HEAT TRANSFER ANALYSIS SINGLE SLOPE SOLAR STILL WITH VACUUM TYPE

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Abstract. Solar desalination technology, based on renewable energy, has been highly praised by researchers worldwide. Many researchers have made various modifications to increase and the improvement solar still production. One of them is the research of Omara and Irfan, who made a single slope solar still vacuum type, but in their study, they did not discuss the heat transfer. Therefore, the basis of this study was to compare the desalination performance of single slope solar still (S4) with vacuum, and the temperature data of each study is used as the basis for calculations heat transfer value and then analyzed. As a result of the value of each temperature (*Tw, Tg, Ta*), the difference is not too significant. The average productivity distilled water produced from the two tools showed a substantial difference during the 9 hours of testing, Omara showed 278.75 mL, and Irfan showed 78.12 mL. This difference results of *qr-0* and *qc-0* resulted in the effect of the rate of condensation on the productivity of distilled water so that the productivity of distilled Omara was more significant than the productivity of distilled Irfan.

Keywords: *Single slope solar still, vacuum, heat transfer analysis.*

1. Introduction

Economic development and population growth in the world have caused the demand for drinking water to increase. one-fifth of the world's population lives in water-stressed areas [1]. global water demand will reach 6900 billion m3 in 2030, while water shortages will reach 240 billion m^3 [2,3]. At present conditions, This water shortage can only be corrected by various desalination processes [4], and it is estimated that 14% of the world's population will be forced to use or drink desalinated water by 2025 [5]. Saltwater desalination is currently considered the best method to solve the problem of shortage of clean water in arid regions or countries [6,7]. Desalination methods like membrane distillation [8,9], multi-effect evaporation [10], and reactive distillation column [11–14], are available in a wide range of applications, however, they consume a lot of fossil fuel resources, and their operation cost is very high [2]. Therefore researchers around the world strongly support renewable energy based solar desalination technology [15–20]. Provision of water in dry areas, sustainable development that prioritizes environmentally friendly energy, where solar energy is included, and sustainable and simple desalination methods such as solar still (SS) are the most suitable [21]. Easy operation, low cost, high quality and pollution-free are the advantages of the conventional solar distiller (SS) and it is the simplest device for producing drinking water [22–26]. The conventional solar still's productivity is very low however [27]. A.E. Kabeel and Emad M.S. El-Said [28,29] reviewed current solar thermal desalination research activities with system production ranging from 10–150 L/day for remote or arid areas. When demand for clean water is low and land is available at low cost then small production systems such as solar distillers can be used. to be used properly, desalination based on solar thermal energy which is more efficient, economical requires more effort to investigate further so that the system can be applied. Various modifications to increase SS's production have been carried out by many researchers

, and the improvement of SS focuses on the following aspects: 1) The type of material that functions as a solar energy storage, (2) The internal structure of the solar distillation that can be modified (3) Improved solar dissipation performance. The heat-storage material that has received the most attention. To better absorb, transfer and store heat in a tubular solar stiller Emad M.S. El-Said [30] used a porous medium (formed from steel wire mesh), and to destroy the surface tension and brine boundary layer, a vibrator was attached to the wire mesh to generate vibrations, in order to increase heat transfer and evaporation rate. Omara [31] shows the design and installation of a solar dish concentrator (SDC), a simple solar collector and a boiler that has been modified so that the concave mirror concentrating effect can increase the heat absorption effect in the brackish water desalination process. Chang [32] designed a new concentrated solar drying system, which uses a multiple parabolic concentrator (CPC) as a heater to collect solar radiation. The new type of solar drying system can improve thermal efficiency, and can also reduce the solar collector area when compared to the old model solar drying system. Sales [33]] in his research made a solar desalination system using a Fresnel lens as an effective solar concentrator. Another study, Omara [34] compared conventional solar distillation (CSS) with corrugated axis solar distillation (CrWSS), where CrWSS increased to about 180% higher than CSS. Omara's research [34] is to make a vacuum in a desalination device which is almost the same as Irfan [35], where the dimensions of the tool were almost the same but the two studies did not discuss heat transfer analysis. The basis of this study is to compare the desalination performance of solar still single slope (S4) with the vacuum type which will then analyze the temperature data from each study to be used as the basis for calculating heat transfer values.

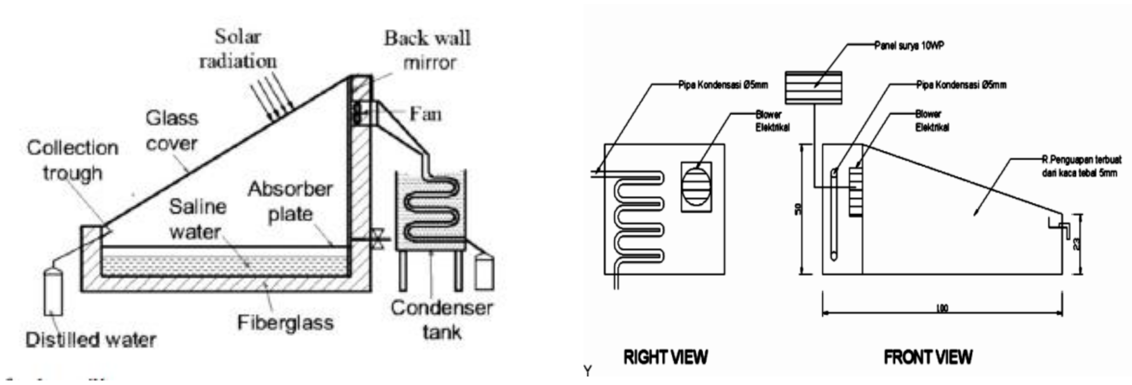
Material and Methods

System Description

Geometry Single Slope Solar Still (S4) in Fig. 1 taken from Omara [34] and Irfan [35] with parameters according in table 1.

