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Environmental and artificial tracers in hydrogeology

title: Identification of recharges of the springs in Liddar watershed of Kashmir Himalaya, India

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Geological, hydrological and $\delta^{18}O$ data of precipitation, streams and springs was used to identify the sources and origin of recharge of the springs in Liddar water shed, Kashmir Himalayas in India. The study area is characterised by temperate climate with an average annual precipitation of 1200 mm. The winter and spring seasons receive most of the precipitation in the form of snow and rain. The winter temperatures are mostly sub zero and the maximum temperature in summer season is about 37 degree centigrade. The data generated indicated the spatial and temporal variability of $\delta^{18}O$ of precipitation was dominantly controlled by temperature, altitude and amount effects. The $\delta^{18}O$ of precipitation ranged from –0.04 to –12.98‰, with 60% of the values greater than –5‰. The $\delta^{18}O$ of each precipitation site showed a large negative shift (>10‰) during January which coincide with low temperature and high amount of precipitation. A good relationship was found to exist between the mean local temperature and mean $\delta^{18}O$ of the precipitation, with depleted $\delta^{18}O$ values during lower temperature and enriched values during higher temperature. However, a marked discrepancy, higher temperature and depleted $\delta^{18}O$ values during September may be attributed to the amount effect and/or local source of the clouds. The isotope ratio showed a depleted trend eastward indicates the main rains brought by westerly winds. The recharge altitude of the springs was calculated as 2700–3600 m a.s.l. according to a mean altitude effect of about –0.2‰/100 m rise, which is the representative for the precipitation at higher altitudes. The altitude effect, however, varied seasonally being lowest in May (–0.5‰/100 m) and highest in September (0.1‰/100 m). The stream waters were more depleted than low level precipitation due to their headwaters at higher altitudes. The $\delta^{18}O$ values of the streams ranged from –11.56 to –6.92‰, the depleted $\delta^{18}O$ value being observed at headwaters and enriched values at lower part of the watershed. This is attributed to fractionation due to evaporation during the journey of melt water from mountainous regions to the plains. The melting and fractionation of snow pack releases more depleted waters to streams during May (<–10‰) and enriched waters in September (>–6.5‰). The depleted $\delta^{18}O$ values of spring waters (–6.3 to –10.05‰) than precipitation and positive Spatio-temporal correlation with stream water indicates that the catchment stream was the major contributor of groundwater recharge, but the enriched isotopic character of some springs showed significant recharge by local precipitation or snow melt.

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