Increasing solar radiation energy in equipment distillation to produce fresh water for airport

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Abstract. Sustainable water management is essential for airports. Due to the lo-cation near the ocean, some airports can get freshwater sources to meet the needs of the airport from the desalination process. One of the desalination technology is solar desalination. Solar energy radiation is produced from nuclear fusion that oc-curs in sunlight. This energy is the engine that powers our environment, turning it into solar energy that reaches the Earth's surface 10,000 times more than the en-ergy consumed by all of humanity today. Radiation is the energy transfer by elec-tromagnetic waves generated directly from a source outward in all directions. These waves do not require a material medium to propagate, and they can travel through interplanetary space and reach Earth from the Sun. This study aims to de-termine the calorific value of solar energy in a solar-powered seawater distillation device with the help of a loop lens and to determine the amount of freshwater produced from the distillation process. The method used is experimental. The re-sults of this study are the highest calorific value of 2251.20 Joules found at 12.30 WIB. This is due to the relatively large TP2-TP1 delta value of 4.2 ºC due to the addition of a convex lens to the distillation apparatus. The amount of fresh water produced from the distillation process is 1,310 ml. With these results, it is hoped that the availability of clean water from desalination can support the airport's needs.

Keywords: Solar Energy, Desalination, Sea Water.

1 Introduction

Sustainable water management is very important for society and industries. One of these is airports, and this is because airports require large volumes of water for infrastructure and operational needs [1]. Today some of the airports are built and are located at the beach. It is feasible that the fresh water from the destination process of seawater may be a good alternative to fullfill the airport needed. In Indonesia, Sukarno Hatta, New Yogyakarta International Airport (NYIA), and I Gusti Ngurah Ray Airport are located near the ocean and can obtain fresh water from seawater by distilling process [2], [3]

R. Andrie Asmara et al. (eds.), *Proceedings of the 5th Annual Advanced Technology, Applied Science, and Engineering Conference (ATASEC) 2023*, Advances in Engineering Research 229,
https://doi.org/10.2991/978-94-6463-358-0_18

In other countries, the location of several international airports is located near the sea, including airports Hong Kong International Airport (HKIA) or Hong Kong's Chek Lap Kok International Airport, which was constructed through the reclamation of two small islands, namely Chek Lap Kok and Lam Chau [4]. Hong Kong International Airport (HKIA) has a water management system to increase its Efficiency in three main sources of water: freshwater, seawater, and treated wastewater. Seawater is used for flushing toilets and for the purposes of cooling media in air conditioning systems in major airport buildings, this case can reduce the demand for portable water and greywater needed for drinking water in several aircraft and airport operations [5], [4].

The other is Copenhagen Airport in Kastrup, 11 km southwest of downtown Copenhagen. The airport is Scandinavia's major airport acting as the transfer point for air traffic traveling between other parts of the world and the many national and re-gional airports located in Scandinavia as well as the area south of the Baltic Sea [1]. the location of Singapore Changi Airport is also located near the sea, Changi Airport comes from beach reclamation, the sand needed for Changi land reclamation origi-nally comes from beachside dredging off the coast of Singapore itself figure [6]. Kan-sai International Airport in Japan is located in the southern area of the very large Osaka Bay in the Kansai Region of western Japan [7]. New Yogyakarta International Airport (NYIA) located in Temon District, near the beach and outside the coast [8], [9], [10].

Therefore, due to the locations of some of these airports, the potential for using seawater with a desalination system is large enough to meet the needs of the airports. This desalination research is intended as an alternative water source to meet the needs of the airport. One of the desalination technology is solar desalination which can produce fresh water distillate by directly applying the collected water solar energy to seawater.

Solar radiation is often called solar power or simply sunlight, a general term for the electromagnetic radiation emitted by the Sun. Solar radiation can be captured and converted into useful forms of energy, such as heat and electricity, using a variety of technologies. However, this technology's technical feasibility and economical operation in a particular location depend on the available solar resources. Every location on Earth receives sunlight for at least part of the year. The amount of solar radiation that reaches a point on the Earth's surface varies by: Geographic location, Time of day, Season, Local views, and Local weather.

