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Utilization of the heat from combustion of water for the heating process in water desalination

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ABSTRACT

The volume of municipal waste has become a national problem so far, so a solution is needed to reduce the waste problem. One solution to reduce the volume of municipal waste is to burn waste. However, the combustion needs to be designed to take advantage of the heat generated by combustion. In this study, the process of burning waste with various types of waste materials was carried out. The heat of burning waste is used to evaporate 1 liter of seawater and the seawater vapor is cooled to produce distilled water. The volume of distilled water and the precipitated salt were weighed. The results of the research from the variation of 6 types of waste materials obtained that the type of clothing waste material gave the fastest time, which was 43.75 minutes, the amount of distilled water was 931 ml, and salt deposited as much as 30 grams. The test results on distilled water showed that almost all parameters met the requirements of drinking water and obtained a salt content of 84%. Further processing by adjusting the hardness is needed to process distilled water into clean water and the addition of iodine can be considered to produce iodized salt.

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1. INTRODUCTION

Industrialization, urbanization, and economic growth have all contributed to a sharp rise in the world's waste production [1]. According to World Bank statistics, municipal solid waste (MSW) produced worldwide reached 2.01 billion tonnes in 2016 and this is predicted to increase above 3.4 billion tonnes per year by 2050. The increasing volume of waste is due to two things, namely population growth and human behavior such as culture, lifestyle, and quality economy [2]. A dense population in an area has an impact on increasingly heterogeneous people's lives, which means there will be a diversity of lifestyles and different economic qualities. This also has an impact on the increasing volume of waste in an area [3]. The government's role in managing national waste has been stated in presidential regulation no. 97 of 2017 concerning national policy and strategy for the management of household waste and household-like waste. In the regulation, it is stated that the target in 2025 is a reduction of 30% and recycle 70% from the predetermined data [4]. One method of processing waste by burning waste is considered more effective than just stacking it. This is a method commonly used in developing countries [5].

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In addition to problems with waste management, there are also concerns about a clean water crisis. The water crisis is a global problem that is expected to worsen in the coming years. More than two billion people do not have access to clean water [6]. The biggest problem with the clean water crisis is climate change and pollution [7]. The supply of clean water can be supplemented by utilizing seawater, the percentage of the seawater on earth reaches 97% [8]. Another factor that increases water scarcity is the growth of urbanization and the depletion of freshwater resources [9]. The importance of utilizing alternative energy such as sea water to meet water needs by exploring technological development. Abundant sea water still contains complexes and large amounts of dissolved salts, so it needs to be treated through desalination [10]. Over the past 50 years, desalination has been the most frequently used technology to meet the demand for clean water supply. Desalination technology aims to be able to separate the salt content from sea water and clean water products that can be used for drinking water, industry, and agriculture so that research and development continue to be carried out to produce technologies that are more cost-effective and efficient.

The separation process with desalination technology can use a phase change process (thermal) through a continuous process of evaporation and condensation [11]. Distillation is the oldest and most commonly used desalination method [12]. Distillation is a separation method by heating sea water to produce water vapor, which is then condensed to produce clean water. The desalination process with the distillation method certainly requires thermal energy. Renewable energy is a solution as an energy source [13]. Previous research has reviewed several aspects of saving energy by replacing the use of fossil fuel energy in the desalination process using renewable energy that is integrated with the desalination process [14]. Even though several industries have taken steps towards implementing renewable energy in the desalination process, difficulties are still encountered due to the high energy demand which results in the high production capacity required. The selection of the factory location has also not found the best place because it needs to be installed with a renewable energy system [15]. The desalination process unit requires depreciation, maintenance, operations, employees, energy, chemicals, and insurance costs [16]. In addition, there will be additional costs if pre-treatment and post-treatment are carried out so that product costs can be estimated. The cost of desalination energy is calculated from the cost of processing steam and electricity determined from the power generation unit [17].

