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Physical and Chemical Characteristics of Fibrous Peat

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Abstract. Banyuasin is one of the regency in South Sumatera which has an area of 200.000 Ha of peat land. Peat soil are characterized by high compressibility parameters and low initial shear strength. Block sampling method was used to obtain undisturbed sample. The results of this paper describe the characteristics of peat soil from physical and chemical testing. The physical and chemical characteristics of peat include water content (ω), specific gravity (Gs), Acidity (pH), unit weight (γ), and ignition loss tests. SEM and EDS test was done to determine the differences in fiber content and to analyze chemical elements of the specimen. The average results ω, Gs, and pH are 263.538 %, 1.847, and 3.353. Peat is classified in H4 (by Von Post). The results of organic content (OC), ash content (AC), and fiber content (FC) are found 78.693 %, 21.310 %, and 73.703 %. From the results of physical and chemical tests, the peat in Banyuasin is classified as fibrous peat. All the results of the characteristics and classification of fibrous peat compared with published data were close.

INTRODUCTION

One type of soil that is found in Indonesia is the peat soil. Indonesia's peat land area of are twenty six million hectares. Indonesia's peatlands are located on four large islands: Sulawesi (3 %), Papua (30 %), Kalimantan (32 %), and Sumatra (35 %), [1, 2, 3]. In Malaysia, 8 % of the country's land or three million hectares is covered with peatland [4]. [5] Described in Sarawak, the peat land about about 1.66 million hectares of Sarawak's total land area (about 13 %).

Furthermore, [6.7] reported about 63.503 hectares found in Ogan Ilir regency, South Sumatra province, Indonesia and approximately 6.300 hectares of peat land found in Pontian, Muar and Batu Pahat areas (Johor Barat, Malaysia). The distribution of peat soil in South Sumatera province are Ogan Komering Ilir regency (500.000 hectares), Muara Enim regency (45.000 hectares), Musi Rawas regency (35.000 hectares), Musi Banyuasin regency (250.000 hectares), and Banyuasin regency (200.000 hectares).

The type of peat soil is divided into two, namely shallow peat and deep peat soil. The shallow peat soil type has a thickness of peat soil less than 3 m and the deep peat soil type has a thickness of peat soil over 5 m.

Commonly, peat soil lands in South Sumatra province has a thickness ranging from very shallow (< 50 cm) to (200-400 cm). Nowadays, the area of peat thickness in more than 400 cm was difficult to be found. [5] describes that 90 % of peat in Sarawak is classified as deep peat (depth of more than 1.5 m).

This research inform the laboratory soil tests results including the characteristics of peat soils from Banyuasin Regency in South Sumatra. Banyuasin located at the position between 1.30°- 4.00° South (LS) Longitude and

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104°00'-105°35' East Longitude (BT) which extend from and the central part of South Sumatra province to the east with extensive the whole territory of 11.832.99 km² or 1.183.299 hectares.

Construction on peat soil needs to be considered because of poor peat soil characteristics such as high compressibility and low shear strength. Peat soils are the result of a mixture of fragmented organic materials where this process occurs in wetlands. According to Mac Farlane, there are two types of peat soil: amorphous peat soil and fibrous peat soil. Amorphous peat soil contains Fiber Content (FC) less than 20 %. Characteristics of amorphous peat soil approach the type of the clay so that the analysis of the characteristics of its compressibility properties can be based on the theory of Terzaghi (one dimensional consolidation).

Fibrous peat soil type has Fiber Content (FC) more than 20 %. Fibrous peat soil is known for its high content of fiber content (FC) and organic content (OC). The characteristics of peat land of fibrous peat soil are not same as clay soil because of the different soil properties and structure [9]. Therefore, the theory of Terzaghi cannot be used to analyze the characteristic of fibrous soil properties.

The fiber arrangement of peat soil can be determined from the results of physical properties and chemical properties test of peat soil. The fiber arrangement of peat soil fiber is significant in determining the characteristics of peat soil. In addition, the high fiber content in peat soils is also very impact in determining the behavior of peat soils. Scanning Electron Micrograph (SEM) is a tool that can analyze the difference of fiber content. SEM is an electron microscope which is designed to probe the surface of a solid object directly. SEM has 10-3000000 x magnification, depth of field from 4 to 0.4 mm and a resolution of 1-10 nm.

