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Nitrate contamination of riverbank filtrate at Srinagar, Uttarakhand, India: A case of geogenic mineralization

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SUMMARY

In place of direct pumping, river bank filtration (RBF) is increasingly being used for collecting surface water for municipal supplies. However, as each site is different, every such scheme needs evaluation and adds to our knowledge about RBF. This work aimed at evaluating the efficacy of a well commissioned in May 2010 on the bank of River Alaknanda in Srinagar (Uttarakhand), India. The well water was monitored for coliform removal and mineral content with reference to the river and surrounding groundwater since the construction of the well. Study showed that the well water is much better in terms of bacteriological quality and turbidity, but is highly mineralized with respect to the river water. The ionic concentrations in the well water were comparable to the groundwater in the region. Stable isotope δ^2H and δ^{18}O values, however, showed that the well water is predominantly river bank filtrate. In addition, the water from the well has been containing unusually high concentrations of nitrate (53–138 mg/L)—much higher than permissible limit for drinking water supply while the river water had much lower concentrations (0.3–4.2 mg/L). Investigations were conducted on groundwater, wastewaters, soils, and rocks in the area to identify the source of excess nitrate. The results suggest the occurrence of phyllite and quartzite bedrocks as the origin of nitrate. These findings underline the need for extensive hydrogeochemical studies before designing a RBF scheme.

1. Introduction

River bank filtration (RBF), a natural filtration process through aquifers at river and lake banks, is increasingly being considered an effective option for obtaining water for municipal supplies, as it leads to substantial pathogen, organics, and turbidity removal and can provide water of drinking quality. It is a well established technique used for municipal water supply systems in several parts of the world including the USA (Louisville, Jacksonville, Sonoma County, Lincoln, Cedar Rapids, etc.) and Europe (Dusseldorf, Berlin, Dresden, Amsterdam, Zurich, Bratislava, Budapest, Belgrade, etc.) since 1870s (Ray et al., 2003). Groundwater derived from infiltrating river water provides 45–50% of the potable supplies in the Slovak Republic & Hungary, 16% in Germany and 5% in The Netherlands. In recent years, its effectiveness for drinking water supply has been established in several towns in India. The river bank filtration wells in the pilgrimage town of Haridwar cater to almost 68% of the drinking water demand of this region (Sandhu and Grischek, 2012). In the popular tourist town of Nainital, almost 100% of the drinking water supply is through lake bank filtration wells (Dash et al., 2008). Even for a highly polluted river such as River Yamuna in Mathura, India, aquifer filtration leads to significant coliform, TOC, and color removal thus reducing the requirements (and cost) of subsequent treatment (Singh et al., 2010). Recently, RBF has been shown as effective local solution for improved water quality in rural areas in India such as Kariyampalli in the state of Karnataka, where the surface water sources are polluted and inhabitants do not have many options for quality water supply (Cady et al., 2013; Boving et al., 2014).

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Water quality changes during bank filtration have been extensively studied by several researchers (Ray et al., 2003). Passage through the bank aquifer not just attenuates microbial load and turbidity in water, but also changes (in most cases, increases) the mineral content of bank filtrate. While mineralization can be advantageous for drinking water supply because some amounts of minerals are conducive for good health, the mineral content should not exceed the permissible limits specified by Indian drinking water standard IS-10500 (2012).

Most RBF schemes in the world so far have been established in plains. Considering the potentials of RBF and with an idea to extend it to the mountainous regions, several RBF schemes have been commissioned recently in the hilly state of Uttarakhand in India. One such scheme comprising of a RBF production well has been constructed at the bank of River Alaknanda in Srinagar town (30°13′20″N, 78°46′43″E) in May 2010. Srinagar and its nearby areas have no significant industries or large agricultural farms. The town has a residential population of about 20,115 (Census of India, 2011) and a dynamic population of tourists visiting from April to September. The settlements largely consist of residential houses, hotels, small farms, and grazing land. The uphill regions are surrounded by forests. RBF scheme at such a site provides an interesting case study for bank filtration in a mountainous town without any industrial or agricultural disturbance.

Therefore, performance of this bank filtration scheme was continuously monitored in terms of water quality changes. The water abstracted from the well was evaluated with reference to the river water and inland handpump water for total and fecal coliform and its major ionic constituents. In addition, waters from nearby wells, handpumps, and springs were also analyzed to understand the hydrogeology of groundwater in the region. Isotopic studies were conducted for ^{18}O and ^{2}H in water to identify the proportions of river water and groundwater in the RBF well and other water sources. To identify potential geochemical and anthropogenic sources for contaminants in the waters, some wastewaters, soils, and rocks in the region were also investigated.

