THE DEPTH DISTRIBUTION OF BERYLLIUM 7 IN THE SOIL STUDY

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ABSTRACT

The main objective of this study is to examine the depth distribution of 7Be in the soil .The study was conducted in an open land area in Bangi, Selangor during the two (2) month rainy season in 2016. All soil core samples taken by using metal corer and brought to Radiochemistry and Environment Group Laboratory (RAS), Malaysian Nuclear Agency for further treatment. All samples have been sectioned into 2 mm increments to a depth of 4 cm and subsequently, oven dried at 45- 60 ºC and gently disaggregated. The sample is passed through a < 2 mm sieve and packed into geometry plastic container for 7Be analysis using gamma spectrometry with a 24-hour count time. Based on the analysis results obtained, the concentration of 7Be is deposited into decreases exponentially with depth, is confined within the top few centimeters at most and similar with other works been reported for all samples. However, a detailed study that is by increasing the number of sampling stations throughout Peninsular Malaysia should be done in ensuring a complete data for a future reference.

Key words: ^{7}Be; Depth distribution; Gamma spectrometry; Exponentially; Centimeters

INTRODUCTION

Soil is part of the earth's surface consisting of mineral and organic matter. Land are important for all life on earth, because the ground is able to support plant life in which plants provide food and oxygen and absorb carbon dioxide and nitrogen. Soil composition vary in one location to another.The land consists of *pedosphere*, located at the interface of the *lithosphere* and the *biosphere*. The soil formation or *pedogenesis*, is the combined effect of physical, chemical, biological and anthropogenic origin in geological materials that produce a layer of soil. Soil is fundamental to agriculture to carry out the cultivation of various plants either for food crops, industrial crops and other crops. Soil is formed from the weathering since millions of years ago and there are many types of soil formed on earth that has a variety of thecharacteristics to be studied. An expert of soil science has made various classifications of land to serve as a guide to all parties on how to manage the land to provide optimal returns in cultivation.In Peninsular Malaysia, the basic unit used for mapping soil is soil series. Soil classification system used in peninsular Malaysia is based on a system of (USDA Soil Taxonomy, 1992) which has been modified according to local conditions. By using this system, the name of a series of land identified. To date, more than 240 series of soil have been created and reorganized into 11 groups based on the parent material, the characteristics of the main land, landscape and how the formation of soil. The depth distribution is based on the criteria in soil taxonomy (Thorp and Smith, 1949) (figure 1).

Figure 1: 12 Orders of Soil Taxonomy (modified by Thorp and Smith, 1949)

Therefore, most of the body of the soil is formed from a mixture of organic matter and minerals. Non-organic soil or mineral soil is formed from rocks so that it contains minerals. On the contrary, organic soil (organosol / humosol) is formed from compaction to degraded organic matter.Organic soil is black and is the main form of peatlands and later can be coal. Organic soil tends to have high acidity because it contains some organic acids (humic substance) resulting from the decomposition of various organic matter. This group of land is usually poor mineral, the supply of minerals comes from the flow of water or the decomposition of living tissue. Organic land can be cultivated because it has a lethal physical condition (nest) so it is able to store enough water but because it has high acidity most of the food crops will give limited yield and under optimal reach. The soil structure is the physical characteristic of the soil formed from the composition of the grain of land and the interregional space. The ground is composed of three phases: solid phase, liquid phase, and gas phase. The liquid and gas phase fills an aggregate space. The soil structure depends on the balance of these three factors. Aggregate space is referred to as porous. The soil structure is good for rooting when big pores are filled with air and small pores (micropores) filled with water.