The Earth is spherical, so the Sun hits the surface at different angles, starting from 0° (right above the horizon) to 90° (directly overhead). When sunlight is vertical, the Earth's surface gets all the energy possible. The tilted the Sun's rays, the longer they pass through the atmosphere, becoming more and more scattered and scattered.

Earth revolves around the Sun in an elliptical orbit and is closer to the Sun for several years. When the Sun is more comparable to Earth, the Earth's surface receives slightly more solar energy. Earth is closer to the Sun in summer in the Southern Hemi-sphere and winter in the Northern Hemisphere. However, the presence of large oceans moderates the hotter summers and colder winters that one would expect to see in the Southern Hemisphere due to this difference.

The tilt of 23.5° on the Earth's axis of rotation is a more significant factor in determining the amount of sunlight that hits the Earth at a given location. The tilt results in longer days in the Northern Hemisphere from the spring (spring) equinox to autumn (autumn) equinoxes and longer days in the Southern Hemisphere for the other 6 months. Day and night are exactly 12 hours long at the equinoxes, which occur each year on or about March 23 and September 22.

The Earth's rotation is also responsible for the hourly variations in sunlight. In the morning and evening, the Sun is low in the sky. Its rays travel farther through the atmosphere than during the day, when the Sun is at its highest. On a clear day, the greatest amount of solar energy reaches the solar collector around noon. Scientists measure the amount of sunlight that falls on a certain location at different times of the year. They then estimated the amount of sunlight falling in areas of the same latitude with similar climates. Solar energy measurements are usually expressed as total radiation on a horizontal surface or on a sun-tracking surface.

Distillation is a chemical separation method based on differences in the speed or ease of evaporation of materials or chemical separation methods based on differ-ences in boiling points. Seawater desalination is a technological innovation in over-coming the water supply in the community to meet their needs [11]. Drinking water treatment systems can be distinguished according to the scale of treatment, namely household scale (household water-treatment systems) and community or industrial scale (community water-treatment systems) [12].

Distillation heats untreated water until the water reaches a relatively low boiling point and begins to evaporate. The hot water is then kept at this temperature to keep the water from evaporating while stopping other elements from evaporating. This process also helps separate water molecules from disease-causing microscopic organisms. After the water evaporates, the steam is channeled into the condenser. Then the water cools, returns to its liquid form, and flows into the receiving vessel.

Throughout history, people have also experimented with using solar power to process water distillation. This is due to the high cost of the heating source to start the process. This version uses solar power, which is more environmentally friendly than most other power sources. Desalination is a process where brackish or sea water is processed into water that can be used and consumed ([13]. Desalination is purifying brackish water or seawater with total dissolved solids within permissible and drinkable limits, namely 200-500 ppm or <500 ppm [14].

Seawater desalination technology uses an evaporation process. using external energy to trap water in a glass, besides that there is also a heat transfer in the water by continuing the evaporation process. After this evaporation, the steam will condense at the top of the desalination device so as to produce water droplets in the form of pure water from condensing steam [15].

Seawater desalination technology is divided into three parts: 1) Thermally activating the system, condensation, and evaporation processes are the main processes. Filtering separates salt into fresh water, 2) Activates pressure which forces saltwater or seawater to pass through the membrane and separate from its salt content, 3) Activates chemically, for example, desalination using ion exchange systems, extraction of liquid and gas hydrates in seawater [16]. Solar desalination is one of the most sustainable ways of facing the clean water scarcity global challenge with emerging technological advancements [17], [18], [19]. It is ironic to see this situation that the world suffers from water scarcity, even though it is more than 70% of the Earth's surface is covered by water. This clean water crisis concern is mainly caused by the lack of effective and energy-efficient desalination technology that converts seawater to fresh water for safe consumption at low cost [20].

Solar desalination systems are classified as pro-direct and indirect processes. Solar desalination depends on the energy pathway to fresh water. An indirect solar desalination system consists of two sub-systems. The systems are a solar collection system and a desalination system. The solar collection sub-syciencystem is used both for collecting heat using lar heat collector and supplying via heat exchanger to thermal the process of converting solar radiation into electricity using photographs of foto-fvoltaic panels to drive the desalination process, and sub desalination system can be any of the conventional desalination systems [17].

