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Hydraulic Fracturing and Water Quality

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ON THE COVER: Hydraulic fracturing, which is needed to recover natural gas from unconventional sources, involves pumping millions of gallons of water into the subsurface. A significant amount of water containing extremely high concentrations of dissolved solids is recovered at the surface together with natural gas. Understanding the source, composition and distribution of these components is the first step to developing sustainable water management approaches.

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Fertilizer-Derived Uranium and its Threat to Human Health

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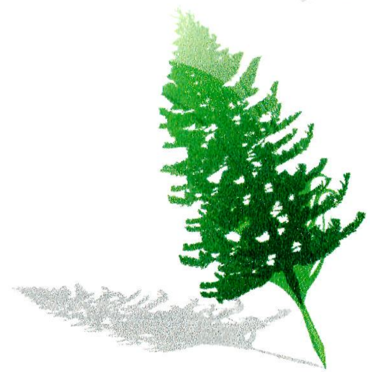

Phosphate fertilization remains the main source of uranium contamination of agricultural land, primarily due to impurities in the phosphate rock used for fertilizer manufacture. In particular, long-term application of uranium-bearing fertilizers can significantly elevate the uranium concentration in fertilized soils. The magnitude of uranium enrichment of cultivated soils varies, depending on phosphate fertilizer application rate, uranium content of applied fertilizer, soil type and prevailing climate. In Germany, the use of phosphate fertilizer from 1951 to 2011 has resulted in a cumulative application of approximately 14 000 t of uranium on agricultural land, corresponding to an average cumulative loading of 1 kg of uranium per hectare.[1]

Fertilizer-derived uranium in soils is prone to leaching because uranium is mobile in surface soils as uranyl complex depending on prevailing pH and Eh conditions. Alternatively, uranium can be immobilized in subsurface materials by sorption or coprecipitation mechanisms. The fate of uranium in soil and subsurface environment is therefore influenced by a delicate balance of U^{6+} association between immobile and mobile phases. Yet, uranium is highly soluble as uranyl (U^{6+}) complex under oxidizing conditions. Consequently, mobility of fertilizer-derived uranium from agricultural soils into ground and surface waters has been recognized in agricultural catchments and, numerous studies have established the transfer of fertilizer-derived uranium from soils into ground, surface and marine coastal waters. For example in Germany, rivers and streams of agricultural catchments have 10 times higher uranium concentrations (0.08 versus 0.8 μg/L U) than those dominated by forestry.[1] Significantly enriched uranium concentrations (>2 μg/L U) were detected in heavily cultivated catchments. Moreover, unconfined aquifers below agricultural land, groundwater has 3 to 17 times higher uranium concentrations than that below forested regions. Generally, there is a concurrent and strong correlation of dissolved uranium concentrations in groundwater with those of other highly mobile and fertilizer-derived elements such as boron, magnesium, and potassium as well as nitrate.[1] The likely reason for the strong uranium-nitrate correlation in groundwater could be due to (a) increased fertilization of agricultural land using NP and NPK fertilizers; (b) significant mobility of fertilizer-derived uranium as uranyl-carbonate complex and transfer into the underlying aquifer; and (c) pronounced solubility of uranium as uranyl–nitrate complex into groundwater. In northern Germany, unmineralized groundwater used as drinking water supply contains variable uranium contents, with one-quarter to two-thirds likely impacted by fertilizer-derived uranium.[1] Thus, agricultural soils and nearby land and water resources are becoming increasingly contaminated by uranium due to fertilizer use. Fertilizer-derived uranium has entered German drinking water supplies.

Principal route of exposure of humans to uranium occurs via ingestion, skin contact, and inhalation. In particular, naturally mineralized groundwaters and bottled mineral waters can contribute significantly to uranium uptake. In Germany, more than 2 million people currently receive drinking water that contains >10 μg/L uranium. Here, a carnivore with a skewed taste for offal, shellfish, and bottled mineral water can achieve the highest uranium uptake.[1]

A considerable body of evidence suggests that overexposure to uranium in drinking water may cause significant health effects in both humans and animals. Reported health effects of uranium derive from experimental animal studies and human epidemiology. Uranium may damage biological systems through its chemical toxicity as well as its radioactivity, with the chemical toxicity perceived as the primary health hazard and the effects from uranium's ionizing radiation being of secondary concern. The main health concerns with respect to uranium are renal, developmental, reproductive, diminished bone growth, as well as DNA and brain damage.[2] In humans uranium is particularly known for its nephrotoxic nature, with short-term and long-term exposure to uranium through drinking water leading to renal effects. The information available on the chronic health effects caused by the exposure to uranium in drinking water points to the fact that regions with elevated groundwater uranium concentrations and more groundwater use have an increased incidence of certain diseases. For example, increasing incidence in chronic kidney disease in Sri Lankan nationals has been related to the low-level fertilizer-

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