Table 1. Parameters of Single Slope Solar Still (S4)

No	Component	Spesification [34]	Specification [35]
1	Hybrid basin solar still dimensions	0.5 m^2	0.6 m^2
2	Basin material	Fiberglass	Glass
3	Angle of inclination of the cover glass	30^0	30^0
4	Basin body cover	Iron sheets	Aluminium foil
5	Condensate pipe	Copper	Copper
6	Solar panels	-	10WP
7	Battery	-	12V 7.2Ah
8	Fan/Blower	yes	yes
9	The volume of sea water in the basin	10.15 kg	0.012 m^3



(a) **(b)**

Figure 1. Design Single Slope Solar Still Type Vacuum (a) Omara [34], (b) Irfan [35]

This research method calculates heat transfer in the single slope tool solar still (S4) vacuum type from the measurement temperature data then analyzes its heat transfer. The calculation of the heat transfer coefficient in the System Single Slope Solar Still (S4) is a vacuum type using the equation : [36]

a) The radiant heat transfer coefficient from the seawater to the glass ($h_{r,1}$);

$$h_{r,1}=0{,}9\sigma\left(T_w{}^2+T_g{}^2\right)\left(T_w+T_g\right) \text{Watt/m}^2\text{K} \quad (1)$$

b) The radiant heat transfer rate from the seawater to the glass ($qr,1$);

$$qr{,}1=Ah_{r,1}\left(T_w-T_g\right) \text{Watt} \quad (2)$$

c) The convection heat transfer coefficient from the seawater to the glass ($h_{c,1}$);

$$h_{c,1}=0{,}884 \text{ x } \left[\left(T_w-T_g\right)+\left(\frac{\rho w_s-\rho w_g}{(268{,}9 \text{ x } 10^3)-\rho w_g}\right) \text{x} T_w\right]^{1/3} \quad (3)$$

d) The convection heat transfer rate from the seawater to the glass ($qc,1$);

$$qc,1 = Ah_{c,1}\left(T_w - T_g\right) Watt \quad (4)$$

e) The radiant heat transfer coefficient from cover glass to ambient air ($h_{r,0}$);

$$h_{r,o} = \varepsilon_g \sigma\left(T_g{}^2 + T_a{}^2\right)\left(T_g + T_a\right) Watt/m^2K \quad (5)$$

f) The radiant heat transfer rate from cover glass to ambient air ($q_{r,0}$);

$$qr,o = Ah_{r,o}\left(T_g - T_a\right) Watt \quad (6)$$

g) The convective heat transfer coefficient from cover glass to ambient air ($h_{c,0}$);

$$h_{c,0}=\frac{\text{Nuxk}}{\text{L}} \text{Watt/m}^2\text{K} \quad (7)$$

h) The convection heat transfer rate from the cover glass to ambient air ($qc,0$);

$$qc,o = Ah_{c,o}\left(T_g - T_a\right) Watt \quad (8)$$

i) Total heat transfer coefficient basin solar still (U_T);

$$U_T=\left[\frac{1}{h_{r,1}+h_{c,1}}+\frac{1}{h_{c,0}+h_{r,o}}+\frac{1}{K_{glass}}\right]^{-1} \text{Watt/m}^2\text{K} \quad (9)$$

j) Heat for the evaporation process (Q);

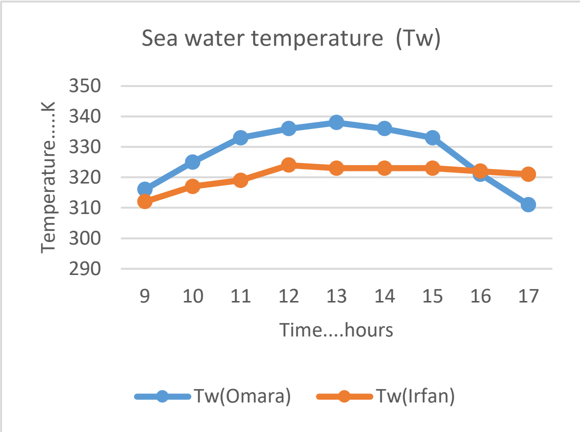
$$Q=U_T \, A \left(T_w-T_a\right) \text{Watt} \quad (10)$$

k) Calculating the total solar intensity (G);

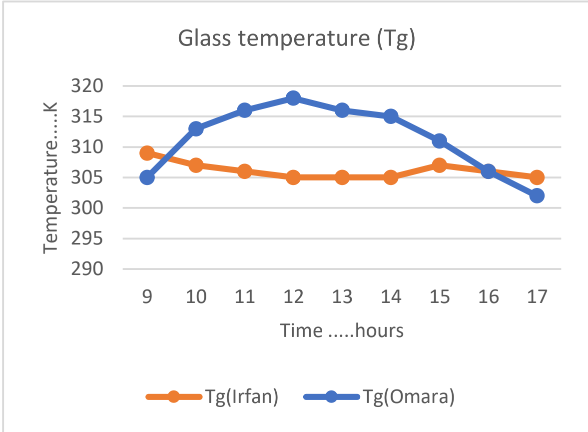
$$G=\frac{(\text{tx}60)\text{x IT}}{10^6} \text{ Watt} \quad (11)$$

2. Result and Discussion

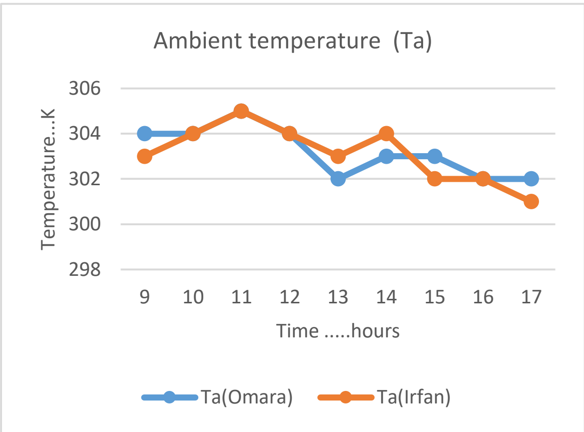
The research temperature data [34] and Irfan [35] are used as the basis for calculating the coefficient and heat transfer rate in a single slope solar still (S4) vacuum type. Temperature data is presented in Fig 2:



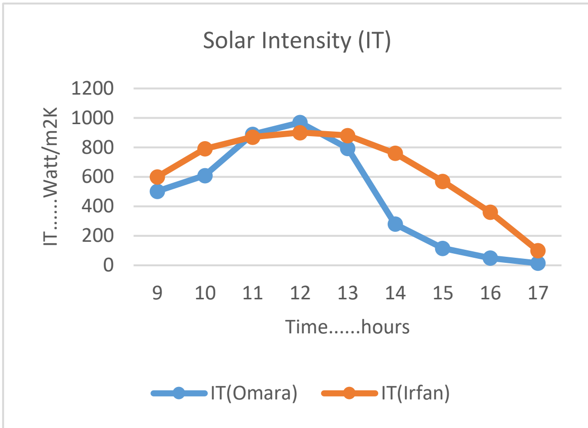
(a)



(b)



(c)

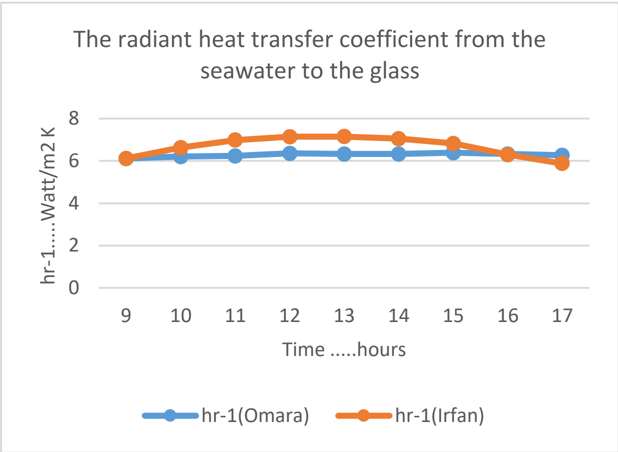


(d)