Moreover, one of the methods to determine the element/chemical parameter of peat soil can use the Energy Dispersive X-ray Spectroscopy (EDS or EDX) method. Energy Dispersive X-ray Spectroscopy works by exploiting the interaction of X-ray excitation source with the sample. The content of mineral elements contained in peat soils such as N (Nitrogen), Mg (Magnesium), Na (sodium), Ca (Calcium), K (Potassium), Al (aluminum), the content of pyrite (FeS2), C (Carbon), P (Phosphorus), Si (silicon), and O (Oxygen). In general, the cation exchange in peat soils is Ca^{+}, Mg^{3+}, Fe^{3+}, Al^{3+}, K^{3+}, Na^{3+}, NH^{4+} [10].

Peat soil can be classified based on several factors such as: (1) fiber content, (2) organic content, (3) fiber decomposition, and (4) the vegetation forming the organic content. Peat land classification can also be based on Von Post scale (H_1 to H_{10}). Von Post classifies peat soils based on the degree of decomposition. The decomposition value of H_{10} explain that peat soils have high degree of decomposition. In addition, peat soil classification can be use American Standard Testing and Materials (ASTM). Result from peat soil classification base on ASTM standards are shown in Table 1.

TABLE 1. Classification of Peat (ASTM Standards)

Classification of Peat Soil		
Fiber Content, FC (ASTM D 4427-13)	Fibric (Fibrous)	> 67 % fibers
	Hemic (Semi-Fibrous)	33 % - 67 % fibers
	Sapric (Amorphous)	< 67 % fibers
Ash Content, AC (ASTM D 4427-13)	Low Ash	< 5 % ash
	Medium Ash	5 % - 15 % ash
	High Ash	> 15 % ash
Acidity, Ph (ASTM D 4427-13)	Highly Acidic	< 4.5
	Moderately Acidic	4.5 – 5.5
	Slighly Acidic	> 5 and < 7
	Basic Acidic	≥ 7

The characteristics of fibrous peat soil can be obtained from physical characteristics, chemical characteristics, and mechanical characteristics. The testing of physical characteristics are: water content (ω), acidity (pH), void ratio (e_o), specific gravity (G_s), and unit weight (γ). And the testing of chemical characteristics of peat soil samples are: Fiber Content (FC), Organic Content (OC), and Ash Content (AC). Table 2 and 3 shows the results of properties (physical and chemical) of peat from previous researcher. Sampling is one of the factor to determined the characteristics of peat soil.

Fiber content and natural water content were factors that effect peat soil sampling methods. Two types of samples are undisturbed and disturbed samples. One method that can be used to obtained undisturbed peat soil samples at shallow depths is the block sampling method. ASTM D 7015-04 outlines the procedures for obtaining

undisturbed block are (a) cubical block sampling and, and (b) cylindrical block sampling. Undisturbed block samples are obtained for laboratory tests to determine the shear strength, permeability, and consolidation. While, the disturbed peat soil sample was used for soil properties such as water content, specific gravity, pH, etc.

