TUBE IN TUBE TECHNIQUE FOR SOLAR DESALINATION

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Abstract

Water is one of the most vital resources of earth. When the early history of mankind is observed, water played a crucial role in its development. Water is abundant, covering three-fourth of the earth's surface. However, about 97% of water is found in the ocean and it is salinized. The rest 3% of the total amount of water is fresh. This tiny fraction of water exists inside ground, rivers and lakes as it continues to fulfill the needs of both plants and animals. It is seen that, an ample amount of water exists in the ocean and its utilization is largely inhibited due to its salinity. The ongoing scarcity of water can be fulfilled by developing systems that permit the desalination of seawater. This paper begins with an extensive analysis on the history of solar desalination in brief and then covers various desalination processes involving both renewable and non-renewable energy sources. Although, a special emphasis is given on the systems involving renewable energy sources, because desalination process consumes a lot of energy and the use of fossil fuels causes detrimental effects to the environment. Each process is presented as a review accommodating the names of the authors, the type of work they performed and necessary outcomes from the experiment in a concise paragraph. When the climax of all the reviews is reached, a new technique of desalination using solar energy is explained and practiced. In this technique, "Tube in tube" mechanism is applied to have a higher distillation collection rate. The apparatus comprises of an inner and an outer tubes. The outer tube is transparent and allows the penetration of solar radiation to the inner tube. This tube is also used as a collection unit to extract fresh water after the completion of desalination process. The inner tube aids in both the absorption and evaporation of water and it is composed of PVC pipe covered with composite fibers. This relatively new desalination mechanism uses economic and readily available materials to remove salt from water using the principles of evaporation and condensation. Also, the apparatus comprising this desalination system is easy to install and convenient to transfer between places. The paper concludes by providing some anticipated and necessary outcomes from the aforementioned method and also comments on its future development.

Keywords: *Fresh Water, Drinking Water, Desalination, Tube in Tube, salinized*

1. INTRODUCTION

The demand for fresh water has become an important issue in many parts of the world. Especially in arid areas, the supply of potable and palatable water is of great concern for the establishment of habitats. Water is indeed essential for sustaining life. Although water is currently an abundant resource, indicated as two-thirds of the planet is occupied by it. 97% of water is from ocean and is salty, whereas, the rest of 3% is fresh. Now, from this tiny fraction of fresh water, around 70% is frozen as snow covers and glaciers. The rest 30% can be found deep within the aquifers that are hard to reach. Only 0.25% of fresh water is found in rivers and lakes that can be extracted easily and used for daily purposes. The concept of seawater desalination originated as early as in the fourth century BC. It was first proposed by Aristotle. He described a method to evaporate brackish water to purify it and collect it by condensation. From historical perspective, the use of desalination by distillation was first originated from sailors. They had to come up with the procedure cause during long distance trips; they needed to produce fresh water in ships to satisfy their thirst for days. This procedure involved, boiling sea water inside a brass vessel and suspending a large sponge from its mouth. The sponge collected evaporated portion of the salty water. When water was collected from sponge, it was found to be palatable. The contribution of Arab Alchemists in the field of desalination is undeniable. Mouchot, a well-recognized French scientist reported that, in the 15th century, Arab alchemists used polished Damascus Concave mirrors to focus solar radiation into glass vessels consisting of salt water in order to make it desalinated. In the upcoming section, some desalination techniques are discussed. A study conducted by Kharabsheh and Yogi (2003) presents a theoretical analysis and experimental results for an innovative water desalination system using low grade solar heat. This water desalination system uses a vacuum using gravitational force and atmospheric pressure to such an extent that water inside it can be quickly evaporated at a much lower temperature and with less energy compared to the conventional desalination systems. The authors concluded that: (i)as the withdrawal rate increases, the system output decreases and (ii)as the heat transfer area, i.e. the number of fins increases then fresh water temperature decreases.Reali and Modica (2007) is introduced basic technological features for simple solar stills using tubes for seawater desalting. Conventional solar stills have two advantages: they can be easily constructed and they can utilize solar energy for desalination process. A study performed by Ali and Nashar (2000) compares the economics of using solar energy to operate small multiple effect seawater distillation systems in remote arid areas. Also, a comparison is made between three configurations: (i) Conventional system, (ii) Solar assisted system and (iii) Solar standalone system. Although for present economy, conventional desalination system may prove to be much more effective but solar based systems can provide an excellent alternative in some remote areas blessed with plenty amount of solar radiation. This is because, conventional system requires a significant amount of energy, costly to operate and causes adverse environmental effects such as global warming. In the end, the authors provided the costs of major economic parameters used in the study are provided in a tabular form. Also, the authors concluded that under the present market price of fossil fuels, solar energy cannot compete effectively, but it can be an excellent alternative in areas where the cost of fossil fuel is very high and there is plenty amount of solar radiation. Also, when using solar standalone system, the cost effectiveness seems to be increased.