Consequently, ^{7}Be is naturally cosmogenic occurring radionuclides is produced by nuclear spallation reactions to high-energy cosmic-rays and atmospherics nuclei. The ^{7}Be quickly attaches to sub-micron atmospheric aerosols that are distributed throughout the atmospherics and deposited to the earth surface from the scavenging process is know as rainfall. The ^{7}Be has a short half-life of 53.29 days, it provides the possibility of document soil redistribution during individual events or about short periods. The ^{7}Be has been shown to offer considerable potential to provide information over shorter timescales. The ^{7}Be reaches the soil surface primarily as the Be^{2+} ion, which is extremely competitive for cation exchange sites, because of its high charge density (Kaste *et al*., 2002) (figure 2). Meanwhile, ^{7}Be is rapidly and strongly absorbed by soil particles in most environments (Hawley *et al*., 1986). (Wallbrink and Murray, 1996; Bonniwell *et al*., 1999; Blake *et al*., 1999; Walling *et al*., 1999; Doering *et al*., 2006; Matisoff *et al*., 2002a) have reported studies of ^{7}Be deposited at the soil surface and have demonstrated that it is predominantly retained in the uppermost of the soil layers. It is rarely found at depths greater than ca.3-4 cm because its short half-life precludes deeper penetration into the soil driven by relatively slow diffusion and migration process. Meanwhile, Magilligan *et al*. (2008) also have reported that sand sized particles can be characterized by a relatively high ^{7}Be activity because organic and chemical coatings on the sand grains bind the radionuclide. The mechanism involved in fixing the radionuclide to the soil or sediment particles are also likely to influence the conservatism of the ^{7}Be as a tracer. Meanwhile, Burch *et al*., (1988) and Wallbrink and Murray (1996) have exploited this feature of the behaviour of ^{7}Be in their studies to distinguish sediment mobilised by sheet and rill erosion in terms of itsfrom the soil surface and from deeper in the profile. In more detail, other researchers also reported in previous studies that when rains containing radionuclides fallout penetrate the soil surface they quickly absorb and strongly fixed by fine particles (Brown & Stensland, 1989; Hawley *et al*., 1986; Owens *et al*., 1996). Moreover, it has also been used as a tracer for studying atmospheric processes (Feely *et al*., 1989; Dibb, 1990; Todorovic *et al*., 1999) to determine the rate of erosion and sedimentation by receiving large amounts of rainfall over a given period. The main objective of this studyis to examine the depth distribution of ^{7}Be in the soil over a period of 2 months during the rainy season that occurred at the site of the open field study, located in bare area, Bangi. This study is important to obtain data on the extent of 7Be penetration of soil depths after receiving rainfall.

MATERIAL AND METHODOLOGY

Soil sampling and preparation of samples

Sampling of core soils were carried out by using plastic core in bare area in Bangi, Selangor, Malaysia. Four core soil samples were taken in the study area for every 2 weeks with a two months sampling period. All these sample samples were brought to Radiochemistry and environment Group laboratory for further treatment. Each core was sectioned into 2 mm increments to a depth of 4 cm and dried in the oven at 45- 60 º C to achieve constant dry weight. Dried samples were then fine grinded and sieved at 2 mm before the samples transfer and packing into the 250 ml Marinelli beaker for ^{7}Be analysis.

Counting of ^{7}Be in soil samples

The determination of ^{7}Be activities in the soil were done using Gamma Spectrometry counting system, consists of Hyper-Germanium detector (HPGe) for 86400 seconds or 24 hours, with energy of ^{7}Be is 477.6 KeV. Meanwhile, the ^{7}Be concentrations or activity from the samples was calculated using equation as below;

$$A = \frac{N}{\varepsilon . p_\gamma . m . t} \qquad (1)$$

Where:
N = the net count under the peak of 477.6 keV gamma line energy that characterized beryllium-7 (in counts),
ε = the efficiency of the detection system for the 477.6 keV gamma line energy (in counts.$Bq^{-1}.s^{-1}$) obtained from equation 1,
p_γ = the absolute probability transition for 477.6 keV gamma line for beryllium-7, ^{7}Be.

