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The produced water temperature reduction system for oil and gas exploitation activities and impact on the environment

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ABSTRACT

Petrogas (basin) limited is an oil and gas mining company that has been operating in the Walio Petrogas (Basin) Limited Operations Area, Sorong Regency, West Papua Province since 1977. Oil and gas exploitation activities produced 60 ^oC produced water in KMT pond. Before being released to the sea, produced water needs to be controlled in order to meet the quality standards according to the Regulation of the Ministry of Environment No. 19 of 2010, which the minimum is 45°C. In this research the various number of sprinklers: 0, 2, 4, 6 and 8 were used along with 9 baffled aeration tub to control the water's temperature. The result of this study showed that the best treatment that reduced water temperature was 8 sprinklers, it reduced up to 33.5^oC. The next step was to analyze the temperature distribution patterns of the existing and planned temperature-reducing ponds with physical treatment using DHI MIKE 21 software, so it can be selected which pond had is the most effective in reducing the temperature of produced water into rivers and the sea. Based on the results of the analysis using DHI MIKE 21, the location of 300 meters from the outfall is the ZID area, where there was a continuous increase in temperature, so it was not possible to have aquatic biota such as seagrasses. Through this research, it is expected to be a consideration in improving the produced water's treatment for Petrogas, so it will not damage the environment.

Key words : *Produced water, Water temperature, Water quality standard, Sprinkler tub, Aeration tub, Water temperature, DHI MIKE 21*

Introduction

Industrial activities must produce waste, including oil and gas production. One of the waste generated from this industry is heat waste. According to Davis (1999), waste heat is a natural process that occurs due to the influence of the location or source of water and the application of the second law of thermodynamics.

The side product of oil and natural gas processing is called produced water. If this waste spreads throughout the marine waters, it will be very dangerous for the marine environment and the livelihoods of marine life, of course. This problem is compounded by the quantity of produced water, the volume of produced water can reach more than 90% of the total production of liquids and gases over the life of the oil well (Mukhtasor, 2016). The temperature of water that comes out of oil and gas activities (produced water) reaches 55 ^oC – 60 ^oC so that it is expected to affect the life of marine life and others. Therefore, it is necessary to conduct research to de-

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termine the impact of hot waste water disposal in its distribution area.

Methodology

The location of this study is in the Operations Area of Walio Petrogas (Basin) Limited, Sorong Regency, West Papua Province, precisely on the KMT Skimpit which was then prototyped in the form of a physical model in the Laboratory.

The prototype dimension is based on some data at the study site, the following data is needed:
1. Pool Size (A) = 1,929 m^2
2. Depth (d) = 19 feet
3. Volume (V) = 11,574 m^3
4. Debit Outlet (Q) = 200,000 BWPD (the highest debit in April 2018)

There are 3 analyzes performed in this study, the analysis of problems in the sewage treatment system, 2) Analysis of temperature lowering models, and 3) Analysis of compliance with wastewater quality standards.The steps to analyze can be seen in Figure 2. Data collection was performed using direct measurement methods in the field and physical models analysis in the laboratory.

Primary data

As for the dataprimer obtained, directly including:
1) Field Condition Data:
   a) Size of the Squeeze and cooling pool
   b) Temperature measurement data on the KMT Skimpit installation and its outlets.
2) Research Data
   a) Temperature measurement data from physical model analysis
   b) Climatology data of the prototype location
   c) Photos of study locations and prototypes
   d) Tidal data, water quality, and biodiversity of Wakanway River waters
   e) Coordinates of the research location
   f) Bathymetry map

Secondary Data

This data was obtained through relevant agencies or data purchases. The data referred to here is as follows:
1) Sorong Regency topographic data.
2) Map of Sorong Regency area.
3) Volume of Water Produced.
4) Data of Wind and Current Movements around PT. Petrogas (Basin) Ltd.

Fig. 1. Location of PT Petrogras (Basin) Ltd.

