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F-Cubed Carocell Panels: A Promising Solution for Distilling Irrigation and Brackish

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Abstract. This study aimed to investigate the performance of Fcubed carocell Panel using two different types of feedwaters i.e. irrigation and brackish water. The environmental condition parameters measured consisted of Illumination, radiation, relative humidity, and temperature, while the parameters of feed water samples measured consisted of volume, temperature, and total dissolved solid of wastewater (disinfected heated water) and distilled water. The analysis showed that the distilled water yield of irrigation water was significantly different than that of brackish water. The difference was caused due to the difference content of Total Dissolved Solids and the environment's relative humidity. The Total Dissolved Solids (TDS) of brackish water was ten times that of irrigation water, while both distilled water TDS of irrigation and brackish water were less than 10 ppm. The discharge of irrigation distilled water was relatively higher than that of brackish water. The distilled water discharge of irrigation and brackish water was 1.06 ± 0.19 l/hr and 0.86 ± 0.14 l/hr respectively. The ratio between distilled and wastewater of irrigation and brackish water were 20:1 and 25:1 respectively.

1 Introduction

Water is a basic need of a human that is important for the survival and quality of human life. However, not all residents get clean water that is suitable for use. Several regions in Indonesia currently experiencing difficulties in supplying their need for drinking water. One attempt that can be done to provide drinking water is to use existing water sources, such as irrigation water and seawater. Referring to the previous studies, most of the irrigation water did not meet drinking water quality standards, due to the colour, turbidity, and coliform bacteria; Likewise, seawater did not meet drinking water standards because of the high levels of salt content [1,2]. Different methods of water purification were used in many countries to overcome the scarcity of drinking water. A various of desalination technologies have been developed over the years based on thermal distillation, membrane separation, freezing, and electrodialysis [3–6].

To provide pure water in the area that does not have drinking water sources, the development of compact, small scale systems for water purification is imperative [7]. There are several technology methods available for producing drinking water, among these methods, solar distillation as one of the best practices and the most economical [8]. Besides thermal solar energy based on renewable energy without causing any fossil energy depletion,

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hydrocarbon pollution, environmental degradation [4,7] it is modular and can be installed in various capacities. The benefit of a compact solar-powered desalination facility is its little energy requirement, predominantly sourced from solar radiation. This advantage should represent the most cost-effective method for supplying drinkable water to communities living in rural places with inadequate infrastructure. The application of solar energy in water distillation has a longstanding history, with technology significantly refined and validated globally [7]. The solar still is probably the most ancient technique for desalinating water. The operation of a solar still is based on the greenhouse effect, wherein solar radiation evaporates water within a sealed, glass-covered chamber at a temperature above that of the surrounding environment.

There are many published paper focused on the solar distillation of various designs [8,9] among these are Pyramid Solar Still [10], Hemispherical Solar Still [11,12], Basin Solar Still [13–15], Tubular Solar Still [16], Inverted Absorber Solar Still [17,18], Compound Parabolic Concentrator (CPC) Solar Still [19], portable active solar still [20], active vibratory solar still [21], and plastic solar still [22]. Review on F Cubed solar Panel to purify water is still relatively rare. Therefore this study aimed to assess the performance of F- cubed Solar Panel in the distillation of irrigation and brackish water to provide the drinking water.

2 Materials and Methods

2.1 Experimental Configuration and Instrumentation

The experiments were performed at the Research Centre for Appropriate Technology facility. Subang District (6033’14.08” S, 107045’41.32”, 86 MAMSL) in August 2017. The weather data were measured using an integrated system based on the Arduino 2560 microcontroller connected to sensors of temperature, relative humidity, light-dependent resistor, uv, distance, liquid crystal display, secure digital card, and real-time clock. Besides weather data this system also was used to measure distilled water volume. Figure 1 shows the circuit of an integrated system.

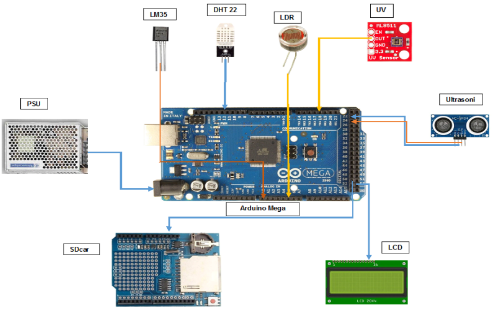

Fig. 1. F- Cubed Carocell Control System Circuit.

