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Issues

Select Decade 2020

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Issue 29 November - Volume 2702, Issue 1

PRELIMINARY

Preface: 2021 5th International Conference on Engineering and Applied Technology (2021 5th ICEAT)

AIP Conf. Proc. 2702, 010001 (2023) https://doi.org/10.1063/12.0017919

View article PDF

CIVIL

Identifying construction waste using lean management in a delay project: Case of emergency department building in Pidie Jaya Regency Hospital, Aceh Province, Indonesia

Hafnidar A. Rani; Aulina Adamy; M. Afifuddin; S. Y. Situmeang

AIP Conf. Proc. 2702, 020001 (2023) https://doi.org/10.1063/5.0157638

Abstract View article PDF

Application of AHP and TOPSIS methods for optional transportation cargo by freight forwarder (Route: Surabaya-Jakarta)

Rezki Setya Irsadi

AIP Conf. Proc. 2702, 020002 (2023) https://doi.org/10.1063/5.0155781

Abstract View article PDF

The effect of faunus ater shell as filler in asphalt concrete wearing course (AC-WC) mixtures

Firmansyah Rachman; Tamalkhani Syammaun; Ramadhansyah Putra Jaya; R. Akmal

AIP Conf. Proc. 2702, 020003 (2023) https://doi.org/10.1063/5.0154763

Abstract View article PDF

Analysis of concrete mixture with marble waste material as a sand filler and bagasse ash as cement filler

Fahrizal Zulkarnain; Sri Frapanti; A. P. Munthe

AIP Conf. Proc. 2702, 020004 (2023) https://doi.org/10.1063/5.0154438

Abstract View article PDF

The comparison of brick as a load and a structure with non-linear analysis of soft storey behaviour in multi-storey buildings

Sri Frapanti; Fahrizal Zulkarnain; S. Asfiati

AIP Conf. Proc. 2702, 020005 (2023) https://doi.org/10.1063/5.0185061

Abstract View article PDF

The effect of using silica fume on medium strength concrete

Husnah; Doni Rinaldi Basri; Puspa Ningrum; Husni Mubarak; Muhammad Yazid; Muhammad Toyeb; Rahmat Tisnawan; Rizki Ramadhan Husaini; Fitri Ramdhani; Campin Veddayana

AIP Conf. Proc. 2702, 020006 (2023) https://doi.org/10.1063/5.0154265

Abstract View article PDF

Study on river morphology in Pabelan river after the Merapi eruption in 2010

Jazaul Ikhsan; U. I. Rahmawati; Ani Hairani

AIP Conf. Proc. 2702, 020007 (2023) https://doi.org/10.1063/5.0154924

Abstract View article PDF

The characteristics of porous asphalt using styrofoam substitution on 60/70 asphalt with rice husk ash with rock ash filler

Cut Nawalul Azka; Rifki Hidayat; Tamalkhani Syammaun; S. Mustikasari

AIP Conf. Proc. 2702, 020008 (2023) https://doi.org/10.1063/5.0154767

Abstract View article PDF

An-Nahl, the multifunction transportation system

Gunawan Gunawan

AIP Conf. Proc. 2702, 020009 (2023) https://doi.org/10.1063/5.0157559

Abstract View article PDF

Sustainable construction concepts on the contractor in Banda Aceh: A comprehension and application analysis

Hafnidar A. Rani; Aulina Adamy; Fatimah Azzahra; Afizah Ayob; Firmanda Firmanda

AIP Conf. Proc. 2702, 020010 (2023) https://doi.org/10.1063/5.0155033

Abstract View article PDF

Review of infiltration rate in tropical coastal areas (a preliminary study in Papua)

Hendrik Pristianto; Achmad Rusdi; Muhammad Rusmin; Asrul Saputra; Iqbal Iqbal

AIP Conf. Proc. 2702, 020011 (2023) https://doi.org/10.1063/5.0154925

Abstract View article PDF

Effect of adding steel fiber and viscocrete 8670-Mn tensile on the strength test of concrete

