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RESEARCH ARTICLE

SOLAR WATER DESALINATION FOR ETHIOPIA RURAL HOUSE HOLDER

***Wondwosen Shiferaw Aga**

Department of Agricultural Engineering, Haramaya Institute of Technology, Haramaya University, Harar, Ethiopia

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ABSTRACT

This project presents the design and testing of solar water still by utilizing solar energy for purification of brackish water which contribute the supply of pure water in Ethiopia. In Ethiopia, due to the lack of pure water about 250000 children die per year. The purpose of this research is to provide potable water by using solar water distiller which can be locally manufacture and flexible. Solar water still natural way of water desalination. The operation principle of single-basin solar distillation is similar to hydrological cycles. The incoming solar radiation from the sun is focused and concentrated onto a receiver pipe using a single basin trough, heating the incoming impure water at which point it is sprayed into our custom designed distillation device where it evaporates and re-condensed into pure potable water. The single basin solar water distiller has the capacity to purify brackish water up to 99.9% and will produce four gallons of pure water per day. Since the daily recommended consumption of pure water per person per day is about two liters, it is sufficient to satisfy the need of pure water for one family. Solar desalinate water have a lot of health advantage such as removing contaminants, elimination of chemicals and no additives. However the result obtained at the end of this paper were not as similar as theoretical figure, from first day experiment the amount of distilled water collect was 750cm3 and second day 1700cm3 which is less than theoretical number. While conducting the experiment different factor are identified the major are types of materials (glazing, insulator) and design parameter (tilt angle, tracking and mechanism) and site (solar radiation and shadow). Generally the efficiency of solar water still can be optimized as much as possible by design modification, material selection and site selection

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INTRODUCTION

It is an established fact that water is the most abundant resources on earth. Water is essential for human use, covering approximately three-quarters of the planet's surface. About 97% of the earth's water is salt water in the oceans, while 3% of all fresh water is in the ground water, lakes and rivers. Therefore, controlling of water quality is one of the essential issues of drinking water management. Despite the abundance of water, availability of potable water is one of the major challenges in developing countries.Water shortage is a worldwide problem, and of which 40% of the world population is suffering from water scarcity. Ethiopiais also one of the country in which access of safe drinking water is critical problem. Because the need for safe and clean drinking water is increasing rapidly with rapid population growth of the country climate change have resulted in an increasing pressure on quality and quantity of water resources especially in rural area.

Corresponding author: **Wondwosen Shiferaw Aga,**
Department of Agricultural Engineering, Haramaya Institute of Technology, Haramaya University, Harar, Ethiopia.

There is often enough water available in Ethiopia about 12 river basins with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6 - 6.5 billion m^3 of ground-water potential [Ministry of heath of Ethiopia, 2004]. This corresponds to an average of 1,575 m^3 of physically available water per person per year, which is relatively large volume, but it is not pure or contaminated bydifferent things such as animal's residue, insects, rodents and pathogenic organisms, unwanted product of industry and by products of hotels. Mergingdistillation technology by using renewable energy (solar energy) is viewed as a reasonable alternative to supply pure water as it can be cost effective and also has potential to transform the life of people living in small communities in rural areas where pipe water is not reached.This project focuses on solar water distiller technology which purifies water by harnessing solar energy by technology called solar still. Distillation is the most widely used process for water purification. Naturally, solar energy heats water in the seas and lakes, and then evaporation takes place. Water vapour condenses in the atmosphere and returns to earth as rain water. Solar distillation represents one of the simplest techniques and is useful for the production of fresh water from brackish or saline water in many parts of the world. This project aimed of introducing the way of utilizing solar energy in water distillation process which is abundant source of energy in Ethiopia as well as to extending availability of potable water for community in the country especially those live in arid area.According to some recent literatures access to water supply and sanitation in Ethiopia is amongst the lowest in sub-Saharan Africaand the entire world. While access to safe drinking water has increased substantially with funding from external aid, much still remains to be done to achieve the millennium development goal of having the share of people without access to safe drinking water and sanitation by 2015, to improve sustainability and to improve service quality [Growth and Transformation Plan Drafted, 2010]. The government's Plan for Accelerated Sustained Development and to End Poverty (PADEP), covering the period 2005-2010, aimed at increasing access to an improved water source to 84% and access to improved sanitation to 80% by 2010. These ambitious targets go well beyond the water and sanitation targets of the Millennium Development Goals, which aim at halving the share of people without access by 2015. According to one set of government figures, which is used by the Ministry of Finance and Economic Development for planning purposes, access to drinking water reached 68.5% in 2010. According to another set of government figures, based on national survey data and used by the WHO and UNICEF to monitor the Millennium Development Goals, in 2008 access to an improved water source was only 38% and to improve sanitation 12 % [Encyclopedia, 2009].

