2023 NIGERIAN STOCKHOLM JUNIOR WATER PRIZE NATIONAL WINNERS' PROJECT

Bithermal Water Distillation Device

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INTRODUCTION

Bithermal Distillation device is an efficient device designed to purify and recycle water in order to increase access to drinkable water in the riverine and rural communities. The device use direct solar energy from the sun and also a solar cell. John snow (1854) discovers a link between water and the spread of cholera during a breakout in London. UNICEF (2020) more than 11 billion people have died of draught. 70% of water at the point of consumption is contaminated and children are the most affected. Also over 20million people, including10million children, in Djibouti, Ethiopia, Kenya and Somalia will need water and food assistance through 2022. Lastly 117,000 children died in Nigeria each year due to water related illnesses, one of this affected area is Makoko.

Makoko is an informal settlement across the third mainland bridge located on the coast of mainland Lagos. A third of the community is built stilts along the lagoon and the rest on land. There is a paradox: while Makoko thrives on water as one of the major source of livelihood of the inhabitant, residents have no access to save drinking. "No potable water". Makoko's biggest challenge involves water: It is polluted. Residents get their water from borehole a mere 200 meters into the polluted lagoon. The water sometimes turns red if kept overnight. A community housing about 85,000—250,000 thousand people, where each person consumes about 47 liters of water. Each family spends about 5000 naira on water every month on groundwater alone. It is not surprising that the disease and death rate are high. Sickness and diseases like cholera, diarrhea etc. is so rampant that it has become a norm.

Our invention was born out of the search for an innovative way to solve the problem or at least mitigate their effect. Pure water is the first and foremost drug (Slovakian Proverb), hence the need for clean affordable water in the society especially in the rural areas. Our device tends to transform dirty water to clean drinkable water

OBJECTIVES

The following are the objectives of our project;

- To improve access to quality water supply in the rural communities.
- To recycle dirty water into a drinkable water.
- To produce efficient device for water purification

MATERIALS AND INSTRUMENT

1. Solar panel
2. Delivery tube
3. Fresnel lens
4. Glass container/ Stainless
5. Airtight Nut
6. Metallic Stand
7. Collector
8. Condenser
9. D.C. Element
10. D.C. Wire
11. Electric wire
12. Activated charcoal
13. Fiber
14. Fine sand
15. Gravel
16. Coal
17. Coal Pot

PROCESS OR STAGES

There are two process involved: Filtration and Distillation Process

1. Filtration: the setup is the first stage of water purification, it contains; Fibers, Charcoal, Gravel and Fine Sand in that order. The fibers serve as a sieve for bigger dirt and particles, the charcoal absorb the bad odor and taste while Gravel and Sand filter the water.
2. Distillation: This is the second stage of the purification. The setup is named Distillation Box which adopts two methods as stated in Method and Approach.

LITERATURE REVIEW

This chapter assesses the efficiency and effectiveness of Water Still device to produce distilled water. The following concepts are discussed in the chapter;

- SOLAR STILL WATER DEVICE
- PASSIVE AND ACTIVE SOLAR STILL
- CHALLENGES OF SOLAR STILL
- STORAGE OF EXCESS HEAT ENERGY

SOLAR STILL WATER DEVICE

Renewable energy sources such as wind, solar can be used for distillation (Anwar and Deshmukh, 2020). Solar energy is green, clean, economical and viable energy source for water purification. Distillation of brackish water using solar energy is recognised as solar distillation. The device used for solar distillation is known as a solar still (El-Sebaii and El-Bialy, 2015). Solar still is capable of removing an inorganic, bacteriological, organic, non-volatile contaminants and bacteria from the water (Hanson et al., 2004). Solar still comes under the low-carbon economy as it does not have any impact on greenhouse gas (Speirs et al., 2010). Territories suitable to use solar energy can be easily located utilising geographical information system (GIS), where solar still can be installed for community drinking (Khalid Anwar, 2018).

According to history, in fourth century B.C., Aristotle demonstrated a method to boil and condense the sea water to make it drinkable. Greek navigators used to boil and condense the saltwater to produce freshwater. In late 1551 Centuries Arab alchemists and in 1742 Nicolo Ghezzi used solar distillation systems. Lavoisier used glass lenses to concentrate solar energy for distillation (Tiwari et al., 2003). In 1872, the first conventional solar still was erected near Las Salinas in Northern Chile by a Swedish engineer Charles Wilson, to supply drinking water to workers and animals living nearby the nitrate mine.

