

Multi-isotope approaches to assess the sources and the fate of fugitive methane and ethane associated with the development of unconventional hydrocarbon reservoirs in Western Canada

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Determining accurately the occurrence, sources and fate of methane and ethane occasionally migrating from the subsurface towards the atmosphere along imperfectly sealed boreholes associated with the development of unconventional and conventional hydrocarbon reservoirs remains challenging. Throughout the last decade, we have systematically characterized the chemical and isotopic compositions of produced gases ($\delta^{13}\text{C}$ of methane and ethane and $\delta^2\text{H}$ of methane) from unconventional hydrocarbon reservoirs in Western Canada, of gases in the intermediate zone, and of dissolved and free gases in shallow aquifers, the soil zone and in surface casing vent flows to fingerprint the sources of fugitive gas. In addition, we analyzed the chemical and isotopic compositions of dissolved inorganic carbon ($\delta^{13}\text{C}_{\text{DIC}}$), sulfate ($\delta^{34}\text{S}$ and $\delta^{18}\text{O}$) and nitrate ($\delta^{15}\text{N}$ and $\delta^{18}\text{O}$) in groundwater and conducted geochemical modeling with the objectives to a) determine the sources of methane and ethane in shallow groundwater and b) assess their fate through processes such as aerobic or anaerobic methane oxidation in the near-surface environment. Our data reveal that natural gases produced from unconventional hydrocarbon reservoirs throughout Western Canada have distinct isotopic compositions for methane and ethane that are markedly different from those typically observed for dissolved methane and ethane in shallow groundwater. This indicates that there is no wide-spread evidence that produced gases from unconventional or conventional hydrocarbon reservoirs impact shallow groundwater. Instead, methane frequently found in shallow groundwater appears to have been either produced in-situ in the aquifers or may have alternately migrated from underlying formations of the intermediate zone. Soil gas analyses and geochemical modeling for dissolved groundwater constituents revealed that methane oxidation can markedly alter the concentration and isotopic fingerprints of the remaining methane in the vadose zone and in shallow aquifers. This makes the identification of the source of methane and ethane, and the depth of potential gas leakage challenging, unless multi-isotope approaches are employed to assess the sources of fugitive gas and its fate in the near-surface environment.