Fahrizal Zulkarnain; Sri Frapanti; Aldi Hadad Alwi

AIP Conf. Proc. 2702, 020012 (2023) https://doi.org/10.1063/5.0154525

Abstract View article PDF

The effect of NaOH molarity on the performance of geopolymer concrete using fly ash from North Sumatera and Aceh

Trio Pahlawan; Johannes Tarigan; Januarti Jaya Ekaputri; Amrinsyah Nasution

AIP Conf. Proc. 2702, 020013 (2023) https://doi.org/10.1063/5.0185802

Abstract View article PDF

Potential of waste tire rubber and rice husk ash in self compacting concrete

Fetra Venny Riza; Josef Hadipramana; Fadly Akbar

AIP Conf. Proc. 2702, 020014 (2023) https://doi.org/10.1063/5.0155314

Abstract View article PDF

Calcium oxide utilization analysis on chloride ion penetration of fly ash concrete

Mochamad Solikin; Mico Hamzah Nata Aji

AIP Conf. Proc. 2702, 020015 (2023) https://doi.org/10.1063/5.0155471

Abstract View article PDF

INDUSTRIAL

Literature review of BPM (BPM) level of maturity in MSMEs in Indonesia

Umi Chotijah

AIP Conf. Proc. 2702, 030001 (2023) https://doi.org/10.1063/5.0154330

Abstract View article PDF

Factor analysis that affects work productivity (case study: Employee PDAM Pamekasan district)

Moh. Jufriyanto; Akhmad Wasiur Rizqi; Hidayat Hidayat; Rifky Maulana Yusron

AIP Conf. Proc. 2702, 030002 (2023) https://doi.org/10.1063/5.0154377

Abstract View article PDF

Proposed material requirement planning on slippers products with the lot for lot approach

Akhmad Wasiur Rizqi; Moh. Jufriyanto; Hidayat Hidayat

AIP Conf. Proc. 2702, 030003 (2023) https://doi.org/10.1063/5.0154953

Abstract View article PDF

Optimizing time and cost of the project using critical path method in the making “lintel set point” (case study: Ravana Jaya Co. Ltd.)

Muhammad Zainuddin Fathoni

AIP Conf. Proc. 2702, 030004 (2023) https://doi.org/10.1063/5.0155119

Abstract View article PDF

The safety culture in the shipbuilding industries

Wisda Mulyasari

AIP Conf. Proc. 2702, 030005 (2023) https://doi.org/10.1063/5.0185488

Abstract View article PDF

Hospital performance measurement based on intangible assets using Skandia navigator model: A case study

Eko Budi Leksono

AIP Conf. Proc. 2702, 030006 (2023) https://doi.org/10.1063/5.0185030

Abstract View article PDF

Abstract View article PDF

Reduction losses rate in filling process of stick ice product using the six sigma approach

Suwaryo Nugroho; Miftahul Imtihan; Wilarso Wilarso

AIP Conf. Proc. 2702, 030012 (2023) https://doi.org/10.1063/5.0154297

Abstract View article PDF

Evaluating the service quality of third party logistics service provider using importance-performance analysis

Annisa Kesy Garside

AIP Conf. Proc. 2702, 030013 (2023) https://doi.org/10.1063/5.0185485

Abstract View article PDF

Business process modeling of the matawolot community convection during the Covid-19 pandemic

Siti Nur Kayatun; Aprisa Histiarini; Asih Ahistasari; Muhammad Arief Nur Wahyudien; Mirga Maulana Rachmadhani

AIP Conf. Proc. 2702, 030014 (2023) https://doi.org/10.1063/5.0154931

Abstract View article PDF

Microplastics in the Indonesian small screen-printing industries: Environment and human possible risks

Mutiara Panca Sari; Yun Arifatul Fatimah; Affan Rifaí

AIP Conf. Proc. 2702, 030015 (2023) https://doi.org/10.1063/5.0156148

Abstract View article PDF

MECHANICAL

Abstract View article PDF

The effect of the tempering process on the hardness and impact strength on NS 4340 steel

Affandi Affandi; Iqbal Tanjung; Arya Rudi Nasution; Ahmad Marabdi Siregar

AIP Conf. Proc. 2702, 040011 (2023) https://doi.org/10.1063/5.0156743

Abstract View article PDF

Study of the utilization of thermoelectric generator and thermocline for improvement of solar still performance