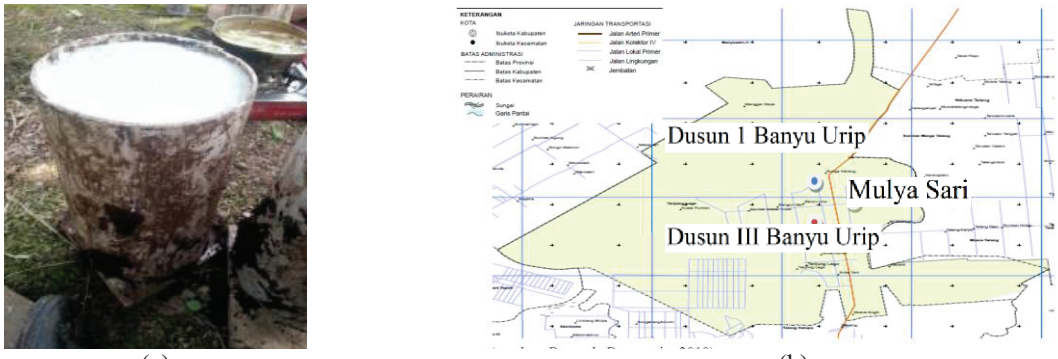
EXPERIMENTAL

The purpose of this research is performed to measure the characteristics (physical and chemical) of peat soils. The physical characteristics of peat include water content (ω), acidity (pH), void ratio (e_o), specific gravity (Gs), and unit weight (γ). And the chemical characteristics of peat include Fiber Content (FC), Organic Content (OC), and Ash Content (AC). The methods of Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectroscopy (EDS or EDX) tests were done to describe differences in fiber content and to analyze chemical elements of the specimen.

Sampling of Peat Soil

Fig. 1 (a) describes the block sampling method. The location of peat soil sampel from Banyuasin Regency in South Sumatra. Peat soil in this research included the category of shallow depth based on the results of site surveys have been conducted. Because of that, a best method of obtaining undisturbed peat soil samples for shallow depths is the block sampling method. Procedure for sampling of peat according to ASTM D7015-04.

The locations of peat soil sampling at three locations (Fig. 1 (b)) from Banyuasin Regency in South Sumatra. The locations are: Dusun I Banyu Urip, Dusun III Banyu Urip, and KTM Telang Banyuasin. Peat soil depth is about 0.5 m. After being excavated, the sample tubes are pushed slowly into the peat soil. The sharpness of the sample tube side and the knife used to cut peat soil samples should be noted in order to obtain good sample quality. Wax and wooden plates (200 mm x 200 mm) were used to cover the top and bottom of peat soil samples.



(a) (b)

FIGURE 1. (a) The Block Sampling Method, (b) Sampling Location

Physical and Chemical Characteristics of Peat

Disturbed peat soil samples were used for testing soil properties of peat soil in the laboratory. Each test of soil properties, such as moisture content, is carried out using six samples. The results of these test were used to determine the characteristics of peat soil (physical, chemical, and classification). ASTM D 2974-87 standard was used to determine water content (ω) of peat soil. While ASTM D 2976-71 standard was used to determine the parameters of pH (acidity of peat soil).

ASTM D 854-14 had been used to determined parameter of the specific gravity (Gs) using kerosene. The results obtained from water content (ω) and specific gravity (Gs) can be used to calculated the parameter of void ratio (e_o). Parameter of unit weight (γ, kN/m^3) calculated based on specific gravity (Gs), initial void ratio (e_o), and water content (ω). Test for fiber content (FC) according to ASTM D 1997-13. While the test for organic content (OC) and ash content (AC) based on ASTM D 2974-14. Table 2. shows the physical and chemical properties of peat.

TABLE 2. Results of physical characteristics of peat soil from previous researcher

Physical Characteristics					Chemical Characteristics				
Reference	**Location**	**ω (%)**	**pH**	**G_s**	**Reference**	**Location**	**OC (%)**	**FC (%)**	**AC(%)**
[7]	Fibrous, Ogan Ilir	409.09-493.01	3.94-4.12	1.40-1.80	[7]	Fibrous, Ogan Ilir	77.40-80.99	70.45-76.66	19.01-22.61
[5]	Fibrous, Sarawak	426-926	3.2-4.3	1.08-1.67	[5]	Fibrous, Sarawak	89-95	23.2-50.3	5-11
[11]	Fibrous, Palangkaraya	412.16-531-33	3.5	1.42-1.74	[11]	Fibrous, Palangkaraya	96.78-97.69	33.15-38.33	2.31-3.22
[12]	Fibrous, OKI	495.67-632.10	4.79-4.86	1.79-1.81	[12]	Fibrous, OKI	33.44-38.22	29.65-32.60	8.31-23.63
[10]	Fibrous, Middleton	510-850	4.2	1.47-1.64	[10]	Fibrous, Middleton	90-95	> 20	5-7
[4]	Fibrous, Malaysia	200-700	3-4	1.38-1.70	[4]	Fibrous, Malaysia	65-97	> 20	3-35
[13]	Fibrous, Iranian	353-501	4.0-5.5	1.50	[13]	Fibrous, Iranian	76-87	39-81	13-24
[14]	Fibrous, Malaysia	140-350	2.65-2.75	1.42-1.56	[14]	Fibrous, Malaysia	70-88	31-75	12-30
[6]	Fibrous, Johore	608	3.14	1.47	[6]	Fibrous, Johore	97	90	3