In 2010 the government presented the equally ambitious Growth and Transformation Plan (GTP) 2011-2015 that aims at increasing drinking water coverage, based on the government's definition, from 68.5% to 98.5%. Water sanitation and hygiene are core part of Ethiopia government policies where more than 250,000 youngsters die every year due to lack of safe water supply. Availability of pure water in the country is about 35% which is the least in Africa. This show that lack of access to safe drinking water makes children especially vulnerable to water borne diseases such as diarrhea [World Bank, 2011]. The water crisis also force millions of people mainly rural women and young girls to spend much hours for collecting and carrying water which is somehow pure for drinking. The availability of cost effective approach to harness the solar energy in solving the problem associated with potable water cannot be overemphasized. This is a major challenge in the developing countries today. Many health disorders in rural communities in the developing countries have been traced to intake of contaminated water. As result of this a lot of children in the country exposed to vulnerable water born disease. In addition to this rural women and children walk long distance for fetching water which is not that much pure. This intern may restrict their opportunities for education. For this reason, purification of locally available water is extremely important. This results in a very challenging situation for individuals trying to prepare pure water in local conditionso as to keep themselves and their families safe from the myriad diseases and toxic chemicals present in untreated water. However, one of the abundant energy sources which the country endowed to make it use for purification water is solar energy. According to Ethiopia metrology agency the total solar energy per annual is 6.25kw/m^2/year. Therefore, there is a solution to this problem. Thus using solar water still allows to utilize this cheap source of energy.

In addition to providing potable water for rural small house hold the students were develop basic concept of thermodynamic, heat and mass transfer and how to utilize alternative energy source for different purpose. Generally purifying water through distillation is a simple, yet effective means of providing portable water in a reliable and cost-effective manner. Solar stills effectively eliminate all water borne pathogens, salts, and heavy metals, and produce ultra-pure water to be superior to most commercial bottled water sources.

Statement of Problem

Ethiopia has huge source of water, however a lot of water source are not potable for drinking directly and not used for cooking need of family. In addition to this solar energy is also one of the most abundant source of energy in the country. Although the country has large potential of solar energy in which sun shine for more than eleven hours throughout the year, the country has not been utilized the solar energy for various purposes particularly for water purification. Single–basin solar still is simple technology which can be able to utilize this cheap and renewable source of energy. Due to use of contaminated and brackish water for drinking and other domestic purposes, most of the people in rural areas are exposed to water borne diseases such as diarrhea, ameba and other related diseases. The wide problems that mentioned above initiate us to come up with designing solar water distiller for addressing lack of potable water especially where pipe water is unreachable. Therefore, this project aimed to solve the problems that the societies face by using single solar water distiller which is simple to design, to operate, low cost, manufactured locally and effective to produce pure water.

Objective

General Objective

- To design, fabricate and evaluate performance solar water distillation.

