Seawater distillation using vacuum pumps and ultraviolet lights to improve desalination process and freshwater quality

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Abstract. Lack of clean water supply quantitatively because of 97% water in earth is seawater with 35% salinity. One effort that can be done to overcome the clean water crisis is through desalination of seawater to produce water with low salinity. Some of the desalination methods that ever existed were MSF (Multi Stage Flash Distillation) and Reverse Osmosis. However, both of these methods have high investment cost. Therefore, a cheaper and easier method to apply such as distillation is required. In this research, distillation system is made of stainless steel and aluminium combined with vacuum pumps and ultraviolet lights. The use vacuum pump can speed up the evaporation process of seawater. Ultraviolet lights function to degrade heavy metal pollutants and eliminate harmful bacteria. Tests carried out include evaporation rate and water quality. This technology can increase water productivity up to 2 times and water quality shows a decrease in some pollutant parameters including 99.7% TDS, 99.93% salinity, 100% total coliform, and heavy metals Fe of 96.1%, Cr of 90.33% and Zn of 98.9%, and pH of seawater being neutral from 7.5 to 6.9. The technology has the potential to be applied to the community.

1. Introduction
Clean water is the most important requirement for human activities. Quantitative lack of clean water is due to 97% of the water on earth being seawater. Seawater has an average salt content of 35%. This means that for every one litter of seawater there are 35 grams of salt dissolved in it [1]. This high salinity level makes seawater cannot be consumed directly, so the processing needs to be done first. In addition, fresh water content is also declining due to sustainable development without regard to the environment to minimize the area of infiltration of rainwater. The freshwater content in the soil is dwindling as it is taken continuously so that more seawater is absorbed into the soil replacing the freshwater position.

In the world's the average sea water oceans has a salinity of 3.5%, which means that for every litter of sea water there is 35 grams of salt dissolved in it. The main salt content found in seawater include chloride (55%), sodium (31%), sulphate (8%), magnesium (4%), calcium (1%), potassium (1%), and the rest (less than 1%) consisting of bicarbonate, bromide, borax acid, strontium, and fluoride. The presence of these salts affects the physical properties of seawater such as density, compressibility and freezing. Water with salinity is certainly not consumable.

Seawater with a high salinity level can actually be used as one solution to meet the needs of clean water by separating the content of mineral salts dissolved with water through desalination.
Desalination technologies have been used rapidly over the past few decades throughout the globe to produce clean drinking water from seawater to improve the quality of already existing supplies of fresh water for human consumption. Several methods of water desalination ever existed were MSF (Multi Stage Flash Distillation) and Reverse Osmosis. However, the disadvantage of these two methods is to have a high investment cost. Therefore, a cheaper, and easier to apply method such as distillation is required.

One of the desalination methods available is distillation. Distillation is a method of separating seawater with salt by heating seawater by utilizing sunlight to produce water vapour, which is then condensed to produce clean water. Distillation can separate mineral salts such as sodium chloride (NaCl), calcium carbonate, magnesium sulphate, and magnesium bromide from water compounds (H2O) so that clean water is produced with a total value of dissolved solids or small TDS (Total Dissolved Solid). Distillation also has the ability to reduce the concentration of various kinds of pollutants including suspended solids, heavy metals, organic matter, ions and radionuclides. However, in its application, the conventional distillation method takes a considerable amount of time and much water falls back into the evaporative container during the condensation process [2].

Increasing the temperature difference between the water cover is the focus when trying to improve the rate of condensation, and consequently the productivity of the still is increased. This can be done by either decreasing the cover temperature or increasing the water temperature. Continuous supply of water film is fed over the cover in order to reduce the temperature. However, this method requires raising the water container to the level of the highest part of the still or using pump water. Therefore, the using vacuum pumps on distillation system is right solution. Water pumps are machines or mechanical equipment used to raise fluids from lowlands to highlands or to drain fluids from low-pressure areas to high-pressure areas. The water pump can be a booster flow rate on a piping network system so that the water speed is faster. By exploiting the nature of this vacuum pumps placed in the distillation system it can speed up the increase of water temperature and water evaporate faster.

Ultraviolet lights have attracted much attention because of their application in the decolourization of bacteria and harmful pollutants such as dyes, chemicals, and toxic gases. UV light can replace sunlight in sterilizing the results of evaporation of seawater against bacteria that remain after the evaporation process. The use of UV with medium pressure mercury lamps can produce ultraviolet radiation output that is greater than lethal mercury low pressure lamps for protozoan microorganisms, viruses and algae [3].

