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Radioactive Contaminants in the Environment: Isotope Geochemistry Unveiling Their Secrets

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Since the 1940s, both civilian and military nuclear activities, along with industries that handle naturally radioactive materials—such as oil and gas production, phosphate mining, and rare earth extraction—have contributed to the release and redistribution of radionuclides at the Earth's surface, raising their concentrations across various environmental compartments. Depending on their persistence, concentration, and behavior, these radionuclides can expose both people and ecosystems to ionizing radiation. Learning from past nuclear releases, such as the residual radioactivity left by historical nuclear tests and accidents, helps us better understand the geochemical legacy of the nuclear era and provides valuable insights for tracking radioactive contamination caused by human activities.

In the field of source contamination fingerprinting, ASNR is developing a diverse array of isotopic and elemental tracers to improve the identification and characterization of radiological contamination sources, while also deepening our understanding of the past environmental transport mechanisms of radioactive contaminants. In this study, we explore U-series disequilibrium alongside stable Pb isotopes, significantly enhancing the accuracy of contamination source identification and providing insights into past transport mechanisms (dissolved or particulate). Some examples dealing with the relevance and the limitations of the use of stable Pb isotopes combined with U-series disequilibrium in sediments and soils contaminated by former uranium mining and milling activities will be discussed. Moreover, the use of a new tool, the minor U isotopes (^{233,236}U) as well as the combination of geostatistical tools with isotope fingerprints will also be presented as a potential perspective for distinguishing contamination sources and bring accurate information regarding environmental monitoring. This presentation aims to emphasize the crucial role of isotope geochemistry, particularly the use of multiple tracers, and the importance of understanding their geochemical behavior. It also highlights the integration of advanced analytical technologies for more accurate environmental interpretations. Information derived from these tracers greatly enhances expertise in current management practices and the control of the achievement of remediation goals for contaminated sediments and soils, enabling us to anticipate environmental and societal consequences before they become apparent.