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Secondary geochemical effects from persistent hydrocarbon sources in the environment

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Changes to groundwater chemistry associated with oil and gas production, transportation, and waste disposal are secondary effects of hydrocarbon degradation; these changes may persist for centuries. These environmental legacies include production of hydrocarbon transformation products and release of arsenic (As) and other trace elements from sediment; these geochemical signatures are not typically measured as part of natural attenuation monitoring. Studies of the toxicity of these byproducts of natural attenuation can aid in quantifying the risks from exposure to groundwater downgradient from historic hydrocarbon-contaminated sites.

Long-term research sites with residual source zones provide unique data sets to document the potential human health impacts from exposure to waters downgradient from these sources. USGS and collaborators showed in laboratory experiments using human cells that groundwater contaminated by a decades-old crude-oil release near Bemidji, Minnesota, had the potential to cause adverse impacts on human development, endocrine, and liver functioning. We demonstrated the importance of measuring non-volatile dissolved organic carbon (NVDOC) in these samples, because the observed toxicity appeared to be associated with oxygenated hydrocarbon metabolites (oxyhydrocarbons) that make up the NVDOC pool. As residual oil ages in the subsurface, NVDOC in groundwater, which is highest near well-degraded oil, is likely to continue to increase over decadal time scales. This observation underscores the importance of considering the oxyhydrocarbons when assessing environmental health impacts of waters associated with aged petroleum source zones.

Long-term research sites allow for studies that elucidate the role of hydrocarbon degradation reactions in the contamination of groundwater by geogenic elements, including As and trace elements, released from aquifer sediments. Modelling at the same crude oil spill site suggests that ~5.7× more groundwater will be contaminated by As than benzene, suggesting that As could pose a greater long-term water quality threat than benzene in petroleum-contaminated aquifers. Similar concerns regarding the release of As from sediment occur in regions where historical waste management of produced water included disposal ponds or where accidental releases of produced water have occurred. Considering the combined stressors of these secondary contaminants may help to better evaluate ecological and health effects when assessing potential risks of exposure to these waters.