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Characteristics of magnetic susceptibility and geochemistry of paddy soils in Malang City, East Java

N Y Daryanti[1], S Zulaikah[1,2]* , N Mufti[1,2] and D S Haryati[1]

[1]Departmen of Physics, Universitas Negeri Malang, Jalan Semarang No.5, Sumbersari, Kec. Lowokwaru, Kota Malang 65145, Indonesia
[2]Advance Material and Mineral Laboratory, Universitas Negeri Malang, Jalan Semarang No.5, Sumbersari, Kec. Lowokwaru, Kota Malang 65145, Indonesia

E-mail: siti.zulaikah.fmipa@um.ac.id

Abstract. Paddy soils are a typical anthropogenic soil resource that has a wet-dry cycle and plays an important role almost all over the world, mainly in Indonesia. Along with the development of the current area of rice farming, the changes of many environmental from natural areas has undergone to settlements area and influenced by human activities. This study examines the magnetic properties and element content in special soils of paddy farming areas in the city of Malang. In this study magnetic susceptibility measurement was conducted on 60 samples taken from 3 locations, using Bartington susceptibilitymeter MS2B. The element determination was conducting by XRF (X-Ray fluorescence) on 3 representative samples. The result showed that the average of magnetic susceptibility low frequency (χ_{lf}) of paddy soils was 3.66×10^{-6} m^{3}kg^{-1}. The chemical elements in paddy soils are dominated by Fe, that is around 41.2 % then followed by Si about 36.7%, Al about 12%, Ca about 10.5% and Ti is the lowest value, that is about 2.13%.

1. Introduction

Paddy soils is a typical antrophogenic soil that plays an important role of agriculture worldwide [1]. Especially, for the region of Malang, East Java whose people rely on rice as a staple food. The availability of paddy depends on the existence of paddy soils, as well as in Malang area which has paddy soil reach 45,890 ha [2]. The existence of paddy soils area due to human activities [2], resulted in different soil conditions. These differences are usually investigated under microscopic conditions. So the effort to understand the difference of paddy soil condition can use the magnetic properties of soil as a proxy due to the process involved in its formation [3,4].

The magnetic properties of soils depend on presence of magnetic minerals in the soil, event it is very small intensity, the existence is sensitive enough to understand the magnetic properties [5]. In general, magnetic parameters are commonly used is magnetic susceptibility. This magnetic susceptibility is very easy to identify, cheap, efficient, and has a strong sensitivity [6–9]. Considering the advantages of these magnetic susceptibility parameters, the measurements have been widely used in the analysis of sedimentary and soil environments, such as in marine sedimentary environments and

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paleosols [10], lakes [11], estuary [12], peat soils [13], and industrial site [14], as well as the contaminated soil environment [15]. Non-magnetic parameters that support to find out the characteristics of paddy soils is by investigating the constituent elements in the paddy soil.

Several studies have been conducted on several agricultural soils, whether fruits, vegetables, or paddy, such as on the dean farms of the Chinese steel mills [16], farmlands close to the forests of Poland [17] and agricultural land in urban areas China [18]. Particular magnetic studies on paddy soils are in Cixi City, China [19], paddy soils in southern China [20], as well as paddy soils in Madiun, Indonesia [21]. However, magnetic studies on paddy soils in Indonesia especially in Malang is still limited, given the geographical location of this city which is surrounded by several volcanoes and dense settlements around paddy soils. So in this study magnetic and non-magnetic measurements were taken as the first step in the development of agromagnetism studies, to understand the magnetic properties of paddy soils.

2. Experimental Method

2.1 Sampling and Preparation
Sampling of paddy soils in Malang with wide area of $\pm$ 45,890 Ha [2]. Geographical location 112.17°-112.57°E and 7.44°-8.26°S. Sampling is selected from paddy soils close to human activities area. Samples taken from Lowokwaru district in three region of Jatimulyo, Mojolangu and Karangwidoro. Sampling points was take random in on area and the less distance of about 3 meters space. The total sample are taken from 30 point and each point provide 2 sample so we get about 60 samples. The sample then marked by PL for the paddy soil of Jatimulyo, SH for an area of Mojolangu and SG for the Karangwidoro. During sample preparation, SG point becomes SG 1.1 and SG 1.2, then SH code samples become SH 2.1 and SH 2.1, and PL, given PL 3.1 and PL 3.2 and so on.