Source: Google Map, 2018

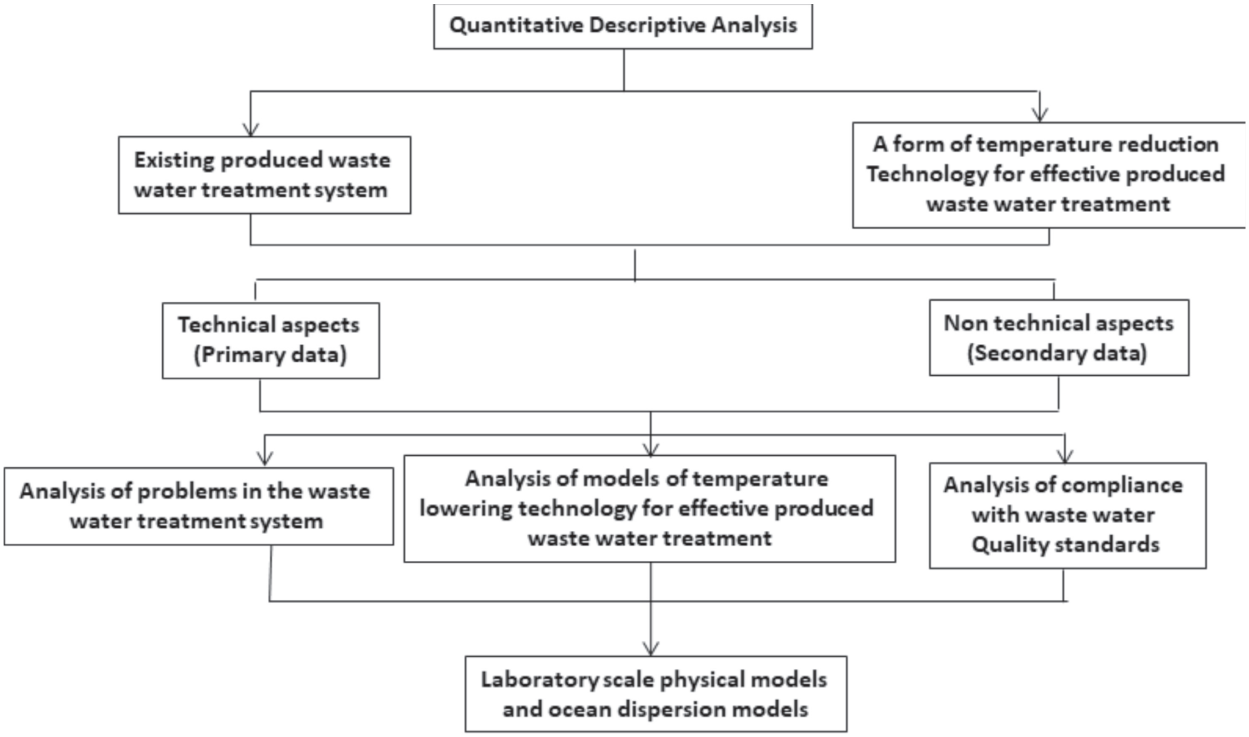

Fig. 2. Writer Analysis Framework
Source: Author's analysis, 2018

5) KMT Schematic Flow Scheme
6) Plan and Detail Cooling System

Results and Discussion

Laboratory Scale Physical Modeling

Debit Conversion

From the study location data, it is known that the discharge at the highest condition is 200,000 BWPD so it needs to be converted into units of m3 / s. The following is a description of the calculation of the debit conversion:

1 BWPD = 159 l/s
Debit (Q) = 200.000 BWPD
= 200.000 x 159
= 31.800.000 l/d

$$= \frac{31.800.000}{24 \times 60 \times 60} \times \frac{1}{1000}$$

= 0.368 m^3/sec

Based on the calculation of unit conversions, the discharge used for this study was 0.368 m^3/sec.

Full Time Calculation

The full time of a pond is influenced by the volume of the reservoir and the incoming discharge. So in the calculation using the formula of water discharge using the Skimpit pond pool volume data of 11.574 m^3 and the converted debit is 0.368 m^3/sec.

$$t = \frac{V}{Q} \quad .. (1)$$

$$= \frac{11574}{0,368}$$

= 31.451,087 seconds

$$= \frac{11.574}{(24 \times 60 \times 60)}$$

= 0.364 dayor 9 hours

Based on the calculation results, the time needed to meet the KMT Skimpit Pool is 0.364 days or equal to 9 hours.

