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Research Article

SEASONAL VARIATION OF SPRINGWATER *IN-SITU* PARAMETERS IN THE BHUSUNDI CATCHMENT, GORKHA, NEPAL

Gunanidhi Pokhrel[1], **Moti Lal Rijal**[2*]

[1]*Ekantakuna-Bhanimandal Road, Lalitpur-4, Lalitpur, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[*]*Corresponding author: moti.rijal@gmail.com*

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ABSTRACT

Spring is a concentrate flow of groundwater that appears at the earth's surface. The seasonal variations of spring water quantity and quality are required to ensure water availability during the dry season. The research focuses on the seasonal variations of spring water quantity and quality with the spatial distribution of springs interlinking with geological settings of the area. Research framework has been established comprising spring inventories before and after the monsoon in 2017 AD of the Bhusundi catchment of the Gorkha district. The study area comprises phyllite and schist rocks of metamorphic origins as well as Nepheline Syenite of igneous origin. A total of 44 perennial springs along with the geological settings of the various springs were investigated for spring *in-situ* spring water parameters including spring discharge, electrical conductivity (EC), and total dissolved solids (TDS). The variations of spring discharge, EC and TDS ranged from 0.16 lpm-62.7 lpm, 24.4-308.0 µS/cm and 14.74-199.00 ppm, respectively, in the study area. Metamorphic rocks of this area were developed secondary porosity creating interconnectivity of these pores and hence creating suitable conditions for spring occurrences. Seasonal variations of spring water quality and quantity provide good insights increasing the water security of local communities in the hilly region. Spring inventory along with their seasonal variability provides information for increasing water security of poor and marginalized people living in the scattered settlements of hilly regions of Nepal.

Keywords: Bhusundi catchment, Chitwan Annapurna landscape, Seasonal variation, Springs, Water quality

INTRODUCTION

Spring water is a form of groundwater that freely flows on the surface. The dependence of spring water has grown significantly over the last few years in the hilly region, where rural municipal water supply is very limited to fulfill the demand of the growing population. Since spring water is widely used for drinking and other household uses, its quality becomes important. In Nepal, many people have lost their lives due to water-borne diseases each year. Therefore, seasonal variation of spring water quality is required to understand in many places for increasing the drinking water security of many people living in the dispersed households of the hilly region.

Groundwater quality, in turn, depends on several factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharging water, and input from sources other than water-rock interaction (Domenico, 1972; Todd, 1980). Walton (1970) had mentioned that groundwater quality data gives important clues to the geologic history of rocks and indications of groundwater recharge, movement, and storage. Assessment of groundwater quality is a necessary and immediate task for present and future groundwater quality management. In the study conducted in the land subsidence site of Armala, Kaski, Nepal; it was mentioned that water chemistry depends upon the surrounding rocks of sub-surface water (Rijal, 2017). Additionally, Gautam and Bhattarai (2008) suggested that the physical and chemical characteristics of waters in reservoirs were influenced by seasonal fluctuations in water and also by agricultural runoff. According to Meinzer (1923), springs are classified according to spring discharge variability, which is named as Constant Spring, Semi-Constant Spring, and Variable Spring. The concept and the importance of springshed management for the conservation of springs in the Nepal Himalaya were also described in Rijal (2016).

The Gorkha-Ampipal area of west Nepal is made up of a variety of metamorphic rocks, such as phyllite, schist, marble, quartzite, and gneiss, The low-grade metamorphic rocks in the Gorkha-Ampipal area, Central Nepal Lesser Himalaya, constitute a rather monotonous and thick succession, which was called série de Kunchha by Bordet (1961). The study area lies in the Kunchha-Gurkha Anticlinorium Zone of Ohta *et al.* (1973) and Kunchha-Gorkha Anticlinorium of Pêcher (1977). Dhital (2015) mentioned that Gandaki region with widest Lesser Himalayan belt comprising inner, intermediate, and outer zones; inner zone within Great Midland Antiform, consisting of the Kuncha Formation and rare Nepheline Syenite intrusive near Ampipal. Similarly, garnetiferous schist and gneiss, and graphitic schist and marble are also present. Furthermore, it was mentioned that the Nepheline Syenite is a unique rock in the Nepal Lesser Himalaya. In this context, the present study mainly focuses on the seasonal variation of spring water quantity and quality with the spatial distribution of springs interlinking geological conditions. *In-situ* physicochemical tests along with spring discharge from the study area contribute to learning about the general chemistry of spring water and spring water dynamics, which provides a preliminary assessment of water quality and available water quantity of the area. The major drainage pattern of Bhusundi catchment is shown along with the altitude of the surroundings in Fig. 1.