2. Site description

Present study was conducted in the Srinagar town and its neighboring upstream town Srikot (30°13′26″N, 78°48′57″E), both of them located at the left bank of River Alaknanda. A topographic map of the region along with sampling locations is shown in Fig. 1. The river flows in a meandering path through the region surrounded by steep mountain ranges. The river is situated at an altitude of ~541 m above mean sea level, and the altitude of land on both sides rises steeply (by ~200 m within a distance of about 500 m).

Geologically, the region consists of phyllite and schist bedrocks with quartzite veins in between. The aquifers at the RBF well consist mainly of coarse to medium sand, medium gravel, and small boulders deposited by the river with bedrock starting at a depth of ~21 m. The aquifer profile changes very sharply at very short distances. For instance, at a distance of ~135 m from the well toward the landside, drilling of another tubewell revealed significantly different aquifer profile than the RBF site with weathered rock starting at a depth of 17 m and extending up to 25 m. There are locations in the town where the bedrock is exposed at the surface.

Other than the river, other major water sources include springs, tubewells and handpumps. A few open wells also exist, but are not much in use. The tubewells are of 200–300 mm diameter drilled to depths ranging from 17 to 80 m and are pumped using submersible pumps. Handpumps are of India Mark II specifications having pipe diameters of ~100 mm and depths ranging from 30 to 110 m. The (perennial) springs have stone structures built around them to facilitate collection of water. Rainfall is predominantly concentrated in the monsoon season extending from June to September with more than 90% of the annual precipitation of >1000 mm occurring in these four months (IMD, 2013).

Sewage in the area is managed by two kinds of systems. Some of the houses use soak-pits for their domestic sewage. Other houses (most houses in the downhill part) discharge their wastewater into open cemented drainage, which flows downhill eventually mixing into the river. A sewage treatment plant of capacity 3.5 ML/d has been installed recently which releases the treated wastewater into the river.

3. Experimental procedures

3.1. Sample collection

Table 1 lists the sampling sites, the period of sampling, and their description. The longitude, latitude, and altitude were measured using a GPS (Garmin eTrex 10). The longitude and latitudes were precise to ±0.5 m, and altitudes were precise to ±5 m.

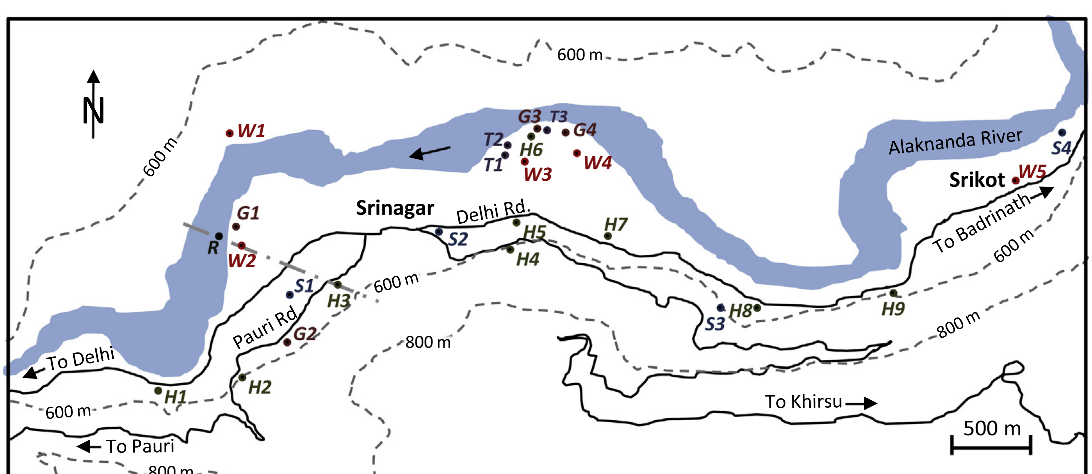

Fig. 1. Topographic map of the Srinagar–Srikot area. The contours (dashed lines) represent height above mean sea level. Alphanumeric labels represent sampling locations for river (*R*), tubewells (*W*), handpumps (*H*), springs (*S*), wastewater (*T*), and soil/rock samples (*G*) with details provided in Table 1, and dash-dot line (– · – · –) represents axis connecting locations *R*, *W2*, and *H3* at which regular sampling was conducted.