Furthermore, the detector efficiency calibration can be calculated or defined as:
$f(M_0) = (C_0/T_0 - Cb/T_b) \times (1/M_0 \times A_0 e^{-\lambda(t-t)}{}_0)$

Where:
f = the activity efficiency of the detector, which is defined as the efficiency τ (emission rate) multiplied by the r (emission probability of the gamma ray),
Mo = the standard mass in kg,
Co = total counts,
Cb = the background of an unspiked sample,
T_o = time count for the sampling was being counted,
Tb = the corresponding background count time, and
λ = the decay constant of the radionuclide, which can be defined as:
$\lambda = \ln_2 / T_{0.5}$

Where, $T_{0.5}$ = the half life for the radionuclide.
Meanwhile, using the model by Walling and Quine., (1990); Zhang et al., (1990) and Walling et al., (2002) which can be assumed and characterize the depth distribution of 7Be in the soil by an exponential function. Thus, modelling using the Fallout Radionuclides (FRNs) method has been successfully used by researchers around the world to identify soil erosion rates and sedimentation in areas involving agricultural activity as well as catchment areas. This model has been successfully used to determine short-term, medium and long-term erosion and sedimentation rates after heavy rains. The depth distribution of ^{7}Be is represented by an exponential decline with depth,
$C(x) = ce^{(-x/h0)}$

Where:

C(x) = the mass activity density of ^{7}Be at mass depth x, $Bqkg^{-1}$,

h_0 = the coefficient describing profile shape kgm^{-2} and also known as the relaxation mass depth. Thus, if the value of h_0 increases, the penetration of the ^{7}Be can be assumed to be greater into the soil profile depth.

RESULTS AND DISCUSSION

The analytical results of this study , the h_0 values or mass relaxation for all samples can be seen in figure 2 to figure 5. All the indicated decreases exponentially with depth and is confined within the top few centimeters, less than 2 cm from the soil surface and almost similar with other researchers had been reported (Wallbrink and Murray, 1996; Bonniwell *et al*., 1999; Blake *et al*., 1999; Walling *et al*., 1999; Blake *et al*., 2000; Matisoff *et al*., 2002a; Doering *et al*., 2006; and Walling *et al* ., 2008). In meantime, the h_0 values from this two months period study showing are ranging from 3.57 kgm^{-2} up to 5.57 kgm^{-2} respectively. The first sampling showed the lowest h_0 value compared with other analysis results, 3.57 kgm^{-2} (figure 2). This condition is due to the small amount of rainfall received over a two-week period. However, the frequency of rain over the next two weeks has caused the h_0 value has changed dramatically for the second sampling. The h_0 value has shown the highest value during the period of this study, which is 5.57 kgm^{-2} (figure 3).

Anyhow, these two h_0 values are not far different for third sampling, which is just dropping by almost five percent, 5.45 kgm^{-2} (figure 4). Hence, this condition is due to the amount of rainfall received still persisting despite having received considerable rainfall during this sampling period. The fourth and last sampling has also shown h_0 value degradation due to the lack of rainfall in the last two (2) weeks, which is decreased from 5.45kgm^{-2} to 4.99 kgm^{-2} (figure 5). Based on these results, h_0 value in the study area is not significantly different compared to the studies conducted in other areas around the world as reported in the literature by other researchers.