Modeling Scale Calculation

There are 4 alternative scales that will be used as consideration for the selection of a scale model, namely 1:50, 1:40, 1:30 and 1:25. However, only one scale model will be used. The example calculation for the scale of 1:40 is as follows:

$$n_v = n_l^3 \quad .. (2)$$

$$\frac{Vp}{Vm} = n_l^3 \quad .. (3)$$

$$Vm = \frac{Vp}{nl^3} \quad .. (4)$$

$$Vm = \frac{11.574}{(40^3)}$$

$$Vm = 0.1808 \text{ m}^3$$

So if the pool volume in the pool is 11,574 m, then it will be 0.1808 m^3 if using a 1:40 scale. Other storage scale conversion results can be seen in Table 1.

Table 1. Calculation of Calculations for Each Alternative Modeling Scale

No.	Alternative	Scale	Vp(m^3)	NI3	Vm(m^3)
1	1	01:50	11574	50	0.0926
2	2	01:40	11574	40	0.1808
3	3	01:30	11574	30	0.4287
4	4	01:25	11574	25	0.7407

Source: Calculation Results, 2018

Vp = volume of existing storage (m^3)
Nl3 = Scale
Vm = model storage volume (m^3)

Determination of the scale of the storage volume in this study considers the cost, time, pump capacity, and no less important is the limited space to conduct research using the physical model simulation. So based on the results of the calculation of the storage volume model scale, the alternative chosen is alternative 2 with a scale of 1:40.

Debit Scale Conversion

It is known that the scale used is 1:40 so there needs to be a conversion of discharge from the scale of the model to the prototype scale. The calculations are:

$$= n_l^{5/3} \quad .. (5)$$

$$\frac{Qp}{Qm} = n_l^{5/3} \quad .. (6)$$

$$\frac{0,368}{Qm} = (40)^{5/3}$$

$$Qm = 3,6371 \times 10^{-5} \text{ m}^3/\text{sec}$$
$$= 36,371 \text{ ml/sec}$$

Based on the calculation of the discharge conversion, the debit from the Skimpit pond study location data of 0.368 m^3 is equivalent to 36.371 mL/sec or 36 mL/sec in the scale model (Qm) 1:40.

Calculation of Sprinkler Tub and Aeration Tub Reservoir Plans

This research used two storage tanks, sprinkler tanks and aeration tanks. Each tub has a different dimension.

1) Sprinkler tub

Planned:
Length (p) = 1.5 m
Width (l) = 1 m
Height (t) = 0.45 m

With the dimensions of the sprinkler tub as above, the volume of the sprinkler tub pool is obtained as follows:

$$V = p \times l \times t \quad .. (7)$$
$$= 1,5 \times 1 \times 0,45$$
$$= 0,675 \text{ m}^3$$

The sprinkler tub design can be seen in Figure 3 and Figure 4.

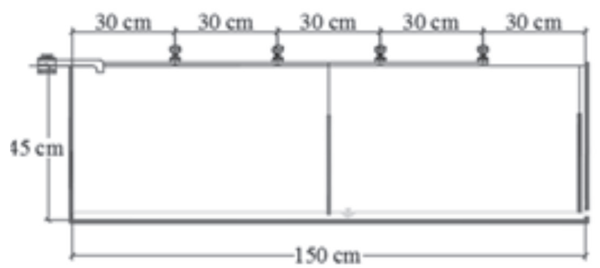

Fig. 3. Side View of Sprinkler Tub
Source: Auto Cad Design 2017, 2018

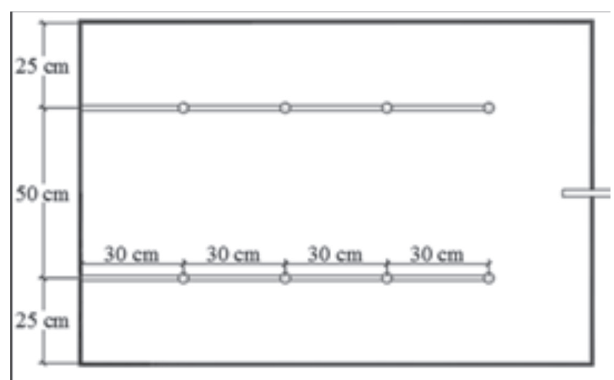

Fig. 4. Top View of Sprinkler Tub
Source: AutoCad Design 2017, 2018

2) Aeration Bak

Planned:
Length (p) = 2 m
Width (l) = 1 m
Height (t) = 0.45 m

With the dimensions of the aeration tank as above, we obtain the volume of the aeration basin as follows:

