Study on Magnesium in Rainwater and Fertilizer Infiltration to Solidified Peat

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Abstract: Magnesium is a component of several primary and secondary minerals in the soil which are essentially insoluble for agricultural purpose. The presence of water infiltrate in the soil allows magnesium to dissolve together into the groundwater. In fertilizers, magnesium is categorized as secondary macronutrient which supplies food and encouraging for plants growth. The main objective of this study was to determine the concentration of magnesium in fibric peat when applied the solidification under different conditions. Physical model was used as a mechanism for the analysis of the experimental data using a soil column as an equipment to produce water leaching. In this investigation, there were four outlets in the soil column which were prepared from the top of the column to the bottom with the purpose of identifying the concentration of magnesium for each soil level. The water leaching of each outlet was tested using atomic absorption spectroscopy (AAS). The results obtained showed that the highest concentrations of magnesium for flush and control condition at outlet 4 was 12.50 ppm and 1.29 ppm respectively. Similarly, fibric with solidified peat under rainwater recorded the highest value of 3.16 at outlet 1 for wet condition while for dry condition at outlet 4 of 1.33 ppm. However, the difference in fibric with solidified peat under rainwater and fertilizer condition showed that the highest value for the wet condition was achieved at outlet 1 with 5.43 ppm while highest value of 1.26 ppm was obtained for the dry condition at the outlet 4. It was concluded that the outlets in the soil column gave a detailed analysis of the concentration of magnesium in the soil which was influenced by the environmental conditions.

1. Introduction

Generally, peat soil is the accumulation of pure organic material which is contains at least 65 % organic matter or less than 35 % mineral content [1]. According to the American society for testing and materials (ASTM) standard (ASTM, 1990) peat classification has been narrowed to only three groups namely fibric for least decomposed with more than 67 % fiber content, hemic for semi-fibrous which intermediate decomposed and sapric is amorphous which most decomposed with less than 33 % fiber content. Fibric peat can be said as a high organic and fiber content because of low degree of humification and easily identifiable and extremely acidic [2]. Von Post classification is related with the Degree of Humification (Decomposition) of organic matter scaled from H1 to H10 which higher numbers indicate stronger peat decomposition [3]. Teong *et al.,* [4] stated, the degree of decomposition for fibric peat is from H1 to H3 because fibric represents the least humification compared to hemic and sapric. The degree of decomposition also is related to the deposition of peat in the environment and the types of decomposed peat-forming plants [5].

As a developing country, Malaysia is not exempted from urbanisation issue where some place has been congested with population while the other place, especially on peat area, the population rate is very low. Construction activities on soft soils require high skill and expertise to avoid any failure as peat is easily influence by climate and subsidence. Stabilization of peat soil is important to minimize the problem. Peat has considerable negative geotechnical properties such as high water content, low shear strength, high organic matter, and low bearing capacity [6]. The critical part to stabilize the soil is the economical and effective mix design because it involves the use of cost and strength of material [7]. According to Abdel Salem [6], binder materials such as cement, lime, fly ash, blast furnace slag, calcium sulfate, and gypsum can be used as admixture in peat stabilization. Soil stabilization in weak soil is apply to improve its geotechnical properties such as compressibility, strength and permeability. However, it depends on the soil property and the component of stabilizer. In this study, the binder material used only focuses on Ordinary Portland Cement (OPC), fly ash (FA) and bottom ash (BA) to stabilize the peat soil.

Soil stabilization is influenced by several factors such as water, physical, chemical, and mineralogical properties; character and amount of organic content, and the pH of the pore water [8]. However, the cement-stabilized peat gains in strength depend on the decomposition of the organic compound to organic acid due to the effects of biological influence, its specific surface area, and cation exchange capacity (CEC) [9]. Cement will enclose soil as a glue but it will not change the structure of soil [10]. A hard material that known as clinker ground together with a small amount of gypsum into a powder to produce Ordinary Portland Cement (OPC) [11]. Unlike cement, FA works as neutralizer in peat soil with the help of its pozzolanic properties [12]. Therefore, FA is suitable for use on peat soil which has high acidity than other soil. FA is divided into class C and class F fly ash based on the type of coal burned [13]. Class C fly ash is generally obtained by burning sub bituminous or lignite coal while Class F fly ash is produced by burning anthracite or bituminous coal [14]. BA on the other hand, is suggested to be used in construction activities. It works well as binder material for soil stabilization and have a few advantages including low cost, low density and very sustainable material [15]. According to Benson [16] the physical properties of BA can be classified as angular particles with very porous surface textures. The ash particles generally range in size from a fine gravel to a fine sand with very low percentages of silt clay sized particles.