The other parameter measured was consisted of total solid dissolved, pH, and undistilled water volume. The instrument used was baker glass, graduated glass, pH-107, TDS -3, Conductivity & pH/ORP Meter TES-1381K. The Total Solid Dissolved meter TDS-3 and) pH metere ATC were used to measured the TDS and pH of the irrigation water, while Conductivity & pH/ORP Meter TES-1381K was used to measured the TDS and pH of brackish water. The undistilled water was measured manually using baker and graduated glasses.

The F Cubed used in this study was The F Cubed 2000 manufactured by F Cubed. Ltd., Carocell Solar Panel, Australia. The F Cubed solar panel was positioned at the angle of 29 degrees from the horizontal plane. The primary construction materials consisted of galvanised steel legs, an aluminium frame, fabric and polycarbonate. The polycarbonate film was coated on the inside surface with a particular substance (patent for F Cubed- Australia) to prevent misting. The specification of the F Cubed solar panel is 2m2 surface area, 1150 mm width, 2100 mm length 50mm thickness, 15 kg weight and 8-10 l/day capacity [23].

The 120-liter reservoir, which was situated at a height of 2 meters, supplied the solar panel with water. A single nozzle supplied the supply water, resulting in a thin layer of water that flowed over the absorbent fabric. A uniform distribution of water throughout the fabric was facilitated by an aluminium plate located beneath the absorbent textile. Water permeated the absorbent fabric in a continuous manner, and solar energy was partially absorbed and captured within the panel. Consequently, the water was heated and evaporated as hot air naturally circulated within the panel. The vapour-containing heated air ascension is directed towards the upper cover of the panel, which will subsequently descend. Under the circumstances, the circulation mechanism induces vapour condensation by causing humid air to interact with the cool surfaces of polycarbonate film. Subsequently, the distilled water stream was collected as the condensed water flowed downstream within the polycarbonate top sheet.

There were two types of water samples used, i.e., irrigation and brackish water. The irrigation water was taken from Cigadung village (6033’14.85” S, 107045’41.36” E, 91 MAMSL), sub-district of Subang, Subang district. The brackish water was taken from Mayangan village (6012’25,36” S, 107046’36,18”E, 1 MAMSL), sub-district of Legon Kulon, Subang district. Figure 2 illustrates the isometric and exploded view of the F Cubed solar panel.

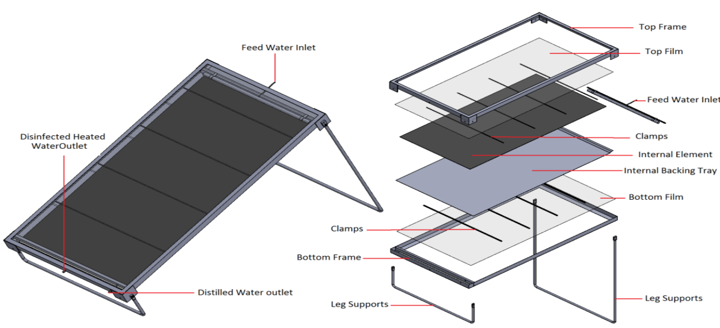

Fig. 2. Isometric and Exploded View of F Cubed Solar Panel.

3 Result and Discussion

3.1 Processing of Irrigation Water

The average of illumination, radiation, humidity and temperature of the environment during the purification of irrigation water were 68.89 ± 2.52 kilolux, 0.42 ± 0.10 kWatt/m2, 48.10 ± 0.00 % and 34.20 ± 0.00°C respectively. Figure 3 shows the measurement per unit of time of illumination, radiation, humidity and temperature of the environment condition. Results of the analysis determined that the average of volume, temperature and total dissolved solids (TDS) of wasted water (disinfected heated water) were 19.54 ± 2.04 l/hr, 38.00 ± 3.61°C, and 165.09 ± 9.07 ppm, those of distilled water was 1.06 ± 0.19 l/hr, 35.27 ± 3.13°C, and 7.09 ± 1.04 ppm respectively. Figure 4 shows the measurement per unit of time of volume, temperature and total dissolved solids (TDS) of waste and distilled water.