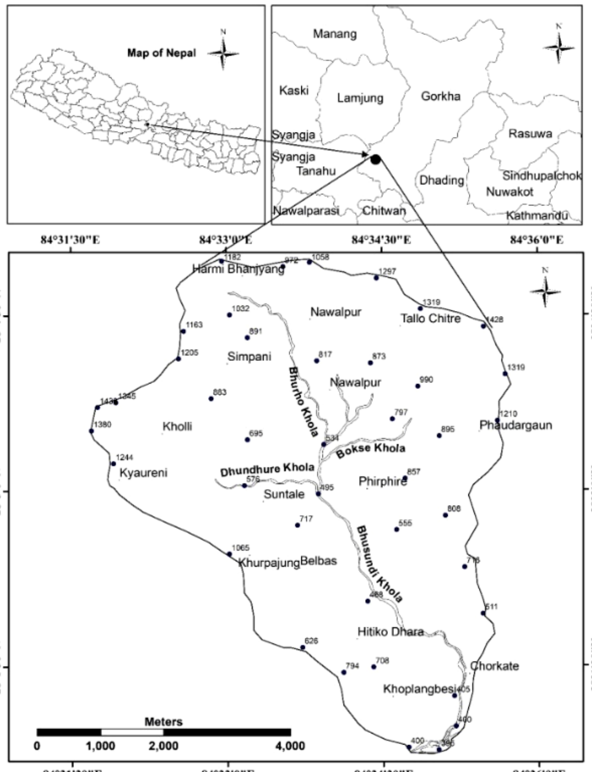

Fig. 1. Location map showing Gorkha district and study area within the Bhusundi catchment. The filled dots are the spot height of various locations extracted from topographic map

MATERIALS AND METHODS

The study area is located in the rural part of the Gorkha district within the catchment of the Daraudi sub-basin. This catchment falls within the Chitwan Annapurna Landscape (CHAL) of the region (Fig. 1). Discharge measurement of all springs was done and water samples of all spring sources were measured *in-situ* by a portable tool-kit of Mettler Toledo (Model SevenGo, US manufacturer). The discharge measurements of all observed springs were taken in both, pre-monsoon (May) and post-monsoon (October) seasons of 2017 AD. Spring discharge was measured using bucket stopwatch method and water level drop method and *in-situ* parameters were measured taking the same samples. All discharges were measured three times to minimize measurement errors. The geological traverse was done to study the lithology of the study area. Most of the lithology and attitudes were collected from spring locations where rock outcrops were seen except in some places covered by dense vegetation and landslides. Interactions with local people were also done to extract supporting information for springs' history and spring uses.

RESULTS

The study area, Bhusundi catchment lies in Lesser Himalaya consisting mainly of three types of rocks of the Kuncha Formation, Garnetiferous schist, and Nepheline syenite. This area consists of fractured and folded rocks of metamorphic and igneous origins, which as a result of weathering developed secondary porosity forming groundwater storage and groundwater flowing channels to trap and transmit water. Springs location, lithology, attitudes, and drainage pattern along with spring symbols were added to the map (Fig. 2). Many springs in this catchment were being used for drinking and household purposes. The distribution of springs according to lithology of the study is shown in Fig. 3.