Specific objective

- To fabricate single-basin solar distiller
- To enable students to commit themselves in further innovation and adoption of technology for community beside their academic duty.
- To test the efficiency of the distillers in terms of pure water output by varying depth of water and time.
- To test quality of pure water obtain from the still

LITERATURE REVIEW

History of solar distillation

Solar distillation has long been considered of making the impure water drinkable. The history goes back to as early as 4th century B.C. Aristotle described a method to evaporate impure water and then condense the vapor use it for drinking Anirudh Biswas *etal*/ VSRD International Journal of Mechanical, Auto. & Prod. Engg., 2012 potable use. Della Porta (1589), used wide earthed pots exposed to the intense heat of solar rays to evaporate the water and collect the condensate into to P.I. Cooper, In his report on development and use of solar stills, insists that Arabian alchemists were the earliest known peoples to use the solar distillation to produce the potable water in the solar stills was introduced for the first time in the Second World War when the large scale solar stills were to support the US military. A solar still operates on the same principle as rainwater: evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. In this research solar still used for distillation of water, purified waters are used in battery, chemistry lab, and other industrial use, so that some short of small scale industries comes in the new world for the manufacturing of the distilled water and get employments.

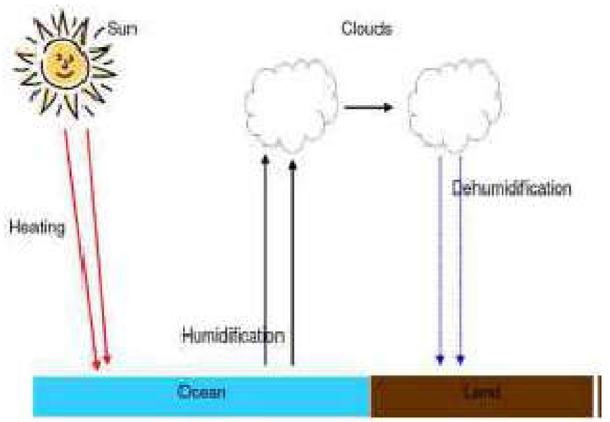

Fig. 1. Rain cycle (Herold D., and Neskakis A., 2001)

The literature also implies, solar energy is an abundant, never lasting, and available on site and it is pollution free. However, the cost of its collection and utilization becomes high because it is diffuse, of low intensity, and intermittent and therefore, requires some kind of thermal energy storage. Muraseetal, (2010), developed an idea to improve the feeding system of a roof type solar still and was tested. The still is composed of bended heat penetrating plates at the centre having a channel for liquid flow below the crease of bending. A laboratory test apparatus of two effects having 500mm by 500mm heat penetrating area was designed and made mainly from polyethylene film. A test under cold conditions has proved the idea to be feasible. Toyama etal, (2010), have studied the performance rating and efficiency of a solar still operating under different conditions. The three major variable factors in the still performance are the solar radiation, the wind velocity and the insulation of the system. Past studies shows that the project done on solar water distiller has some constraints such as high cost, low efficiency, not affordable and complex in design. However, the project which proposed to design will overcome the problem faced on previousresearches. Single-basin still which we have been designed was low cost, simple in construction, high efficiency, affordable, require low maintenance cost, easily movable and produce high quality water.

Types of Solar Still

The distillation system can be classified under two categories: Passive and active. Malik et al.,(2011),have reviewed the work on passive solar distillation. Further work was carried out by Tiwari.etal. (2010), which also includes work on active solar distillation. They have carried out a study on the present status of research work on both passive and active solar distillation systems.

Tiwari.etal.(2010) recommended that only passive solar stills can be economical to provide potable water. As a result of large interest for water purification; several types of solar still have been evolved. Some of them are single or multiple wick stills, the multistage flash distillation stills, solar film coveredstill, and solar concentrator stills. Only the basin type stills usingsingle effect distillation have been used for the supply of large quantities of water for isolated communities or for small supplies of water such as for battery charging and analytical purposes. There are several minor variations in the geometric configuration of single basin stills. Some of solar still are discussed below.

Roof type solar still

A roof type solar still is simple in construction. This still is composed of bended heat penetrating plates at the centre having channel for liquid flow below the crease of bending. Bags of 500 mm were made from polyethylene film of 1 mm thickness. Each of them was penetrated by a tube of 15 mm in diameter at the centre and bended by stretching both sides at an arbitrarily given angle. Fibrous sheet of 1.3 mm thickness as wick attached inside the upper film of the bag. The dual holes were for manipulating the balance of liquid flow to both wings of the sheet. The side angle and inclination angle were fixed at 14.68 and 9.78, respectively. Brackish water for purification is fed to the central tube from a head tank. The upper plate of the still is heated by infrared lamps through two sheets of frosted glass to attain uniform irradiation.

