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THE POTENTIALS OF ULTRASONIC ATOMIZER AUGMENTED THE SEA SALT PRODUCTIONS

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Abstract. Ultrasonic atomizers can potentially augment the production of sea salt through a process known as ultrasonic nebulization. While the traditional method of sea salt production primarily relies on natural evaporation, ultrasonic atomization can accelerate the evaporation process. The process typically involves the following steps: collection of seawater, evaporation, brine crystallization and then harvesting process of the sea salt. After processing, the sea salt is typically dried and packaged for distribution and sale. In this project, the influence of the ultrasonic atomizer in the process of converting saline water into brine, before crystallization, can be assessed. The ultrasonic atomization process significantly increases the surface area of the seawater by converting it into fine droplets. Droplets evaporate more efficient due to large surface area of the droplets. According to testing of the research apparatus which had been conducted, an ultrasonic atomization can increase the salinity by brine evaporation or of droplet productivity of sea salt. This result had been shown in this process can be used to increasing the salinity of sea water. For further steps, this technique can potentially augment the production of sea salt.

Keywords : Ultrasonic, Atomizer, sea salt,evaporation.

1. INTRODUCTION

Sea salt is produced by the evaporation of seawater. The process typically involves the following steps: collection of seawater, filtration, evaporation ponds, evaporation, crystallization and then harvesting process of the sea salt. After processing, the sea salt is typically dried and packaged for distribution and sale [1]. Seawater is collected from the ocean or sea. It is essential to ensure that the water is relatively clean and free from contaminants. The collected seawater is usually passed through a series of filtration systems to remove larger debris, such as sticks, seaweed, and other organic matter. The filtered seawater is then pumped into large, shallow evaporation ponds or basins. These ponds are designed to maximize the surface area of the water exposed to the sun and wind, which accelerates the natural evaporation process. As the seawater sits in the evaporation ponds, it is exposed to sunlight and wind. The sun's heat causes the water to evaporate, leaving behind the dissolved salt and other minerals. The wind helps to concentrate the brine by continually mixing and evaporating the water. As the water evaporates, salt crystals start to form. These crystals are usually a combination of sodium chloride (table salt) and other minerals present in seawater, such as magnesium, calcium, and potassium salts. Once a sufficient amount of water has evaporated, and the salt crystals have formed, they are harvested. This can be done by using rakes, machinery, or even by hand, depending on the scale of production. The harvested salt crystals may contain impurities, such as clay or other minerals. To remove these impurities, the salt is washed and processed. The exact method of processing can vary, but it often involves dissolving the salt in water, filtering it to remove impurities, and then evaporating the water to leave behind pure salt crystals. It's important to note that sea salt can come in various forms, including coarse sea salt, fine sea salt, and specialty sea salts with unique colors and flavors, depending on the specific location and impurities in the seawater. Sea salt is often marketed as a more natural and less processed alternative to table salt, as it retains some of the minerals and elements found in seawater, which can impart distinct flavors and colors to the salt.

Ultrasound has been shown to have a positive effect on the evaporation process of liquids in a vacuum chamber.[2] The use of ultrasound in such processes is often referred to as "sonoevaporation" or "sonochemical evaporation." This technique has several applications in various fields, including chemistry, materials science, and industrial processes. A study conducted by Trushlyakov et al. investigated the process of heat and mass transfer in the evaporation of model liquids (distilled water, alcohol mixture, kerosene TC-1) in a vacuum chamber under parametric ultrasonic influence and vacuum influence on a liquid with the purpose of using the obtained results for the development of methods for designing the evaporation system of unused liquid residues of rocket fuel remaining in the launch vehicle tanks at the end of the mission [3]. The study found that the evaporation rate increases with increasing amplitude of the bath bottom vibrations, with the highest evaporation rate under the same conditions for kerosene TC-1 [3],[4]. Ultrasonic waves create cavitation bubbles in the liquid, which implode and generate shockwaves upon collapse. These shockwaves can increase mass transfer rates, leading to more efficient evaporation. The agitation caused by cavitation bubbles can also prevent the formation of a stagnant layer at the liquid-vapor interface, which can hinder evaporation in a vacuum. Ultrasonic evaporation can be used to promote the crystallization of solutes from a liquid, making it a valuable technique for processes like freeze-drying and also other similar technology. [5],[6].