$$V = p \times l \times t \quad .. (8)$$
$$= 2 \times 1 \times 0,45$$
$$= 0.9 \text{ m}^3$$

The aeration body design can be seen in Figure 5 and Figure 6.

Fig. 5. Aeration Side View
Source: AutoCad Design 2017, 2018

Fig. 6. Top View of the Aeration Tub
Source: AutoCad Design 2017, 2018

So it can be seen that the total storage volume of the sprinkler and aeration tanks is as follows:
V total = V sprinkler tub + V aeration tub
= 0.675 + 0.9
= 1,575 m3

Pump Calculations

In this study, using two pumps, namely to drain water from the reservoir to the sprinkler tub and drain the water from the sprinkler tub to the sprinkler. The pump used in this study has the following specifications:

Model = DP-537
Maximum pressure = 0.68 MPa
Maximum speed = 4.0 L / minute
Volt = 12 VDC
Maximum strength = (60-65) W

Meanwhile, the discharge used in this study was 36 mL/sec which if converted to L/minute units the result was 0.0006 L/min. This means that the discharge used is still below the maximum pump speed, so that pumps with the DP-537 model can still be used.

Results

Based on the research that has been done, there are several things that can be conveyed, including:

1) Water that has a temperature of 60 ^{o}C is flowed to the sprinkler tub with the tub outlet closed. The stopwatch starts when the water flows into the sprinkler tub.
2) Water fills the sprinkler tub to a height of 1.5 cm, then pumped and flowed into the nozzle pipe to be crushed through a sprinkler that has been installed.
3) The condition of the closed sprinkler tub outlet results in height increasing to 3 cm, then the sprinkler tub outlet is opened so that water can flow into the aeration tub.
4) Water coming out of the sprinkler tub outlet is measured and tap/valve set up so that the discharge is 36 mL/sec. When the water discharge has reached 36 mL/sec, recorded at 23 minutes.
5) So that the reading of water height, discharge and water temperature is carried out at 23 minutes with time intervals every 5 minutes.
6) Water entering the aeration tank is allowed to flow with the condition of the aeration tub fully open until the discharge is 36 mL / sec.
7) Based on the results of the study, the majority of treatments had flowed 36 mL / sec discharge through the aeration tub outlet in the 63rd minute.
8) However, to ensure that the debit did not change, the analysis continued until the 68th minutes.

Results of Analysis of Water Height in Sprinkler Tubs against Time on Each Model

The results of the analysis of the height of water in the sprinkler tub showed high or low water that was accommodated in the sprinkler and aeration tanks during the study. The results of the analysis can be seen in Figure 7.

Based on Figure 7 it can be seen that the change in maximum water height increase of +0.6 cm from 3 cm occurred in model 2. The change in the maximum water height change - 0.2 cm from 3 cm occurred in model 3.

Changes in the increase and decrease in height can be caused by several factors including: instability of the inlet channel pump in flowing discharge from the main reservoir to the sprinkler tub, instability of the outlet sprinkler outlet to the aeration