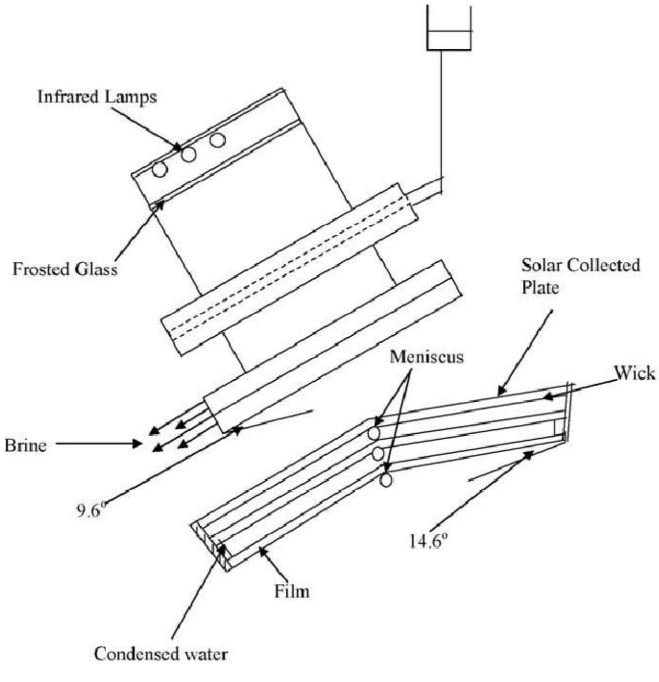

Fig. 2. A roof type solar still (A.Kaushal.varun, 2010)

A portion of salt water is evaporated from the surface of fibrous sheet by receiving heat from the upper plate and condensed above the opposite surface. The condensed fresh water is collected in rectangular tubes at the both sides of the still as shown in Fig. 1.Murase et al., have analyzed a specific problem associated with the feeding system of a roof type solar still and they have also analyzed a specific problem associated with the metallic material; which may difficult to construct locally and a lot of part need welding.

Tilted wick solar still

Tilted wick still with flat plate reflector is very simple in construction. It consists of a glass cover, evaporating wick and a vertical flat plate external reflector of highly reflective materialssuch as mirror finished metal plate. Saline water is fed to the wick constantly. The direct and diffuse solar radiation and also reflected solar radiation from external reflector are transmitted through the glass cover and absorbed on to the wick. Tanaka et al. have carried out the study to improve the productivity of tilted wick solar still by using flat plate reflector and also carried out numerical analysis for this purpose. Malik et al.havealso indicated one of their still, which can be useful to increase the productivity for the tilted wick solar still. Sodha et al. have given their concepts to increase the productivity of the still Similarly, Minasian et al.

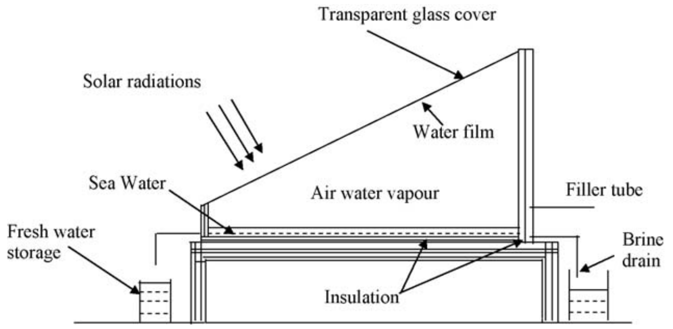

Fig. 3. A schematic diagram for sea water desalting. (A.Kaushal.varun, 2010)

MATERIALS AND METHODS

Site Description

The Experiment was conducted at Haramaya University in east-central Ethiopia. Located in the East Hararghe Zone of the Oromia Region, the town has a latitude and longitude of 9°24′N 42°01′E Coordinates: 9°24′N 42°01′E with an elevation of 2047 meters above sea level.The daily average temperatureHaramaya area is 23^{o}c and the average solar radiation of semi-arid is 6.25kw/m^2/day. (Ethiopia Metrology Agency Haramaya branch, 2014).

