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IMPROVING FRESHWATER YIELD FROM SIMPLE SEAWATER DISTILLATION DISPENSERS THROUGH CONDENSER PIPE MODIFICATIONS

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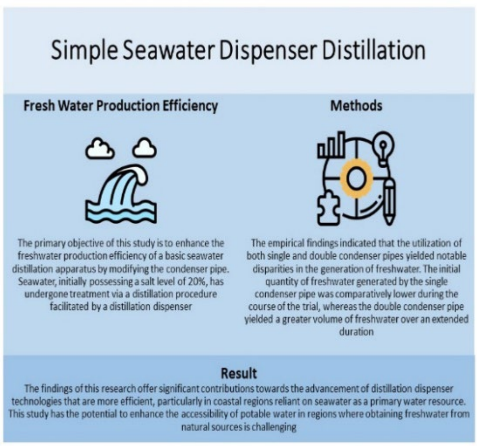


Abstract

The primary objective of this study is to enhance the freshwater production efficiency of a basic seawater distillation apparatus by modifying the condenser pipe. Seawater, initially possessing a salt level of 20%, has undergone treatment via a distillation procedure facilitated by a distillation dispenser. The empirical findings indicated that the utilization of both single and double condenser pipes yielded notable disparities in the generation of freshwater. The initial quantity of freshwater generated by the single condenser pipe was comparatively lower during the course of the trial, whereas the double condenser pipe yielded a greater volume of freshwater over an extended duration. Hence, the careful choice of condenser pipes has the potential to significantly impact the effectiveness and operational capabilities of the distillation dispenser system. The findings of this research offer significant contributions towards the advancement of distillation dispenser technologies that are more efficient, particularly in coastal regions reliant on seawater as a primary water resource. This study has the potential to enhance the accessibility of potable water in regions where obtaining freshwater from natural sources is challenging.

Keywords: Distillation, Pipe Condenser, Sea water, Fresh water, Salinity

1.0 INTRODUCTION

Ensuring access to uncontaminated water is a crucial element in maintaining human welfare and improving the general standard of living. The provision of clean water has wide-ranging effects on different aspects of human life, including ordinary water consumption, sanitation practices, and industrial activities [1]. Drinking water businesses or the use of efficient groundwater drilling techniques usually manage the provision of clean water in urban areas. However, communities living in remote coastal areas have unique challenges due to their significant distance from natural sources of freshwater, such as springs. The residents in this area often have challenges in obtaining drinkable water due to the absence of nearby freshwater sources. The water sources in these areas often consist of seawater, which is unsuitable for immediate consumption [2].

To tackle this problem, the use of distillation has become a widely adopted method for producing drinkable water from seawater. Distillation is a separation technique that exploits the differences in boiling points between the various components of a homogeneous liquid [3]. The process entails applying heat to a mixture of seawater until it reaches its boiling point, causing the liquid phase to evaporate. Afterwards, the vapor is cooled, causing it to condense and transform back into a liquid condition. Distillation equipment often includes heating and cooling systems to control the evaporation and condensation processes.

A seawater distillation dispenser has been developed using the multi-effect distillation technique. The dispenser in question incorporates a heater that has been adapted from a conventional dispenser, with both a heating tube and an effect tube. The tubes are linked to a spiral pipe and a nozzle, which leads to the creation of a distillation effect [4][5][6]. However, despite its natural capacity to produce cleaner waters, this simple distillation device still faces challenges in terms of efficiency. During the initial studies, a small amount of the evaporated saltwater was successfully converted into drinkable water [7].

A research study has been conducted to examine the many parameters that impact the efficiency of the distillation process in these dispensers. The main aim of this study is to examine the influence of various condenser pipe arrangements on the generation of freshwater. As stated in reference [8], altering the diameters of condenser pipes can improve the production of freshwater by aiding the conversion of vapor into liquid through more efficient cooling. The main goal of this research was to conduct a thorough examination of how improvements in condenser pipe design can improve the efficiency of freshwater generation in distillation dispensers [9]. The expected results of this research project are positioned to make a significant contribution to the progress of distillation dispenser technology, namely by improving its efficiency. This advancement is highly significant for people living in coastal areas, where there is a strong need for this technology. This study aims to fill the current knowledge gap on the influence of condenser pipe size on the production of freshwater in distillation equipment.

