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LABORATORY EXPERIMENTS ON HEAT PROPAGATION OF PEAT SAMPLES FROM FREQUENTLY BURNT AREAS IN JAMBI

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

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ABSTRACT

Peat fires are relatively difficult to extinguish due to the character of peat fires that smolders below soil surface. This research aims to analyze propagation of smoldering fires on frequent burnt peat with various moisture content. (dry base). Variables measured are changing of temperature to time, propagation rate, and mass loss rate. The result obtained from this research is further compared to previous research done on peat samples burnt only once on 1997/1998. Moisture contents from frequently burnt area that are dried 16 and 24 hours are 272.00% and 494.00%. Moisture contents in previous research on peat samples that are dried for 16 and 14 hours are 577.52% and 713.24%. Analysis on both sample shows that peat samples burnt in 1997/1998 holds higher temperature than frequently burnt peat samples. Propagation on peat samples burnt in 1997/1998 lasts longer (9-10 hours) than propagation on frequent burnt peat (6-7 hours). Vertical propagation rate on frequent burnt peat are slower (6-30 cm/hour) than on peat samples burnt in 1997/1998 (9-41 cm/jam) but, horizontal propagation rate on frequently burnt peat are faster (5-35 cm/hour) than peat burnt in 1997/1998 (11-21 cm/hour). Mass loss rate on frequent burnt peat are lower (9-22 gram/hour) than on peat samples burnt in 1997/1998 (25-32 gram/hour).

Keywords: peat, moisture content, combustion

ABSTRAK

Kebakaran gambut relatif sulit dipadamkan karena karakter kebakaran gambut yang membara di bawah permukaan tanah. Penelitian ini bertujuan untuk menganalisis perambatan api yang membara pada gambut yang sering terbakar dengan berbagai kadar air. Variabel yang diukur adalah perubahan suhu terhadap waktu, laju propagasi, dan laju kehilangan massa. Kadar air dari daerah yang sering terbakar yang dikeringkan selama 16 dan 24 jam adalah 272,00% dan 494,00%. Kadar air pada penelitian sebelumnya yang dilakukan terhadap sampel gambut yang dikeringkan selama 16 dan 14 jam adalah 577,52% dan 713,24%. Analisis pada kedua sampel menunjukkan bahwa sampel gambut yang dibakar pada tahun 1997/1998 memiliki suhu yang lebih tinggi daripada sampel gambut yang sering dibakar. Perambatan panas pada sampel gambut yang terbakar sekali pada tahun 1997/1998 berlangsung lebih lama (9-10 jam) dibandingkan dengan gambut yang sering terbakar (6-7 jam). Laju perambatan vertikal pada gambut yang sering terbakar lebih lambat (6-30 cm/jam) dibandingkan dengan sampel gambut yang terbakar tahun 1997/1998 (9-41 cm/jam), tetapi laju perambatan horizontal pada gambut yang sering terbakar terjadi lebih cepat (5-35 cm /jam) dibandingkan gambut yang terbakar sekali pada tahun 1997/1998 (11-21 cm/jam). Laju kehilangan massa pada gambut yang sering terbakar adalah lebih rendah (9-22 gram/jam) dibandingkan dengan contoh gambut yang terbakar sekali pada tahun 1997/1998 (25-32 gram/jam).

Kata kunci: gambut, kadar air, pembakaran

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INTRODUCTION

Indonesia has been 20.6 million hectares or about 10.8% of the land in Indonesia (Wahyunto 2003) that shows the largest of peatland in the world. Peatland have important function in maintaining the balance of carbon, water and climate because of the organic matter in peat. Peat is formed from various plant organic matter that decomposes and decomposes at various levels where the percentage can reach more than 65% (Sahputra 2017). Fires on peatlands are difficult to extinguish and can last a long time. In peatland, fires do not only burn vegetation and the litter layer, but also burn the peat layer above and below the surface in the form of smouldering peatland fires (Usup 2015).

The impact of smoldering fires on peatland can cause the damage of tree roots, tree trunks, and loss of large amounts of biomass (Rein *et al*. 2008). It also changes the physical, chemical, and biological structure of peat soils. The other impact of non-igniting heat propagation peat is the release of large amounts of emissions such as erosion and subsidence of the soil. Fires not only cause depletion of the peat layer, but also cause pollution through the production of greenhouse gases (GHG) due to the release of carbon in the form of CO2. Peatland fires also reduce the water conservation capacity of peatlands (Sarwani *et al*. 2006, Masganti *et al*. 2014).

