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Linking the dynamics of the total mobile inventory to the co-evolution of structure and function in the subsurface

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Structural dynamics, fluid flow, and reactive transport in permeable media are affected by the presence of and interactions with components of the total mobile inventory (TMI). With the term TMI we take into account the fact that the inventory of mobile substances in natural permeable media extends over an extremely wide range of sizes (spanning five orders of magnitude from the truly dissolved matter in the nanometre range to the large microaggregates and biota, around 250µm) and an almost incomprehensible diversity of proprietary and foreign materials (e.g., organic, inorganic, organo-mineral associations, microaggregates, biota, viruses, MGE, etc.; Lehmann et al. 2021 DOI:10.1016/j.scitotenv.2020.143774). Despite the essential role the larger particles of TMI up to a size of 250µm play for the functions, ecology, and intercompartment exchange in the subsurface and in between the surface and subsurface (Zerfaß et al. 2022 DOI:10.1016/j.watres.2022.118998; Herrman et al. 2023 DOI: 10.1016/j.soilbio.2023.109192), the majority of studies on the subsurface water resources and the biogeochemical cycling are dedicated to the operationally defined dissolved fraction, and, to a lesser extent, to the colloidal sized materials. Larger mobile materials beyond the 2µm size limit are vastly omitted. With increasing size beyond the “magical” 450nm size boundary, however, the understanding of the mechanisms that control the fate of TMI-components gets more demanding. With increasing size, morphology and surface properties control the interactions with the mobile and immobile surfaces and thus the transport behaviour. With increasing size, the effects of gravity on interactions and transport can no longer be neglected (Guhra et al. 2021 DOI: 10.1016/j.jcis.2021.03.153). And with increasing size, the pore-network structure, void-size-distribution, and connectivity constrain the accessibility to fractions of the void space by exclusion. The story does not end here: Interactions of TMI-components with the immobile solid phase change the structure of the void-network (Ritschel et al. 2023, DOI: 10.1016/j.geoderma.2022.116269). And TMI change the properties of the – frequently aqueous fluids in natural systems, e.g., the density, the viscosity, and the surface tension. In sum, fluid dynamics and reactive transport in natural systems like soils, sediments, the vadose and the phreatic zone are rather complex phenomena that are intimately intertwined with the physical and biogeochemical weathering and alteration in the subsurface and pedogenesis at the regolith-atmosphere interface. In view of the growing awareness of the subsurface as a mosaic of habitats and ecosystems (Lehmann and Totsche, 2020 DOI: /10.1016/j.jhydrol.2019.124291; Yan et al. 2020 DOI: 10.1016/j.watres.2019.115341), affected by land-use and climate change, this presentation

pleads for a more general and synoptic understanding of fluid flow and reactive transport in natural permeable media and the consequences for their properties, functions and finally life sustaining ecosystem services. Given the power provided by multi-omics in combination with the wide spectrum of (non-invasive) spatio-temporal observational techniques, and the rapid progress in E-science and model-Big-data integration, the reconstruction of the “true” complexity of the subsurface compartments and their development in response to climate and land-use change is possible and allows to define the objectives for ambitious future coordinated research.