1.1 Literature Review

Distillation is a method of separating substances in a homogeneous mixture by exploiting the variations in their boiling or melting points. The distillation process consists of two stages: evaporation, followed by the condensation of vapor back into liquid or solid form. Distillation equipment utilizes heating and cooling apparatuses for this purpose. The distillation process commences with the application of heat, causing substances with lower boiling points to vaporize, and the resulting vapor to migrate towards the condenser (which is cooler). The cooling process is initiated by circulating water to the exterior surface of the condenser, causing the vapor to condense back into liquid form. This process persists indefinitely and ultimately allows for the segregation of all chemicals within a homogeneous mixture [10].

The distillation method employed in the seawater distillation dispenser for this research is multi effect distillation. Multi Effect is a procedure comprising multiple flash chambers referred to as "effects". During this procedure, steam from the boiler is only provided to the first effect, while the second and subsequent effects get the steam produced by the preceding effect.

In a multi-effect evaporator, the hot sample tubes are horizontally positioned and exposed to sea air through spraying. Within the tube, the elevated temperature causes the vapor to condense, resulting in the creation of fresh water. Simultaneously, the seawater around the tank is heated to the point of boiling, generating more water vapor that subsequently enters the adjacent heat exchange tube. Each of its pressure-reducing actions occurs at a level below the saturation pressure of the brine temperature (seawater that has become more concentrated through evaporation).

The process of condensation and vaporization is repeated from the first effect to the last effect. In this scenario, evaporation occurs repeatedly based on the number of effects, resulting in the production of fresh water with a high level of thermal efficiency. Figure 1 depicts the sequential flow process involved in multi-effect evaporation.

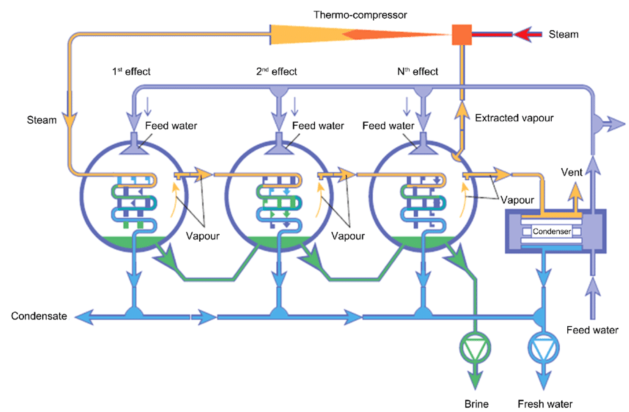


Figure 1. Illustration of Multiple Effect Distillation (MED) desalination technique [11]

2.0 METHODOLOGY

In the first phase of the experiment, the relevant instruments and supplies are collected and organized. This includes correctly situating the boiler and condenser according to the exact dimensions to be studied [12]. Following that, the gathering of measurements and recording of essential data regarding relevant parameters, such as the initial temperature, volume of water added to the boiler, and surrounding temperature, were carried out. Afterward, the boiler is heated to produce water vapor, which is subsequently condensed in the condenser pipe. During the experiment, crucial data regarding temperature and pressure at various sites within the system are methodically recorded at regular intervals [13]. Figures 2 and 3 depict the distillation dispenser system that was created and tested.