Even though study for soil stabilization has been conducted for decades, but the work is limited to laboratory scale only. For the formulation to be applied on-site, environmental factors are important and need to be analyzed. The climate, rain water and fertilizer are amongst the main factors that influence the environment condition. Since 1990s, about 25 % of peatland area in Malaysia has been converted to oil palm plantations [17]. Johor also makes agriculture as an economic sector where conversion of peat swamp forest for agricultural purposes began in early 1974 involving of 95,000 ha [18]. Hence, agricultural areas comprising various types of soil according to area and environment are often linked to the use of fertilizers as food to plants. In this study, the magnesium element was analyzed to find out the content present in the soil based on the different conditions. In addition, magnesium is also present in the fertilizer and can be categorized as second macronutrient other than the rain water itself [19].

Nutrient supply through fertilizer or modification of the soil environment to influence nutrient availability is important to treat plant diseases and integral components of production agriculture [20]. According to Uchida [21], the function of magnesium is to aid chlorophyll formation, phosphorus metabolism and helps regulate uptake of other nutrients. Magnesium depletion in soils also is a growing concern for high-productivity agriculture. However, due to its potential for leaching in highly weathered soils and the interaction with aluminum, magnesium deficiency is a critical concern in acid soils [22].

In addition, tabulation of rainfall also affects the concentration of magnesium in the soil. Malaysia's climate can be classified as hot and humid throughout the year. In the dry weather, Malaysia tends to experience average rainfall approximate 100 mm of rainfall per month while for wet weather, the Peninsular Malaysia and East Malaysia (Sabah and Sarawak state) are averaging at 2500 mm and 5080 mm respectively [23]. Beside magnesium, other chemical composition present in rainwater including NH^{4+}, $Ca^{2+,}$ K^{+}, Na^{+}, Mg^{2+} and SO^{2+} for cations and NO_2^{-3}, CL^{-}, $HCOO^{-}$ and CH_3COO^{-} for anion [24]. After the precipitation process the water move into soil structure through the process of infiltration where the water may reach another compartment known as groundwater. Most severe chemical threats to groundwater quality originate from incidental surface releases of various types of wastes and products generated by the industrial, agricultural and public sectors [25]. Several places use groundwater for drinking and cooking as primary sources. The high magnesium in drinking water have many beneficial effects and are therefore essential to human health although, very high levels can have some negative health effects [26]. The objective of this study is to determine the concentration of magnesium in fibric peat under different on-site conditions.

2. Materials and Methods

Fibric peat has been collected from Kampung Medan Sari, Pontian, Johor, Malaysia by placing a sample in plastic and stored in a close bin to prevent loss of soil moisture. This study is divided into three part which are sample preparation, mixing and physical simulation using soil columns. Preparation of peat soil samples begins by separating fibers larger than 1 cm from peat containers. The purpose of segregating the wet peat is to remove coarse material such as roots, stones and large fiber that greater than 1 cm size. Next, the peat sample was mixed using food mixer at low speed for 1 minute and medium speed for 4 minutes. For the preparation of binder and filler, it started with oven dried first to ensure no moisture before the mixing process takes place. The amount of OPC, FA and BA generally were calculate based on dry mass of peat. OPC was equivalent to dry mass of peat meanwhile for FA was 25 % from total binder and combination of BA and peat fiber was 23 -24 % of total binder. All binder and filler were then mixed together at separate bowl before added to the peat. The mixing of peat with binders and filler is based on the water- to- binder ratio (w_w/w_b) and water-to- peat ratio (w_w/w_p). W_w/w_b is adaption of water to cement ratio (w_w/w_c) that is commonly used in concrete study. All specimen were formed into UCS samples with size of 38 mm x 76 mm and cured for 28 days in a container before use in physical simulation study.

Finally, is the preparation of soil column to simulate the on-site condition (Figure 1). The detail dimension of the soil column used for the experiment was 280 mm height and 110 mm diameter. The design of the soil column comprises of 4 outlets. The difference between the outlets was 70 mm from the top and bottom of the soil column. The aim was to determine the concentration of metal ions that leach out based on the depth of the column. Soil samples were placed in the soil column by compacting the soil each time it was inserted into the column. Six condition has been carried out to this simulation study.