Classification, SEM, and EDS of Peat

The peat soils were classified based on ASTM D 4427-13, von Post degree of decomposition and Mac Farlane. The parameter were used to classification such as: Fiber Content (FC), Ash Content (AC), and Acidity (pH). The Von Post scale H_1 to H_{10} was used to classify peat soil based on the degree of decomposition. Muffle furnace equipment (440 ° C) also used for testing organic content and ash content on peat soil. The classification test using six samples for each test.

The equipment used to describes the orientation of fibrous peat soil is Scanning Electron Microscope (SEM). This SEM equipment uses a combination of X-Ray and micro analysis with a maximum magnification of 3.000.000 x. In addition, to analyze the elements/chemistry of peat soils using Energy Dispersive X-ray Spectroscopy (EDS or EDX) equipment.

RESULTS AND DISCUSSION

The results of this research define the results of laboratory tests such as testing of physical and chemical properties and classification. Peat land is taken from Banyuasin regency (Dusun I Banyu Urip, Dusun III Banyu Urip, and KTM Telang Mulya Sari), South Sumatra, Indonesia. Based on survey results in the field, peat soils include shallow peat soil types where the thickness of peat soil does not reach 3 m. Because of that sampling of peat soil was therefore retrieved from between 1 and 2 m depth. The sampling process was designed and established carefully as to avoid disturbance as much as possible. The samples of the peat soil was obtained using block sampling method.

The sample tube had been used to obtained undisturbed samples of peat soil [14]. The samples of this research were taken from West coast of Peninsular Malaysia. [6,7] also used the block sampling method for the sample of fibrous peat soil. The general characteristics of peat soils were determined by the results of laboratory testing. The physical properties of peat soil include: water content (ω, %), void ratio (e_0), specific gravity (G_s), and unit weight (γ, kN/m^3). While testing for the chemical properties of peat soil were fiber content, ash content, organic content, Scanning Electron Microscope (SEM), and Energy Dispersive X-ray Spectroscopy (EDS/EDX). Peat soil

classification based on Von Post and ASTM standards. Physical and Chemical Properties of peat soils are shown in Table 3. As well as Table 4 describes the results of peat soil classification.

TABLE 3. The summary of physical and chemical characteristics of peat

Parameter	Characteristics		
	Dusun I Banyu Urip	**Dusun III Banyu Urip**	**KTM Telang Mulya Sari**
Water Content (ω, %)	236.523	294.300	259.790
Acidity (pH)	3.200	3.160	3.700
Void Ratio (e_0)	3.445	3.092	3.351
Specific Gravity (G_s)	1.869	1.799	1.873
Bulk unit weight (γ_b, kN/m^3)	13.132	15.050	13.132
Dry unit weight (γ_d , kN/m^3)	4.122	4.132	4.122
Organic Content (OC, %)	77.690	77.400	80.990
Ash Content (AC, %)	22.310	22.610	19.010

Based on Table 3, the results of testing the average water content of peat soil is 263.538 %. If the results of peat soil water content compared with the results of previous researchers (Table 2) then the results were still within range. Another peat soil parameter is acidity (pH). Generally, peat soils have low pH value. The range of acidity values obtained was 3.16 (Dusun III Banyu Urip) - 3.70 (KTM Telang Mulya Sari) which is the results was in the range of published researcher. Based on [7] reported pH = 3.94-4.12, [5] reported pH = 3.20-4.30, and [11] reported pH = 3.50. While the test results of specific gravity (Gs) is 1.80-1.87. Range this value is higher compared with previous researchers. [5] reported G_s=1.08-1.67, [11] reported G_s=1.42-1.74, and [12] also reported G_s=1.79-181. Moreover, the result of other peat soil parameters was void ratio (e_0) of 3.296.

