

Natural occurring uranium nanoparticles and the implication in bioremediation of surface mine waters.

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There are a number of open questions on application of laboratory successful microbial immobilisation of uranium in natural surface water. In view of this, we investigated the behaviour of dissolved uranium in a tailing pond of a former uranium mine site in eastern Germany. Water samples were collected at a gradient in the ponds and they were subjected to sequential ultrafiltration in the laboratory. The samples were filtered on a 0.45 µm pore of cellulose acetate filter membrane before centrifugation. After centrifugation, the samples were sequentially filtered through 0.2 µm pore, 30 kDa, 1 kDa and 500 Da filter membranes. The concentration of uranium in initial and permeate solutions were determined in the samples using ICP-MS. Further, SEM-EDX analyses were used to determine the colloid population, and to determine the major elements present in the colloids. The results revealed that the retention of low molecular weight uranium on the membranes were in the order of 30 kDa > 500 Da > 1 kDa. The actual percentages of retention were estimated to as much as 45% by a 1 kDa membrane and 20 % by 500 Da membrane. Concentrations of total dissolved U increased immediately after filtration on 0.45 µm pore membrane were ca. $298 \pm 69.9 \mu\text{g L}^{-1}$. The retention of uranium by the 30 kDa, 1 kDa and 500 Da membranes suggested that uranium was associated with colloids. Thus, colloidal U accounted for ca. 30-40% of the total dissolved U in the mine waters with increasing trends in the lower parts of the pond. REM-EDX results showed that probably the major types of colloids were either biogenic (organic-bound uranium because of high C), iron containing colloids or silicon containing colloids were predominant in the waters. There was also a small amount of colloids containing aluminium and calcium as major elements.

There is evidence from literature that nanoparticles are often the by-products of remediation efforts in systems with heavy metal or radionuclide contamination. One of the most reported is the bioremediation of soluble uranium by metal-reducing bacteria, which involves microbial-induced redox-transformations from U(VI) to an insoluble U(IV) phase. U(VI) is reduced in contaminated U(VI) is reduced concurrently with Fe(III) and prior to reduction of sulphate by a number of Geobacteraceae and Desulfovibrionaceae, whose the growth is attributed to electron transfer to Fe(III). These U(IV) precipitates exists predominately as nanoparticles of uraninite (UO₂). Further, nanoparticles of uraninite (UO₂) can also be produced abiotically when U(VI) is reduced by Fe(II)-oxides. Other studies have also shown that solid-phase U(IV) precipitate actually contained a large fraction of unreduced U(VI). The uraninite (UO₂) particles formed from uranium by bacterial reduction are typically less than 2 nanometres across and that the small size has important implications for uraninite reactivity and fate. These uranium nanoparticles are, therefore, still mobile and can be transported as flocculation in the aquatic environment. Thus, precipitation of uranium as insoluble uraninite or adsorption of uranium on nano-biocolloids cannot be presumed immobilised.