Dan Mugisidi; Berkah Fajar; Syaiful Syaiful; Tony Suryo Utomo

AIP Conf. Proc. 2702, 040012 (2023) https://doi.org/10.1063/5.0154948

Abstract View article PDF

Optimization of the type-L savonius wind turbine design

Firmansyah Azharul; M. Dwi Trisno; Dahmir Dahlan; Wilarso Wilarso

AIP Conf. Proc. 2702, 040013 (2023) https://doi.org/10.1063/5.0154270

Abstract View article PDF

Engineering of multicore type cable isolation machine with the DMAIC method to reduce product scrap

Miftahul Imtihan; Suryanto Suryanto; Wilarso Wilarso

AIP Conf. Proc. 2702, 040014 (2023) https://doi.org/10.1063/5.0154296

Abstract View article PDF

Failure bushing small end connecting rod diesel engine 3500 series

Wilarso Wilarso; Firmansyah Azharul; Awang Surya; Asep Dharmanto

AIP Conf. Proc. 2702, 040015 (2023) https://doi.org/10.1063/5.0154252

Abstract View article PDF

Effect of baffle distance on heat exchanger performance

Munawar Alfansury Siregar; Wawan Septiawan Damanik; Sudirman Lubis

AIP Conf. Proc. 2702, 040016 (2023) https://doi.org/10.1063/5.0155089

Abstract View article PDF

ELECTRICAL

Three phase radial generator knockdown

Ronny Dwi Agusulistyo; Martanto Martanto; Dwiseno Wihadi; Tjendro Tjendro

AIP Conf. Proc. 2702, 050001 (2023) https://doi.org/10.1063/5.0156152

Abstract View article PDF

Vocal letter classification with audio processing for nursing room notification system with “Mel frequency cepstrum coefficient and backpropagation-neural network methods”

Yoedo Ageng Suryo; Joko Siswanto; Misbah; Pressa Perdana Surya Saputra

AIP Conf. Proc. 2702, 050002 (2023) https://doi.org/10.1063/5.0154352

Abstract View article PDF

Experimental study of tilt angles on the performance of solar panels in medan’s

Chandra Amirsyah Siregar; Munawar Alfansury Siregar; Ahmad Marabdi Siregar; Partaonan Harahap

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Abstract View article PDF

INFORMATICS

Three dimensional Salah guide application based on augmented reality

Yusup Hidayat Winata; Retnani Latifah; Yana Adharani

AIP Conf. Proc. 2702, 060004 (2023) https://doi.org/10.1063/5.0155060

Abstract View article PDF

Implementation of the multi-factor process evaluation method to determine mustahik priorities

Rita Dewi Risanty; Jumail Jumail; Rully Mujiastuti

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Abstract View article PDF

Implementation of GPS for tracking of street vendor

Irvan Nauval; R. Arri Widyanto; Agus Setiawan; Nuryanto Nuryanto; Nugroho Agung Prabowo; Tuessi Ari Purnomo

AIP Conf. Proc. 2702, 060006 (2023) https://doi.org/10.1063/5.0154610

Abstract View article PDF

Implementation of Hajj and Umrah Q&A system using case-based reasoning (CBR)

Farid Sanitas Bachtiar; Setio Basuki; Galih Wasis Wicaksono

AIP Conf. Proc. 2702, 060007 (2023) https://doi.org/10.1063/5.0185777

Abstract View article PDF

IT-based education online learning in the middle of Covid-19 pandemic

Doddy Teguh Yuwono; Muhammad Azhari; Siti Juhairiah

AIP Conf. Proc. 2702, 060008 (2023) https://doi.org/10.1063/5.0154439

Abstract View article PDF

IMU-based joystick: Usage and interaction schemes in simulation game

Muhammad Imanullah; Onsardi Onsardi; Muntahanah Muntahanah; Agung Kharisma Hidayah; Gunawan Gunawan

AIP Conf. Proc. 2702, 060009 (2023) https://doi.org/10.1063/5.0154940

Abstract | View article | PDF

Deep learning hyperparameter optimization on power transformers lifetime prediction

