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IMPROVING THE EFFECTIVENESS OF EVAPORATION IN SOLAR DISTILLATION UNITS THROUGH AIR FEEDING IN THE EVAPORATION CABIN

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Abstract

Solar distillation has been used to distill seawater into clean water. The distillation process is largely determined by the effectiveness of the evaporation and condensation processes. This study aimed to investigate the method of condensing air into the water and evaporator space on the effectiveness of the evaporation process. The solar distillation is designed as two units with a single basin type. Type-I solar distillation is designed with the evaporator and condenser chambers in one room. The solar distillation type-II is designed with a modified evaporator chamber so that water vapor can be circulated out and without a condenser room. The solar distillation length and width are 600 mm and 400 mm, respectively, which are made of a 0.6 mm thickness stainless steel plate. At the top, it is covered by a 5 mm thickness glass with a slope of 10°. The test was carried out for 7 days together between the type-I solar distillation and the type-II solar distillation. Data on raw water temperature, room temperature, glass surface temperature, ambient temperature, and solar intensity were recorded during the test. The data is recorded every 30 minutes starting at 08.00 GMT+7 until 17.30 GMT+7. The test results show that the solar distillation performance is influenced by the high and low solar intensity. The volume production of water vapor in the type-II solar distillation is greater than that of the type-I solar distillation. This shows that condensing air into the water and evaporator space can increase the evaporation process's effectiveness on the solar distillation.

Keywords: effectiveness, evaporation, solar distillation, vapor volume

1 Introduction

Indonesia is an archipelago consisting of several islands. Samantha (2017), stated that the number of Indonesian islands is 13,466 islands and a coastline length of 99093 km. Most of Indonesia's population lives in coastal areas and is spread over several small islands. People who live in coastal areas and small islands are faced with the problem of meeting the needs of clean water and the availability of electricity. Meanwhile, the area is very abundant with sources of seawater or brackish water.

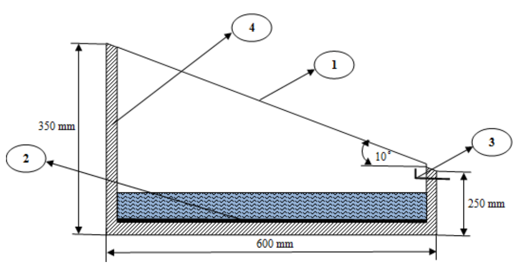
Several technologies for the distillation of clean water from seawater have been developed and applied (Arunkumar et al., 2019; Becker, 2019; Wang et al., 2019) including distillation involving a thermal process (phase change process) (Al-Weshahi, Anderson, & Tian, 2013; Nishikawa, Tsuchiya, Narasaki, Kamiya, & Sato, 1998; Schwarzer, Vieira, Faber, & Müller, 2001) and distillation with a membrane process (one-phase change process) (Li et al., 2019; Wang et al., 2019). On the one hand, a distillation with a thermal process requires thermal energy for evaporation. On the other hand, distillation with reverse osmosis technology requires a lot of electrical energy to drive a high-pressure pump. Therefore, solar distillation with thermal processes or phase changes using solar thermal energy is the right solution to meet the needs of clean water for people who live in coastal areas and small islands.

A simple single basin type solar distillation is a means of distilling seawater into clean water by heating. Several studies have studied the distillation process of seawater by utilizing solar radiation (Amaya-Vías & López-Ramírez, 2019; Chiavazzo, Morciano, Viglino, Fasano, & Asinari, 2018; Widiantoro & Panggayudi, 2019). The simple single basin type solar distillation consists of a coverslip, absorber plate, and water reservoir. This tool's working system is to heat the absorber plate by solar energy so that it means the water in the distillation container. Evaporation occurs due to heat transfer from the absorber plate to seawater. Condensation occurs when water vapor rises on the cover glass and sticks to the glass cover, so heat transfer occurs from the steam to the cover glass.

The evaporation process's performance is crucial in distilling seawater into clean water in a solar distillation. The more steam is produced, the more vapor is condensed into a liquid. The evaporation efficiency (evaporation) in solar distillation is still low because the evaporation process is not optimal. If the evaporation process's effectiveness can be increased, the efficiency of the solar distillation to heat seawater to become water vapor is expected to increase. Therefore, this study aims to improve the seawater evaporation process's performance by feeding the air in the water and the evaporator room to the effectiveness of evaporation in the solar distillation. This research studies the effect of feeding air in the water and the evaporator room on evaporation's effectiveness in a solar distillation. The shrinkage of water volume can be found and compare with the rate of evaporation.