Because of the importance of freshwater for airports and the significance of understanding the distillation process, the study of solar distillation needs to be conducted. This study aims to determine the calorific value of solar energy in a solar-powered seawater distillation device with the help of a loop lens and to determine the amount of freshwater produced from the distillation process port and the This study aims to determine the calorific value of solar energy in a solar-powered seawater distillation device with the help of a loop lens and to determine the amount of freshwater produced from the distillation process.

2 Research Methodology

The flow of this research will explain the research steps to be carried out, with the existence of this research flow it is hoped that it will make it easier for researchers to carry out research so that the tools that are designed and scrutinized can be as expected. The flow of this research can be seen in the diagram below :

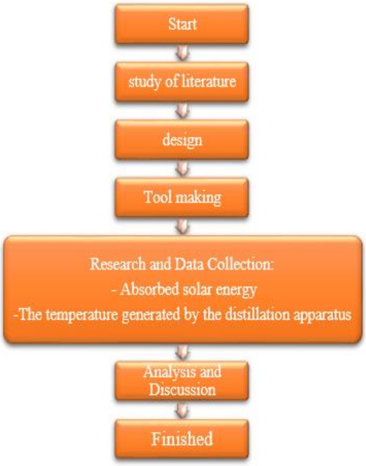

Fig. 1. Research flow chart

In Figure 1 above is the research flow, in this figure we can see the design of the research flow from the initial stages of the research to the final stages of the research. In Figure 1 above it is also seen that the data to be retrieved is data absorbed solar energy and temperature generated by the destilation apparatus.

In making a tool, a design and sketching or arrangement of several separte elements is needed into a unified whole so that the planned tool can be made accord-ing to calculations and analyzed so that a tool that functions properly and as ex-pected is achieved. Below is a sketch of the design of a simple seawater distillation device that will be made for research needs, accompanied by drawings and sizes that have been planned.

After designing the tool that will be made, then the next step is to realize the design. Manufacture of tools with several processing steps such as collecting raw materials, calculating tool specifications, supporting components, main components and meas-uring instruments. then after the tool is made, research and data collection is carried out by measuring, calculating, and recording the results of all calculations and measurements.

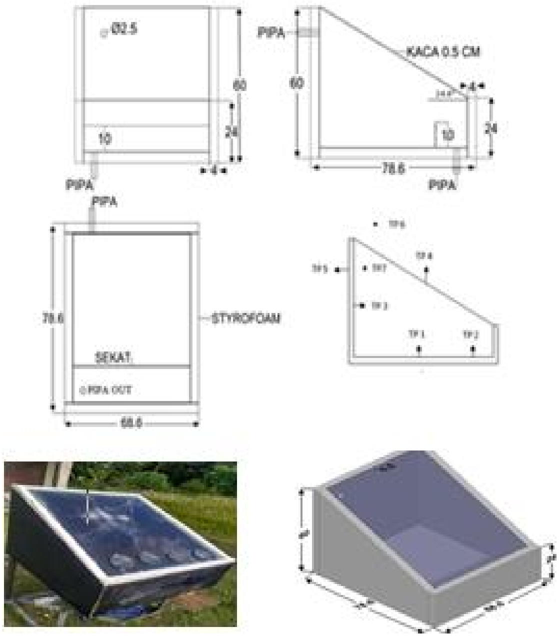

Fig. 2. The design of the distillation apparatus

3 Result and Discussion

From the results of experiments carried out on a solar seawater distillation appa-ratus with the help of a loop lens, it has quite an effect on the yield of water produced in the distillation apparatus, the initial amount of seawater to be distilled is 3000 m,l. The results of this distillation tool can be seen in the data below.