Ayu Ahadi Ningrum; Rudy Ansari; Ichwan Setiawan; Ihdalhubbi Maulida; Finki Dona Marleny; Nahdi Saubari; Muhammad Syahid Pebriadi; Windarsyah Windarsyah; Kamarudin Kamarudin; Mukhaimy Gazali

AIP Conf. Proc. 2702, 060010 (2023) https://doi.org/10.1063/5.0154959

Abstract | View article | PDF

Wood species identification with transfer learning

Sri Winiarti; Nur Rochmah Dyah Puji Astuti

AIP Conf. Proc. 2702, 060011 (2023) https://doi.org/10.1063/5.0155575

Abstract | View article | PDF

Image classification with support vector machine to identify Indonesian traditional building types

Sunardi Sunardi; Sri Winiarti; Ulaya Ahdiani; Agung Parmono

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Abstract | View article | PDF

CHEMICAL

Application of chitosan and catechin to improve the color intensity and UV protection in the dyeing of cotton fabrics with natural dyes from peristrophe bivalvis

Rachma Tia Evitasari; Edia Rahayuningsih; Aswati Mindaryani

AIP Conf. Proc. 2702, 070001 (2023) https://doi.org/10.1063/5.0154606

Abstract View article PDF

The effect of acrylic acid on the characteristics of chitosan-based superabsorbent hydrogen

Haryanto Haryanto; A. Y. Setiawan

AIP Conf. Proc. 2702, 070002 (2023) https://doi.org/10.1063/5.0154952

Abstract View article PDF

The effect of clay and SiO_2 composition on the physical properties of wall tile ceramic body

Irfan Purnawan; A. T. Prabowo; S. E. Rudiatin

AIP Conf. Proc. 2702, 070003 (2023) https://doi.org/10.1063/5.0181074

Abstract View article PDF

Modification of PVC mechanical and migration properties by substitution of DOP plasticizer with epoxidized rice bran oil

Ahmad Muhamad Rizki Triaji; Nurul Hidayati Fithriyah; Ratri Ariatmi Nugrahani

AIP Conf. Proc. 2702, 070004 (2023) https://doi.org/10.1063/5.0155827

Abstract View article PDF

Carbon intensity-based approach for analyzing the environmental performance of nickel production in Indonesia

Joni Safaat Adiansyah; Diah Rahmawati; Alpiana Alpiana

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Study of the utilization of thermoelectric generator and thermocline for improvement of solar still performance FREE

Dan Mugisidi ; Berkah Fajar; Syaiful Syaiful; Tony Suryo Utomo

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Study of The Utilization of Thermoelectric Generator and Thermocline for Improvement of Solar Still Performance

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Abstract. Solar stills generally work because they are energized by solar energy, making them very economical. Unfortunately, solar still productivity is still low and lowers further when solar irradiance decreases. This is one of the reasons for the low efficiency of solar stills. This study uses a thermoelectric generator attached to the solar still to overcome this inefficiency. The heating temperature for the thermoelectric generator is obtained from the outer side of the solar still heat absorber, while the cold temperature is from the thermocline layer. The heat absorber of the solar still size is 400 mm x 300 mm using 3 mm of aluminium material. The thermoelectric generator uses 48 pieces of TEHP1-1263-1.5-1.3A type, and the thermocline is set at a temperature of 5 °C. The results show that the efficiency of the solar still increased by 129% with the addition of a thermoelectric generator and thermocline.

INTRODUCTION

The availability of clean water is a big problem faced by many countries [1] because its use is increasing along with the increase in population and industrial development [2], while the amount is limited. Therefore, an alternative source is needed for use as clean water, namely seawater. The earth's surface is 71% covered by the ocean [3], so seawater can be used to overcome the limited availability of clean water. Unfortunately, seawater cannot be used directly to meet daily needs [4] because it contains large amounts of minerals [5] and must be purified.

One method of purifying seawater as freshwater is solar distillation [6] using a solar still. A solar still is filled with seawater, which is then heated using the sun's heat to evaporate and condense into freshwater [7,8]. This process can be used for up to 200 m3/day [9]. Since the productivity and efficiency of solar stills are still low [10], many researchers are researching to improve them. Solar stills' low productivity and efficiency are due to the variation in solar radiation used as its energy source, especially during the hot afternoon sun [11]. If solar radiation decreases, solar still productivity also decreases [12-14].