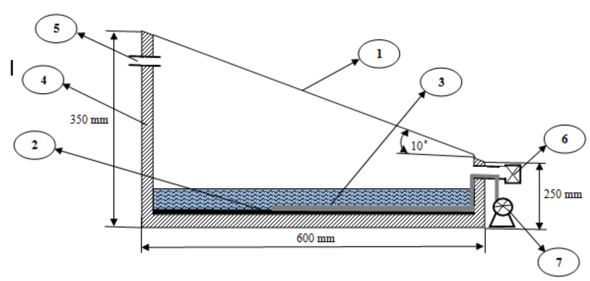
2 Methodology

The solar distillation to be tested consists of two units: type-I solar distillation (Figure 1a) with a basin in the form of a single basin where the evaporator and condenser rooms are in one room. Type-II solar distillation (Figure 1b) is designed with a single basin where the evaporator room is given an air pump to feed the air to water. Furthermore, in this type, a blower is attached to feed air into the evaporator room to be circulated without passing through the condenser room.



1-Cover glass, 2-Absorber plat, 3-Channel water reservoir, 4-Insulation

(a)

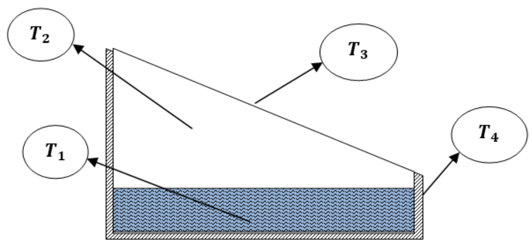


1-Cover glass, 2-Absorber plat, 3-Air channel, 4-Insulation, 5- Air circulation channel, 6-Blower, 7-Water pump

(b)

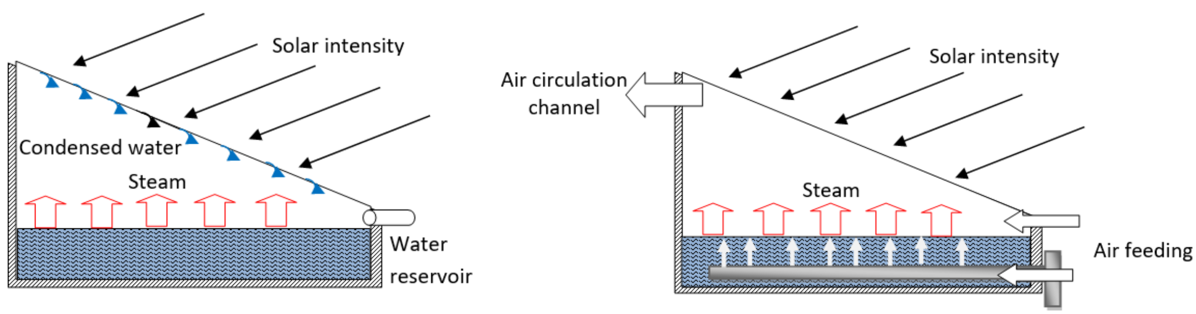
Figure 1. Solar distillation (a) type-I (b) type-II

The measurement points of solar distillation are presented in Figure 2. This study's measuring instruments include the mercury thermometer, the SL 100 solarimeter, and the AM-4200 anemometer. Tests were carried out from 08.00 GMT+7 to 17.30 GMT+7. Data recording is performed every 30 minutes. Figure 3 shows the schematic of the solar distillation I and II testing process.



T1- Seawater temperature (°C), T2- Room temperature (°C), T3- Glass surface temperature (°C), T4- Environmental temperature (°C)

Figure 2. Penempatan alat ukur pada alat uji distilator surya I dan II



(a) **(b)**

Figure 3. Schematic of the work process of testing (a) type-I and (b) type-2 solar distillation

3 Results and Discussion

3.1 Relationship between temperature and solar intensity

Overall, the relationship between temperature and solar intensity with type-I and type-II solar distillation has a relatively similar pattern. In general, the test results of type-I and type-II solar distillation can be shown in Figure 4 and Figure 5. The solar's intensity increases until it reaches the maximum value at 14.30 GMT+7. After that, the solar's intensity decreases until it reaches the minimum value at 17.30 GMT+7. The highest temperature for both distillations is known to be in the distillation room. This is in line with the research report of Schwarzer et al. (2001) and Sampathkumar, Arjunan, Pitchandi, and Senthilkumar (2010), who obtained the phenomenon that the distillation room will have a higher temperature because of the many waves of solar energy that are trapped for a while after passing through the glass media. This also makes the solar's intensity at its highest peak, but the distillation's room temperature has not yet reached its peak.

