/day. The exceptional result was recorded when using violet dye and the performance accelerated by 29%. They concluded that addition of dissolved salts is novel technique to enhance the performance, and while the theoretical and experimental evaluation of quantity of water produced by way of the solar still turned into agreed each other.

## 5. Thermal Analysis

The energy balance equation for the basin, water to be distilled and glass cover can be written as [19]: Amount of energy received by the water to be distilled in the still $I_t$ solar radiation and $Q_{cbw}$ convective heat transfer rate between basin and water are equal to the summation of energy lost by $Q_{cwg}$ convective heat transfer rate between water and glass, $Q_{rwg}$ radiative heat transfer rate between water and glass, $Q_{ewg}$ evaporative heat transfer rate between water and glass and energy gained by the water.

$$I_t \alpha_w A_w + Q_{c_{bw}} = Q_{c_{wg}} + Q_{r_{wg}} + Q_{e_{wg}} + m_w c_{pw} dT_w/dt \quad (1)$$

**Radiative heat transfer coefficient:** the rate of radiative heat transfer $q_{rwg}$ from water surface to the condensing glass cover can be obtained as;

$$\dot{q}_{rwg} = \varepsilon\sigma[T_w{}^4 - T_g{}^4] \quad (2)$$

Or it can be expressed as

$$\dot{q}_{rwg} = h_{rw}(T_1 - T_2) \quad (3)$$

Radiative heat transfer coefficient $h_{rw}$ can be calculated.

$$h_{rw} = \varepsilon\sigma\left\{\frac{(T_w + 273)^4 - (T_g + 273)^4}{T_w - T_g}\right\} \quad (4)$$

Where;

$$\varepsilon = \left[\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_g} - 1\right]^{-1} \quad and\ \sigma = 5.67\ x\ 10^{-8}\ W/m^2\ K^4$$

**Convective heat transfer coefficient:** the convective heat transfer coefficient $h_{cw}$ can be obtained from;

$$h_{cw} = 0.884\left\{(T_w - T_g) + \frac{(P_w - P_g)\ x\ (T_w + 273)}{(2.689\ x\ 10^5 - P_w)}\right\}^{\frac{1}{3}} \quad (5)$$

The volume of partial pressure of saturated water *Pw* and partial pressure of glass saturated *Pg* (for range of temperature 10 °C to 90 °C) can be obtained at water and condensing cover temperature from the relation considering *Pw* and *Pg* as a function of temperature.

$$P(T) = exp\left[25.317 - \frac{5144}{T + 273}\right] \quad (6)$$

The rate of convective heat loss $q_{cwg}$ in (W/m$^2$) from water surface to condensing glass cover can be obtained.

$$\dot{q}_{cwg} = h_{cw}(T_w - T_g) \quad (7)$$

**Evaporative heat transfer coefficient:** Dunkle 1961, the rate of evaporative heat loss $q_{ewg}$ from water surface to condensing inner glass cover is given by;

$$\dot{q}_{ewg} = 0.0166\ x\ h_{cw}\ x\ (P_w - P_g) \quad (8)$$

It can be expressed as;

$$\dot{q}_{ewg} = h_{ew}(T_w - T_g) \quad (9)$$

The evaporative heat transfer coefficient can be rearranged

$$h_{ew} = \frac{\dot{q}_{ewg}}{(T_w - T_g)} = 0.016\ x\ h_{cw}\ x\ \frac{(P_w - P_g)}{(T_w - T_g)} \quad (10)$$

Using Eqs. 4, 5 and 10, total heat transfer coefficients h can be written as;

$$h = h_{rw} + h_{cw} + h_{ew} \quad (11)$$

The rate of heat transfer from water surface to the condensing glass cove can obtained as

$$\dot{q} = h(T_w - T_g) \quad (12)$$

The solar still efficiency is defined as the ratio of heat energy used for vaporizing the water in the basin to the total solar intensity of radiation absorbed by the still. The overall thermal efficiency of the still η is obtained by summing up the hourly condensate production $m_w$, multiplied by the latent heat of vaporization $h_{fg}$ and divided by daily average solar radiation $I_t$, over the still area $A_b$, given by

$$\eta = \frac{\sum m_w\ x\ h_{fg}}{\sum A_b\ x\ I_t}\ \ or\ \ \frac{q_{ew}}{I(t)} \quad (13)$$

The cost of distillate water can be estimated using economic analysis. The capital cost (P) of the solar still, sinking fund factor (SFF), annual salvage value (ASV), annual maintenance cost (AMC), and interest rate per year should be considered. The capital recovery factor (CRF) is defined in terms of the interest per year i and also the number of lifetimes of the system in years n [22].