To overcome the decrease in productivity due to reduced solar heat, another heat source is needed to replace it. One solution is to use an electric heater with a thermoelectric generator (TEG) source of electricity because it can utilize solar heat and convert it into electrical energy [15]. TEG is a tool for converting heat energy into electrical energy because there is a temperature difference on both sides [16,17]; the hot and cold sides, so to obtain a high amount of electrical energy, the temperature difference on the hot and cold sides needs to be as large as possible. The heat required by the TEG can come from the exhaust heat; [18] Therefore, several studies have made use of water vapor heat by placing the TEG's hot side in the condenser of the solar still [19-21] or placing the TEG in the heat plate absorber to increase the thermodynamic efficiency [22]. In contrast to previous studies that used airflow as a coolant, in this proposal, the TEG generates electricity utilizing the heat at the bottom of the heat absorber and seawater thermocline as a coolant. The thermocline of the thermal layer is a thin but distinct layer in a large body of fluid in which temperature changes more drastically with depth [23]. Therefore, the temperature at sea level ranges from 28–

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30 °C, and the temperature gets lower as the depth increases. At a depth of 220 m, the water temperature is around 13 °C, and at a depth of 600 m, the water temperature is around 5 °C [24] with an average distance of 110.67 m [25], which is influenced by the circulation that occurs in the surface layer [26].

Therefore, this study proposes a solar still system whose performance is enhanced by utilizing the heat from the absorber using a TEG and, on the cold side, using water with a temperature of 5 °C. The electrical energy generated will be stored in the battery and used at night.

SYSTEM DESCRIPTION

This study combines experimental results with calculations to predict system efficiency. Water temperature, heat absorber plate temperature, solar radiation, and freshwater yield measurements were obtained on the day of the experiment results. Other than that, battery charging, basin water, inner side glass cover temperature, and freshwater yield at night were obtained using a calculation. The entire system configuration is shown in Figure 1.

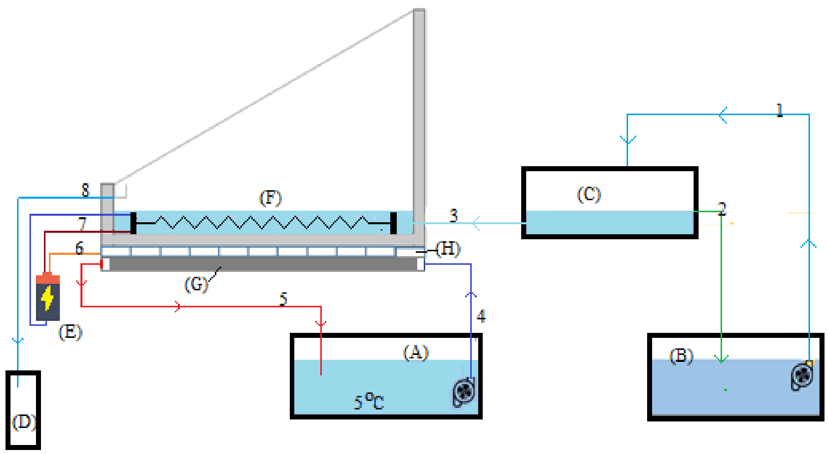

FIGURE 1. Proposed system diagram; (A)=Thermocline water box, (B)=Basin water tank, (C)= Level control tank, (D)=Fresh water collecting jar, (E)=Battery, (F)=Water heater, (G)=Colling water box, (H)=TEG, 1=Circulation line, 2=Overflow line, 3=Supply line, 4=Colling water inlet, 5=Colling water outlet, 6=Charge line, 7=Discharge line, 8=Fresh water line

Figure 1 shows seawater flows from the water tank basin to the level control tank. The water level at the control tank level is the same as in the solar still. Water level adjustment is made by adjusting the overflow. Water from the level control tank will flow into the solar still when the water evaporates and causes its level to decrease. The water vapor will condense in the solar still cover glass and flow to the freshwater collecting jar through the freshwater line. In this approach, the water used on the cold side of the TEG is kept at a temperature of 5 °C in the thermocline water box and circulated with a pump through the cooling water box. The TEG uses 48 pieces TEHP1-1263-1.5-1.3A.

