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Multi-hazard risk assessment applied to hydraulic fracturing operations

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Without exception, the exploitation of any energy resource produces impacts and intrinsically bears risks. Therefore, to make sound decisions about future energy resource exploitation, it is important to clearly understand the potential environmental impacts in the full life-cycle of an energy development project, distinguishing between the specific impacts intrinsically related to exploiting a given energy resource and those shared with the exploitation of other energy resources.
Technological advances as directional drilling and hydraulic fracturing have led to a rapid expansion of unconventional resources (UR) exploration and exploitation; as a consequence, both public health and environmental concerns have risen. The main objective of a multi-hazard risk assessment applied to the development of UR is to assess the rate (or the likelihood) of occurrence of incidents and the relative potential impacts on surrounding environment, considering different hazards and their interactions. Such analyses have to be performed considering the different stages of development of a project; however, the discussion in this paper is mainly focused on the analysis applied to the hydraulic fracturing stage of a UR development project.
The multi-hazard risk assessment applied to the development of UR poses a number of challenges, making of this one a particularly complex problem. First, a number of external hazards might be considered as potential triggering mechanisms. Such hazards can be either of natural origin or anthropogenic events caused by the same industrial activities. Second, failures might propagate through the industrial elements, leading to complex scenarios according to the layout of the industrial site. Third, there is a number of potential risk receptors, ranging from environmental elements (as the air, soil, surface water, or groundwater) to local communities and ecosystems.
The multi-hazard risk approach for this problem is set by considering multiple hazards (and their possible interactions) as possible sources of system's perturbation that might drive to the development of an incidental event. Given the complexity of the problem, we adopt a multi-level approach: first, perform a qualitative analysis oriented to the identification of a wide range of possible scenarios; this process is based on a review of potential impacts in different risk receptors reported in literature, which is condensed in a number of causal diagrams created for different stages of a UR development project. Second, the most important scenarios for quantitative multi-hazard risk analyses are selected for further quantification. This selection is based on the identification of major risks, i.e. those related with the occurrence of low probability/high impact extreme events.
The general framework for the quantitative multi-hazard risk analysis is represented using a so-called bow-tie structure. It is composed of a fault tree on the left hand side of the graphic plot, identifying the possible events causing the critical (or top) event, and an event tree on the right-hand side showing the possible consequences of the critical event.

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