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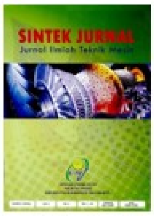

# THE INFLUENCE OF NOZZLE INJECTION PRESSURE ON SEAWATER EVAPORATION INSIDE AN EVAPORATOR TUBE

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**ABSTRACT**

Indonesia, the largest archipelagic country in the world, possesses a vast marine area. Despite being surrounded by the sea, many coastal communities in Indonesia lack access to clean water. Seawater distillation presents a viable solution to this scarcity. This process involves separating salt from seawater to produce fresh water. This study aims to analyze the effect of nozzle spray pressure on the evaporation process of seawater to optimize fresh water production. Experiments were conducted using a fogging nozzle with a diameter of 0.3 mm, varying the nozzle pressure at 40 psi, 70 psi, and 100 psi. The data were statistically analyzed to determine the impact of nozzle pressure on seawater evaporation. The results indicate that the highest evaporation occurred at a nozzle pressure of 40 psi, yielding 10 g of condensed seawater, whereas the lowest evaporation was observed at 100 psi, producing 4 g.

**Keywords:** Seawater; Distillation; Evaporation; Pressure.

***ABSTRAK***

*Indonesia sebagai negara kepulauan terbesar di dunia mempunyai wilayah laut yang sangat luas. Meski dikelilingi laut, banyak masyarakat pesisir di Indonesia yang kekurangan akses terhadap air bersih. Distilasi air laut memberikan solusi yang tepat untuk mengatasi kelangkaan ini. Proses ini melibatkan pemisahan garam dari air laut untuk menghasilkan air tawar. Penelitian ini bertujuan untuk menganalisis pengaruh tekanan semprotan nozzle terhadap proses penguapan air laut untuk mengoptimalkan produksi air tawar. Percobaan dilakukan dengan menggunakan nozzle fogging berdiameter 0,3 mm, tekanan nozzle divariasikan pada 40 psi, 70 psi, dan 100 psi. Data dianalisis secara statistik untuk mengetahui dampak tekanan nosel terhadap penguapan air laut. Hasil penelitian menunjukkan bahwa penguapan tertinggi terjadi pada tekanan nosel 40 psi, menghasilkan 10 g air laut yang terkondensasi, sedangkan penguapan terendah diamati pada 100 psi, menghasilkan 4 g.*

***Kata Kunci**: Air Laut; Distilasi; Evaporasi; Tekanan.*

## 1. Introduction

Indonesia, the largest archipelagic country in the world, boasts an extensive maritime territory [1]. With 17,499 islands, 81,000 km of coastline, and 2.7 million km of inland waters, Indonesia also possesses an exclusive economic zone extending 3.1 million km, culminating in a total sea area of 5.8 million km [2]. Despite its vast maritime resources, many communities in Indonesia still face challenges in accessing clean water. This scarcity, particularly pronounced on small islands, constitutes a significant social issue [3], as clean water is an essential need for the population [4]. Consequently, the provision of clean water remains a substantial challenge [5], especially in regions experiencing a clean water crisis, notably coastal areas. Coastal communities are especially vulnerable to saline water contamination [6], which they often use for daily activities such as bathing, washing, and consumption.

Prolonged use of saline water can lead to health issues such as hypertension, kidney disease, and skin ailments[7,8], given that clean water standards require a salt content of no more than 0.5% [9]. Seawater distillation presents a viable solution to the clean water scarcity problem [10], recognized as a promising technology[11,12].

Distillation involves heating seawater to produce steam, which is then condensed into fresh water [13]. In this study, seawater evaporation occurs within an evaporator tube [14]. Seawater is injected into the evaporator tube through a nozzle [15] and sprayed onto a heating plate [16]. The jet of seawater hitting the heating plate surface undergoes evaporation [17], which occurs when the vapor pressure of water is lower than the liquid's saturation pressure [18,19]. Additionally, evaporation is driven by the vapor pressure differential between the evaporator and the condenser due to temperature differences [20]. Water vapor moves from the evaporation chamber above the water surface in the evaporator to the low-pressure condenser, resulting in a drop in vapor pressure above the water level [21,22]. The water vapor is then condensed in the cooling pipe within the evaporator tube, forming water droplets that coalesce into fresh water [23]. Various studies have examined evaporation, including the impact of nozzle pressure on the evaporation process[24-29] and the influence of sunlight on evaporation [30-35]. However, no research has specifically investigated the effect of nozzle pressure on seawater evaporation with pressure variations of 40 psi, 70 psi, and 100 psi. Therefore, this study aims to analyze how nozzle pressure affects seawater evaporation and determine the effectiveness of each pressure variation in producing fresh water.