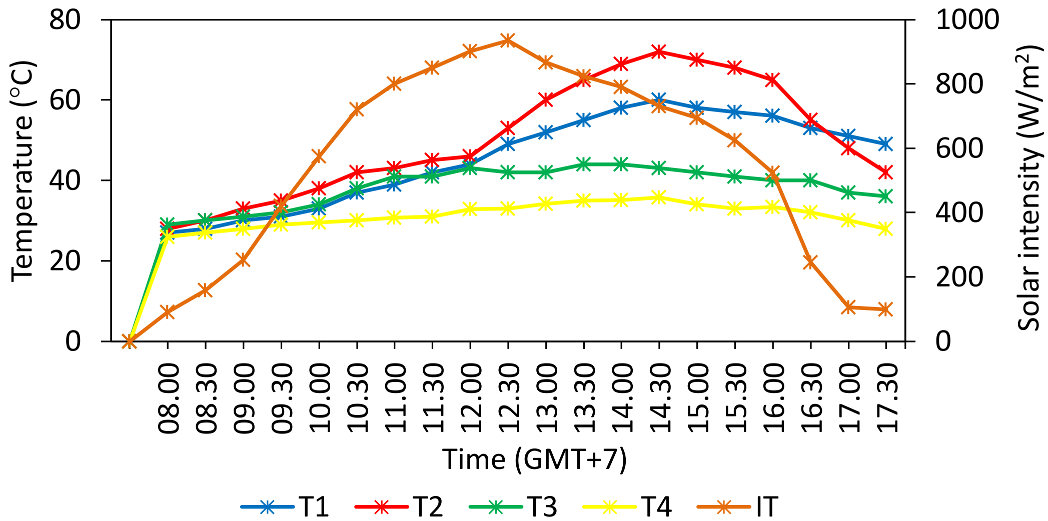


Figure 4. Relationship between temperature and solar intensity type-I solar distillation

3.2 Relationship between temperature and water evaporation rate

The relationship between temperature and water evaporation rate in the type-I and type-II solar distillation tests can be analyzed based on the shrinkage of water volume. The rate of evaporation is directly proportional to the shrinkage of water volume in the basin. The higher the evaporation rate, the faster the water volume shrinks. In the type-I solar distillation, the air in the seawater and the evaporator room does not flow.

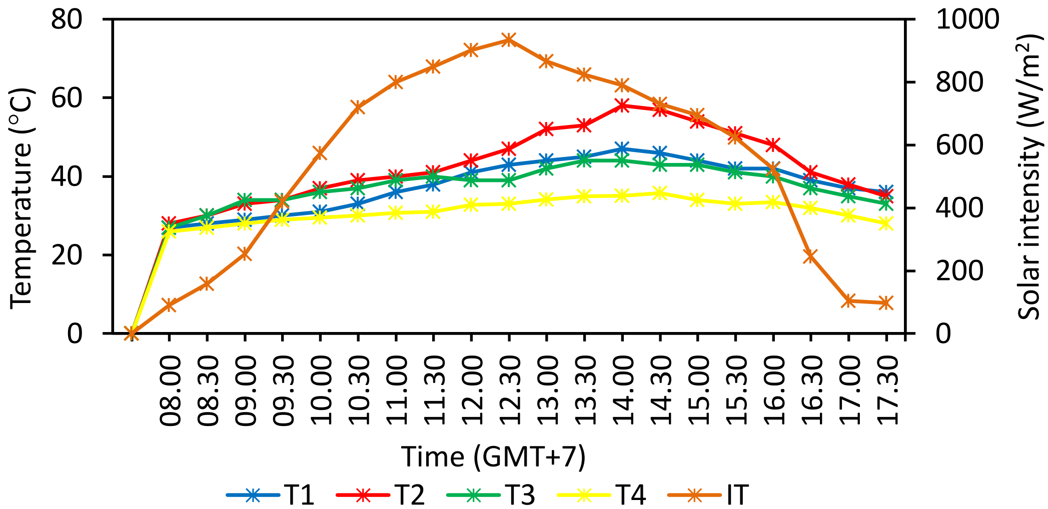


Figure 5. Relationship between temperature and solar intensity type-II solar distillation

The performance of the type-I solar distillation (Figure 6) shows that the rate of evaporation of water increases, marked by a decrease in water volume and an increase in raw water temperature at 11.30 GMT+7. The seawater sample's heat energy undergoes heat transfer by natural convection, which causes the movement of small bubbles to rise to the surface of the water. This causes the room temperature to be higher. At 14.30 GMT+7, the maximum temperature in the raw water and the distillation chamber causes heat absorption to take longer so that the water evaporation rate does not increase. At 17.30 GMT+7, a decrease in temperature occurs so that the rate of evaporation of water does not occur. This is indicated by the volume of water that does not shrink anymore.

