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Monte Carlo study to evaluate the paraffin cylinder dimensions for the surface effect correction

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ABSTRACT

Measuring of soil moisture level is important for many hydrological, biological and biogeochemical processes. Using of neutron meter equipment to measure soil moisture is limited close to the soil surface due to the escaping of neutrons which known as surface effect. In present work, the dimension of a cylindrical paraffin cylinder has been evaluated to correct the surface effect in order to use neutron moisture meter close to the soil surface by MCNPX code. The result show a cylindrical paraffin cylinder with 16 cm radius and 4.8, 5, 5.3, 5.6, 6 cm thickness can correct the surface effect well for 0.10, 0.20, 0.30, 0.40, and 0.50 g/g soil moisture, respectively. As well as, the paraffin cylinder is a good shield to reduce the radiation dose.

Introduction

The neutron scattering method is an indirect way of determining soil moisture content. This method measures the moisture content of the soil by measuring the thermal or slow neutron density. The neutron method of soil moisture measurements are affected by losing neutrons to the air and abrupt changes in soil moisture content. This effect is particularly evident near the soil surface where neutrons are lost into the air (Mowlavi, 2006; Hignett and Evett, 2002; Evett et al., 2003; Li et. al., 1999). So, the usefulness of the neutron meter is limited if it is necessary to determine moisture near the soil surface. Hignett and Evett (2002) discussed this problem and give some solutions; Evett et al. (2003) studied the problem in the field, and proposed a solution that involved using a depth control stand, to ensure very accurate positioning of the probe below the soil surface, coupled with specific calibrations for depths closer to the surface than 30 cm. Recently, the surface effect correction of moisture determination by neutron probe using particle swarm optimization method and Monte Carlo simulation are published in world scientific by me and my colleagues (Mowlavi et al., 2009). Furthermore, I found calibration curves near the soil surface in my previous paper (Mowlavi, 2006).

In this work, a neutron moderator-reflector paraffin cylinder is designed to correct the surface effect moisture measurement by a neutron probe which evaluated from Monte Carlo simulation using MCNPX code (Waters, 2002).

The geometry configuration for Monte Carlo simulation of moisturemetry

MCNPX code has been used to simulate moisturemetry by neutron probe. The F4:n tally with Fm4 multiplayer card has been calculated in the ^{3}He detector to compute the ^{3}He(n, p) ^{3}H reaction rate. The detector has been considered as a cylindrical shape with 2cm diameter and 2cm length which a ^{241}Am-^{9}Be neutron source is located 3cm below the center of the detector (Mowlavi, 2006). The soil composition elements are selected as used in my previous paper (Mowlavi, 2006). As it mentioned before, a proper paraffin cylinder can remove the surface effect; it may have square or circle base with t_w thickness to moderate or reflect neutrons and decrease the fraction of escaping neutron near the soil surface. Figure 1 shows the normal configuration of moisturemetry by neutron probe. In Figure 2 the suggested configuration for correction surface effect by using a paraffin cylinder over the soil surface is presented. The paraffin cylinder has a 16cm radius with t_w thickness which has a cylindrical hope with 4 cm diameter in the center for neutron probe.

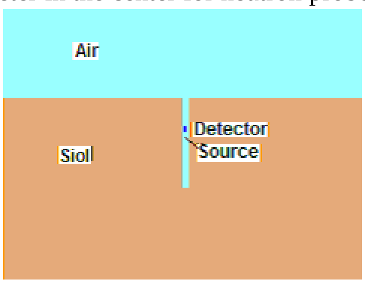

Figure 1: Normal configuration of moisture measurement by neutron probe used for simulation.

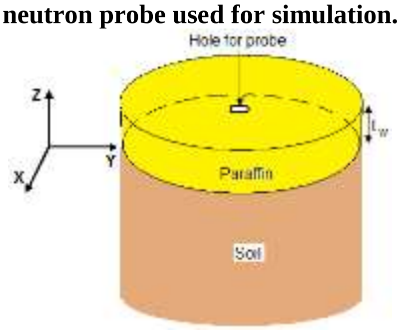

Figure 2: The suggested configuration for correction surface effect- a paraffin cylindrical cylinder over the soil surface.