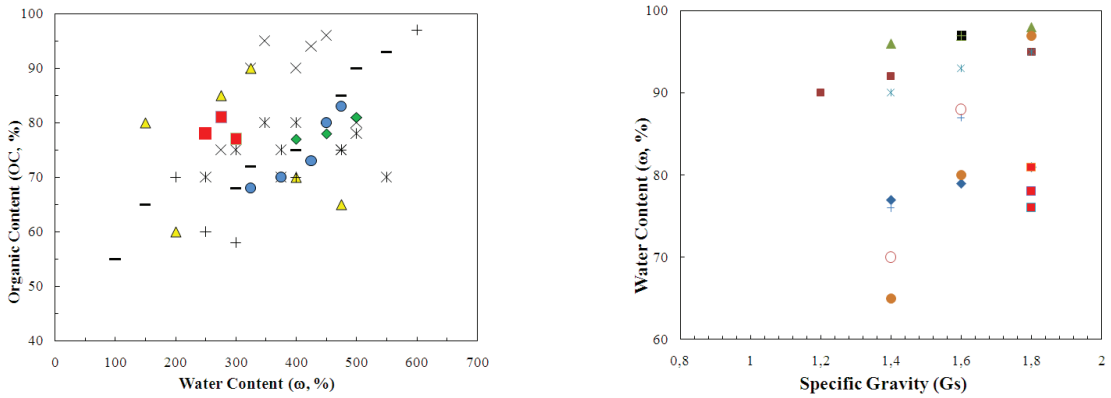
In this research, peat soil classification based on test results of chemical properties such as: Fiber Content (FC), Ash Content (AC), and Organic Content (OC). In addition, peat soils were classified by Von Post and ASTM standars. Fig. 2 illustrates the results of the Von Post scale classification. From the figure it can be seen that when peat soil is taken then brown muddy water out of between hands and peat soil was also seen to have a lot of fiber. Based on this scale, peat soils are classified as H_4. [17] state that compotition of soil organic matter in peat soil was not related with the degree of humification. The results of classification of peat soil from Dusun III Banyu Urip (Table 4) are: ASTM D 4427-13 (based on Fiber Content) is fibric peat; ASTM D 4427-13 (based on Ash Content) is high ash peat; and ASTM D 4427-13 (based on pH) is highly acidic.

TABLE 4. The results of classification of peat soil

Parameter	Classification		
	Dusun I Banyu Urip	**Dusun III Banyu Urip**	**KTM Telang Mulya Sari**
Mac Farlane (1969) (FC)	Fibrous peat	Fibrous peat	Fibrous peat
ASTM D 4427-13 (FC)	Fibric peat	Fibric peat	Fibric peat
ASTM D 4427-13 (AC)	high ash peat	high ash peat	high ash peat
ASTM D 4427-13(pH)	Highly acidic	Highly acidic	Highly acidic
Von Post (1992)	H_4	H_4	H_4

FIGURE 2. Von Post Scale

The results of chemical characteristics of peat soil based on Table 3 described that the organic content (OC, %) =77.40-80.99, the fiber content (FC, %) = 70.45-76.66, and the ash content (AC, %) = 19.01-22.31. Compared with previous researcher (Table 3), [5] reported OC = 89 % - 95 %, [11] reported OC = 96.78 % - 97.69 %, and [16] reported AC 20 %. The organic content results showed that of the peat soil used in this research is in the lower value of the range previous researcher (Fig. 3 (a)). Furthermore, the relationship between specific gravity and organic content parameters for peat soils was described in Fig. 3 (b).