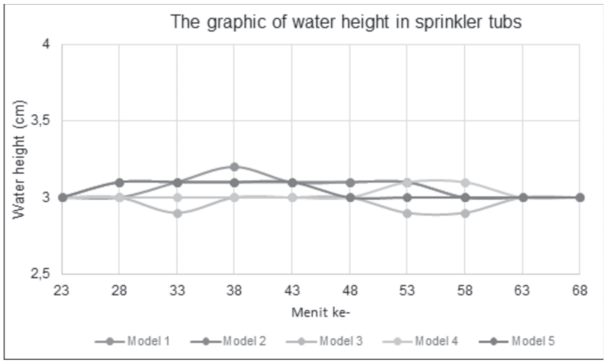

Fig. 7. Graphic Height in the Sprinkler Body against the Time of Each Model

Source: Research results, 2018

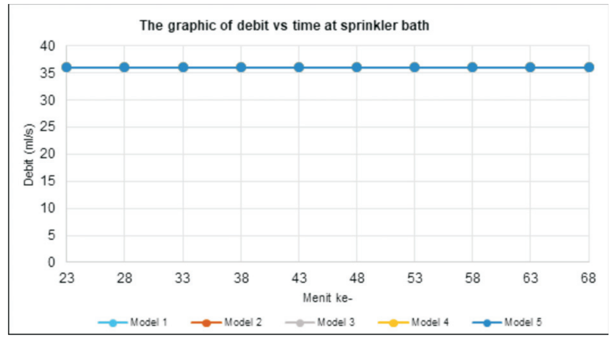

Fig. 9. Graph of Comparison of Discharge to Time in a Sprinkler Tub

Source: Research results, 2018

tub, and the water surface conditions that are bumpy at the time of measurement due to water fall from inlet and sprinkler ducts.

Results of Analysis of Water Height in Aeration Tubs Against Time on Each Model

Based on Figure 8, it can be seen that the height of water tends to increase. The increase in the height of water in each model in the aeration tank can occur because water is increasingly flowing from the end of the aeration tank to the aeration tank outlet.

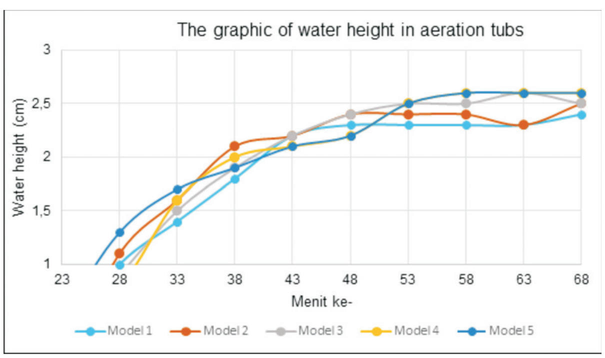

Fig. 8. Height Charts in the Body of Aeration aainst Time on Each Model

Source: Research results, 2018

Water Discharge Analysis Results

Results of Analysis of Water Discharge at the Sprinkler Bath Inlet

Based on Figure 9, it can be said that the ratio between the incoming debit to the inlet with the start time of the 23rd to 68th minutes in each model is fixed at 36 mL / sec.

Water Discharge Analysis Results at Aeration Box

In this study, aeration tub outlets were fully opened. Water discharge from the outlet of the aeration tank must be the same as the flow of water from the inlet of the sprinkler tub to reach equilibrium. The results of reading the flow of water at the aeration tub outlet can be seen in Figure 10.

Water Temperature Analysis Results

Water temperature analysis is reviewed through a comparison between thermometer 1 and thermometer 5.

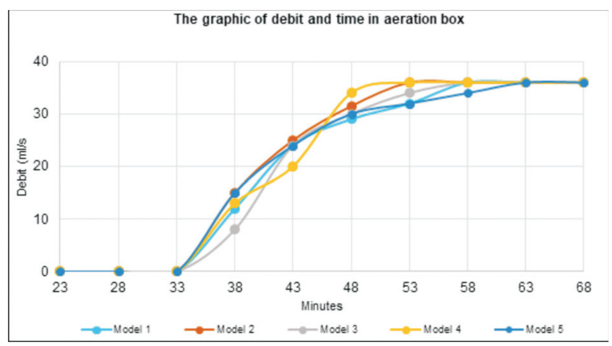

Fig. 10. Comparison Graph of Debit to Time Results at Aeration Box

Source: Research results, 2018

Water Temperature Analysis Results on Thermometers 1

Based on Figure 11 it can be seen that water still has a fairly high temperature, but it decreases with increasing time.