A study conducted by Banat, et. al.(2001) evaluates technical feasibility of producing potable water by combining membrane distillation module with a solar still. Membrane distillation can be divided into two categories: process with a phase change e.g. distillation and freezing and process without phase change e.g. reverse osmosis (RO) electro dialysis. The cumulative effect(s) of the solar still and membrane filtration system is also studied.The experiments were conducted in both indoor and outdoor conditions. Indoor condition provides a constant amount of solar radiation and outdoor condition provides a variable amount of solar radiation. In the results, the authors implied that the contribution of solar still in the production of potable water is no more than 20% when the experiment is carried out in outdoor condition, and less than 10% in the indoor experiment. Also, brine flow rate greatly affects water production rate of membrane distillation module

A study carried out by Diagoet. al. (2006) deals with the different advantages of coupling an absorption heat pump to a multi-effect distillation system which could increase competitiveness of both conventional and solar powered multi-effect distillation plants. A heat pump is a device that transfers heat from a low temperature to a high temperature source. Absorption heat pumps require heat input to function and this is governed by the second law of thermodynamics. The authors concluded that:(i) An absorption heat pump can reduce the mass flow rate of seawater in the multiple effect distillation process, thus reducing the pumping requirements and seawater intake capital cost, (ii)absorption heat pump lowers the boiling temperature of multiple effect distillation unit and (ii) The addition of double effect absorption heat pump to solar multiple effect distillation results in better energy efficiency when fossil fuel is used as an alternative source.

Jiang, et. al. (2015) reports a new method of seawater desalination technique using electrolysis system and newly invented turbo-electric-nano-generator (TENG).TENG is a unique technology that converts various forms of mechanical energy to electrical energy. For this desalination process, TENG is used to convert kinetic energy produced by water waves to electrical energy required to run the electro dialysis system. Using the configuration described above, desalination can be achieved up to 98% in 16 hours.

Most of the techniques will use renewable energy sources and a few will use non- renewable sources as mentioned in the abstract. Each process is presented as a review accommodating the names of the authors, the type of work they performed and necessary outcomes from the experiment in a concise paragraph.When the climax of all the reviews is reached, a new mechanism of desalination using solar energy is innovated and practiced. The new mechanism is named as 'Tube in tube'technique is applied to obtain a higher distillation collection rate. The paper concludes by providing some anticipated and necessary outcomes from the aforementioned method and also comments on its future development.

2. METHODOLOGY

The new innovated apparatus comprises of an inner and an outer tubes. The outer tube is transparent and allows the penetration of solar radiation to the inner tube. This tube is also used as a collection unit to extract fresh water after the completion of desalination process. The inner tube aids in both the absorption of raw water & heat and provide evaporation of water. It is composed of PVC pipe covered with composite fibers. This relatively new desalination mechanism uses economic and readily available materials to remove salt from water using the principles of evaporation and condensation. Also, the apparatus comprising this desalination system is easy to install and convenient to transfer between places.

