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Purification of salty water by solar distillation process

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Abstract

Most of our earth surface is covered by water; however, less than 1% of total available water is fresh water which is mostly available in lakes, rivers and underground. Again, about one-third of that potential fresh water can only be used for human needs due to mixed factors. Approximately 1.1 billion people in this world have inadequate access to safe drinking water. There are 26 countries that do not have enough water to maintain agriculture and economic developments. At least 80% of arid and semiarid countries have serious periodic droughts. A third of Africans and most of Middle-East people live without enough water. This experiment was performed at the National Centre for Energy Research and Development, University of Nigeria, Nsukka.15 litres of salty water was poured inside the solar distillation basin with black surface absorber to enhance absorption of solar radiation. The experiment was monitor daily and appropriate quantity of water produced was recorded. The result gave maximum yield of 3.3 litres of distillate. The atmospheric temperature produced varied from 27°C to 31 °C. The bar chart represented 3 hourly production of distillate from day 1 to day 4.

Keywords: Salty water, Distillate, Solar Distillation, Good health, Atmospheric Temperature

1. Introduction

Water, environment and economy

Clean water is essential for good health which influences the social and economic development of any nation (Amos Madhlopa, 2009) [1]. People who use contaminated water are prone to waterborne diseases (WHO, 2006) [20], and they cannot effectively engage themselves in economic activities. Moreover, financial resources that could have been allocated to developmental projects are channelled to disease-curing efforts. The rising waves of water born diseases have also affected mankind as a result of poor quality water intake across society (Amos Madhlopa, 2009) [1]. Consequently, ill health contributes to the retardation of economic growth. However, there is limited access to drinking water that meets acceptable standard levels of biological, chemical and physical constituents. Over 97 % of water available on the earth's surface is salty (Tiwari *et al*., 2003) [15], and environmental pollution caused predominantly by anthropogenic activities is also contributing to the degradation of fresh water resources. The WHO (2008) [22] reported that 78 % and 96 % of the rural and urban populations used clean drinking water in 2006 on a global scale respectively. So, 4 billion cases of diarrhoea are reported annually, with 88 % of them being ascribed to the use of unclean water, and insufficient sanitation and hygiene (WHO, 2007) [21]. This indicates the need for interventions that aim at providing clean water. In view of this, the millennium development goals incorporate a target to halve the percentage of the population without access to safe water by 2015 (UN, 2007) [18]. Indeed, this goal can be achieved through a multi-faceted approach which includes the development of appropriate technologies for water desalination (Amos Madhlopa, 2009) [1]. Nevertheless, a sustainable source of energy is required to provide fresh water to a larger proportion of the world population. Recently, there have been concerns about environmental degradation arising predominantly from the exploitation of non-renewable energy resources. Anthropogenic activities are generating greenhouse gasses (GHG) that account for most of the ambient air temperature rise (Saikku *et al*., 2008) [14]. In particular, the burning of fossil fuels is significantly contributing to climate change through the emission of carbon dioxide (major GHG) and other substances (UNEP, 1988; IPCC, 1995; UN, 2007). Parry *et al*. (2008) [13] reported that the impacts of climate change are currently observable. Consequently, application of renewable energy technologies in the provision of fresh water can assist in alleviating environmental degradation.