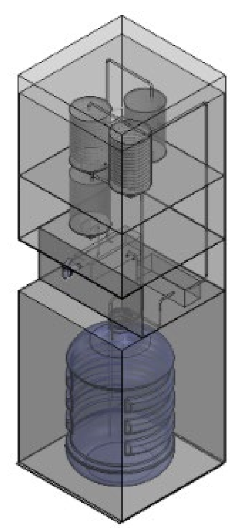


Figure 2. Distillation Dispenser

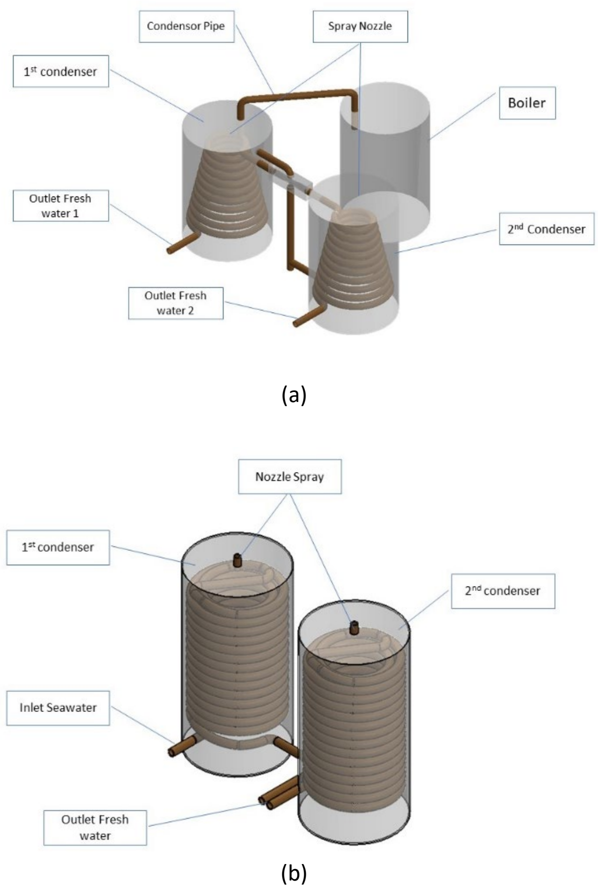


Figure 3. (a) a single pipe condenser and (b) a double pipe condenser

Figure 4 depicts The research provides a clear explanation of the testing methods used, as referenced in [14]:

1. The first stage involved preparing a 2000-mL volume of saltwater, which was used as the main material for the following processes. The equipment used in this study includes a boiler, copper pipes to connect the boiler and first condenser, a seawater pump, a seawater reservoir, a K-type thermocouple for monitoring temperature, and a measuring cup for quantifying the volume of fresh water produced.
2. Seawater is fed into the boiler to facilitate heating. Afterwards, the flame is ignited on the boiler while ensuring that the specified pressure limit of 2 bars is maintained nearby. The purpose of this heating technique is to expedite the transformation of seawater into vapor.
3. The water vapor generated by the boiler is conveyed via copper pipes to reach the initial condenser. On the other hand, the seawater pump enables the movement of seawater into the condenser. Seawater is mostly utilized in this context to aid in the cooling process within the condenser. The seawater used for cooling is then circulated back to the sump using a recirculation mechanism.
4. Temperature Measurement: The temperature at various sites inside the system was evaluated during the experiment using a type K thermocouple. Obtaining temperature data is crucial for understanding the variations in temperature that occur during the procedure.
5. The quantification of freshwater production entailed measuring the volume of freshwater generated by the condenser using a measuring cup. It is important to evaluate the effectiveness of the system in converting seawater vapor into drinkable water.

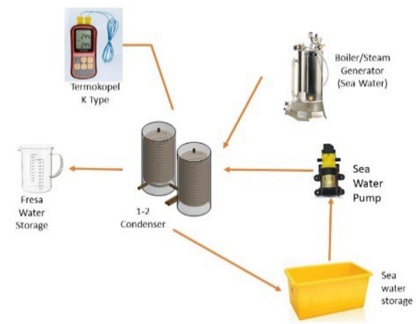


Figure 4. The flow of the testing procedure.

The examination of the experiment's outcomes involved a comparison of the effectiveness of the two experimental procedures. By considering the possible differences in the sizes of the condenser pipes, the gathered data is used to assess the effectiveness of creating purified water in the distillation dispenser. The aim of this study is to improve understanding of how changes in the size of the condenser pipe affect the production of purified water in a distillation apparatus. This section discusses the utilization of relevant charts and graphs to graphically represent the findings of the research.

3.0 RESULTS AND DISCUSSION

The results of the conducted investigations are depicted in the following figure:

Table 1. Results of the 2 bar test conducted on a single pipe condenser.

