Hydrophilic and hydrophobic characteristics of dry peat

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Abstract. Indonesia is a country with the largest peatland in Southeast Asia. These vast peatland is spread throughout the country. In the last 2 decades, Indonesia encounter land fires and now becomes an annual land fire event. Later, observed that the land fire occurred because dry season in Indonesia causing the peat becomes dried enough to have hydrophobic characteristics and easily burned. This fire phenomena on peatland is determined by some factor such as, physical properties, organic content, oxygen concentration, etc. Peat has hydrophilic and hydrophobic properties as physical properties when treated differently. Initially raw peat has hydrophilic properties. However, in certain low level of moisture content, peat becomes hydrophobic. To examine this phenomenon, mechanical understanding based experiment was done. For hydrophilicity, the experiment will be using Shimadzu MOC63u Moisture Balance Analyzer. The peat sample which are used are Indonesian natural peat. The wet peat was dried by using moisture balance equipment with various time (0.5 till 6 hours with interval 0.5h) at 100°C. and loading peat into a tube with 2.15 cm in inner diameter and 5.5 cm long where both end are covered by wire mesh. Afterwards, the tube was being dipped into water in a certain depth. As for hydrophobicity, the experiment was done with the same method as hydrophilicity by using some of the dried peat. From the experiment, the mass loss, adsorption time, volume shrinkage and adsorption capacity and as well as hydrophobicity of peat will be shown in the result.

1. Introduction
The vast territory makes Indonesia an archipelago. Within Southeast Asia, Indonesia has a best estimate of 149,056 km² of peatland [1]. By having a lot of islands, means a lot of soil types around Indonesia. Peat is a heterogeneous mixture of more or less decomposed plants (humus) material that has accumulated in a water-saturated environment in the absence of oxygen. It is also known as the “forgotten fossil fuel” [2] as it is able to store a large amount of carbon. The peat condition will be determined by the environmental condition. Basically, in normal environmental, peat soil tends to have water retention trait. Although at some certain condition where the climate is hot, that water retention trait would weakened due to the change of its characteristics and structure. This state is called hydrophobicity, and where the strong water retention state is called hydrophilicity.

Peat works as water storage and also carbon storage. It has high water retention ability to store water. However, peat soil can only provide a few spaces for plant’s growth compared to mineral soil. The decomposition of peat soil affect water retention ability [3], and the decomposed peat could retain...
water twice till six time than its dry weight. Soil water has three different types classified from physical classification, they are: (1) gravitational water, water that move freely while drained due to gravitational force and do not absorbed by the micro pores, (2) capillary water, water that absorbed to the micro pores and become moisture content in peat, (3) hygroscopic water, this water forms very thin films around soil particles and it is hard to remove just by normal heat treatment.

Hydrophobicity is a state of peat that is unable to retain water or water repellency. Most peat is dominated by wooden plants which have hydrophobic trait [4]. This hydrophobic trait may cause problems in agricultural industries. Hydrophobicity makes peat easy to burn at high temperature. While in hydrophobic state which unable to retain water, makes it harder to be extinguished.

2. Materials and Methods

2.1. Sampling and methods

This study analyzed the characteristics of peat taken from Papua, Indonesia as in previous work [5, 6]. The peat was sealed to preserve the initial condition until it reached the laboratory and until it was ready to be used as sample. To have the initial condition as similar as possible will resulting in better data acquired. By sealing the peat, the less change occurred in peat condition. For lab experiment, the sample was done by inserting a pack of peat into a holed aluminum with the dimension of 2.15 cm in diameter. Afterwards, the sample would be put into Shimadzu MOC63u Moisture Balance Analyzer to had its moisture content controlled. After that, the sample would be sunk into water and let it absorb water and soaked for 30 minutes and drained for 12 hours. Lastly, the sunken sample was taken to be weighed to see the difference in mass that will give the result whether the sample was in hydrophilic or hydrophobic state.

2.2. Hydrophilicity observation

Hydrophilicity of the peat determined when the peat still able to absorb water to a certain point or called wettability. To proof that, the experiment was done by observing the mass gained after sinking the controlled moisture content peat for a certain period of time. This simple method was conducted to obtain a series of data with controlled moisture content peat sample ranging from wet to dry. Ten samples went through this experiment with ten different time taken using Shimadzu MOC63u Moisture Balance Analyzer at 100 C with real time data acquisition. The difference in time taken will result in different moisture content and later will change the characteristics of peat although slightly and also the hydrophilicity of the peat. The variable of the experiment can be seen in table 1.

| Sample         | Drying time (hours) |
|----------------|---------------------|
| Papuan peat    | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 5 | 6 |