## 2. Methods

This research is field-based and conducted experimentally using a seawater distillation prototype [36]. The study employs a fogging nozzle with a diameter of 0.3 mm, which is injected into the evaporator tube. Seawater is distributed into the evaporator tube through the nozzle by spraying, and the nozzle pressure is controlled by an adjustable pump. Nozzle pressures of 40 psi, 70 psi, and 100 psi were used to compare the efficiency of the distillation process at different pressures. It is necessary to vary the pressures to observe their influence on the seawater evaporation process. Higher nozzle pressure can increase the rate of evaporation; however, selecting the correct nozzle pressure is crucial to avoid imperfect evaporation rates [37]. Therefore, varying nozzle pressures can help identify optimal conditions to maximize the rate of seawater evaporation. The following tools were used to measure the data in this study:

**Table 1**. Research Tools

| No | Tool | Specifications |
|---|---|---|
| 1 | Thermostat XH-W3001 | Range -50 ºC - 110 ºC, ± 0.1 ºC |
| 2 | Heater Plate | Range -50 °C – 300 °C |
| 3 | Thermometer digital | Range -50 ⁰C - 110 °C, ± 0.1°C |
| 4 | Pompa Sprayer | DC 12V 100 psi |
| 5 | 40 kg digital scale | Maximum load 40 kg, resolution 0.005 kg |
| 6 | 5 kg digital scale | Maximum load 5 kg, resolution 1 gr |

This study utilized the tools illustrated in Figure 2 and the schematic diagram shown in Figure 1. The research was conducted at the Mechanical Engineering Laboratory, Faculty of Industrial and Information Technology, Universitas Muhammadiyah Prof. Dr. HAMKA.

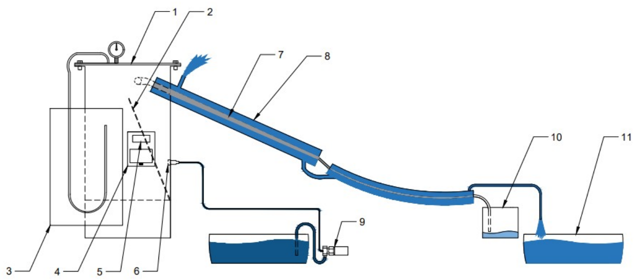


**Figure 1.** Distillation Device Scheme 1. Evaporator tube, 2. Heating plate, 3. PG, 4. Thermostat, 5. SH1, 6. Nozzle, 7. Steam flow, 8. Cooling water flow, 9. Pumps, 10. Freshwater reservoirs, 11. Reservoir of the outgoing cooling water flow.

**Figure 2.** Distillation Tools

Figure 2 illustrates the distillation device used in this study. Seawater, amounting to 5000 g, is distributed from the main container into the evaporator tube through a nozzle with a diameter of 0.3 mm, utilizing nozzle pressure variations of 40 psi, 70 psi, and 100 psi. The seawater is sprayed onto a heating plate maintained at 100°C by a thermostat. Data collection was conducted over 30 minutes at 5-minute intervals, recording the mass of water on a digital scale to determine the amount of seawater evaporated.

In Figure 2 data retrieval is performed on PG, SH1, AT1, SAL1 and SAL2.

Information:

PG : Evaporation pressure in the tube

SH 1 : Heating plate temperature

AT1 : Fresh water produced

SAL1 : Remaining seawater

SAL2 : Non-evaporating seawater

Based on the results of the trial, the equipment used worked well including checking for leaks in the joints.

## 3. Results and Discussion

To make it easier to do the analysis, the test result data is presented in the form of tables and graphs. In this study using nozzle pressure variations, namely 40 psi, 70 psi, and 100 psi. Sampling is carried out for 30 minutes with a time interval of 5 minutes. The data obtained include the evaporation pressure on the tube, the temperature of the heating plate, the container for holding fresh water, the remaining seawater, and the remaining seawater that does not evaporate in the tube. The following are the results of data collection which can be seen in the form of tables and graphs below.