2.2 Sample Characterization
Testing of magnetic susceptibility was done using Bartington MS2B Susceptibility meter in Mineral Laboratory and Advanced Material Universitas Negeri Malang. The device sensors display the value of the magnetic susceptibility volume which will then be calculated to obtain magnetic susceptibility values by dividing with sample volume, ie $\chi = \kappa / \rho$. The magnetic susceptibility test was performed with a low frequency of 0.46 Hz and a high frequency of 4.6 Hz [9,22]. Further characterization to see the abundance of elements in paddy soils using non-magnetic methods is by conducting XRF (X-ray Fluorescence) test Merk PANalytical, Type: Minipal 4 [23]. XRF is a non-destructive testing of chemical analysis of rocks, minerals, sediments and liquids [24]. The test shows the constituent elements in paddy soils in percentage value.

3. Result and Discussion

3.1 Magnetic Susceptibility
The result of measurement was obtained the average value of magnetic susceptibility on 30 samples. Measurements was conduct in two different frequencies, ie high frequency and low frequency are shown in Table 1. The samples with PL code have the highest mean of χ_{lf} 4.94 $\times 10^{-6}$ m^{3}kg^{-1}, χ_{hf} 4.84 $\times 10^{-6}$ m^{3}kg^{-1} and χ_{fd} 1.37 %. The lowest mean is in SH samples, with the value of χ_{lf} 2.18 $\times 10^{-6}$ m^{3}kg^{-1}, χ_{hf} 2.15 $\times 10^{-6}$ m^{3}kg^{-1} and χ_{fd} 1.12 %. While, SG samples has a moderate mean value, located between PL and SH, i.e., the χ_{lf} of about 3.89 $\times 10^{-6}$ m^{3}kg^{-1}, χ_{hf} 3.83 $\times 10^{-6}$ m^{3}kg^{-1} and χ_{fd} 1.78 %. A representative samples were then selected based on the highest, lowest and medium of χ_{lf} to determine the element content for geochemistry analysis are shown in Table 2. Other things that also affect magnetic susceptibility value are related to rice processing activity according to [18] such as heavy metals derived from antrophogenic activity, fertilization, pesticide application and dry wet cycle in paddy soil. In some studies, the value of magnetic susceptibility in paddy soil has a characteristic that is quite low when compared to other soil types [17,20].

Based on the results of magnetic susceptibility measurements can be plotted graph between χ_{lf} with χ_{fd} (%), which allows to see the correlation between magnetic mineral grain size with domains position. It can also predict the initial classification of magnetic properties. The frequency dependent measurement of magnetic susceptibility utilizes repeated measurements of different frequencies. At low frequency measurements can approach the limit of semi-stable magnetic mineral grains so as to contribute fully to the value of magnetic susceptibility.

Referring to the plot of the χ_{lf} versus χ_{fd} (%) [25], states that the difference in magnetic susceptibility values at different measurement frequencies is capable of indicating the presence and amount of superparamagnetic (SP) minerals. However this is true if the dominant size of magnetic mineral grains is very small (<0.03 μm). With the small grain size, magnetic susceptibility at high frequency can be reduced. If the magnetic mineral grain size consists of a mixture of fine grains and coarse it will be easy to find minerals with multi domains (MD).

Through Figure 1 it can be seen that the whole sample of paddy soil land has a tendency to accumulate at the bottom. Low values of χ_{fd} (%) tend not to find fine grains of minerals, but on the contrary many rough magnetic minerals are found. Furthermore, for the value of χ_{fd} (%) medium, ie 2 - 10% indicates the presence of a coarse magnetic mineral grain mixture, or possibly a very fine and non SP SP grain mixture. This indicates that the paddy soil in Malang is a magnetic field whose magnetic mineral has many domains, so it is included in MD.

3.2 Geochemistry Content

Table 2 shows the elements contained in the three representative samples of paddy soils. Based on the test results, the sample is dominated by Fe element, followed by Si, Al, Ca, and Ti respectively. The rest are other elements that are quite small, less than 1%. In a row of minority elements, in SG1.1 paddy soil samples found the presence of Pb elements. This element belongs to heavy metal elements, which become one of the elements harmful to the environment. The Pb element in paddy soil has a low percentage of 0.5% of the total sample. The existence of this element can not be separated from the location of paddy soils that are close to the settlement, so the waste of daily activities impact on the soil surface of the paddy soil.

Table 1. The average value of magnetic susceptibility in each paddy soils.

