# Influence of Carbon-activated Foam to Gain Fresh Water Production on Ultrasonic Vibration Assisted Water Purification System

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Abstract: Increasing demand for freshwater has been necessary for the development of the urban community. Saline water is one of the problems for urban society in coastal areas. Separation techniques to distilled water from saline water were performed by using many different kinds of systems. In recent years, many kinds of technology had been developed to convert saline water into freshwater with various methods and apparatus. Ultrasonic atomization is one of the methods to generate very narrow water droplets on atmospheric pressure and ambient temperature. This project has experimented to observe the performance of new technology within the water purification process from saline water and it's assisted by an ultrasonic humidifier for the humidification process. It has been performed a miniature technology which utilized a commercial ultrasonic humidifier with a power rating of 10 watts and resonance frequency 0f 1,65 MHz. Utilization of carbon-activated foam had been conducted to gain the performance of the humidification and dehumidification process. This work had been also analysed the measurement of the production of freshwater by its quality and quantity. The quality of the freshwater has been indicated by total dissolved solids (TDS) or salt concentrations of the output of this technology and also the number of output freshwater flow rates as their quantity. It has been measured about 2750-2850 ppm and the rate of freshwater production about 60-86 ml/h by a single unit of ultrasonic humidifier. It also indicated that influence of carbon activated foam to gain water output rate.

## 1 INTRODUCTION

Utilization and demand of freshwater studied for both present and past for the future demand projection. Commonly, water is utilized for agricultural, domestic and industrial, hydroelectric power and other water uses. Freshwater is a part of life and our life necessities. There are two main problems for sustainable fresh water supply for domestically purposed, scarcity of fresh water and increasing demand for freshwater. The world's water consumption is enormous and spread across various applications and industries. The biggest problem faced developing the technology of freshwater production that is the maintenance costs of equipment. Freshwater is generally characterized by concentrations of dissolved salts and other total dissolved solids. Indonesia is an archipelago that has a large amount of seawater. Different kinds of systems in separation technique to distilled water from saline water/seawater were performed by

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several technologies (Shehata et al. 2019). One of the methodologies is humidification and dehumidification (HDH) for the distillation of saline water.

Many researchers designed HDH to reduce power consumption or increase the use of free renewable energy (Shehata et al. 2019)(Rahimi-Ahar, Hatamipour, and Ahar 2020)(Dumka, Jain, and Mishra 2020)(El-Said and Abdelaziz 2020). In line with this technology development, various design and capacity becomes an important parameter for sustainable technology and appropriated by the user in several communities.(Agustriputra et al. 2021).

This research has been proposed a humidification and dehumidification system which utilized an ultrasonic piezo's vibrations to generate mist from saline water. Carbon activated foam has been utilized in the humidification and dehumidification process to gain the output of fresh water in this system. Carbon activated is prevalent material that occupies in water purification technology.

# 2 LITERATURE REVIEW

## 2.1 Ultrasonic Vibration for Liquid Atomization

One of the atomization processes applied an ultrasonic vibration produced by a piezoelectric disc. Unlike traditional atomization, ultrasonic atomization of liquid uses solely electrical energy, which is delivered to a piezoelectrically vibrating disk. There are no moving parts, only mechanical vibrations generated by the supplied electrical energy to use in the generation of the droplets. The ejection of small droplets from a liquid film formation on an ultrasonically vibrating surface known as an ultrasonic atomization. This is mixed by two major conventions, namely, the capillary wave hypothesis and the cavitation hypothesis have been proposed to explain the ejection of droplets from a vibrating surface. (Spotar et al. 2015) The capillary wave hypothesis considers the production of a capillary wave consisting of peaks and troughs on a vibrating surface, which can't be observed visually. The cavitation theory proposes that cavitation, which has defined as the creation of cavities in the liquid film on the piezo electric's vibrating surface. these is responsible for droplet generation. A cavitation event around the vibration of piezoelectric disk expels directly from collapse the droplets of these bubbles, especially near the superficial. (El-Said and Abdelaziz 2020) (Yasuda et al. 2010) (Khmelev et al. 2017)

The cavitation theory proposes that cavitation, which is defined as the creation of cavities in the liquid film on the piezo electric disc vibrating surface. A cavitation event around the oscillating piezoelectric disk expels directly from the droplets the collapse of these bubbles, especially near the surface. (Kudo et al. 2017). Because the droplets produced are fast and small in size, often only a few micrometers in diameter, ultrasonic atomization has been used in a wide variety of applications. the most widely used for commercial application are humidifiers for home appliance. Ultrasonic humidifiers have been used in air conditioning systems, and these are commonly used in subtropical areas for household appliances and cold chains for fresh fruit and vegetables. The formation of a very fine mist can also be applied in the fumigation of fresh food or the sanitization of food service equipment.