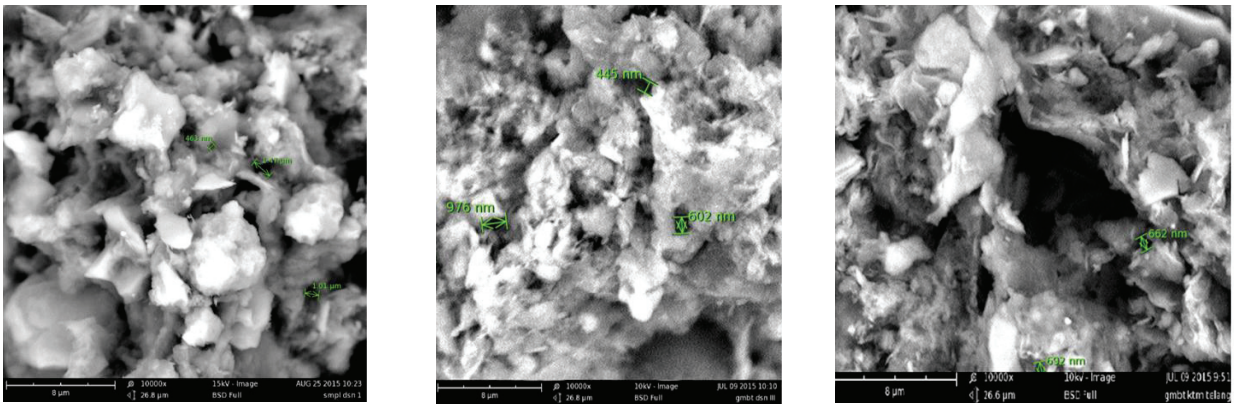


(a) (b)

FIGURE 3. (a) Organic Content - Water Content compare with published data, (b) Specific Gravity – Water Content compare with published data

In accordance with Mac Farlane, peat soil is divided in two groups: (1) amorphous peat soil, and (2) fibrous peat soil. Fiber peat soil is peat soil type that has fiber content (FC) of more than twenty percent. From Table 3, Fiber content = 70.45 % - 76.66 %. It means that the Fiber content is more than 20 %. So, it can be classified the peat as fibrous peat. In this research, Table 3 and 4 explained the results of physical characteristics, chemical characteristics, and classification of peat soil. From this table, it can be concluded that the peat soil type in Banyuasin Regency is classified as fibrous peat soil.

Differences in fiber content of peat soils were tested using Scanning Electron Microscope (SEM) equipment. The results of fiber content of peat soil testing which is taken from Banyuasin district, South Sumatra were shown in Fig. 6. SEM results in Fig. 6 of the location: Dusun I Banyu Urip, Dusun I Banyu Urip, and KTM Telang Mulya Sari. The sample has been used in this test was a sample which is cut horizontally with magnification up to 10.000 times. Based on test results established on the Scanning Electron Microscope fibrous peat soil in the Chemical Laboratory of Chemical Engineering Department of the Sriwijaya Polytechnic visible pores and fibers contained in fibrous peat. Scanning Electron Microscope from KTM Telang Mulya Sari in Fig. 6 illustrates structural behavior of fiber for the fibrous peat with the void spaces larger than other locations in the horizontal direction.



(a) Dusun I Banyu (b) Dusun I Banyu Urip (c) KTM Telang Mulya Sari

FIGURE 4. Results of analysis of SEM

Energy Dispersive X-ray Spectroscopy (EDS/EDX) has been to analyze chemical elements of the specimen. Testing of EDS was performed from Dusun III Banyu Urip and KTM Telang Mulya Sari fibrous peat soil. This test was done to analyze the elements/chemical elements contained in the fibrous peat soil. The results of the testing of EDS/EDX on fibrous peat soil sample can be seen in Table 5 and 6, and Fig. 5 (a), Fig. 5 (b). Table 5 and Table 6 showed the results of Energy Dispersive X-ray Spectroscopy (EDS/EDX) from Dusun III Banyu Urip and KTM Telang Mulya Sari based on element (number, symbol, name) and concentration.