Solar stills are primarily categorized as passive and active systems (Varun Raj and Muthu Manokar, 2017). The most commonly used solar still consists of simple passive still, where the heat collection and distillation process take place within the same equipment. The active solar still comprises of an additional source (such as solar collectors, solar ponds, waste heat from industries as well as power plants) to supply extra heat to saline water in the basin to increase its evaporation rate (Lal et al., 2017). The active stills are found costly and inconvenient to use for domestic applications; however, passive stills are simple in design and more effortless in fabrication at a low cost, therefore suitable for household use. Distil water needed for many industrial applications such as wet batteries, pharmaceuticals, hospital laboratories can be easily generated using active solar stills (Zhang et al., 2018).

PASSIVE AND ACTIVE SOLAR STILL

Single-slope single-basin passive solar still is a basic design of conventional solar still (Maddah, 2019). At a water depth of 2 cm, efficiency and daily freshwater yield were reported as 34.4% and 3.21 kg/m2 per day (Agrawal et al., 2017). These results indicate that conventional still has poor energy efficiency and low distillate output as compared with its size and cost, hence not fully commercialized until today as compared with other methods of distillation. Many investigators altered the design of solar still components to make it more efficient and productive. Several research investigations are available in the literature on the control of design, and operating parameters to maximize the energy efficiency and designs of solar stills are primarily categorized as passive and active systems (Varun Raj and Muthu Manokar, 2017). The most commonly used solar still consists of simple passive still, where the heat collection and distillation process take place within the same equipment. The active solar still comprises of an additional source (such as solar collectors, solar ponds, waste heat from industries as well as power plants) to supply extra heat to saline water in the basin to increase its evaporation rate (Lal et al., 2017). The active stills are found costly and inconvenient to use for domestic applications; however, passive stills are simple in design and more effortless in fabrication at a low cost, therefore suitable for household use.

CHALLENGES OF SOLAR STILL

From the installation of the first solar still in 1872, very few communities started using solar still. After the comprehensive research on solar still by many investigators till date, solar stills are neither popular nor commercially available for common households and industries. It is required to take out the solar still from laboratory to the public utility. Well designed and energy-efficient solar still will reduce the carbon footprint on the environment caused by conventional desalination system (Cheng et al., 2011). However, from the available literature on modified solar still, it is not possible to specify the best design of solar still for domestic and industrial use. For this reason, it is required to compare different solar stills from the application and economic standpoint. Many investigators have written widespread reviews on solar stills to understand technological development, to investigate and compare the thermal performance such as Yield of solar stills with porous basins (Madani and Zaki, 1995), Present status of solar distillation (Tiwari et al., 2003), A review of desalination by solar still (Aybar, 2007), Researches and developments on solar stills (Kabeel and El-Agouz, 2011), Wick type solar stills (Manikandan2013), Energy and thermo-economic analysis of solar distillation systems (Ranjan and Kaushik, 2013), Factors affecting basin type solar still productivity (Muftah et al., 2014), Different parameters affecting the rate of evaporation and condensation on passive solar still (Muthu Manokar et al., 2014), Techniques used to improve the performance of the stepped solar still (Kabeel et al., 2015), Parameters influencing the productivity of solar stills (Prakash and Velmurugan, 2015), Advanced designs of solar desalination systems (El-Sebaii and El-Bialy, 2015), Solar stills system design (Vishwanath Kumar et al., 2015), Various special designs of single basin passive solar still (Durkaieswaran and Murugavel, 2015), Thermal models of solar still (Elango et al., 2015).

To store the thermal energy in solar still, some energy storing materials are used. Black rubber, gravel, sand, metallic wiry sponges and surfactant additives are some of the energy storing materials used in solar still. The influence of the variation of the rubber sheet thickness on the still productivity is investigated by Nafey et al. The experimental results showed that black rubber of 10mm thick improves the productivity by 20% at the conditions of 60 l/m2 brine volume and 15° glass cover angle. In addition, they studied the influence of black gravel on the productivity of the solar still. Using black gravel of 20–30 mm size improves the productivity by 19% at the condition of 20 l/m2 brine volume and 15◦glass cover angle. Also Velmurugan et al. added pebbles in the solar still and found that the productivity increased by 20% than the conventional solar still. Different types of absorbing materials like metallic wiry sponges (coated and uncoated) and black volcanic rocks are used to study their effect on the yield of solar stills. The results showed that the uncoated sponge has the highest water collection during day time, followed by the black rocks and then coated metallic wiry sponges. On the other hand, the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks, respectively. Sharaka integrated basin solar still with a built-in sandy heat reservoir. The results showed that, integrated heat reservoir causes significantly higher solar still productivity during nights and cloudy days. An energy storing material is used in the basin solar still. (Habib and Khalifa). Also a flat plate solar collector and a separate condenser are coupled with the solar still to increase the daily productivity by increasing the temperature of the water during the day and to store the hot water excess that would extend water desalination beyond sunset.