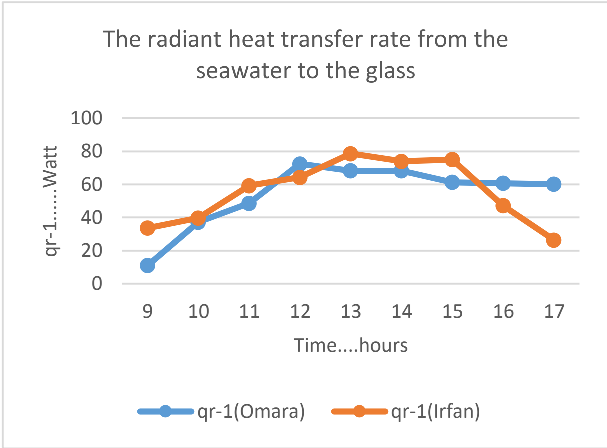
Figure 2. Graphics of each temperature (a) Temperature of the sea water -*Tw*,(b) Cover glass temperature -*Tg*, (c) ambient temperature -*Ta* and (d) Solar intensity (*IT*)

Seawater temperature graph (*Tw*) Figure 2(a) both research data show that the temperature has increased from 11 to 15.00. Then the glass temperature (*Tg*) shows a significant difference between the two temperatures, but at ambient temperature (*Ta*) for 9 hours, the test showed a nominal value. Then, the value of the sun's intensity indicates almost the same power for 9 hours of measurement.

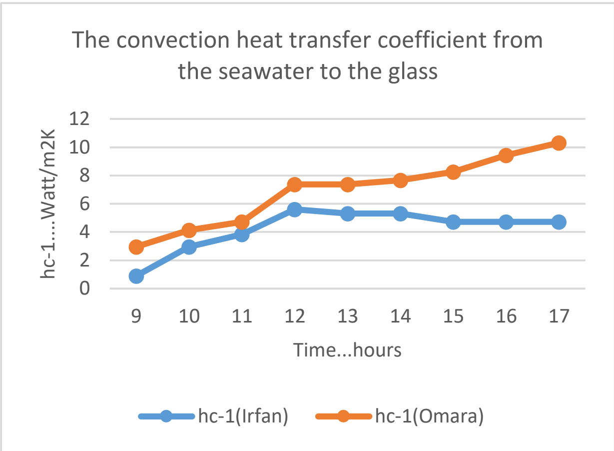
From the temperature and intensity solar data above, the coefficient value and heat transfer rate are shown in Figure 3 :


The radiant heat transfer coefficient from the seawater to the glass
hr-1.....Watt/m2 K
0 2 4 6 8
9 10 11 12 13 14 15 16 17
Time .....hours
hr-1(Omara)
hr-1(Irfan)

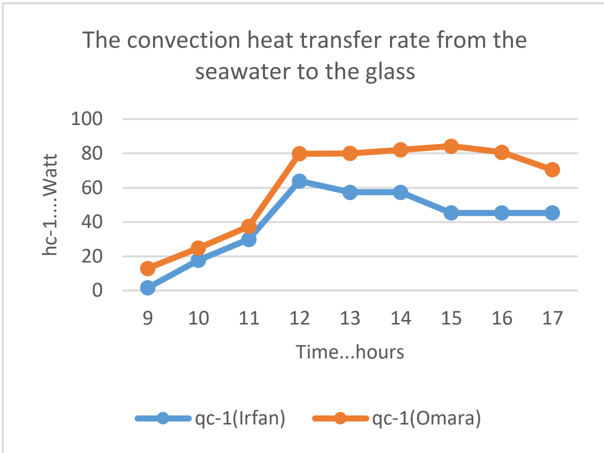
(a)


The radiant heat transfer rate from the seawater to the glass
qr-1......Watt
0 20 40 60 80 100
9 10 11 12 13 14 15 16 17
Time....hours
qr-1(Omara)
qr-1(Irfan)

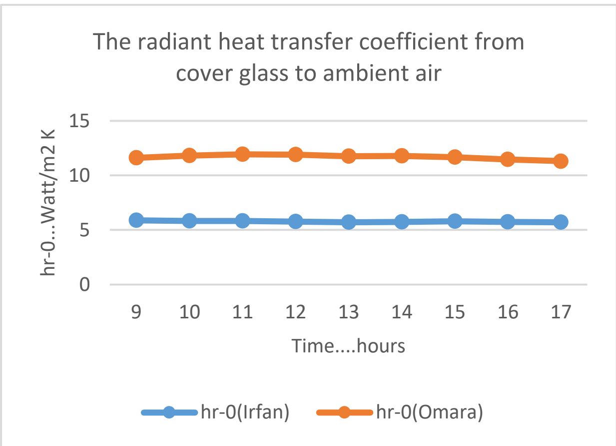
(b)


The convection heat transfer coefficient from the seawater to the glass
hc-1....Watt/m2K
0 2 4 6 8 10 12
9 10 11 12 13 14 15 16 17
Time...hours
hc-1(Irfan)
hc-1(Omara)

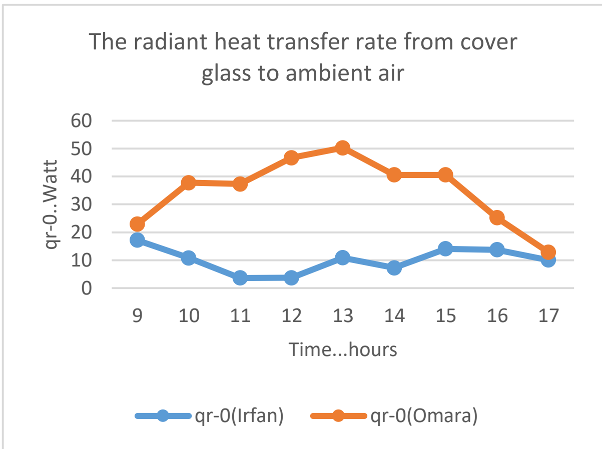
(c)


The convection heat transfer rate from the seawater to the glass
hc-1....Watt
0 20 40 60 80 100
9 10 11 12 13 14 15 16 17
Time...hours
qc-1(Irfan)
qc-1(Omara)

