Self-Ignition Temperature of Peat

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Self-Ignition Temperature of Peat

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Abstract. Neighboring countries that have experienced major impact from forest and land fires in Indonesia, are concerned about the effects of smoke and ash on the well-being and health of the inhabitants of those country. These fires have also significantly raised the temperature of the earth's surface. Peat is a source of water and vegetation which is quite abundant in the two main islands of Indonesia, namely Kalimantan and Sumatra. This study was conducted to calculate the temperature at which the peat will ignite. Several samples taken from four different depths underground in peat soil areas were tested using the Thermogravimetry Analyzer.

Keywords: Peat, Thermogravimetry, Self-Ignition.

1. Introduction

The 2015 forest and land fires occurring in the two major Indonesian islands of Sumatra and Kalimantan were a great disaster for all living creatures. Humans and animals exposed to smoke from these forests and land fires suffered from shortness of breath or dyspnea. There is no information yet about the long-term effects of smoke on the health of human beings and animals.

According to the Head of the Data and Information Center of the National Disaster Management Agency, the area of forest and land fires that occurred in 2015 is equivalent to 32 times the area of the Province of Jakarta, the Capital city or four times the size of the island of Bali. According to Teraa Modis data of October 20, 2015, the extent of forests and land burned reached 2,089,911 hectares. The destruction of Indonesia's natural resources was greatest in Kalimantan, where 196,987 hectares of peatland were burnt, while the peatlands burned on the island of Sumatra covered an area of 267,974 hectares with an area of 144,410 hectares in the South Sumatra province alone. Data from the National Disaster Management Agency, show that forest and land fires in 2015 were not dominated by peatlands. The extent of non-peat land fires up to October 20 2017 reached 1,471,337 hectares [1]. Spreading smoke from forest fires are seen in the fire spots of Figure 1. Smoke, which is brownish, originates from fire hotspots.

Judging from this news, actually two types of land were ignited, namely plants and vegetation on the soil surface and subsurface peat. Figure 2 shows the peat found on the soil surface. Figure 3 shows the burning peatland.

Peatland is land that has a layer of soil rich in organic matter (C-organic> 18%) with a thickness of 50 cm or more. Organic peatland composite material is formed from the remains of plants that have not completely decayed due to environmental conditions of saturated water and poor nutrients. Therefore, peatlands are often found in the back swamps or basins where the drainage is bad [2].

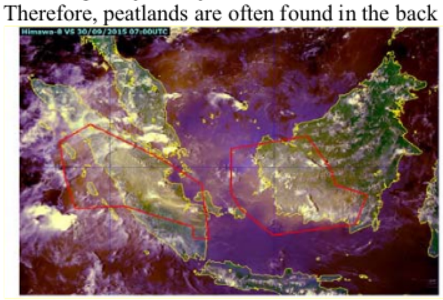

Figure 1. The extent of areas covered by smoke in South Sumatera and South Kalimantan.

Figure 2. Peatland

The peatland ecosystem is very important in the downstream hydrology system of a watershed because it is able to absorb up to 13 times its weight of water. In addition, the peatlands are also very large surface or subsurface reservoirs of carbon [2]. It is believed that the destruction of peatland areas has a huge impact on the environment. The incidence of downstream flooding is one of the results of the destruction of the peat ecosystem. Deforestation of forests and peatland used for agricultural systems requiring deep drainage (> 30 cm) and burning or fires cause very high CO2 emissions [2]. Figure 4 shows the Remains of forest fires.

Thus, it is apparent that the destruction of peatlands due to mismanagement will lead to environmental damage. Peatland fires will result in large numbers of CO_2 pollutants. Proper and correct peatland management will provide tremendous benefits to life. Prevention of fire is the best thing to do before the occurrence and widespread of land fires. An introduction to the nature of peat is necessary for this prevention. An important characteristic of peat that should be understood is the amount of water needed to keep minimum moisture in peat, the density of the peat species in proportion to the main element which is soil, and the ignition temperature at which peat starts to burn.