STORAGE OF EXCESS HEAT ENERGY

A new way of storing excess heat energy in horizontal solar desalination stills during daytime for the continuation of the process at night has been center of discussion. This technique divides the horizontal still into evaporating and heat storing zones and combines the advantages of shallow and deep stills. The performance of heat storing zone was studied over one year and exhaustive data were collected, analyzed and presented. To show the effectiveness of the system, its performance was compared with that of the shallow still. The heat storing capacity of the system during the daytime was found to be an average of 35.7% of the total amount of solar energy entering the system. The efficiency of recovering process, in the form of portable water produced at night, was found to be an average of 47.2% of the total amount of energy stored during the day. Furthermore, this technique does not require any kind of external power for storing and recovering processes.

The existing conventional small solar desalination basin stills suffer from some drawbacks, which make them inefficient to be used as domestic solar desalination units. Many attempts have been made to improve the efficiency of these small units. To mention a few, Kudish et al. proposed a low cost solar desalination still, Cooper studied the effect of reducing the water depth on the productivity of the horizontal still and found that this will effectively improve the productivity of insulated still, Lawrence and Voropoulos et al. Couple a solar still with a panel of collectors through heat exchanger, Riffat designed a single and multi-effect absorption system for water desalination powered by solar energy, Rahim and Taqi proposed a new technique called force condensing technique where the water vapor was extracted from the solar desalination still and forced to condense in copper tubes held at lower temperature than the vapor produced, Kwatra presented a theoretical analysis to show the effects of enlarging water evaporation area on the performance of the solar still, Rahim highlighted some drawbacks that exist in the evaporating and condensing zones of the horizontal solar desalination stills and proposed new techniques to improve the efficiency of such units. Other researchers improved the efficiency of the solar desalination units by building multiple-effect solar stills.

Tilted stills were suggested by some researchers, several designs were proposed to improve their productivity. The results of those studied show that although the yields of tilted still is larger than those of the conventional ones during sunshine; the nocturnal production of the tilted still is almost zero.

The mass of the water at the basin affect the productivity of the deep basin still device. The heat input, the increase in the water temperature, and the rate of evaporation, is inversely proportional to the mass of the water in the basin. Though the shallow basin still has better efficiency than the deep basin still at sunshine hours, but due to its limited heat storage capacity its nocturnal production is almost zero.

Efficiency of solar desalination system depends on its ability to store excess heat energy gained during sunshine hours for the continuation of the process at night. Although many studies were performed to store excess heat energy in solar water heating system, little work was carried out to store heat energy in solar desalination units.

METHODOLOGY

METHOD AND APPROACH

This research work utilized experimentation method. This method enables us to check the efficiency of our device mostly by Trial and Error. The two processes involved are Filtration and Distillation.

FILTRATION

The set up for filtration (filter Bed) consist of fine sand, gravel, charcoal and fiber;

1. Fine sand of about 60 to 70 cm thick having effective size
2. Gravel about 40 to 60 cm thick bed. The gravel is graded in different layer
3. Activated Charcoal help to remove bad odor from the dirty water
4. Fiber helps to trap some microorganism and also act as sieve for bigger particles from the dirty water.

DISTILLATION

The distillation box is made up of Fresnel lens, D.C. Wire, D.C. Element Insulation Material, Condensing Glass, Delivery tube, Collector, Battery, and Solar Panel. Our device can use two source of heat for the distillation process; Solar Energy directly from the sun and Heat energy from D.C. element. It can also be design to make use of Charcoal. Though Charcoal is not environmentally friendly but it still remains the most accessible and most affordable source of heat for people in African Localities. According to statistics Africa contribute just 2% of the total Green House Gases. If

1. The Fresnel lens will absorb the solar energy directly from the sun and convert it into heat energy which breaks apart the water molecules to produce pure H2O in form of vapor that is then condensed by the glass. This is collected as liquid by the collector into the container.
2. The panel attracts solar energy from the sun which is then converted into electrical energy to charge the battery. The battery then powers the boiling ring. The energy is then converted to heat energy by the boiling. The impure water gets heated up and turns to vapor which also passes through the delivery tube to the container of the pure and distilled water.
3. The coal pot containing coal is place directly under the distillation box with an opening below which allows heat energy from the coal to have direct contact with the stainless steel inside the distillation box. This heats up the impure water in the distillation box. The water then evaporates and it is condensed on reaching the glass surface of the distillation box. The distilled liquid is collected by the collector which is passed through the delivery tube in to the container of the pure distilled water.

