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Quality assessment and status of spring water in Helambu area, Sindhupalchok district, central Nepal

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ABSTRACT

The quality of spring water in the Higher Himalaya of Helambu area, Sindhupalchok district, Central Nepal was carried out. A total of fifty seven springs were surveyed to study different physical and chemical parameters, i.e. electric conductivity (EC), total dissolved solids (TDS), potential of hydrogen (pH), dissolved oxygen (DO) and temperature. Among them, six springs were tested for chemical parameters. The results show that the distribution of EC and TDS is greater towards the lower elevation i.e. southern part near the settlement and agricultural land with the value ranging from 13 – 219 µS/cm and 7.08 – 161 mg/l respectively. The distribution of pH is inconsistent with the elevation and ranges from 2.27 – 6.66 throughout the area.

The distribution of DO is greater at the central region and towards the lower elevation with the value ranging from 2.77 – 6.33 mg/l. The temperature ranges from 12.4 – 22.8°C and increases with a decrease in the elevation. All the physiochemical parameters, except for pH, lies within the permissible range given by National Drinking Water Quality Standards (NDWQS, 2005) and WHO (2004) standards. The Water Quality Index (WQI) shows that overall area has excellent to good water quality in terms of drinkability, agricultural and industrial purposes. However, increasing urbanization might degrade the quality in future so proper and sustainable management strategies must be adopted to protect and preserve these groundwater resources.

Keywords: Higher Himalaya; Spring-water; Physio-chemical parameters; Water quality index; Correlation

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INTRODUCTION

Helambu is a gateway to trekking and adventure tourism activities in Sindhupalchok district that connects Langtang National Park and many other beautiful trekking routes in central Nepal. The rapid urbanization in Helambu area has brought the significant changes in land use patterns and agricultural activities which result in increasing demand of water in daily life. Due to the seasonal fluctuation in river flow, steep and rocky topography and poor economic condition, it seems quite difficult to fulfill the needs of water for the people living in the higher altitude. Thus, the only way to fulfill the needs of water is to use the stream and spring water sources for drinking, household and agricultural purposes (Chapagain et al., 2017; Ghimire et al., 2019; Smadja et al., 2019). Although, the availability of spring water is sufficient, use of organic and chemical fertilizers on the agricultural land can degrade the drinking water quality; which led us to study the hydrochemistry, its geochemical evolution and possible health hazards.

Safe drinking water is a human right. Thus, water must be within the permissible limits for chemical pollutants and photogenic agents in order to sustain all living organisms (Singh, 2002; Yaduvams et al., 2017). It has been assumed that the groundwater is relatively safe from surficial pollutants in most geological environments (MacDonald and Calow, 2009). However, this is not always true, as water quality depends upon a variety of factors, including the rock type, groundwater flow paths, residence time in aquifers and the vadose zone, and anthropogenic pollutants (Leschik et al., 2009; MacDonald and Calow, 2009).

To date, there is no comprehensive study about the Himalayan groundwater, specifically in the Nepal (Dixit et al., 2009; ICIMOD, 2015). Some studies have endeavored to understand the quality of water and its relation with human socio-economic activities, urbanization and industrialization regarding pollution of water and its hazard, but lack in more rural, mountainous region of Nepal (Hem, 1985; WHO, 2004; UNICEF, 2008; Subramani et al., 2010). It has been reported that, climate change due to the rise in temperature and monsoonal and orographic precipitation played an important role in formation of springs in Himalayan region (Negi and Joshi, 2004; Chinnasamy and Prathaper, 2006; Mahamuni and Kulkarni, 2012). The seasonal variation in precipitation has a great effect on discharge and the quality of the natural water system in Himalayas and its direct consequence can be seen in the Nepal Himalaya (Sharma et al., 2005; Dixit et al., 2009; ICIMOD, 2009, 2015; Chapagain et al., 2017).

The present pre-monsoonal study was carried out in April, 2019 in order to evaluate of quality of spring waters in Helambu area, their availability, discharge, geochemical properties, sources, usage and potential health hazards.

STUDY AREA

The Helambu area lies in Sindhupalchok district, about 68 km northeast to the capital city. Geographically, the area extends from 27.832 °N to 28.018 °N and 85.533 °E to 85.677 °E (Fig. 1). The monsoon season falls between June and September, and the region is located in a humid climate with an annual average temperature of 28°C (overall study area). Annual average precipitation, the major source of groundwater recharge, ranges from 4.21mm in the Dubachaur area to 11.06 mm to the north in Sermathang area and 10.21mm along the Tarkeghyang area (Department of Hydrology and Meteorology, Nepal). Villages like Tarkeghyang, Ghyankharka, Hotanbran, Yangri, Semathang, Helambu, Setighyang have snowfall during winter.

