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Variations of immobile water content and first-order mass exchange coefficient in three soil profiles

Y. Coquet (1), L. Alletto (2) and P. Vachier (1)

(1) UMR INRA/INAPG Environment and Arable Crops, Institut National de la Recherche Agronomique / Institut National Agronomique Paris-Grignon, BP 01, 78850 Thiverval-Grignon, France, (2) Ecole Supérieure d'Agriculture de Purpan, 75 voie du TOEC, BP 57611, 31076 Toulouse cedex 3, France (coquet@grignon.inra.fr / Phone: +33-1-3081-5204 / Fax: +33-1-3081-5396)

Physical non-equilibrium is a key process for explaining many cases of transport of contaminants to groundwater. The presence of immobile water has been identified in topsoils. However, little is known about mobile/immobile water (MIM) non-equilibrium in subsoil horizons. We used tension disk infiltrometers to determine the immobile water fraction (θ_{im}/θ) and the mass exchange coefficient (α) in three soil profiles of an agricultural field cropped with winter wheat (*Triticum aestivum* L.). A significant effect of soil horizonation was found for both parameters and could be related to soil structure as determined either by tillage for surface horizons or by pedogenetic factors for subsurface horizons. The immobile water fraction was most variable in the seedbed (0-7 cm depth) with values between 0.21 and 0.88 while α ranged from 0.0006 to 0.0115 h^{-1}. Values of θ_{im}/θ and α in the plough layer below the seedbed (7-28 cm depth) were on average similar but less variable than those measured in the seed bed. Significant immobile water fractions have been found in the subsurface horizons. The lowest value of θ_{im}/θ among all subsurface horizons, 0.26, was found for a heavy clay horizon and was probably related to the high conductive mesoporosity (equivalent radius > 50 μm) of that horizon. In illuvial and heavy clay horizons (depths between 28 and 88 cm), both θ_{im}/θ and α had a small variability. High variability and high average values of both θ_{im}/θ (0.51 to 0.93) and α (0.0006 to 0.0425 h^{-1}) were found in limestone horizons located at depths from 0.63 cm to more than 1.2 m. The existence of subsoil horizons with large θ_{im}/θ and low α values may lead to pronounced preferential flow effects in the transport of solutes toward groundwater.