Internal Heat Transfer and Charging

The evaporation process in the solar still starts with an increase in water pressure so that it has a difference in pressure with the cover glass. The energy balances in solar still are [27]:

$$M_w C_{p-w} \frac{dT_w}{dt} + h_{tw}\left(T_w - T_{gi}\right) = \alpha_w I_{(t)s} + h_{ba}(T_b - T_w) + q_u \quad (1)$$

T_w and T_{gi} are water and inner side cover glass temperature, respectively. T_b is basin temperature, and $I_{(t)s}$. The heat transfer that occurs includes convection, radiation, and evaporation [28].

$$qt = \mathrm{qc} + \mathrm{qr} + \mathrm{qe} \quad (2)$$

$$ht = hc + hr + he \quad (3)$$

Convection, radiation, and evaporation heat transfer can be calculated using:

$$q_c = h_c\left(T_w - T_{gi}\right), \quad (4)$$

$$h_c = C(G_r P_r)^n \frac{k_f}{d_f}, \quad (5)$$

$$K_f = 0{,}0244 + 0{,}7673 \times 10^{-4} \times T_w, \quad (6)$$

$$q_r = h_r\left(T_w - T_{gi}\right), \quad (7)$$

$$h_r = \varepsilon_{eff}\sigma\left[(T_w + 273)^2 + \left(T_{gi} + 273\right)^2\right]\left(T_w + T_{gi} + 546\right), \quad (8)$$

$$q_e = h_e\left(T_w - T_{gi}\right) \quad (9)$$

and

$$h_e = 16.273 \times 10^{-3} \times h_c\left[\frac{P_w - P_{gi}}{T_w - T_{gi}}\right] \quad (10)$$

Water temperature is predicted using equation [28]:

$$T_w = \frac{ft}{a}[1 - e^{-at}] + T_{w0} \cdot e^{-at} \quad (11)$$

The values of C and n were searched using the Nusselt and Rayleigh (Nu-Ra) power-law relation [29]. Battery capacity can be determined using:

$$C = \frac{E_k}{V \times Pf} \quad (12)$$

and

$$E_k = Q \times t_p \quad (13)$$

The power required to heat water over a period of time is:

$$Q = m \times C_p \times \frac{\Delta T}{t} \quad (14)$$

The equations can calculate the time required for filling:

$$t = \frac{C}{C_c} \quad (15)$$

Where t is charge time, C is battery capacity and C_c is battery charging capacity. Then:

$$C_C = I_o \times n \quad (16)$$

Io is the output current, and n is the number of TEG. The result of the evaporation of solar still per hour can be calculated by using the following equation [30]:

$$m_w = \frac{h_e\ (T_w - T_{gi})}{h_{fg}} \times 3600 \quad (17)$$

The efficiency calculation of the solar still is [31]:

$$\eta = \frac{m_d \times h_{fg}}{A \times I_{(t)s} \times 3600}\ x\ 100\% \quad (18)$$

Where h_e is the evaporation heat transfer coefficient. Efficiency (h) is provided by multiplying freshwater yield (md) and latent heat of evaporation divided by solar radiance ($I_{(t)s}$) in solar still area (A) for one hour in a second.

RESULTS AND DISCUSSION

Evaporation in a solar still occurs due to differences in the surface pressure of the water and the cover glass [32] caused by temperature differences. Therefore, when solar radiation has decreased, the heat source is diverted to a water heater that uses electrical energy. Electrical energy is obtained from batteries that are charged with electricity from a TEG. The amount of power generated by the TEG can be calculated using the open-circuit voltage equation [17].

$$Y = -7 \cdot E^{-05} \cdot x^2 + 0.064 \cdot x - 0.9553 \quad (19)$$

The power required to keep 2,738 kg of basin water at a temperature above 40 ^oC for 15 hours at night is 8025.08 Watts, so the required battery capacity is 572.2 Ah, and the charging time is estimated at 8 hours and 1 minute. Figure 2 shows the measurement of solar radiation (I), water temperature (Tw), and the inner glass cover temperature (Tgi). The values of C and n are 0.3919 and 0.4659, respectively, calculated from the experimental results. After time 17.00, the water temperature is predicted by equation (10), and the energy source is a battery regulated to keep the temperature above 40 ^oC. Tgi is approached using equation 0.8892.x + 2.2023, which is obtained using the linear fitting between Tw and the Tgi of the experimental results.

