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LABORATORY EXPERIMENT OF HEAT PROPAGATION PATTERNS FROM BURNT PEAT SAMPLES IN JAMBI

(*Uji Laboratorium Pola Perambatan Panas pada Sampel Gambut yang Terbakar di Jambi*)

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ABSTRACT

Peat moisture content is one of the factors affecting peat fires. This study aimed to observe the effect of peat moisture content on the peat combustion process and the pattern of peat combustion at the laboratory test scale. We used a heating reactor measuring 10x10x10 cm^3 and a 3x3 thermocouple. This study revealed that the combustion process occurred on all peat samples with different moisture content (350.91%, 577.52%, and 713.24%). The combustions pattern was relatively the same at all levels of moisture content, which Thermocouple# 8 performed the longest combustion time with the highest temperatures compared to other thermocouples. Vertical propagation on 16, 24 and 48-hours dry-oven treatment were 9.62 cm/hour, 24.99 cm/hour, and 41.72 cm/hour respectively, while the horizontal direction propagation values are 11.74 cm/hour,17.31 cm/hour, and 21.42 cm/hour, respectively.

Keywords: peat, moisture content, combustion

ABSTRAK

Kadar air gambut adalah salah satu faktor yang memengaruhi terjadinya kebakaran gambut. Penelitian ini bertujuan untuk mengetahui pengaruh kadar air gambut terhadap proses perambatan pembakaran, serta pola perambatan pembakaran gambut pada skala uji laboratorium, menggunakan reaktor panas berukuran 10x10x10 cm^3 dengan 3x3 thermocouple Penelitian ini menunjukan bahwa proses pembakaran terjadi pada seluruh sampel gambut pada kadar air yang hilang (350.91%, 577.52%, dan 713.24%). Pola perambatan pembakaran yang terjadi relatif sama pada semua tingkat kadar air yang hilang, dengan termokopel 8 paling lama bertahan dengan suhu yang tinggi dibandingkan dengan termokopel lainnya. Perambatan pembakaran pada gambut yang diteliti berbeda. Nilai perambatan arah vertikal padagambut perlakuan oven 16, 24, dan 48 jam secara berurutan yaitu 9,62 cm/jam, 24,99 cm/jam, dan 41,72 cm/jam, sedangkan nilai perambatan arah horizontal secara berurutan yaitu 11,74 cm/jam, 17,31 cm/jam, dan 21,42 cm/jam.

Kata kunci: gambut, kadar air, pembakaran

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INTRODUCTION

Peat fires in Indonesia always occur every year, especially on the islands of Sumatra and Kalimantan. Land clearing may become the main reason for the occurrence of peat fires. The fires are supported by certain conditions that make fire-prone occur, such as the El Nino phenomenon, the physical condition of degraded peat, and socio-economic conditions of the community (Pantau Gambut 2019). Degraded peat may result in high fire rates. The function of water absorption in dry-degraded peat will be decreasing; peat has no more extended functions as soil and has the same properties as dry wood.

Meanwhile, when the water content decreases in the dry season, peat drainage activities carried out by humans will increase the potential for fires on the peatlands. In such conditions, the fire will burn materials on the surface of the peatland, such as trees, shrubs, and others. Subsequently, the fire spreads erratically beneath the surface, vertically and horizontally, and burns organic matter through the peat pores. Burning peat produces more heat energy than burning wood/charcoal. The fire that spreads beneath the surface of the ground causes a smoldering fire with only white smoke seen above the surface, resulting in the challenge of extinguishing peat fires (Pantau Gambut 2019).

Peat fires may influence by peat characteristics and weather, namely peat water content, peat decomposition rate, water level, and rainfall. Peat fires can still occur at a moisture content of 119%, which is the critical water content of peat fires (Syaufina et al., 2004). The level of peat decomposition also affects peat fire; the more mature peat (sapric type), the more difficult it is to burn compared to immature peat types (fabric and hemic types). Peat water content will affect the water level, while rainfall affects peat water level. This study aims to determine the effect of water loss on peat fires and the propagation pattern of peat burning on a laboratory test scale. This research also analyzed temperature fluctuations during peat burning and the burning speed.

