Understanding the fundamental processes that control U-mobility, mobilization of earth's resources, but get disrupted by human activities due to exploitation and environmental mineralogy as 'interdisciplinary field dealing with areas. However, the role of nano-pores in controlling the mobility of are main carrier of U. The host mineral nano-particles are nano-porous (like nano-ferrihydrite, nano-goethite and nano-hematite) and their nanopores greatly affect the sorption behavior of uranium. These iron oxide minerals, having nano-dimensions, are more essential sorbents for both U (VI) and U (IV). U (VI) is readily soluble in water, particularly in oxic environment, and highly soluble than U (IV). Moreover, sizable amount of U (VI) is irreversibly bound to nanopore surfaces of iron oxide minerals; the binding strength is found to be directly related to nano-pore size. The population of fine nano-particles is identified as mix of nano-porous goethite with ferrihydrites, associated with clay minerals (illite/smectite) in the coating layers. These nano-particles with nano-pores and iron oxides are typical in surface/sub-surface soils/sediments and water, microbial remediation may be utilized. Bacterial activity can fix these radio-nuclides into insoluble form that cannot be readily desorbed. Uraninite particles in sediments, formed by microbial reduction, are typically less than 2nm across and this small size has important implications for uranium reactivity and fate. These fine particles can still be transported in aqueous environment and precipitation of uranium as insoluble uraninite cannot be presumed to immobilize it.

Nano-pores within nano-crystalline Fe oxides strongly influence the sorption of uranium and hence the extent of mobility and transport of U (VI) in sub-surface environments. Chemically speaking, the mobility of U depends on its speciation and redox state. It is present as mobile U (VI) in oxidizing conditions. Under reducing conditions, relatively insoluble and immobile U (IV) predominates typically as the mineral uraninite (UO2) but non-uraninite phases may also be transferred. Soluble U (VI) can be reduced by microbes ultimately to U (IV) and precipitated, thereby reducing the mobility of U (VI). Microbial cycling has significant impact on radionuclide behavior across a wide range of environment and are important in managing contaminated land sites and geological disposal scenarios, where biogeochemical processes are likely to occur and be considered in safety case development. U (V), on the other hand, is generally considered as transient though signs are emerging, which suggest that it might be stable for few weeks under certain conditions.

NOM are known to be an important component of uranium fate and transport (Aiken et al., 2011). Uranium has high affinity for both dissolved and particle-associated NOM fractions and NOM is implicated in increased nano transport of uranium in natural waters. Complexation of U (VI) with dissolved NOM increases mobility in water, but when associated with solid phase, NOM can result in accumulation of uranium. In fact, hexavalent uranium may lose its mobility by adsorption. Common cations like Fe and Ca play significant role in uranium mobility through NOM-stabilized metal (Fe) nanoparticles.

To fix the problem of actinide contamination of soils, sediments and water, microbial remediation may be utilized. Bacterial activity can fix these radio- nuclides into insoluble form that cannot be readily desorbed. Uraninite particles in sediments, formed by microbial reduction, are typically less than 2nm across and this small size has important implications for uranium reactivity and fate. These fine particles can still be transported in aqueous environment and precipitation of uranium as insoluble uraninite cannot be presumed to immobilize it.

Fe-oxidic mineral nano-particles/nano-minerals in high Fe(III) soils/sediments and water may have transport-facilitating and transport-impeding effects on uranium contaminants in a mining/milling area depending on the chemical ambience of the medium structure of nano-pores as well as the NOM characteristics. Most reactive surfaces in fact are nano-pore surfaces. The behavior of geological fluids and minerals in nano-pores (Sun et al., 2010) is significantly different from those in normal non-nanoporous environments. The effect of nano-
pore surfaces like enhancing U (VI) sorption and reduction is significant in clay-associated sub-surface environments.

A preliminary enquiry was carried out by present workers on uranium contamination around the mines at Jadugoda, east Singbhum district, Jharkhand state to set the stage for a comprehensive study on the complexity of challenges of uranium contamination.

Detailed geological information on Jadugoda mines exhibits an exotic assemblage of uranium minerals like dominant uraninite, subordinate brannerite, davidite, autunite, torbernite, etc., sulphides, telluridites and native metals (Singh and Minz, 2009). Goethite, associated with ferrihydrite and clay minerals, is more common than hematite. It may be pointed out that nano-goethite is the major carrier of uranium.

In nearby Turamdih mine, U-mineralization isapatite borne in host feldspathic chloride-sericite schist. Presence of shaly clay is interesting. Goethite nano-particles are closely associated with clay minerals.

U-concentration from different localities of mining complex, contaminated by U-mining, may show considerable variation. Observed U-concentration range encompasses six orders of magnitude in a range from pH 1.5 to 8.0.

U (VI), excited by sunlight (common at Jadugoda), is a strong oxidant, readily able to oxidize organic substances in an aqueous solution being itself reduced to U (IV) and subsequently sorbed. Interaction of U (VI) with naturally occurring organic material in the aqueous medium depends on the U-species present in the solution. Microbial activity further modifies its behavior. Thus a detailed study of U-behavior in natural water bodies, surface or subsurface may provide further insight into the geochemistry.

The groundwater table at around 40 meter below the surface negates the possibility of flooding of the mines and water transgression onto the mine floors; thus the absence of reducing conditions in the mine is suggested. But the old mine dumps and the tailing pond display an anoxic state, indicating conducive conditions for the presence of U (IV). It may be mentioned in the context that U (V) plays almost no role in nature.

The water samples collected from the Subarnarekha river as well as from adjacent wells had high levels of radioactive alpha particles that damage the food chains in the area and beyond. Under such circumstances, the only way is setting up of PRBs (Preventive Reactive Barriers) and chemical treatment of aquifer as required in situ. PRB will bring down the concentration of uranium substantially and significantly, but it will do little in respect to radioactivity. Simply quarantining the area for sometime after PRB installations may be good safety measure. Monitoring of results will guide to action strategy and implementation.

PRB is a porous wall containing reactive material like zero-valent iron. PRB can be constituted by digging a deep trench and filling it with zero-valent iron particles (nanoiron particles). This would depend on local hydrology of the site and direction of ground flow. As the contaminated groundwater permeates the porous and reactive wall, uranium will get adsorbed onto the iron and get reduced to UO₂ that remains immobile.

The sub-surface cracks in soil may also be injected with zero-valent iron, creating PRB. It will adsorb uranium. Uranium here is similarly reduced to UO₂ and remains immobile.

Any detailed study on Jadugoda uranium should look into arsenic contamination as well. Secondly, molybdenite in Rakha and Jadugoda Mines contain Rhenium in economic quantities. Rhenium is very important for space engineering, rare in occurrence; a pyrometallurgical plant to extract the metal is worth looking into. A holistic outlook will change the total mining/metallurgical/environmental scenario of the region.

References


Announcement

XXVI Indian Colloquium on Micropaleontology and Stratigraphy (ICMS - 2017)

The Department of Geology, University of Madras, Guindy Campus, Chennai, proposes to organize “The XXVI Indian Colloquium on Micropaleontology and Stratigraphy (ICMS - 2017)” from 17 to 19 August, 2017. Please refer to the website: https://www.icms2017chennai.com

For further details kindly contact Dr. S.M. Hussain, Convener; Dr. M. Suresh Gandhi, Co-convener, Department of Geology, University of Madras, Guindy Campus, Chennai – 600 025. E-mail: smhussain7@hotmail.com; msureshgandhi@gmail.com Mobile: 09444415027; 09443806534.