Water Purification by Solar Distillation Process.

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ABSTRACT

One of the aims of the United Nations stated in the Millennium development goals (MDGs) is to provide access to potable water and to reduce hunger. Most of the water from sea, river, and pond sources are not safe for both drinking and domestic purposes. This study aimed at providing quality drinking water from salty or brackish water to both rural and urban dwellers. The solar water distillation system used in this study has a glass cover, still basin, a tap, and insulation as component parts. The solar collector was inclined to an angle of 14 degree to receive maximum sun radiation. The experiment was performed with 10 liters of water and an average of 1.8 liters of drinking water was obtained per day. The maximum atmospheric temperature recorded during the experiment was 30°C. The efficiency of the solar still was determined to be 35%. The chemical and physical properties of the water obtained correspond to the World Health Organization (WHO) standard.

(Keywords: drinking water, domestic purposes, potable water, solar distillation, salt water)

INTRODUCTION

Water quality, as is the quality of any item or phenomenon, is the combination of properties (water in this case) that are manifested in relation to human, other living creatures, usage of the substances [1]. The most important substance for human in their surrounding material world is natural water [2]. The exclusive position of water on the planet as a whole was expressed most objectively by the one of the outstanding Russian scientist of the twentieth century, V.I Vernadsky: “There is not any natural body that can be compared (with water) by its influence of the course of fundamental and most colossal geological process. Not only earth surface but deeper parts of the planet (in the scale of biosphere) are determined in the most important of their manifestations by its existence and its properties”.

The need for good drinking water is on the increase over recent years due to increasing populations and the importance of good health [1]. The rising waves of water born diseases have also affected mankind as a result of poor quality water intake across society [2].

Water consumption in the world increases every day due to geometric world population increase. Water and energy are two inseparable items that govern our lives and promotes civilization [3]. Looking into the history of mankind one finds that water and civilization were also two inseparable entities [3]. It is not a coincidence that all great civilizations were developed and flourished near large bodies of water [4]. Rivers, seas, oasis, and oceans have attracted mankind to their coasts because water is the source of life [5].

The transportation of drinking water from far-off regions is usually not economically feasible/desirable. Desalination of available brackish water has been considered as an alternative approach [5]. More than two-third of the Earth's surface is covered with water [5]. Most of the available water occurs either as seawater or icebergs in the Polar Regions [5]. About 97% of the Earth's water is salty, while the rest is fresh water, of which less than 1% is within human reach [6]. This small percent is still adequate to support life on Earth and is replenished through a large scale solar distillation process through what is known as the hydrological cycle [7].

Distillation is one of many processes that can be used for water purification [8]. Most

commercial stills and water purification systems require electrical or other fossil-fuel power sources [9]. The use of electricity in distillation apparatus, like in fractional distillation, is energy intensive [7]. Air pollution, acid rain, global warming, and climate change are but a few of the consequences that are attributed to use of fossil fuels and have been widely investigated [7 & 10].

Single-basin stills have been much studied and their behavior is well understood. The efficiency of solar stills which are well-constructed and maintained is about 50% although typical efficiencies can be around 25%. Daily output as a function of solar irradiation is greatest in the early evening when the feed water is still hot but when outside temperatures are falling. At very high air temperatures such as over 45ºC, the plate can become too warm and condensation on it can become problematic, leading to loss of efficiency.

OPERATIONAL PRINCIPLE

The water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation to pass into the still, which is mostly absorbed by the blackened base. This interior surface uses a blackened material to improve absorption of the sunrays. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The heated water vapor evaporates from the basin and condenses on the inside of the glass cover. In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle.

MATERIALS AND METHOD

Collection of Water

The water used in this experiment was collected from the pond located at Nsukka Urban in Nsukka local Government Area of Enugu State, Nigeria. The pond has a lot of dirty materials inside it and has been deserted for over 5 years. It also has calcium which causes hardness of water and consumes a lot of soap during washing.

Experimental Method

The 10 liters brackish water was poured into a container having sieve on it to remove some material that might block solar still tap during discharge. The sieved water was then poured into distillation basin. The set up was exposed to the sun to receive the sun radiation. The essence of exposing it to sun is that the solar radiation provides the energy which will heat the absorber basin painted black. The water in the basin will receive energy and increase in temperature. As the temperature of the water rises, vapor evaporates to the glass and condenses; it then trickles down from the sliding glass cover to the storage basin, where the pure water is collected.