GEOLOGY

Helambu area is located in the Higher Himalayan zone including six geologic formations (Fig. 2) (DMG, 2005). The Hadi Khola Schist is a grey, thin to thickly foliated, fine grained garnet-biotite bearing schist with thick bed of quartzite and gneiss bands. It has numerous small-scale folds, fractures and two large anticlinale and synclinale folds as well as large scale faulting. The Dhad Khola Gneiss is grey-black, fine to medium grained gneiss with thin bands of quartzite and augen gneiss.

The Gyalthung Quartzite is a grey to dark grey, fine grained, medium to thickly bedded, garnet-biotic quartzite with bands of crystalline quartzite and biotite schist. Small scale folds and fractures can be seen because of intense deformation. The Sermathang Formation is a white to dark grey, fine to coarse grained, inter-foliated feldspar containing schist with quartzite bed and augen gneiss.

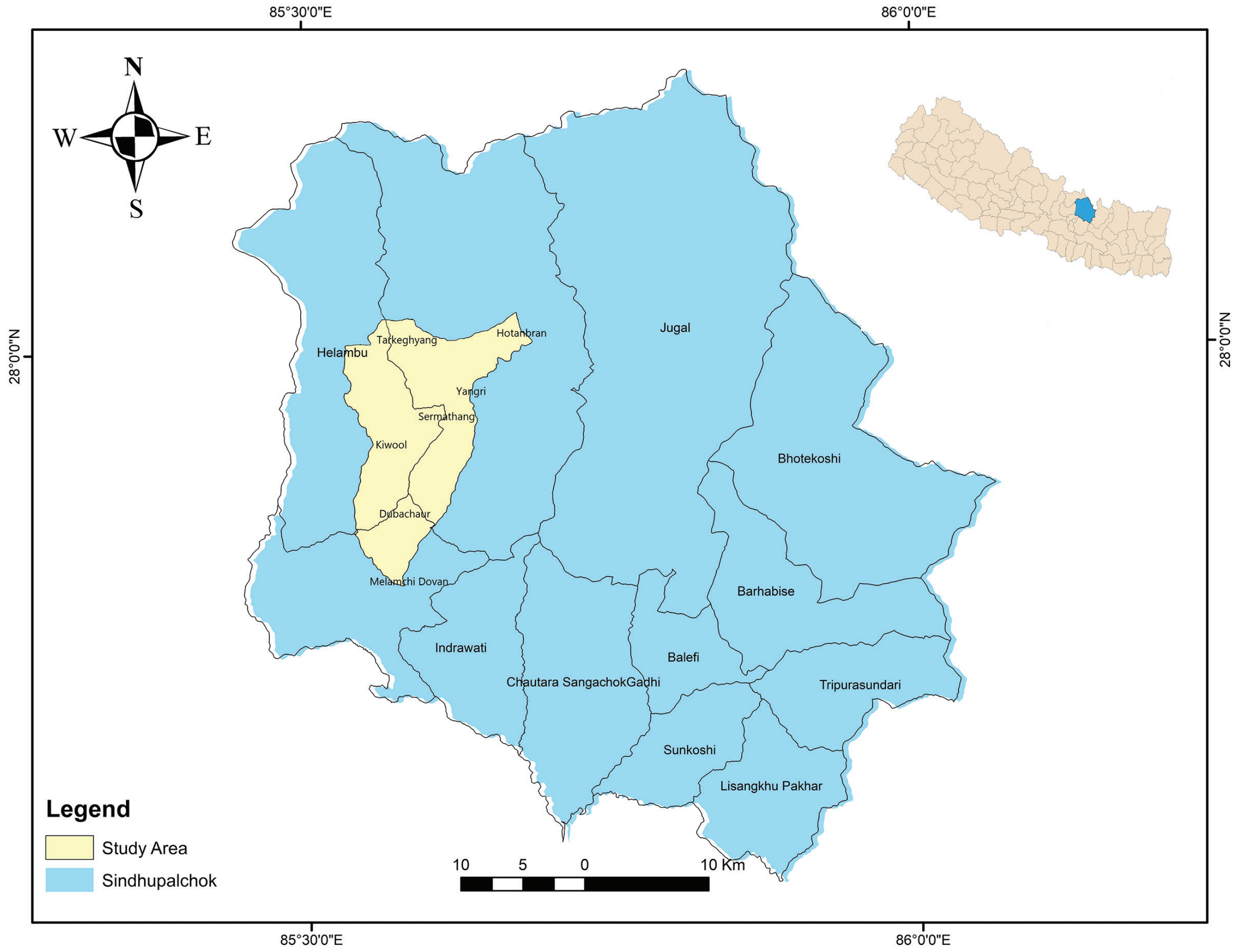

Fig. 1: Location map of the study area.

The Simpani Formation is confined by the overlying and underlying Sermathang Formation. Simpani Formation consists of a kyanite-biotite schist with bands of quartzite. The Pangang Formation contains dirty white to grey, thick bedded sillimanite bearing gneiss with fine grained garnetiferous schist and is the least present in the study area.

