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Isotope characterization of major rivers of Indus basin, Pakistan

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Pakistan lies between latitudes 24˚ and 37˚N and longitudes 61˚ to 76˚E and possesses different physiographical features including high mountains of Himalayan ranges covered with glaciers, dry mountains of Balochistan, Indus plains and coastal areas in the south. The river Indus, which is one of the longest rivers in the World, has five major tributaries viz. Bias, Satlej, Ravi, Chenab and Jhelum joining from eastern side, while a number of small rivers join the Indus on the right side. Physiography and climate of the catchments of these rivers vary widely. Going from the catchment of the River Satlej to the catchment of Indus River, altitude increases and temperature decreases. All the rivers have vide ranges of stable isotopes and tritium. The headwaters of river Indus coming from highest altitude have the most depleted values of δ^{18}O (–14.5 to –11.0‰) and δ^{2}H (–106 to –76‰) because of major contribution of snowmelt coming from glaciated peaks in Northern Areas. The rivers Sutlej and Ravi have the most enriched values of δ^{18}O (–10.6 to –6.8‰) and δ^{2}H (–65 to –36‰) because their catchments have relatively low altitude and contribution of snowmelt is also less. The river Chenab at Marala has the widest ranges of δ^{18}O (–12.8 to –6.4‰) and δ^{2}H (–80 to –35‰) because of mixing of snowmelt originating from higher altitudes and rainfall of piedmont areas. Temporal variations of δ^{18}O, δ^{2}H and the reservoir level of the river Indus at Tarbela Dam Reservoir show year wise cyclic behavior. The most depleted values of δ^{18}O are in August-September when the reservoir level is generally highest and the most enriched values are found during April-May when the reservoir is at its minimum level. The cyclic enrichment is not due to evaporation effect but dominantly

due to change in contributions of snow/glacier melt coming from high mountains of Himalayas and relatively enriched rains in heavy isotopes at low altitude. Slopes of δ^{18}O–δ^{2}H regression equations for different stations/rivers are significantly less than 8 but most of the data points lie above the GMWL. The departures of the points having highly depleted values of δ^{18}O and δ^{2}H are more than those corresponding to the points having enriched values. Generally the highly depleted values are during the major contribution of snowmelt, which have high d-excess due to some climatic effects or having source of winter precipitation from western air masses/Mediterranean Sea. The data points with enriched δ^{18}O and δ^{2}H have relatively less d-excess because of contribution from monsoon rains originating from Bay of Bengal. Average tritium of rivers ranges from 12 to 18 TU. High tritium in Himalayan tributaries might be due to contribution of snowmelt of bomb period or it is still high in precipitation at middle latitudes.