Figure 3. Burnt vegetation on surface

Figure 4. Remains of Forest Fires

Self-Ignition

Self-ignition of a material has been investigated by experts who stated that in general there are two types of ignition of fuel-burning material, namely external warming and internal warming (self-heating). In general, ignition is caused by external sources; for example, a match that burns a sheet of paper or a halogen lamp that burns a curtain. In these examples the ignition is caused by external sources. The researchers on fires are well acquainted with the term internal ignition. When a pile of clothing is saturated with sesame oil, it could burst into flames caused by internal ignition. Internal ignition is more complex than external ignition, due to factors such as airflow or the exact details of chemical oxidation, which is simple in external lighting but is of great interest in internal ignition. Pipes containing hot water at temperatures between 88^o to 93^o C can burn wood which is in contact with the pipes. The pipes filled with hot water are part of the space heating system [3].

Self-Ignition can be regarded as a temperature at which a material in the form of gas, liquid or solid will burn. Setchkin (1954) mentions two methods, namely rising-temperature and constant-temperature [4]. A mixture of combustible material that is placed in an incinerator and then the temperature is increased continuously until combustion takes place. The combustion temperature itself is usually set at a point where the Time-Temperature curve for the material shows a definitive increase on a slope or as an intersection point between the time-temperature curve for the material and that for heating the medium. Whereas in the constant temperature method, the determination of the temperature is based on preheating to a constant temperature selected before the sample is subjected to/ brought near the heat, and no heat is applied to the apparatus prepared after the imposition of the sample.

Buda-Ortins (2010), stated that cooking oil is a major cause of fire in homes [5]. He stated that from about 40 causes of fires in households, it is estimated at 2/3 of fires occurring during cooking were started by cooking oil. Three types of cooking oil have been researched, i.e. Canola Oil, Soybean Oil and Olive Oil as well as margarine and butter, as samples of self-heating. The ignition temperature of Canola oil is 424^{o}C, Soybean Oil 406^{o}C, and Olive oil 379^{o}C. In comparison, the initial ignition temperature of butter is 432^{o}C and it does not ignite easily. In addition, he also disclosed that the burning of cooking oil only starts after the smoke point, the boiling point when the Auto-ignition point is reached. The ignition of the five samples depends on the duration of heating. Auto-ignition usually starts after 6 (six) to 7 (seven) minutes.

Other researchers have also studied self-ignition with a variety of samples, among others Beamish and Arisoy (2008). Research was conducted on coal from Queensland Australia at temperatures between 40 to 160^{o}C. This self-heating study was conducted in an adiabatic oven using nitrogen gas[6].

Peatland

Because of their fertility level, not all types of peatland in Indonesia can be used as plantation land. Peatland in Indonesia is usually low in fertility, which is influenced by the mineral content and bases. It is said that the important physical characteristics of peat if it is to be used for agriculture include moisture content, bulk density (BD), bearing capacity, subsidence (surface drop), and non-recycle drying. These four physical properties are interrelated. Water content has a major effect on these physical properties. High water levels make the soil become soft and causes low carrying capacity of the soil. Low water levels can cause a decrease in water content (caused by drainage, and other natural factors) which in turn causes the peat volume to shrink and decreases subsidence. Subsidence can also be caused by decomposition and erosion [2].

Peat that has dried up due to reduced moisture content caused by drying that is not reversed, will have the characteristics of dry wood. In other words, it is highly flammable. This drying process which is not reversed has a big influence on the peat's water absorption ability. Thus, it is easy to understand that during the dry season, the water content of peat soil is very low. This happens because water that is not absorbed by the peat will flow into the surrounding environment. It is understandable that

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peatland fires easily occur during the dry season. The reduced water content makes the peatland very dry, so at a certain depth in peatland temperatures can reach 180 to 200°C, or even 500°C [7].

In such cases it is clear that below the surface peat fires are caused by excessive temperatures. Fires can be triggered by soaring soil temperatures, while the peat as a medium burn because it contains very little water. Forestry experts estimate the contact between high temperatures and very low peat moisture cause self-ignition.