HYDROGEOLOGY

The Indrawati river is one of the tributaries of the Koshi river, the largest river in the country, which is continuously fed by the Melamchi river in the west and the Larke and the Yangri river in the northeast. The area has dendritic river system. The fractures lines and openings which correspond with the elongated landform are the main area of water percolation and infiltration to form the rock aquifer in Higher Himalaya (Fig. 2).

Deep seated joints, faults and minor openings acts as flow paths or conduits for infiltrating water into aquifers at depth. In the vadose zone, specifically in the overlying colluvium and regolith, depression springs form. In the same way, the NE region has less number of spring sources whereas NW and south part of the area has a large number of spring sources, which provide us the tentative idea regarding the availability of aquifer in the whole area (Fig. 2).

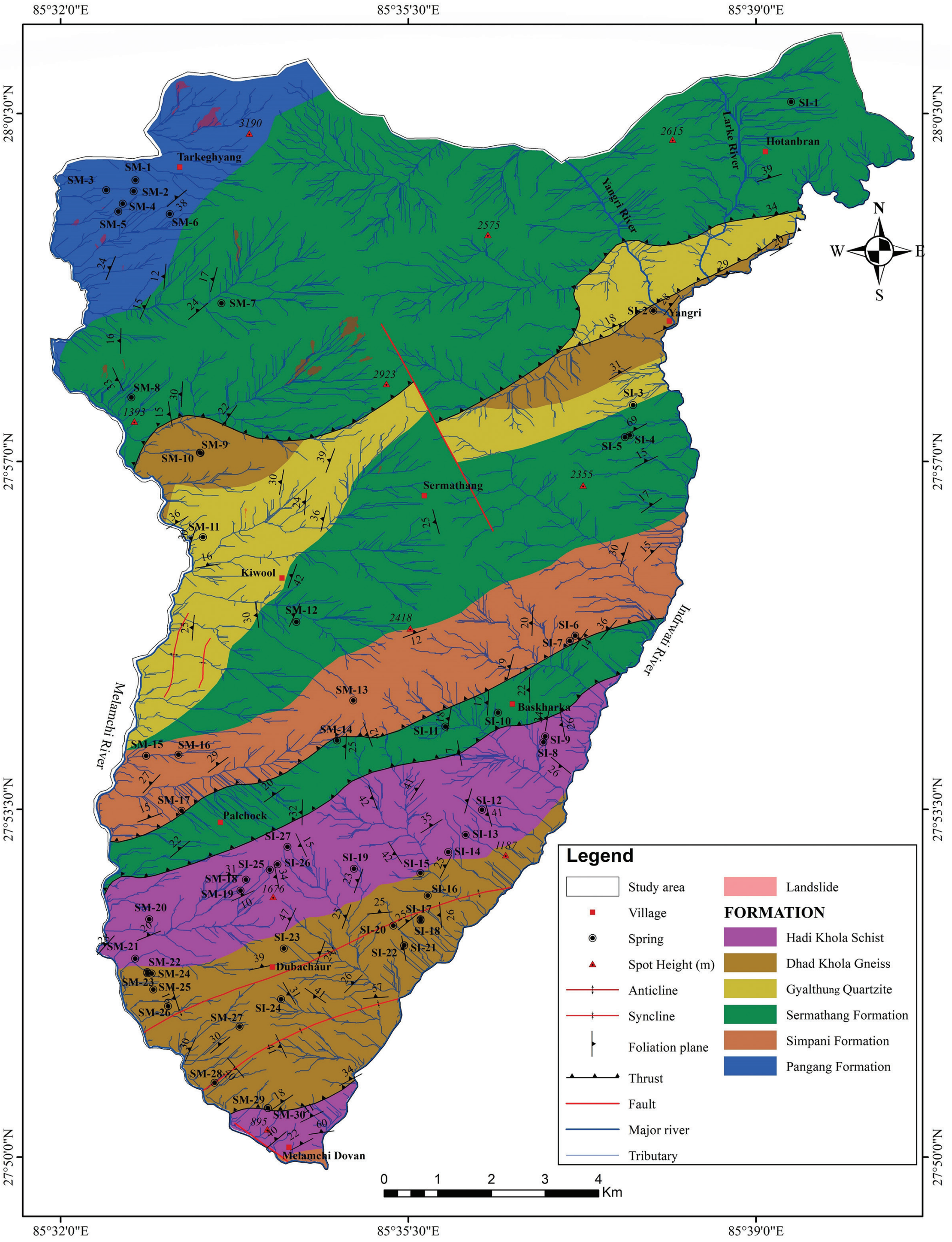

Fig. 2: Geological map along with spring location in the study area (Modified after DMG, 2005).

