State-by-state comparison of off-normal occurrence frequencies for US underground natural gas storage facilities

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Natural gas (methane) has rapidly become a critically important component to the energy economies of the United States and other countries. Because storage capacity in the above-ground pipeline network is insufficient to meet demand, natural gas is stored in large underground (UGS) facilities both in the US and, to an increasing extent, throughout the world. Defining a baseline for the frequency of reported and documented off-normal occurrences, including human error, process safety, mechanical or operational issues, or natural events with or without leakage, at UGS facilities is critical to maintaining safe operation and to the development of appropriate risk management plans and regulatory approaches.

We have analyzed the frequency of off-normal occurrences at US UGS facilities hosted by each US state. Some 31 states host UGS facilities in porous rock (depleted oil-and-gas field and aquifer), and/or solution-mined salt cavern storage facilities. Data are based upon extensive searches of information available in the public domain and not all occurrences involve the stored gas or its release but which, in combination with other factors, could lead to significant problems. The number of reported occurrences, normalized by the number of facilities and the years of active operation, define the mean occurrence frequency per facility-year for each state. Bayesian probabilistic analysis then characterizes the historical occurrence frequencies and uncertainties, parsed by storage facility type, above-ground or below-ground causes, and severity of occurrence.

Both UGS facility-years and nuisance-level occurrences for depleted field storages are highly variable from state to state, for both above-ground and below-ground causes. Aquifer storage facilities show large numbers of occurrences relative to the number of facility-years, with above-ground occurrences identified for four states and a smaller number of below-ground occurrences found for a larger number of states. Salt-cavern storage has a large number of occurrences over a relatively small number of facility-years: most of which are associated with below-ground causes.

Nuisance-level occurrence frequencies for porous-rock storage facilities and for both above-ground and below-ground causes, are generally in the range of $10^{-1}$ to $10^{-3}$ occurrences per facility-year except for those in California, which exceed $10^{-1}$ occurrences per facility-year. Serious or catastrophic occurrence frequencies for depleted field storage facilities decrease to less than about $10^{-2}$ occurrences per facility-year for most states. Nuisance-level occurrence frequencies for salt-cavern storage facilities exceed $10^{-2}$ occurrences per facility-year for below-ground causes,
whilst serious or catastrophic occurrences decrease to about $10^{-3}$ to $10^{-1}$ occurrences per facility-year.