Table 1. Experimental setup

2.3. Hydrophobicity observation

Peat has a unique trait that perhaps only peat has. When reach a certain moisture contain, hydrophilic trait of peat which absorb water weakened and it becomes hydrophobic which decline water. The probability of hydrophobicity determined by the low moisture contain of peat condition. By using the same method as to observe hydrophilicity with the difference in moisture content, the hydrophobicity of peat can be observed. There are other advanced methods to observe hydrophobicity such as, Fourier Transform Infrared (FTIR) spectroscopy method and water drop penetration time method (WDPT) method [7].
2.4. Moisture content observation
Moisture content determine the condition of peat. Generally, high moisture content will result in peat still in hydrophilic state. On the other hand, while at low moisture content which change the dryness of peat, will result in hydrophobic state. The critical limit of moisture content was defined as a point where hydrophobicity phenomenon manifested [8]. The occurrence of hydrophilicity of peat was hypothetically estimated around 60-80% of moisture content. Thus, that makes the occurrence for hydrophobicity has lower percentage of moisture contain which go around 40-10%.

3. Results and Discussion
From the experiment, it can be seen that the more time taken for drying, the lower the moisture content became. While low in moisture content, means that the weaker the peat soil can retain water. The weaker the peat soil retain water the more hydrophobic peat become.

Mass loss phenomenon occurred because the moisture content evaporated. From figure 1 below, the percentage of mass loss after the drying process and mass gain after re-wetting process can be seen. The dryness of the peat affects the ability to re-adsorb water. The dried peat will not be able to fully return to the initial mass, even after re-wetting process. The weakened ability to adsorb water caused by the damaged structure of peat while in drying process and also causing irreversible drying. Following the drying time process, the water which can be adsorbed decrease. For sample no. 10 from table 1 (6 hours drying time), the mass of dried peat was 1.863 gram (10.3% of the initial mass) and after re-wetting process the mass increased to 2.1 gram (11.5% of the initial mass). It proved that dried peat cannot fully return to its initial mass. Thus, the longer the drying process, the more mass loss occurred. Meanwhile in re-wetting process, the mass gained from re-wetting was almost constant. However, at longer drying time which means low moisture content, the mass gained decreased caused by hydrophobicity.

![Figure 1](image_url)

**Figure 1.** Mass measurement of after drying and after re-wetting at various drying time.

The ratio of hydrophilic and hydrophobic of peat as shown in figure 2, gave the information the hydrophilicity and also hydrophobicity of the peat. When the ratio almost reached 1, that means
the hydrophobicity of the peat is lower, which also means the peat is hydrophilic. On the other hand, when the ratio almost reached 0, that means it becomes hydrophobic.

**Figure 2.** Hydrophilic and hydrophobic ratio of peat sample

**Figure 3.** Ratio of adsorption with evaporation
In this experiment, adsorption and evaporation occurred where peat was heated and sunk into the water. To see the tendency from hydrophilicity and hydrophobicity, it can be done by comparing the amount of water adsorbed and evaporated while in drying and re-wetting process as shown in Figure 3. Following the time taken in drying process, the ratio of water which is adsorbed and evaporated decrease. At 85% of moisture content (0.5 hours drying time) after re-wetting process, the ratio of adsorbed and evaporated water is 25.2% which is only \( \frac{1}{4} \) can be re-adsorbed by the peat from evaporated moisture content. The drier the peat, the lower the ratio becomes.

![Figure 3. Volume shrinkage of after drying and re-wetting peat samples](image)

Shrinkage analysis was done to observe the shrinking volume as the peat dried. It was also done to observe the damage and macro structural changes of peat. As seen in figure 4, the loss of moisture content affects the peat volume from drying process. At 75% moisture content (1 hour drying time), the remainder volume (shrinkage volume) is 68% from initial volume. Meanwhile, at 10% moisture content (6 hours drying time), the remainder volume is only at 15% of the initial volume. Thus, the more time taken for drying process, the smaller the remainder volume becomes.

4. Conclusion
Peat is a heterogeneous mixture of decomposed organic matters. Dried peat will become hydrophobic. To reach hydrophobic, the shrinkage volume and density and also mass loss will occur in the process. Shrinkage volume and mass loss will occur in drying process, while the water in the peat evaporated leaving the peat drying. While the volume shrinking and the mass loosing, the peat become more packed thus resulting in increased density. The denser the peat sample, the smaller the sample become.

Dried peat with low moisture content becomes hydrophobic. There was a critical point where peat started to change from hydrophilic to hydrophobic. Thus, this experiment indicates that the peat that undergoes heat treatment tends to be hydrophobic. Meanwhile from this experiment, it was known that moisture content played an important role to define peat as hydrophilic and hydrophobic. However, hydrophobic peat could still slightly adsorb water but not necessarily mean hydrophilic.
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