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Groundwater Vulnerability to Contamination from Fossil-Fuel Development

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Unconventional oil and gas development (UOGD), which involves horizontal drilling and hydraulic fracturing ("fracking"), has made economic recovery of hydrocarbons from low-permeability, geologic formations possible. While UOGD has been largely restricted to North America and China, its application to other regions of the world, including Europe, is being considered. Contaminant releases from UOG sites via spills of wastewater and hydraulic fracturing fluids or from improperly isolated oil and gas wells have impaired groundwaters in areas where residents rely on domestic wells for drinking water and other household purposes. To better understand UOGD risks to drinking-water quality, we have advanced a hydrologically based approach for quantifying vulnerability, which we define as the likelihood that contaminants released from a UOG site will reach a residential water well. We apply this vulnerability framework to the northern Appalachian Basin, USA, where more than ten thousand UOG wells have been completed to extract oil and gas from the Marcellus and Utica shales and where our project team has conducted water-quality testing of more than 300 household wells. Our estimates of vulnerability are lower than those based solely on water-well proximity to UOG sites, reflecting the that our analysis imposes hydrologic constraints on vulnerability by excluding those UOG sites that lie outside the capture zones of residential drinking-water wells. Our well-water measurements suggest that detectable effects of UOGD on household water quality are infrequent, but occur more commonly in households present within hydrologically vulnerable locations. Beyond the application described here, our vulnerability framework can be used to support contaminant-source attribution analyses, disaggregate pollution exposure pathways (e.g., groundwater vs. air), inform decisions on science-based setback distances between drinking-water receptors and potentially polluting sources, and optimize sampling locations for groundwater-monitoring programs intended to safeguard public health. This approach can also be used to infer drinking-water vulnerability to contamination from other extractive industries (e.g., coal mining) or, more generally, to other agents of point-source pollution.