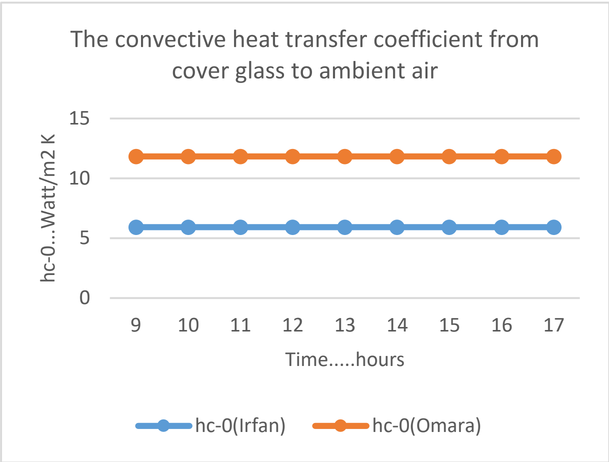
(d)


The radiant heat transfer coefficient from cover glass to ambient air
hr-0...Watt/m2 K
0 5 10 15
9 10 11 12 13 14 15 16 17
Time....hours
hr-0(Irfan)
hr-0(Omara)

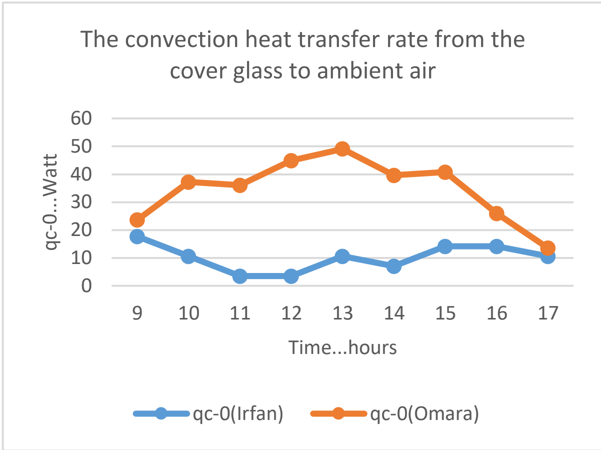
(e)


The radiant heat transfer rate from cover glass to ambient air
qr-0..Watt
0 10 20 30 40 50 60
9 10 11 12 13 14 15 16 17
Time...hours
qr-0(Irfan)
qr-0(Omara)

(f)



(g)



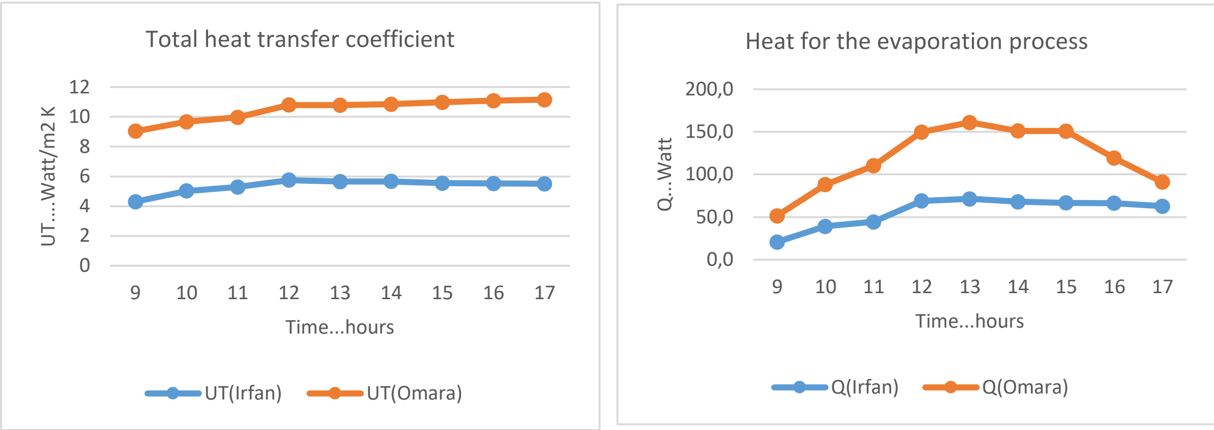
(h)

Figure 3. Graph of heat transfer analysis (a) radiant heat transfer coefficient from the seawater to the glass, (b) radiant heat transfer rate from the seawater to the glass, (c) convection heat transfer coefficient from the seawater to the glass, (d) convection heat transfer rate from the seawater to the glass, (e) radiant heat transfer coefficient from cover glass to ambient air, (f) radiant heat transfer rate from cover glass to ambient air, (g) convective heat transfer coefficient from cover glass to ambient air, (h) convection heat transfer rate from the cover glass to ambient air

Calculating the average fig.3 value of the radiation heat transfer rate from seawater to glass (*qr-1*), calculating the average value of the convection heat transfer rate from seawater to glass (*qc-1*), calculating the average value of the transfer rate radiant heat from glass to the environment (*qr-0*), calculation of the average value of the convection heat transfer rate from glass to the environment (*qc-0*), the measure of the average value of the total heat transfer coefficient (*UT*), calculation of the intermediate heat value required for evaporation (*Q*), the average value of the solar constant (*G*) and the average value of the productivity of distilled water (*V*) are shown in Table 2:

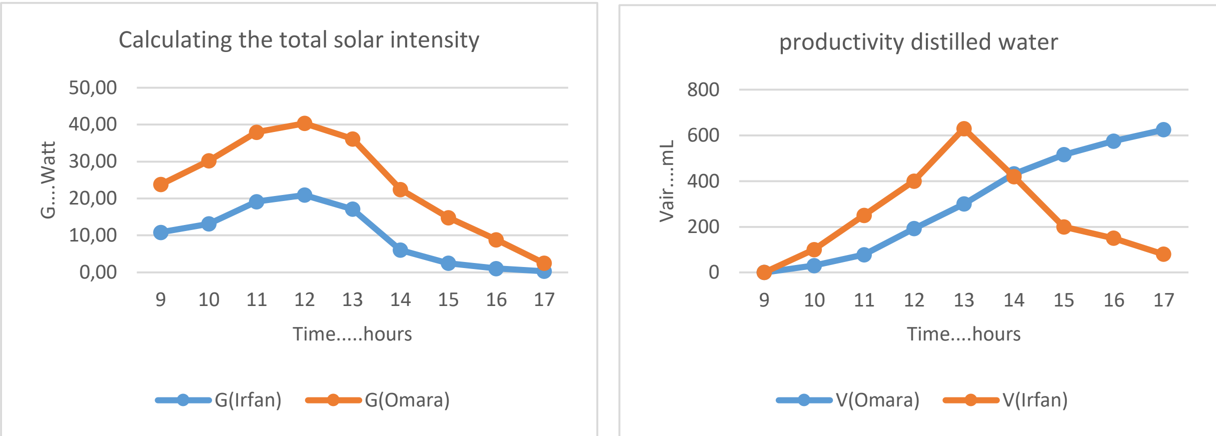
Table 2. Average value of radiant and convective heat transfer

