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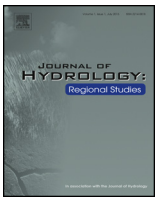

Isotopic characterization and mass balance reveals groundwater recharge pattern in Chaliyar river basin, Kerala, India

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ABSTRACT

Study region: The Chaliyar river basin, Kerala State, India.
Study focus: Detailed understanding about spatio-temporal variation in the interaction and exchange of water between surface and sub-surface reservoirs is important for effective watershed management. Spatio-temporal variations in the oxygen isotopic composition ($\delta^{18}O$) were used to understand the interaction between groundwater and river water, and to estimate the groundwater recharge from river water in the Chaliyar river basin.
New hydrological insights for the region: Based on the spatio-temporal variation in $\delta^{18}O$ values of river and groundwater and fluctuation in ground water levels, following important inferences are made: (1) estimated river water contribution to post-monsoon groundwater recharge is ~16% in the lowland coastal area of the Chaliyar river basin and 29% in midland region; (2) north-east winter monsoon rains contribute to the groundwater of Chaliyar river basin only in an insignificant manner, and with a delayed response; (3) unlike river water samples which exhibit both seasonal and spatial variation of more than 3‰, the groundwater samples vary only marginally (~1‰) between the seasons and across the physiographic zones; (4) groundwater samples exhibit inverse altitude gradient in $\delta^{18}O$ values in the highland zone, in all the three seasons. This may be due to flow of the isotopically depleted groundwater down the gradient and evaporation of residual water in the upper reaches of the basin.

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1. Introduction

The water balance of a river basin is governed by precipitation, evapotranspiration, and overland and subsurface flows into and out of the basin, which may be highly variable in space and time (Winter, 1989; Van der Kamp and Hayashi, 2009). Groundwater recharge mainly occurs through infiltration of rainwater as well as surface water. On the other hand, groundwater can also play an important role in sustaining stream flow (Sear et al., 1999). Therefore, detailed understanding about spatio-temporal variation in the interaction and exchange of water between surface and sub-surface reservoirs is necessary for effective watershed management.

Stable isotopes of oxygen (^{16}O and ^{18}O) and hydrogen (^{1}H and ^{2}H or D) forming water molecules are inert and conservative in mixing relationship and hence used worldwide as a tracer to understand various hydrological processes including groundwater–surface water interaction and recharge characteristics (Gat, 2010; Criss, 1999; Kendall and Mc Donnell, 1998; Clark and Fritz, 1997). There are also several Indian studies in which stable isotopes have been used to understand various hydrological processes (Deshpande et al., 2003; Deshpande and Gupta, 2012; Deshpande et al., 2013; Achyuthan et al., 2013; Gupta et al., 2005; Sukhija et al., 2002; Saravana Kumar et al., 2010; Nachiappan et al., 1995; Nachiappan, 2000; Datta, 1999; Datta and Tyagi, 1995; Datta et al., 1994a,b; Navada and Rao, 1991; Gupta, 1983).

The isotopic composition of ground water is controlled by relative contribution from local rainfall, rivers and other surface water bodies. Rivers usually originate in high altitude regions where precipitation is isotopically depleted compared to that in the plains. Therefore, rivers are usually isotopically depleted compared to groundwater and local precipitation in the plains. In contrast, surface water bodies in plains are isotopically enriched in heavier isotopes due to continuous evaporation. Simultaneous monitoring of temporal variation in isotopic composition of groundwater and surface water can provide useful insights about spatio-temporally varying recharge characteristics and can help to estimate the recharge contribution of rain and river water to groundwater or vice versa. The isotopic difference between groundwater and other hydrological components (precipitation, river, lake, etc.) has been used to estimate the ground water recharge using simple mass balance (Yeh et al., 2009; Langhoff et al., 2006; Mathieu and Bariac, 1996; Payne, 1988). There are also a few Indian studies in which stable isotopes have been used to quantitatively estimate the groundwater recharge. For example, in the state of Karnataka, storm water contribution to ground water recharge was estimated to be ~19–27% (Shivanna et al., 1994). In Pushkar Canal Command area in the state of Andhra Pradesh, contribution of canal water to groundwater at Ellamilli and Kodavali locations was estimated to be, respectively, 41% and 13%; and contribution of precipitation to groundwater at these two locations was estimated to be 59% and 87% (Vijayakumar et al., 2011).

In this study, observed spatiotemporal variations in stable oxygen isotopic composition of groundwater and river water in the Chaliyar basin have been used to estimate the seasonally varying contribution of river water to groundwater recharge. In addition, regionally varying pattern of interaction between river water and groundwater, and the role of recycled vapour in local precipitation has been highlighted (Mukherjee et al., 2015).

2. Study area

The Chaliyar river basin is the third largest river basin in the state of Kerala in south India (Fig. 1). Chaliyar river originates from the Ilambalari hills in Gudalur taluk of Nilgiris district in Tamil Nadu, at an elevation of 2066 m above mean sea level. This interstate river has a total drainage area of 2923 km^2 of which 2535 km^2 lie in Kerala State and rest 388 km^2 in Tamil Nadu. The river has a length of about 170 km. In the lower reaches the river is also known as Beyporepuzha. The main river is contributed by the important tributaries Chaliyarpuzha, Punnapuzha, Maruthapuzha, Karimpuzha, Kanchirapuzha, Kuthirapuzha, Iruvenhipuzha and Cherupuzha (PWD, 1974). The drainage map of the Chaliyar river basin with sampling location is shown in Fig. 1.