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Extraction of fluids to mitigate the seismic risk associated with post-injection aseismic slip

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Subsurface fluid injections are commonly accompanied by seismicity which can sometimes result in earthquakes of relatively large magnitude that pose a serious hazard for the geo-energy industry. Current efforts to manage the seismic risk associated with fluid injections work generally under the tacit assumption that mitigation measures will become shortly effective in preventing the occurrence of earthquakes of larger magnitude than some pre-defined threshold. A common operational measure is shutting in the wells indefinitely. Unfortunately, seismicity after shut-in is common and, even more, it is not rare that the largest events of injection-induced seismic sequences occur during the post-injection stage. Understanding the physical mechanisms underpinning post-injection seismicity is thus of first importance for the successful development of geo-energy projects. Moreover, gaining knowledge in this matter may ultimately help to design physics-based strategies to mitigate the seismic risk associated with fluid injection operations. From a pure hydro-mechanical perspective, there are two well-known triggering mechanisms for post-injection-induced seismicity, namely, the diffusion of pore-fluid pressure (Parotidis *et al*., 2004) and poroelastic stressing (Segall and Lu, 2015). Recently, Sáez and Lecampion (2023) have investigated a third mechanism where injection-induced aseismic slip in pre-existing fractures and faults may keep propagating after shut-in and continue stressing even larger and more distant regions from the injector during time scales that could span even months for fluid injections of only few days, if the reactivated fracture/fault is critically stressed. This result has motivated us to develop a physics-based strategy to mitigate the seismic risk associated with post-injection aseismic slip. The idea is to extract fluids as an operational measure instead of just stopping the injection. It is shown that fluid withdrawal has not only the effect of reducing the further increase of pore pressure during the post-injection stage, but also the effect of decreasing both the spatial extent and exposure time of the surrounding rock mass to quasi-static changes of stresses due to aseismic slip. The main parameter controlling the reduction of the spatial extent and exposure time is the ratio between the extraction rate and injection rate. We make use of realistic field configurations to provide examples that show the significant reduction of the exposure time that can be achieved by extracting fluids. We also discuss some field evidence that support the plausibility of this extraction strategy.