The average value of heat transfer based on temperature data	**Omara[34]**	**Irfan[35]**
qr-1	55,36 Watt	54,22 Watt
qc-1	20,99 Watt	40,39 Watt
qr-0	24,74 Watt	10,16 Watt
qc-0	24,31 Watt	10,25 Watt
UT	5,122 Watt/m^{2}K	5,35 Watt/m^{2}K
Q	62,69 Watt	56,41 Watt
G	13,99 Watt	10,12 Watt
Productivity (*V*)	278,75 mL	78,12 mL



(a) (b)

Figure 4(a).Total heat transfer and (b) heat required for evaporation



(a) (b)

Figure 5. Graph (a) the value of the solar constant and (b) the productivity of distilled water

From table 2 data, the average value of distilled water productivity based on data [34] = 278.75 mL, which is greater than data [35] = 78.12 mL, although from seawater temperature data (*Tw*), ambient temperature (*Ta*), and the cover glass temperature (*Tg*) both are not a too significant difference. Then the average value of the radiation heat transfer rate from seawater to the glass and the average value of the convection heat transfer rate of each *qr-1* = 55.36 Watt and *qc-1* = 20.99 Watt [34], then the value *qr-1* = 54.22 Watts and *qc-1* = 30.39 Watts [35].

The significant difference is the calculation of the average value of the radiation heat transfer rate from the glass to the ambient temperature and the analysis of the average value of the convection heat transfer rate from the glass to the environment, resulting in *qr-0* = 24.74 Watt and *qc-0* = 24, 31 Watt [34], while the results of *qr-0* = 10.16 Watt, *qc-0* = 10.25 Watt [35]. This difference results in *qr-0* and *qc-0* in the effect rate condensation on the productivity distilled water so that the productivity [34] was more significant than the productivity [35].

3. Conclusion

The conclusion of this study shows that the vacuum desalination made by Omara and Irfan that the dimensions of the tool are almost the same, indicating the value of each temperature (*Tw, Tg, Ta*) the difference is not too significant, but the average value of productivity distilled water produced from the two tools showed a substantial difference during the 9 hours of testing Omara showed 278.75 mL, and Irfan showed 78.12 mL because there is a difference in the value of the radiation heat transfer rate (*qr-0*) and the value of the convection heat transfer rate (*qc-0*) from the glass to the ambient air.

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Submission date: 23-May-2023 03:27AM (UTC+0300)
Submission ID: 2099647025
File name: 10._HEAT_TRANSFER_ANALYSIS_S4_1.pdf (679.56K)
Word count: 3673
Character count: 18555

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Abstract. Solar desalination technology, based on renewable energy, has been highly praised by researchers worldwide. Many researchers have made various modifications to increase and the improvement solar still production. One of them is the research of Omara and Irfan, who made a single slope solar still vacuum type, but in their study, they did not discuss the heat transfer. Therefore, the basis of this study was to compare the desalination performance of single slope solar still (S4) with vacuum, and the temperature data of each study is used as the basis for calculations heat transfer value and then analyzed. As a result of the value of each temperature (*Tw, Tg, Ta*), the difference is not too significant. The average productivity distilled water produced from the two tools showed a substantial difference during the 9 hours of testing, Omara showed 278.75 mL, and Irfan showed 78.12 mL. This difference results of *qr-0* and *qc-0* resulted in the effect of the rate of condensation on the productivity of distilled water so that the productivity of distilled Omara was more significant than the productivity of distilled Irfan.

Keywords: *Single slope solar still, vacuum, heat transfer analysis.*

1. Introduction

Economic development and population growth in the world have caused the demand for drinking water to increase. one-fifth of the world's population lives in water-stressed areas [1]. global water demand will reach 6900 billion m3 in 2030, while water shortages will reach 240 billion m^3 [2,3]. At present conditions, This water shortage can only be corrected by various desalination processes [4], and it is estimated that 14% of the world's population will be forced to use or drink desalinated water by 2025 [5]. Saltwater desalination is currently considered the best method to solve the problem of shortage of clean water in arid regions or countries [6,7]. Desalination methods like membrane distillation [8,9], multi-effect evaporation [10], and reactive distillation column [11–14], are available in a wide range of applications, however, they consume a lot of fossil fuel resources, and their operation cost is very high [2]. Therefore researchers around the world strongly support renewable energy based solar desalination technology [15–20]. Provision of water in dry areas, sustainable development that prioritizes environmentally friendly energy, where solar energy is included, and sustainable and simple desalination methods such as solar still (SS) are the most suitable [21]. Easy operation, low cost, high quality and pollution-free are the advantages of the conventional solar distiller (SS) and it is the simplest device for producing drinking water [22–26]. The conventional solar still's productivity is very low however [27]. A.E. Kabeel and Emad M.S. El-Said [28,29] reviewed current solar thermal desalination research activities with system production ranging from 10–150 L/day for remote or arid areas. When demand for clean water is low and land is available at low cost then small production systems such as solar distillers can be used. to be used properly, desalination based on solar thermal energy which is more efficient, economical requires more effort to investigate further so that the system can be applied. Various modifications to increase SS's production have been carried out by many researchers

, and the improvement of SS focuses on the following aspects: 1) The type of material that functions as a solar energy storage, (2) The internal structure of the solar distillation that can be modified (3) Improved solar dissipation performance. The heat-storage material that has received the most attention. To better absorb, transfer and store heat in a tubular solar stiller Emad M.S. El-Said [30] used a porous medium (formed from steel wire mesh), and to destroy the surface tension and brine boundary layer, a vibrator was attached to the wire mesh to generate vibrations, in order to increase heat transfer and evaporation rate. Omara [31] shows the design and installation of a solar dish concentrator (SDC), a simple solar collector and a boiler that has been modified so that the concave mirror concentrating effect can increase the heat absorption effect in the brackish water desalination process. Chang [32] designed a new concentrated solar drying system, which uses a multiple parabolic concentrator (CPC) as a heater to collect solar radiation. The new type of solar drying system can improve thermal efficiency, and can also reduce the solar collector area when compared to the old model solar drying system. Sales [33]] in his research made a solar desalination system using a Fresnel lens as an effective solar concentrator. Another study, Omara [34] compared conventional solar distillation (CSS) with corrugated axis solar distillation (CrWSS), where CrWSS increased to about 180% higher than CSS. Omara's research [34] is to make a vacuum in a desalination device which is almost the same as Irfan [35], where the dimensions of the tool were almost the same but the two studies did not discuss heat transfer analysis. The basis of this study is to compare the desalination performance of solar still single slope (S4) with the vacuum type which will then analyze the temperature data from each study to be used as the basis for calculating heat transfer values.