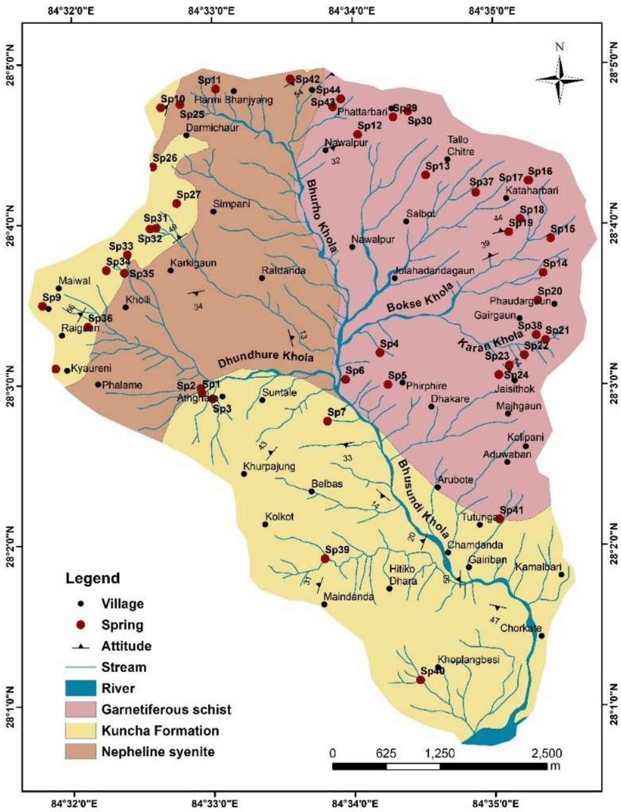

Fig. 2. Springs location and drainage of the study area shown on the geological map of the Bhusundi Catchment; the Geological map is used from Dhital (2015)

In the Bhusundi Catchment, a total of 44 springs were identified from the field survey before and after the monsoon season in 2017 AD (Fig. 2). All of these springs are perennial and seasonal springs were not considered for this study. The seasonal variations of *in-situ* water parameters of the spring discharge, dissolved oxygen (DO), total dissolved solids (TDS), hydrogen ion concentration (pH), electrical conductivity (EC), and temperature were determined, and the results are summarized in Table 1. During spring inventory, discharge of the springs was measured. A total of six springs in the form of seepage were observed in the study area which were stored in a small ditch that is, locally called *kuwa*. Three of them (Sp42, Sp43, Sp44) were directly connected to the cemented pond from their origin. Therefore, their discharge measurements could not be carried out. Discharge measurements of remaining forty-one springs were carried out in pre- and post-monsoon seasons.

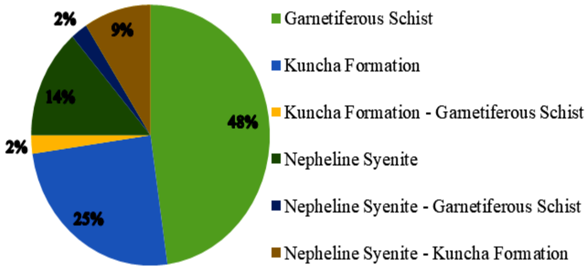

Fig. 3. Pie chart of spring distribution according to lithological distributions of the study area

Springs can be classified using the discharge variability of Meinzer (1923), which takes accounts of the percentage of discharge variability of springs and is classified into constant, semi-constant, and variable springs. The springs were classified and variation of springs discharge was seen (Table 2), in which post-monsoon discharge is higher than pre-monsoon discharge, but in the case of Chhoprak Pahara (Sp19) discharge decreased from 38.6 lpm to 13.46 lpm from pre-monsoon to post-monsoon season, respectively. Mungre Pani (Sp26) has the highest average discharge of 62.7 lpm and Koplan Dhara (Sp40) has the lowest discharge of 0.16 lpm.

The spring (Sp19) is an exceptional case, which was disturbed from newly occurred landslide during monsoon so its discharge decreased in post-monsoon season measurement and was excluded from further calculation and classification.

There were mainly two types of springs dominated in the study area. As examples, the layouts of springshed of depression spring and fracture spring are shown (Fig. 4). In the depression spring as depicted in Fig. 4(a), the depression zone that contributes for spring discharge is shown whereas in the fracture spring; fracture networks are indicated along with the foliation plane as shown in Fig. 4(b). This springshed is clearly shown in the types of origin of spring indicating depression zone and fracture network. These layouts clearly distinguish how their recharge areas are linked with the types of spring in the study area.