Ultrasonic Atomizers (UA) can potentially augment the production of sea salt through a process known as ultrasonic nebulization [7], [8]. While the traditional method of sea salt production primarily relies on natural evaporation, ultrasonic atomization can accelerate the evaporation process and improve the yield in controlled environments, such as greenhouses or specialized facilities. In the first step, we can collect and filter seawater to remove larger debris and contaminants, as in traditional sea salt production and then an UA uses high-frequency sound waves to break up liquid into tiny, fine droplets or mist. In sea salt production, seawater will be passed through an ultrasonic nebulizer or atomizer, which creates seawater droplets.[9]

2. METHODS

2.1 Study and Literature Review for Sea Salt Productions Methods

A preliminary study has been conducted to one of the sea salt farming in Kusamba village. This village is a coastal area in the Klungkung regency, Bali province-Indonesia. This village has several farming that produces table salt from sea water in the coastal area of Kusamba bay. Kusamba, a village in the Klungkung region of South Bali, is known for its traditional salt farming practices [10]. The salt farmers in Kusamba use a centuries-old technique to produce 100% natural salt by sun and wind evaporation. The process begins with the farmers repetitively fetching seawater in palm leaf buckets on carrying poles, then splashing them out onto the smoothened black sand under the scorching sun. The salt begins to crystallize after several hours of drying. The mid-day tropical sun bakes the sand into flakes and the salt is ready to be harvested by late afternoon. The farmers take the flakes to the salt-making hut where more seawater is added to leech the salt over several days. The resulting brine is placed in long troughs for further evaporation. The sea salt produced in Kusamba is often characterized by its coarser texture and natural purity. It is typically unrefined and retains some of the minerals and trace elements from the seawater, giving it a unique flavor and appearance. Many people appreciate the taste and quality of this traditional sea salt, which is often sought after for culinary purposes and as a souvenir from the region.

Visitors to Kusamba may have the opportunity to observe the salt farming process and purchase locally produced sea salt as a memento of their visit. It's a traditional and sustainable practice that has been a part of the local culture for generations. Kusamba farmers yield a few kilograms of salts per day on average and the process is dependent to the sunny day, which means it can only be produced during the dry months. Despite the intensive process of sea salt making, Kusamba’s salt farmers live in the natural beauty of the beach environmental with shiny-black and mineral-rich sand. This preliminary study also reported that these farmers might be the last generation of salt farmers in Bali since fewer young generations are interested in doing this job. In this study, we are also looking for potentials technology that can increase the capacity of productions of the sea salt farmer. A controllable technology and simply to operate will transform to sustainable salt farming and improving the economic growth of the sea salt farmer.

To increase the salinity of seawater for sea salt production, one of the possible viable strategies is to improve the rate of brine evaporation [11], [12]. The traditional method of harvesting salt relies on the rate of brine evaporation utilizing free solar energy. However, to meet the rising demand for salt, increasing the rate of brine evaporation is one of the possible viable strategies to improve the yield of solar salt production. Several researchers have looked at various methods to enhance the evaporation rate of brine. The various practical approaches reported in the literature for the enhanced brine evaporations are the use of different kinds of materials, mechanical devices, different types of dyes, carbon foam-based porous media, hollow carbon beads, etc. Few literatures discussed the maximum use of renewable energy approaches such as solar energy and wind energy to enhance the brine evaporation [13],[14].

Crystallization is a separation process that relies on the limited solubility of salt in a solvent at a certain temperature and pressure [15]. Nucleation spontaneously commences as the ion concentration exceeds that of the saturated solution. A cluster of crystalline atoms forms firstly in the solution. The crystalline cluster must a attain mass sufficient free energy to surpass the energy needed to establish an interface between the crystalline phase and the liquid. The nucleation thermodynamics can be understood by considering the interplay between interfacial free energy and the difference in free energy between the liquid and crystal.