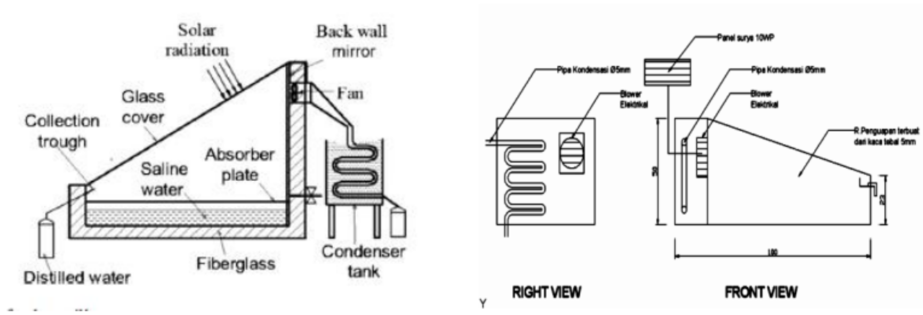
Material and Methods

System Description

Geometry Single Slope Solar Still (S4) in Fig. 1 taken from Omara [34] and Irfan [35] with parameters according in table 1.

Table 1. Parameters of Single Slope Solar Still (S4)

No	Component	Spesification [34]	Specification [35]
1	Hybrid basin solar still dimensions	0.5 m^2	0.6 m^2
2	Basin material	Fiberglass	Glass
3	Angle of inclination of the cover glass	30^0	30^0
4	Basin body cover	Iron sheets	Aluminium foil
5	Condensate pipe	Copper	Copper
6	Solar panels	-	10WP
7	Battery	-	12V 7.2Ah
8	Fan/Blower	yes	yes
9	The volume of sea water in the basin	10.15 kg	0.012 m^3



(a) **(b)**

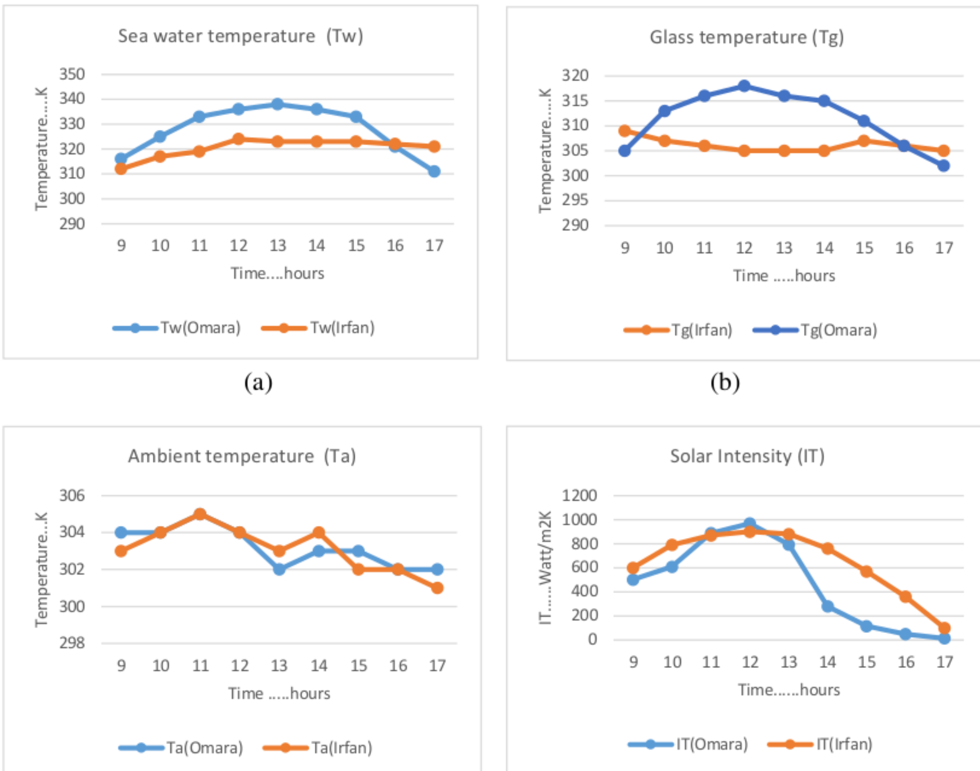
Figure 1. Design Single Slope Solar Still Type Vacuum (a) Omara [34], (b) Irfan [35]

This research method calculates heat transfer in the single slope tool solar still (S4) vacuum type from the measurement temperature data then analyzes its heat transfer. The calculation of the heat transfer coefficient in the System Single Slope Solar Still (S4) is a vacuum type using the equation : [36]

a) The radiant heat transfer coefficient from the seawater to the glass ($h_{r,1}$);
$$h_{r,1}=0,9\sigma\left(T_w^2+T_g^2\right)\left(T_w+T_g\right)Watt/m^2K \qquad (1)$$
b) The radiant heat transfer rate from the seawater to the glass ($qr,1$);
$$q_{r,1}=Ah_{r,1}\left(T_w-T_g\right)Watt \qquad (2)$$
c) The convection heat transfer coefficient from the seawater to the glass ($h_{c,1}$);
$$h_{c,1}=0,884 \times \left[\left(T_w-T_g\right)+\left(\frac{\rho w_s-\rho w_g}{(268,9 \times 10^3)-\rho w_g}\right)xT_w\right]^{1/3} \qquad (3)$$
d) The convection heat transfer rate from the seawater to the glass ($qc,1$);
$$qc,1 = Ah_{c,1}\left(T_w-T_g\right)Watt \qquad (4)$$
e) The radiant heat coefficient from cover glass to ambient air ($h_{r,0}$);
$$h_{r,o} = \varepsilon_g\sigma\left(T_g^2+T_a^2\right)\left(T_g+T_a\right)Watt/m^2K \qquad (5)$$
f) The radiant heat transfer rate from cover glass to ambient air ($q_{r,0}$);
$$qr,o = Ah_{r,o}\left(T_g-T_a\right)Watt \qquad (6)$$
g) The convective heat transfer coefficient from cover glass to ambient air ($h_{c,0}$);
$$h_{c,0}=\frac{Nuxk}{L}Watt/m^2K \qquad (7)$$
h) The convection heat transfer rate from the cover glass to ambient air ($qc,0$);
$$qc,o = Ah_{c,o}\left(T_g-T_a\right)Watt \qquad (8)$$
i) Total heat transfer coefficient basin solar still (U_T);
$$U_T=\left[\frac{1}{h_{r,1}+h_{c,1}}+\frac{1}{h_{c,0}+h_{r,0}}+\frac{1}{K_{glass}}\right]^{-1} Watt/m^2K \qquad (9)$$
j) Heat for the evaporation process (Q);
$$Q=U_T\,A\left(T_w-T_a\right)Watt \qquad (10)$$
k) Calculating the total solar intensity (G);
$$G=\frac{(tx60)x\,IT}{10^6}\,Watt \qquad (11)$$

