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Energy Development and Water Contamination: Challenges in Distinguishing Geogenic from Anthropogenic Sources - *C.C. Patterson Medal Lecture*

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Naturally occurring (geogenic) contaminants ubiquitously occur in global water resources with concentrations often exceeding health benchmark guidelines. In the Piedmont aquifers of the Eastern U.S., for example, the co-occurrence of arsenic, hexavalent chromium, vanadium, uranium, radium, and lithium have been detected in domestic wells associated with different aquifer lithology and geochemical conditions. Yet in areas of extensive energy development, contaminants from energy waste products are often released to the environment, causing water, soil, rivers, and lake sediments' contamination. The era of coal combustion has left a legacy of coal ash; the development of unconventional oil and shale gas drilling has generated large volumes of toxic flowback and produced water. Today, the intensification of critical minerals' mining to address the green energy transition also produces different types of wastes. Each of these sources is characterized by different types of contaminants and geochemical fingerprints with notable environmental effects. The challenge facing society is to delineate adequately these sources of water contamination and to distinguish between the anthropogenic energy-related and geogenic contaminants. This distinction has important implications for policy, public perception, protection, and remediation strategies. Geochemical and isotope tracers have played a major role in delineating the source of water contamination through characterization of the isotope fingerprints of the different contamination sources and investigating potential isotopic modifications induced from water-rock interactions. This presentation will provide an overview of how the integrative multi-isotope approach can provide an informed assessment to evaluate sources and mechanisms of water contamination. Results from several long-term reserach studies will be highlighted to demonstrate the utility of using water geochemistry combined with boron, strontium, radium, and lithium isotopes in detecting the environmental impacts of coal ash storage and spills, produced and flowback waters from conventional oil and shale gas, and wastes of lithium mining from hard rocks and brines. With the transition from fossil fuels to renewable energy, we need to address the potential water quality impacts of mining and processing of critical minerals to avoid a similar legacy of contamination left by the fossil fuels industry during the last century.