The mist generated by acoustic atomization has a very large surface area per unit volume of solution, due to the small diameter of the droplets. Series of experiments were performed to analyses the influence of physical parameters such as temperature, carrier gas flow, and position of mist collection on the enrichment of ethanol distillation. Besides, droplet size measurements of the atomized mists and visualization of the oscillating fountain jet formed during ultrasound application were utilized to understand the separation mechanism. However, the level of concentrations that can be achieved is limited by the rate of mass transfer of generated mist through the liquid to the surface of the droplets as their form. (Zhang, Yuan, and Wang 2021)(Hamai et al. 2009). So far, there is no convention in the literature about the actual mechanism which is responsible for ultrasonic atomization. Cavity evidence has been reported only in situations where the forcing acceleration is very high, such as in the horn atomizer. On the other hand, no evidence of cavitation was reported in the case of ultrasonic atomization occurring on the surface of the vibrating piezoelectric disc.

A desalination plant is a technology for the separation of freshwater from saline water. The amount of salt will be removed by the distillation process or other similar separation processes. Solar still is common technology from a conventional method. This technology had been developed significantly by various research and methods cause of the utilization of solar thermal energy which has been free energy. (Rahbar, Esfahani, and Asadi 2016),(Shehata et al., 2020). The utilization of ultrasonic atomization becomes favourable technology in recent years for application in several fields such as room air humidification, aroma diffuser, reduce air solid contaminant, and nanoparticle synthesis. An easy operation is one of the advantages of ultrasonic atomization and is maintenance-free. An ultrasonic atomization process utilized more efficient electric energy, generating mist by mechanical vibrations supplied by ultrasonic frequency of electrical power. (Putra et al. 2020)

## 2.2 Adsorption to Desalinate of Saline Water

One of the most popular methods in water purification has been used an activated carbon material as an adsorbent. In an aqueous solution, adsorption of an activated carbon involves three interactions: first interactions are adsorbate to liquid, second interactions are adsorbate and surface area, and third interactions are liquids to adsorbate. The strength of physical adsorption to surface contacts indicates degree of adsorption in absorbent materials, as opposed to adsorbate to liquid and liquid to surface interactions. The chemical properties of the surface determine adsorbate to surface interactions, whereas the solubility of the adsorbent material determines adsorbate to liquid interactions. Surface chemistry determines the interactions of liquids with the adsorbate's surface area. (Bowen 1969)

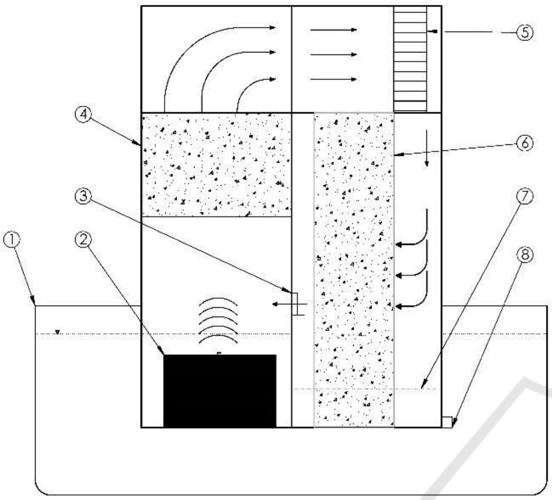
There are several types of activated carbon, most notably granular form of an activated carbon, extruded activated carbon, and there are also many uses of powdered activated carbon. they are not limited to water treatment and gas purification, but it's also needed for several adsorption process. Only certain materials can be adjusted in the industry as required, such as high tensile strength, tolerance of high temperature, derived from Activated Carbon Fiber (ACF) or cellulosic fibre which was made from natural and synthetic material.