2. Result and Discussion

The research temperature data [34] and Irfan [35] are used as the basis for calculating the coefficient and heat transfer rate in a single slope solar still (S4) vacuum type. Temperature data is presented in Fig 2:

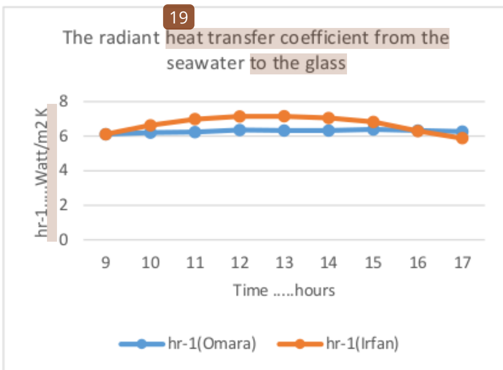


(a) (b) (c) (d)

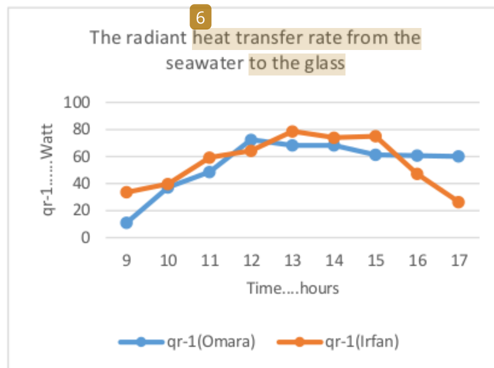
Figure 2. Graphics of each temperature (a) Temperature of the sea water -*Tw*,(b) Cover glass temperature -*Tg*, (c) ambient temperature -*Ta* and (d) Solar intensity (*IT*)

Seawater temperature graph (*Tw*) Figure 2(a) both research data show that the temperature has increased from 11 to 15.00. Then the glass temperature (*Tg*) shows a significant difference between the two temperatures, but at ambient temperature (*Ta*) for 9 hours, the test showed a nominal value. Then, the value of the sun's intensity indicates almost the same power for 9 hours of measurement.

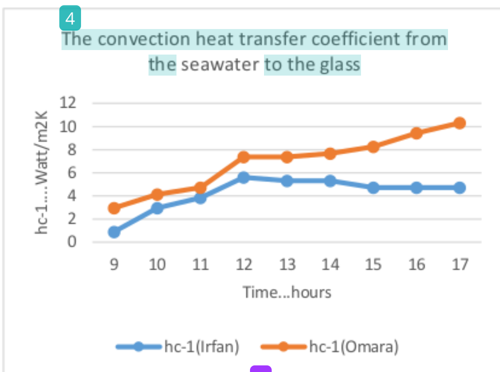
From the temperature and intensity solar data above, the coefficient value and heat transfer rate are shown in Figure 3 :


The radiant heat transfer coefficient from the seawater to the glass
hr-1.....Watt/m2 K
0
2
4
6
8
9 10 11 12 13 14 15 16 17
Time .....hours
hr-1(Omara)
hr-1(Irfan)

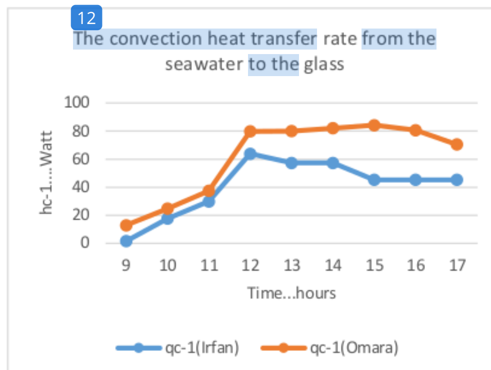
(a)


The radiant heat transfer rate from the seawater to the glass
qr-1......Watt
0
20
40
60
80
100
9 10 11 12 13 14 15 16 17
Time....hours
qr-1(Omara)
qr-1(Irfan)

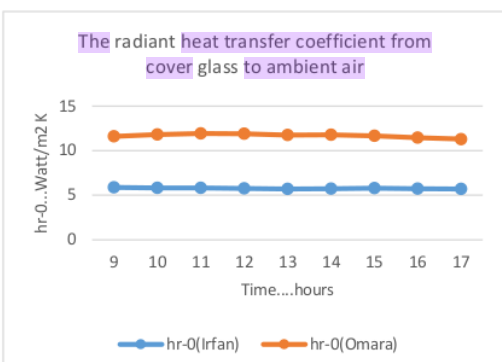
(b)


The convection heat transfer coefficient from the seawater to the glass
hc-1....Watt/m2K
0
2
4
6
8
10
12
9 10 11 12 13 14 15 16 17
Time...hours
hc-1(Irfan)
hc-1(Omara)

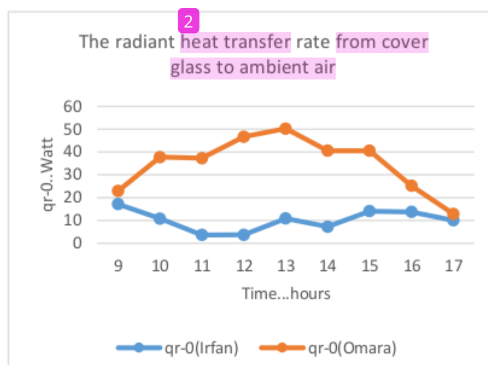
(c)


The convection heat transfer rate from the seawater to the glass
hc-1...Watt
0
20
40
60
80
100
9 10 11 12 13 14 15 16 17
Time...hours
qc-1(Irfan)
qc-1(Omara)

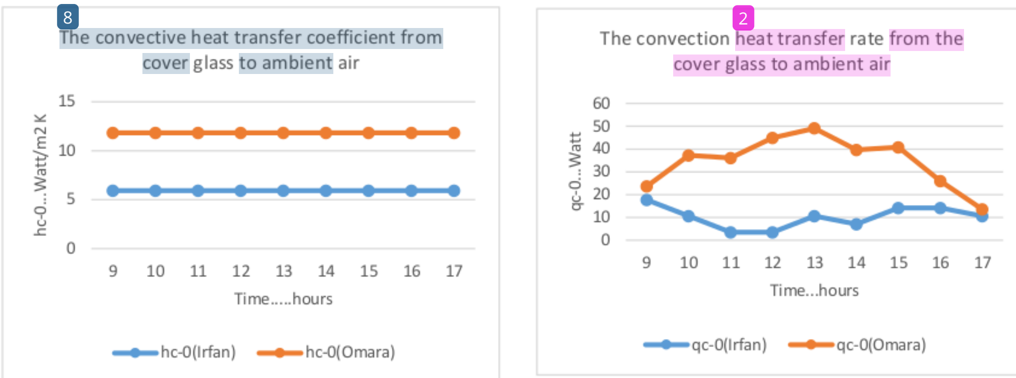
(d)