METHODOLOGY

Samples of peat soil that burned in 1997/1998 were taken from Sungai Buluh Peat Protection Forest, Pematang Rahim Village, Mendahara Ulu District, East Jabung Regency, Jambi at coordinates S 1º 14' 11.227”, E 103º 35' 4.851 ". Peat soil samples were then tested at the Thermodynamics Laboratory, Department of Mechanical Engineering, Faculty of Engineering, University of Indonesia, using the heating reactor measuring 10x10x10 cm3 and 3x3 thermocouples (Figure 1).

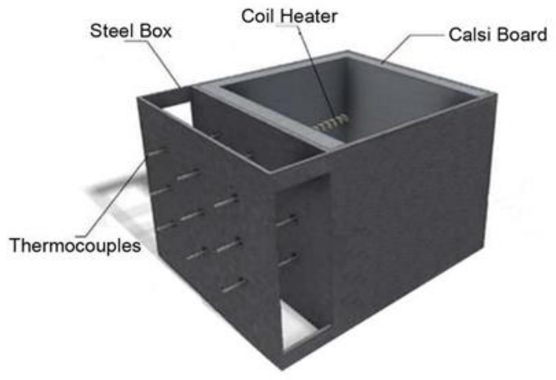

Figure 1 Heating reactor used in this study

Loss of water content in peat soil

The method used in calculating the moisture content lost in the oven is the gravimetric method. The gravimetric method is the simplest, conceptually determining the lost soil water content. This method principally includes measuring water loss by weighing the soil sample before and after drying at 105ºC in an oven. The result is expressed as a percentage of water lost, which can be described as a percentage of dry weight, wet weight, or volume (Kurnia et al. 2006), with the formula:

Water Content Loss = (Initial Weight – Final Weight) / Final Weight x 100%

Peat soil was dried-oven for 16 hours, 24 hours, and 48 hours. This method is taken from Nurdin's research (2011) with several modifications.

Vertical Direction Propagation

Figure 2 shows the location of Thermocouple# 1 to Thermocouple# 9 in the combustion reactor, with the heater coil located parallel to Thermocouple# 4. Vertical combustion is defined as the combustion path that occurs from top to bottom or bottom to top, which is calculated perpendicular to the position of the thermocouple. The combustion propagation in the vertical direction is obtained from a distance between the thermocouples, which are located perpendicularly divided by the time difference when the temperature reading of the thermocouple (Th) reaches 300^0C.

From the time difference between the thermocouples, the average velocity in the vertical direction for each thermocouple will be obtained, with the following formula:

$$\boldsymbol{V}_{\text{average}} = (\boldsymbol{V}1+\boldsymbol{V2}+\boldsymbol{V3}+\boldsymbol{V4}+\boldsymbol{V5}+\boldsymbol{V6})/6$$

Note: $\boldsymbol{V}$ = Velocity (cm/sec)

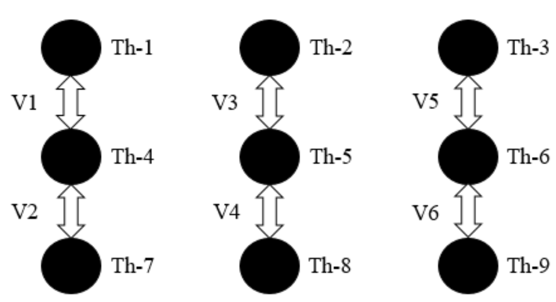

Figure 2 Schematic of vertical direction propagation

Horizontal Direction Propagation

Figure 3 illustrates the flow of calculations for the horizontal velocity. The measures were the same with vertical velocity but had a difference in the direction and order of the thermocouples. Thermocouples# 1, 2, and 3 are counted consecutively, and the rest of the sequence follows. The location of the heater coil is parallel to Thermocouple# 4 so that the heat that propagates will be stable in the opposite direction to Thermocouple# 4, namely Thermocouples# 3, 6, and 9.