Determination of Chemical Properties of the Water

Color of Water: The water color was determined by measurement of optical density (absorbance) on a spectrometer which has various wavelength of light passage. This works with the principle that the wavelength that was maximally absorbed by water is the characteristic of its colors. The water that was used for the investigation was first filtered to eliminate possible turbidity. The value of the optical density is a measure of color intensity. In this experiment the 575-590 wavelength was maximally absorbed by the water.

pH Determination

Water reaction is usually expressed as concentration of hydrogen ion. When pH=7, water reaction is neutral; if pH is > or < 7 then the reaction change in the alkaline or acid direction, respectively. In natural waters, the concentration of hydrogen ions depends on the dissociation and hydrolysis of the combination occurring in it. The table used for determination of the pH value of the water used in the experiment is shown below. The pH meter was used for the determination of hydrogen ion and the value of pH of the water obtained was 6.9.

Table 1: Range of Wavelength of the Absorbed Light and Color.

Wavelength of the absorbed light, nm	Color of the absorbed radiation	Supplementary(visual) color of the investigated water
400-450	Violent	Yellow green
450-480	Dark Blue	Yellow
480-490	Green Blue	Orange
490-500	Blue red	Red
500-560	Green	Purple
560-575	Yellow green	Violent
575-590	Yellow	Dark blue
590-605	Orange	Green blue
605-730	Red	Blue green
730-760	Purple	Green

Table 2: pH Value.

Water Type	Water Characteristic	pH
Acid	Water of volcanic exhalation	>2
Acid	Mine waters	3-4
Acid	Swamps	4-6
Acid	Ground waters	5-7
Alkaline	Rivers	6.8-7.8
Alkaline	Fresh lakes	7.3-9.2
Alkaline	Ocean	7.8-8.3
Alkaline	Salt (soda) lakes	Up to 10.5

Physical Properties of Water

Boiling Point of Water: 2 liters of water was used to determine the boiling point of water. The 2 liters of water was poured inside electric kettle with specification (Panasonic Automatic Electric Kettle, model NC-430, AC 220/240V, 2.0-2.4KW,9-10A,50-60Hz) of 4.3- liter capacity. The kettle was plug and monitored for about 15 minutes. The temperature of the water was determined to be 106°C. The rise in the boiling point of water above 100°C was due to the impurities in it.

RESULTS AND DISCUSION

The result obtained showed that the portable solar still design could provide a drinking water for an individual for a day. From Figure 1 above the volume of distillate water obtained from the brackish water used was not steady from day 1 to day 10. This was due to unsteady solar radiation during the experiment.

The experiment was performed at National Centre for Energy Research and Development, University of Nigeria, Nsukka. The average insolation at the center is 450W/m^2. The water distillate was tested for its boiling point and was discovered that the distillate boils exactly at 100°C.The distillate also froze at 0°C. It was tested with $CuSO_4$ anhydrous and it changed the purple color of $CuSO_4$ to colorless. This indicated that the physical and chemical properties of the distillate obtained correspond with World Health Organizational standards.

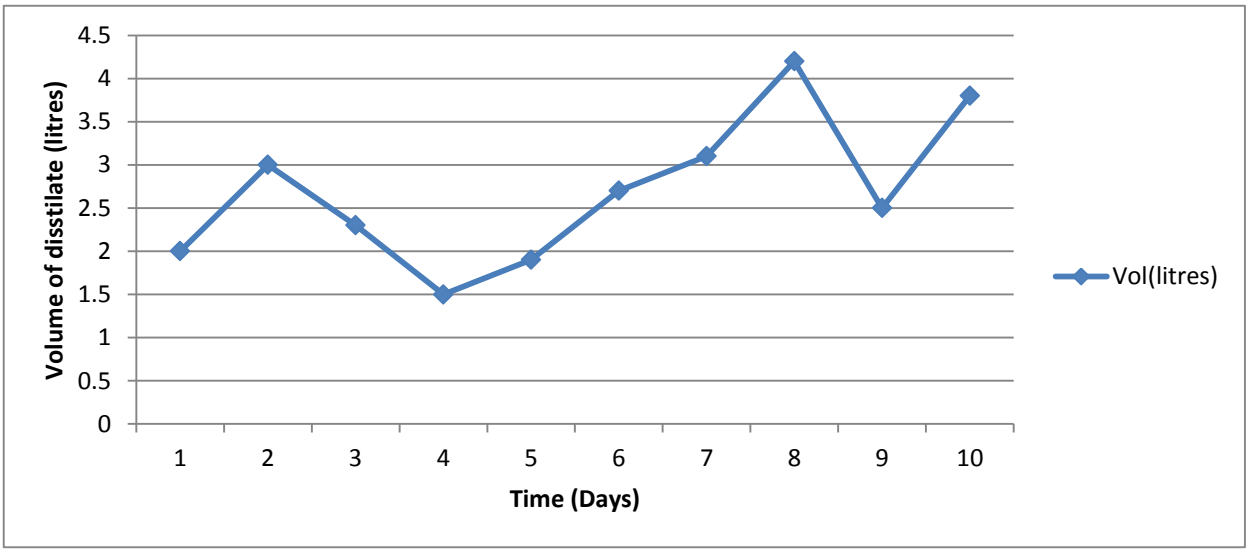

Figure 1: A Graph of Volume of Distillate Produced (Liters) versus Time (Days).