Activated carbon has various uses, most notably water purification, gas purification and conservation, medical use, heavy metal release, and energy saving devices. (Marsh and Rodríguez-Reinoso 2006). Especially, carbon activated foam was used to gas and water purification. A composite fibre has been manufactured by inserting of carbon activated for gas and water filtration. It applied to gas and water purification technology. Synthetic mesoporous carbon also required to an easy tuneable pore size and improving others mechanical properties. It's just

Activated carbon has many uses, mainly due to its adjustable pore size, better quality and durability, as well as its thermal properties and large surface area. The most common and used materials for commercial activated carbon production include various animal residues, pitches, coke, which affect their recycling and economic potential. Various reports indicate that activated carbon production affects production efficiency. Many researchers have reviewed and explored various methods for producing activated carbon, including production methods, physical activation, chemical activation, physiochemical activation, and energy conservation.(Paul et al. 2019) Solar desalination already has taken valuable place in brackish or desalination process. Various water desalination processes have been being operated with the help of solar thermal energy (Li et al. 2013). The current solar desalination systems still have relatively high capital cost, low proficiency and productivity and dependency on location, weather and season which make it uncompetitive with the others desalination technology. However, solar desalination is a feasible choice for the arid region with a minimum water demands for developing countries, due to the elimination the cost of the water transportation and cost of energy source. The most practical renewable desalination technique could be solar distillation which is a simply natural evaporation–condensation process with a low-cost energy source.

# 3 EXPERIMENTAL APARATUS AND METHODS

In this project, we perform ultrasonically experiments to observe the atomization of saline water in the humidification process at vibration frequency of 1.65 MHz. This provides insight into the dynamics of ultrasonic atomization. we were looking into whether we consider examining 'ultrasonic humidifier' presumably as an evaporation (or humidification) process in part of this technology. An ultrasonic transducer occupied as a mechanical work through vibrations to generate the mist or water fountain on the circulation of the air as a carrier gas. Our analysis is based on the cavitation wave mechanism by ultrasonic vibrations module that generates water mist in a chamber. Recent works, such as the use of ultrasonic atomization on solar still technology, separation of ethanol from water solutions, and other similar work to increase humidification processes via ultrasonic atomization, have considered this decision. (Shehata et al. 2019) (Dumka and Mishra 2020) (Shehata et al. 2020). This experimental study also conducts to analyse the production of fresh water and reduced the total dissolved solids of saline water. it utilized a portable ultrasonic humidifier module to formed water mist which is in the humidification chamber. The thickness of saline water layer and mass flow rate of the air will be an important parameter on installation of ultrasonic humidifier.




1. Saline water container
2. Ultrasonic humidifier module
3. Circulation gas carrier
4. Activated Carbon Foam (first Stage)
5. DC blower 5015
6. Activated Carbon Foam (dehumidification)
7. Fresh water reservoir
8. Fresh water out conduit

Figure 1: Schematic of experimental apparatus.

## 3.1 Material and Equipment

A commercially available mist-maker or ultrasonic humidifier (also known as a nebulizer) was used to carry out the experiments. The resonant frequency of the disc is about 1.65 MHz with a ceramic piezo electric disc, which is diameter of 20 mm and power rating of about 10-15 W. An acrylic material was utilized for designing and constructing two chambers on this prototype technology. A DC blower unit (type 5015) serves to circulate air as a carrier gas into the dehumidification chamber. A PWM module was applied to the speed controller of the blower unit. (Figure 1). DC power supply used to supply electrical power for ultrasonic generator (24 volts) and blower.

Carbon activated foam was utilized to adsorb of total dissolved liquid of salt in the saline water. This is typically a synthetic fiber that has been manufactured by the amount of powdered activated carbon. There are two parts of carbon-activated foam in the installation of this experimental apparatus. In the humidification chamber, 4 cm of activated foam thickness were installed. It purposed to reduce the number of salts at the first stage of condensation. This thickness of carbon-activated foam had been determined by passing observable water mist. Then, the influence of carbon activated foam thickness was investigated by the thickness of about 1,2,3, and 4 cm respectively. it aims to increase of condensation of fresh water in the dehumidification chamber.