Freshwater obtained from the solar still during the day is 371.2 gr/m^2 and at night is 114.65 g/m^2, so the total accumulation of freshwater obtained is 485.68 gr/m^2. Because the main energy source is solar heat, the solar's efficiency of the solar still at day time is 34%, increasing the efficiency to 44% for 24 hours' usage. The system efficiency increases by about 10% due to the low efficiency of TEG. This result is similar to the experiment of Rahbar which has an efficiency of 7% [33]. Since the source of solar energy is used to evaporate water in the solar still and, at the same time, it is converted into electrical energy using TEG, the efficiency increase.

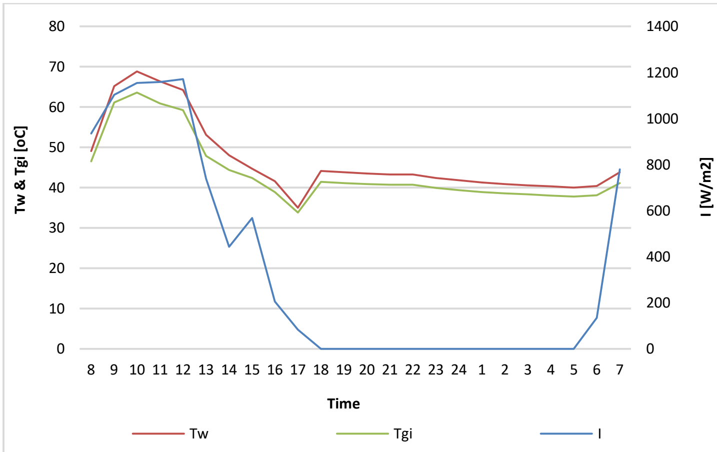

FIGURE 2. Solar irradiance (I), water temperature (Twi), and inner cover glass temperature (Tgi).

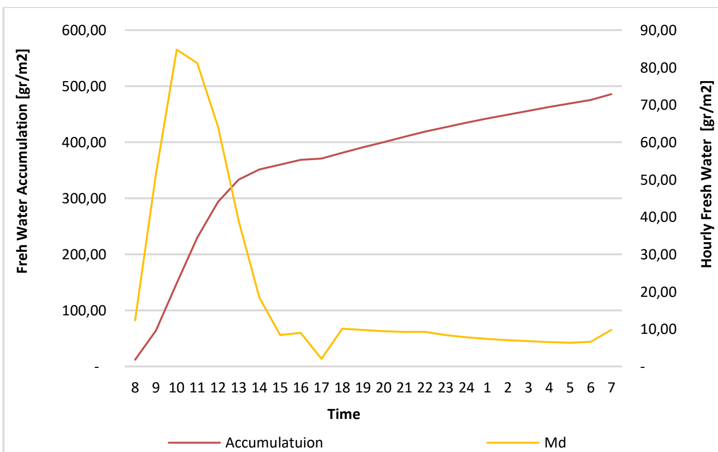

FIGURE 3. Hourly freshwater yield and daily accumulation.

CONCLUSION

The efficiency of the solar still with the addition of a TEG and thermocline is increased by 129% when compared to the same solar still without a TEG. This shows that the productivity of solar stills can still be improved. Electrical energy can be sourced, apart from using a TEG, from photovoltaics, wind energy, wave energy, or a combination of renewable energy sources. It can then be used at night or when the water temperature becomes low. Using energy from various sources, a solar can still operate 24 hours a day without depending on only one main energy source, the sun.

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Certified that

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has presented a paper entitled

"Study of the Utilization of Thermoelectric Generator and Thermocline for Improvement of Solar Still Performance"

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