2.2 Parameters and Variables for The Phenomenon of Liquid Atomization Ultrasonically

The piezoelectric effect is a phenomenon where certain materials, like quartz or ceramics, generate an electrical charge when subjected to mechanical stress, and conversely, they experience mechanical deformation when an electrical voltage is applied. In ultrasonic atomization, the piezoelectric transducer undergoes various phenomena to create the fine mist. The piezoelectric transducer is driven by an alternating electrical signal, usually at ultrasonic frequencies (higher than 20 kHz). When the electrical voltage is applied to the piezoelectric material, it undergoes rapid mechanical deformation or vibration due to the piezoelectric effect. The transducer's diaphragm or surface oscillates at the same ultrasonic frequency.

Ultrasonic atomization, which involves the generation of fine droplets or mist using high-frequency sound waves, relies on a piezoelectric transducer as an actuator. The piezoelectric effect is a phenomenon where certain materials, like quartz or ceramics, generate an electrical charge when subjected to mechanical stress, and conversely, they experience mechanical deformation when an electrical voltage is applied. In ultrasonic atomization, the piezoelectric transducer undergoes various phenomena to create the fine mist. In the case of ultrasonic atomization of a liquid, the piezoelectric transducer is typically in direct contact with or submerged in the liquid to be atomized. The rapid mechanical vibration of the transducer generates high-frequency pressure waves in the liquid. These pressure waves create tiny, high-velocity liquid jets that break up into fine droplets or mist. This is often referred to as the Rayleigh-Taylor instability, where the liquid jet disintegrates into droplets due to the pressure fluctuations caused by the ultrasonic waves. The size and characteristics of the droplets can be controlled by adjusting the frequency and power of the piezoelectric transducer.

The phenomena of liquids atomization were first reported around 1927. Ultrasonic atomization is a process driven by the intricate interplay of shock waves, vibration amplitude waves, and surface tension, all stemming from the phenomenon of cavitation beneath the liquid's surface. Once the amplitude reaches a critical threshold, tiny droplets are propelled from the wave crest, coalescing into a fine mist. These remarkable ultrasonic atomizers harness the power of ultrasonic waves to transform liquids into minute droplets or a delicate mist, with the ability to fine-tune droplet size simply by selecting the appropriate ultrasonic frequency.[16]

Despite a significant amount of study, the process of droplet formation when exposed to the range ultrasound is still not entirely understood. Two main phenomena have been proposed, such as: cavitation wave and capillary wave. Prior studies proposed the relationship between ultrasonic driven frequency and diameters of droplets. When ultrasonic vibration is reached to a liquid surface, a capillary wave is generated and the wavelength of ultrasounds which is shown by equation [17][18]:

$$\lambda = 0{,}34\left(\frac{8\pi\sigma}{\rho f^2}\right)^{1/3} \quad \dots\dots 1$$

Where λ is the wavelength (m), σ the surface tension (N/m), ρ is the density (kg/m^3) and f is the frequency of surface waves, considered as the half of the device ultrasound frequency. Lang calculated a constant number-of 0.34 for the averaged droplet diameter produced by ultrasound at frequencies between 10 and 800 kHz. The capillary wavelength is consistently divided by the mean diameter.[19]. Then, the constant was modified to 0.96 for averaged droplet diameter of aqueous alcohols solution [20] The average droplet size anticipated by Lang's calculation would fall into multiple micrometer ranges when aqueous solutions were atomized using 1-2 MHz ultrasound.

Another study introduced dimensionless numbers that combined the physico-chemical characteristics of the atomizing liquid with the operating parameters of the ultrasound to propose a connection [21], which is given below:

$$\lambda = \left(\frac{\pi\sigma}{\rho f^2}\right)^{1/3}\left[1 + A(N_{We})^{0.22}(N_{Oh})(N_{In})^{-0.0227}\right] \quad \dots\dots 2$$

N_{we} was defined by weber number and also another dimensionless number (N_{Oh}) was indicated by Ohnesorge number. A Novel dimensional number was defined by Intensity number (N_{In}). it was introduced as an ultrasonic intensity. The Weber number (We) is a dimensionless number in fluid mechanics that is used to analyze fluid flows where there is an interface between two different fluids, especially for multiphase flows with strongly curved surfaces. The Ohnesorge number (Oh) is a dimensionless number that relates the viscous forces to inertial and surface tension forces. it is used to relate to free surface fluid dynamics such as dispersion of liquids in gases and in spray technology.