Table 1. Observation Data

No	Time	Radiation Sun W/m^2	Wind velocity m/s	TP1 C^o	TP2 C^o	TP3 C^o	TP4 C^o	TP5 C^o	TP6 C^o	TP7 C^o	Produced water (ml)
1	10.00	987,1	1,0	31,7	31,7	48,7	41,1	40,4	34,1	45,1	0
2	10.30	993,8	1,5	47,9	49,9	53,9	44,5	46,7	37,1	56,2	40
3	11.00	1129	0,7	52,6	56,1	65,1	53,9	50,7	39,2	68,9	90
4	11.30	1198	1,7	65,3	69,8	69,3	56,7	54,3	39,9	72,7	150
5	12.00	1221	2,3	75,4	79,1	73,4	61,5	57,1	40,7	80,2	175
6	12.30	1123	1,1	74,1	78,3	77,9	59,7	58,3	39,1	79,3	165
7	13.00	1092	0,5	74,0	77,9	82,3	58,1	58,0	37,2	78,7	160
8	13.30	1137	1,8	75,8	78,0	82,9	59,9	57,7	37,4	78,1	150
9	14.00	983,7	2,1	69,7	70,2	80,3	58,3	54,1	35,3	77,3	125

10	14.30	997,6	1,8	68,8	68,2	83,7	58,9	52,4	34,6	75,9	105
11	15.00	884,5	1,9	62,1	59,9	80,1	56,7	51,1	33,7	73,2	80
12	15.30	739,1	1,3	59,7	57,1	77,8	52,7	49,2	32,1	71,4	70
Average		1040	1,4	63,0	64,6	72,9	55,1	52,5	36,7	71,4	109
Total water produced											1.310

Table description:

TP 1 : Water temperature in the collector without lens (ºC)
TP 2 : Water temperature in the collector with lens beam (ºC)
TP 3 : Wall temperature (ºC)
TP 4 : Glass temperature (ºC)
TP 5 : Insulator temperature (ºC)
TP 6 : Ambient temperature (ºC)
TP 7 : Room temperature of the distillation apparatus (ºC)

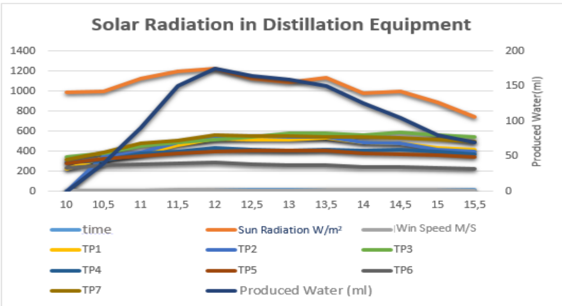

Fig. 3. Graph of Solar Radiation in Distillation Equipment

In figure 3 in the distillation apparatus, the maximum water production results oc-cur at 12.00 WIB as much as 175 ml in 30 minutes. This is due to the large value of solar radiation 1221 W/m2 . The difference in the value of TP2 minus TP1 of 4.2 ºC is an indicator that the production equipment is working properly so as to produce a product that meets expectations. In a solar powered seawater distillation device, the resulting distilled water is a parameter that the tool uses destilasi tersebut bekerja sesuai harapan that the tool can work to produce a product. But in its work, a distilla-tion apparatus must go through an analysis of whether it has obtained the maximum work to produce fresh water or is it still not optimal in producing fresh water. The ambient temperature changes very often every hour, the factors that make changes in ambient temperature are wind speed and the condition of the thickness of the clouds in the sky. Evaporation involves changing the liquid state to vapor.

Evaporation rates from brine resources are largely dependent on the saturated vapor pressure above their surface. On the other hand, the saturated vapor pressure is affected by the ion activity coefficient, which is derived from the concentration of the chemical salts of water. When salt is present in the water, the rate of evaporation increases. The simple reason is that the boiling point of salt is more than that of wa-ter. As a result, the concentration of solutes will be more than that of the water itself. The rate of evaporation obviously depends on the vapor pressure of the air or the rate at which the air leaves the surface. The difference between the water vapor pres-sure and the air vapor pressure is the main factor affecting evaporation

The efficiency of a water distillation device is the ratio of the useful energy to the heat energy provided by solar radiation.