The self-ignition phenomenon of leaves, pieces of chips of wood and coal, has been disclosed by Nugroho (2002) as the result of oxidation between matter and air at room temperature [8]. It is said that the oxidation reaction produces heat which, when it cannot be released into the environment, increases the temperature of the material. Critical temperatures will be reached when this oxidation reaction occurs continuously, which in itself will give rise to self-ignition.

In this case, the water content the peat below the surface of the soil is reduced considerably during the dry season, thus making it very dry. With a very limited oxygen content, it is estimated that peat will not burn. But in fact, the opposite happens. Fires in dried up peatland always occur. Noting the high-temperature soil environment and the possible rise in peat temperatures as well as the occurrence of oxidation due to the oxygen sources cannot be predicted, and thus the peat can self-ignite.

This research has been done considering the fact that the problem of peat fires is no longer just a national problem. Some neighboring countries have suffered from the excessive smoke caused by peatland fires. Countries such as Singapore, Malaysia, Brunei Darussalam and Thailand have been disturbed by the smoke from these forest fires. Not many people have done research in peat, as this problem has arisen in recent years. However, research has been done and books have been written by authors dealing with self-ignition as well as activation energy.

According to research carried out by Nukman (2008), the decomposition of coal material begins with the release of moisture content, although the peak water release temperature of these three coal types is less than 100°C, but the following process which is the release of moisture present in the coal pores takes place at 177°C to 211°C. In this final temperature range the process of decomposition or devolatization of coal volatile matter level occurs. The peak of this process for semi anthracite and bituminous turns out to be the same, i.e. at temperatures of 211° C, which is different from that of sub-bituminous at 420.8 ° C [9].

Another researcher, Kotoyori (1986) examined the critical temperature of combustion for wood sawdust. Some samples of wood chips have a critical temperature ranging from 118° to 142°C. The lowest temperature values indicate how easily the wood chips ignite, while the highest temperature indicates the difficulty of burning the wood [10].

Other researchers, Beamish and Arisoy (2008), revealed that the self-ignition rates for coal are affected by the presence of mineral matter in the coal. The researchers indicated that one of the most important materials for self-heating is the mineral content. The change in mineral content of a matter is influenced by the moisture content and other proximate components. The rate of warming is the beginning of the coal's own burning process [6].

Research conducted by Yulianto (Nugroho, 2002) was conducted on samples from Kalimantan in dry conditions. An electric oven was used to burn the coal. The ignition temperature of peat was 177°C [8].

Sonibare et al. (2005) examined several types of coal from Nigeria. The combustion profile showed that the peak temperature and the temperature at the end of the burning phase of coal, coal was analyzed using the Thermogravimetry Analyzer (TGA) in the oxygen atmosphere [11].

Coal from Nigeria was also investigated using TGA by Nyakuma (2016). The Peak decomposition temperature of 3 (three) types of coal was recorded, indicating the peak temperature or initial temperature of coal combustion [12].

Islam et al. (2016) analyzed the kinetics of burning *karanja* fruit hulls using thermogravimetric. Peak temperature and burn out temperature were obtained from this research [13].

Barlin et al. (2016) analyzed the thermal evolution profile of a mixture of coal and acacia manganium. The results showed that there are two peak temperatures, showing the temperature of each material in the mixture. It is apparent that two different kinds of matter will have two temperature peaks [14].

Using all this research and the knowledge gained from various discussions, this research has been carried out successfully.