The combustion propagation in the vertical direction is obtained from a distance between parallel thermocouples divided by the time difference when the thermocouple reading temperature (Th) reaches 300^{0}C so that the velocity (V) will be obtained from one thermocouple to another from the time difference between the thermocouples, the velocity in the vertical direction of each thermocouple will be obtained, with the following formula:

$$\boldsymbol{V}_{\text{average}} = (\boldsymbol{V}1+\boldsymbol{V2}+\boldsymbol{V3}+\boldsymbol{V4}+\boldsymbol{V5}+\boldsymbol{V6})/6$$

Note: $\boldsymbol{V}$ = Velocity (cm/sec)

RESULTS AND DISCUSSIONS

Loss of water content in peat soil

The loss of water content is directly proportional to the length of time of the dry-oven of peat soil (Table 1). This study shows that a long heating time has resulted in extensive evaporation without any change in the heating temperature in the oven (105º).

This study required a minimum weight of 300 g of the peat soil for the reactor. The longer the dry-oven process, the more peat soil is needed to have the relatively same final weight that will be sufficient for the combustion process in the reactor. Therefore, the initial weight required in the oven was also varying.

Vertical Direction Propagation

The fastest vertical propagation (99.49 cm/hour) was obtained at V6 (48 hours), while the lowest value (1.58 cm/hour) was obtained at V3 (16 hours). The burning speed in the vertical direction corresponds to the heat propagation in the drying time in each treatment (Table 2).

The most extended result in propagation is the drying treatment for 16-hours with heat propagation of 9.62 cm/hour, while the fastest obtained at 48-hours with an average propagation speed of 41.72 cm/hour. The results of 24-hours treatment (24.99 cm/hour) in heat propagation are faster than the results obtained by Orion and Martin (2018) at the same drying time for the vertical propagation of peat burning from Pelalawan, Riau (14.3 cm/hour).

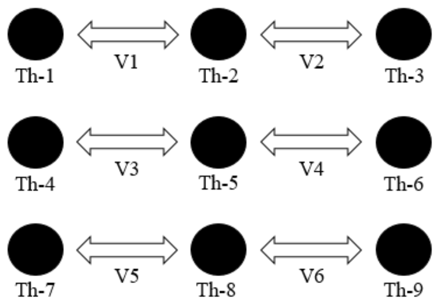

Figure 3 Schematic of horizontal direction propagation

Horizontal Direction Propagation

The fastest horizontal propagation (52.52 cm/hour) was obtained at V5 (48 hours), while the lowest (0.69 cm/hour) was at V2 (16 hours). The burning speed in the vertical direction corresponds to the heat propagation during the drying time in each treatment (Table 3).

Table 3 shows the value of the horizontal propagation speed. The horizontal propagation speed is lower than the vertical propagation speed because all the plotted points are not adjacent to the heater coil. This study showed the same vertical and horizontal propagation speed pattern, with the smallest at 16-hour treatment and the largest at 48-hour treatment, proving that the propagation speed that occurs both horizontally and vertically is directly proportional to the water content.

The peat moisture content obtained at 16 hours of drying time is smaller than the drying time for both 24 hours and 48 hours. Density is a physical property of matter and therefore becoming a fundamental characteristic of matter. Density is used to compare two substances with the same volume (occupying the same amount of space but having different masses). An object with a larger mass per volume is denser than an object with a smaller mass per volume (Mariana 2012). In this case, the soil density obtained by the 16-hour drying treatment was the largest because the water contained in the soil is greater than the others, which also affects the length of the combustion carried out. The burning time of the 16-hour drying treatment was faster than the 24-hour

Table 1 Data on lost peat water content

Treatment	Initial Weight (g)	Final Weight (g)	Loss of Water Content (%)
16 Hours	1777.24	394.15	350.91
24 Hours	2493.63	368.05	577.52
48 Hours	2915.56	358.51	713.24

Table 2 Burning speed in vertical direction

Treatment	V1	V2	V3	V4	V5	V6	$V_{average}$ (cm/hour)
16 Hours	14.82	9.82	1.58	5.62	5.21	20.67	9.62
24 Hours	40.11	21.84	23.39	6.20	5.06	53.33	24.99
48 Hours	46.07	28.99	26.15	41.27	8.32	99.49	41.72

Table 3 Burning speed in horizontal direction

Treatment	V1	V2	V3	V4	V5	V6	$V_{average}$ (cm/hour)
16 Hours	15.30	0.69	32.32	9.26	6.05	6.82	11.74
24 Hours	14.50	3.26	37.62	10.68	25.79	6.24	17.31
48 Hours	16.29	9.52	17.62	15.71	52.52	11.09	21.42

drying time because the peat soil sample with 16 hours drying time was still solid with a density value of 0.39 g/cm3. The greater the density value, the less oxygen will enter the soil so that the burning time cannot last long, and the combustion results will not be perfect (turned into ash).