Figure 2: The Depth distribution in Bangi – A with *ho* value, 3.57 kgm^{-2}

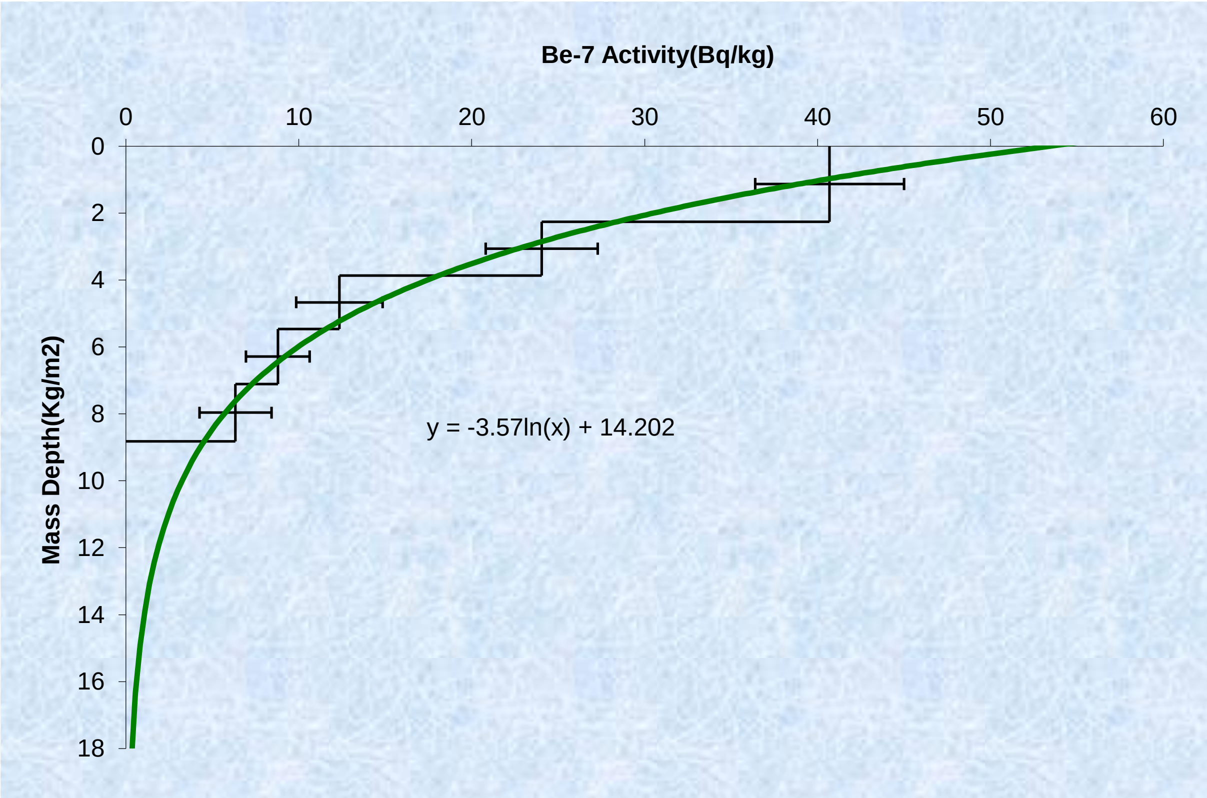
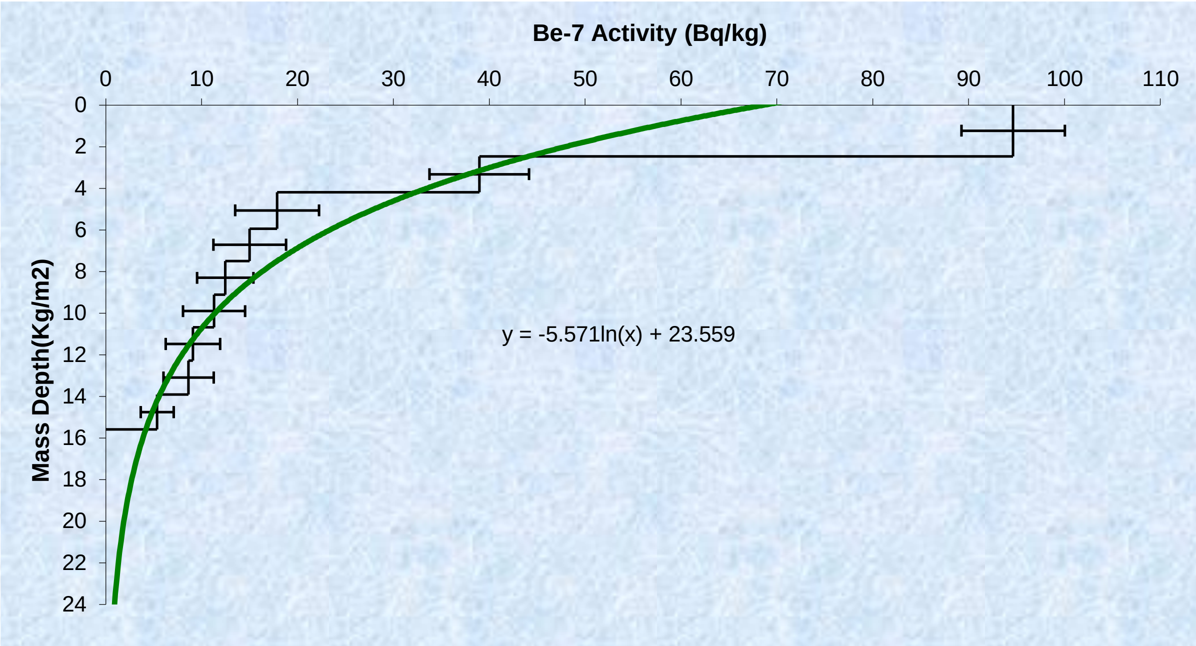


