Nuclear Laboratory Setup for Measuring the Soil Water Content in Engineering Physics Teaching Laboratories

Supplementary Material

The following figure illustrates the simplified gamma-ray attenuation (GRA) system used in the soil water content measurements.

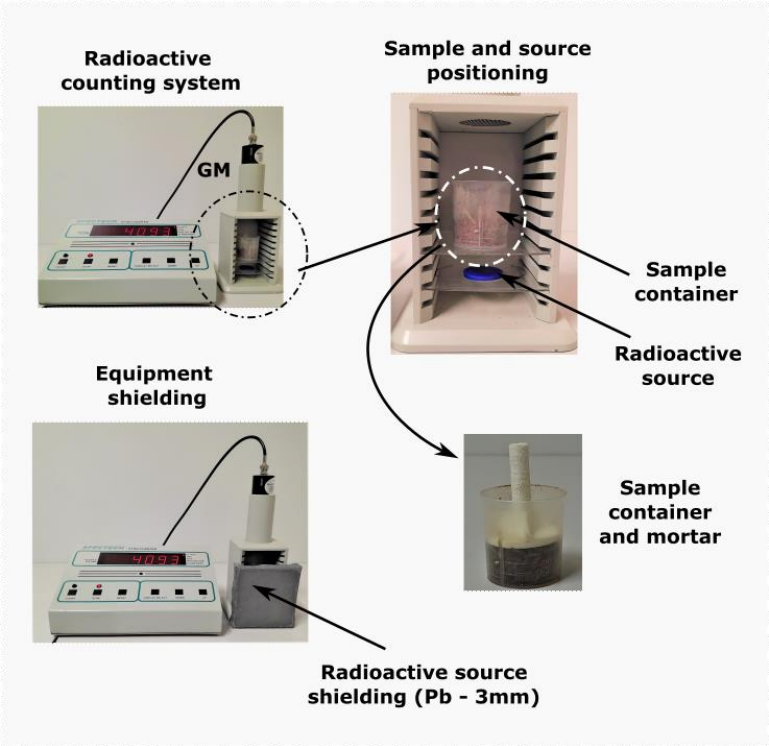

Figure S1. Photo showing the experimental apparatus used in the soil water content measurements. GM: Geiger-Müller detector.

Table S1 shows some of the data used in the calculations presented in the paper.

Table S1. Parameters employed for the measurement of the soil water content through the gamma-ray attenuation (GRA) method.

Soil/Parameter	HeCa	Cla	SaCLo	SiLo
μ_w (cm^2 g^{-1})	0.0767	0.0767	0.0767	0.0767
ϱ_s (g cm^{-3})	1.08	1.20	1.10	1.03
ϱ_p (g cm^{-3})	2.63	2.16	2.22	2.25
m_c (g)	3.51	3.51	3.51	3.51
V_s (cm^3)	25.0	25.0	25.0	25.0
m_{c+s} (g)	30.41	33.47	30.99	29.38
x_s (cm)	2.696	2.696	2.696	2.665
φ (cm^3 cm^{-3})	0.591	0.445	0.505	0.540
V_{por} (cm^3)	14.77	11.13	12.62	13.50

μ_w: water mass attenuation coefficient; ϱ_s: soil bulk density; ϱ_p: soil particle density; m_c: container mass; V_s: volume of soil inside the container (leveled with the aid of a piston); m_{c+s}: contained + soil mass; x_s: soil sample thickness; φ: soil total porosity; V_{por}: volume of pores. HeCa: Heavy Clay soil; Cla: Clay soil; SaCLo: Sandy Clay Loam soil; and SiLo: Silt Loam soil.

The water mass attenuation coefficient (μ_w) was obtained based on the value presented in the work by Ferraz and Mansell [1] for the Cs-137 radioactive source. The ratio between the dry soil mass (m_s) and the soil volume (V_s) inside the container was utilized to calculate the soil bulk density (ρ_s). The particle density (ρ_p) was obtained using the helium gas pycnometer method [2]. The thickness of the soil inside the container (x_s) was measured using a caliper with a resolution of 0.02 mm. The porosity (φ) was calculated using the ratio of the soil bulk density to the particle density [3]. Finally, the volume of the pores (V_{por}) was calculated by the product between the total porosity and the soil volume inside the container.

In Tables S2 and S3 the gravimetric soil water content and the beam intensity transmitted through the moist sample for each of the soils studied are presented.

Table S2. Gravimetric water content (G) during experimental soil moisture measurements by the gamma-ray attenuation method.

Soil/Water content level	HeCa	Cla	SaCLo	SiLo
G_1	0	0	0	0
G_2	0.109	0.149	0.090	0.105
G_3	0.215	0.222	0.180	0.210
G_4	0.324	0.295	0.272	0.314
G_5	0.436	0.366	0.366	0.431

G_1 (g g^{-1}) stands for dry soil. HeCa: Heavy Clay soil; Cla: Clay soil; SaCLo: Sandy Clay Loam soil; and SiLo: Silt Loam soil.

Table S3. Transmitted beam intensity (I) for the different gravimetric soil water content (G) values analyzed.

Soil/Water content	HeCa	Cla	SaCLo	SiLo
G_1	29248	9594	9729	27605
G_2	28540	9293	9440	26759
G_3	27374	9062	9291	26024
G_4	27051	8905	9176	25858
G_5	26891	8836	9115	25168

G_1 (g g^{-1}) stands for dry soil. HeCa: Heavy Clay soil; Cla: Clay soil; SaCLo: Sandy Clay Loam soil; and SiLo: Silt Loam soil.

References

1. Ferraz, E.S.B.; Mansell, R.S. Determining water content and bulk density of soil by gamma-ray attenuation methods. Technical Bulletin No. 807, University of Florida, Gainesville, 1979.
2. Amoozegar, A.; Heitman, J.L.; Kranz, C.N. Comparison of soil particle density determined by a gas pycnometer using helium, nitrogen, and air. *Soil Sci. Soc. Am. J.* **2023**, *87*, 1–12.
3. Hillel, D. *Environmental Soil Physics*; Academic Press: San Diego, USA, 1998.