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Water quality of few springs in outer Himalayas – A study on the groundwater–bedrock interactions and hydrochemical evolution

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ABSTRACT

Springs in the Kandela valley in a part of outer Himalayas, India were sampled and analyzed for their major ion chemistry in order to assess their water quality, possible origins and hydrochemical evolution of the waters. Analyses of springs water samples show that the concentrations of Ca^{2+} exceed that of Mg^{2+} in all springs; the concentrations of Na^{+} are next to Mg^{2+} and are higher than that of K^{+}; HCO_3^{-} and SO_4^{2-} are most dominant among anions compared to Cl^{-} and NO^{3-}. The spring waters are categorized into two end-member hydrochemical facies: (1) pH-mildly alkaline, Ca–Mg–HCO_3 water with low to moderate EC; (2) mildly alkaline, Ca–Mg–HCO_3–SO_4 water with moderate EC. The facies 1 water occur mainly due to easy dissolution of carbonate minerals. This facies may occur during recharge which results in low ionic concentration in shallow zone in regional carbonate aquifer. The facies 2 waters are chemically distinct from waters in the valley. PHREEQC geochemical modeling show that all water are supersaturated with respect to carbonate mineral but are undersaturated with respect to evaporite and precipitation of carbonate, dissolution of evaporite and ion exchange are important process during the groundwater–bed rock interactions and hydrochemical evolution. Groundwater generally occurs under water table condition and is fit for drinking and irrigation purposes in study area.

1. Introduction

Springs are the most important source of water for the people living in the Himalayan terrain. They are found almost everywhere and play a vital role in supporting the lives of Himalayan people. Most of the settlements are located in remote at the top of the ridge, springs act as life for their survival there. Since rivers are flowing in valleys therefore not serving the purpose for domestic and agriculture for the population settled at the top of the hills. Springs water has been used as source of water for domestic (washing, drinking), cattle care and irrigation for the agriculture field by the villager in the studied area. People are also using springs for running flour mills for grinding the grain in the presently studies area. So the importance of springs cannot be ignored for the Himalayan people. Occurrence of these springs depends on recharge area characteristics such as surface cover, geology of the area, permeability of top soil, soil structure and slope of ground surface (Joshi, 2006). Generally springs occur where ground surface and the impermeable subsurface strata intersect with the ground water table. The discharge of the spring water fluctuates seasonally and mainly depends on rainfall pattern in the recharge area and variation in the amount of rainwater that is able to infiltrate the ground. The melting of glaciers, reduced snowfall, more frequent heavy rainfall and wide spread flooding has affected the water resources of the Himalayan region. Deforestation, change in land use pattern, intense grazing and climate change has affected the discharge and water quality of these springs. Hence a hydrochemical investigation has been carried out on the springs, to study the groundwater – bed rock interaction, their hydrochemical evolution and to evaluate the quality of spring water.

The hydrochemical techniques can provide important information about the working of aquifer systems. For this, if a sufficient number of hydrochemical data exists, the hydrochemical approach can help to establish and quantify the geological formations ascribed to water mineralization. Thus, water chemistry should be considered as a natural tracer that provides information about the structure and dynamics of aquifers. The hydrochemistry of spring water is mainly controlled by composition of source water, geological mineralogy and structure of aquifer as well as geochemical processes in the aquifer. All these factors together cause various hydrochemical facies. The spatial variability of hydrochemical facies can provide information about aquifer heterogeneity and connectivity. The application of geochemical methods

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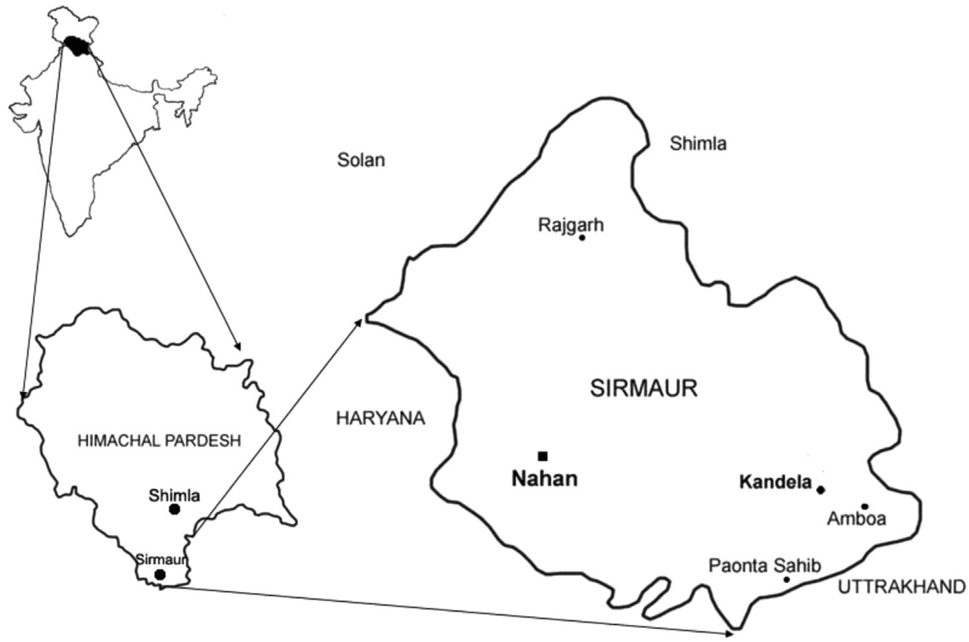