Figure 3: The Depth distribution in Bangi - B with *ho* value, 5.57 kgm^{-2}



All figures presented the characteristic soil depth distribution of ^{7}Be from sampling site study. From the figure show the ^{7}Be depth penetration decreases exponentially with depth and is confined within the top few centimeters and similar with other works been reported (Wallbrink and Murray, 1996; Bonniwell *et al*., 1999; Blake *et al*., 1999; Walling *et al*., 1999; Blake *et al*., 2000; Matisoff *et al*., 2002a; Doering *et al*., 2006; and Walling *et al* ., 2008). However, the ^{7}Be depth penetration from this study is occurred in the uppermost soil layer, which is lesser than 2 cm. Thus, since the study periods of short duration involved, it is impossible for the individual value h_0 or depth penetration study area is might be progressively increased or higher due to slowly downward movement of the ^{7}Be input.

Subsequently, ^{7}Be in the study sample reaches the soil surface primarily as the Be^{2+} ion or high charge density, which is extremely competitive for cation exchange sites and its difficult to penetrate more than 2cm uppermost layer . In addition, ^{7}Be deposited in the soil study was not whole absorbed in the first 2 cm of soil, which dependent of the pluviometric precipitation . Moreover, a comparable ^{7}Be deposited or depth distribution in figure 2 is totally different from this study , whichwas whole absorbed in the first 2 cm of soil, independent of the the pluviometric precipitation. Wallbrink and Murray (1996) and Blake *et al* (1999) mentioned that if the used cautiously in conjunction with the record of rainfall, ^{7}Be input can complement other longer-lived radionuclides for studying erosion of topsoils associated with individual events in short periods. Thus, since the short half-life, 53.4 days for ^{7}Be is necessarily limit any possible increase penetration during short and long period of rainfall. Blake *et al* (1999) mentioned that ^{7}Be input for the depth distribution in the soil is depends on a few factors such as the amount of rainfall and others. However, an average values h_0 or depth penetration for this study is 2.69 kgm^{-2} and which that depended on the amount of rainfall received over a two (2) week each sampling period.