The performance of the type-II solar distillation (Figure 7) shows an increased water evaporation rate. This is indicated by a decrease in volume and an increase in raw water temperature at 12.30 GMT + 7. The heat energy at the surface of the raw water experiences a forced convection heat transfer. This is caused by air feeding in the evaporator room to accelerate the high room temperature heat transfer rate. At 14.30 GMT + 7, the maximum temperature in raw water experiences heat transfer to room temperature so that the temperature increases. This causes a very high temperature in the evaporator room so that the rate of evaporation of water does not increase.

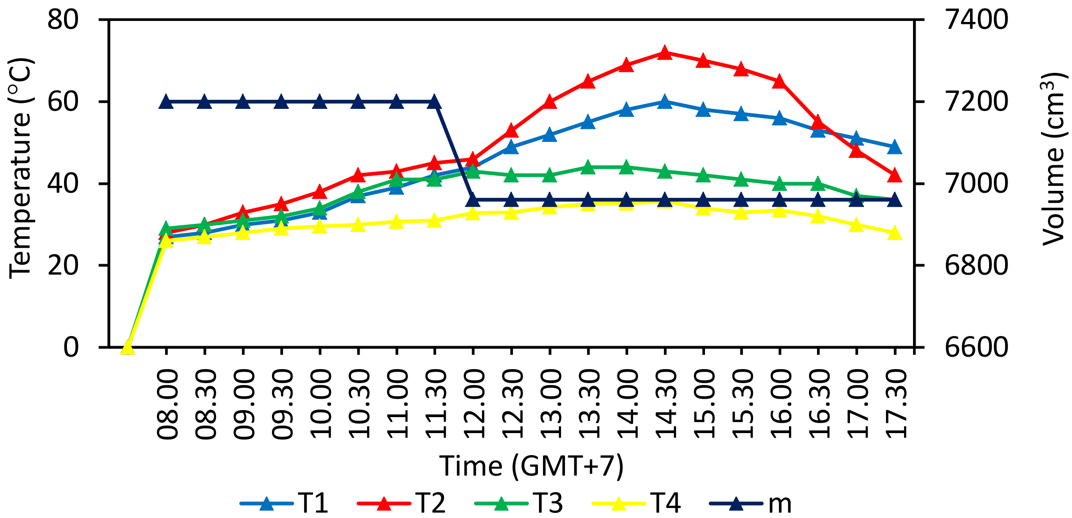


Figure 6. Relationship of temperature and evaporation rate of type-I solar distillation

At 15.00 GMT + 7, the raw water temperature and room temperature decreased. However, the evaporation rate of water increases, which is indicated by a decrease in the volume of water. This is due to the feeding of air to the evaporator space, which accelerates the heat energy transfer rate by forced convection on the water surface. Besides, the condensation of air in the water accelerates the energy of water vapor. The decrease in temperature until 17.30 GMT + 7 means that the shrinkage of water volume is no longer happening.

3.3 Comparison of water vapor volume production

The evaporation process is a phenomenon expected in a solar distillation. The production of steam volume in a solar distillation is the sum of the steam volume produced per time. The greater the shrinkage of water volume, the greater the volume of steam produced. The volume production of water from these two distillations is presented in Figure 8. Steam volume production can be studied by looking at the shrinkage of water volume in the solar distillation basin.