2.3 Research Apparatus and Devices Measurement

Particularly before the crystallization stage, brine processing is one of important role in sea salt production. It involves concentrating and purifying the brine, which is the highly concentrated saltwater solution, to prepare it for salt crystal formation. Ultrasonic atomization can be employed in various stages of brine processing to enhance efficiency and yield. As the first step, the collected seawater is typically passed through filtration systems to remove larger debris and contaminants. The salinity of this water is typically close to the natural seawater salinity, which is about 35,000 ppm. The seawater is concentrated to increase the salt content (salinity). This concentration is usually done by evaporating some of the water. Ultrasonic atomization can be used to create a fine mist or spray of the concentrated brine. This mist has a higher surface area and facilitates faster evaporation.

The role of ultrasonic atomization in brine processing lies in its ability to create fine sprays or mists that increase the surface area of the liquid exposed to the environment, thus accelerating the evaporation and crystallization processes. This can result in more efficient salt production with potentially higher yields. Ultrasonic atomization also offers the advantage of being controllable and adaptable to different processing conditions. It can help maintain consistent and favorable conditions for salt crystallization and minimize the risk of impurities or uneven crystal formation. Overall, ultrasonic atomization can be a valuable tool in enhancing the brine processing stage of sea salt production, ultimately leading to higher-quality and more efficient sea salt production.

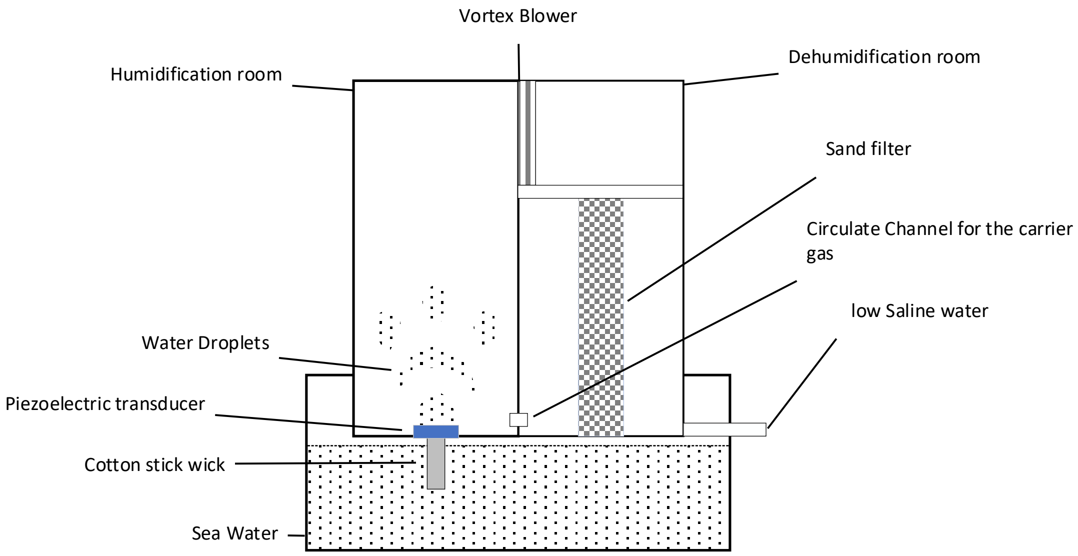

Figure 1. Experimental apparatus for brine production

We have conducted an experimental for understanding the behavior of ultrasonic vibrating mesh in brine processing. This testing apparatus involves two chambers, such as: humidification chamber and dehumidification chamber. The humidification chamber is a chamber that has been installed a piezoelectric. This is an actuator to process atomization ultrasonically. Then in other side, dehumidification chamber will distill the mist into liquid solutions. Measurement devices used in this research to obtain data from brine, include: Total Dissolve Solid (TDS) in water and weighing measurement to indicate the bottom product. TDS of brine solutions were measured by using a portable Digital Salinometer which have wide range measurement 0.00-9.99 ppm and also 1.00 ppt-50.0 ppt. This measurement device depends on the specific research and the type of data being collected. Weighing measurement is a process of determining the output weight of lower saline water, in every 30 minutes data collecting. It also measured the TDS of fresh water production. In the figure 2, schematic of the water purification system has been shown by the functional equipment and the component. An ultrasonic module is needed to drive a piezoelectric transducer ultrasonically.

