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Hybrid physical and stochastic modelling to assess the water pollution risk associated to unconventional hydrocarbon exploitation

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We have implemented a quantitative multi-hazard risk assessment applied to unconventional gas (UNG) development activities. The method is based on a logic structure based in a bow-tie approach (which implies the coupled use of fault trees and event trees) combined with a wide range of probabilistic tools that rely on Bayesian data analysis concepts. This approach allows the analyst to encode different sources of information and to propagate uncertainties. Likewise, a set of Integrated Assessment Models (IAMs) are used as tools for gathering data from the physical/stochastic modelling of processes in which direct data is unavailable.
For testing the performance of the developed modelling tools, a virtual site has been conceived considering physical and operational parameters resembling the characteristics found in a real UNG development project. Since there is a perception that one of the biggest environmental issues with unconventional hydrocarbon exploration and production is the potential for water contamination, the focus of this study has been the analysis of risk pathways scenarios related to the pollution of groundwater and surface water in different stages of a UNG project. The data used for quantitative analyses are collected from available literature and/or by integrated modelling tools (IAMs).
Different scenarios have been analysed considering different system configurations: for example, in pathways considering wellbore failures, failures at different depths (with respect to the groundwater layer) are considered; likewise, for hydraulic fracturing operations, different scenarios characterized by different factors such as the depth of the target formation and the volume of fluids injected are considered. Taking in consideration the results obtained for the probability of groundwater pollution, for example, assessments were performed considering three project phases (i.e. site preparation, drilling, and hydraulic fracturing). The analyses for the site preparation phase are basically dominated by the assessment of potential impacts of incidental spills during the transport of hazardous materials (HazMat). Regarding the drilling and hydraulic fracturing operations, in particular, the use of IAMs resulted in a efficient tool for studying and inferring leak probabilities taking into account different physical (e.g., stress field, fracture size distribution, fracture density, depth of target formation, etc.) and operational (as e.g., HazMat volume on site, injected volume, downhole pressure, etc.) parameters for building different configurations of the system under analysis. In this way, probabilities of pathways considering elements as fracture network generation and connection are systematically calculated considering different operational and geo-mechanical conditions. The obtained results, presented in terms of leak probabilities and volumes, are summarized using risk matrices, highlighting the sensitivity of the results to some key parameters considered in the modelling process.

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