MATERIALS AND METHODS

Questionnaire survey

Individual questionnaire survey and FGDs (Focus Group Discussions) were carried out by following the set of questions regarding the details about the spring source, its discharge, its hazards, effects of 2015 Gorkha Earthquake, its current uses, number of users and its future promotion and management.

Geological survey

A geological survey was carried out to update the current geological map as well as confirm geological contacts and discontinuity. Besides that, attitudes of the rock were also measured as the data in previous maps were not sufficient.

Water sampling

Physical parameters of the springs were measured at each springs using an Extech pH and DO probe (model no. DO700). Measurements were taken for pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC) and temperature.

For sampling, 1L sterilized plastic bottles, silicon tubing (approx. internal dia. 4mm) and 20L bucket were used. Before collection, sample bottles were rinsed with the spring water three times. Bottles were then filled using the tubing while submerged in the bucket and capped underwater. Similarly, volumetric method (Q=V/T) was used for measuring the rate of flow of spring water, where Q is the flow rate, V is the volume of water filled (normally 1L) and T is time (in seconds) required to fill the desired water volume. Altogether six water samples were collected, one from each geological formation.

Geochemical Analysis

Water samples were analyzed at Department of Environmental Science, Kirtipur. Six water samples were measured for cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^{-}, SO_4^{2-}, Cl^{-}). The EDTA method was used for finding major cations (Ca^{2+}, Mg^{2+}), flame photometry method for Na^{+}, K^{+}, acid titration method for HCO_3^{-}, SO_4^{2-} and spectrophotometer method for Cl^{-}.

Water quality measurement

The Water Quality Index (WQI) was adopted for assessing the water quality by assigning weights to available parameters. Generally, WQI provides a numerical grade which indicates the overall quality of spring water at that time based on several water quality parameters with reference to the national or international permissible limit standards. The weighted arithmetic water quality index method by Brown et al. (1972) was used for calculating the WQI. Altogether twelve physio-chemical parameters were considered from each of the six water samples for calculating WQI using the following expression:

$$WQI = \sum Q_i * W_i / \sum W_i \text{ .... (1)}$$

Where, Q_i = Quality rating of i^{th} water quality parameter.

W_i = Unit weight of i^{th} water quality parameter.

For Q_i,

$$Q_i = [(V_i - V_{id}) / (S_i - V_{id})] * 100 \text{ ....(2)}$$

Where, V_i = Actual value from the field and lab of i^{th} water quality parameter at a given sample location.

S_i = Standard permissible value of i^{th} water quality parameter.

V_{id} = Ideal value of i^{th} parameter in pure water (this value is 0 for all except for pH and DO, i.e. 7.0 for pH and 14.6 mg/L for DO)

For unit weight W_i,

$$W_i = k / S_i \text{ .... (3)}$$

Where, k = Proportionality constant and calculated as,

$$k = [1 / (\sum 1 / S_{i=1, 2 \dots n})] \text{ .... (4)}$$

After WQI was calculated, the water is then classified as excellent, good, poor, very poor and unsuitable based on the WQI value of each water samples. (Table 1).

Table 1: Water quality based on WQI range (Brown et al., 1972).

WQI RANGE	Description	Possible usage
0 – 25	Excellent	Drinking, Irrigation and Industrial
26 – 50	Good	Drinking, Irrigation and Industrial
51 – 75	Poor	Irrigation and Industrial
76 – 100	Very Poor	Irrigation
> 100	Unsuitable for Drinking	Required proper treatment before use

RESULTS

Characteristics of springs

Altogether 57 springs and the distribution of these springs were examined based on land use patterns, its occurrence and uses. Springs were located across a variety of land use areas: bush (32%), sparse forest (23%), cultivated land (19%), dense forest (17%) and barren land (9%).

Springs are the only water source for drinking and household use in the area. According to local residents, 51 (89%) of the springs surveyed are used for drinking, household and even irrigation purposes. The six springs (11%) are not used due to lack of accessibility. There is no record of health hazards from the consumption of spring water in this region. The 2015 Gorkha earthquake had a major effect on springs in the area, according to resident surveys: nineteen springs were said to have decreased in flow rate, six springs were found to be formed after earthquake and remaining thirty two spring source were found unaffected.

Being the higher drainage density ($6.19*10^{-6}m^{-1}$) at higher elevations (>2000 m) with steep slopes (>50^o), the number of springs are lower whereas at lower elevation (<1500 m) with gentle slope (<10^o) and slightly lower drainage density ($5.22*10^{-6}m^{-1}$) the number of springs are greater. The flow rate is random with respect to the elevation (Table 2). Also, the majority of springs (30 springs) were found in gentle and lower elevation zone (southern aspect) than at steep and higher elevation zone (12 springs) (northern aspect) and the remaining springs (15 springs) were found between these two zones (1500-2000 m). Despite the largest formation, Sermathang Formation has the least number (8 springs) of spring source relative to its area i.e. low spring density. The occurrence of springs is greater along the thrusted and folded area in the Hadi Khola Schist (16 springs) and the Dhad Khola Gneiss (19 springs) formation where the occurrence of springs are caused by fractures and sheared rock of gneiss and schists. Pangang and Simpani Formation (6/6 springs) along with Gyalthum Quartzite Formation (2 springs) are less influenced by the geological structures and the occurrence of springs here are mostly in the colluvium and regolith deposition (Fig. 3).