2.1 Materials

1. Stainless steel tray with supports at the end: 34″ length, 4″ wide and 2″ depth.
2. PVC pipe: 3″ diameter and 34″ length.
3. Styrofoam: 6″ diameter and 1.5″ thickness.
4. Transparent hollow plastic tube: 6″ diameter and 40″ length.
5. Composite fabrics (Jute and black jeans)
6. Digital and analogue thermometers.

2.2 Fabrication of still

A transparent plastic sheet is cut and rolled to form a plastic tube of 40″length and 6″ diameter (Width of the sheet is taken to be approximately 19″).The rolled up tube is held with super glue. Using the Styrofoam, two circular shaped discs are prepared so that they cover up the end of the transparent tube.PVC pipe is wrapped up with composite fabrics and placed inside the tray as shown in Figure 1. Then, the whole tray is positioned inside the transparent tube. In the end, the tube including all its contents is sealed at both ends using the previously prepared Styrofoam discs. It is to be made sure that the handles of the tray are kept outside of the tube and necessary adjustments are made to the discs to help the handles probe out of them and act as supports. Caution is practiced to eliminate any air gap present in the apparatus, especially and the sealing zones and the gaps created when insertions are made in the discs to facilitate the passing of the tube supports.A small hole is made at the top of the tube for water inlet. Similarly, an outlet is also made at the bottom of the tube.The process described above is used again to make two other tubes, one with tube containing only tray and another with tray containing different composite fabrics.