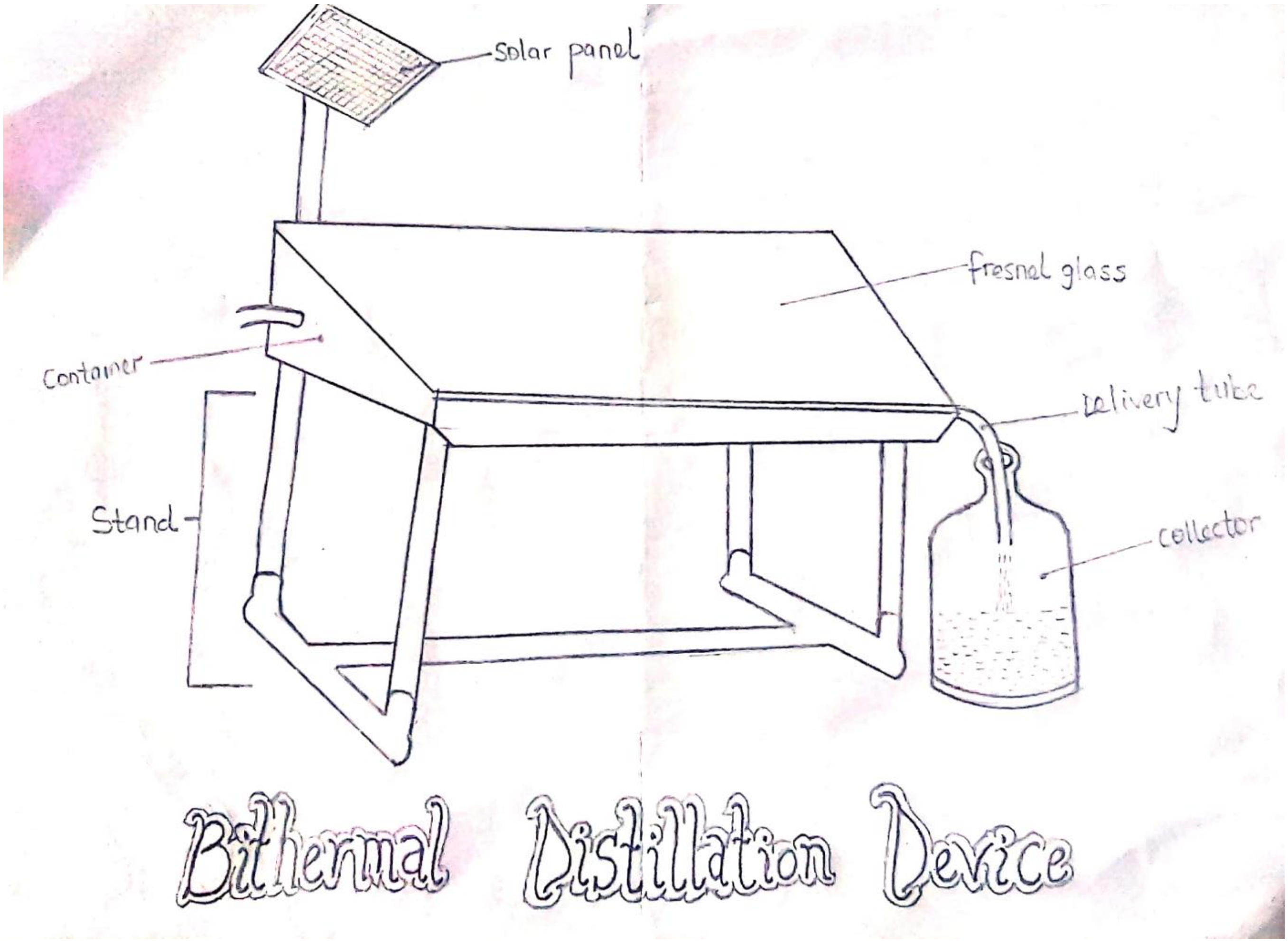
RESULT ANALYSIS

The following data were obtained from our bithermal Still water device using different source of heat namely Solar through Fresnel lens, chemical energy from battery powered by solar panel, and from Coal (easily accessible and cheap for people in our localities).