For the beginning, 3000 ml of distilled water was used to flush the soil sample in order to clean the soil from fertilizer and heavy metals before proceed to experimental condition. The flush can also be used as guideline for determining actual magnesium concentration in fibric peat. The process was followed by control condition where the combination of fibric, solidified peat and distilled water was applied to identify magnesium content leach out from the soil column. Solidified peat position was in the middle of the upper soil column. Through this process, the result can be analyze whether solidified peat affects magnesium in soil or vice versa. 1500 ml distilled water is required for this process control.

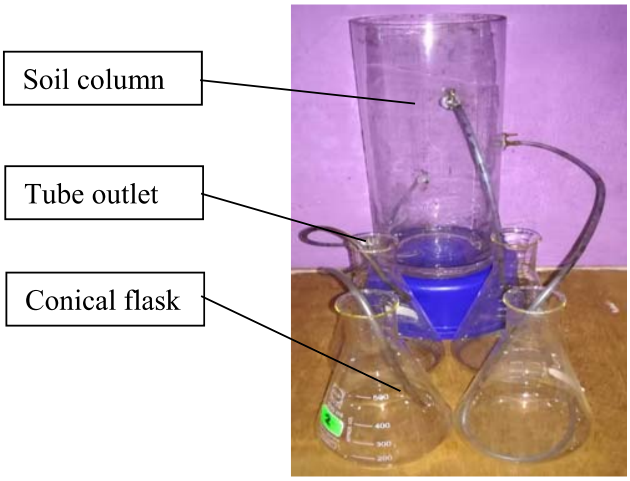

Figure. 1 Soil column

Next, the process was followed by combination of fibric, rainwater and solidified peat condition to identify the likely contaminants in the medium of soil and rainwater in two different seasons where involving the dry and wet season. 100 ml was used to simulate the soil in dry season while 1500 ml was used to saturate the soil in the wet season. The evaluation of the amount water that is required for the retaining capacity of the soil was based on the seasonal conditions. For instance, 1500 ml acts as a saturated condition based on volume of soil column and pore size. The comparison between volume of soil column and tabulation of rainfall was done according to the wet season. Reverse calculations was done for dry season with comparison between volume of soil column and tabulation of rainfall by using 1500ml as a subject. The position of solidified peat at upper level of soil sample in soil column. This study illustrate the effect with combination of fibric, rainwater, solidified peat and fertilizer condition and can act as an initial expectation if the solidified peat will be applied on agricultural area. Wet and dry seasons were also conducted to determine the concentration of magnesium leached into the water. About 0.1 mg of fertilizer was used for the study. The concentration of magnesium was determined using the Atomic Absorption Spectroscopy (AAS).

3. Results and Discussion

The investigation of the presence of magnesium in peat soil was demonstrated using soil column. Based on flush reading in Figure 1, the presence of magnesium was detected in the soil. Magnesium presence in the peat soil probably due to the source of the soil sample which was obtained from agricultural land. The intake of fertilizers as a source of nutrient was aimed to increase crop production. However, according to Huber [20], magnesium availability may vary depending on environmental conditions, the previous crop, microbial activity in the rhizosphere, herbicide program for weed control and ratios with other mineral nutrients.

According to the Environmental Quality Standards Regulations, 1999, water quality standard is divided into two, namely surface water standard and groundwater standard. This studies is more focused on groundwater quality and the standards were utilized as the reference point to determine the condition of the soil. The groundwater standard limit for magnesium is usually less than 30 mg/l or 30.01 ppm. .

Figure 2 shows having high concentration of magnesium (12.50 ppm) at outlet 4. This value is the highest compared to outlet 1, 2 and 3 with values of 0.54 ppm, 1.97 ppm and 2.67 ppm respectively. Although outlet 4 has the highest value compared to other outlets, the value is still below groundwater standard limit. Based on observation, fertilizer use in agriculture activity affects to the presence of magnesium in the soil. Beside working as food suppliers to the plant, the chemical fertilizer is also use to increase soil fertility [27]. According to Haghnazari *et al.,* [28], infiltration rate occurs until saturation is almost entirely caused by force of gravity and pressure. However, soil texture is the major inherent factor affecting infiltration. The flow and storage of water are intimately related to the physical properties of peat, and thus to the degree of decomposition and soil compression [29]. Fibric peat particles are very large and very high void ratios because peat particles are porous, and surficial peat deposits have experienced very small effective overburden pressures [30]. This is a description where the concentration of magnesium is higher at outlet 4 than other outlets. The presence of water passing through each outlet due to soil texture factors makes magnesium dissolve into the body of water.