Figure 4: The Depth distribution in Bangi - C with *ho* value, 5.45 kgm^{-2}

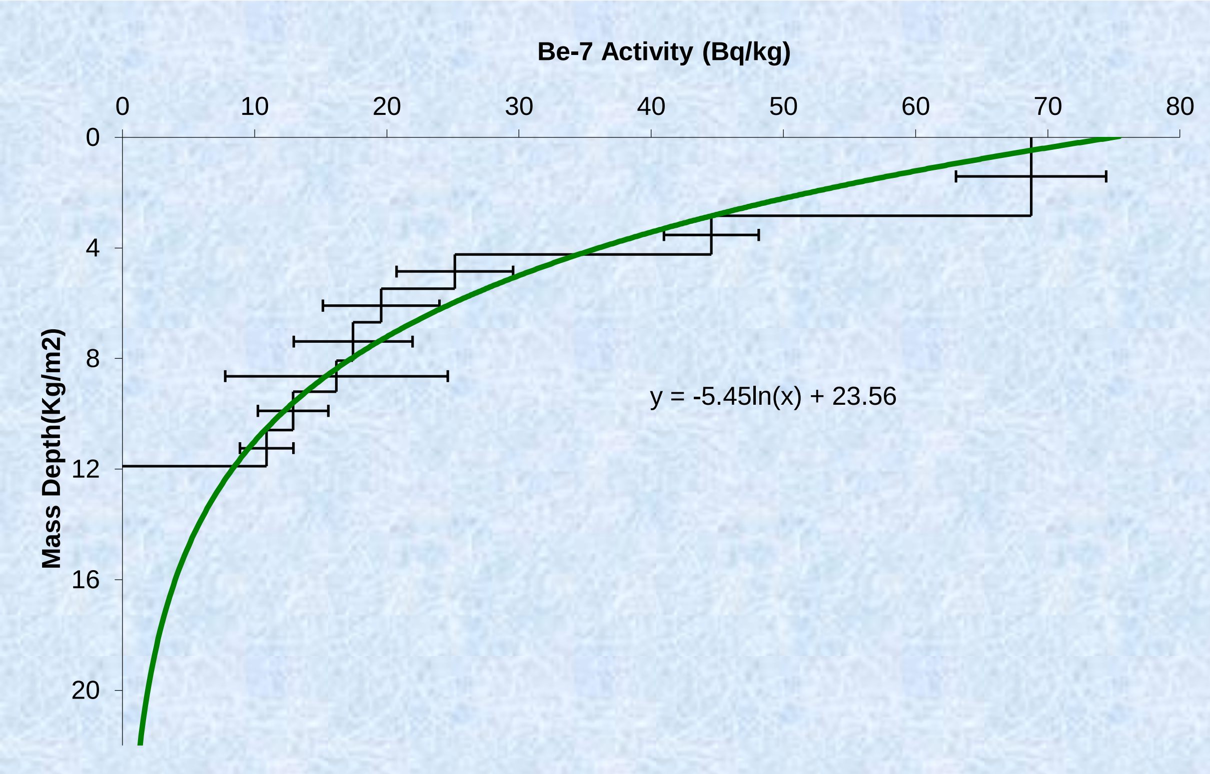
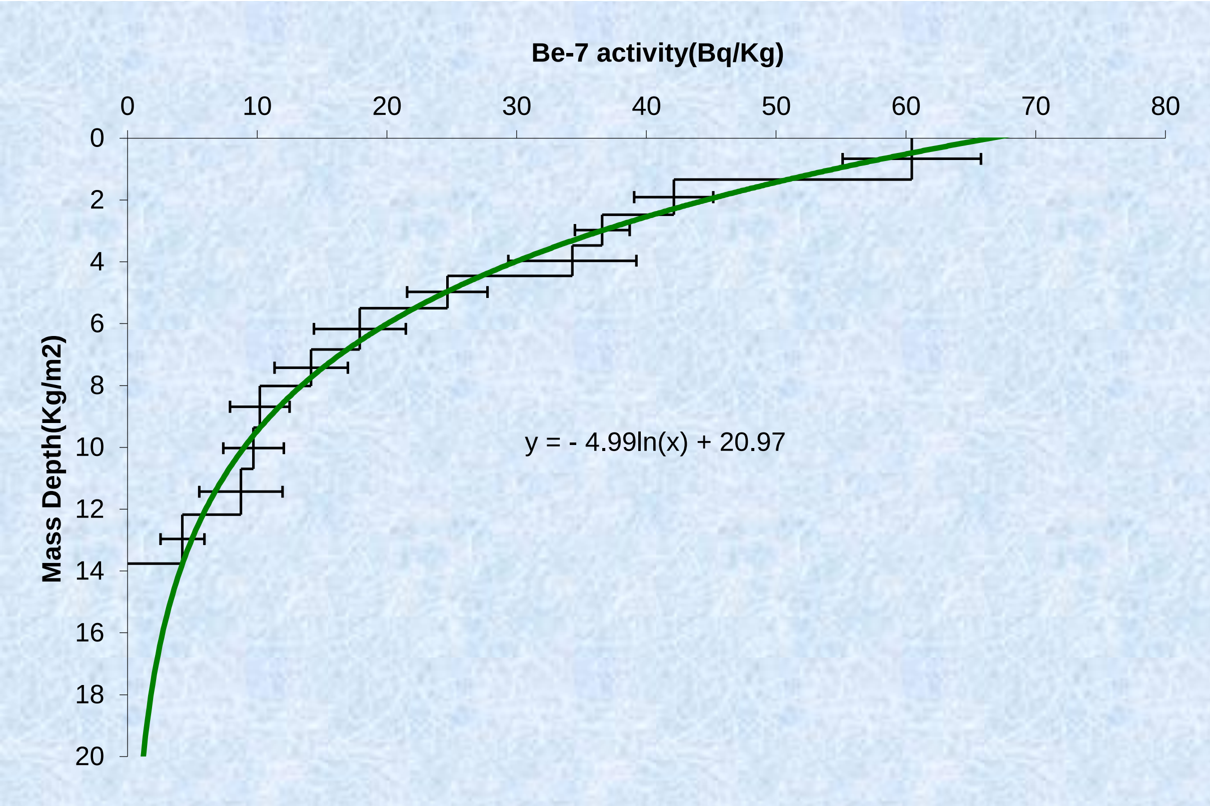