The efficiency of the distillation apparatus is:

Where :

ηd = Efficiency of the distillation apparatus

mk = Mass of distilled water (kg)

hfg = Latent heat of water (kJ/kg)

Ac = Absorbent plate area (m2)

GT = Intensity of solar radiation (W/m2)

t = Length of testing time (s)

It is known that the mass of distillate water is 1310 ml, the mass of distillate water is 1.310 kg, the heat of water vapor is 71.4oC with a latent heat of water vapor of 2325.2 kJ/kg, the area of the absorber plate is 0.5391 m2, the average solar radiation intensity is 1125 W/m2. The length of testing time is 23400 seconds or 6 hours 30 minutes. The efficiency of the distillation equipment in 1 day which was carried out from 10.00 WIB to 15.30 WIB. can be determined by

$$\eta_d = \frac{m_k \cdot h_{fg}}{Ac \cdot G_T \cdot t} \text{X } 100\% \tag{1}$$

the formula :

$$\eta_d = \frac{1{,}34 kg \cdot 2325{,}2\ kj/kg}{0{,}5391\ m^2 \cdot 1125\ W/m^2 \cdot 23400 s} \text{ x } 100\% \tag{2}$$

$$\eta_d = 21{,}8\ \% \tag{3}$$

From the data carried out, the resulting distillate water was as much as 1310 ml in 5 hours 30 minutes (330 minutes). From the results of the distillate water produced and the evaporation time, the evaporation rate of seawater temperature can be calculated.

Seawater temperature evaporation rate = Distillate yield: time

= 1310 ml : 330 minuteseral is in the Very Satisfied category.

= 3.97 ml/minute

So that the evaporation rate of sea water temperature is 3.97 ml/minute. This is because the day in the study had sunny weather and the intensity of solar radiation was very stable.

The calorific value produced in the distillation apparatus is as shown in table 2

Table 2. Calorific value

No	Waktu	Radiasi matahari W/m^2	TP1 (ºC)	TP2(ºC)	ΔT= TP2-TP1 (ºC)	Kalor (J)
1	10.00	987.1	31.70	31.7	-	-
2	10.30	993.8	47.9	49.9	2.00	1,072.00
3	11.00	1129	52.6	56.1	3.50	1,876.00
4	11.30	1198	65.3	69.8	4.50	2,412.00
6	12..30	1123	74.1	78.3	4.20	2,251.20
7	13.00	1092	74	77.9	3.90	2,090.40
8	13.30	1137	75.8	78	2.20	1,179.20
9	14.00	983.7	69.7	70.2	0.50	268.00
10	14.30	997.6	68.8	68.2	0.60	321.60
11	15.00	884.5	62.1	59.9	2.20	1,179.20
12	15.30	739.1	59.7	57.1	2.60	1,393.60

In table 2 you can see the results of the calorific value every hour and the solar radiation starting from 10.00 am to 15.30 pm, in table 2 above the peak time of solar radiation is between 12 noon to 13 o'clock ready.

Conclusion

This study concludes that the highest calorific value of 2251.20 Joules is 12.30 WIB. This is due to the relatively large TP2-TP1 delta value of 4.2 ºC due to adding a convex lens to the distillation apparatus. The amount of freshwater produced from the distillation process is 1,310 ml.

Acknowledgment

The authors would like to express special gratitude to the adisutjipto institut of aerospace technology (itd adisutjipto) for funding incentive for this research activity.

