THE EFFECT OF VARIATION IN THE NUMBER OF SPRAYS AND DISCHARGE ON THE TECHNOLOGY SPRAY FOR EVAPORATION

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Abstract

Spray technology is an innovative salt production process technology that is able to increase seawater salinity and accelerate the salt production process. This study aims to determine the effect of variations in the amount of spray and discharge in spray technology on increasing seawater salinity. The experimental method was carried out by varying the spray and water discharge amount in spray technology according to the variables. This research has been successfully carried out to increase the salinity of synthetic seawater where to increase from the initial seawater salinity of 2.5 °Be to 24 °Be. It takes 16 hours taken in 3 days using the number of sprays as much as 5 sprays with a seawater flow rate of 0.2424 m^3/hour in an evaporation pond of 15×7 m. The use of the spray method proved effective in accelerating the rate of increase in salinity of synthetic seawater, which was tested to increase the salinity of synthetic seawater from 2.5 °Be to 12 °Be with an evaporation time in traditional methods of 15 days to only 11 hours. This can also happen because the temperature, humidity and wind speed were relatively stable when the research took place.

***Keywords**: evaporation, flow rate, salinity, spray technology*

Introduction

The demand for salt from various industries in Indonesia is very large but not proportional to its production capacity. The process of making salt in Indonesia mostly still uses conventional technology. The process of evaporating seawater using solar power and carried out in open spaces under conditions of T = 30 °C and 1 atm pressure. This traditional method has not been able to provide satisfactory results in both production quantity and quality. In terms of quantity, traditional methods have not been able to produce salt to comply with national salt needs. Each salt farmer has a land area for salt production within the range of 1–3 ha, with the average salt product being 60 tons/ha/year. This relatively low productivity is due to the fact that the traditional salt production process is similar from year to year, and no significant developments have been performed (Susanto *et al.*, 2015). In terms of quality, salt production with traditional methods is not sold to industry because the quality is still below the Indonesian National Standard (SNI) or industrial salt standards (Triajie and Insafitri, 2012).

With the development of the times, there is a technology in the form of geomembranes. Geomembrane technology is an effort to avoid direct contact between the base of the crystallization table (soil) with seawater to be crystallized by coating the base of the crystallization table with a geomembrane so that the quality of the salt produced is free from dirt or not mixed with soil (Nurherdiana *et al.*, 2023).In addition, the use of this traditional method requires a long time to be able to increase the degree of seawater Baume. Seawater salinity levels are

influenced by several factors including climate and environmental salinity (Afnani *et al.*, 2022). Salt production by solar evaporation can take weeks to obtain salt. Generally, evaporation in pond plots is carried out until the salinity level reaches 22-24˚Be where seawater is ready for the crystallization process (Muljani *et al.*, 2022)

The development of appropriate, effective, efficient, and environmentally friendly technology to obtain salt in a relatively short time is needed to overcome the imbalance of salt demand and production. One method of transforming salt production that has been widely practiced is using spray technology. Spray technology has been applied quite a lot but still on a small scale. Spray technology is very helpful in shortening the time when the evaporation process is carried out because spray technology will expand the surface of the liquid dried with dry air so that the evaporation process will occur faster and to reach 24 ˚Be takes 90 hours with a storage capacity of only 25 liters using 3 sprays and an evaporation table measuring 100 x180 cm (Syafii *et al.*, 2022)

Various factors affect the spray technology process, including the flow rate and the number of sprays. Flow discharge affects the evaporation rate where the greater the flow discharge, the faster the seawater evaporation process (Verbiawan *et al.*, 2023).The number of sprays installed has an influence on the seawater evaporation rate, where the more the number of sprays installed, the greater the volume of seawater sprayed and the faster the evaporation time, but if too many sprays are installed, the evaporation rate will decrease due to the decreasing length of the spray reach (Muljani *et al.*, 2021). Therefore, spray technology to accelerate the seawater evaporation process needs to be reviewed and developed both on a slightly larger scale and with the variables to be used. This research aims to increase the degree of seawater Baume using spray technology on an evaporation field measuring 15×7 m with HDPE geomembrane base and determine the effect of the number of sprays used with a 1.5 cm diameter nozzle as well as knowing the effect of flow discharge on increasing the degree of seawater Baume and various environmental factors such as relative humidity, temperature and wind speed.