Now, the research on the characteristics of tropical peat fires is still limited and rarely. The research by Syaufina (2002), Rein *et al*. (2008), Palamba *et al*. (2018) showed that water content affects fire propagation on peat. Therefore, it is important to analyze the character of fires on peat in Indonesia as the first step to control and prevent peat fires. This research aims to analyze the burn propagation in peat samples that are frequently burned with different moisture content at a laboratory scale and compare the results of the analysis with previous research conducted by Iskandar (2019) on peat samples that were once burned in 1997/1998. This research is expected to be a reference for mitigating peat fires and as a reference for research related to the characteristics of tropical peat fires.

METHOD

Materials

The tools used in this research are: paralon, electric heating device, heating reactor measuring 10x10x10 cm^3, 3x3 thermocouple, data acquisition tool, ignition wire, oven, analytical balance, wire, large exhaust fan, voltmeter, aluminum foil, and laptop. The material used in this study was a peat sample that was frequently burned from Sinar Wajo Village, Mendahara Ulu District, Tanjung Jabung Timur Regency, Jambi.

Data Processing Procedure

Peat extraction at the site uses the intact soil sampling method. The soil is taken by the pipe with a diameter of 4 inches (10.16 cm) and the lenghth is 60 cm with a pipe lid (Palamba *et al*. 2018). Sampling of peat soil by pipe aims to maintain the integrity of the physical properties and soil moisture after collection.

Moisture content was obtained by roasting the peat sample for 8, 16, and 24 hours. The water content is calculated by the formula (Frandsen 1997):

$$\text{Moisture Loss (\%)} = \frac{m1 - m2}{m2} x100\%$$

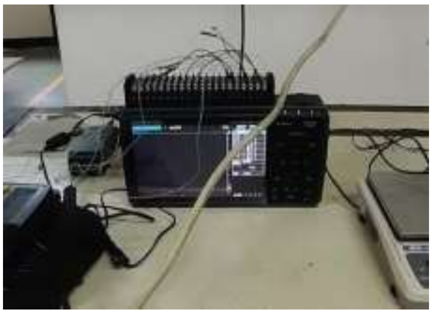
Description:
m1= Initial Weight (gram)
m2= Final Weight (gram)

Data Analysis Procedure

For Temperature Propagation Test, we must bake the peat and measure the moisture content. Then it put into the reactor. The smoldering combustion test was carried out by connecting the heater to the reactor, coil heater, and turning it on for 45 minutes. Heating for 45 minutes is carried out because after 45 minutes the peat around the coil heater has burned and can propagate. This method refers to the research conducted by Rein *et al*. (2008) with some modifications.

The analysis of heat peat propagation uses calculation of the vertical and horizontal propagation of the peat sample. It was calculated using formula the distance between the thermocouples divided by the time differences each thermocouple when the thermocouple temperature reaches 300°C. In vertical propagation, V1 is the combustion propagation speed from the thermocouple position 1 (Tc1) to thermocouple position 4 (Tc4), and V2 is the speed of combustion propagation from thermocouple position 4 (Tc4) to thermocouple position 7 (Tc7), and others (Figure 2). In horizontal

(a)



(b)

Figure 1 (a) The reactor used during the data collection process, (b) the data acquisition tool propagation, V1 is the speed of combustion propagation from thermocouple position 1 (Tc1) to thermocouple position 2 (Tc2), and V2 is the speed of combustion propagation from thermocouple position 2 (Tc2) to thermocouple position 3 (Tc3), and others (Figure 3). The average speed of heat peat propagation was calculated by the formula:

$$Average\ v = \frac{v1 + v2 + v3 + v4 + v5 + v6}{6}$$

where:

Average v = average speed of heat peat propagation (cm/hour)

V = speed propagation between each thermocouple (cm/hour)

We analyze the mass loss rate using the formula:

$$mass\ loss\ rate = \frac{mass\ loss}{time}$$

where,

mass loss rate = mass lost in a time (gram/hour)

mass loss = the reducing of the mass before and after combustion (gram)

time = mass measurement duration (hour)

The combustion test method used in this study is an experimental method. The burning test is carried out by connecting a heater to the peat. The heater (coil heater) is turned on until the heat energy from the heater is able to maintain the burning of the peat and can burn by itself. The temperature in this test is detected on the thermocouple and will be converted in the form of numbers by the DAQ system using MS Excel software. The results of the study were then compared with the results of previous research conducted by Iskandar (2019) on samples of burned peat in 1997/1998.

