Applications of Ecological Engineering Remedies for Uranium Processing Sites, USA

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The U.S. Department of Energy (USDOE) is responsible for remediation of environmental contamination and long-term stewardship of sites associated with the legacy of nuclear weapons production during the Cold War in the United States. Protection of human health and the environment will be required for hundreds or even thousands of years at many legacy sites. USDOE continually evaluates and applies advances in science and technology to improve the effectiveness and sustainability of surface and groundwater remedies (USDOE 2011).

This paper is a synopsis of ecological engineering applications that USDOE is evaluating to assess the effectiveness of remedies at former uranium processing sites in the southwestern United States. Ecological engineering remedies are predicated on the concept that natural ecological processes at legacy sites, once understood, can be beneficially enhanced or manipulated. Advances in tools for characterizing key processes and for monitoring remedy performance are demonstrating potential. We present test cases for four ecological engineering remedies that may be candidates for international applications.

Hydraulic Control of Groundwater

USDOE is responsible for characterizing and remediating groundwater at several former uranium mill sites. Groundwater contamination at these sites is attributable primarily to large volumes of processing liquids that seeped from tailings impoundments during the years that mills operated. We evaluated evapotranspiration (ET) by native plants to hydraulically control groundwater flow as an alternative to pump-and-treat remedies at three sites in Arizona and New Mexico. We characterized the plant ecology of sites, strategically transplanted native desert phreatophytes, and developed an empirical algorithm that combines satellite imagery and ground data to estimate landscape-scale ET. Results show that by managing livestock grazing and planting native phreatophytes, we can use ET to control upland recharge, enhance groundwater discharge, and thereby sustainably help control groundwater flow and contaminant transport (Bresloff et al. 2013).

In Situ Plant and Microbial Remedies for Soil and Groundwater

Uranium processing fluids leaching from tailings left residual contamination in soil and groundwater at many legacy sites. We combined phytoremediation and microbial cycles to reduce nitrate and ammonium levels at a former uranium mill site in Arizona. Contaminants were leaching into groundwater from a denuded soil area where a tailings pile had been removed. We planted and deficit-irrigated this source area with two species of native shrubs, and then discontinued irrigation. ET curtailed leaching, and total soil nitrogen levels dropped >80% over 15 years. Nitrogen isotope analyses indicated that the drop was attributable to coupled microbial nitrification and denitrification processes. We also greatly enhanced rates of microbial denitrification in groundwater by injecting ethanol (Borden et al. 2012), which reduced sulfate and uranium levels and led to our current investigation of ethanol injection to enhance biosequestration of uranium in groundwater at the site.[1]

[1] Biosequestration generates reducing conditions in groundwater by stimulating the growth of microbial populations through injection of electron donor compounds into the subsurface.

Land Farm Phytoremediation of Groundwater

USDOE evaluated land-farm phytoremediation as a pump-and-treat approach for nitrate, ammonia, and sulfate contamination in groundwater at a former mill site in Arizona (Waugh and Glenn, 2012). We irrigated a planting of native shrubs with nitrogen-contaminated groundwater pumped from an alluvial aquifer. Plant uptake and microbial denitrification and nitrification cycles kept nitrogen levels from building up in the land-farm soil, plant growth and transpiration limited recharge and leaching of nitrate and ammonia back into the aquifer, sulfate pumped from the plume remained in the soil profile sequestered as calcium sulfate, and the land farm produced a native seed crop that indigenous people could use for rangeland revegetation and mine land reclamation.

Evapotranspiration Covers for Tailings Disposal Cells

USDOE is evaluating ET covers as an alternative to conventional covers for tailings disposal cells (Waugh, et al., 2009). ET covers consist of thick, fine-textured soil layers that retain precipitation, which is seasonally removed by plants (Albright et al. 2010). Capillary barriers composed of coarse-textured sand and gravel placed below this soil "sponge" can enhance soil water storage capacity and limit unsaturated flow. The sustainability of ET covers depends, in part, on the establishment and resilience of a diverse plant community. We used a series of increasingly larger lysimeters to design an ET cover to enhance the performance of a uranium mill tailings disposal cell in Utah. The design used sandy clay loam soil from the site and native shrub-steppe vegetation. Lysimetry offers the only direct means for measuring percolation at field scale and allows comprehensive evaluation of the soil water balance. Percolation, as recorded with a 3-ha drainage lysimeter installed within the cover during construction, was approximately 0.1% of precipitation during 15 years of monitoring.

References

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