Research Methods

Materials

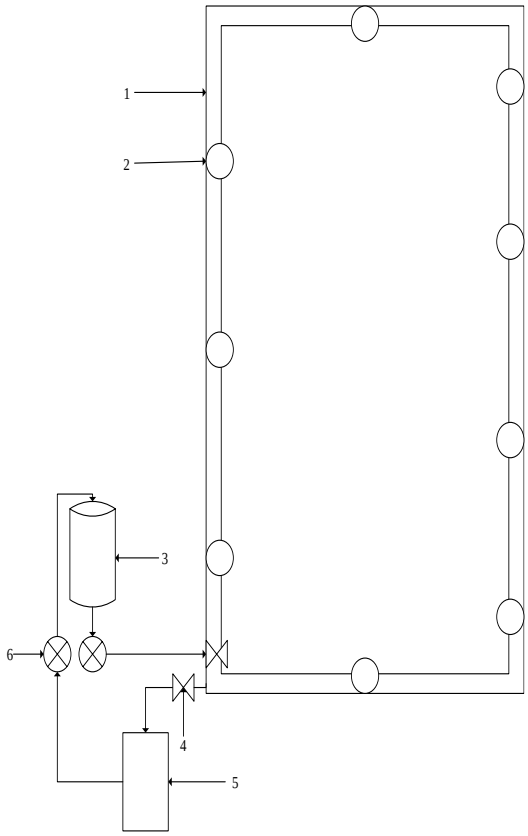
The materials used are wholesale salt and water

Instrumentation

The tools used in this research include an evaporation pond (Figure 1), Baumemeter EB 158P, Thermo Hygrometer TAOT-250-U and Anemometer Digital Thermometer.

Procedure

1) Raw material preparation
   Crushed salt is obtained from a salt company in the Benowo sub-district of Surabaya City.
2) Manufacturing process of synthetic seawater
   The process of making synthetic seawater is carried out using raw materials of whole salt which is dissolved using 750 liters of water to reach a Be content of 2.5 °Be
3) Evaporation process
   Once the synthetic seawater is ready, the evaporation process using spray technology will be run as shown in Figure 2.



Explanations:
1. Evaporation pond measuring 15 × 7 meters equipped with a table mat using HDPE Geomembrane
2. Spray Evaporation totaling 9 pieces equipped with a nozzle with a diameter of 1.5 mm
3. 750-liter capacity holding tank
4. Valve totaling 2 pieces
5. Pump totaling 2 pieces
6. Temporary catchment basin