Distilled water had been used to make initial brine concentrations and number of grams. Normal concentrations of sea water are 35 ppt. We need to prepare brine solutions with a salt concentration of 35 ppt. In this work, we have to add 30 grams sea salt into 1000 ml of distilled water. These solutions will be tested in the apparatus that we have made to carry out the experiment.

3. RESULTS AND DISCUSSION

3.1 Increasing of Salt Concentrations by Ultrasonic Atomization

The process of ultrasonic atomization breaks down the liquid into droplets or mist. These droplets contain a portion of the salt from the original solution, but because they are smaller and spread out, the concentration of dissolved solids in each droplet is lower than in the original liquid [22]. In this testing, the range of Total Dissolved Solids (TDS) of brine water that was prepared has been measured. Brine solutions is 35 ppt. Then, brine water in the container measured for duration time in every 30 minutes. In figure 3, we can show that the number of TDS will be indicated increasing of TDS irregurally in every testing. The average TDS of pure water calculated to 354.6 ppm and the lowest TDS is 35.6 ppm.

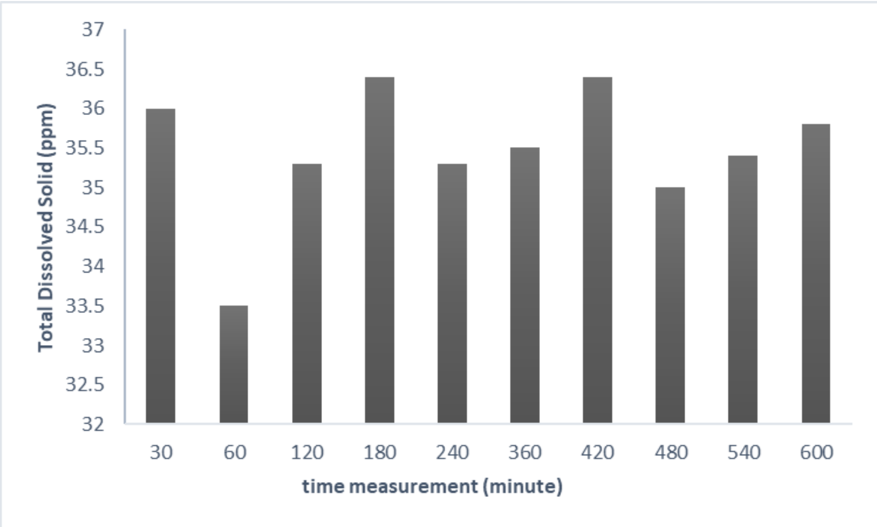

Figure 2. TDS of Brine in container

The specific influence of decreasing TDS will depend on factors such as the initial TDS concentration, liquid properties, atomizer design, and operating conditions. Therefore, it is recommended to conduct thorough experimental investigations or consult scientific literature for a more detailed understanding of the influence of decreasing TDS in a specific application. The presence of dissolved solids in a liquid can affect the size distribution and uniformity of the atomized droplets. Higher TDS levels may result in larger droplets or uneven spray patterns. By reducing TDS, it is possible to achieve finer droplet sizes and more consistent spray characteristics.

3.2. Productions Rate of Brine

This experiment was carried out by utilizations of apparatus that due to brine solutions as the bottom's product. Measurement of brine concentrations will be indicated by the reductions of TDS in saline water output. Flow rate of saline water will be reaching the minimization of brine. Even though, it can be analyzed to the brine productions as other part of productions output.