Fields	Average χ_{lf} ($\times 10^{-6}$ m^3/kg)	Average X_{hf} ($\times 10^{-6}$ m^3/kg)	Average χ_{fd}
SH	2.18	2.15	1.12
PL	4.94	4.84	1.37
SG	3.89	3.83	1.78
Average	3.66	3.60	1.42

The elements contained in paddy soil can be correlated with the results of magnetic susceptibility (χ_{lf}) measurements. In PL 5.2 sample, is obtained that Fe elements 41.2% with χ_{lf} 3.73 ($\times 10^{-6}$ m^{3}kg^{-1}) which is the largest percentage of element. Next, on SH 9.2 sample contained Fe element 40% with χ_{lf} 0.88 ($\times 10^{-6}$ m^{3}kg^{-1}). And the last of the lowest Fe content of 39.8% in SG 1.1 sample as a value of χ_{lf} 5.10 ($\times 10^{-6}$ m^{3}kg^{-1}). Other elements that have a high percentage of Si respectively valued 36.7%, 34%, and 32.4%, Al elements which has each value of 9.9%, 12%, 11%. Then followed by Ca element with the value of 7.86%, 7.44%, 10.5%, and Ti element of about 2.09%, 2.09% and 2.11% respectively.

Based on the results of magnetic susceptibility measurements and Fe element percentages, then correlate with Table Minerals and Magnetic Susceptibility [25] which deals with the magnetic properties and Fe element percentages, we can obtain information about the provisional conjecture for magnetic properties contained in paddy soil. In paddy soil in Malang city, the lowest χ_{lf} 0.88 and the highest χ_{lf} 5.10 ($\times 10^{-6}$ m^{3}kg^{-1}) and the percentage range of Fe element is 39.8 % – 45.52 %. Therefore, the initial suspicion of the soil is paramagnetic, and based on the elements contents, that is divided into macro and micro elements [26], the percentage of elements found in the three representative samples,

generally, paddy soils condition in Malang city can be said to be feasible and included in arable soils to cultivation.
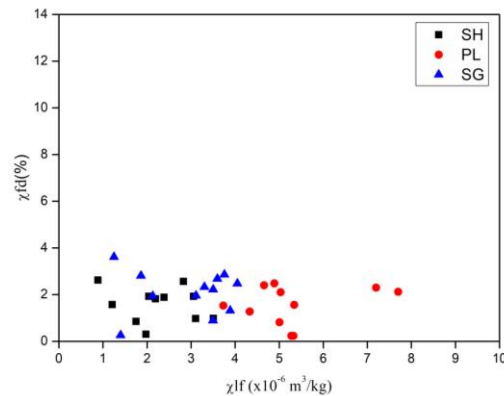

Figure 1. Plot χ_{lf} with percent χ_{fd} (%)

4. Conclusion

Based on measurement of 60 samples from 3 area of paddy soil in Malang city, the magnetic susceptibility ranged from 0.88 to 7.70 ($\times 10^{-6}$ m^3/kg) with the average dependent frequency magnetic susceptibility of about 3.7%. An area called Dinoyo has the highest susceptibility than that of the two paddy soils of Jatimulyo and Mojolangu. The magnetic susceptibility in paddy soils has a lower value when compared to forest land or other agricultural land. As well as the percentage of the largest constituent element is Fe, then followed by elements Si, Al, Ca, and Ti. The elements of the land in Malang are classified as a good, feasible and included in arable soil to cultivation.

Tabel 2. Elements content in paddy soils

Element (%)	Sample ID		
	SH 9.2	*PL* 5.2	*SG* 1.1
Al	9.9	12	11
Si	36.7	34	32.4
P	0.59	0.71	0.88
K	0.86	1	1.1
Ca	7.86	7.44	10.5
Ti	2.09	2.09	2.13
V	0.14	0.13	0.14
Cr	0.07	0.07	0.07
Mn	0.7	0.6	0.5
Fe	40	41.2	39.8
Cu	0.2	0.19	0.19
Zn	0.05	0.07	0.13
Eu	0.57	0.4	0.4
Re	0.3	0.3	0.3
Pb	-	-	0.51
Ba	-	0.2	-
χ_{lf} ($\times 10^{-6}$ m^3/kg)	0.88	3.73	5.10
χ_{hf} ($\times 10^{-6}$ m^3/kg)	0.86	3.67	5.04
χ_{fd} (%)	2.62	1.53	1.04

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