Fig. 1. The location map of the study area situated at the Sirmaur District, Himachal Pradesh, India.

Table 1
Generalized geological succession of the study area (Srikantia and Bhargava, 1998).

Era	Period	Formation	Lithology
Quaternary	Recent to Pleistocene	Alluvium/valley fills/older alluvium	Sand with pebble and clay & multiple cyclic sequence of medium to coarse grained sand with pebble of sandstone and lenses of clay
Tertiary	Pliocene – M-Miocene	Siwalik group	Sandstone, shale, conglomerate, mudstone, clay, gravel & boulder beds beds
	L-Miocene – Oligo-Eocen	Kasauli/Dagshai/Subathu	Gray, purple sandstone, shale, nodular clay, shale, Limestone etc.
Pre-Tertiary Group	Pemo Carboniferous	Karol/ Infra-Karol, Blainis boulder beds	Limestone, shale, red shale carbonaceous shale, slate, graywacke, dolomitic limestone, gypsum, anhdrite.
	Devonian	Jaunsar series	Slates schist phyllite,
	Pre-Cambrian	Chail series	Slates called Shimla slates
	Achaean	Jutogh series	Quartzites, schist and limestone.

can provide information on water sources, mixing, and water–rock interactions that are difficult to obtain by any other techniques. Now a days advanced geochemical modeling is being used to infer the chemical and physical processes controlling the hydrochemistry of groundwater and to trace their flow paths (Belkhiri et al., 2010). In addition, hydrochemical studies are often used to solve problems related to water quality such as identification of source and origin of water contamination.

The relationship between groundwater flow, hydrogeologic properties and hydrochemistry has been studied by many researchers worldwide (Ophori and Toth, 1989; Domenico and Schwartz, 1990; Bayarı and Kurttas, 1995). The chemical composition of the groundwater which moves from the recharge area to the discharge area reflects changes by various geochemical processes. Dissolved and colloidal solids, and microbiota in groundwater provide information about the geology of the recharge area, flow paths and environment.

2. Geological and hydrogeological settings

2.1. Physical geography

The study area lies in the lower Siwalik ranges of the Himalayas (Fig. 1) and falls in the Sirmaur District of Himachal Pradesh, India. It is located about 20 km from Ponta Sahib in the north-east direction and covered approximately 4 km^2 of the area. The study area experiences temperate climatic conditions with summer and winter temperature varies from 30 to 35 °C and 0 to 3 °C, respectively. The mean annual rainfall is 982 mm and receives rainfall mainly from the south-west monsoon (July–September) and winter rains (December–February). The months of March, April, October and November are generally dry. However, occasional hailstorms occur from April to June.

The area has an intricate mosaic of high mountain ranges, hills and valleys with altitude ranging from 600 to 2000 m above msl. There is a general increase in elevation from south to north and from east to west. The area is dominated by high hill ranges of Himalayas, the valleys are narrow and deep with steep slopes. Two small rivers, Dophaire Khale and Dhouli Rao, originate in the north and join with the Giri river in the south.

2.2. Geological settings

Geologically, the rock formations occupying the area range in age from Precambrian to Quaternary. The generalized geological succession is shown in Table 1. The main rock types in the study area are limestone, dolomite, sandstone, shale, conglomerate, slate, gypsum, anhydrite etc. The Jaunsar formation which lies on Pre-Cambrian Chail formation is composed of quartzite, dark slate, phyllites and conglomerates. The Blaini formation which lies on Simla slates is composed of pebbly mudstone alternating with slates. The Infra-Krol formation of black fine-grained sandy slate and Krol formation of limestone and dolomite overlay the Blaini