The aim of control conditions is to identify whether chemical compound from binder and filler dilute if there is water in the soil. Based on observation, concentration of magnesium can be said to be at low level for all outlets compared to flush condition. The presence of magnesium in the control condition is probably due to the magnesium oxide that found in the solidified peat material. According to SLS 107-2 [31], limit of maximum magnesium oxide (MgO) content in OPC is 5 %. Whilst, major element in FA are magnesium, calcium and iron which can be the cause of the presence of magnesium in the leachate [32]. However, the concentration of magnesium occurs in small quantities and does not give any significant effect to the quality of the ground water as the value is still below the standard limit for groundwater. The difference in value between outlet 2 and 4 is less significant which is 1.22 ppm and 1.29 ppm respectively. The concentration of magnesium at outlet 1 is 0.24 ppm while at outlet 3 is 1.07 ppm. The water that transports to the bottom of the soil column is the factor of the magnesium concentration at outlet 1 is low. The position of solidified peat also affects the amount of water passing through the solidified material surface where outlet 1 is in a position parallel to the solidified material. Therefore, the water passing through the soil only passes some part of the surface of solidified material and which then exit through outlet 1.

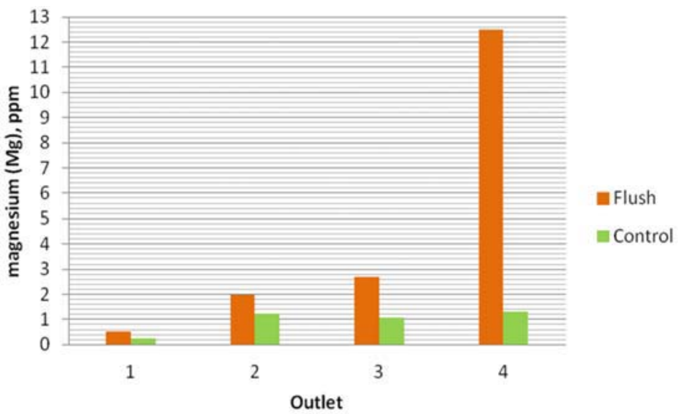

Figure 2. Concentration of magnesium for flush and control condition

Fibric can be categorized as unsaturated soil when compared with hemic and sapric. The large and complex porosity of fibric peat, storage of water and transmission properties to make the fibric as unsaturated zone [33]. However, Defo *et al.,* [34] stated that the amount of heavy metals at soil surface is high in saturated soil compared to the concentrations of metal at the unsaturated soil. This is contrast to the concentration of magnesium for wet condition in Figure 3 where magnesium is high at outlet 1 which is located on the soil surface with value was 3.16 ppm followed by outlet 3, 2 and 4 with values were 2.78 ppm, 2.61 ppm, 1.34 ppm respectively. The difference in concentration of magnesium between wet and dry condition is 88.62 % and can be said to be a big difference. Among the factors that can be attributed to evidence of high concentration of magnesium in outlet 1 is pore

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spacing for fibric is large, with regular pores up to 10 μm, reflecting the high permeability of the material [35]. Hence the presence of rainwater that carrying magnesium is the reason for the concentration of magnesium at outlet 1,2 and 3 is high compared to outlet 4. Beside that, the possibility that magnesium is trapped in the soil during dry condition and does not transported to leachate also is one of the factors for high magnesium content. In addition, the difference between wet and control condition also high with a difference of 92.43 % due to different water sources where wet condition uses rainwater as experimental material, while control condition using distilled water.

Based on observation, dry condition shows an uneven graphic patent with outlet 4 having the highest value with 1.33 ppm compared to other outlet. In terms of the difference between wet, dry and control condition, there is a slight difference for the three conditions where the difference between wet and dry condition is 0.97 % while the difference between dry and control condition is 2.63 %. This can be attributed to the arrangement of the fibric peat soil particle where porosity factors which allow the infiltration process occurs. Infiltration process also involves the average pore size, distribution of pore sizes and connectivity of pores are of greater importance [29]. The second highest value is outlet 2 with 1.03 ppm followed by outlet 3 and 1 with 0.39 ppm and 0.36 ppm respectively. This could be probably of uneven soil compression during experimental work especially on the outlet side that can prevent water from leach out thereby affecting the concentration of magnesium. Soil compaction can reduce porosity and prevent water from passing into the soil [36].