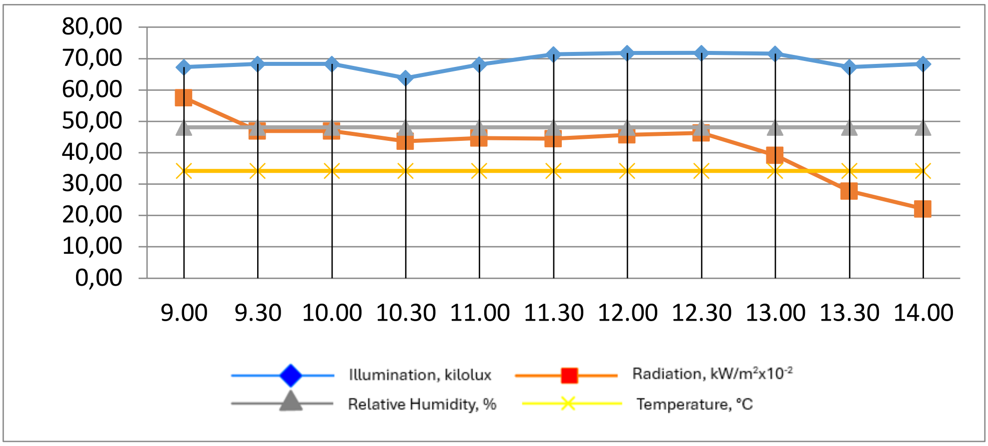

Fig. 3. Graphic of the environment condition for irrigation water.

The bivariate correlation analysis showed a correlation between the discharge of wastewater and distilled water and between the temperature of waste and distilled water. The relationship was pointed out by the value of Pearson correlation of 0.813 ($p=0.02$) for the discharge of wastewater (Qww)and distilled water (Qdw), and of 0.947 ($p=0.00$) for the temperature of wastewater (Tww) and distilled water (Tdw). Further analysis result of the stepwise regression method showed that the correlation between discharge and temperature of waste and distilled water were: Qww = 8.707 Qdw + 10.339 with $R2= 0.661$ and Tww = 1.090Tdw – 0.441 with $R2= 0.897$.

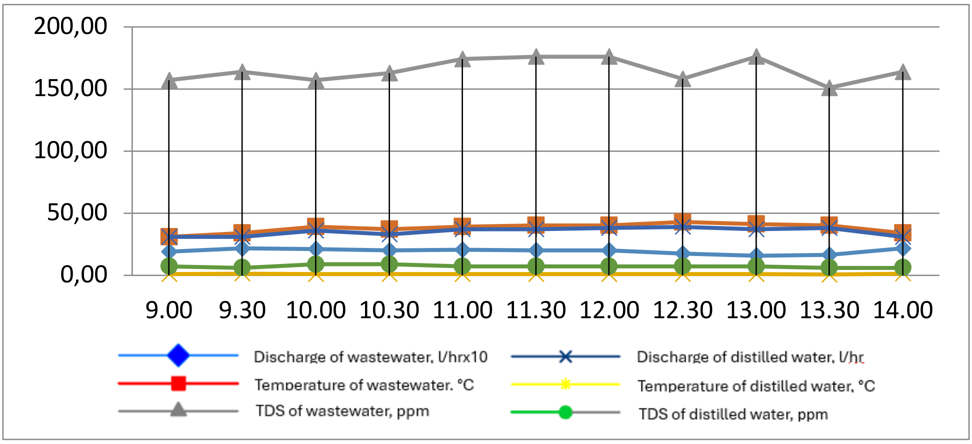

Fig.4. Graphic of measurement of waste and distilled water.

The bivariate correlation analysis showed a correlation between the discharge of wastewater and distilled water and between the temperature of waste and distilled water. The relationship was pointed out by the value of Pearson correlation of 0.813 ($p=0.02$) for the discharge of wastewater (Qww)and distilled water (Qdw), and 0.947 ($p=0.00$) for the temperature of wastewater (Tww) and distilled water (Tdw). Further analysis result of the stepwise regression method showed that the correlation between discharge and temperature of waste and distilled water were: Qww = 8.707 Qdw + 10.339 with $R2= 0.661$ and Tww = 1.090Tdw – 0.441 with $R2= 0.897$.

3.2 Processing of Brackish Water

The The average of illumination, radiation, humidity and temperature of the environment during the desalination of brackish water were 68.74 ± 2.47 kilolux, 0.44 ± 0.13 kWatt/m2, 52.37 ± 4.57 % and 35.59 ± 2.92 °C respectively. Figure 5 shows the measurement per unit of time of illumination, radiation, humidity and temperature of the environment condition.