The purpose of this research is to determine the temperature at which self-ignition occurs in peat land. By doing this research some necessary data was obtained which will later become a source data about the main nature characteristic of peat, which is self-ignition. The magnitude of the resulting temperature is influenced by the decrease of water content in the peat soil composition. However, natural causes cannot be avoided. The influence of the annual dry season, preceded by el Nino storms in January and February of 2015, greatly affected the drought. Drought on the soil surface will gradually reduce the subsurface water content of the soil. Although the reduction of this water content occurs at shallow ground position, at a maximum depth of 6 (six) meters, it has a great influence on the evaporation rate of water and followed by a decrease in soil moisture. Under these conditions, it is certain that peat soil temperatures will increase. This data on self-ignition temperatures on peat soil can be used as a guide for stakeholders to run fire prevention on peatlands. It is hoped that with this knowledge, fires caused by self-ignition on peatlands can be minimized.

2. Method and Materials

Sample drilling was carried out to collect test samples to be measured. The drilling was done by a field team using a peat sampler, carried out at depths of 1, 2, 3 and 4 meters. The drilling area was in Ogan Ilir District, South Sumatera Province, along the road between Palembang and Inderalaya, an area where land and peat fires frequently occur.

The measuring instrument was prepared at the multipurpose laboratory of Grha Pertamina, Faculty of Engineering, University of Sriwijaya. The main tool used was the Thermogravimetry Analyzer (TGA-Q500), with pure oxygen and pure nitrogen tanks. This tool was used to measure the temperature at which self-ignition of peat occurs. The air-fuel supply, i.e. oxygen and nitrogen, was supplied to the sample, which is. The combustion air was applied to the sample as a function of time and temperature to measure the rate of the reduction of burning peat mass. Sample preparation was carried out using the process of sampling in the field. The samples were taken using a peat sampler which were then stored in an airtight plastic to retain the sample moisture.

In the laboratory, the samples were divided into several small parts. Some samples were measured with TGA in the as-receipt state and other samples were measured in a very low water content state. The sample heating used an oxygen atmosphere coupled with nitrogen as combustion (peat burns in soil with limited oxygen). Analysis was conducted on the data generated by TGA to obtain peat peak temperature and burn out temperature.

3. Results and Discussion

Peat samples were taken at Ogan Ilir. Peat in this case was a mixture of congenital soil and fiber of peat vegetation. It is said to be a fiber because peat is at the roots of the vegetation found in the outcrop. The samples analyzed in the TGA instrument were a mixture of soil and peat fibers. A small portion of peat material taken from the field was used. The samples were not heated to dry and not cleaned. Measurements were made without taking into accounts the composition of soil and peat, with the consideration that peat burning in the TGA instrument is considered to be a replication of true peat conditions in the soil.

Heating is done with a heating rate (ramp) of 10^{o}C/min with 12 mL/min for oxygen and 8 mL/min oxygen for nitrogen. Heating in TGA was done by entering four samples simultaneously. The measurement results of the TGA machine are shown in Figure 5, showing the relationship between weight (%), time (min) and temperature (^{o}C).

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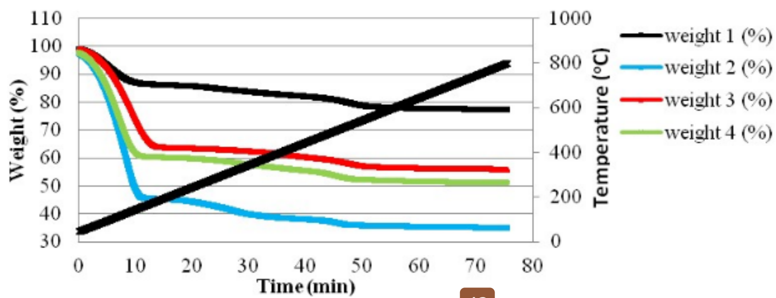

Figure 5. The Relationship between Weight (%), Time (min) and Temperature (°C)

The time set for the heating was 75 minutes and the temperature set to 800°C. Samples were not weighed, but placed on an aluminium pan, where the TGA instrument l measured the weight of the samples. The four samples represent the samples at drilling depths of 1, 2, 3 and 4 meters.