The goal of this study is to develop a optimize the freshwater productivity by distillation method using vacuum pumps and ultraviolet lights as accelerator and degradation with good visible-light driven activity and effectively solve desalination by distillation method problem [4]. By using vacuum pumps and ultraviolet lights, the seawater can evaporate faster and improve freshwater productivity and quality.

2. Methodology
This technology is made from stainless steel and aluminium, the use of aluminium aims to hold the heat received so that the system heat faster and as a good conductor to receive heat from an electric stove. With these materials, the heat can be channelled well to seawater so that the desalination process can take place faster.

Vacuum pumps are used for accelerators and accelerate the process of evaporation of seawater. The vacuum pump used is a pump type vacuum pump rocker 300 oil. This vacuum pump is placed in the upper corner of the beam-shape evaporated water container. The vacuum pump can suck and drain the water vapour received through the water in the evaporation process of seawater so that waters from the desalination process is received more and the desalination process can take place faster [5].

Ultraviolet light is used to produce ultraviolet light. Ultraviolet lights used are ultraviolet lamps with a sterilization rate of 180 gpm (medium pressure). This ultraviolet lamp is placed in the evaporation water container. Ultraviolet light can sterilize the results of seawater evaporation of
bacteria and protozoa microorganisms, viruses and algae that remain after the evaporation process [6]. So that we get the results of clean water that comes out through the tap to the reservoir of clean water.

The distillation process is carried out on a laboratory scale. 5 L of seawater is put into a beaker and then covered on top with a box that is given ultraviolet light and combined with a vacuum pump. The technology tests carried out include the speed test of the desalination process and the water quality test of desalination results including heavy metal Atomic Absorption Spectrophotometry (AAS) test, electrical conductivity adapter and multimeter test, concentration pH meter test, Salinity Meter salinity test, TDS tester turbidity and test MPN (Most Probably Number) of total coliform and E-coli bacteria.

3. Results and discussion
In this section, we discuss how to format the title, authors and affiliations. Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

3.1. Rate evaporation testing of water production speed
To determine the speed of production of water, in this technology testing is carried out on the effect of using a vacuum pump as a fixed parameter that continues to run during the desalination process. Water productivity testing is carried out by using the initial capacity of 5 litres of seawater.

Table 1 show effects of using vacuum pumps on water capacity. It can be seen that in the first 30 minutes after distillation heating without using a vacuum pump, the water produced was 200 mL, compared to distillation using a vacuum pump, the water produced was 400 mL, the use of this vacuum pump could increase the productivity of the resulting water twice as much distillation. This happens because the use of a vacuum pump can focus the direction of the water vapour produced [5]. It is different from without the use of a water pump where the direction of water vapour spreads to several parts such as the walls of the evaporation container so that it slows down the water production process.

| Desalination time | Volume without pump | Volume with pump |
|-------------------|---------------------|------------------|
| 30 minute         | 200 mL              | 400 mL           |
| 60 minute         | 450 mL              | 950 mL           |
| 90 minute         | 650 mL              | 1400 mL          |
| 120 minute        | 900 mL              | 1950 mL          |

3.2. Atomic Absorption Spectrophotometry (AAS) analysis
Atomic Absorption Spectrophotometry (AAS) (Figure 1) is one type of spectrophotometric analysis where the basis of its measurement is the measurement of absorption of a ray by an atom, a light that is not absorbed, is transmitted and converted into a measured electrical signal. Welsh (Australia) first introduced AAS in 1955. AAS is a popular method for metal analysis, because besides being simple, it is also sensitive and selective [7].

Figure 1. Atomic Absorption Spectrophotometry (AAS).
Table 2 can be explained that the test of this chemical parameter includes testing of heavy metals Pb, Cd, Cu, and Fe which were tested using the AAS (Atomic Absorption Spectrophotometry) testing method. From the results of testing the AAS heavy metals obtained results include, Fe decreased by 96.1%, Cr by 90.33%, and Zn by 98.9%.

| Characteristic test | Unit | Quality standard | Sea water | Distillation | Ultraviolet and distillation |
|---------------------|------|------------------|-----------|--------------|-----------------------------|
| Fe                  | ppm  | 7,4285           | 1,4491    | 0,2896       |
| Cr                  | Ppm  | 0,3              | 0,208     | 0,207        | 0,293                       |
| Zn                  | Ppm  | 0                | < 0,0001  | < 0,0001     | < 0,0001                    |