Types of springs

Fetter's (1994) has classified springs directly in the field by topography, fault and contact zone and origin landscape. Based on this classification system, 42 springs are depression springs, 9 springs are fracture springs and 6 springs are contact springs. The residential survey shows 49 springs are perennial springs and only 8 springs are seasonal springs. All springs are non-thermal springs with the temperature less than 37.8^{o}C (Bryan, 1919).

Physical parameters

Physical parameters of all springs are presented in Table 2 and summarized in Table 3. To assess the quality of water, EC, TDS and pH are the most important physical parameters, with DO and temperature being secondary. Higher concentration of organic and inorganic solids increases EC and TDS measurements. EC and TDS vary greatly from one sample to another (CV > 70%) throughout the study region (Fig. 4a; 4b). The pH value ranges from

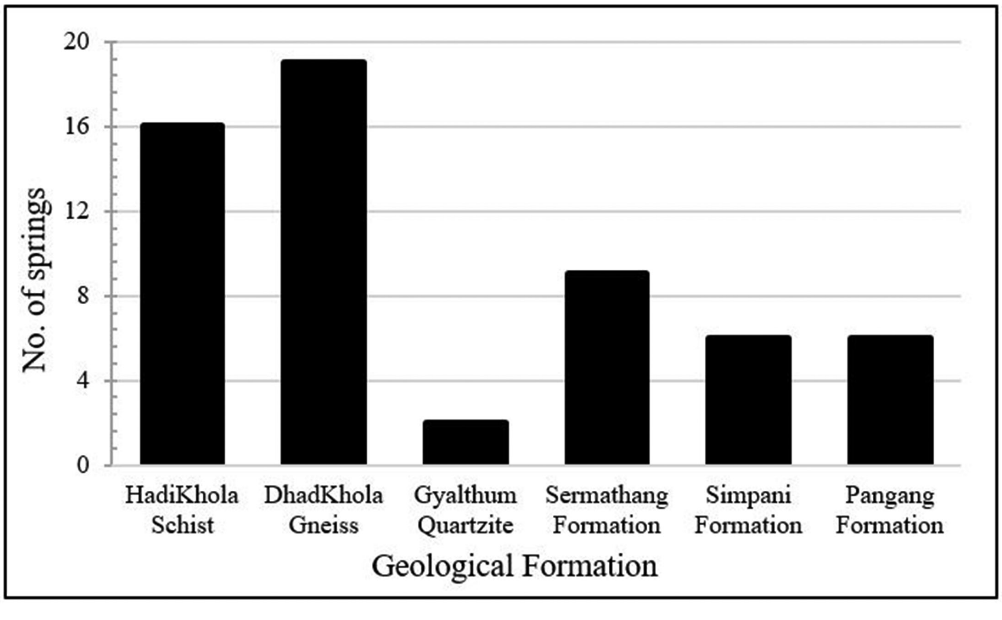

Fig. 3: Number of springs in each geological formation.

2.7-6.66 with an average of 5.30. The pH value vary slightly (CV < 20%) with 96% of the water samples acidic in nature (Tables 2 and 3) (Fig. 4c).

The DO concentrations ranges from 2.77 mg/l (Paragan spring, SM-6) to 6.63mg/l (Riphetol spring, SI-15) with an average of 4.46 mg/l (Figure 4d; Tables 2 and 3). Temperature can be both the physical and chemical character of water (SCCG, 2006). As expected, water temperatures were higher at lower elevations with a maximum temperature of 22.8°C (Kharkadada spring, SM-28) and minimum of 12.4°C (Paragan spring, SM-22) (Figure 4e; Table 2; Table 3). There was considerable variation in distribution of DO (CV = 20%) and Temperature (CV < 20%) between different springs.