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (14)$$

Fixed annual cost (FAC) becomes:

$$FAC = P\ (CRF) \quad (15)$$

Where, P is the capital cost of solar still.

$$FAC = \frac{i}{(1+i)^n + 1} \quad (16)$$

Sinking fund factor (SFF) and annual salvage value (ASV) can be

$$ASV = (SFF)S \quad (17)$$

For, S = 0.2P

Annual maintenance operational cost (AMC) of the system consists of collecting the fresh water, cleaning the glass cover, washing inside the unit to remove the deposited salt:

$$AMC = 0.15(FAC) \quad (18)$$

Therefore, the annual cost (AC) is

$$AC = FAC + ASV \quad (19)$$

Finally, the cost of fresh water per liter can be estimated as: Where M is the average annual yield

$$CPL = AC/M \quad (20)$$

## 6. Experimental Construction

The experiment was built where at Mechanical Engineering workshop, college of Engineering Debre Berhan University, Debre Berhn, Ethiopia of 9$^o$ latitude and 39$^o$ longitude. From many other possible configurations and materials, the following subsequent experimental setup is constructed to examine the productiveness of double slope solar still at stated location weather circumstance as shown in figure 12. The black painted basin is made up of galvanized Iron sheet metal of 200 cm x 100 cm area acting as absorber and height of 30 cm to soak up better incident solar radiation [13]. The reflector which made of aluminum to increase the effect of radiation on the basin surface, and to enhance the productiveness of the solar still, we add 20 – 30 mm size black basalt on the surface of the basin surface act as a storage medium. The outer box structure with size of 105 cm by 105 cm manufactured from fly wood to preserve and enclose the still, the space between box and basin polyurethane foam (PUF) with of 0.024 W/m$^2$K thermal conductivity and 4 cm thickness insulation is furnished at the facet and bottom to reduce heat dissipations. The top of the basin where the water condensed is covered by ordinary window glass installed at an angle of 12$^o$ from horizontal which a thickness of 0.4 cm. The condensed water from the glass cover collected by U form PVC in the lower facet of the distiller, then purified water collect with rubber pipe into a measuring tank. Silicon rubber sealant is used to fixing components and prevent vapor leaks from the distiller. Upper and bottom side holes are made for inlet and outlet pipe.

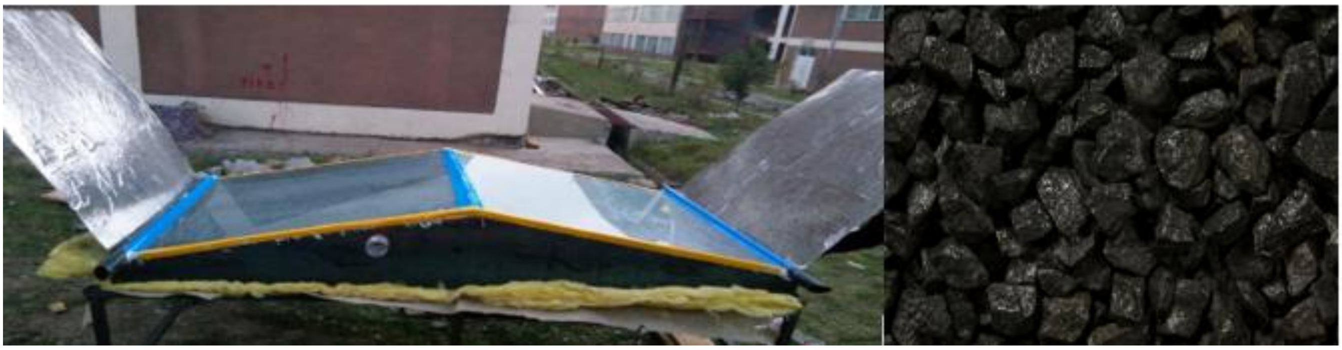


**Figure 12:** Experimental construction of proposed double sloped solar still

The temperature of water inside the still was recorded by means of K-type thermocouple connected with a digital meter, and the amount of distillate water output is recorded with the help of graduated jar on an 1hour basis. Compensate water in the basin ensured by adding water gently from upper tank. according to Mikias Hailu (2018), [23], it is stated that daily average solar incident radiation during 7 to 8 sunny hours are 900 W/m² at above stated locations.

## 7. Experimental Measurement Observations

Measurement was taking for three successive days on May 27 to 29 of 2019. From experimental observation the maximum temperature of the water inside the basin recorded was 45.7 $^o$c. The daily maximum temperature at Debre Berhan city was 23 $^o$c for the days while measurements are recording. The system was productive continuously for 15 hours and we can able to collect about 5.7 liters of distilled water daily but, no distilled water output within the time 23:00 PM – 09:00 AM. Hourly average quantity of distillated water measured for three days as presented in Table 1. Three parameters are mostly important for the quality of drinking water: total dissolved solids (TDS), pH and electrical conductivity. All three parameters were prepared in laboratory and measured for the raw water before and after distillation as shown in figure 13, and the results are presented in Table 2.