Temperature Change Against Time

16-Hours Drying Time

Figure 4 shows the temperature changes that occur when the combustion takes place in the drying treatment for 16 hours. The highest temperature when the heater coil is still turned on reaches 684.5^{0}C in 48 minutes at Thermocouple# 4. Thermocouple# 4 is located adjacent to the heater coil.

When the heater coil is turned off, all temperatures drop to the highest temperature of 460.8^{0}C, when the combustion lasts for 6 hours and 8 minutes. The most stable thermocouple during combustion is Thermocouple# 8. Thermocouple# 8 remains stable when the heater coil is turned off, even increasing to 460.8^{0}C. Likewise, thermocouples# 7 and 9 have higher temperatures because peat fires occur below the soil's surface layer (ground fire). In this type, the fire spreads erratically slowly beneath the peat surface. Fire burns organic matter by smoldering so that only white smoke can be seen above the surface (Adinugroho et al., 2004).

Temperatures of Thermocouples# 1, 2, and 3 do not last very long during the combustion process (Figure 8) due to these thermocouples' position at the top. In addition to the nature of peat fires that propagate below the surface, soil in Thermocouples# 1, 2, and 3 will run out faster and decrease, resulting in the loss of the soil located on Thermocouples# 1, 2, and 3. Therefore the temperature read by the data acquisition tool will continue to decrease.

24-Hours Drying Time

Change of peat temperature in a drying time of 24 hours is shown in Figure 5. The method used is the same as the 16-hour drying treatment with the heater coil on Thermocouple# 4. Therefore, the results obtained are almost the same as the 16-hour drying time treatment, with Thermocouples# 7, 8, and 9 being the most stable and lasting until the end of combustion. Especially on Thermocouple# 8, which is consistent with the combustion temperature between 6 - 8 hours of combustion. However, Thermocouples# 1, 2, and 3 became the fastest, decreasing the combustion temperature.

The highest temperature occurred when the heater coil turned on at Thermocouple# 4 with a temperature of 698.4^{0}C with a burning time of 8 minutes and 24 seconds. This result is almost the same as Ramadhan et al. (2017),