Figure 1. Evaporation Pond

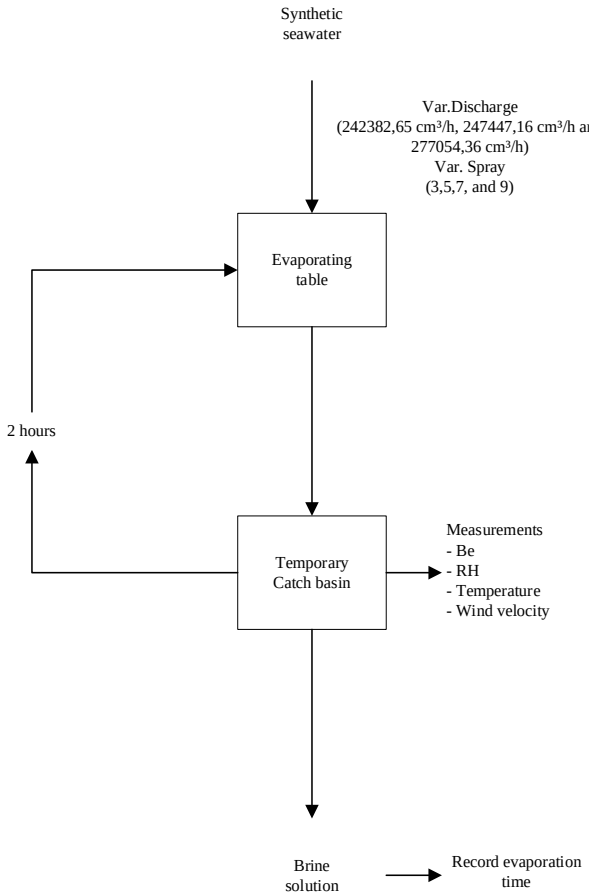


Figure 2. Flowchart of the evaporation process

Synthetic seawater is obtained by dissolving crushed salt using tap water and obtaining an initial synthetic seawater content of 2.5 °Be. Then, the synthetic seawater is collected into a holding tank with a capacity of 750 liters. The valve rotation of the holding tank is varied to regulate the flow rate with variable conditions of valve openings, namely ¼, ½, and 1 or variations in the discharge of 0.2424 m³/hour, 0.2474 m³/hour and 0.2770 m³/hour. Then, the evaporation process is carried out by pumping synthetic seawater from the holding tank to a series of spray technology tools that have been designed with variable conditions of the number of nozzles 3, 5, 7, and 9. The synthetic seawater is then sprayed into the evaporation pool for the evaporation process. The evaporation pond is 15×7 meters in size. Synthetic seawater that is not evaporated or in the evaporation pond is flowed using a pipe to a temporary reservoir and then to the storage tank. This process is carried out until the degree of salinity reaches 22–24 °Be. In a period of 2 hours, check and measure the temperature, degree of salinity, Relative Humidity levels and wind speed. Record the total time obtained to evaporate according to the variables run.

Results and Discussion

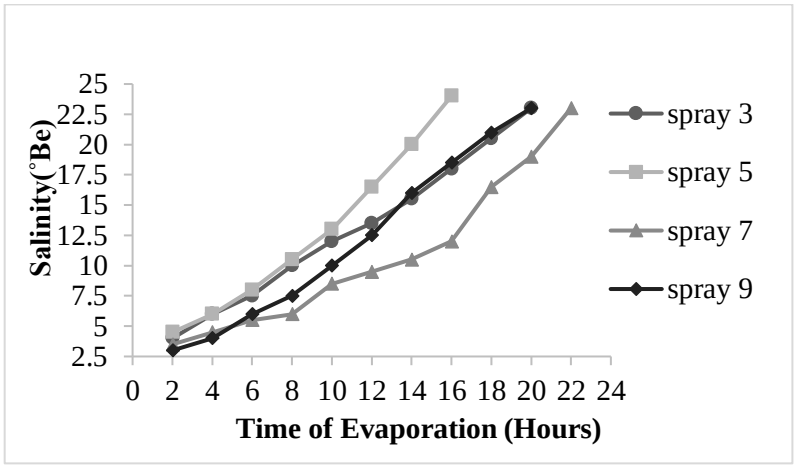
The increase in the Be content of synthetic seawater varies greatly, and this is distinguished based on the variable number of nozzles and the discharge used. Synthetic seawater that is sprayed into the evaporation pond undergoes evaporation because the synthetic seawater is sprayed on the geomembrane and uses the help of sunlight to warm up in order to obtain the desired degree of Baume (°Be). Some other factors that are also an important part of determining salinity, in addition to flow discharge and evaporation time in this experiment were also measured: humidity, wind speed and ambient temperature as listed in Table 1.

Table 1. Observation and measurement data of synthetic seawater evaporation experiments using spray technology

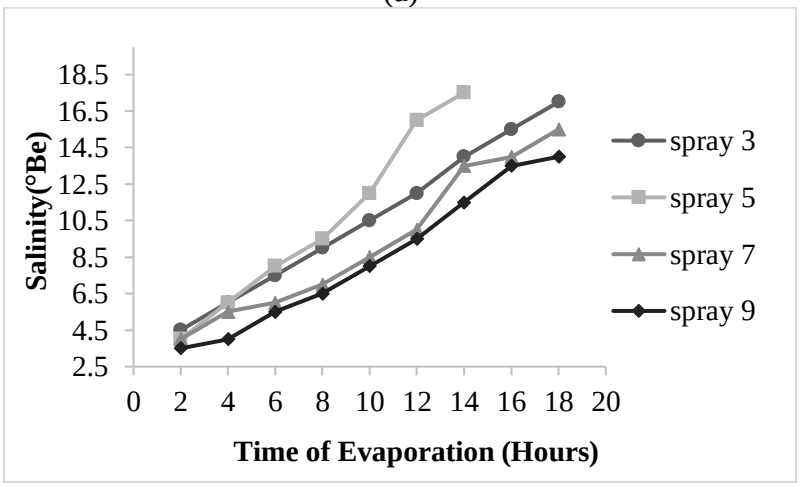
Evaporation time (Hours)	Evaporation time (Day)	Salinity (°Be)	Relative Humidity (%)	WindVelocity (m/s)
2	1^{st}	4.5	27	0.4
4		6	29	0.2
6	2^{nd}	8	30	0.2
8		10.5	23	0
10	3^{rd}	13	28	0.3
12		16.5	24	0.4
14		20	22	0.2
16		24	25	0.4