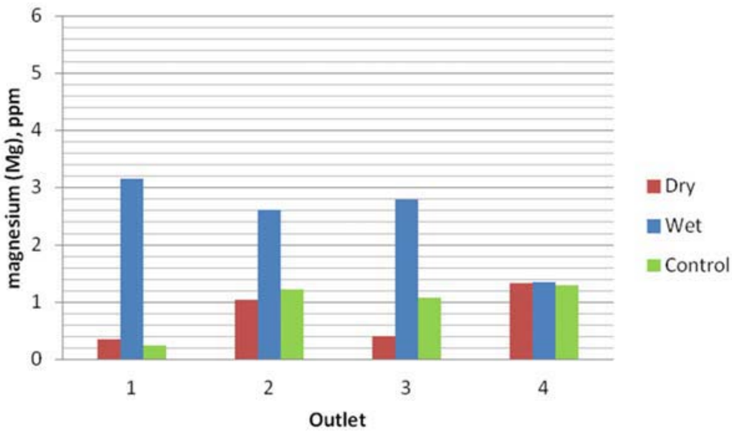

Figure 3. Concentration of magnesium by comparing between fibric under rainwater and solidified peat with control.

Figure 4 shows the patent graph of wet condition have higher value on all outlets than dry and control condition. Outlet 1 has the highest value of 5.43 ppm followed by outlet 4, 2, 3 with 3.19 ppm, 2.81 ppm, 2.17 ppm respectively. There are several possibilities that can be related to the consistent high value for all outlet compared to dry condition. The presence of magnesium in rainwater plus the amount of water used affects the concentration of magnesium in leachate. In addition, fibric properties that are active in water retention are also contributes to the high concentrations of magnesium in the soil. According to Rocha *et al.,* [37], the highest humid content on fibric affects gravimetric moisture and high retention capacity. Hence magnesium content does not leach out completely with water during flush, dry and control condition experiments which resulting high concentration of magnesium in wet condition. In terms of the difference between wet, dry and control condition, there was huge difference in outlet 1 where the difference between wet and dry condition was 95.41 % while for wet and control condition was 95.60 %. This difference is influenced by the use of fertilizer in accordance with this condition that was placed on the soil surface. This is attributed to the occurrence of low water solubility in very low mobility especially in cases prone to the accumulation in surface horizons of the soil [38].

Dry condition shows that outlet 4 recorded high magnesium value compare to another outlet with a value of 1.26 ppm. The difference between dry and wet condition is 60.6 % while dry and control condition is 3.01 %. This can be related to the nature of the fibric that has a large size pore allowing the water to pass between the soil particles to the ground. According to Huat *et al.*, [2] fibric have very high void ratios because peat particles are large and porous. However, the value of concentration of magnesium is low at outlet 1 compared to wet condition due to the amount of rainwater that imposed to make the fertilizer dissolve partly. The concentration of magnesium is decrease at outlet 3, 2 and 1 which are 0.39 ppm, 0.32 ppm and 0.25 ppm respectively. Although fertilizer is used, the concentration of magnesium in all conditions and outlets is still below the standard limit of ground water quality. Hence this condition is still under control and safe.

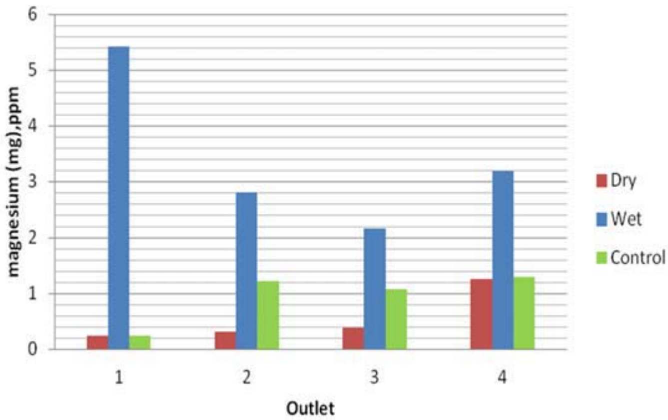

Figure 4. Concentration of magnesium by comparing between fibric under rainwater, solidified peat and fertilizer with control

Conclusion

The influence of environmental conditions on the concentration of magnesium in the fibric peat has been investigated. The effect of soil nutrient showed that magnesium in fibric was recorded as 17.69 ppm based on the total value for all outlets. The use of chemical fertilizers can affect groundwater quality especially if it is used excessively. Thus, this experiment can serve as useful guide for farmers on the application of fertilizers for crops.

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