**Table 2.** Nozzle Pressure 40 psi

| t (Minutes) | p (Pa) | T (°C) | m (g) | SAL1 (g) | SAL2 (g) |
|---|---|---|---|---|---|
| 5 | 20 | 81.2 | 5 | 4900 | 855 |
| 10 | 120 | 82 | 6 | 4760 | |
| 15 | 220 | 82.2 | 7 | 4625 | |
| 20 | 270 | 82.7 | 8 | 4480 | |
| 25 | 300 | 84.6 | 8 | 4370 | |
| 30 | 320 | 86.1 | 10 | 4135 | |

**Table 3.** Nozzle Pressure 70 psi

| t (Minutes) | p (Pa) | T (°C) | m (g) | SAL1 (g) | SAL2 (g) |
|---|---|---|---|---|---|
| 5 | 60 | 57.3 | 1 | 4750 | 1050 |
| 10 | 130 | 58.1 | 2 | 4525 | |
| 15 | 140 | 59.4 | 4 | 4470 | |
| 20 | 155 | 60 | 6 | 4300 | |
| 25 | 170 | 60.9 | 8 | 4150 | |
| 30 | 185 | 60.9 | 9 | 3935 | |

**Table 4.** Nozzle Pressure 100 psi

| t (Minutes) | p (Pa) | T (°C) | m (g) | SAL1 (g) | SAL2 (g) |
|---|---|---|---|---|---|
| 5 | 10 | 55.4 | 1 | 4650 | 1345 |
| 10 | 20 | 57.1 | 2 | 4360 | |
| 15 | 40 | 57.9 | 3 | 3980 | |
| 20 | 70 | 58.2 | 3 | 3670 | |
| 25 | 110 | 58.2 | 4 | 3370 | |
| 30 | 160 | 59.7 | 4 | 3100 | |

Based on the results of the study, data were obtained on the evaporation of seawater at various variations in nozzle pressure for 30 minutes. The results showed that the higher the nozzle spray pressure against the heating plate, the lower the evaporation pressure in the tube. This is because if the nozzle spray against the heating plate is higher, the seawater droplets that are in direct contact with the heating plate become few and only condense so that the seawater does not experience evaporation. At a burst pressure of 40 psi, the highest evaporation pressure in the tube is 320 Pa, resulting in 10 g of fresh water. At a burst pressure of 70 psi, the highest evaporation pressure in the tube is 185 Pa, resulting in 9 g of fresh water. At a burst pressure of 100 psi, the highest evaporation pressure in the tube is 160 Pa, producing 4 g of fresh water.

Figure 3 shows the difference in evaporation pressure and the amount of fresh water produced at each variation in burst pressure. The factor of mass flow rate also affects the difference in evaporation pressure at each variation in burst pressure. The mass flow rate can be obtained using the following equation:

$$\dot{m} = \rho \, . \, A \, . \, v \quad (1)$$

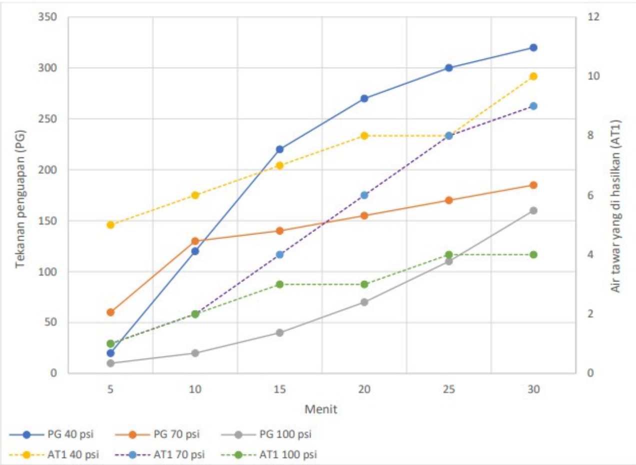


**Figure 3.** Evaporation Pressure Graphics (p), Nozzle Spray Pressure (Psi), Produced Fresh Water (m)

The results of the calculation show that at a burst pressure of 40 psi, a mass flow rate of 0.375 kg / s, an evaporation pressure in the tube of 320 Pa and produces fresh water as much as 10 g. At a burst pressure of 70 psi, a mass flow rate of 0.488 kg/s, an evaporation pressure in the tube of 185 Pa and produces 9 g of fresh water. At a burst pressure of 100 psi, a mass flow rate of 0.579 kg/s, an evaporation pressure in the tube of 160 Pa and produces 4 g of fresh water.

## 4. Conclusion

The results of testing, observation, and analysis in this study revealed a comparison of each pressure variation 40 psi, 70 psi, and 100 psi. Over a 30-minute period, the highest evaporation occurred at a nozzle pressure of 40 psi, producing 10 g of fresh water. Conversely, the lowest evaporation was observed at a nozzle pressure of 100 psi, yielding 4 g of fresh water. Based on the study's objective to analyze the effect of nozzle pressure on seawater evaporation and determine the effectiveness of each pressure variation in producing fresh water, it can be concluded that a pressure of 40 psi is the most effective for fresh water production.

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