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Scale and definition challenges in quantitative hydrogeology

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Many basic hydrogeology definitions are relative and influenced by anthropocentrism. The aquifer definition is an obvious example. Spatial and time scales influence the values of the main parameters/properties to be used for answering in a quantified way any practical question.
For example, porosity describes the ratio between the volume of pores, cracks, and fissures and the total volume of a studied geological medium. This notion implies a volume averaging of the medium characteristics using the concept of Representative Elementary Volume (REV). Small volumes can contain only pores while larger volumes typically contain both pores and fissures. Porosity can be highly scale-dependent, and different porosity values can be measured for the same geological formation. Furthermore, groundwater in the pores and cracks can be partly immobile or mobile. So, the porosity actively involved in groundwater flow can be discussed. A 'mobile water porosity' can be defined, but this remains highly dependent on the existing pressure conditions in the geological medium. In unconfined conditions, the term 'effective porosity' corresponds usually to the drainage porosity corresponding also to the specific yield or the storage coefficient.
When dealing with solute transport and remediation of contaminated sites, another 'effective porosity' is needed to describe the advection velocity of the contaminant. This 'mobile water porosity' acting in solute transport processes takes typically lower values than the 'effective porosity' of drainage (Payne, Quinnan and Potter 2008, Hadley and Newell 2014, Dassargues 2018). There also, scale issues must be expected as shown by field and lab tracer tests.
Different groundwater velocities can be defined in function of the adopted 'effective porosity', and all are averaged over the entire volume of the saturated porous medium considered as the chosen REV. The term 'Darcy velocity' is to be banished herein because it induces much confusion. For the sake of clarity, we propose to distinguish 'drainage effective porosity' and 'transport effective porosity'. Physically, this means that the porosity available to transmit solute concentrations is not automatically the same as that corresponding to mobile water for drainage. The transport effective porosity corresponds probably to the most mobile part of the water occupying the pores, fissures and fractures implying to some extent a channeling effect of the solute transport by advection. This channeling being described at the macroscopic scale of the considered REV with a lower value of the solute transport effective porosity leading (for a constant solute flux) to an increased advection velocity. This distinction to be made between different 'effective porosities' is still surprisingly not mentioned in most of the traditional texts on hydrogeology. However, this is confirmed by well-known and accepted observations by hydrogeologists, especially by those dealing with aquifers affected by multiple porosities (Worthington 2015) but not only by them (Derouane and Dassargues 1998, Brouyère 2001, Hoffmann et al. 2019). Examples of such observations are presented for illustration and discussion.

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