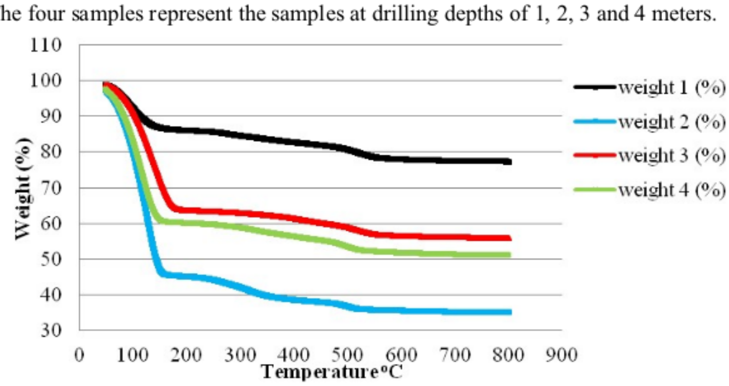

Figure 6. Correlation between Weight (%) and Temperature (°C)

Figure 6 shows weight 1 (%) is the sample weight for a meter depth, weight 2 (%) for a depth of 2 meters, and so on. Heat mass reduction for weight 1 sample (%) was lower than other samples. This indicates that at a depth of 1 meter in the drilling area there was less peat mass. The mass reduction analysis was calculated from the initial heating to a temperature of 800 ° C. The burned mass in sample weight 2 (%) was more than that of the samples at the other depths. In this case it can be said that peat at a depth of 2 meters was more than the samples at other depths. A peat sample at a depth of 1 meter may have been burned in the past. This is understandable considering that this peat sampling site is a large area of peatland which is always under the government's scrutiny to prevent peat fires. This possibility is reliable, because in this area there are often fires on the surface of the ground which possibly penetrate into the soil's subsurface, but can be extinguished by the authorities before the fire enlarges and extends further. From Figure 6 it can be understood that in the burnt areas of peatlands that have been extinguished, peat vegetationis still thick and has the potential to become a source of future fires. The sample mass is not burned out and does not turn into ash, because the soil on which peat grows cannot burn and become hard.

The DTG curve (Differential Thermogravimetry) - dw/dt in figure 7 shows that there are three areas where there is peak temperature and burnt out temperature. This area indicates the positions of certain elements of the burnt sample. Areas with temperatures ranging from 0 to 200 ° C is were areas of burning peat, and this corresponds to the research of Kotoyori (1986) and Nugroho, (2002). From Figure 7 it can be seen that regions with temperatures of 0 to 200°C are areas at which peat ignites and the final temperature of combustion. This is the same as suggested by Sonibare et al. (2005), Nyakuma (2016) and Islam et al. (2016) that there are two peak temperatures during the burning of the material.

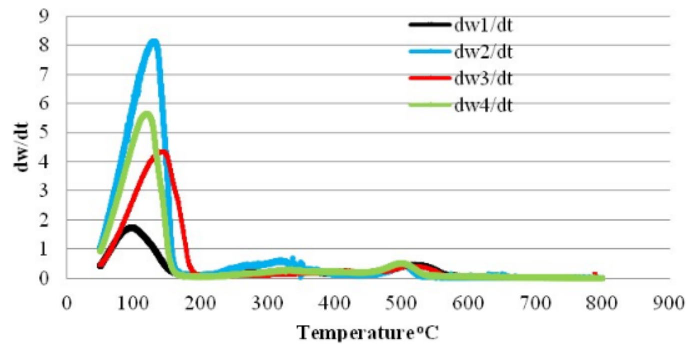

Figure 7. The relationship between the mass derivative of dw/dt heating time and the Temperature (°C).

The burning temperature of peat has been identified (see Table 1). Peak temperature is the initial temperature for peat to burn and the burn-out temperature is the final temperature for burning peat. Thus, it can be seen that it will be more difficult for peat at a depth of 3 meters to burn than peat at depths of 1, 2 and 4 meters. It can also be seen that peat at a depth of 1 meter will burn more easily. However, the burn-out temperature for a depth of 1 meter is greater than at other depths. Thus, it can be said that the danger of peat fires is at a depth of 1 meter where the peat is flammable and the final temperature or burn-out temperature is greater, which indicates that the heat generated will be greater.