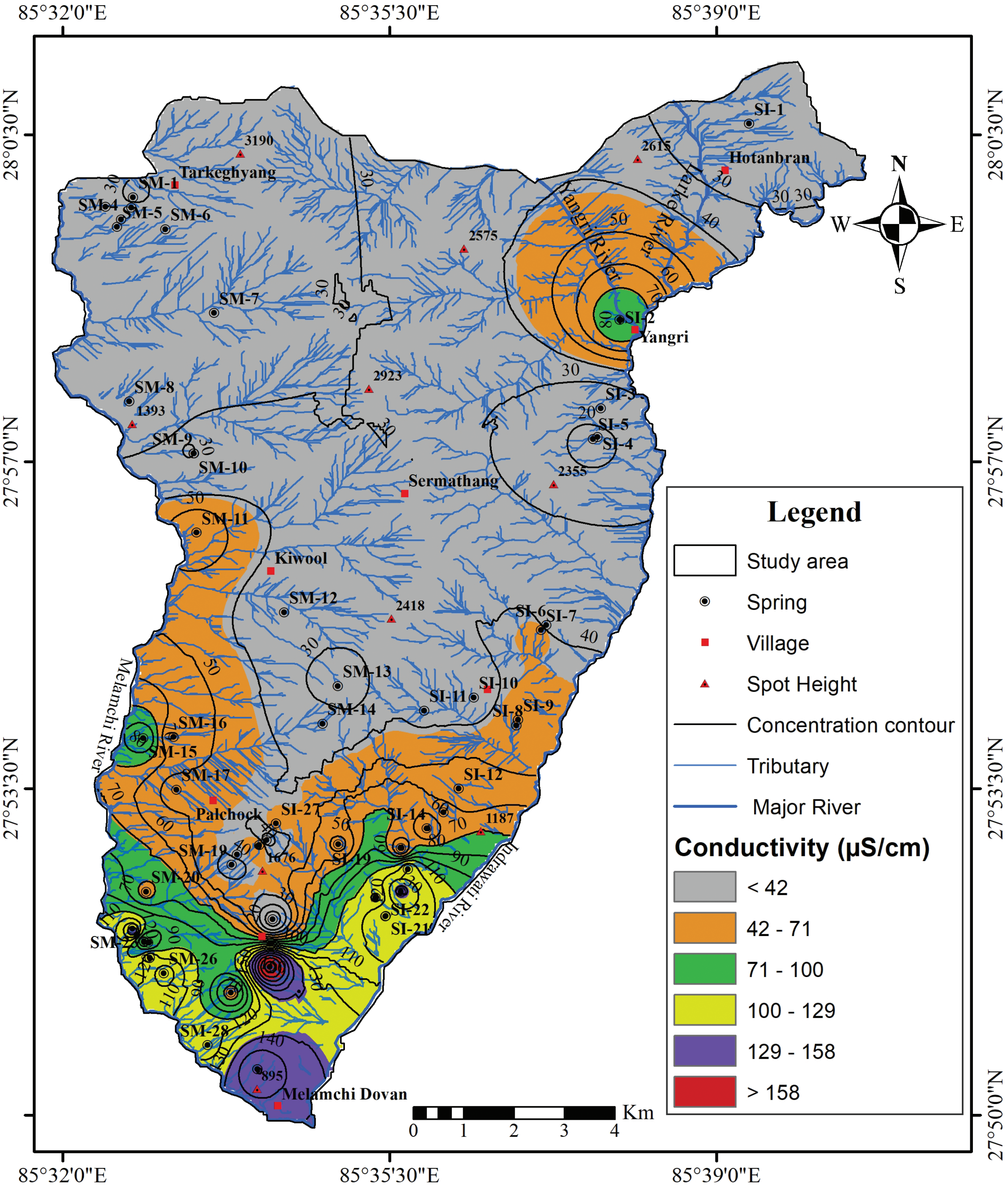

Fig. 4(a): Spatial distribution map of Electric Conductivity (EC).