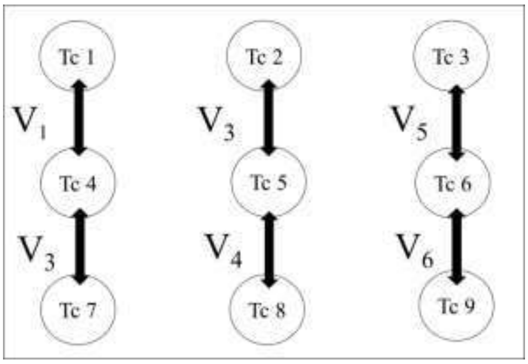


Figure 2 Vertical propagation

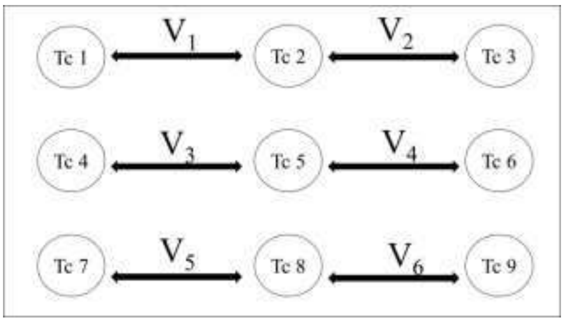


Figure 3 Horizontal propagation

RESULTS AND DISCUSSION

Moisture Loss

Based on Table 1, if the duration of drying is longer, it will make the moisture lost even greater. The increase in heating temperature and heating time causes a large evaporation rate so that the lost moisture content will be even greater (Nurdin 2011). The moisture content obtained from peat samples frequently burnt with 16 and 24 hours drying treatment is different from the moisture lost in peat samples burned in 1997/1998 with 16 and 24 hour drying treatments. It showed that, the moisture lost our reference was greater than our peat samples.

Heat Propagation in Peat Samples

Based on Table 2 and Table 3, The two samples showed differences in the speed of propagation in each drying treatment. In the 16 and 24 hours drying treatments, the burning peat quickly propagated in a vertical direction compared to the 16 and 24 hour drying treatments for burning peat in 1997/1998. Peat samples burned frequently and once burned showed differences in the speed of propagation in each drying treatment. In the 16 and 24 hour drying treatments, the peat has been burned frequently in a vertical direction, compared to the 16 and 24 hour drying treatment for peat burned in 1997/1998. This result is also the same in the horizontal propagation in Table 4 and Table 5. Research conducted shows that the water content is directly proportional to the drying time. Research conducted on peat samples burned in 1997/1998 showed slower propagation rates than research conducted on frequently burned peat samples.

Temperature Distribution

The temperature distribution is analyzed from the direction of the thermocouple so that the position of the heater is on the left of the figure. Figure 4 present a comparison of the temperature distribution of the peat sample frequently burned and the 1997/1998 peat burnt sample with 16 hours of drying treatment. Comparison between the frequently burned samples and the 1997/1998 samples burned at 15 minutes, 30 minutes, and 45 minutes heating showed that the fire spread faster in the peat soil samples burned frequently. The peat sample burned frequently in 1 hour of burning had a higher temperature distribution in the middle and lower areas of the reactor, while the peat sample burned in 1997/1998 had the highest temperature in the heating position. After 2 hours of burning the peat sample was

Table 1 Moisture loss in peat samples

Duration of drying	Moisture loss in peat frequently burned (%)	Moisture loss in burned peat 1997/1998 (%) (Iskandar 2019)
8	48.35	N/A
16	272	350.91
24	494	577.52
48	N/A	713.24

frequently burned, the temperature decreased with a focus of heat in the lower center area (thermocouple 8). The peat sample burned in 1997/1998 had a higher temperature with the hottest point in the lower right position (thermocouple 7). The peat sample frequently burned after 3 hours of burning showed the highest temperature of 318°C with a decrease in temperature below 54°C on the right and left positions of the reactor, while the sample burned in 1997/1998 showed the highest temperature distribution at the bottom with a temperature of 107°C to 378°C.

