

# Mitigation of U(VI) and Se(VI) contaminated groundwater via forward osmosis: Insights on removal mechanism and co-ion effect

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Uranium (U) and Selenium (Se) are groundwater contaminants, primarily of geogenic origins, that need to be regulated in drinking water to avoid health hazards. In this study, we had set out to investigate the mechanisms underlying Forward Osmosis (FO) process, a low energy-intensive technology, for uranium and selenium mitigation from contaminated groundwater under environmentally-relevant conditions representative of the regional scenario of Punjab, India. Laboratory experiments with aqueous solutions containing either uranium or selenium were performed with FO membrane under varied pH, draw solution concentration, and including common co-ions. Further, to elucidate the feasibility of FO process in complex water matrix, experiments were conducted using uranium and selenium-contaminated field groundwater obtained from Ludhiana district and Nawanshahr district of Punjab, India, respectively. Results of the hydrogeochemical modelling performed using PHREEQC indicated that the removal mechanism of uranium and selenium were highly dependent on aqueous speciation. Uranium rejection was maximum at alkaline pH with ca. 99% rejection due to charge-based interactions between membrane and dominant uranyl complexes. Whereas, selenium rejection was observed to be higher when the feed solution pH was greater than the isoelectric point of membrane (i.e. pH 4.65) with 97% rejection attributable to charge-based interactions. The results of the co-ion study indicated that nitrate and phosphate decrease uranium rejection whereas bicarbonate, calcium, and magnesium concentrate uranium in the feed solution. Further, the uranium uptake onto the membrane surface primarily depend on the pH of aqueous solution with maximum uptake at pH 5.5. In the case of selenium removal, all the co-ions considered viz. calcium, magnesium, nitrate, and sulphate, reduced selenium rejection. No uptake onto the membrane surface has been observed in the pH range between 4.0 and 10.0. Our results show that the World Health Organization's drinking water guideline value of 30 µg of U per liter and Bureau of Indian Standards drinking water acceptable value of 10 µg of Se per liter could be achieved consistently using FO technology for the mitigation of contaminated field groundwater of Punjab, India. The mechanistic understanding gained from this study would facilitate scaling up of this technology for field level implementation.