Time (minutes)	1st Condenser		2nd Condenser	
	Temperature (C)	Fresh water (mL)	Temperature (C)	Fresh water (mL)
1	56,7	24,5	-	-
5	53,7	63,5	-	-
10	58,4	140,5	-	-
15	65,7	231	-	-
20	75,7	318	-	-
25	96,4	428	-	-
30	76,2	483,5	-	-
36	68,4	569,5	-	-

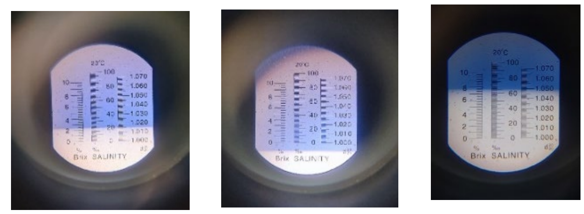
Table 1 displays the empirical findings of the condenser with a solitary pipe under a pressure of 2 bar. Within the experiment employing a solitary pipe condenser, the operational pressure inside the boiler is approximately 2 bar, while the quantity of saltwater designated for distillation is 2000 mL. The total length of the condenser pipes is 6 meters, with each individual pipe tube measuring 3 meters in length. Within the first minute of the experiment, the initial condenser produced a volume of 24.5 mL of distilled water, while the temperature of the pipe tube was measured at 56.7°C. The experiment with a single pipe condenser was stopped after reaching a seawater volume of 500 mL in the boiler. The experimental results of the test using the single pipe condenser showed that 569.5 mL of freshwater was obtained, with a salinity level of 0%. This study investigates the correlation between temperature variations and the volume of fresh water produced by a single pipe condenser at various time intervals during the distillation process [15]. The importance of this data lies in its capacity to offer valuable information about the effectiveness of a system designed to generate drinkable water from seawater using a single pipe condenser operating at a pressure of 2 bar.

Table 2. Results of the 2 bar test conducted on a double pipe condenser.

Time (minutes)	1st Condenser		2nd Condenser	
	Temperature (C)	Fresh water (mL)	Temperature (C)	Fresh water (mL)
1	31,2	0	-	-
5	41,1	35	-	-
10	56,8	164,5	-	-
15	58,3	269,5	-	-
20	56,5	353,5	-	-
25	60	483,5	-	-
30	63,4	584	-	-
35	62,6	668,5	-	-
40	67,7	788,5	-	-
45	67,1	843,5	-	-
50	70	938,5	-	-

The results of the experimental tests conducted at a pressure of 2 bar using a condenser with a single pipe are displayed in Table 2. The dataset consists of multiple variables, such as the duration in minutes, the temperature recorded at the first condenser pipe, the volume of fresh water produced by the first condenser pipe, the temperature measured at the second condenser pipe, and the volume of fresh water generated by the second condenser pipe. At the beginning of the experiment, the temperature of the first condenser pipe was measured at 31.2 degrees Celsius. However, no fresh water had been produced at this stage [16]. During this time, the second condenser pipe was not used, leading to a lack of recorded data. The experiment entailed gathering data at different time intervals until the 50th minute. At this time, the initial condenser pipe reached a temperature of 70 degrees Celsius and produced 938.5 mL of fresh water. It is important to mention that the second condenser pipe was not used in this specific test [17].

Furthermore, in the double-pipe condenser experiment, the pressure within the boiler was roughly 2 bar. The volume of seawater that underwent distillation was 2000 mL. In addition, the condenser pipe had a combined length of 13 meters, comprising two tubes, each with a length of 6.5 meters, organized in a double spiral pattern [18]. The experiment with the twin condenser pipe was stopped after the kettle had 500 mL of seawater. The result of the experiment with a single condenser pipe was a volume of 938.5 mL of freshwater, with a salinity level of 0%.



(a) (b) (c)

Figure 5. Different states of seawater before and after the process of distillation (a) represents the initial state of seawater (b) depicts the seawater after undergoing the distillation process (c) showcases the resulting brine.

The sample material shown in Figure 5(a) is seawater, which has a salinity level of 20%. This is the raw seawater prior to undergoing the distillation process. The Figure 5(b) illustrates the freshwater generated by the distillation operation. The salinity of this freshwater is insignificant, as it contains no measurable amount of salt, with a salt level of 0%. As stated in reference [19], the distillation process has successfully removed a substantial amount of salt from seawater, resulting in the production of potable or usable freshwater. On the other hand, Figure 4(c) depicts the brine, which represents the remaining seawater in the boiler following the distillation process. The salinity of this brine is remarkably elevated, measuring at 65%. As stated by [18], brine is the leftover substance that is produced after the process of distillation, which involves extracting salt from saltwater. The above figures illustrate the changes in the composition and salinity levels of the initial seawater, the distilled freshwater, and the resulting brine. These changes are being studied to understand the effects of condenser pipes on the production of freshwater in distillation devices [20].