After 4 hours of burning, the peat sample was frequently burned and the temperature decreased below 54°C in the middle of the reactor (caused by subsidence) with the highest temperature being 411°C, while the peat sample once burned the highest temperature was at the bottom and middle of the reactor with a temperature of 115°C-394°C. The peat sample was frequently burned after 5 hours of experiencing a decrease in temperature in the center of the reactor with a larger area, while the peat sample burned in 1997/1998 had a smaller area. After 6 hours of burning the peat sample was frequently burned, the temperature decreased constant in the center of the reactor, the same thing happened for 7 hours of burning. The subsidence area is getting bigger and the hot spot focus is only at the bottom of the reactor. However, the sample burned in 1997/1998 after 6 hours of burning the area in the middle of the reactor experienced an increase in temperature so that the temperature in the middle of the reactor was around 56°C-104°C, after 7 hours the sample experienced a decrease in temperature in the middle of the reactor which was getting bigger until 9 hours of combustion.

Figures 5 present a comparison of the temperature distribution of the frequently burned sample with the 1997/1998 burnt sample with 24 hour drying treatment. The peat samples burned frequently had lower temperatures than the peat samples burned in 1997/1998. The peat sample in the first 1 hour showed a warmer temperature at thermocouple 8, this was due to flaming during the combustion process so that the burned soil sample experienced a faster temperature propagation so that the peat soil sample was exhausted faster and the temperature decreased faster. Peat samples burned frequently have a temperature range of 195°C-468°C. The peat sample burned in 1997/1998 at 1 hour of burning had a temperature range of 322°C-635°C with the highest temperature at the thermocouple position 4. The peat sample frequently burned during 2 hours of burning there was an area in the middle of the reactor with a temperature below 85°C, with the highest temperature at the thermocouple position 8. The temperature range for 2 hours of burning peat soil samples frequently burned is 85°C-372°C. Peat samples burned in 1997/1998 at 2 hours of burning showed that high temperatures were in the middle and bottom of the reactor. The temperature of the burned soil samples in 1997/1998 had a temperature range of 149°C-469°C. After 3 hours of burning, the peat soil sample was frequently burnt showing an increase in temperature again with the highest temperature position being at the bottom center (thermocouple 8). The temperature range for frequently burned soil samples is 64°C-267°C. The burned soil sample in 1997/1998 at 3 hours of burning experienced a decrease in temperature with a hot area at

Table 2 Analysis of the vertical propagation of peat samples from frequently burnt areas

Duration of Drying	v1 (cm/hour)	v2 (cm/hour)	v3 (cm/hour)	v4 (cm/hour)	v5 (cm/hour)	v6 (cm/hour)	v average (cm/hour)
8 hours	5.40	5.76	7.2	5.04	11.88	2.52	6.30
16 hours	18.36	20.16	8.67	6.40	6,940	9.64	11.69
24 hours	26.28	29.88	25.56	45.36	42.12	16.20	30.90

Table 3 Analysis of the vertical propagation of the burned peat samples in 1997/1998 (Iskandar 2019)

Duration of Drying	v1 (cm/hour)	v2 (cm/hour)	v3 (cm/hour)	v4 (cm/hour)	v5 (cm/hour)	v6 (cm/hour)	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 4 Analysis of the horizontal propagation of peat samples from frequently burnt areas

Duration of Drying	v1 (cm/hour)	v2 (cm/hour)	v3 (cm/hour)	v4 (cm/hour)	v5 (cm/hour)	v6 (cm/hour)	v average (cm/hour)
8 hours	2.52	3.60	6.73	2.52	11.52	3.96	5.14
16 hours	12.60	19.80	18.00	10.08	18.72	21.96	16.86
24 hours	10.00	20.16	22.32	34.56	58.32	68.40	35.62

Table 5 Analysis of the horizontal propagation of the burned peat samples in 1997/1998 (Iskandar 2019)

Duration of Drying	v1 (cm/hour)	v2 (cm/hour)	v3 (cm/hour)	v4 (cm/hour)	v5 (cm/hour)	v6 (cm/hour)	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