## 3.2 Experimental Setup

Dry air (carrier gas) is circulated in two chambers, humidification and dehumidification, through the inlet of the air blower. After ultrasonic atomization, dry air mixed with air mist flows into the dehumidification chamber through the dry air temperature and relative humidity being measured. (Figure 1)

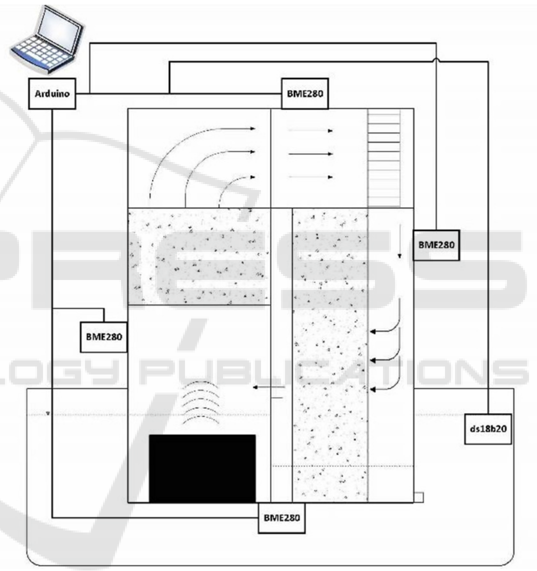



Figure 2: Schematic of data measurement.

The effect of water layer thickness and mass flow rate determines to humidity and air temperature of carrier gas. Next procedure, the blower's rotation speed was controlled by using of PWM module. 4 steps of the blower's speed rotations were controlled to indicate 4 set points of air mass flow rate. Several sensors had been installed in the humidification and dehumidification chamber (Figure 2 Schematic of data measurement. 4 sensor bme 280 were installed to measure the temperature of airflow on the chamber of humidification and dehumidification technology. 2 Sensor ds18b20 has been used for the measure of saline water and air temperature. The experiments were conducted to evaluate the overall performance of the application ultrasonic humidifier into a saline water purification system. (e.g., dry temperature, relative humidity (RH), and Total Dissolved Solids (TDS) on the output of freshwater. An Arduino environment has been designed for an embedded system on measuring system and collecting data of this experiment. Arduino UNO R3 installed for collecting and digital reading all sensors and modules.

## 4 RESULT AND DISCUSSIONS

Firstly, measurement of the electric current concluded with the ultrasonic humidifier module. this measurement observes the limitations of saline water layer thickness. it is indicated by the visible amount of mist that had been generated as fountain fog.

Table 1: Electrical current supply to ultrasonic humidifier module.

| Saline Water | Electric Current (Ampere) |
|---|---|
| 3 | 0.42 |
| 3.5 | 0.42 |
| 4 | 0.42 |
| 4.5 | 0.42 |
| 5 | 0.43 |
| 5.5 | 0.43 |
| 6 | 0.43 |

According to electrical current measurement (Table 1 Electrical current supply to ultrasonic humidifier module), saline water limited to layer thickness and air mass flow rate were considered by the gain of electrical supply and fog formation. We have decided to the testing limit of saline water layer thickness on 3 – 5 cm and also air mass flow rate about 0,000093-0,000558kg/s, according to 4 set points of PWM module. Saline Water layer thickness influenced on increasing of electrical current up to 0,01 Ampere at thickness 4 to 5 cm water layer.

Based on the measured results, the absolute humidity is determined by humidity ratio, relative humidity, and partial pressure of water vapor could be obtained by following equations:

$$\omega = 0{,}622\varphi/(P_b - P_{sw}\omega) \quad \text{..................} (1)$$

where $\omega$ is humidity ratio (kg/kg), $\varphi$ is relative humidity, $P_b$ is atmospheric pressure (Pa), $P_{sw}$ is partial pressure of water vapor (Pa), then it has been determinated by dry air function (T);

$$\ln P = C_1/T + C_2 + C_3T + C_4T^2 + C_5 \ln T \quad \text{.......} (2)$$

and coefficient of $C_1$ = -6069.9385; $C_2$ = 21.2409643; $C_3$ = 0.027111929; $C_4$ = 1.673952x 10-5; and $C_6$ = 2.433502, which could be utilized to describe the relationship between air temperature and partial pressure of water vapor. Measurement of Total Dissolved Solids utilized a digital salinometer and also the number of productivities freshwater measured by measuring cup and stopwatch. It is not easy to configure the flow rate of freshwater out Figure 1) by digital measurement because of low-velocity flows.