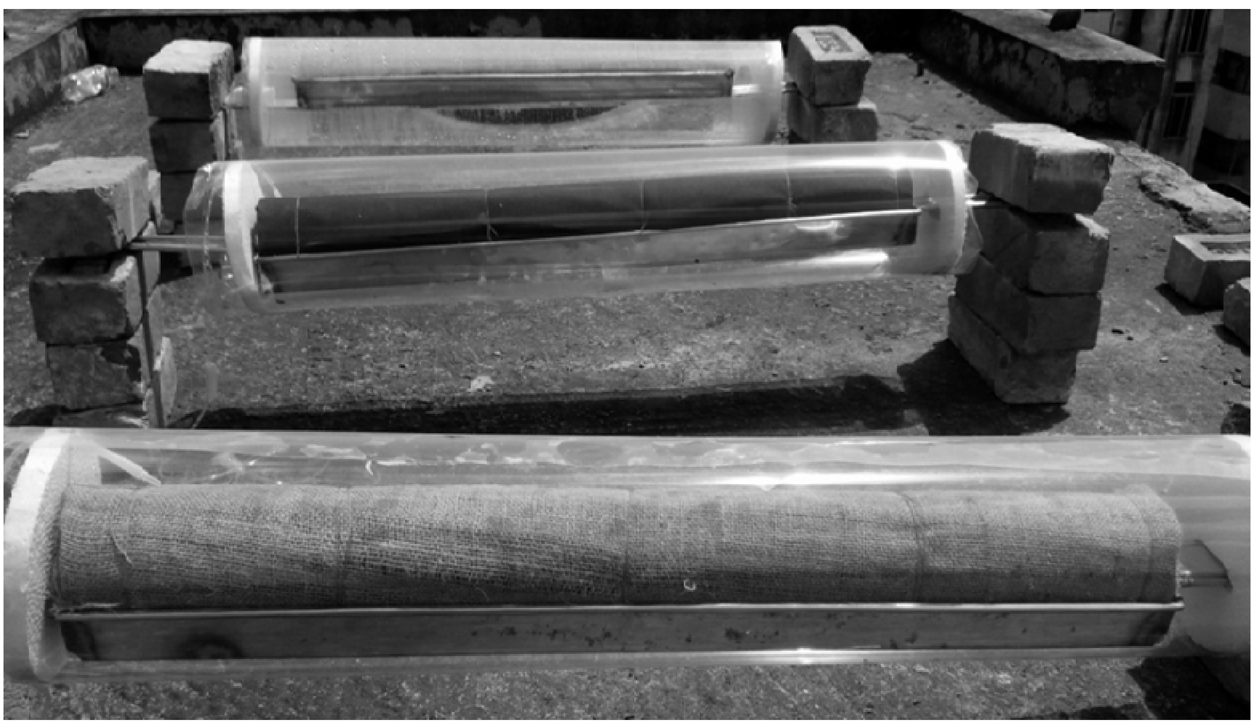

Figure 1:Different types of tube in tube solar desalination system

2.3 Temperature Measurements:

On the transparent surface of each tube in tube apparatus, 4 holes are made to allow access to various regions inside the tube to take temperature readings. Different zones provide different temperature readings. The four temperature measurements here to be made are ambient temperature (Ta), temperature inside the transparent tube (Tt), temperature on composite fabrics (Tc) and water temperature in the tray (Tw).Digital thermometer is inserted inside each hole inside the tube and kept for a full minute. In the end, temperature reading is taken. Readings are taken at every 1 hour interval for 12 hours. The holes should be temporarily sealed up by proper insulating material after the completion of temperature measurement. Accuracy of the readings are ensured by crosschecking with analogue thermometer.

2.4 Distillate Collection:

When water undergoes condensation after evaporation, the distillate gets collected at one end of the tube as the tube is positioned at 30 degree angle with the horizontal. Water is collected from the end through an outlet pipe connected to a sealed container so that the collected water doesnot further evaporate.Water collection is carried out every 24 hours and volume is measured by using a measuring cylinder to have an understanding about the quantity.

3. RESULTS AND DISCUSSION

The data and accompanying information presented in Figure 2 to Figure 7 are obtained by carrying out temperature measurements for 12 hours. It also includes temperature readings for various zones inside and outside each tube per hour and water production rate per day. Graphs bearing temperature readings for comparisons between different zones in each tube and also temperature readings between different tubes are provided for analysis. Distilled water collection records are shown in Table 1.

Mainly six observations are made regarding the variation in temperatures in different zones inside a transparent tube. Also, comparisons of temperature readings at a specific zone for different tubes are made. From Figure 2, it is seen that water temperature (Tw) in the 'Tube in Tray' system reaches the peak value of about 54°C in the 6th hour. Ambient temperature (Ta) has the lowest range of temperature values, and temperature range inside the tube (Tt) falls in between Ta and Tw.From Figure 3, temperature variations for 12 hours in zones Ta, Tc, Tt and Tw are provided for "Tube in Tube (Jeans). As expected, Tw has the highest set of temperature readings peaking about 54°C. As usual, Ta has the lowest range of temperature readings with the maximum temperature of about 36°C. Tt and Tc have temperature ranges that lie in between. Their maximum values are 45°C and 48°C with a difference of 3°C only.

Temperature variations in four zones with respect to time for "Tube in Tube (Jute)" are provided in Figure 4. Water temperature inside the tray (Tw) reaches the maximum temperature of 50°C during the 12 hour period. This temperature is comparatively 4°C lower than other tubular systems discussed above. Maximum Ta temperature remains to be as same as the other three systems, around 36°C. Max temperatures for Tt and Tc are found to be 45°C and 48°C, same as in with tubular desalination system with Jeans fiber.

A comparison is made between three different tubular systems regarding the temperature inside each tube as shown in Figure 5. It is seen that there is no significant temperature variation between the three systems when it comes to temperature inside each system. The maximum temperature attained by each system is in the range of 44°C to 45°C.

Figure 6 demonstrates temperature variation of water present in tray of each tube. The maximum temperature of 'Tray in Tube' and 'Tube in Tray (Jeans)' matches with a reading of 54°C. The peak temperature attained by 'Tube in Tray (Jute)' remains to be at 50°C. This variation in temperature is not significant.Temperature variation in different composite fibers (Jeans and Jute) with respect to time is shown in Figure 7. Practically, both curves follow the same path with no noticeable differences to mention. They both generate a peak value of 48°C in at 6th hour.