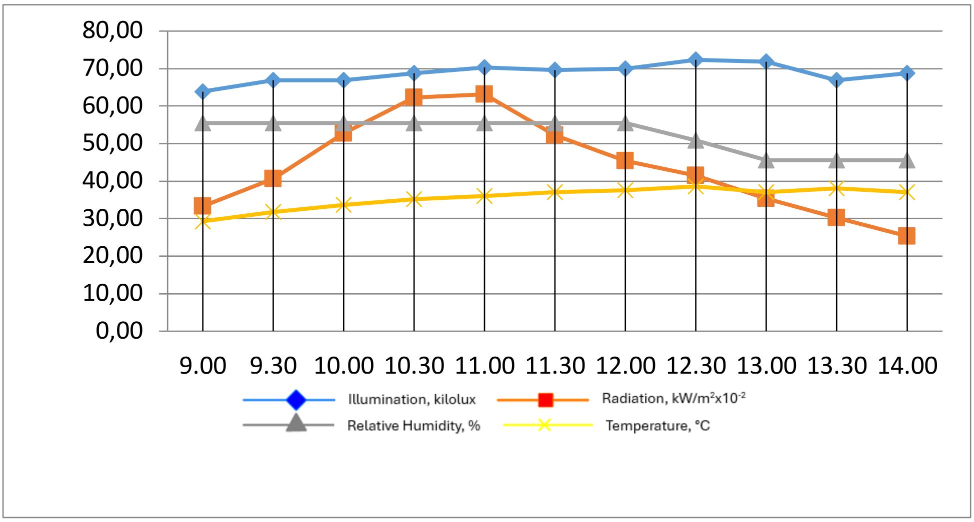

Fig. 5. Graphic of the environment condition for brackish water.

Results of analysis determined that the average volume, temperature, and total dissolved solids (TDS) of wasted water (disinfected heated water) were 20.15 ± 3.39 l/hr, 35.64 ± 2.20 0C, and 1546.36 ± 139.66 ppm, those of distilled water was 0.86 ± 0.14 l/hr, 33.55 ± 1.97 0C, and 9.00 ± 2.72 ppm respectively. Figure 6 shows the measurement per unit of time of volume, temperature, and total dissolved solids (TDS) of waste and distilled water.

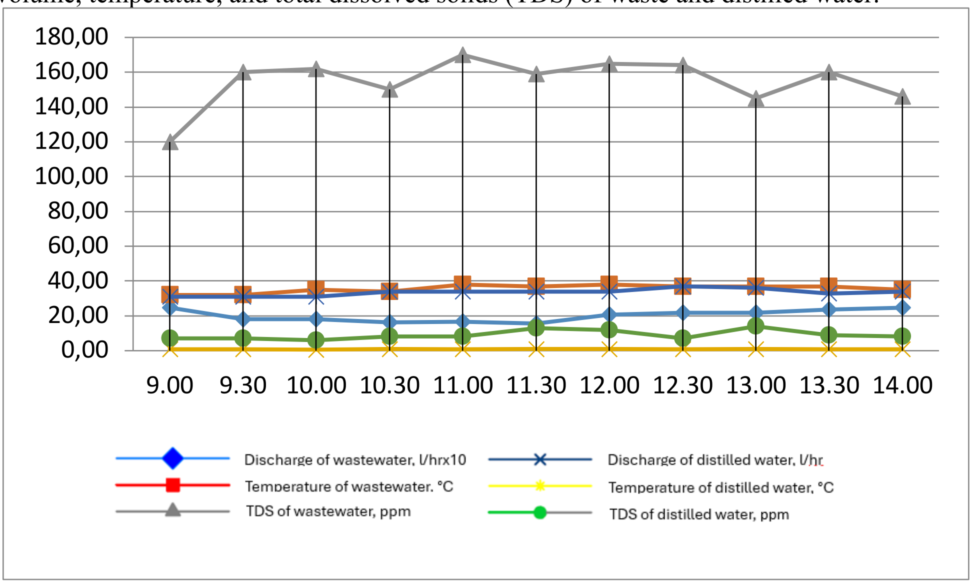

Fig. 6. Graphic of measurement of waste and distilled water.

The analysis of bivariate correlation pointed that illumination had an association with the temperature of the environment, wastewater and distilled water, the Pearson correlation of those were respectively 0.792 (p=0.04), 0.733(p=0.01) and 0.921 (p=0.00). Radiation (R) had a relation with humidity and discharge of wastewater; the Pearson correlation of those were 0.721 (p=0.01) and -0.902 (p=00). Humidity (RH) associated with wastewater discharge wit the Pearson correlation -0.667 (p=0.025). The temperature of the environment (Te) related to the temperature of waste (Tww) and distilled water (Tdw) with Person correlation respectively were o.866 (p=0.00) and 0.797 (p=0.00). The temperature of wastewater was associated with TDS of wastewater and the temperature of distilled water, with Pearson correlation of 0.613(p=0.05) and 0.673 (p=0.02) respectively. The discharge of distilled water (Qdw) correlated with its TDS, with a Pearson correlation of 0.702 (p=0.02). Further analysis of stepwise regression analysis of those relations is summarised as follows.