**Table 1:** Average quantity of distillated water collected

| Time | Quantity of distillated water | Time | Quantity of distillated water |
|---|---|---|---|
| 09 – 10 AM | 70ml | 17 – 18 PM | 560ml |
| 10 – 11 AM | 220ml | 18 – 19 PM | 500ml |
| 11 – 12 AM | 350ml | 19 – 20 PM | 380ml |
| 12 – 13 PM | 440ml | 20 – 21 PM | 350ml |
| 13 – 14 PM | 550ml | 21 – 22 PM | 220ml |
| 14 – 15 PM | 620ml | 22 – 23 PM | 100ml |
| 15 – 16 PM | 650ml | 23 – 00 PM | 50ml |
| 16 – 17 PM | 640ml | After 00 PM | n/a |

WHO Guidelines for Drinking-water Quality [25], the palatability of water with a TDS level of less than 600 mg/liter is generally considered to be good for drinking purpose. Actually, the pH content has no direct impact when we consume, but, it's one of the most important operational water quality parameters. The optimum pH required varies in the range 6.5–8.5. Electric conductivity of pure water increases as the concentration of dissolved ions increases. Thus, clean water is not a good conductor it's allowed for drinking values from 0.005 – 0.05 S/m of conductivity. The conductivity, TDS, pH and other parameters was not far out from maximum allowable standard values.

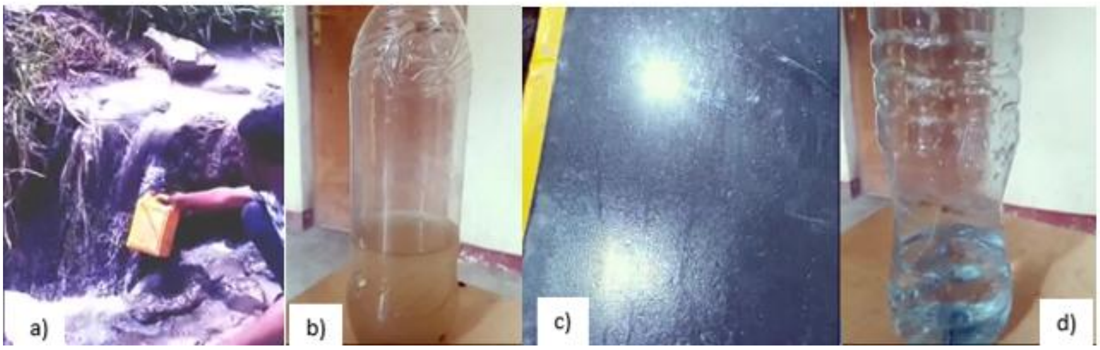



**Figure 13:** photograph of a) raw water source from Beressa Stream located Debre Berhan town (Tebasse), b) raw water for lab analysis before distillation, c) distillation process in double slope solar still and d) distilled water for lab analysis

**Table 2:** Quality of tested water before distillation, after distillation and standard drinking water quality

| Quality | Before distillation | After distillation | Recommended |
|---|---|---|---|
| TDS (ppm or mg/liter) | 759.7 | 84.72 | < 600 |
| pH | 7.59 | 5.08 | 6.5-8.5 |
| Conductivity (mS/cm) | 85.3 | $88.5 \times 10^{-3}$ | 5 – 50 |
| TSS (mg/liter) | 4.0 | 1.02 | 0 – 152 |

## 8. Conclusion

In this work, specific review on solar still recent technologies was presented and experimentally discussed the productiveness of solar still at North Showa Ethiopia (Debre Berhan) town weather conditions. The proposed double slope solar still are made as simple as possible, low in cost with less energy losses, since it is going to implement for rural communities. From the literature review and experimental observation, we conclude that solar stills are verified technology to be highly effective alternative for cleaning up any available water sources and to provide safe drinking water. Most commercial water purification systems require electrical or other fuel power sources, but this technology can produce the same drinking water using green energy source from the sun. The home size solar still experimental test was conducted to observe how able to fulfill daily demand of drinking water for a family member based on literatures technical data. The system produces about 6 liters of water per day, which is enough quantity for a family member consumption recommended by WHO. Coming up with the cooperation of governmental and nongovernmental organizations it's possible to implement for rural communities to provide clean water.

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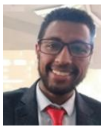
## Author Profile



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