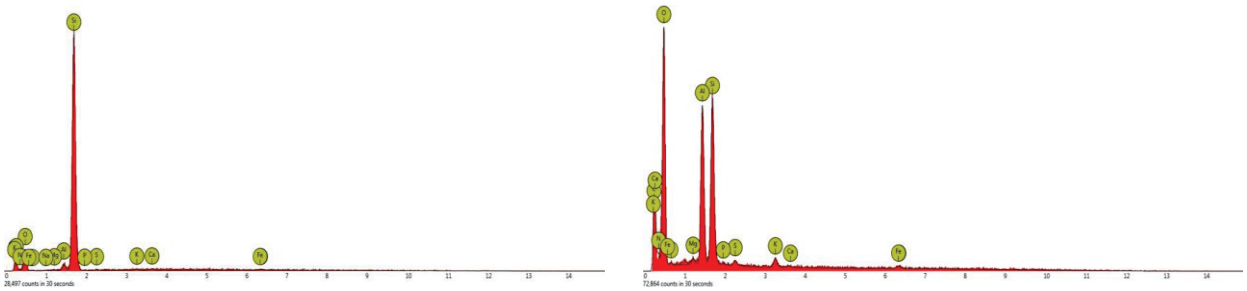
TABLE 5. Test results of EDS from dusun III Banyu Urip

Element Number	Element Symbol	Element Name	Concentration
	O	Oxygen	64.7
14	Si	Silicon	11.4
13	Al	Aluminium	12.9
6	C	Carbon	5.2
7	N	Nitrogen	2.9
19	K	Potassium	0.7
12	Mg	Magnesium	0.8
16	S	Sulfur	0.4
26	Fe	Iron	0.7
15	P	pHosphorus	0.2
20	Ca	Calcium	0.1

TABLE 6. Test results of EDS KTM Telang Mulya Sari

Element Number	Element Symbol	Element Name	Concentration
8	O	Oxygen	38.6
6	C	Carbon	5.9
13	Al	Aluminium	1.9
20	Ca	Calcium	0.7
19	K	Potassium	0.7
7	N	Nitrogen	2.9
26	Fe	Iron	1.0
16	S	Sulfur	0.6
12	Mg	Magnesium	0.5
15	P	pHosphorus	0.4
11	Na	Sodium	0.6

The results of the EDS/EDX explained that the oxygen (O) and carbon (C) contents of the fibrous peat soils were 44.50 % (Dusun III Banyu Urip) and 76.1 % (KTM Telang Mulya Sari). The results of carbon (C) and oxygen (O) contents is lower than previous researcher [13, 2015]. [13] reported results of X-Ray Fluorescence (XRF) from Iranian fibrous peat. The results of this X-Ray Fluorescence test show the value of carbon (C) and oxygen (O) content. Chaghakhor peatlands were 78.6 % and Gavkhuni at 89.2 %. The organic particles present in the peat soil have inner pores. So that the characteristics of peat soil in this location based on the pores of the inside and outside of soil particles and fiber content.



(a) (b)

FIGURE 5. (a) Results of EDS from Dusun III Mulya Sari; (b) Results of EDS from KTM Telang

Beside of that, the results of [15] explained the chemical characteristic of peat soil. The chemical properties were affected by the chemical composition of the peat soil components, the decomposition, and the environment. The chemical characteristics of peat soils such as: acidity, chemical composition, and cation exchange capacity (CEC). The results of percentage chemical composition are carbon (C) 40 to 60 %, oxygen (O) 20 to 40 %, hydrogen (H) 4 to 6 % and nitrogen (N) 0 to 5 %.

CONCLUSIONS

Based on the results of this research it can be taken some conclusions as follows:

1. Peats soil in Banyuasin Regency was included in shallow peat soil with peat soil thickness less than two meters. Based on field observations, peat soil samples were taken at a depth of 0.5 -1 m.
2. The water content (ω) of the peat is 264 % which corresponds to acidity (pH) of about 3.353. The specific gravity (Gs) is 1.847. From some of the test results it can be known characteristics of peat soil in Banyuasin regency.
3. Peat soils are classified based on chemical properties of peat soil, von Post scale, and standard ASTM. The results of chemical characteristics of peat soil: the Fiber Content (FC) = 70.45 % - 76.66 %, the Organic Content (OC) = 77.40 % - 80.99 %, and the Ash Content (AC) = 19.01 % -22.31 %. From these results, peat soil Banyuasin Regency can be classified as fibrous peat.
4. The results of the Energy Dispersive X-ray Spectroscopy (EDS/EDX) based on the oxygen (O) and carbon (C) contents: (a) 44.50 % from Dusun III Banyu Urip, and (b) 76.1 % from KTM Telang Mulya Sari

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