References

1. G. Baxter, P. Srisaeng, and G. Wild. :An assessment of airport sustainability: Part 3-water management at Copenhagen Airport in : vol. 8, no. 3, Resources. doi: 10.3390/resources8030135. (2019).
2. F. M. C. Valenti, A. Primadi, and B. Setyo, :Quality Analysis of Health, Safety, Environment and Services of Cargo Company at PT Jasa Angkasa Semesta (Soekarno-Hatta International Airport, Jakarta), in: Adv. Transp. Logist. Res., pp. 67–75. [Online]. Available: https://proceedings.itltrisakti.ac.id/index.php/ATLR/article/view/146. (2019).
3. A. Refaldi, M. Emraldi, and W. Rizaldy , In vol. 147: Impact of Passenger Growth in Soekarno-Hatta Airport.. no. Grost. pp. 808–816, 2018, doi: 10.2991/grost-17.2018.71. (2017).
4. A. C. Chávez-mejía, R. Magaña-lópez, J. C. Durán-álvarez, and B. E. Jiménez-cisneros. In: International Journal of Environment , Agriculture and Biotechnology (IJEAB). pp. 16–32, 2019, doi: 10.22161/ijeab. no. November (2019).
5. International Civil Aviation Organization (ICAO). Water Management at Airports. In: Int. Civ. Aviat. Organ. (ICAO), ECO-AIRPORT TOOLKIT. [Online]. Available: https://www.icao.int/environmental-protection/Documents/Water management at airports.pdf. (2019).
6. W. Lin, Infrastructure's Expenditures: Changi Airport, Food Cargo and Capital's Technosphere. In: vol. 43, no. 1 Int. J. Urban Reg. Res. pp. 76–93. doi: 10.1111/1468-2427.12737. (2019).
7. P. Srisaeng and G. Wild, Sustainable Airport Energy Management : the Case. In: vol. 8, no. 3, pp. 334–358. (2018).
8. B. G. Dewanto, Y. Haryanto, and S. N. Purnomo, Land Subsidence Potential Detection in Yogyakarta International Airport using Sentinel-1 Insar Data. In: ., vol. 23, no. 2, Civ. Eng. Dimens. pp. 91–99. doi: 10.9744/ced.23.2.91-99. (2021).
9. A. I. Tinasar, R. H. Saputra, and Sahid. Evaluation of New Yogyakarta International Airport (Nyia) in Temon District Based on Tsunami Disaster Risk Using Geographic Information System (Gis). Pengelolaan Sumberd. Wil. Berkelanjutan, pp. 90–102. (2017).
10. M. Kadarisman, Policy Implementations of New Yogyakarta International Airport Development, In: vol. 28, no. 3, DLSU Bus. Econ. Rev. pp. 113–128. (2019).
11. K. M. Abdullaev, M. M. Agamaliev, and D. A. Akhmedova. Technology for Combined Desalination of Sea Water. In: ., vol. 41, no. 2, J. Water Chem. Technol. pp. 119–124. doi: 10.3103/s1063455x19020097. ,(2019).
12. M. S. L. Iswadi, "Rancang bangun alat pemurni air laut menjadi air minum menggunakan sistem piramida air ((green house effect) bagi masyarakat pulau dan pesisir di kota Makassar. In: 12(3), Jurnal Sains dan Pendidikan Fisika, 12(3).pp. 300–310. (2016).
13. A. Rodríguez-Calvo, G. A. Silva-Castro, F. Osorio, J. González-López, and C. Calvo. Reverse osmosis seawater desalination: current status of membrane systems. In: vol. 56, no. 4, Desalin. Water Treat. pp. 849–861 doi: 10.1080/19443994.2014.942378. (2015).
14. A. A. Ragetisvara and H. S. Titah. Studi Kemampuan Desalinasi Air Laut Menggunakan Sistem Sea Water Reverse Osmosis (SWRO) pada Kapal Pesiar. In: J. Tek. ITS, vol. 10, no. 2, . doi: 10.12962/j23373539.v10i2.63933. (2021)
15. A. W. Krisdiarto, A. Ferhat, A. W. Krisdiarto, and M. P. Bimantio. Penyediaan Air Bagi Masyarakat Pesisir Terdampak Kekeringan dengan Teknologi Desalinasi Air Laut Sederhana. In: vol. 4, no. 2, DIKEMAS (Jurnal Pengabdi. Kpd. Masyarakat). pp. 25–31. doi: 10.32486/jd.v4i2.532. (2020).

16. P. G. Youssef, R. K. Al-Dadah, and S. M. Mahmoud. Comparative analysis of desalination technologies. In: , vol. 61, Energy Procedia. pp. 2604–2607. doi: 10.1016/j.egypro.2014.12.258. ,(2014).
17. S. Wijewardane and N. Ghaffour, Inventions, innovations, and new technologies: Solar Desalination. In: vol. 5, no. January. Sol. Compass. pp. 100037, 2023, doi: 10.1016/j.solcom. 100037. (2023.).
18. W. He, G. Huang, and C. N. Markides. Synergies and potential of hybrid solar photovoltaic-thermal desalination technologies. In: Desalination. pp. 116424: 10.1016/j.desal. 116424. (2023).
19. A. Arango-gonzález et al., l P re of, no. Current Opinion in Green and Sustainable Chemistry. Elsevier Ltd. (2022).
20. R. Sirohi et al., Engineered nanomaterials for water desalination: Trends and challenges. In: ., vol. 30, Environ. Technol. Innov. p. 103108. doi: 10.1016/j.eti.2023.103108. (2023).