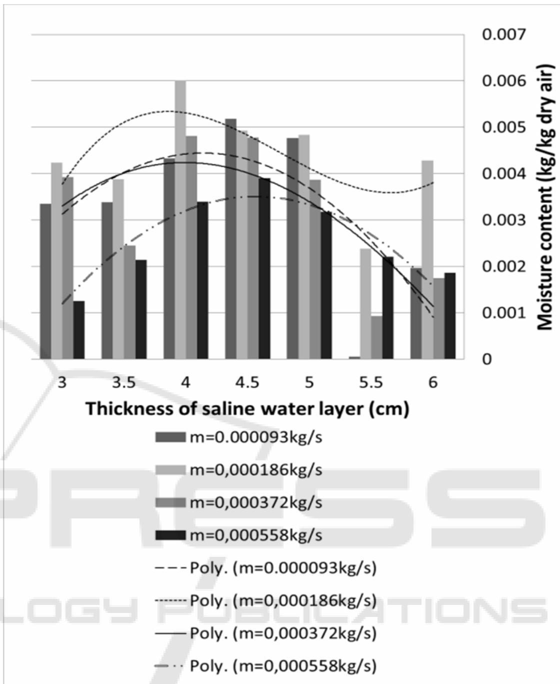



Figure 3: Moisture content of humidification and dehumidification process.

In this experiment, we have been collected data relative humidity and dry air temperature from sensors bme280 and then, data have been determined for moisture content of dry air. Based on the psychrometric of the air we calculate the flow rate of the moisture content, Figure 3 shows the rise of moisture content by gained of ultrasonic humidifier on the chamber. On the higher limit of mass flow rate increased their moisture content but lower mass flow rate reduced moisture content of dry air on humidification process. Humidification process have been determined for effective limits of water layer thickness about 4 – 4,5 cm and also air mass flow rate about 0,000186kg/.

The temperature difference of carrier gas is the deviation of dry air temperature between dry air temperature in the outlet of dehumidification chamber and temperature humid air on the humidifier chamber. Figure 3 shows that almost all of the testing is increased the temperature of dry air (carrier gas). Electrical equipment produced heat which was transferred to saline water on humidification and dehumidification chamber. Increasing dry bulb temperature had been held on 4,5 cm water layer thickness and it's maximized on 5 cm water layer thickness. The Air mass flow rate of 0,000186kg/s shows that the temperature deviation is higher relatively than others air mass flow rates.

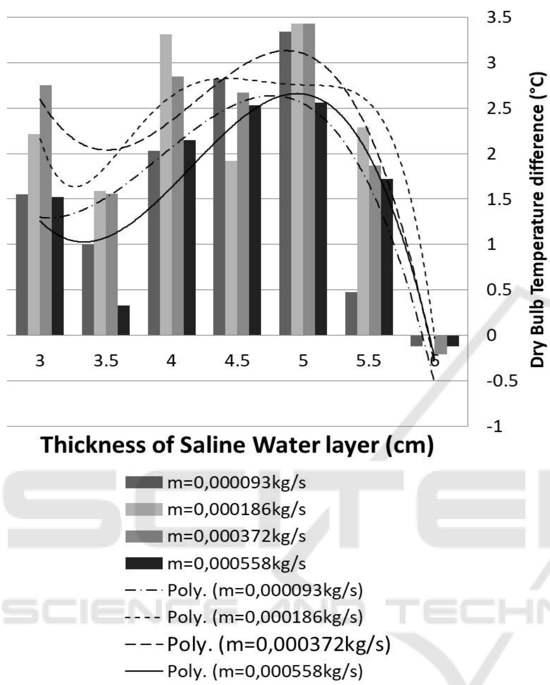



Figure 4: Dry bulb temperature difference.

Performance of saline water in humidification and dehumidification process indicated by measurement of freshwater output flow rate and reduction of salt concentrations as the quality of freshwater production. Measurement had been performed by 30 minutes of time interval and we have been observed repetition for 10 times measurement. Based on preliminary testing we have decided to adjusted the 4 cm thickness of the seawater layer on the surface of the piezoelectric disc.