Table 3: Volume of the Distillate Produced.

Time (Days)	1	2	3	4	5	6	7	8	9	10
Vol.(Liters)	2	3	2.3	1.5	1.9	2.7	3.1	4.2	2.5	3.8

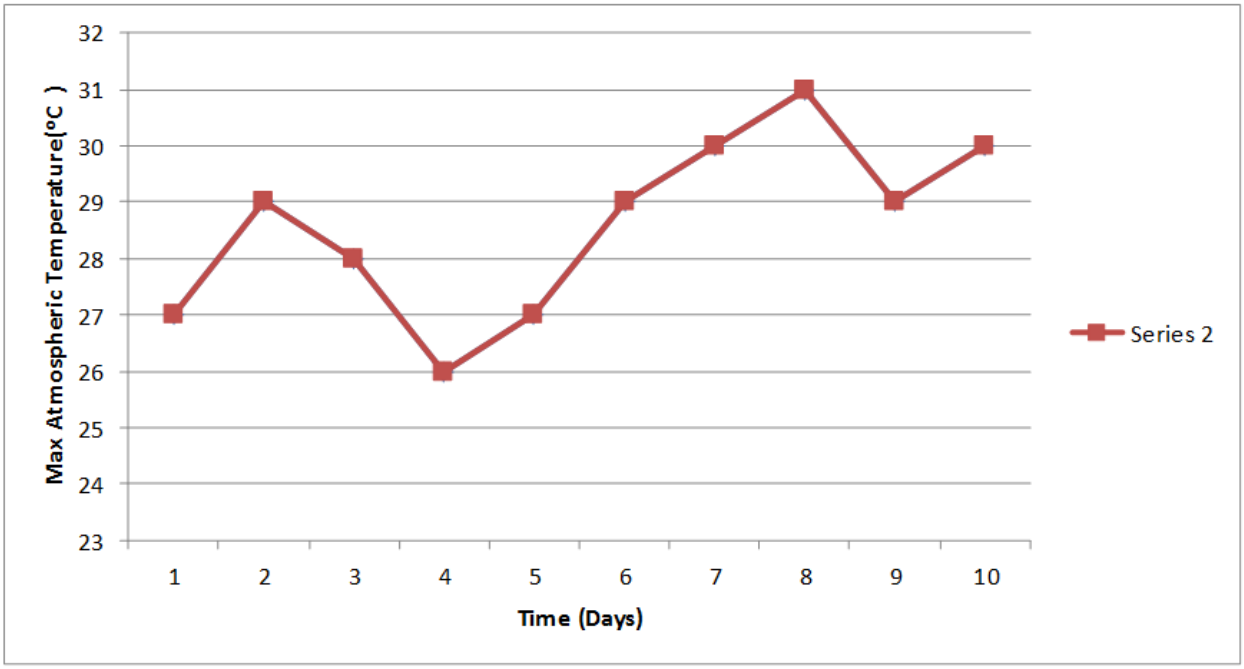

Figure 2: Atmospheric Temperature versus Time (Days).

Table 4: Maximum Atmospheric Temperature.

Time (Days)	1	2	3	4	5	6	7	8	9	10
Max. Atm temp(°C)	27	29	28	26	27	29	30	31	29	30

The atmospheric temperature also fluctuates between 26°C-30°C and has significant value in the amount of distillate produced daily or hourly. The experiment performed by Alpesh Mehta et al yielded 1.5 liters using 14 liters of water but they also got 2.33 liters theoretically.

The efficiency of the solar still as determined by Alpesh et al was 64.37%. Also Márcio Claudio Cardoso da Silva et al Water level in the evaporation pan, cover inclination, and water quality were assessed at two points: a) between the parallels 27°10' and 27°50'S latitude and meridians 48°25' and 48°35'W longitude, from 2003 to 2005, with maximum production of 6.2 L m^{-2} day, and monthly averages from 3.1 to 3.7 L m^{-2} day. b) in the parallels 5°47' and 5°57'S latitude and meridians 35°12' and 35°22'W longitude, from 2003 to 2004, with monthly averages of 3.0 to 3.7 L m^{-2} day.

CONCLUSION

Unclean water could be made clean by exposing the water in direct solar radiation and allowing the water to evaporate in a well design system called solar water distillation

system otherwise known as solar still. This work was able to achieve water purification for an individual for one day. The minimum volume of water obtained from the experiment was 1.5 liters. The efficiency of the solar still was determined to be 35%.

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