Investigations of Source of Uranium and its Geochemical Pathways in Aquifer Systems in Parts of Southwest Punjab using Environmental Isotope Techniques

Uranium in drinking water has been a subject of great concern in India and rest of the world as prolonged consumption might lead to nephrotoxicity and osteotoxicity in humans. U is considered as a confirmed human carcinogen (group A) and WHO has set a safe acceptable limit of 30 µg/L and AERB has established the radiological limit of 60 µg/L for drinking purposes. In this research work, two districts, Bathinda and Mansa districts of SW Punjab (5538 km^2) were investigated to obtain deeper insights into the sources and processes responsible for uranium contamination in groundwater. The tools applied were hydrogeology, hydrochemistry, environmental stable and radioisotopes, geochemical and statistical modeling.

The entire study area showed groundwater uranium concentration from 0.6 to 590 µg/L (Fig.1(a)) while canal waters showed negligible U values (<2 µg/L). A declining trend was observed in U concentration along the depth. U dose calculations indicate that there is chemical as well as radiological toxicity health risk to the inhabitants of this region. Geogenic factors show high positive values with U while anthropogenic factors show poor correlations indicating geogenic sources being the actual controls on U distribution. NO_3^- showed fairly positive correlation with dissolved U hinting that NO_3^- can be a potential agent to drive U release into groundwater. Saturation indices of U minerals indicate that groundwater is under-saturated with most of the uranium containing minerals and hence there is a possibility of more U leaching into groundwater with time. Speciation calculations indicate that the dominant species of U in groundwater are, UO_2CO_3, $UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$. $^{234}U/^{238}U$ Activity Ratio (AR) values reflect stable accumulation zone and leaching of low AR U source. A very narrow range of AR values in both seasons reflect that similar process governs the U distribution in groundwater.

Isotope data indicates that zone (i) is recharged by local precipitation with some component from evaporated surface water (irrigation return flow) and recycled vapor source. In the case of zone (ii), the main recharge is by precipitation. $\delta^{13}C$ values show that groundwater in zone (i) indicate mostly root respiration. The contribution of irrigation return flow to zone (i) and (ii) was examined by employing ^{222}Rn. A clear indication of surface water contribution to zone (i) is noticed from ^{222}Rn depth profiles. ^3H values indicate modern recharge to both zones. Both fast and slow recharge occurs in zone (i) while groundwater in zone (ii) is relatively older.

Groundwater fluctuations affect the geochemical condition of the water i.e. oxidation and redox potential and trigger the release of U on the sediments by oxidation of U (IV) to U (VI). In addition, hydrogeological processes like recharge and discharge also impact U distribution in groundwater. The schematic representation (Fig.1(b)) displays irrigation return flow and water logging favor the release of U into the zone (i) groundwater while sand dunes aids in diluting the U concentration in groundwater by easy percolation of precipitation. No significant changes in U concentration are noticed in groundwater of zone (ii). From the above research findings, the following hypothesis is proposed: U present in sediment is mobilized by reacting with oxidants (DO and NO_3^-). Once U oxidizes to UO_2^{2+}, it complexes with the dissolved HCO_3^- in groundwater and forms $UO_2(CO_3)_2^{2-}$ and $UO_2CO_3)_3^{4-}$ complexes, which are stable and mobile in groundwater. Zone (ii) shows less U contamination as the dissolved HCO_3^- and oxidants are less in concentration.

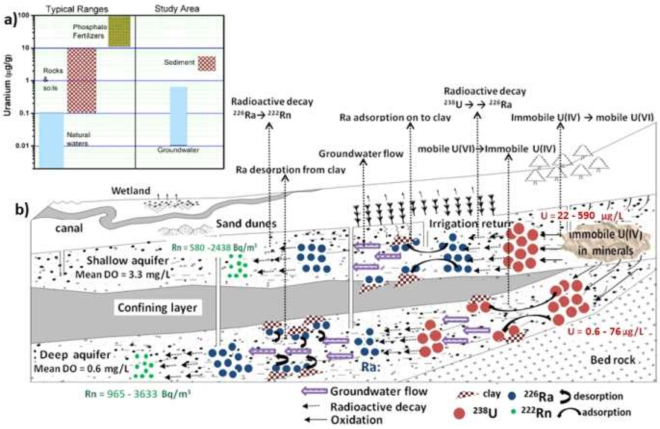

Fig.1(a) Uranium concentration in different environmental media vs study area, (b) Conceptual model for Uranium distribution in groundwater

Based on the above studies, it is recommended that canal water may be used for drinking and domestic purposes in the affected regions of Punjab after treatment with conventional techniques. Secondly, places where canal network is not accessible, usage of deep groundwater for drinking can be recommended.

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