Seawater had been used to approach the total dissolved solids of saline water. Seawater was collected from Jimbaran beach in the Badung regency Bali. Based on Figure 5, this prototype of the humidification and dehumidification process could be reduced the salt concentrations of saline water. It's normally, about 3500-3800 ppm which has been reduced up to 2800 ppm of total dissolved solids on freshwater outputs. This quality of the freshwater output still shown higher limits for utilization domestically. However, this experiment had been proved that the utilization of ultrasonic modules and carbon-activated foam can reduced salts or the total dissolved solids or salinity in the seawater.

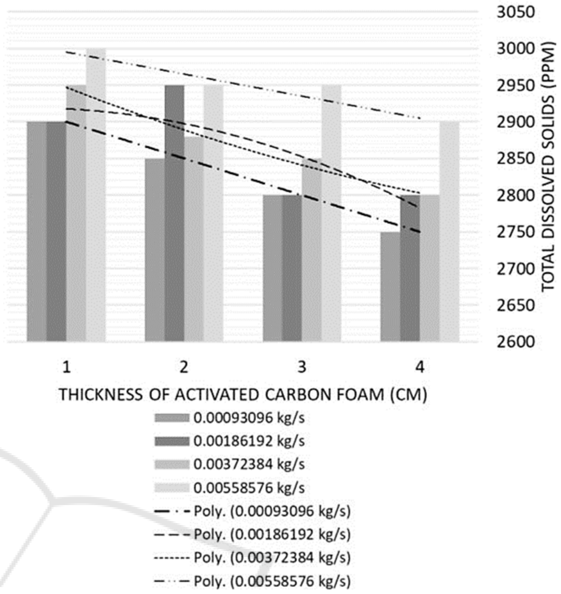



Figure 5: Fresh water output quality.

The flow rate of freshwater is about 60-86 ml/h. (Figure 6). The influence of carbon-activated foam had been mentioned by increasing of output fresh water. Because of addition, carbon activated foam thickness can increase compression of water mist in the dehumidification chamber. It also influences the rate of water generated from the mist stream in carbon-activated foam. In the humidification chamber, we also use activated carbon to reduce the salinity of mist generated by the ultrasonic module. Design considerations determined the thickness of carbon activated foam which have been installed in the dehumidification chamber.

Based on the quality and quantity of fresh water output, post-treatment of fresh water is needed to meet the needs of fresh water for water consumption. However, the development of this technology is still promising for the use of free renewable energy (Photo Voltaic system) and also a sustainable supply of fresh water for coastal areas. Low power rating of ultrasonic humidifier and DC vortex blower is considerable choice in water purification technology. The pressure difference between the humidification and dehumidification chambers and flow velocity of the carrier gas take effect in increasing of freshwater productivity.

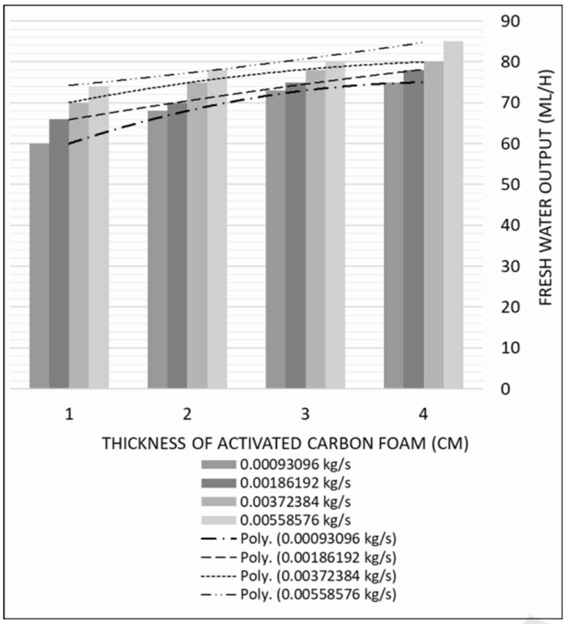



Figure 6: Fresh water output quantity.

## 5 CONCLUSIONS

The utilization of ultrasonic vibration/ultrasonic humidifier for humidification process had been tested their performance experimentally. Their performance had been also influenced by installing carbon-activated foam in the humidification and dehumidification process to gain freshwater output quality and quantity. It had been reduced salinity up to 2750 ppm from ordinary seawater and maximum freshwater production is 86 ml/h.

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