Water desalination

Conventional techniques for desalting water can broadly be classified into thermal and membrane based categories (Fritzmann *et al*., 2007) [4]. The former class of techniques includes multi-stage flash (MSF), multi-effect distillation (MED) and vapour compression distillation (VCD) while the latter class comprises reverse osmosis (RO), nanofiltration (NF) and electrodialysis (ED). In thermal desalination, salts are removed from water by evaporation-condensation processes. Membrane based techniques employ a membrane through which water diffuses with a high proportion of the salts being retained. However, these techniques require a large input of energy and are not cost effective for low demands of clean water (Mowla and Karimi, 1995) [9]. According to Bouchekima *et al*. (1998) [2], improvements in solar distillation technology makes it ideal for desalinating water in remote areas with water demands below 50 m^3 per day. Nevertheless, there is still need to increase the productivity of solar stills at an affordable cost especially in developing parts of the world. UN (2008) [19] reported that regions with developing economies were: a) Africa, b) Asia and Pacific (excluding Australia, Japan, New Zealand, and the member states of the Commonwealth Independent States in Asia) and c) Latin America. Amongst these regional groupings, access to clean water was most limited in the African region (46 % in rural areas and 82 % in urban areas in 2006), (WHO, 2008) [22]. Moreover, many African countries receive relatively high levels of solar radiation (Diabaté *et al.*, 2004) [3]. Thus, solar distillation can be a potential method of providing fresh water in the region. One of the developing African countries with limited access to clean water is in this country; the major sources of water in remote areas are shallow wells, boreholes, gravity-fed piped systems, springs, rivers and lakes. However, these water sources are threatened by depletion and degradation mainly due to population increase, improper disposal of wastes and poor agricultural practices (Mumba *et al*., 1999 [11]. Pritchard *et al*. (2007) studied 21 protected and 5 unprotected shallow wells during four different times of the year. They found that drinking water was significantly polluted with faecal waste. Over 50 % of 176 boreholes studied by Msonda *et al*. (2007) [10] had fluoride concentrations exceeding the limit of 1.5 x 10-6 kg/ litre set by the WHO. Several other authors have reported on the low quality of drinking water, especially in rural areas of Malawi. The WHO (2008) [22] reported that 72 % and 96 % of the population in rural and urban areas respectively have access to improved drinking water sources. So, there is need to find sustainable ways of improving the quality of water, especially in remote areas. Fuel wood is the major source of energy in Malawi. Unfortunately, the heavy and inefficient consumption of fuel wood is contributing to deforestation and other environmental problems (Hyde and Seve, 1993) [5]. Moreover, grid electricity is not available in most rural areas of the country. Consequently, a sustainable source of energy is needed to produce clean water in such areas. It appears that solar energy is a potential source of energy for powering thermal and photovoltaic systems because the country has a suitable solar climate for exploiting solar technologies (Diabaté *et al*., 2004[3]; Madhlopa, 2006a) [7]. In Malawi, distilled water is mostly produced by using electrical heaters, and it is generally used in industries and laboratories where water of analytical grade is required. In addition, distilled water is needed in rechargeable accumulators for automobiles and electronic appliances that are used even in rural areas. Nevertheless, this commodity is hardly found in such areas of the country. One potential technique for providing clean water to communities in these areas is to use solar energy. Nevertheless, very limited work has been done on solar distillation in Malawi. Madhlopa (2006b) [8] studied the diurnal performance of a single-slope conventional solar still under outdoor weather conditions in Malawi. Distillate data was captured over a period of 32400, with symmetry Malawi. So, it is used as a representative of the developing parts of the world where solar desalination systems can possibly be exploited to improve the quality of water.

2. Materials and Method

Salty Water

The water collected is from contaminated Salty pond located at Abakiliki Ebonyi State, Nigeria. It is important to note that Ebonyi State is a salt producing Area of the Country. I t has for long been supplying the country with salt for a very long time. These salt are been process locally by a process called Filtration. The contaminated water was removed of organic matter and other floating weds such as green algae.

Procedure for the Experiment.

The 15 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, Ofili and Ugwuoke *et al* (2016) [12]. 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.

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: pH Value Ugwuoke *et al* (2015) [17]

Water Type	Water Charecteristic	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

3. Results and Discussion

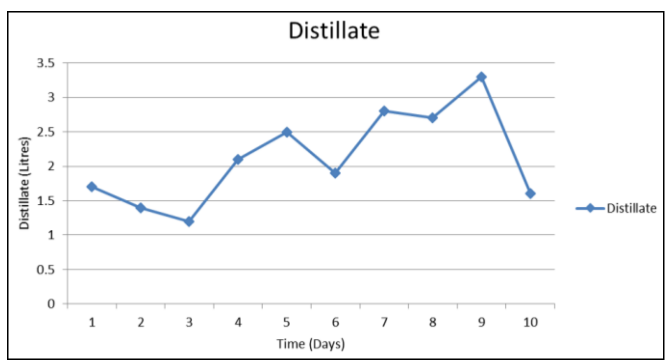

Fig 1: Distillate produced for 10 days.