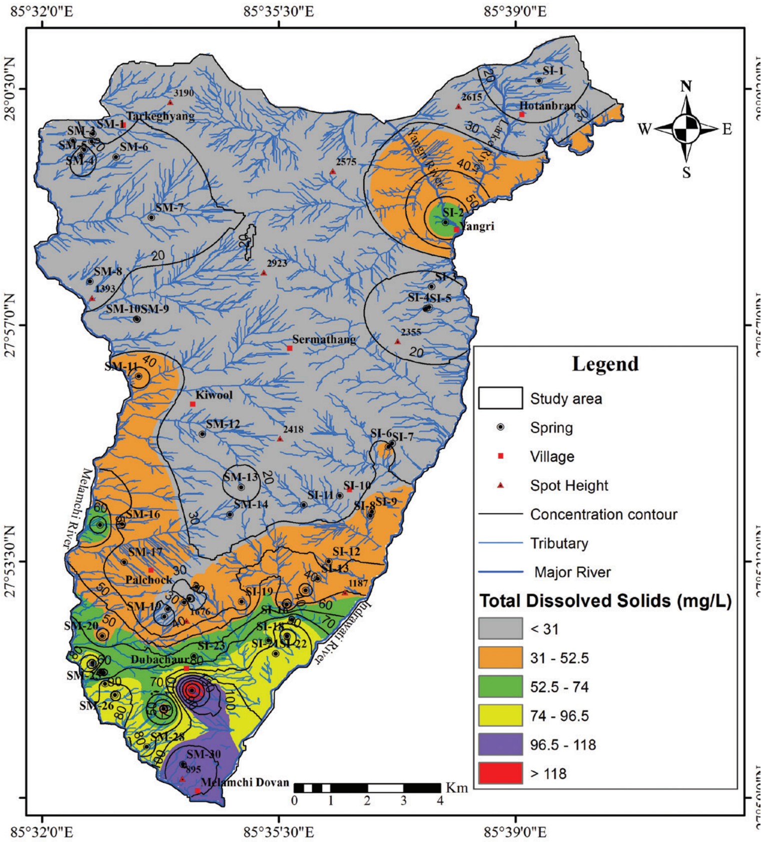

Fig. 4(b): Spatial distribution map of total dissolved solids (TDS).

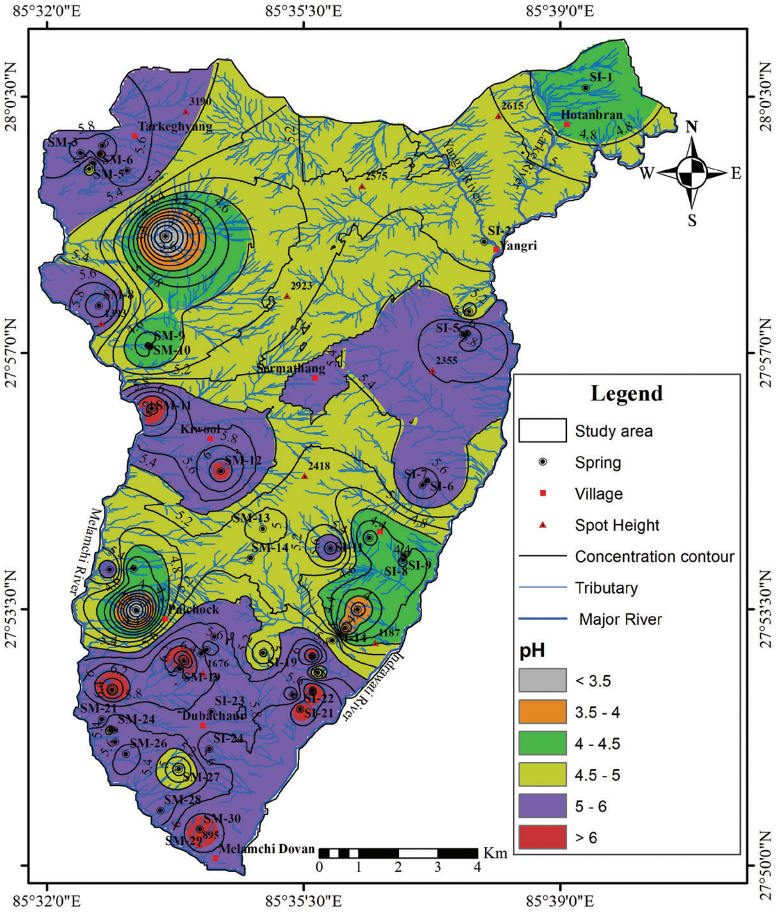

Fig. 4(c): Spatial distribution map of potential of hydrogen (pH).

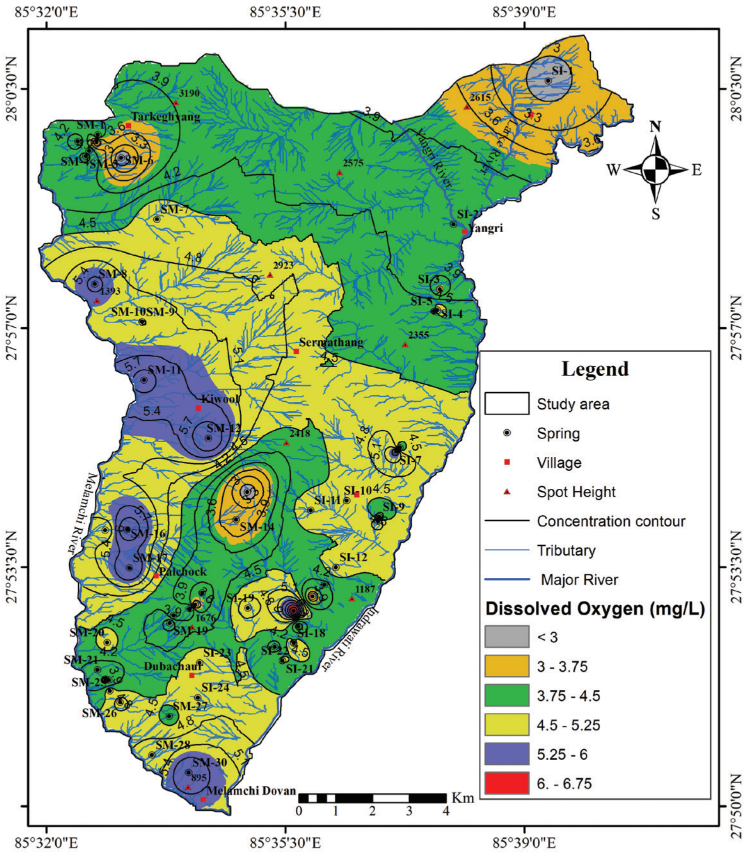

Fig. 4(d): Spatial distribution map of dissolved oxygen (DO).

