Colloidal transport of U, Ni, and As and their sequestration in meromictic mine pit lakes in northern Saskatchewan

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This study investigated the biogeochemistry of uranium (U) and the co-occurring elements nickel (Ni) and arsenic (As) in colloids and sediments of two meromictic pit lakes formed after uranium mining in northern Saskatchewan, Canada. The pits are diverse in shape and chemistry. The deeper (90 m) and larger pit lake has two major chemoclines, has high concentrations of Ca and Mg; its deep water is acidic (pH 5.5) and oxygenated. The shallower pit (30 m) has only one major chemocline, below which the water is alkaline (pH 8), anoxic and rich in Fe. The distribution and speciation of the elements in colloidal size fractions was analyzed using ultrafiltration in combination with in-situ chemical separation techniques and transmission electron microscopy. The filtrations were performed on fresh water samples on site, as well as in the laboratory on aged samples after one month of incubation. The sediments in both pits were investigated by sequential extractions, scanning electron microscopy, synchrotron-based X-ray absorption and diffraction techniques, and 16S rRNA gene sequencing. Colloids smaller than 450 nm consisting of Ca, S, Si, and Fe were found in fresh and old pit water. Through aging, As, U, and Mo-rich colloids formed, suggesting that those elements can be removed from the water column by the naturally occurring colloidal pumping process. In the sediments, U was dominant in the acid soluble and reducible fractions, the latter being especially important in the deeper and oxygenated pit, suggesting the potential mobilization of U due to acidification or oxygen depletion. Synchrotron-based analyzes indicated the presence of the mineral vandendriesscheite (uranyl oxyhydroxide) present in 10-100 µm large grains, a mineral which can benefit the

overall U stability in the far future. Compared to U, As was more strongly bound to the sediments and mostly present in the oxidizable and residual (high recalcitrance) fractions. Ni, on the other hand, was mostly present in the more mobile fractions of the sediments. Colloidal pumping and metal/metalloid sequestration are ongoing processes in the two investigated pit lakes. However, the mobility of U, Ni, and As in the sediments is dependent on the future stability and development of the pits' meromictic conditions.