Utilization of waste as fuel in the process of heating sea water is a solution to reduce the accumulation of waste and the use of fossil energy. Plastic waste is better utilized as fuel than having to be stockpiled or disposed of into the sea which will certainly have a negative impact on marine ecosystems [18]. Non-organic waste is also a problem that causes environmental damage and takes a very long time to decompose [19]. The effectiveness of burning waste in reducing waste reaches 80-90% [20]. In this research, several types of waste were burned to evaporate sea water to obtain distilled water and salt. The need for each type of waste material and the duration of desalination to evaporate 1 liter of sea water can be known from this research.

2. RESEARCH METHOD

2.1. Time and place of research

The research was conducted from 18 July 2022 to 12 August 2022 at the Faculty of Industrial Technology, Ahmad Dahlan University. Tests for the content of sea water, distillate water, and mineral water were carried out by the UPT Health Laboratory in the city of Yogyakarta, located on Sisingamangaraja Street no. 21 Brontokusuman, Mergangsan, Yogyakarta. While testing for salt content was carried out by the DIY Health Office located in Ngadinegaran MJ III/62 Yogyakarta.

2.2. Research tools and materials

This study used sea water from Parangtritis Beach in Yogyakarta and various types of waste from the Sleman area of Yogyakarta as research materials. The varied waste consists of charcoal, plastic, leaves, twigs, cloth, and paper. The tools used in the seawater desalination process consist of a furnace, presto, aluminum pipes, buckets, hoses, thermometers, static, fans, scales, measuring cups, used bottles, stopwatches, spoons, and plastic.

2.3. Research procedure

The seawater desalination process begins with preparing the tools and materials to be used during the experiment. After the tools and materials are ready, the experimental equipment is assembled as shown in Figure 1. Before burning, the variable waste to be burned is weighed first, and then 1 liter of sea water is prepared which is then put into the presto. The burning process begins after the presto is placed on the stove. The stopwatch is run to determine the burning time until the sea water has completely evaporated. The steam resulting from condensation on the aluminum pipe is cooled by contacting it by convection with cooling water. The cooling water temperature is maintained at 30 °C and the temperature is controlled by changing

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the water in the bucket. When the aluminum pipe has no water dripping anymore, this shows that the water in Presto has all evaporated, then the desalination process. Then the weight of the salt in the presto and the volume of condensed water in the bottle are weighed. Furthermore, the content of sea water, distillate water, mineral water, and salt is tested.

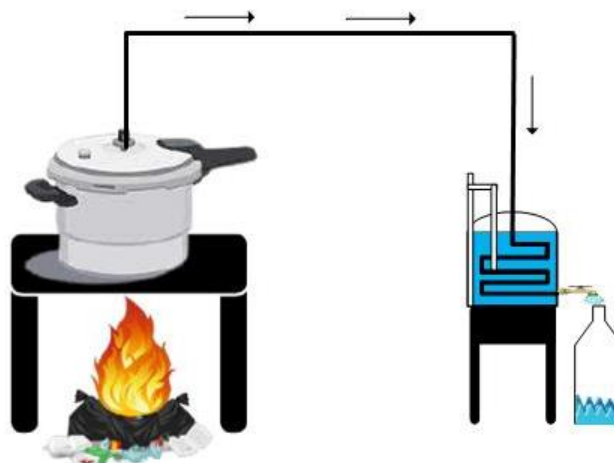


Figure 1. Desalination process equipment

3. RESULTS AND DISCUSSION

3.1. Comparison of evaporation time with the amount of water and salt based on various types of waste burned

Desalination process of 1 liter of seawater using a variety of organic and non-organic waste. The desalination process is carried out by utilizing heat from burning waste. The experiment was carried out 3 times for each type of waste. Research data on various types of waste can be seen in Tables 1 and 2.

Table 1. Research results on various types of charcoal, plastic, and leaf waste

No	Parameter	Charcoal			Plastic			Leaf		
		1	2	3	1	2	3	1	2	3
1	Evaporation time (minutes)	136	131	143	50.8667	53.05	57.1667	101	117	108
2	Waste weight (kg)	2	2	2	0.89	0.818	0.849	1.9	1.7	2
3	Distilled water volume (ml)	872	920	976	915	965	974	965	895	930
4	Distillate water weight (g)	869	918	943	879	933	941	935	865	897
5	Salt weight (g)	26	29	28	26	28	31	29	31	30

Table 2. Research results on variations in the types of twigs, cloth, and paper waste