The radiant heat transfer coefficient from cover glass to ambient air
hr-0...Watt/m2 K
0
5
10
15
9 10 11 12 13 14 15 16 17
Time....hours
hr-0(Irfan)
hr-0(Omara)

(e)


The radiant heat transfer rate from cover glass to ambient air
qr-0..Watt
0
10
20
30
40
50
60
9 10 11 12 13 14 15 16 17
Time...hours
qr-0(Irfan)
qr-0(Omara)

(f)



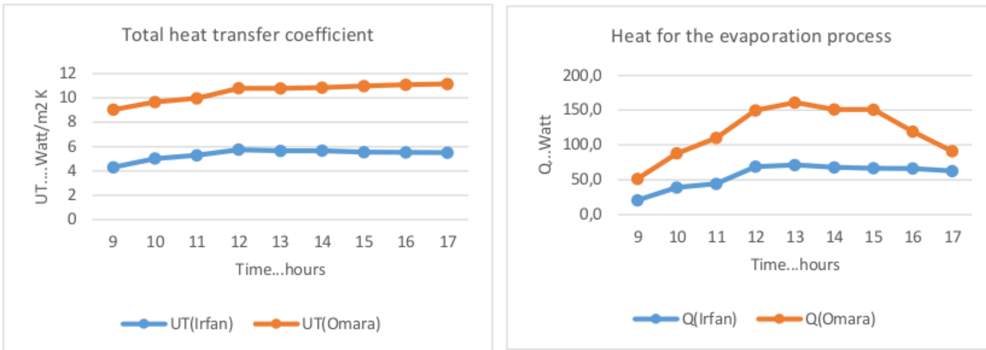
(g) (h)

Figure 3. Graph of heat transfer analysis (a) radiant heat transfer coefficient from the seawater to the glass, (b) radiant heat transfer rate from the seawater to the glass, (c) convection heat transfer coefficient from the seawater to the glass, (d) convection heat transfer rate from the seawater to the glass, (e) radiant heat transfer coefficient from cover glass to ambient air, (f) radiant heat transfer rate from cover glass to ambient air, (g) convective heat transfer coefficient from cover glass to ambient air, (h) convection heat transfer rate from the cover glass to ambient air

Calculating the average fig.3 value of the radiation heat transfer rate from seawater to glass (*qr-1*), calculating the average value of the convection heat transfer rate from seawater to glass (*qc-1*), calculating the average value of the transfer rate radiant heat from glass to the environment (*qr-0*), calculation of the average value of the convection heat transfer rate from glass to the environment (*qc-0*), the measure of the average value of the total heat transfer coefficient (*UT*), calculation of the intermediate heat value required for evaporation (*Q*), the average value of the solar constant (*G*) and the average value of the productivity of distilled water (*V*) are shown in Table 2:

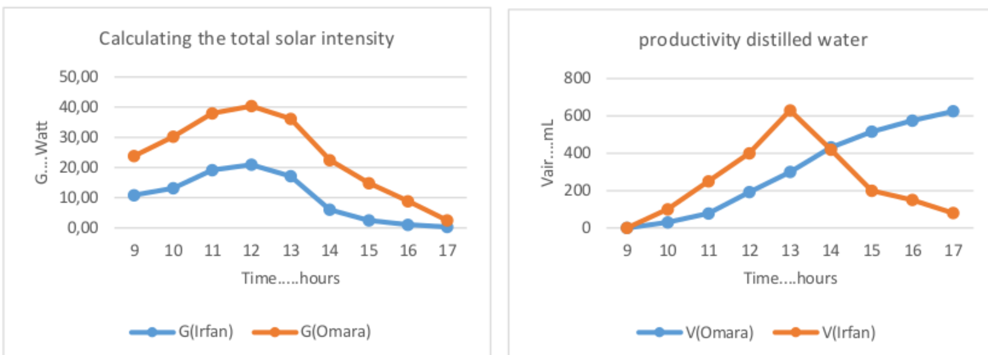
Table 2. Average value of radiant and convective heat transfer

The average value of heat transfer based on temperature data	**Omara[34]**	**Irfan[35]**
qr-1	55,36 Watt	54,22 Watt
qc-1	20,99 Watt	40,39 Watt
qr-0	24,74 Watt	10,16 Watt
qc-0	24,31 Watt	10,25 Watt
UT	5,122 Watt/m^{2}K	5,35 Watt/m^{2}K
Q	62,69 Watt	56,41 Watt
G	13,99 Watt	10,12 Watt
Productivity (*V*)	278,75 mL	78,12 mL



(a) (b)

Figure 4(a).Total heat transfer and (b) heat required for evaporation



(a) (b)

Figure 5. Graph (a) the value of the solar constant and (b) the productivity of distilled water

From table 2 data, the average value of distilled water productivity based on data [34] = 278.75 mL, which is greater than data [35] = 78.12 mL, although from seawater temperature data (*Tw*), ambient temperature (*Ta*), and the cover glass temperature (*Tg*) both are not a too significant difference. Then the average value of the radiation heat transfer rate from seawater to the glass and the average value of the convection heat transfer rate of each *qr-1* = 55.36 Watt and *qc-1* = 20.99 Watt [34], then the value *qr-1* = 54.22 Watts and *qc-1* = 30.39 Watts [35].

The significant difference is the calculation of the average value of the radiation heat transfer rate from the glass to the ambient temperature and the analysis of the average value of the convection heat transfer rate from the glass to the environment, resulting in *qr-0* = 24.74 Watt and *qc-0* = 24, 31 Watt [34], while the results of *qr-0* = 10.16 Watt, *qc-0* = 10.25 Watt [35]. This difference results in *qr-0* and *qc-0* in the effect rate condensation on the productivity distilled water so that the productivity [34] was more significant than the productivity [35].

3. Conclusion

The conclusion of this study shows that the vacuum desalination made by Omara and Irfan that the dimensions of the tool are almost the same, indicating the value of each temperature (*Tw, Tg, Ta*) the difference is not too significant, but the average value of productivity distilled water produced from the two tools showed a substantial difference during the 9 hours of testing Omara showed 278.75 mL, and Irfan showed 78.12 mL because there is a difference in the value of the radiation heat transfer rate (*qr-0*) and the value of the convection heat transfer rate (*qc-0*) from the glass to the ambient air.

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HEAT TRANSFER ANALYSIS SINGLE SLOPE SOLAR STILL WITH VACUUM TYPE

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