Distilled water collection records are shown in Table 1. Raw water flow in each Tube in Tube apparatus was 920ml/d. Water collection is done per day for 30 days. Average amount of water collected per day from 'Tray in Tube' is 4.44 L/m^2-day, from 'Tube in Tube (Black Jeans)' is 7.64 L/m^2-day and that of 'Tube in Tube (Jute)' is 7.37 L/m^2-day. When efficiency of each tube is analyzed at the end of the day, 'Tray in Tube' gives 42.39 %, 'Tube in Tube (Black Jeans)' gives 72.87 % and 'Tube in Tube (Jute)' gives 70.21 %.

After reviewing various other desalination systems, especially that utilize renewable energy, the need for a method that only uses solar radiation and locally available materials is realized. This innovated technique from this research is finally named as 'tube in tube'. Some advantages that this desalination system possesses are that it is portable and it does not take much of an effort for installation.

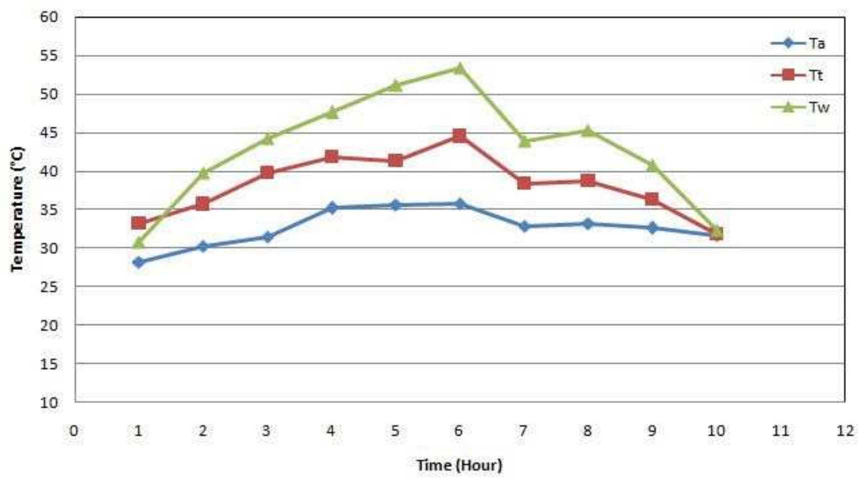

Figure 2:Temperature variation in Tray in Tubefrom 8:00 a.m. to 5:00 p.m.

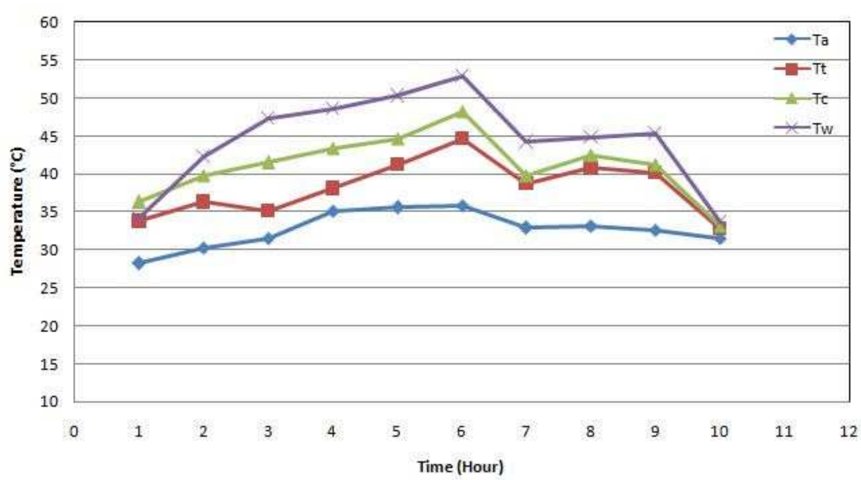

Figure 3:Temperature variation inTube inTube (Jeans)from 8:00 a.m. to 5:00 p.m.