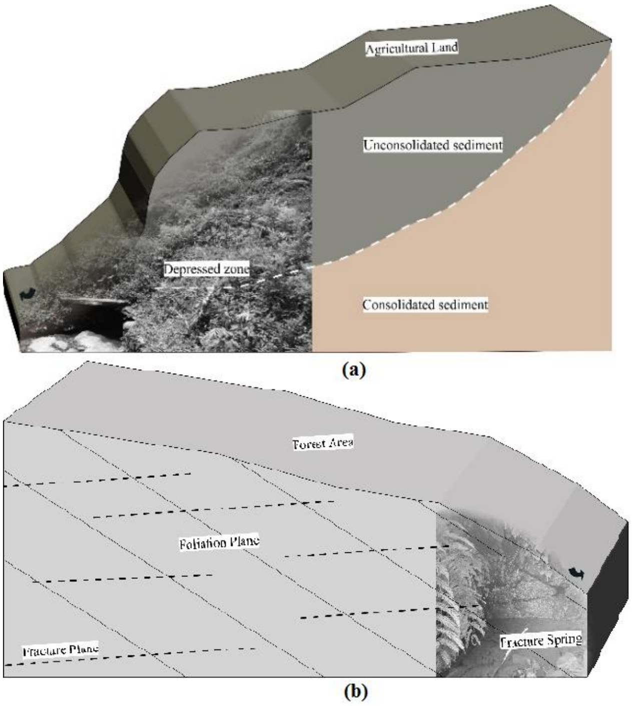

Fig. 4. The layout of the selected (a) depression spring and (b) fracture spring in the study area (The springs are shown with black curvy arrows)

Table 1. Selected descriptive statistical parameters of pre- and post-monsoon *in-situ* physicochemical parameters

Statistics	EC (µS/cm)		DO (ppm)		pH		TDS (ppm)	
	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
Minimum	26.50	24.40	3.25	2.78	4.85	5.15	18.90	14.74
Maximum	308.00	270.00	6.69	7.30	7.26	7.56	199.00	135.10
Standard Deviation	64.07	58.81	0.62	0.83	0.57	0.52	42.44	29.01

Table 2. Classification of springs based on discharge (Meinzer, 1923)

Spring Id	Discharge (Q, lpm)			Meinzer Classification	Discharge Variability (%)	Spring Type
	Q_{min}	Q_{max}	Q			
Sp1	3.42	5.16	4.29	Seventh	40.56	Semi-Constant
Sp2	4.12	5.79	4.95	Seventh	33.7	Semi-Constant
Sp3	1.27	16.62	8.94	Sixth	171.6	Variable
Sp4	1.42	26.32	13.87	Sixth	179.52	Variable
Sp5	0.94	2.76	1.85	Seventh	98.38	Semi-Constant
Sp6	0.08	0.6	0.34	Eighth	152.94	Variable
Sp7	0.17	1.85	1.01	Seventh	166.34	Variable
Sp8	0.3	2.25	1.28	Seventh	152.94	Variable
Sp9	2.78	9.2	5.99	Seventh	107.18	Variable
Sp10	3	4.4	3.7	Seventh	37.84	Semi-Constant
Sp11	1.69	4.27	2.98	Seventh	86.58	Semi-Constant
Sp12	4.01	6.08	5.05	Seventh	41.03	Semi-Constant
Sp13	7.41	34.58	21	Sixth	129.41	Variable
Sp14	0.73	3.56	2.15	Seventh	131.93	Variable
Sp15	1.79	7.11	4.45	Seventh	119.55	Variable
Sp16	1.3	3.61	2.46	Seventh	94.09	Semi-Constant
Sp17	0.09	0.72	0.41	Eighth	155.56	Variable
Sp18	21.6	24.32	22.96	Sixth	11.85	Constant
Sp19*	38.6	13.46	-	-	-	-
Sp20	8.56	42.85	25.71	Sixth	133.4	Variable
Sp21	2.17	8.33	5.25	Seventh	117.33	Variable
Sp22	0.77	13.7	7.24	Sixth	178.71	Variable
Sp23	3.98	12.65	8.32	Sixth	104.27	Variable
Sp24	1.01	2.89	1.95	Seventh	96.41	Semi-Constant
Sp25	1.58	14.6	8.09	Sixth	160.94	Variable
Sp26	38.9	86.5	62.7	Fifth	75.92	Semi-Constant
Sp27	1.8	5.3	3.55	Seventh	98.59	Semi-Constant
Sp28	0.28	1.56	0.92	Seventh	139.13	Variable
Sp29	6.65	7.63	7.14	Sixth	13.73	Constant
Sp30	0.65	2.82	1.74	Seventh	125.07	Variable
Sp31	2.85	5.27	4.06	Seventh	59.61	Semi-Constant
Sp32	1.86	3.51	2.69	Seventh	61.45	Semi-Constant
Sp33	1.62	4.91	3.27	Seventh	100.77	Variable
Sp34	1.5	6.2	3.85	Seventh	122.08	Variable
Sp35	0.76	3.2	1.98	Seventh	123.23	Variable
Sp36	2.43	6.75	4.59	Seventh	94.12	Semi-Constant
Sp37	4.67	8.07	6.37	Sixth	53.38	Semi-Constant
Sp38	4.63	13.68	9.16	Sixth	98.85	Semi-Constant
Sp39	0.12	0.31	0.22	Eighth	88.37	Semi-Constant
Sp40	0.08	0.25	0.17	Eighth	103.03	Variable
Sp41	1.3	3.26	2.28	Seventh	85.96	Semi-Constant