Table 1 shows an increase in the Be content of synthetic seawater at a spray amount of 5 with a flow rate of 0.2424 m³/hour. The resulting experiment is in accordance with the variables to be achieved, namely at a level of 23–24 °Be. A good old solution or brine to be able to carry out the salt crystallization process is at levels of 22–29 °Be (Apriani *et al.*, 2018). In this case, it took 16 hours to get the 24 °Be level. The volume of water that evaporates is inversely proportional to the operating time, where the longer the operating time, the smaller the evaporation rate. This is because the volume of synthetic seawater in the tank decreases over time, and the °Be content also increases so that the evaporated

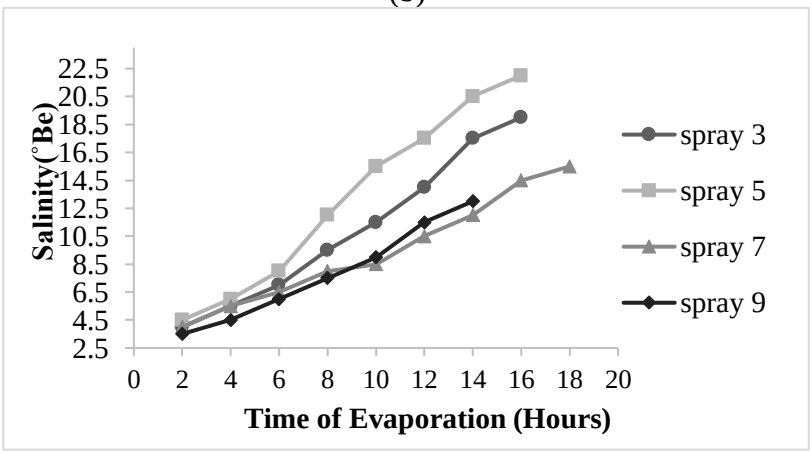
solution is more concentrated. While the evaporation time with °Be content is directly proportional, where the longer the operating time the greater the °Be content. Table 1. also shows that humidity and wind speed have a less significant effect on the increase in Baume degree. This could be because the weather conditions during the experiment were relatively stable. In general, evaporation can take place faster in extreme heat conditions because when the ambient temperature is high enough the humidity level and wind speed are relatively low.



(a)



(b)



(c)

Figure 3. (a) Relationship between evaporation time and Baume degree at variation amount with discharge 0.2424 m³/hour (b) Relationship between evaporation time and Baume

degree at variation amount with discharge 0.2474 m³/hour (c) Relationship between evaporation time and Baume degree at variation amount with discharge 0.2770 m³/hour.

Figure 3 shows the relationship between evaporation time and degree of Be at different numbers of spray and discharge variations. Figure 3 (a) shows that at a discharge of 0.2424 m³/hour, when the number of sprays used is 3 sprays, the degree of be is 23 °Be with an evaporation time of 20 hours. At spray 5, a Baume degree of 24 °Be was obtained with an evaporation time of 16 hours. When spray 7 is used, the Baume degree is 23.5 °Be with an evaporation time of 22 hours. Finally, when spray 9 is used, the Baume degree is 23 °Be with an evaporation time of 20 hours. Figure 3 (b) shows that at a discharge of 0.2474 m³/h when the number of sprays used is 3 sprays, the Baume degree is 17 °Be with an evaporation time of 18 hours. At spray 5, a Baume degree of 17.5 °Be was obtained with an evaporation time of 14 hours. At spray 7, a Baume degree of 15.5 °Be was obtained with an evaporation time of 18 hours. Finally, the use of spray number 9 obtained a Baume degree of 14 °Be with an evaporation time of 18 hours. Figure 3(c) shows that at a discharge of 0.2770m³/h when the number of sprays used is 3 sprays, a Baume degree of 19 °Be is obtained with an evaporation time of 16 hours. At spray 5, a Baume degree of 22 °Be was obtained with an evaporation time of 16 hours. When spray 7 obtained a Baume degree of 15.5 °Be with an evaporation time of 18 hours. Then, the use of spray number 9 obtained a Baume degree of 17.5 °Be with an evaporation time of 14 hours.

