Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33132

Mobilization mechanism of LNAPL in unsaturated zone during seasonal freeze-thaw process

XIAOSI SU, RONG ZHONG AND WEIHONG DONG
Institute of Water Resources and Environment,Jilin University

Unsaturated zone is the key area where pollutants enter the aquifer from the surface.Under the influence of seasonal freeze-thaw, the transport process of petroleum hydrocarbon pollutants with LNAPL (Light Non-Aqueous Phase Liquid) as the main component is a dynamic process, which is a four-phase system including water-ice-gas-LNAPL.However,it is difficult to set freezing/thawing conditions consistent with natural conditions,and suitable non-destructive visualization quantitative methods for LNAPL are still lacking in the exploratory stage.The migration regularity and driving mechanism of LNAPL in the unsaturated zone during seasonal freeze-thaw are not fully understood, which limits the deep understanding of the mass transfer process of LNAPL in soil-groundwater system.

The site polluted by petroleum hydrocarbon in the seasonal frozen soil area of northeast China was selected as the study area.Field monitoring shows that after an annual freeze-thaw cycle,petroleum hydrocarbon pollutants in the unsaturated zone have an obvious downward migration trend.The migration of water and the change of water phase state during freeze-thaw process are the important factors driving the remobilization of petroleum hydrocarbons in the unsaturated zone.

Based on the indoor one-dimensional sand column dynamic simulation experiment with improved light transmission method,the dynamic migration law of water and LNAPL in the vespa zone during seasonal freeze-thaw process was explored.The final migration depth of LNAPL in the freeze-thaw condition was 33.6% lower than that in the unfreeze-thaw condition.The remobilization of LNAPL during freeze-thaw process is mainly controlled by freeze-induced driving forces, rather than frozen micro-cracks as previously suggested.During the freeze-thaw process,LNAPL remobilization mainly occurred in the early freezing period and the late thawing period.Freeze-induced expulsion and freeze-induced truncation are the remobilization mechanisms of discontinuous discrete LNAPL (Ganglia).The remobilization of LNAPL is mainly influenced by freezing potential, freezing induced pressure and capillary force.The quantization of potential energy shows that the capillary force is controlled by the LNAPL property and the radius of pore throat of porous media.Freezing potential is controlled by medium type, specific surface area and solute salinity. Freezing induced pressure is controlled by initial LNAPL saturation and freezing rate.