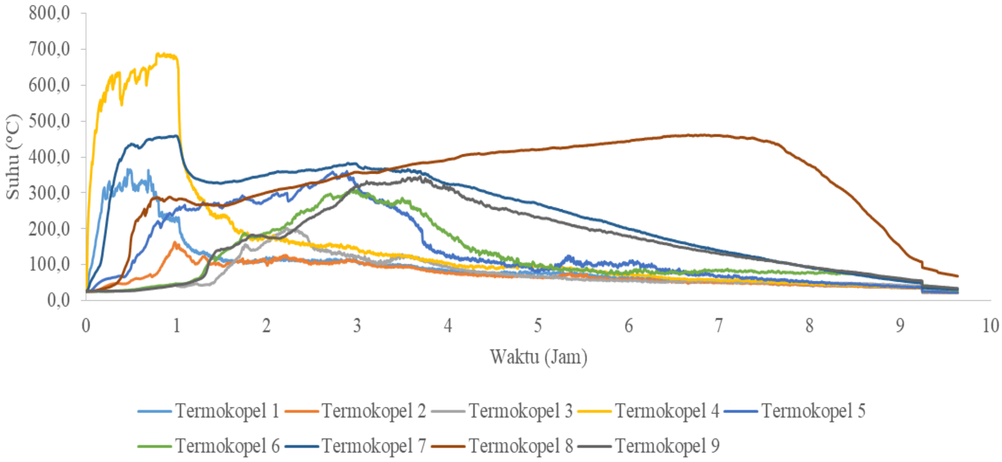

Figure 4 Changes in peat temperature for 16-hours drying time

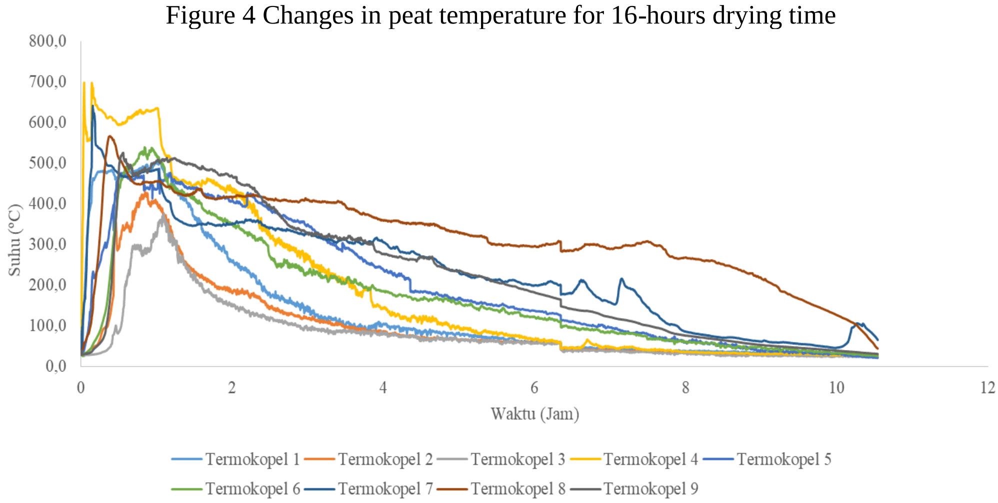

Figure 5 Changes in peat temperature for 24-hour drying time

which found that the maximum combustion temperature on a drying time of 24 hours was 628^{0}C and 686.9^{0}C for peat samples from Papua and South Sumatra, respectively.

After the heater coil is turned off, the highest temperature is 513^{o}C with a burning time of 1 hour 12 minutes on Thermocouple# 9. However, during that time, the temperature is still under the influence of the heater coil, even though the heater coil turned off for 1 hour. The highest temperature data were obtained during 2 - 6 hours because the effect of the heater coil had disappeared during that time. The highest temperature (410.4^{0}C) was obtained at a burning time of 3 hours on Thermocouple# 8.

From Figure 5, we can see that the temperature suddenly rises in the 6 - 8 hours of drying time due to subsidence that may result from the empty bottom layer of the peat, so that the peat in the top and middle layers will fall to the bottom of the reactor. The soil in the lower layer will be added by soil that sinks from the top and intermediate layers of the reactor. The subsidence mainly occurs between 6 - 8 hours, possibly because, at that time, the burnt soil had begun to be burnt to ashes.

The soil that has become ash will be brittle, and the soil on the top layer will drop to the bottom layer. The burning time should be faster in the 24-hour drying treatment than the 16-hour treatment. The soil samples were burned to ashes in the drying treatment of 24-hours, while the 16-hour drying treatment did not wholly burn the soil samples. After 24-hour and 16-hour drying time, the remaining soil was 45.67 g and 81.27 g, respectively.

48-Hours Drying Time

Figure 6 shows the change in peat temperature from the drying time of 48 hours. When the heater coil is turned on, the highest temperature reaches 789.9^{0}C on Thermocouple# 4 with a burning time of 5 minutes and 24 seconds, faster than the drying treatment of -16 and -24 hours. Peat with drying treatment for 48 hours has a very dry soil texture due to the high evaporation rate of water in the soil. The drying time of 48 hours showed an enormous value for the lost water content (713.24%). Thus, it takes only 5 minutes to reach the maximum temperature when the heater coil is turned on.

When the heater coil is turned off, the highest temperature is 437.8^{0}C on Thermocouple# 8 with a burning time of 2 hours and 42 seconds. The total burnt of all peat soil samples was 8 hours 6 minutes, with a residual weight of only 32.33 g, which means that the burned peat soil has wholly turned to ashes. Thermocouple# 8 has a stable temperature and is the highest among others due to the types of peat fires are ground fires. Thermocouples# 7, 8, and 9 have a higher temperature due to the position of these thermocouples at most bottom parts of the reactor. The changes in Thermocouple# 7 showed that subsidence at several points might occur between 3 - 5 hours.