Figure 5: The Depth distribution in Bangi - D with *ho* value, 4.99 kgm^{-2}



In continuing the discussion, there is a few study of the h_0 value around the world by other researchers in determining evolution the ^{7}Be depth distribution in the soil profile. For example, Walling *et al.*, (2008) have determined the h_0 value in the agricultural area at Valdivia, Southern Chile for a few months study. From this findings, the h_0 value or mass relaxation depth remains slightly constant during a few months period and might progressively increase in response to the slow downward movement towards the ^{7}Be input. Therefore, the results of the h_0 value for ^{7}Be mass relaxation depth at Valdivia, Chile ranged from 1.28 to 2.15 Kgm^{-2}. Meanwhile, this study can also be compared with a study conducted in Brazil, where the h_0 values are ranging from 1.48 to 2.86 Kgm^{-2}. The h_0 value results from these two different part of the world sampling sites studies are far lower than the results to compare with the result from the open land area in Bangi, Selangor. However, the h_0 value from this study shows a slightly lower compared to those obtained from the reference sites (a bare area at The University of Exeter) and Devon agricultural sites are ranging from 3.06 and 6.41 Kgm^{-2}. The difference in the results is due to several factors that need to be taken into account throughout the study as these factors determine the value of the h_0 from each other.

CONCLUSION

The ^{7}Be depth distribution from this study areas was decreased exponentially with depth and is confined within the top few centimetres and similar with other works been reported in the literature. This can be seen from the results of all the analyzes ranging from 3.57 to 5.57 Kgm^{-2}. In addition, all of these results yielded higher values of h_0 than those reported by other researchers Walling et al (2008) in Valdivia, Chile and other studies have been conducted by researchers in Brazil, 1.28 to 2.15 Kgm^{-2} and 1.48 to 2.86 Kgm^{-2}. However, the h_0 value from this study shows a slightly lower compared to those obtained from a bare area at The University of Exeter and Devon agricultural sites, 3.06 and 6.41 Kgm^{-2}. However, the analytical results of this study cannot be fully compared with other studies because various factors need to be taken into account. Among these factors are the frequencies of sampling, time, sampling, geographical position as well as the change in weather over the study period. The amount of rainfall received is a key factor in determining the value of h_0 during the course of the study. This can be seen as the amount rainfall received during the two (2) week sampling period increases with the depth penetration rate into the soil surface. Based on the analysis results obtained, the concentration of ^{7}Be is deposited into decreases exponentially with depth, is confined within the top few centimetres at most and similar with other works been reported for all samples. As conclusion, this study has proven that ^{7}Be can be used as a short-term tracer for soil erosion and sedimentation rates studies in catchment areas. In addition, to ^{137}Cs used as a medium-term tracer as reported by Jalal *et al.,* (2019) from previous studies. However, such studies need to be extended to other research sites based on various factors that need to be prioritized in order to obtain more data in the future. The data from this study will be shared with the local authorities' to help of local or state governments such as the Drainage and Irrigation Department (DID) as well as the Department of Agriculture (DOA) to assist in addressing significant land and mud erosion issues in Malaysia since recent times.

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