Table 1. Regression analysis

I	=	$1.154T_{dw} + 30.036$	$R^2 = 0.848$	SEE = 1.0147
R	=	$-0.34Q_{ww} + 1.117$	$R^2 = 0.814$	SEE = 0.0576
RH	=	$-0.899Q_{ww} + 70.500$	$R^2 = 0.667$	SEE = 3.5867
T_e	=	$0.798T_{ww} + 0.580\ T_{dw} – 12.306$	$R^2 = 0.835$	SEE = 1.3252
T_{ww}	=	$0.007TDS_{ww} + 0.620\ T_{dw} +3.287$	$R^2 = 0.663$	SEE = 1.4305
Q_{dw}	=	$0.035\ TDS_{dw} + 0.547$	$R^2 = 0.493$	SEE = 0.1023

3.3 Comparison of Fcube Carosell Performance in Processing Irrigation and Brackish Water

Y During the measurement of Fcubed carocell performance in processing irrigation and brackish water, results of the paired sample t-test analysis as shown in Table 2, indicated that there was not any different environment condition of illumination (I), radiation (R) and temperature (Te) where (t(10); p>0.05). However, there was a significant difference related to relative humidity (RH), where (t(11); p<0.05).

Table 2. Comparation of Environment Condition During Measurement.

Pairs	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
I.1 - I.2	0.1500	2.2867	0.6895	-1.3862	1.6862	0.218	10	0.832
R.1 - R.2	-0.0118	0.1197	0.0361	-0.0923	0.0686	-0.327	10	0.750
RH.1 - RH.2	-4.2727	4.5666	1.3769	-7.3406	-1.2048	-3.103	10	0.011
T_e1 - T_e2	-1.3909	2.9156	0.8791	-3.3497	0.5678	-1.582	10	0.145

Results of F-cubed carocell performance assessment obtained that there was not any difference between wastewater discharge, wastewater temperature, distilled water temperature and distilled water TDS, of irrigation and brackish water. Table 3 shows that at t(10) the probability of significant 2-tailed more than 0.05 (p>0.05).

Table 3. Comparison of Environment Condition During Measurement

Pairs	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Q_{ww}.1 - Q_{ww}.2	-0.6182	4.6196	1.3929	-3.7217	2.4853	-0.444	10	0.667
T_{ww}.1 - T_{ww}.2	-0.4546	10.6147	3.2005	-7.5856	6.6765	-0.142	10	0.89
TDS_{ww}.1 - TDS_{ww}.2	-1381.2727	137.9095	41.5813	-1473.9216	-1288.6239	-33.219	10	0.00
Q_{dw}.1 - Q_{dw}.2	0.1927	0.2445	0.0737	0.0285	0.3570	2.614	10	0.026
T_{dw}.1 - T_{dw}.2	-1.0909	10.2319	3.0850	-7.9648	5.7830	-0.354	10	0.731
TDS_{dw}.1 - TDS_{dw}.2	-1.9091	3.0807	0.9289	-3.9788	0.1606	-2.055	10	0.067

The significant difference between the Total Dissolved solid of irrigation and brackish water ($t(10)$; $p=0.00$) impacted the considerable difference of distilled water discharge ($t(10)$; $p=0.026$). The relatively lower distilled water discharge of brackish water was due to the high amount of TDS, in which TDS is one of the parameters that affect the evaporation rate[24], [25]. Another parameter that affects the discharge of distilled water is the relative humidity. The increase in humidity causes a decrease of the distilled water discharge [25]. The ratio between the waste and distilled water of irrigation and brackish water were 20:1 and 25:1 respectively. The total dissolved solids of both irrigation and brackish water were in accordance with the specification of the F cubed carocell panel 2000.

4 Conclusions

There was a significant difference in the relative humidity of environment conditions during collecting data, in which the relative humidity while processing the brackish water is higher than that of irrigation water. The characteristic of brackish water was also significantly different with irrigation water; The average of Total dissolved Solids of brackish water was about nine times compared to that of irrigation water. The distilled water discharge of irrigation water was relatively higher than that of brackish water, and this was caused due to the brackish water had a higher Total Dissolved Solids than that of irrigation water, and also the difference of relative humidity of the environment condition during the collecting data. The Total dissolved Solids of both irrigation and brackish water was under the specification of the F cubed carocell; The Total Dissolved Solids of distilled water of irrigation and brackish water were less than ten ppm.

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