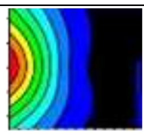
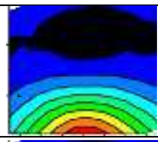
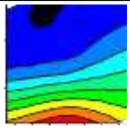
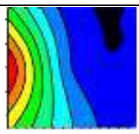
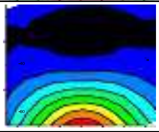
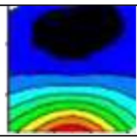
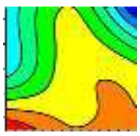
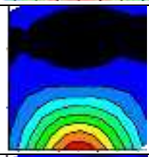
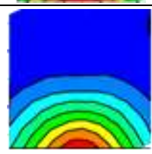
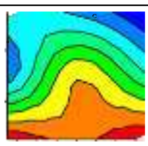
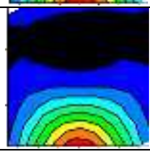
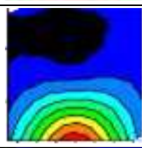
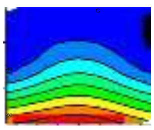
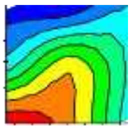
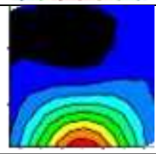
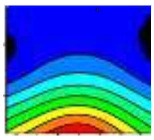
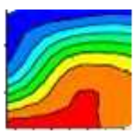
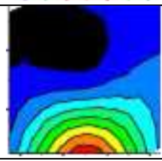
the thermocouple position 8. The temperature range of the sample was 91°C-411°C. The peat sample was frequently burned for 4 hours of burning, with a temperature range of 42.5°C-199°C.

During 4 hours of combustion, the middle position of the reactor has a lower temperature (62°C) than the top of the reactor (81°C). The same thing happened at 5 and 6 hours of burning. The temperature at the top of the reactor propagates to the middle causing an increase in temperature. The peat sample burned in 1997/1998 after 4 hours of burning showed a temperature of 81°C-359°C with the hottest point at the thermocouple position 8. After 5 hours of burning the contours of the sample were still the same but with a temperature range of 61°C-330°C. The burned soil samples in 1997/1998 experienced a gradual decrease in temperature after 6-10 hours of combustion with subsidence in the center of the reactor at 9 hours and 10 hours after combustion. The temperature at subsidence is below 27°C.

The difference in distribution pattern in the two peat samples was caused by the soil texture. The temperature distribution pattern in the first hour showed a different shape compared to the burned peat samples in 1997/1998. The peat samples burned frequently had a soil texture in the form of larger grains than the peat samples burned in 1997/1998. Larger grains cause more oxygen to enter than finer soil grains. This causes flaming in the sample to be frequently burned due to excess oxygen so that the temperature is lower than the peat sample once burned.

Mass Loss

Table 6 shows the mass loss in each drying treatment. Drying treatment for 8 hours showed loss the lowest mass is 70.06 grams at a rate of 9.22 grams/hour. The 8 hour drying treatment took the longest time to extinguish because the water content released was lower than the other treatments at 48.35%. The drying treatment for 16 hours showed the highest mass loss of 165 grams with a mass loss rate of 22.6 grams/hour this is because at 16 hours the soil texture was in the form of small lumps with a higher released moisture content of 272%. The 24-hour treatment showed a mass loss of 123.99 grams at a

Duration of heating	Peat samples were frequently burned with 16 hours drying treatment	Peat samples burned in 1997/1998 with 16 hours drying treatment	Duration of heating	Peat samples were frequently burned with 16 hours drying treatment	Peat samples burned in 1997/1998 with 16 hours drying treatment
15 minutes			4 hours		
30 minutes			5 hours		
45 minutes			6 hours		
1 hour			7 hours		
2 hours			8 hours		
3 hours			9 hours		

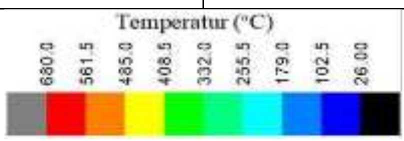


Figure 4 Comparison of temperature distribution in samples of peat frequently burned and in samples of peat burned in 1997/1998 with 16 hours of drying

slower rate than the 16-hour treatment of 19.74 grams/hour. However, the 24-hour treatment had the highest released water content of 494% so that the time required for all samples to run out was the least.

CONCLUSION

The water content released by the peat sample has an effect on the length of time for burning, fire propagation, and mass loss. Less water released the amount then the combustion lasts longer and vice versa. The fire propagation at the lost moisture content was 48.35% slower than in the peat sample with the released moisture content of 272% and 494%, respectively. The temperature distribution in the peat samples from frequently burnt areas has a wider average shape than in the 1997/1998 burned sample, this is in accordance with the vertical and horizontal propagation speed where the frequently burnt peat sample has a higher propagation speed value. The released water content of 272% has the most mass loss. This is different from the research conducted on burnt peat soils in 1997/1998. Research on burnt peat soil in 1997/1998 showed that mass loss was greater (25.46-32.13 gram/hour), slower propagation, and longer burning time than peat samples that were frequently burned.

