Uranium Retention in a Bioreduced Region of an Alluvial Aquifer Following the Influx of an Oxidant

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Reduced zones in the subsurface represent biogeochemically active hotspots which are not only enriched in buried organic matter but also reduced metals. The change in redox state can alter metal/radionuclide behaviour and contribute to the generation of soluble and mobile species including that of U. The prevailing hypothesis is that an influx of oxidants such as dissolved oxygen (DO) into reduced zones will result in net oxidation. Within a shallow alluvial aquifer located near Rifle, CO, reduced zones are recognized to play a major role in the fate and transport of uranium (U). While an influx of DO would be expected to lead to U mobilization, we report a result counter to the prevailing hypothesis; an influx of low concentrations of DO stimulated reducing conditions leading to uranium immobilization. Here we observed a decrease in groundwater U concentration concurrent with a decrease in ORP from -132 mV to -317 mV following the injection of oxygenated groundwater (21.6 mg DO/well/hr) into a bioreduced region of the Rifle aquifer. After 23 days, the injection of oxygenated groundwater injection was paused and resulted in the rebound of both groundwater U concentrations and ORP to pre-injection levels. When the injection resumed (day 51) groundwater U concentrations again decreased. The injection was halted on day 82 again allowing groundwater U concentrations to rebound. DO delivery rate was increased (54 mg DO/well/hr; day 95) this time resulting in an increase in groundwater U concentrations, consistent with the prevailing hypothesis whereby an influx of oxidants would stimulate mobilization of U. The addition of DO also stimulated microbial activity concurrent with an increase in viral activity. Planktonic cell abundance remained stable over the course of the experiment, but virus-to-microbial cell ratio increased 1.8-3.4 fold with the delivery of oxygenated groundwater, further supporting stimulation of microbial activity in response to the additon of DO and implicating a biological response putatively tied to controls on U biogeochemicstry and mobility. Together these results indicates a “tipping point” exists whereby the influx of oxidants can have one of two effects, i) stimulating reducing conditions or ii) oxidants above a threshold concentration results in net U oxidation and increased mobility in the groundwater.