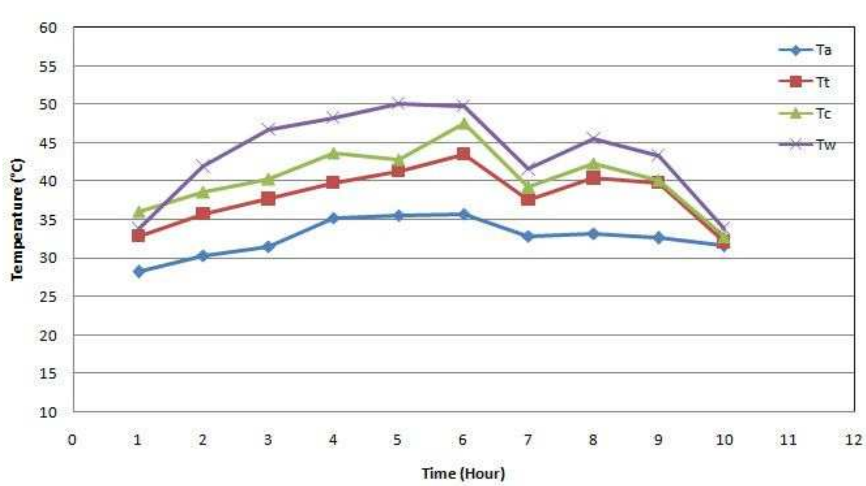

Figure 4: Temperature variation in Tube inTube (Jute)from 8:00 a.m. to 5:00 p.m.

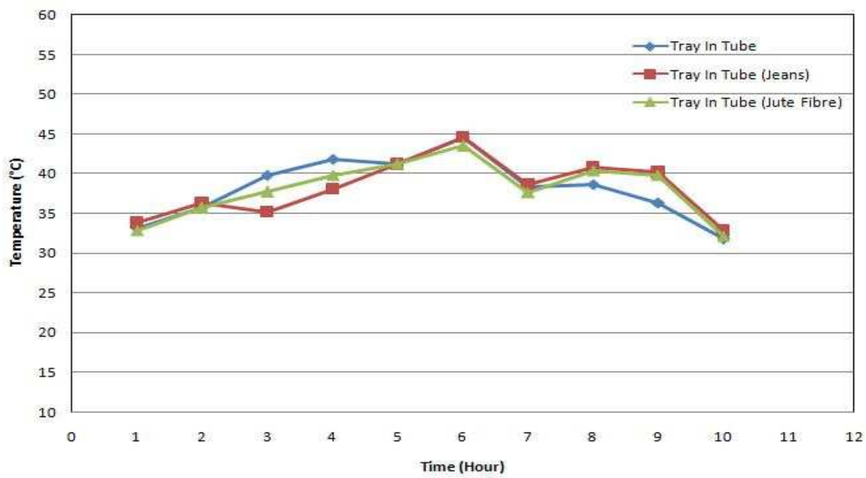

Figure 5: Temperaturevariationinsidetransparent tubes.