Materials used

For the construction of the still, timber, transparent condensing cover (glass), two tanks, galvanized sheet metal, screws, rivet, rectangular iron tube, nails, pvc tube, elbow, black and white paint, silken glue,tap, and outlet valve were used. To test the still, thermometer and stop watch were used. Machine and hand tool used for assembling of the still were drilling machine, arc welding machine, screw driver, hotter gun, hummer, hacksaw and wood cutter

Design of Single-basin Solar Still

Among the many factors considered in the design and fabrication of a solar water distillation system are cost implication and efficiency. To determine the total volume of solar still, the daily water consumption per person was considered. According to (Medical Journal, 2002) the daily water consumption of one person per day in tropical area is 1.5 litters/day. Thus, the total volume of water required per house hold or family is calculated as follows;

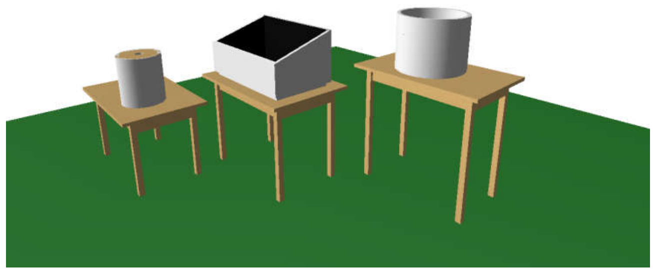

Fig.4. schematic diagram of single basin solar still

V_s= q*N (3.1)

Where, V_s=Total volume of water required per house hold (Littre)

q = Daily water consumption per person
N = Number of family

Assume that, if the average family household in Ethiopia are 5 members

Therefore, V_s=q*N
=6*2
V_s=12litres/day per person

To determine aperture area of the still, Transportation and rate evaporation was considered;

So, A_b= w*l (3.2)

Where, $A_{b=}$aperture area of still

w=width of the still
l=length of the still

Therefore total volume (V) of brackish water in the still is equal to the total aperture area of the still multiply by the maximum height (h) at which water should filled:-

V= A_b*h

Construction procedure of the still

Fabrication of the whole unit is pretty straight forward and involves metal cutting, welding, glass cutting, sealing, painting and drilling. All these processes can be done at IOT workshop using drill, welding, brush, cutting machine etc. Once the area of aperture and the maximum volume required for individual house hold was assumed the following steps were followed to fabrication or assemble solar water still;

Step1. Construct wood box with dimension of 150*100cm. the outer or the box is constructed from timber or wood since it is none conducting material as result timber hold heat energy develop inside the distiller or prevent from escaping to surround.

Step2. After assembling the box cover or tight the internal surface of the box by galvanized sheet metal and paint black color. This is because sheet metal has property of conductor and black paint assist for abortion incident solar radiation. Three mode of heat transfer takes place radiation from sources heat energy sun then penetrating through glazing cover above the box and black body absorb solar radiation and metal sheet emit or give out to water due to temperature difference betweensheet metal and water then due to molecular movement water temperature to increase.

Testing the solar still

While conducting the experiment the efficiency of the still is calculated in terms of pure water output to input water ratio and also measure the daily output of pure water from the still throughout the trough by using jar.

RESULTS AND DISCUSSION

During the experiment, properly calibrated thermometer was used to measure the inner and outer surfaces of condensing covers and temperature of brackish water before added to the still and water in the still. The basin was then filled with required quantityof water and the condensing cover is cleaned properly before the start of experiment. Experiments were conducted at the water depth of 0.01 m and 0.013 m. During experiment when water depth was varied from 0.013 m to 0.01m the output ratio also varies due to evaporation rate.