No	Parameter	Twigs			Clothes			Paper		
		1	2	3	1	2	3	1	2	3
1	Evaporation time (minutes)	49.9833	46.6167	46.9	43.75	43.85	45.0667	55.5667	58.15	59.9167
2	Waste weight (kg)	2	2	2	1	1	1	1.4	1.5	1.8
3	Distilled water volume (ml)	935	970	918	931	824	956	940	929	951
4	Distillate water weight (g)	894	924	877	895	790	923	904	895	914
5	Salt weight (g)	28	28	29	30	30	31	30	32	28

Based on the data in Tables 1 and 2, it can be concluded that the type of waste that can vaporize 1 liter of seawater in the fastest time is fabric-type waste in 43.75 minutes, the volume of distillate water is 931 ml and salt deposits are as much as 30 grams. The use of cloth-type waste for evaporation of seawater is more effective than charcoal, leaves, twigs, and paper because only 1 kg of waste can carry out the fastest evaporation process. This also correlates with the results of the average calculation in Table 3. It is known that the fastest average evaporation time is using a type of cloth waste with a time of 44.2222 minutes. In

28 addition, it can also be seen that the weight of the salt produced from the desalination process is in the range of 26 to 32 grams. The highest gain of salt content occurred in the use of paper waste with a weight of 32 grams. Based on the calculation of the average research results, it is known that the evaporation time sequence starts from the fastest, namely cloth (44.2222 minutes), twigs (47.8333 minutes), plastic (53.6945 minutes), paper (57.8778 minutes), leaves (108.6667 minutes), and charcoal (136.6667 minutes).

Table 3. Average of research results

No	Parameter	Charcoal	Plastic	Leaf	Twigs	Clothes	Paper
1	Evaporation time (minutes)	136.6667	53.6945	108.6667	47.8333	44.2222	57.8778
2	Waste weight (kg)	2.2333	0.8523	1.8667	2	1	1.5667
3	Distilled water volume (ml)	922.6667	951.3333	930	941	903.6667	940
4	Distillate water weight (g)	910	918	899	898	869	904
5	Salt weight (g)	27.6667	28.3333	30	28	30	30

3.2. Sea water content test results, distillate water, and mineral water

22 The water content test is carried out to determine the quality of water in the initial sea water content before the desalination process, distillate water, and mineral bottled water on the market according to quality standards. The composition of sea water before the desalination process presented in Table 4 has a major difference from the composition of distillate water presented in Table 5. The significant decrease in the mineral content of iron (Fe), manganese (Mn), fluoride (F), chloride (Cl), nitrate (NO₃-), nitrite (NO₂-), and total hardness before and after the desalination process can be observed in Tables 4 and 5.

Table 4. Seawater content test results

Parameter	Results	Unit	Quality standard	Method
Smell	smelly	-	smelly	Organoleptic
pH	7.5	mg/l	6.5-9.0	Potentiometry
Iron	0.029	mg/l	1.0	SNI 06-4138-1966
Mangan	0.019	mg/l	0.5	SNI 06-6855-2002
Fluoride	1.475	mg/l	1.5	SNI 06-6989.29-2005
Nitrate (NO ₃ -N)	2.690	mg/l	10	APHA 2017. Section 4500-NO3 B
Nitrite (NO ₂ -N)	0.003	mg/l	1.0	SNI 06-6989.9-2004
Total Hardness	61480*	mg/l	500	SNI 06-6989.12-2004
Chloride	20635.75*	mg/l	600	SNI 6989.19-2009
Flavor	Tastes salty	-	Tasteless	Organoleptic
Turbidity	11.6*	NTU	5	SNI 06-6989.25-2005
Temperature	23.3	°C	Air temperature ±3 °C	SNI 06-6989.23-2005
Color	5	TCU	15	Photometry