1. Solar energy from Fresnel lens: we observed that the time T_S taken for 500ml sample of impure water from Makoko to form the first set of bubbles is between 2 – 3 hours. The first set of condense particles started forming 3-4 hours after setup. The first drop of distilled water into the delivery tube takes place between 4-5 hours after set. Due to excess heat loss to the surrounding and unavoidable water vapor escape the volume of the distilled water produced is just 10ml 30mins after condensation. The surface area of the glass cover used is 21 inches by 13 inches and 40 pieces of small Fresnel lenses were used. The experiment was carried out on a sunny day Tuesday 9th of May 2023 in Yaba, Lagos mainland Nigeria.
2. Battery powered by Solar Panel: 100amps of 12volts Car battery was to connect to a 10mm D.C. cable which was also connected to a 12 volt boiling ring. On top of the battery is a charging regulator for solar panel connected to the 60watts solar panel. The first set of water bubbles was generated just few minutes after the device was switch on. An average of 100ml of Distilled water was generated per hour with this device.
3. Heat from Coal: Though Charcoal is not environmentally friendly but it still remains the most accessible and most affordable source of heat for people in African Localities. According to statistics Africa contribute just 2% of the total Green House Gases. If it cost another 2% of Emission to provide drinkable for 40% of African who lack drinkable water. The design for coal can also be as efficient as that of the battery.

WATER TEST

Pure (distilled) water free from impurities will be collected by the collector. The final product was subjected to series of test. We find out that it pass all the necessary test. The filtration process will take care of the odor, the color and some microorganism. The distillation process which is the final process can reduce the microorganism level to Zero. Only water molecule will vaporize and condense inside the distillation box.



RECOMMENDATION

Government and Private Cooperate Organization can setup a bigger scale of this project in the riverine area where drinkable water is a problem .e.g. Makoko.

CONCLUSION

An individual need s at least 75liters of water in a day, this device has a surface dimension of 14inches by 22inches and is capable of generating more than 100ml per hour. if properly funded and improved in different dimension and sizes our device can take care of the water needs of individual, family and community at large.

REFERENCE

V. Velmurugan, KJN Kumar, TN Haq, and K Srithar (2009): Performance analysis in stepped solar still for effluent desalination Energy

M. Dashtban,and FF Tabrizi (2011): Thermal analysis of a weir-type cascade solar still integrated with PCM storage *Desalination*

A.M. El-Zahaby AE Kabeel, Al Bakry, and SAEl-Aqouz (2010): Augmentation of solar still performance using flash evaporation *Desalination*

Z.M. Omara. AE Kabeel, and MM Younes (2013) : Enhancing the stepped solar still performance using internal reflectors *Desalination*

S.N. Rai, GN Tiwari (1983): Single basin solar still coupled with flat plate collector

A.A. Badran, LAAl-Hallaq, IAE Salman, and MZ Odat (2005): A solar still augmented with a flat plate collector. *Desalination*

Y.P. Yadav and AS Prasad (1995): Performance analysis of a high temperature solar distillation system

B. Prasad and GN Tiwari (1996): Analysis of double effect active solar distillation

K. Sampathkumar, TV Arjunan, and P Pitchandi (2010): Active solar distillation — a detailed review

Renewable Sustainable Energy Rev.

A.S. Nafey, M Abdelkader, A Abdelmotalip (2001) : Solar still productivity enhancement

Energy Conversion

V. Velmurugan, M Gopalakrishnan, and R Raghu (2008): Single basin solar still with fin for enhancing productivity. *Energy Conversion and Management.*

E. Delyannis (2003): Historic background of desalination and renewable energies

Solar Energy

H.M. Qiblawey and F Banat (2008): Solar thermal desalination technologies. *Desalination*

H.E.S. Fath(1998): Solar distillation, a promising alternative for water provision with free energy, simple technology and clean environment. *Desalination*

M.T. Chaibi (2000): An over view of desalination for domestic and agriculture water needs in remote arid areas. *Desalination*

S.A. Kalogirou (2005): Progress in Energy and Combustion Science

M.N. Bahadori and FE Edlin (1973): Improvement of solar stills by the surface treatment of the glass *Solar Energy*

N.H.A. Rahim (2003): New method to store heat energy in horizontal solar desalination still.

Renewable Energy