By using these data rate of rate of heat transfer can be calculated between absorber plate and fluid and also out late temperature of the water can be estimate but for this case the out late temperature was measure by using thermometer during the experiment. The experiments were carried out to study the effect of water depths (0.01 and .013m) on the performance of single slope passive solar stills.

The aim of measuring the outer, inner, ambient and water temperature in the still were to detect or observe the effect of temperature difference on condensing rate of vaporized water under the condenser. As observed from table 1 the temperature difference between the inner and outer glass were minimum. These affect the amount of pure water output or condensing rate of vaporized water. Therefore, in addition to depth of water the temperature difference also affect the amount of pure water output per day from the still. As we observed from table 2 the amount of pure water increases, due to fair temperature difference than the first day difference test. Weight of distilled during first day or efficiency of the still (e)

e=output water/input brine water

Table 1. Summary of the materials components of the solar still considered

No.	Component	Material(s)	Properties and comments
1.	Collector/ glazing transparent	Glass	❖Low water absorbance ❖High thermal conductivity ❖Transparent to short wave radiation ❖Can withstand the effect of weather, wind, sunshine, rain, dust, etc
2.	Basin (Absorber)	Galvanized sheet metal	❖High radiation absorptivity ❖Stable to corrosion ❖ High thermal conductivity
3.	Insulator	Timber / wood	❖Very cheap ❖ Poor conductivity and radiation of heat ❖ Very effective for insulation
4.			

Table 1. Measured parameters for 0.013 m water depth

	Temperature			
Time	$T_a(^0c)$	T_{og}(in ^{o}c)	T_{ig}(in^{o}c)	T_{iw}(in^{o}c)
11:00am	21	20	20	20
12:00am	24	34	43	33
1:00pm	31	35	47	52
2:00pm	31.5	37	53	59.6
3:00pm	31	52	59.7	66.7
Overall pure water out put	750cm^3			

Table 2. Measured parameters for 0.01 m water depth

	Temperature			
Time	T_a(in ^{0}c)	T_{og}(in ^{o}c)	T_{ig}(in^{o}c)	T_{iw}(in^{o}c)
10:00am	27	20	20	20
11:00am	32	35	47	40
12:00am	35	39	56	60
1:00pm	32	34	57	70
2:00pm	30	39	61	95
3:00pm	31	43	69	120
The overall output pure water per day 1700cm^3				

In the experiment, the following data were collected every hour for a period of 5 hours at first day and 6 hours at second day ofexperiments.

- Outer glass cover temperature (Tog)
- Inner glass cover temperature(T_{ig})
- Water temperature in the still(T_{iw})
- Ambient air temperature(T_a)

From this experiment the efficiency of still was too much below what expected before. The reasons of this efficiency reduction are due to the following factors;

- Depth of water or volume of water added to the still
- Clearance between cover glass and insulator
- Ambient temperature
- Starting time of the experiment

- Clearance or gap between condenser and trough or leakage

Weight of distilled during second or efficiency of the still (e)
e=output pure/input brine water. Experiment two shows that the efficiency of solar still is increased. The increment in efficiency was due to the following reasons;

- Depth of brine water added
- Clearance between trough and condenser was minimized
- Sealed the gap between glass and insulator

From two experiments we conclude that if still design improved perfectly the efficiency are increased. That means construction materials such as; condensing glass, absorber, insulator, trough and reflector should be selected for construction.

General Distilled Water Quality Analyses

Clean water is essential for good health. In today's industrialized world, many waterways are polluted and water requires treatment to become safe for consumption. Small-scale approaches to water treatment can help people who don't have access to mains water supplies. Solar distillation is the process of removing salts and other impurities using the energy of sun to get pure water for drinking.

BENEFITS AND BENEFICIARIES OF THE PROJECT

General health benefit of drinking distilled water

Distilled water is water that's been purified of contaminants through distillation. The process is relatively simple; water is brought to a boil and converted to steam. The steam flows through cooling tubes and condenses back into pure water. This is different than simply filtering water in that this process removes all potentially harmful organisms and chemicals. As you may imagine, there are benefits to drinking and using distilled water beyond superficial smell and taste improvements. The following are the most important benefit that one individual gained by using distilled water.