Based on Figure 3, it can be seen that the relationship between evaporation time and the degree of Be at different flow rates. The greater the degree of Be to be achieved, the longer the time required. However, the selection of variations in the amount of spray needs to be considered because it affects the evaporation time. The experiments carried out are in accordance with the existing theory. Where the contact surface area of water and air is a factor that affects the evaporation rate. The wider the contact surface, the higher the evaporation rate(Cleary Wanta *et al.*, 2023). In general, evaporation ponds for salt crystallization are located on the coast with strong winds and very supportive sunlight. Therefore, the use of spray evaporation can accelerate the evaporation rate and make the evaporation time faster. The increase in evaporation rate, along with the increase in salinity, is more influenced by the flow rate of seawater (Muljani *et al.*, 2022).

Based on Figure 3. (a), (b), (c), it can be seen that the best results occur at the number of sprays 5 at a discharge of 242382.65 cm³/hour with an evaporation time of 16 hours. The valve opening used must be proportional to the volume of synthetic seawater to be evaporated and the number of sprays used in the evaporation pool. If the volume of synthetic seawater to be evaporated and the amount of spray used is not balanced with the discharge, then the experiment does not achieve a Be content of (22–24) °Be. Spray technology plays an important role in this research because it accelerates the evaporation process by expanding the liquid surface. This is reinforced by research conducted by (Syafii *et al.*, 2022) where spray technology in the evaporation process will accelerate the evaporation process because spray technology expands the surface of the liquid to be dried using dry air so that the evaporation process will occur faster.

Table 2. Comparison of the improvement of synthetic seawater Be degree using traditional method and spray technology

Parameter	Spray Technology	Traditional Method
Salinity	2.5–12 °Be	2.5–12 °Be
Evaporation Time	11 Hours	15 Days
Reference	Experiment	Soemargono and Widodo, 2018

From Table 2, the spray technology can produce synthetic seawater with a higher salt content and a relatively shorter evaporation time. The spray technology was able to produce 12°Be synthetic seawater in only 11 hours of evaporation time. This can happen because spray technology has a nozzle that is able to turn synthetic seawater into small droplets. This can be reinforced by the opinion (Soemargono and Widodo, 2018) which argues that in the field, reaching 12 °Be NaCl can take up to 15 days, depending on weather conditions, but from 12 to 25 °Be NaCl only takes about 6 days. This is consistent with conventional ponds because the longer the time in the evaporation process, the faster the increase in °Be NaCl levels.

This shows that the use of spray technology in salt production can accelerate the process of increasing the degree of Baume. This can happen because variations in discharge with varied water flow are used in the spray technology. In this case, it can be strengthened by the statement (Verbiawan *et al.*, 2023) which states that the greater the discharge of the outgoing flow, the greater the volume of evaporated synthetic seawater. This is because the volume of seawater that is sprayed out is greater as the flow rate increases, so the contact of water with environmental hot air is also more frequent every second, which causes the evaporation process to accelerate.

Conclusions

The results showed that the salinity of synthetic seawater increased by using spray technology. Optimum conditions were obtained at a flow discharge of 0.2424 m^3/hour with 5 sprays. With this spray technology, it can speed up the evaporation time of seawater compared to traditional methods. It also shows that this method can be applied to real seawater, and the principle of spray technology can be applied to improve and streamline the use of industrial equipment in seawater evaporation.

Conflict of Interest

The authors have no conflict of interest.

Author Contributions

All authors discussed the results and contributed to the final manuscript.

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