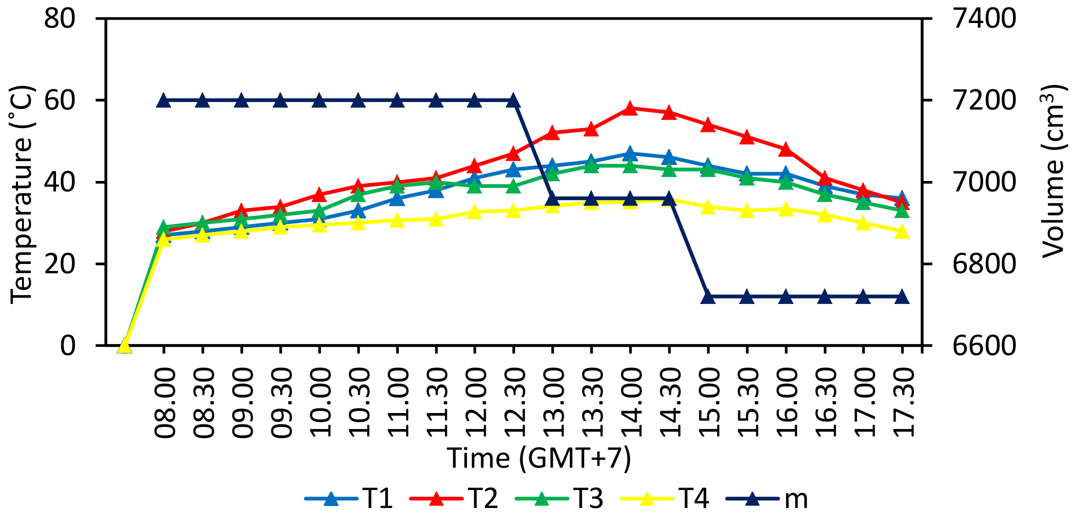


Figure 7. Relationship of temperature and water evaporation rate of type-II solar distillation

The solar distillation type-I shows the volume of water vapor production occurs at 11.30 GMT+7. This is due to the increasing volume of seawater moving above the water surface. Therefore, there is a natural convection heat transfer process that causes the rapid transfer of water density from liquid to a gaseous substance called the evaporation process. Type-I solar distillation shows a fixed volume of vapor production from 15:00 GMT+7 to 17:30 GMT+7. This is because the type-I solar distillation produces steam that sticks to the inner glass surface, which, consequently, blocks the evaporator room's solar intensity.

Production of water vapor volume type-II solar distillation occurs at 12.30 GMT+7. Furthermore, at 15.00 GMT+7 to 17.30 GMT+7 indicates an increase in water vapor production volume. This is caused by the feeding of air in the evaporator chamber to accelerate heat transfer by forced convection. As a result, water vapor from evaporation will not stick to the inner glass. This makes the water vapor does not block the solar's intensity into the evaporator room. Therefore, the evaporation process's effectiveness runs well, and the feeding of air into the water can expand the interface of the steam input movement so that the heat transfer process can take place more quickly.

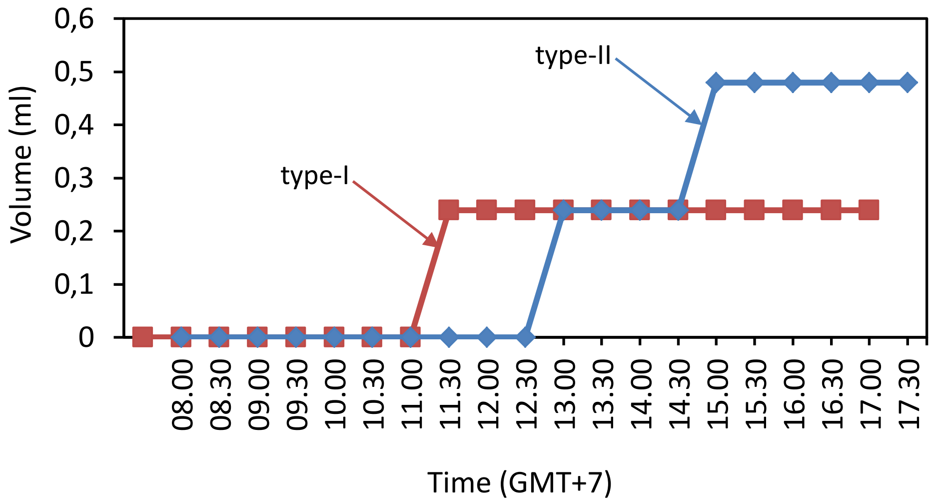


Figure 8. Comparison of vapor volume production in type-I and type-II solar distillation

4 Conclusion

The effectiveness of the type-I and type-II solar distillation evaporation processes, influenced by the solar's intensity, has been investigated in depth. The temperature difference in the evaporation process impacts the solar's heat absorption capacity so that it takes a long time to evaporate seawater. It is known that the supply of air to the seawater sample and the evaporator room will increase the effectiveness of evaporation. Therefore, this study suggests using an air circulation system to increase the effectiveness of solar distillation evaporation to produce clean water from seawater.

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