Water Temperature Analysis Results on the Thermometer 2

Based on Figure 12, it can be seen that water has decreased more than the thermometer 1. This is be-

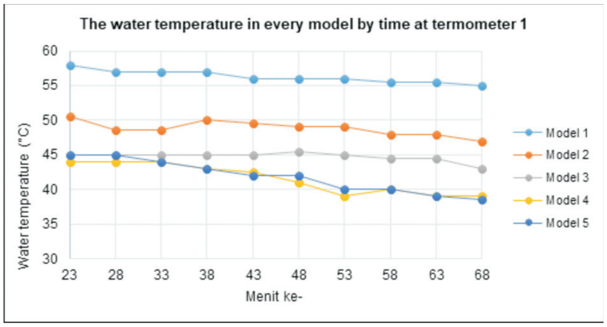

Fig. 11. Results of Air Temperature on Thermometer 1
Source: Research results, 2018

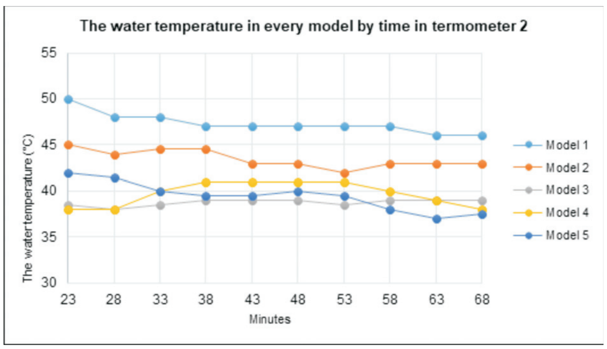

Fig. 12. Results of Air Temperature on Thermometers 2
Source: Research results, 2018

cause water has been affected by the amount of sprinklers used.

Water Temperature Analysis Results on Thermometers 3

Based on Figure 13 it can be seen that the water temperature tends to fluctuate from the 23rd minute to the 68th minute. This is due to the location of the thermometer in the mixing area so that the water temperature is still not stable.

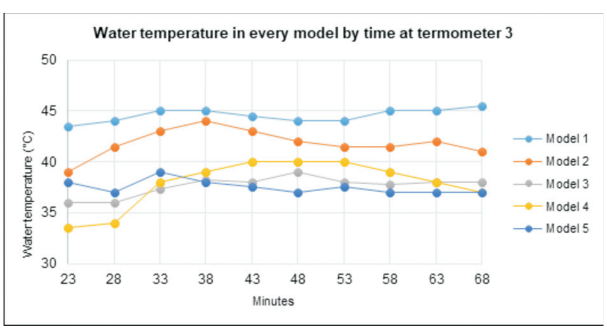

Fig. 13. Results of Air Temperature on Thermometers 3
Source: Research results, 2018

Water Temperature Analysis Results on Thermometers 4

Based on Figure 14 it can be seen that the lowest water temperature is at the 23rd minute, this is because the water still has not reached the thermometer 4. However the water temperature gradually increases because the water starts flowing and passes through the thermometer 4.

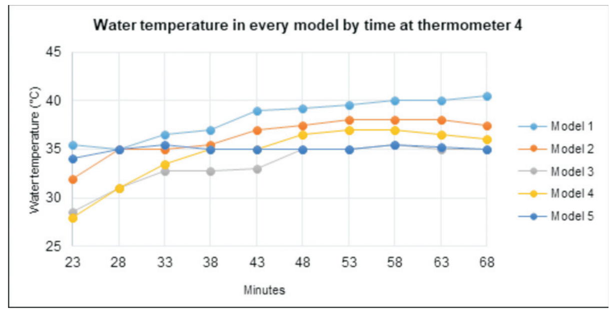

Fig. 14. Results of Air Temperature on Thermometers 3
Source: Research results, 2018

Water Temperature Analysis Results on Thermometers 5

Based on Figure 15 it can be seen that the water temperature in the 23rd minute is the lowest water temperature and has increased gradually until the 68th minute. The condition is the same as the condition in thermometer 4, that is water has not yet reached thermometer 5 in the 23rd minute.

Relationship of Meteorological Data to Water Temperature on Thermometers 5

Based on Table 2, it can be concluded that the results of the water temperature in each model are also influenced by factors such as weather conditions, air temperature, air pressure, dew point, wind speed and humidity.