Results and discussion

I have done the simulation for different value of t_w to find its best value. The simulation results for relative count in the ^{3}H detector are presented in Figure 3, with and without the paraffin cylinder. The results show a paraffin cylindrical shape with 16

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cm radius and 4.8, 5, 5.3, 5.6, 6 cm thickness can correct the surface effect well for 0.10, 0.20, 0.30, 0.40, and 0.50 g/g soil moisture. Now the collaboration data for deep depth is suitable and usable for measurement close to the soil surface. It is evident that the thickness of paraffin cylinder increases by crowing up of soil moisture.

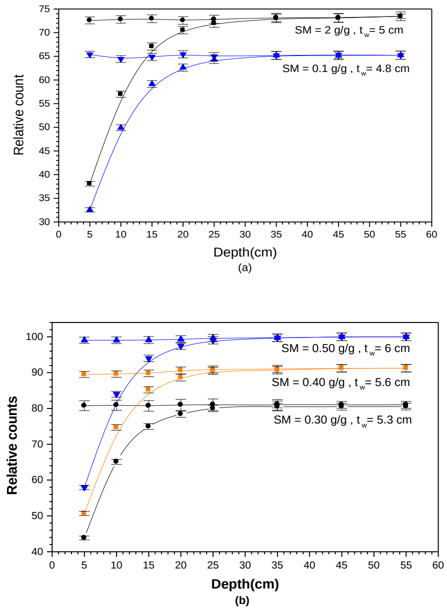

Figure 3: The Mont Carlo result of relative count against depth with and without the proper paraffin cylinders (SM: Soil Moisture).

As well as the paraffin cylinder is operate as a radiation shield especially for using neutron probe at low depth. Figure 4 shows the effect of paraffin cylinder as a neutron shield; variation of neutron dose calculated with F5z: n tally – a ring detector 5 cm radius over the paraffin cylinder at Z=6 cm while soil surface is Z=0 cm– for different soil moisture values. It is evident that the paraffin cylinder reduces the neutron dose by 1.64 to 1.88 factors for 0.0 to 0.5 g/g soil moisture range. On the other hands, the paraffin cylinder can reduce the mean radiation dose around 45%. The neutron energy flux spectra with and without paraffin cylinder for 0.50 g/g moisture are presented in Figure 5, which the flux is decreases up to 50%. Two advantages of this optimization are:

- Using a single collaboration equation for all depth;
- The cylinder operates as a good radiation shield.

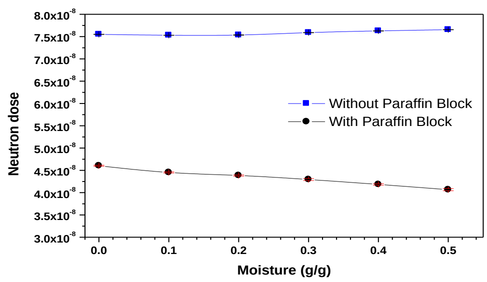

Figure 4: Variation of the neutron dose with and without paraffin against the soil moisture.

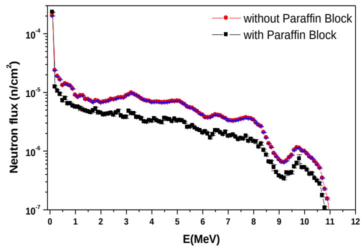

Figure 5: The neutron energy flux spectra with and without paraffin cylinder at 0.50g/g soil moisture per one particle source.

Conclusion

The Monte Carlo calculation guide to design a paraffin cylinder with 16 cm radius and 4.8, 5, 5.3, 5.6, 6 cm thickness can correct the surface effect fairly for 0.10, 0.20, 0.30, 0.40, and 0.50 g/g soil moisture. Also, the paraffin cylinder is a good neutron shield to reduce the dose radiation. It can reduce the mean radiation dose around 45% and decrease the neutron flux up to 50%. As it is well known, the moisturemetry with neutron probe is an easy and suitable but expensive method. This study presents a simple way to overcome of the limitation of usage of the method close the soil surface. The present work demonstrates a useful application of MCNPX code is soil sciences.

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