DISCUSSION

Geologically, the study area is covered by the Kuncha formation, Garnetiferous schist, and Nepheline syenite. A large number of springs were located in the Kuncha Formation and Garnetiferous schist, whereas few numbers of springs were situated in the Nepheline syenite. Out of 44 springs, 17 springs were found in the Kuncha Formation, 24 springs in the Garnetiferous schist, and 3 springs in the Nepheline syenite. As mentioned by Kansakar (2001), the area of Lesser Himalayan in Nepal was 61,345 km^2 and the total annual groundwater discharge from Lesser Himalaya region in Nepal was estimated to be 1713 million cubic meters. Groundwater discharge was higher from Lesser Himalayan basins than Siwalik basins.

Springs are a major component of groundwater discharge that is linked with the groundwater recharge zone as explained in this study with different types of spring layouts (Fig. 4). In Nepal, at least 20 % of its total area has rock formations that are highly suitable for forming good aquifers. Potential geological formations are carbonate rocks (12.5 %), igneous rocks mainly granite (4 %), and quartzites (3.95 %). Other suitable rocks, though with relatively lower potential, are the high-rank greywacke (15.29 %), and the regional metamorphic rocks (27.59 %) (Kansakar *et al*., 1986). Winter (1999) emphasized that surface water bodies are integral parts of groundwater systems even if a surface water body is separated from the groundwater system by an unsaturated zone.

Andermann *et al.* (2012) studied that in the course of the transfer of precipitation into rivers, water is temporarily stored in soils, groundwater, snow, and glacier reservoirs with different residence times. They also suggested that in the Central Himalaya, the water budget is thought to be primarily controlled by monsoon rainfall, snow and glacier melt and secondarily by evapo-transpiration and an additional contribution from deep groundwater has been deduced from the chemistry of Himalayan Rivers, but its importance in the annual water budget remained to be evaluated. The researchers also found that time lag between precipitation and discharges in both glaciated and un-glaciated catchments are independent of the geological setting. Tolman (1937), Fetter (Jr.) (1990) and Meinzer (1923) suggested that spring classifications are usually based on their occurrence and physical characteristics such as geology, magnitude, variation, and permanence of flow, quality, and mineralization of the spring water, the temperature of the spring water.

To understand how the springs behave over time and space, it is necessary to identify the type of springs. Spring types that were commonly used in practice, modified after Tolman (1937) were depression spring, contact spring, fracture spring, fault spring, and karst spring. According to the altitudinal range, all the springs were distributed in the elevation range of 450m to 1450 m. Most of the springs and seepages were depression types and others were fracture type springs. Besides, spring was distributed mostly towards dip slope. In terms of the natural slope, spring occurrence was related within a gentle slope between 10° to 30°. The aspects of most of the springs were west, southwest, south, and east direction.

Springshed can simply be understood by surface water recharge to the particular spring. Springshed differs from watershed because the source of spring water is determined by aquifer characteristics, not surface topography, and the movement of spring water, is determined by underlying geology, their nature, inclination, and structure as in Shrestha *et al.* (2018). Springwater chemistry of the study area was determined by the comparison of in-situ physicochemical parameters such as DO, TDS EC, pH, and temperature. Water chemistry is mainly influenced by temperature, atmospheric precipitation, dilution, and slightly from the weather product of the rock type (Gibbs, 1970).

In the study area, the average value of EC ranged from 33.9 to 289.0 µS/cm and the average TDS ranged from 14.74 to 199.0 ppm. EC and TDS values normally decreased after the monsoon season (i.e. post-monsoon). The main reason for this decreasing trend is related to the process of leaching of accumulated salt and wash down during the rainy season. The pH values of the springs increased in the post-monsoon season than the pre-monsoon season. In pre-monsoon, every spring was acidic in nature whereas in the case of post-monsoon pH value tends to be neutral (i.e., nearly 7) as shown in Fig. 5. The pH of groundwater will vary depending on the composition of the rocks and sediments that surround the travel pathway of the recharge water infiltrating to the groundwater. Groundwater chemistry also varies depending on how long the existing groundwater is in contact with a particular rock.