Removing Contaminants

The most important health benefit distilled water offers is the elimination of water borne contaminants that may potentially be found in water. Drinking contaminated water is one of the fastest ways to spread disease, toxic metals and industrial pollutants. By removing the contaminants from water through distillation, we can help alleviate the risk of future illnesses and toxic buildup.

Elimination of Chemicals

The most common problem with drinking municipal water is that chlorine and/or fluoride are added as part of the water treatment process. The addition of fluoride is a huge can of worms alone and perhaps one of the greatest scams perpetrated in modern times. Among a host of other problems, too much fluoride in your drinking water can have adverse effects such as tooth discoloration and breakdown of tooth enamel. Chlorine can be harmful to your skin in undiluted amounts, it can also be harmful to your body in the diluted amounts of city water. Distilled water has filtered out these chemicals as well as others to make what is called pure water.

No Additives

Many municipal water supplies also contain calcium. While calcium is essential to maintaining good health, too much calcium can be a precursor to kidney stone formation. For some people, kidney stones can be a constant and painful problem and drinking distilled water can reduce the risk of developing more kidney stones and, if you just prefer to be in complete control of how you receive your vitamins and minerals, there is no substitute for distilled water. (By Dr. Edward Published on November 20, 2012)

The benefits that could be derived from this project are the following:

- It produces water of high quality.
- Maintenance is almost negligible.
- Any type of water can be purified into potable water by means of this process
- The system will not involve any moving parts and will not require electricity to operate.
- Low initial investment
- No high technology exchange parts like batteries
- Simple production (often locally)
- Independent drinking water supply for individual families
- No consumption of fossil fuel
- Leading to zero greenhouse gas emissions and
- Reduce health problem and save the time to fetch water

The beneficiaries of this research include

- Small farmers and individual households;
- Small-scale entrepreneurs engage in local fabrication of solar still and distribute the still.

Especially serves for those where pipe water is not reached.

Conclusion and Recommendation

Conclusion

The distillate output varies with the water depth and it decreased with increase of water depth in the basin. In addition to depth of water the temperature difference between the inner and outer glass also affect the amount of pure water output per day from the still. To study the effect of the water depth in basin different amount of water is added into the solar still. Then we observed that as depth of water in the still increase the efficiency decreases and as depth the water in the still decrease the increase as well as if the temperature difference increases the condensing rate of vaporized water increases. Since solar still is simple technology, locally constructed, run without electricity, no movable part that may require lubrication, and affordable for the small house holder or family. Generally, solar still is affected by depth of water andtemperature difference. However, it's simpletechnology, locally constructed and affordable.

Recommendation

It is recommendable to this set concrete basement and extension for further case study and replacement of some components to increase the still efficiency more than what we obtain. In addition modification of materials used for fabrication of solar still. Depending on what we had observed while conducting the experiment and performance evaluation of single basin solar still, the following parts should be replacedto increase the efficiency of the still.

- Condenser by solar glass (timbered glass)
- Angle of inclination should be increased
- The size and types pvc tube should be changed or use Stainless
- Steel in place of pvc.
- The volume of water added to the still at time should be minimized
- Testing of the water still should select based on ambient temperature w
- Position of drain plug

Generally this project come up with inspire result which shows that if further modification of both materials and site of test will selected with optimum atmospheric temperature the efficiency of the will be improved well and the technology of will the future solution for thousands of water born disease death in the country.

Acknowledgment

I would like to pass my gratitude for many individuals those who have contributed to make this project a successful. Specifically, I would like to express my great appreciation to Mr. Yonas Alemu for his financial support required for publication process and Kasahun Yimer (PhD) for his guidance and comprehensive comment. Last but not least, I would like to thanks Asfew Kebede (PhD) Dean of Haramaya Institute Technology and Prof. Kebede W/Tsedik Head of Haramaya Research and Community Engagement for providing me the materials and some equipment I have used in this work.

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