

## Final Executive Summary Report

### Development of A Novel One-step Process for Uranium Production Bleed Water to Filter Trace Metals using Cupric Oxide (CuO) Nanoparticles

Kyle McDonald<sup>1</sup>, Brandon Reynolds<sup>2</sup>, K.J. Reddy<sup>3</sup>, Tex Taylor<sup>4</sup>, and Donna Wichers<sup>5</sup>

<sup>1</sup>Trihydro Corporation, 1252 Commerce Drive, Laramie, Wyoming 82070

<sup>2</sup>State Engineers Office, Cheyenne, WY 82002

<sup>3</sup>Department of Ecosystem Science and Management, College of Agriculture and Natural Resources, 1000 E. University, Laramie, Wyoming 82071

<sup>4</sup>Department of Agriculture and Applied Economics, College of Agriculture and Natural Resources, 1000 E. University, Laramie, Wyoming 82071

<sup>5</sup>Uranium One, 907 North Poplar Street #260, Casper, Wyoming 82601

The demand for clean and economical energy sources, such as uranium, is expanding worldwide. Within the US, Wyoming holds largest deposits of uranium. Since the early 1990's Wyoming has been pioneered *in-situ* recovery of uranium. Currently, approximately 2 million pounds of uranium per year is produced in the state using *in-situ* recovery. *In-situ* recovery is a process where injection and production wells are drilled into an ore body containing commercial concentrations of uranium. Typically an oxidizing agent (e.g., gaseous oxygen plus sodium bicarbonate solution) is injected into the formation and flushed through the ore body where it dissolves the uranium. The resulting leachate is then pumped to the surface at the production wells. Uranium within the leachate is isolated through a filtering (e.g., ion exchange process) and drying process.

However, *in-situ* recovery process can mobilize not only uranium but also other metals (e.g., arsenic, vanadium) that subsequently could concentrate in production bleed

water (the liquid waste generated during uranium recovery). In addition, small amounts of residual uranium, that could be unrecovered during the filtration process, also concentrates in production bleed water. Production bleed water accounts for approximately 1-3 percent of the process flow rate and can result in approximately 1.6 million gallons of production bleed water per year for a small sized *in-situ* facility. It is important for the uranium industry to reclaim and, if possible, reuse this water for beneficial uses, particularly in semi-arid areas such as Wyoming where water availability is limited.

Widespread efforts are being made to develop effective and affordable treatment technologies for energy related produced water. Some of these technologies include conventional sorbents (e.g., activated carbon and oxides of aluminum, iron, titanium, zirconium, and manganese) and Reverse Osmosis (RO). Conventional adsorbents have various limitations such as requirement of pH adjustments, oxidation of water, and removal of competing ions (e.g., phosphate, silicate, and sulfate). Due to these problems field application of conventional adsorbents is limited. Reverse Osmosis works well in filtering contaminants from produced water, and is the primary method of cleaning the produced water in the uranium industry today. However, it is an energy intensive process and produces large volumes of reject brine water, which require special handling in disposal.

The in-situ recovery uranium (ISRU) process produces substantial amounts of production bleed water (PBW). The objective of this research is to study effectiveness of cupric oxide (CuO) nanoparticles in the removal of trace elements (arsenic, vanadium, and residual uranium) from PBW. Batch experiments in the lab were conducted with

PBW using CuO nanoparticles to remove trace elements and to develop a flow-through reactor for field studies. Based on batch experiment results, a flow-through adsorption column for use with CuO nanoparticles was developed and tested in the field. The flow-through adsorption column effectively removed arsenic and vanadium and to some extent residual uranium from PBW in the field. For example, 1.5 g of prepared CuO nanoparticles decreased arsenic concentrations from 16 to 7 $\mu$ g/L in 10 L of PBW. Further, the prepared CuO nanoparticles decreased vanadium from 860 to 340 $\mu$ g/L. The removal of vanadium is likely due to an adsorption process by the CuO nanoparticles. This could be of potential economic importance to the uranium industry as vanadium is a costly contaminant in uranium production and yellowcake processing. No other chemical constituent of the water was significantly affected except for copper, which increased from 10  $\mu$ g/L to 3.5 mg/L due to a low pH of approximately 6.5. Regenerated CuO nanoparticles performed similarly to prepared CuO nanoparticles. Analysis of the regeneration wash fluids suggests an incomplete regeneration of the CuO nanoparticles in the field. Further testing of the flow-through reactor in the field using ISRU pre-ion exchange water suggested that CuO nanoparticles could also removed vanadium. However, copper concentrations increased significantly in the treated water due to the low pH. Preliminary cost economics of this process suggest that the system may represent a fairly cost effective approach to removing arsenic and vanadium for ISRU PBW. Two more domestic groundwater well samples in Wyoming were tested in the field using CuO nanoparticle flow-through reactor. Results from these field studies suggested that flow-through reactor could also remove arsenic from domestic groundwater wells without any significant changes to groundwater quality, including copper.