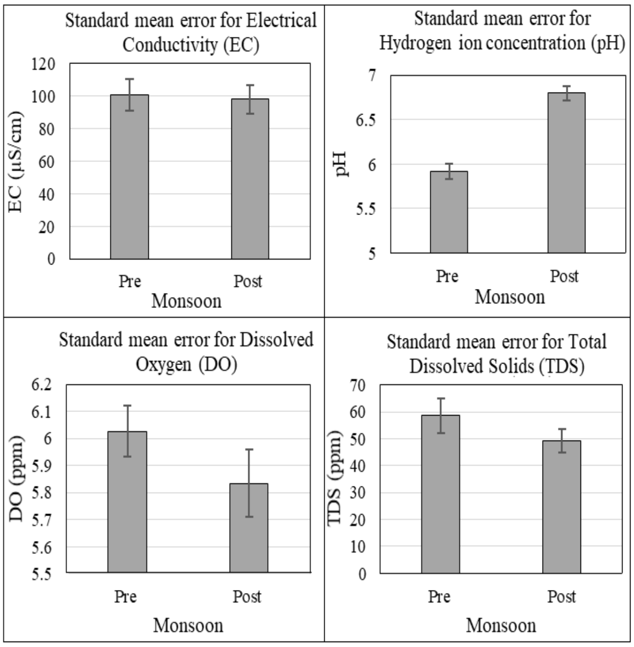

Fig. 5. Seasonal variation of *in-situ* physicochemical parameters: EC, pH, DO and TDS

The chemical composition of the bedrock tends to stabilize the pH of the groundwater. The longer contact time of groundwater with minerals influenced groundwater chemistry (Nelson, 2002). In the study area, the geology of the aquifers' feedings to springs contained phyllite, schist, and few basic rocks like Nephiline Syenite. But, the overall spring water chemistry is the result of recharging water and its interactions with host rocks in the present study area.

The average DO value of the springs in the study area was within the average range. In the case of spring Sp2, DO was less than 4, which indicates the DO variation is influenced by types of water sources, its temperature as well as its salinity. The standard mean errors for *in-situ* physicochemical parameters were shown in Fig. 5. Seasonal variations of DO and TDS were higher than EC and pH that are related to a water source and water-rock interactions.

From water discharge of the sources measured before and after the monsoon of the year 2017, the discharge was found to significantly increase after monsoon except in spring Sp19, which was disturbed due to landslide after massive earthquake activated by monsoon rain. According to the Meinzer (1923) classification system, springs and surface seepage falls in the order, 7^{th} order $>6^{th}$ order $>8^{th}$ order $>5^{th}$ order. More than 50 % of spring has discharge variations from 0.6-6.0 lpm. The average discharge of the springs in the whole watershed was 7.44 lpm.

The Gorkha-2015 earthquake had destroyed many parts of the country, with a severe impact on spring water resources in many districts of Nepal resulting in low spring discharge as well as drying of several springs. This impact was visible during the fieldwork after two years of this massive Gorkha earthquake demonstrated by decreasing of post-monsoon discharge in Sp19 in the present study area and also described by the spring water users about drying of their traditional springs.

CONCLUSIONS

Generally, igneous and metamorphic rocks are relatively impermeable and hence serve as poor aquifers when rocks are formed. However, with their continuous surface and near-surface exposures, the containing fractures are modified generating secondary porosity and permeability, which leads to creates favorable conditions by various earth's near-surface processes to form local aquifer systems. Mainly, two types of geological formations of metamorphic rocks and a formation of igneous rock were observed in the sampling sites. A small area (23 %) was covered by the igneous rock of Nepheline syenite and also had less number of springs. The Garnetiferous schist and the Kuncha Formation both have similar area coverage (38 %) but the number of springs was higher in the garnetiferous schist than Kuncha Formation. The average discharge of spring in the Kuncha Formation and Garnetiferous schist were 6.90 and 8.03 lpm, respectively. However, the highest discharge containing spring was located in the Kuncha Formation with 62 lpm and the largest discharge of spring of the Gartniferous schist only had 26.70 lpm discharge. Despite these parameters, the *in-situ* water quality parameters EC was the highest in the Kuncha Formations (289.0 µS/cm) than the Gartnetiferous schist (272.50 µS/cm), whereas TDS was higher in Garnetiferous schist (165.75 ppm) than the Kuncha Formation (144.55 ppm). Hence, springs occurrences and nature of springs, as well as their in-situ water quality parameters, are the result of the functions of the lithology of rocks, fractures networks, types and amount of precipitation, weathering and erosional processes in the region. The contributions of major factors are required to investigate in future research.

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