Table 2: Distillate produced for 10 days

Time (Days)	1	2	3	4	5	6	7	8	9	10
Distillate (Litres)	1.7	1.4	1.2	2.1	2.5	1.9	2.8	2.7	3.3	1.6

Table 3: Atmospheric Temperature

Time (Days)	Atmospheric Temperature(°C)
1	29
2	31
3	30
4	32
5	28
6	31
7	27
8	29
9	30
10	28

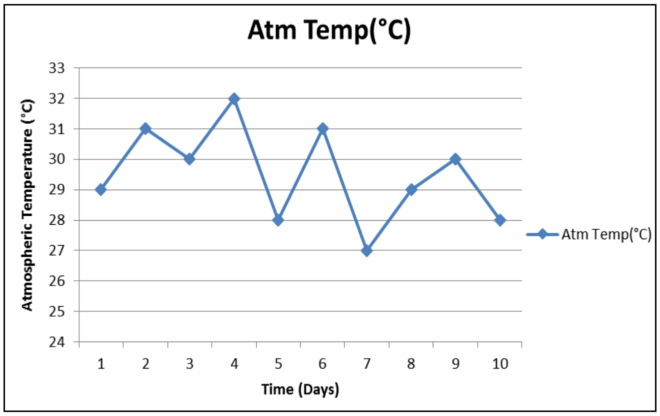

Fig 2: Atmospheric Temperature of the day.

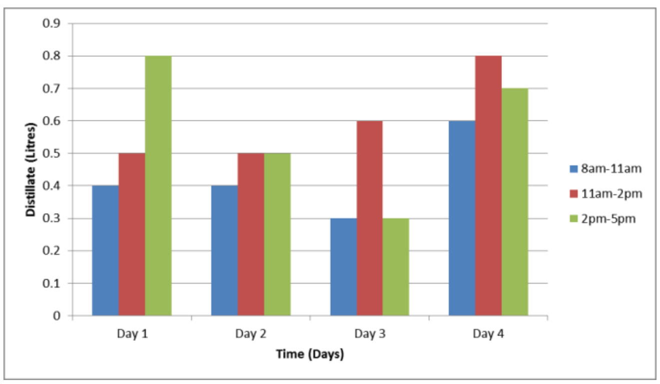

Fig 3: A 3-hourly distillate production for four days

The experiment conducted at University of Nigeria Nsukka showed that clean water is produced from salty or brackish water by the use of solar water distillation system otherwise known as solar desalinization. There several factors that affected the result of the experiment such as fluctuation in solar radiation, angle of inclination, humidity and absorption surfaces. Several surfaces have been tested as absorption material which includes mild steel, Aluminium and zinc. It was discovered that combination of selected material otherwise known as selective surface give the best result as absorption material. The absorptive material used in this work is mild steel. The maximum distillate produced during the experiment was 3.3 litres in day 9. The 1.2 litres of water produced on day 3 was the minimum. Ugwuoke *et al* (2015) [17] had 2.3 litres maximum distillate production on day 5 of there experiment. Also Tiwari and Tiwari (2005) [16] found a daily yield of up to 1.714 kgm^{-2} in their study. The atmospheric temperature showed in table 3 fluctuated between 27 °C-31 °C. Ofili I and Ugwuoke E.C recorded maximum temperature of 30 °C on day 7 and day 10 respectively. The both also recorded minimum distillate production of 1.5 litres. The temperature of brackish water obtained by Ugwuoke *et al* (2015) on day 1 varied from 54 °C -22 °C [17]. A 3-hourly distillate production from day1 to day 4 at time range of 8am-11am, 11am-2pm and 2pm-5pm is shown in fig 3. The production of distillate recorded ranged from 0.3 to 0.8 litres at 3 hour period.

4. Conclusion

The fresh water crisis is already evident in many parts of world in varied scale and intensity at different times of the year. Also, the demand for fresh water increases with the growth of its population. The conventional desalination technologies are expensive for the production of small amount of fresh water. Also, use of conventional energy sources is costly and not always eco-friendly. Solar distillation is most attractive and simplest technique among other distillation processes especially for small-scale units located at places where sufficient solar energy is available. This study aimed at producing good drinking water from salty and brackish water. The maximum distillate produced in the experiment was 3.3 litres. The atmospheric temperature varied from 27 °C to 31 °C.

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