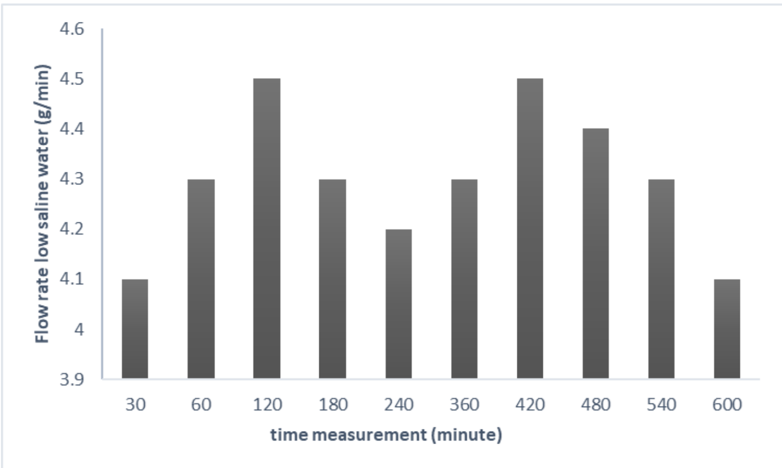

Figure 3. Flow Rate of saline water output

Figure 3 show that the irregular conditions conclude in the collecting of the low salinity water output. The design of this apparatus led to difficulty of collecting the output of low salinity water. Residue of the pure water has been inhibited when collect the output. The average output flow rate is 4.3 g/min. After 10 hours of testing, 1 liter of saline water can be separated to 0.8 l of brine solutions (36.5 ppm). This technique can produce brine as bottom product with 80% efficiency rate.

Ultrasonic vibrating mesh can improve liquid separation techniques through a phenomenon known as ultrasonic atomization. When a liquid layer or dense liquid is subjected to power ultrasound, fine mist is produced from the liquid surface. This process is characterized by the following points:

- Very fine droplets, ranging from several to several tens of micrometers in size, are obtained with a narrower size distribution.
- There is no need to pressurize the fluid, making the equipment simpler.
- The droplet density and transfer can be easily controlled.
- Ultrasonic atomization is used in various fields that require fine droplets or aerosols due to their small size and narrow size distribution. Compared to conventional nozzles that use high shear to break up liquid, ultrasonic at-omization produces smaller droplets with a narrower size distribution [19],[20]. The phenomenon of atomization by vibrating meshing occurs in frequency 120 kHz as the frequency that generates by ultrasonic module. It enables solute partitioning between mist and bulk liquid, which has led to new aspects of separation in ultrasonic atomization.

3.3. Disadvantages to Transfers this Technology into the Industrial Practice

Brine preparation ultrasonically is a relatively recent technique. More research and analysis will be required by researchers to make ultrasonic systems easier to design. They must continue to build theoretical data models in order to standardize the design of ultrasonic devices. Once these models are created, we will be able to use ultrasonic devices more regularly. Most significantly, we will be able to scale them up to filter larger amounts of water.

Ultrasonic technology can be expensive to maintain. This is related to the repair and maintenance of the ultrasound probe, which becomes damaged during ultrasonic activity. If ultrasonic devices fail, they may require the services of an expert to be repaired. This requirement may cause a region to be without water treatment for an extended period of time. As a result, technologies that are less expensive and easier to fix are becoming increasingly popular. Hopefully, ultrasonic technology will become more widely available, dependable, and economical. This technique is yet another useful instrument for making sea salt for household appliances.

4. CONCLUSION

The potentials of ultrasonic atomization in brine processing lies in its ability to create fine sprays or mists that increase the surface area of the liquid exposed to the environment, thus accelerating the evaporation and crystallization processes. This can result in more efficient salt production with potentially higher yields. Ultrasonic atomization also offers the advantage of being controllable and adaptable to different processing conditions. It can help maintain consistent and favorable conditions for salt crystallization and minimize the risk of impurities or uneven crystal formation. Overall, ultrasonic atomization can be a valuable tool in enhancing the brine processing stage of sea salt production, ultimately leading to higher-quality and more efficient sea salt production.

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