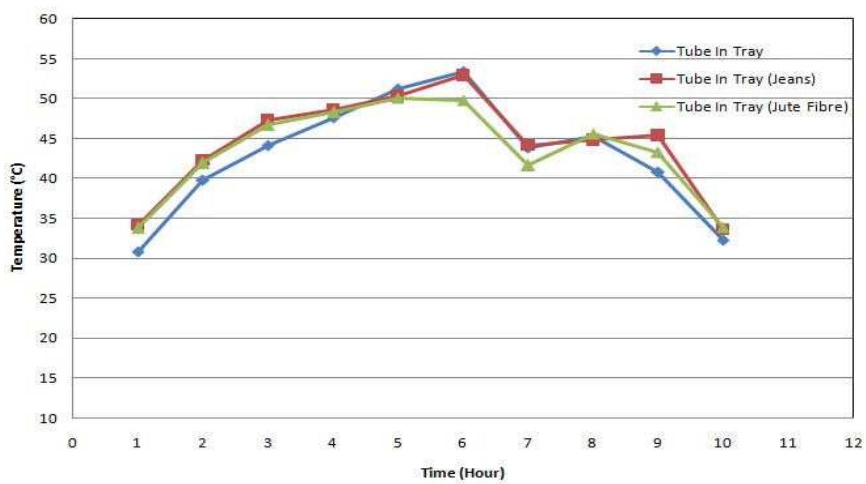

Figure 6: Temperaturevariation inwater in different tubes.

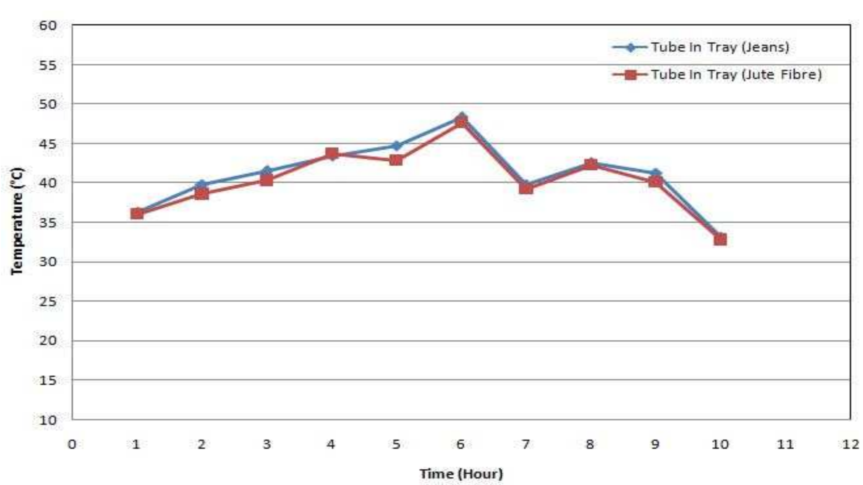

Figure 7: Temperature variationin different composite fibers

Table 1: Distilled water collection in different Tubes. Raw water flow in each Tube in Tube apparatus was 920ml/d.

Date	Amount of fresh water collected from		
	Tray In Tube (ml)	Tube In Tube (Black Jeans) (ml)	Tube In Tube (Jute Fabrics) (ml)
22/10/2015	386	679	613
23/10/2015	403	657	623
24/10/2015	396	653	586
25/10/2015	381	662	623
26/10/2015	365	656	628
27/10/2015	413	682	647
28/10/2015	398	673	637
29/10/2015	389	678	632
30/10/2015	394	674	643
31/10/2015	371	654	612
01/11/2015	407	663	649
02/11/2015	383	658	644
03/11/2015	386	651	625
04/11/2015	400	655	636
05/11/2015	405	623	598
06/11/2015	382	619	596
07/11/2015	379	643	612
08/11/2015	368	665	615
09/11/2015	396	662	646
10/11/2015	409	676	643
11/11/2015	402	637	632
12/11/2015	382	633	627
13/11/2015	388	635	631
14/11/2015	393	636	625
15/11/2015	385	642	636
16/11/2015	396	643	632
17/11/2015	357	583	549

18/11/2015	391	653	647
19/11/2015	369	623	618
20/11/2015	385	618	632
21/11/2015	393	627	641

4. CONCLUSIONS

Tubes in tube system along with composite fabrics provide more desalinated water per day compared to the simple tray in tube system. The collection for 'Tube in Tube (Black Jeans)' is 7.64 L/m^2-day and that for 'Tube in Tube (Jute)' is 7.37 L/m^2-day. However, there can be little or no evidence to establish the relationship between water collection rate and the type of composite fiber used as both black jeans and jute almost generate the same water collection rate and their efficiency difference is negligible.

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