3.3. Salinity meter analysis

The more ions in water the greater the current value. Conversely, the fewer ions in the water, the smaller the current value. By decreasing the value of electrical conductivity, it also indicates that the water becomes tasteless because the ionic salt content has been reduced to solids so that it cannot deliver electricity anymore [8]. This is also proven by the reduced salinity of seawater [9]. It can be seen that the treatment using ultraviolet lamps can reduce salinity with an efficiency of 99.93%.

Table 3. Data result of salinity testing.

| Sample                  | Salinity | Unit | Method               |
|-------------------------|----------|------|----------------------|
| Sea Water               | 29.460   | ppm  | Salinity meter       |
| Distillation Water      | 165      | ppm  | instrument           |
| Distillation and UV Water | 20,7    | ppm  |                      |
3.4. pH meter analysis

Figure 3. pH meter analysis from seawater.  
Figure 4. pH meter analysis from distillation water.  
Figure 5. pH meter analysis from distillation and UV water.

The test results of the water pH before processing were 7.5 while the water after treatment was 6.9. A decrease in pH value to pH 7 (neutral). The deposition of impurities that make water acidic results in an increase in pH [10]. Moreover, in the presence of ultraviolet light it triggers a decrease in pH near pH 7 (neutral).

Table 4. Data result of pH concentrate testing.

| Sample                  | Value pH | Method     |
|-------------------------|----------|------------|
| Sea Water               | 7.5      | pH meter digital instrument |
| Distillation Water      | 6.5      |            |
| Distillation and UV Water | 6.9      |            |

3.5. Total Dissolved Solid (TDS) tester analysis

Figure 6. Total dissolved solid tester analysis from seawater.  
Figure 7. Total dissolved solid tester analysis from distillation.  
Figure 8. Total dissolved solid tester analysis from distillation and UV.
The total test results for dissolved solids before processing were 5670 ppm while the water after treatment was 17 mg / L. There was a decrease in the total value of dissolved solids 99.7%. The distillation function can reduce the value of dissolved solids. Dissolved solids are retained with mineral salts during the evaporation process. Impurity mass greater than the mass of evaporating water particles causes impurity particles to be lifted along with water vapour [11].

| Sample                  | Value TDS | Unit | Method                  |
|-------------------------|-----------|------|-------------------------|
| Sea Water               | 5670      | mg/L | TDS meter digital instrument |
| Distillation Water      | 22        | mg/L |                        |
| Distillation and UV Water | 17       | mg/L |                        |

3.6. Most Probably Number (MPN) analysis

The results of the bacterial test for total coliform of water before processing were 8400 MPN / 100 mL while the water after processing 0 MPN / 100 mL. There was a decrease in the total coliform bacterial value of 100%. During the desalination process, seawater is heated to cause some bacteria found in seawater to die due to the influence of high temperatures. In addition, the presence of ultraviolet lights can also reduce the amount of bacteria present in water. Ultraviolet light has a photon energy of 3.2 eV which can kill bacteria in water [12].

| Sample                  | Quantity | Unit     | Method |
|-------------------------|----------|----------|--------|
| Sea Water               | 8400     | MPN/100 mL | 0,399  |
| Distillation Water      | 3000     | MPN/100 mL | 0,121  |
| Distillation and UV Water | 0        | MPN/100 mL | 7,4285 |

4. Conclusion
Seawater distillation using a vacuum pump and ultraviolet light has been successfully carried out. A systematic study of the effect of vacuum pumps and Ultraviolet lamp content on changes in seawater temperature and water productivity during distillation and ultraviolet activity in degrading harmful
pollutant pollutants has been carried out. From testing the vacuum pump, the changes in water productivity increase, it can be concluded that the use of vacuum pumps affects water in increasing water productivity. From the AAS data, it can be seen that ultraviolet lights can reduce heavy metal content. From the results of bacterial tests, it can be seen that the bacteria contained decreased and died. Quality analysis shows that ultraviolet lamps are placed on the roof surface, degrades bacterial bacteria and harmful pollutant pollutants through the process of ultraviolet radiation. Test result of water quality show that seawater distillation with ultraviolet activity is better than conventional seawater distillation method.

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