CONCLUSIONS

The peat samples at all water content studied (350.91%, 577.52%, and 713.24%) burned with different combustion residues. In the peat sample with a lost moisture content of 350.91%, the peat sample was not completely burned with combustion product still in the form of soil (only a small part of it became ash). The value of the lost water content affects the rate of heat propagation. The higher the water content lost in the sample, the higher the speed of propagation that occurs, both vertically and horizontally. The highest heat propagation speed was obtained at a water content of 713.24%, which was 21.42 cm/hour (horizontal propagation speed) and 41.72 cm/hour (vertical propagation speed). The pattern of temperature changes that occur is relatively the same. At the beginning of combustion, Thermocouples# 1, 4, and 7 showed a rapid temperature increase due to their parallel location to the heater coil. When the heater coil is turned off, automatically, all temperatures will decrease slowly. Still, Thermocouples # 7, 8, and 9 show a consistent temperature change due to their location at the bottom of the surface, which corresponds to the nature of peat fires as ground fire.

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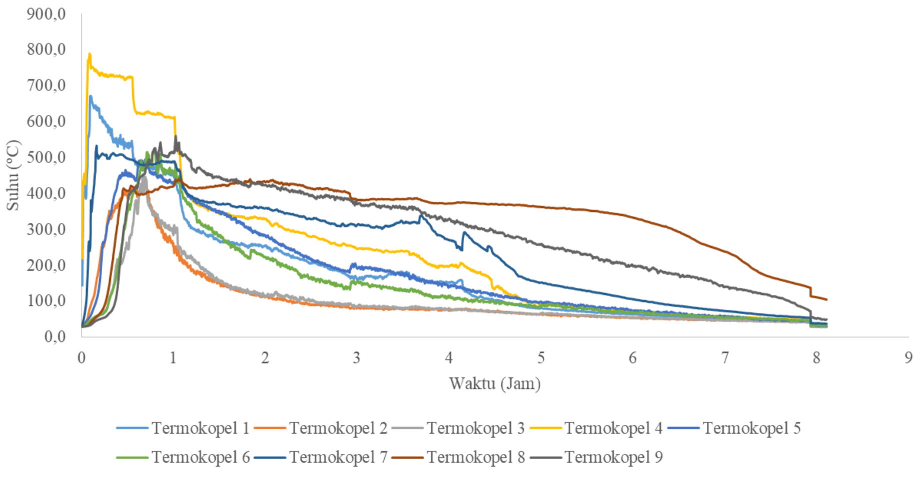

Figure 6 Changes in peat temperature for 48-hours drying time

REFERENCES

Adinugroho W, Suryadiputra A, Saharjo BH, Siboro L. 2004. Panduan Pengendalian Kebakaran Hutan dan Lahan Gambut. Bogor (ID): Weatlands International.

Kurnia U, Agus F, Adimihardja A, Dariah A. 2006. Sifat Fisik Tanah dan Metode Analisisnya. Bogor (ID): Balai Besar Litbang Sumberdaya Lahan Pertanian.

Mariana Z. 2012. Penuntun Praktikum Fisika Pertanian. Bandung (ID): Politeknik Sekolah Tinggi Teknologi Tekstil.

Nurdin S. 2011. Analisis perubahan air dan kuat geser tanah gambut Lalombi akibat pengaruh temperatur dan waktu pemanasan. Jurnal Smartek. 9 (2): 88-108.

Orion H, Martin A. 2018. Kaji eksperimental perambatan pembakaran pada gambut (smoldering combustion propagation of peat) dari gambut tropis Kabupaten Pelalawan pada skala laboratorium. Jurnal Teknik. 5(2): 1–5.

Pantau Gambut. 2019. Dampak Kerusakan Lahan Gambut [internet]. [Diunduh 2019 Mei 12]. Tersedia pada: https://pantaugambut.id/pelajari/dampak-kerusakan-lahan-gambut

Ramadhan ML, Palamba P, Imran FA, Kosasih EA, Nugroho YS. 2017. Experimental study of the effect of water spray on the spread of smoldering in Indonesian peat fires. Fire Safety Journal. 91: 671–679.

Syaufina L, Saharjo BH, Tiryana T. 2004. The estimation of greenhouse gases emission of peat fire. Working Paper No. 04. Bogor (ID): Bogor Agricultural University.