Table 5. Distillate water content test results

Parameter	Results	Unit	Quality standards	Method
Smell	smelly	-	smelly	Organoleptic
pH	6.7	mg/l	6.5-9.0	Potentiometry
Iron	<0.009	mg/l	1.0	SNI 06-4138-1966
Mangan	0.078	mg/l	0.5	SNI 06-6855-2002
Fluoride	<0.001	mg/l	1.5	SNI 06-6989.29-2005
Nitrate (NO ₃ -N)	4.454	mg/l	10	APHA 2017. Section 4500-NO3 B
Nitrite (NO ₂ -N)	0.006	mg/l	1.0	SNI 06-6989.9-2004
Total Hardness	1127.84*	mg/l	500	SNI 06-6989.12-2004
Chloride	108.35	mg/l	600	SNI 6989.19-2009
Flavor	Tastes salty	-	Tasteless	Organoleptic
Turbidity	13.5*	NTU	5	SNI 06-6989.25-2005
Temperature	23,3	°C	Air temperature ±3 °C	SNI 06-6989.23-2005
Color	30*	TCU	15	Photometry

The test results on distillate water showed that almost all of the parameters met the requirements for mineral water (Table 6). Hardness that has not yet reached the quality standard caused by the presence of carbonate ions can be overcome by increasing the potential of hydrogen (pH) through the conversion of bicarbonate ions to carbonate which has a neutral pH (+7). Chemical compounds that can be added to overcome problems with the hardness parameter are Na₂CO₃ or K₂CO₃ [21]–[23].

Table 6. Mineral water content test results

Parameter	Results	Unit	Quality standards	Method
Smell	-	-	-	Organoleptic
Flavor	Tasteless	-	Tasteless	Organoleptic
Color	0	TCU	15	Photometry
Turbidity	1.13	NTU	5	SNI 06-6989.25-2005
Temperature	23.4	°C	Air temperature ±3 °C	SNI 06-6989.23-2005
Iron	<0,009	mg/l	0.3	SNI 06-4138-1996
Fluoride	<0.001	mg/l	1.5	SNI 06-6989.29-2005
Total Hardness	86.92	mg/l	500	SNI 06-6989.12-2004
Chloride	12.31	mg/l	250	SNI 6989.19-2009
Mangan	0.021	mg/l	0.4	SNI 06-6855-2002
Nitrate (NO3-)	7.095	mg/l	50	APHA 2017. Section 4500-NO3 B
Nitrite (NO2-)	<0,006	mg/l	30	SNI 06-6989.9-2004
pH	6.8	-	6.8-8.5	Potentiometry

3.3. Comparison of levels of iodine salt and distillate salt

The results of the research from the desalination process, it was found that the salt was left behind in the presto during the separation process. The data for iodized salt in Table 7 is obtained from the salt that is commonly produced and consumed by the public. Based on Table 7 it is known that the yield of distillate salt has a content of 84.89%, so it is recommended to add iodine to produce iodized salt. Adding iodine to salt is effective in meeting the needs of iodine in the human body [24], [25]. The desalination process has a significant effect, but there are still drawbacks, namely hardness, turbidity, and color which are higher than the quality standards, and the purity of the salt produced is still low. High hardness is caused by the presence of bicarbonate ions which can be overcome by increasing the pH through the conversion of bicarbonate ions to carbonate which has a neutral pH (+7). In addition, chemical compounds can also be added to overcome problems in the hardness parameter, namely Na²CO₃ or K₂CO₃. The turbidity and color values in distilled water that have not reached quality standards can be overcome by advanced processes such as using membrane filtration and adsorbents.

Table 7. Salt content test results

Parameter	Unit	Result	Method specifications
Iodine salt	%	98.94	Titrimetry
Distillate salt	%	84.89	Titrimetry

4. CONCLUSION

We provide solutions for handling the volume of municipal waste by utilizing the burning of the waste to distill sea water. Waste that is obtained free of charge and used for the sea water desalination process provides many benefits such as producing fresh and salt water that the community needs. The salt obtained can be further processed into food salt or pharmaceutical salt. Apart from that, sea water desalination efforts can be a solution to the reduced availability of groundwater. According to our research, clothing material is the type of waste with the fastest time to evaporate 1 liter of sea water (43.75 minutes). The result of the distillate salt has a content of 84.89%. Further research is needed to improve the purity of the salt obtained and the addition of iodine to obtain the iodized salt needed by the community. Another thing is handling combustion smoke so that air pollution due to smoke can be minimized as much as possible

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