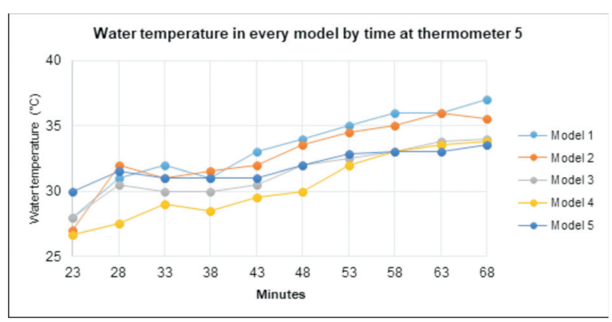

Fig. 15. Results of Air Temperature on Thermometers 5
Source: Research results, 2018

Table 2. Relationship of Meteorological Data to Each Model on the Thermometer 5

Meteorological data	Model				
	Model 1	Model 2	Model 3	Model 4	Model 5
Weather	Mostly sunny	Cloudy	Sunny	Sloudy	Cloudy
Air temperature (°C)	25.7	24.4	24.4	24	24
Pressure (kPa)	101.28	101.3	101.3	101.6	101.6
Thermometer temperature (°C)	27.5	28.7	25	2.5	28.5
Dew point (°C)	16	13	14	15	15
Wind (mg/j)	7	4	6	6	6
Humidity (%)	65	64	64	64	64
Sample temperature (°C)	60	60	60	0	60
Temperature of Thermometer 5 (°C)	37	35.5	34	33.8	33.5

Source: Research results, 2018

Factors of the variation in the number of sprinklers also influence, that is because the water that is destroyed by the sprinkler interacts with air. The more the number of sprinklers used, the more water fountains that also interact with air. This interaction is called heat transfer by convection. According to Ariffin (2001, p.80), the principle of the convection process is the transfer of heat from a medium to the air, and vice versa an example of a convection process is condensation and boiling.

The Study Implication

The results of this study are expected to be implicated for further research development and can be used as a reference to reduce the temperature of produced water to meet quality standards.The practical implications of the results of research on the reduction in temperature of waste water produced in the KMT Skim Pit using a temperature-lowering tub are as follows:

1) The data and results of this study can be used as a basic reference in reducing the temperature of waste water produced by the oil and gas industry so that it does not have a negative impact on marine biota.
2) Decreasing the temperature of waste water produced is used for commercial purposes so that it is designed to not cause other problems.
3) The temperature-lowering tub model is a combination of existing temperature-lowering innovations, namely spray pond and cooling pond which are expected to be effective, efficient and economical to reduce the temperature of produced wastewater.
4) The design of the temperature-reducing tub can be adjusted to the availability of land owned by each oil and gas industry.

Practical Implications for Policy

Based on the Minister of the Environment Regulation No. 19 of 2010 concerning the quality standards of land waste water from oil and gas exploration and production, the maximum temperature of waste water that can be discharged is 45oC. the results showed the final water temperature on the thermometer 5 is below 45oC or meets the quality standard.

So that this temperature-reducing tub can be used as an effort to realize the development of oil and gas industries that are safe for the marine ecosystem.

Conclusion

Based on the research results that have been obtained, there are several conclusions, including:

1) The more the number of sprinklers shows the more effective decrease in temperature. This is because, more and more water interacts with the surrounding air. So the process of reducing the temperature by the surrounding air is quite effective.
2) Sprinklers facing upward are more effective in lowering the temperature of the water because the jet of water from the upward sprinkler interacts with the surrounding air and takes less time to fall into the tub.
3) The magnitude of the temperature decrease is directly proportional to the thickness of the existing water conditions. This is known from the data which shows that the higher the water h the smaller the decrease in temperature that occurs.

4) Discharge 36 mL/S indirectly affects the temperature of the water in the temperature-reducing bath. This is because the water is stored longer in a sprinkler or aeration tank, so that the heat is stored longer.

Suggestion

There needs to be further development related to the research carried out in order to get more effective results from previous studies.
2. To the KMT Skim Pit must manage the temperature of waste water produced before discharging into the free environment and there must be optimization so that it does not damage the environment.

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