**The risks to water resources from unconventional energy development and hydraulic fracturing ­**

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The rise of unconventional shale gas and tight sand developments through horizontal drilling and high volume hydraulic fracturing has significantly expanded oil and gas exploration in the USA and will soon be launched on a global scale. The rapid rate of shale gas exploration has triggered an intense public debate regarding the potential environmental and human health effects. Active research by the Duke team in different parts of the USA (Pennsylvania, West Virginia, New York, Arkansas, North Carolina, Texas, Colorado, North Dakota) has identified four potential risks for impacts on water resources: (1) stray gas contamination of shallow aquifers near shale gas sites resulted in elevated methane levels in some drinking water wells located < 1 km from shale gas wells; (2) contamination of surface water and shallow groundwater from accidental spills, leaks, and disposal of inadequately treated oil and gas wastewater resulted in elevated levels of halides, ammonium, barium, radium among other contaminants in downstream waterways, with high potential to trigger the formation of disinfection byproducts in downstream drinking water; (3) accumulation of toxic and radioactive residues in soil and stream sediments near disposal or spill sites; and (4) over-extraction of water resources for drilling and hydraulic fracturing that could induce water shortages and conflicts with other water users, particularly in water-scarce areas. New state-of-the-art geochemical and isotopic techniques have been developed for delineating the origin of gases and contaminants in water resources. In particular, multiple geochemical and isotopic (carbon isotopes in hydrocarbons, noble gas, strontium, boron, lithium, radium isotopes) tracers have been utilized to distinguish (1) fugitive gas induced from leaking of shale gas wells relative to background naturally occurring methane flux in the subsurface; and (2) contamination from hydraulic fracturing fluids relative to produced waters from conventional oil and gas wells and/or naturally occurring salinization. Evaluation of the inorganic chemistry of flowback water reveals that the majority of the flowback and produced waters are composed of naturally occurring hypersaline formation water. Mobilization of inorganic contaminants such as radium, ammonium, and iodide from the formation rocks resulted in elevated levels of these contaminants in the oil and gas wastewater. In the USA over 80% of the oil and gas wastewater is disposed through deep-injection wells, but this practice induces seismicity in some areas and might not be possible in other parts of the world. Overall, the environmental effects of unconventional shale gas exploration and hydraulic fracturing can be mitigated by improving the wells integrity and preventing leaking of stray gas, treating or preventing the release of flowback and produced waters to the environment, enhance the recycling of the oil and gas wastewater, and using alternative water resources instead of fresh water for hydraulic fracturing.