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Editorial

Editorial for Special Issue "Environmentally Sound In Situ Recovery Mining of Uranium"

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This Special Issue features seven articles that cover a range of topics pertaining to the environmentally sound in situ recovery mining of uranium (U ISR). The topics include: (1) methods for assessing the potential environmental impacts of future U ISR operations using historical operational records and available geohydrologic, geochemical and climate data in a specific regional setting; (2) laboratory column studies to parameterize a uranium surface complexation model that can be used to predict uranium fate and transport in groundwater; and (3) a field evaluation of both a chemical reductant and a biostimulant to promote reducing geochemical conditions after oxidative mining at a U ISR facility.

The first topic above is addressed in a series of five complementary articles by authors from the United States Geological Survey (USGS). These papers have a theme of drawing from existing publicly available information to assess both past and potential future environmental impacts of U ISR in the Texas coastal plain of the United States, where abundant U ISR operational records and robust hydrogeological, geochemical, geologic, and climate data sets exist. The authors make the case that the presented methodologies are readily transferrable to other locations, although the practical extent to which this can be achieved will depend on the availability of suitable information and data sets in those locations. In "A Methodology to Assess the Historical Environmental Footprint of In-Situ Recovery (ISR) of Uranium ... " by Gallegos et al. [1], historical records on the environmental impacts and consumptive water use at south Texas U ISR operations are regressed with historical U3O8 production data (and other variables related to U3O8 production) to provide correlations that can, in principle, be used to predict environmental impacts at potential future south Texas U ISR mining operations. Two other USGS articles focus on the development of a hydrogeologic framework (Teeple et al. [2]) and a geochemical framework (Blake et al. [3]), respectively, for the Texas coastal plain, with emphasis on the hydrogeology and geochemistry that influence contaminant mobility and transport. A fourth USGS article (Walton-Day et al. [4]) presents the development of a geo-environmental model for the Texas coastal plain that combines the characteristics of the ore deposit type, derived from literature review and a published ore-deposit model (Hall et al., 2017 [5]), with the geographic, climatic, and regulatory framework where the deposits occur. The last USGS article (Gallegos et al. [6]) presents a methodology for conducting a geo-environmental assessment for U ISR in the Texas coastal plain. This article builds on and ties together the hydrogeologic and geochemical frameworks, the historical impacts of U ISR operations, and the geo-environmental model that are presented in the other four USGS articles. All of the USGS articles, with the exception of the one on historical impacts of U ISR operations, present methods and results that apply to a regional scale that significantly exceeds the scale of individual U ISR operations, but they nonetheless provide insights and context for assessing potential impacts of future U ISR operations within the overall regional domain.

In the article "Column-Test Data Analyses and Geochemical Modeling to Determine Uranium Reactive Transport Parameters at a Former Uranium Mill Site (Grand Junction, Colorado)" by Johnson, Tigar, and Richardson [7], a 1-D transport model implemented in the geochemical modeling software PHREEQC [8] is used to manually fit effluent chemistry data from laboratory column tests in which different water chemistries were sequentially injected into columns packed with uranium-contaminated sediments taken from a contaminated site. A principal goal of the study was to parameterize a generalized composite surface complexation model capable of describing uranium sorption and desorption over a relatively wide range of groundwater chemistries that could occur at the site to make it possible to provide more accurate predictions of uranium mobilization and transport under variable geochemical conditions. Although the details of the study are site-specific and the application is not U ISR, this article demonstrates an innovative experimental and modeling approach to robustly describe uranium sorption and desorption that could be readily applied to predict the uranium mobilization and transport downgradient of a mined area at a U ISR site after mining has ceased. The only additional geochemical processes that would have to be included in a fate and transport model for U ISR applications would be uranium oxidation and reduction reactions, which were not needed for this study because the site was predominantly oxidizing and the dominant uranium oxidation state was U(VI). The editors believe that uranium oxidation and reduction processes relevant to a U ISR setting could be readily described using appropriate adaptations of the experimental and modeling approach employed by the authors in this article.

The article "Restoration Insights Gained from a Field Deployment of Dithionite and Acetate at a Uranium In Situ Recovery Mine" by Reimus, Clay, and Jemison [9] describes a field experiment in which both a chemical reductant (dithionite) and a biostimulant (acetate) were deployed in a previously mined ore zone at a U ISR mine in an attempt to re-establish reducing geochemical conditions in the ore zone. It was apparent that both amendments promoted reducing geochemical conditions, as indicated by significant decreases in oxidation-reduction potentials, significant increases in ferrous iron concentrations, and large decreases in selenium concentrations in the groundwater of the test area. However, uranium concentrations in the groundwater increased rather than decreased during the experiment, which was attributed to the desorption of U(VI) in the ore zone (promoted by geochemical perturbations caused by the amendments) coupled with insignificant U(VI) reduction to insoluble U(IV). A key conclusion from the study was that most or all of the ferric iron (Fe(III)) that was generated in the ore zone when oxidants were introduced during mining would have to be reduced before significant U(VI) reduction could be expected to occur. Modeling revealed that a large fraction of the aqueous U was present in the form of Ca–Uranyl–Carbonate complexes, which are very thermodynamically stable. This enhanced the tendency for reductants to be consumed by ferric solids rather than dissolved U. It is also likely that the reduction of the ferric iron to ferrous iron may have been a significant contributor to the observed increases in U(VI) concentrations because U(VI) is known to strongly sorb to ferric iron, and the reduction of the ferric iron to soluble ferrous iron would cause sorbed U(VI) to be released into the groundwater. While the field experiment was unsuccessful in promoting significant U(VI) reduction and lowering U(VI) concentrations, it provided numerous insights for improving reductive amendment strategies to restore groundwater at U ISR mines, which are discussed in the article.

All of the articles in this Special Issue emphasize the importance of identifying site-specific conditions that must be assessed to gauge the environmental impact of uranium mining. The USGS manuscripts [1–4,6] outline what might be described as a "first cut" or macroscopic overview that attempts to establish useful predictive relationships between spatially distributed environmental variables and environmental impacts ranging from airborne radon and radioactive dust to surface disturbances and groundwater contamination. Column studies of the type described by Johnson et al. [7] aim to describe uranium sorption and transport over a wide range of groundwater geochemical conditions, and their work shows how important site-specific groundwater chemistry can be in determining uranium fate and transport. Reimus et al. [9] describe results from a field-scale deployment of reductive amendments at a U ISR mine that highlight the many site-specific geochemical variables that must be considered when attempting groundwater restoration at U ISR sites. The takeaway message is that optimal U ISR mining and restoration techniques will have significant site-specific components to them.

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