Table 1. Peak and Burn Out-Temperature

No.	DTG	Peak Temperature (°C)	Burn-Out Temperature (°C)
1.	dw1/dt	101,63	213,86
2.	dw2/dt	133,13	196,33
3.	dw3/dt	147,59	212,28
4.	dw4/dt	115,26	191,30

Conclusion

From the results of the discussion it can be concluded that by using the Thermogravimetry Analyzer the temperature at which peat will ignite can be identified. A simple method can be used to measure the temperature of peat soil at certain depths. This study yields a new way of measuring the temperature at which the peat will ignite.

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References

[1] Utama, A., 2015, 'BNPB: Kebakaran Hutan 2015 Seluas 32 Wilayah DKI Jakarta', *CNN Indonesia*. Palembang. Available at: http://www.cnnindonesia.com/nasional/20151030133801-20-88437/bnpb-kebakaran-hutan-2015-seluas-32-wilayah-dki-jakarta/.

[2] Agus, F. and Made, I. G., 2008, *Lahan Gambut: Potensi untuk Pertanian dan Aspek Lingkungan*. Bogor: Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF). Available at: http://balittanah.litbang.pertanian.go.id/ind/index.php/en/publikasi-mainmenu-78/24-buku/89-lahan-gambut.

[3] Babrauskas, V., 2003, '*Pyrophoric Carbon and Long-term, Low-temperature Ignition of Wood*', 14, pp. 1–7. Available at: https://www.doctorfire.com/low_temp_wood1.pdf.

[4] Setchkin, N. P., 1954, '*Self-Ignition Temperatures of Combustible Liquids*', 53(July).

[5] Ruda-Ortins, K., 2010, '*Auto-Ignition of Cooking Oils*'. University of Maryland.

[6] Beamish, B. B. and Arisoy, A., 2008, '*Effect of mineral matter on coal self-heating rate*', 87, pp. 125–130. doi: 10.1016/j.fuel.2007.03.049.

[7] Sriwijaya Post, 2015, '*Sumsel dapat Tambahan Satu Heli Pemadam Kebakaran Lahan*', Sriwijaya Post, 10 November.

[8] Nugroho, Y. S., 2002, '*Sifat Self-Ignition pada Gambut, Sabut Kelapa Sawit dan Kayu*', Jurnal Makara edisi Teknologi, 6(3), pp. 123–131.

[9] Nukman, 2008, '*The Decompositioning of Volatile-Matter of Tanjung Enim Coal by using Thermogravimetry Analyzer (TGA)*', Makara Journal of Technology, 12(2), pp. 65–69. doi: 10.7454/mst.v12i2.509.

[10] Kotoyori, T., 1986, '*Critical Ignition Temperatures of Wood Sawdusts*', in Fire Safety Science-Proceedings of The First International Symposium, pp. 463–471. Available at: http://iafss.org/publications/fss/1/463/view/fss_1-463.pdf.

[11] Sonibare, O. O., Ehinola, O. A., Egashira, R. and Keangiap, L. (2005) '*An Investigation into the Thermal Decomposition of Nigerian Coal*', 5(1), pp. 104–107.

[12] Nyakuma, B. B., 2016, '*Physicochemical characterization and thermal analysis of newly discovered Nigerian coals*', 48(4), pp. 746–752.

[13] Islam, A., Auta, M., Kabir, G. and Hameed, B. H., 2016, '*Bioresource Technology A thermogravimetric analysis of the combustion kinetics of karanja (Pongamia pinnata) fruit hulls char*', Bioresource Technology. Elsevier Ltd, 200, pp. 335–341. doi: 10.1016/j.biortech.2015.09.057.

[14] Barlin, Gunawan, Arifin, A. and Pratiwi, D. K., 2016, '*Thermal Evolution Profile Analysis for Pyrolysis ff Coal – Acacia Mangium Wood Blends*', International Journal of Technology, (2), pp. 881–888.

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