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Assessment of the potential impact of hydraulic fracturing in shale gas reservoirs: Methane leakage from a decommissioned wellbore into groundwater aquifers

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Water quality impacts on the environment from oil and gas development has gained considerable attention over the last decades. The migration of contaminants (fracturing fluid/brine and methane) from the hydrocarbon bearing formation (source) into the shallow aquifers (receptors) involves a variety of factors, each with different type and degree of influence on transport. Across US and around the world millions of abandoned wells are reported to exist which may represent pathways for the hydraulic fracturing fluid and methane. Measurements of the methane emissions from abandoned wells were reported recently in the literature. The leaked methane influences groundwater quality and enhances greenhouse gas emission to the atmosphere. This research study aims to quantify the mass flux of methane from an abandoned wellbore into a shallow groundwater aquifer. We compiled data from the North German Basin to develop a three-dimensional two-phase flow multi-component transport model. The mathematical model is implemented in free- and open-source numerical simulator DuMuX. The numerical model assumes isothermal conditions using a fully implicit time discretization scheme and a vertex centered finite volume method spatial discretization. We analyzed the relative importance of the influence of geological geometry, hydrogeological conditions as well as the influence of the hydraulic parameters on the migration of methane towards the groundwater aquifer. Our modeling results indicate that methane migration is mainly controlled by the wellbore hydrodynamic properties. It is observed that a properly sealed wellbore can prevent upward flow of methane over a long-time scale.