Table 6 Mass loss of peat samples from frequently burnt areas

Duration of Drying (hours)	Mass before burned (gram)	Mass after burned (gram)	Mass loss (gram)	Duration burning of samples	Mass loss rate (gram/hour)
8 hours	458.74	388.68	70.06	7 hours 36 minutes	9.22
16 hours	306.5	141.5	165	7 hours 18 minutes	22.6
24 hours	149.99	26	123.99	6 hours 17 minutes	19.74

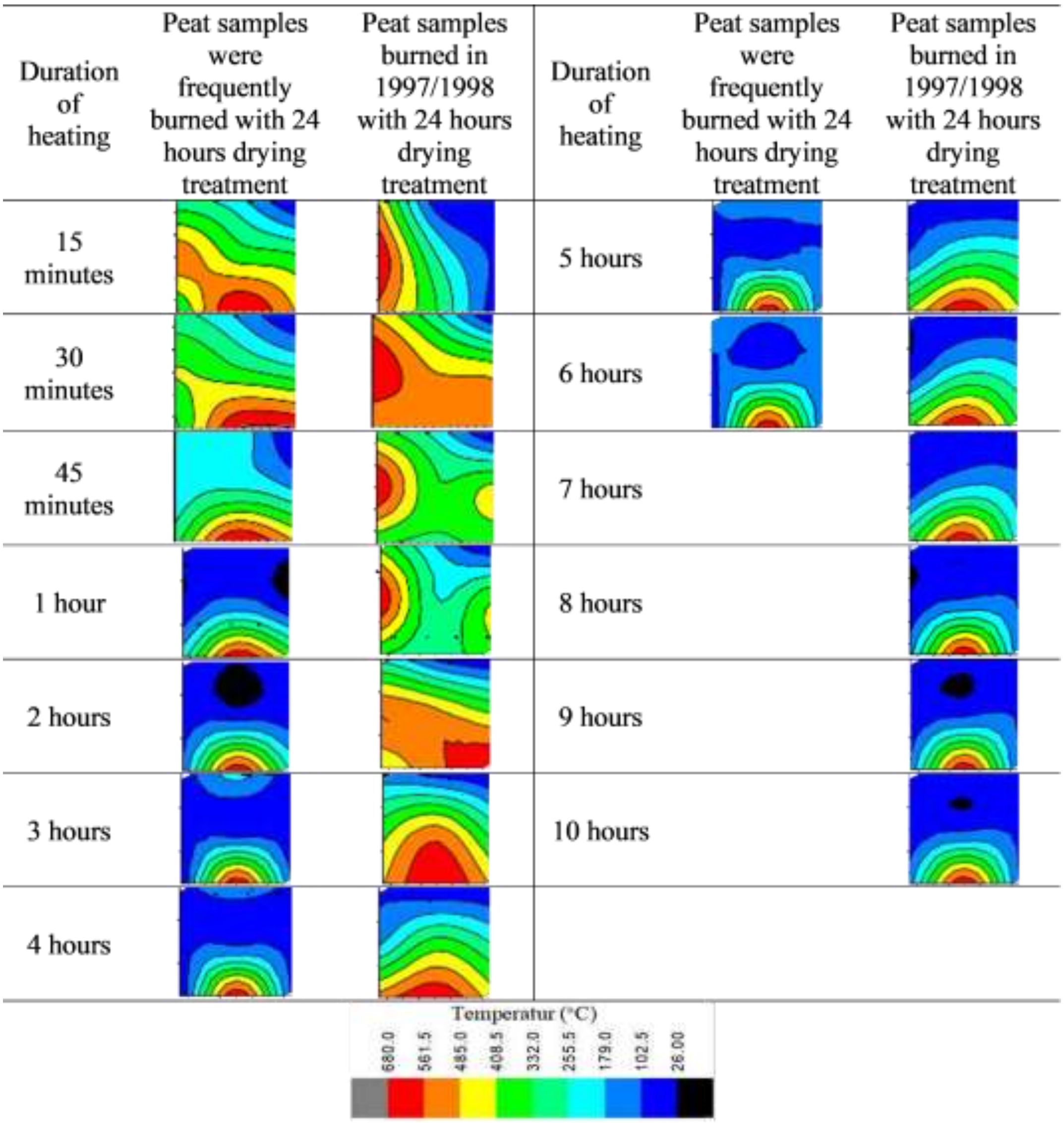


Figure 5 Comparison of temperature distribution in samples of peat frequently burned and in samples of peat burned in 1997/1998 with 24 hours of drying

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