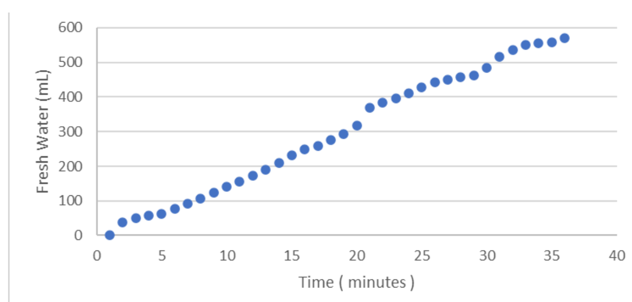


Figure 6. Fresh Water Production (Singe Pipe Condensor).

Test results for the single pipe condenser are displayed in Figure 6. The experiment was carried out using seawater containing a salinity concentration of 20% and a volume of 2000 mL for the feed water. The test was halted once the volume of feed water had decreased to 500 mL. The test yielded a cumulative volume of 569.5 mL of fresh water for a duration of 35 minutes. During the initial minute of the distillation process, it is possible to generate potable water.

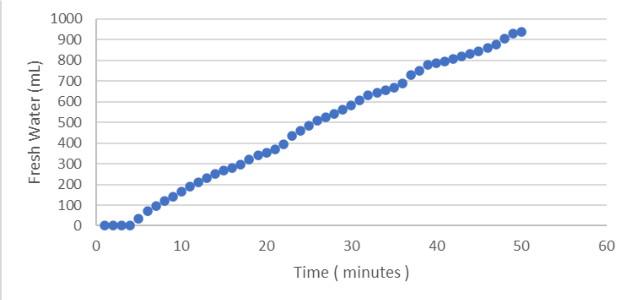


Figure 7. Fresh Water Production (Double Pipe Condensor)

Based on figure 7, the results of the experiment suggest that the twin-pipe condenser produces a larger amount of freshwater. More precisely, the twin-pipe condenser generates 938.5 mL of freshwater from the evaporated seawater, or around 46.9% of the total freshwater produced in the boiler. However, it is crucial to recognize that the generation of freshwater by the dual-pipe condenser did not begin until the fifth minute of the experiment. This phenomena arises from the discrepancy in cross-sectional areas between the double-pipe condenser and the single-pipe condenser. Conversely, the production of freshwater began during the first minute of the experiment in the condenser with only one pipe. The single-pipe condenser produced 569.5 mL of freshwater, or around 28.4% of the total volume of evaporated seawater, which was 2000 mL.

The disparity in pipe diameter between the two condensers significantly impacts the efficiency of freshwater production. As stated in reference [21], the dual-pipe condenser exhibits improved freshwater generation in a shorter period of time, but with a slight delay of a few minutes. However, the single-pipe condenser started producing freshwater earlier than the dual-pipe condenser, albeit it produced a smaller amount in comparison. Therefore, it can be inferred that the configuration and measurements of the condenser pipes have a substantial influence on the efficiency of the distillation system. This information can be advantageous in the development of more efficient distillation dispenser technology [22][23].

4.0 CONCLUSION

Modifying the configuration of the condenser pipe significantly affects the amount of potable water produced in a simple seawater distillation device. The experimental configuration using a solitary condenser tube exhibited the capacity to promptly produce drinkable water, resulting in an output of roughly 569.5 mL of uncontaminated water within a duration of 30 minutes. The attainment of this result was accomplished by the treatment and processing of a cumulative quantity of 2000 mL of seawater. On the other hand, using two condenser pipes instead of one increased the duration to approximately 50 minutes, resulting in the production of about 938.5 mL of freshwater from the same amount of seawater. In this study, employing two condenser pipes led to a better overall output, but at the cost of increased time investment. However, it is important to acknowledge that a solitary condenser pipe has a higher rate of freshwater production, but with a smaller quantity. Hence, the choice between employing single or dual condenser pipes in a distillation dispenser necessitates meticulous assessment of the trade-off between the length of production and the quantity of fresh water generated. The research findings provide useful insights for improving distillation dispenser technologies, making them more efficient and customizable to meet the specific needs of coastal cities that rely on seawater as their main water source.

Research is required in the subsequent phase to develop a connecting mechanism between the first condenser tube and the second condenser tube. The objective of the research is to enhance the functionality of the second condenser in order to augment the production of fresh water.

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