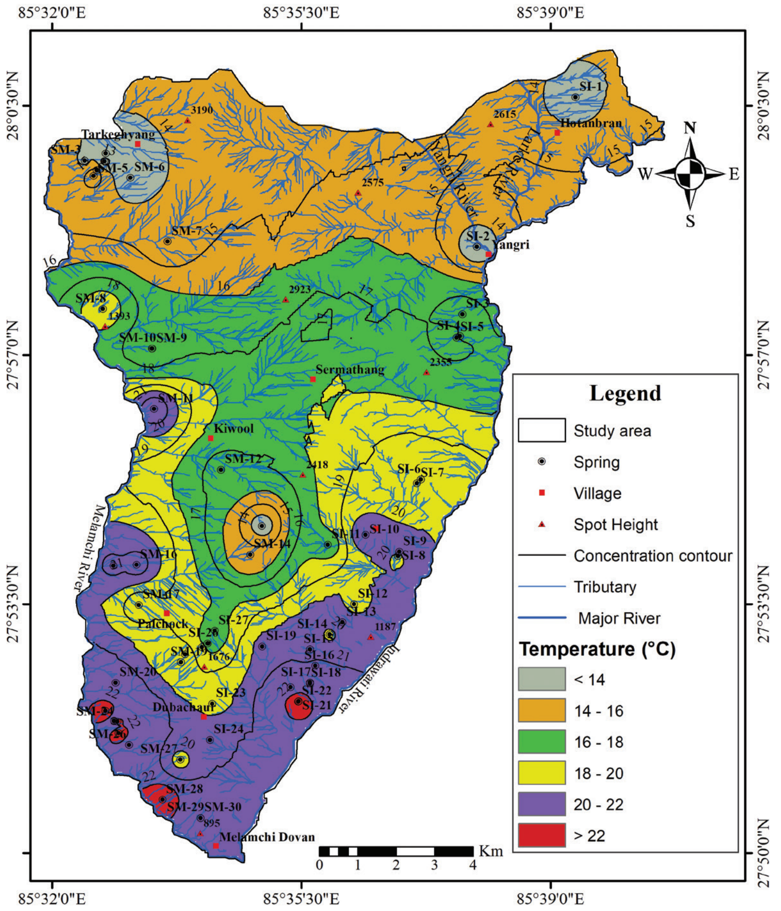

Fig. 4(e): Spatial distribution map of temperature.

Table 2: Observed statistics of all physical parameters and discharge along the study area.

Spring Code	Elevation (m)	Formation	Dissolved Oxygen (mg/L)	Temp. (°C)	EC (µS)	TDS (mg/L)	pH	Discharge (sec/L)
SI-25 ^{df}	1700	HadiKhola Schist	4.62	18.7	53.8	39	5.98	140
SI-26 ^{df}	1838	HadiKhola Schist	3.28	16.8	18.32	12.7	5.36	73.57
SI-27 ^{df}	1920	HadiKhola Schist	3.75	17.5	45.8	33	5.64	158
SM-19 ^{nf}	1550	HadiKhola Schist	3.67	19.6	35.2	25.1	5.92	25.91
SM-18 ^{nf}	1632	HadiKhola Schist	4.49	19.6	41.6	29.8	6.66	42.97
SI-13 ^{fe}	1415	HadiKhola Schist	4.18	20.9	63.61	45.8	3.84	41.91
SI-12 ^{nf}	1453	HadiKhola Schist	4.69	19.7	50.2	36.2	3.88	28.34
SI-8 ^{df}	1296	HadiKhola Schist	5.26	19.5	43	30.9	4.26	49.80
SI-9 ^{df}	1352	HadiKhola Schist	3.88	21	45.5	32.6	4.72	152.8
SM-21 ^{nf}	980	HadiKhola Schist	3.11	22.7	141.2	7.08	2.27	94.46
SM-24 ^{nf}	1039	HadiKhola Schist	4.11	22.5	76.1	55	5.7	86.86
SI-14 ^{df}	1340	HadiKhola Schist	3.35	19.8	49	35.3	5.4	77.97
SI-15 ^{fe}	1278	HadiKhola Schist	6.63	20	47.4	34.1	6.28	86.40
SI-19 ^{fe}	2157	HadiKhola Schist	4.96	20.1	46.4	33.3	4.96	65.71
SI-10 ^{df}	1568	HadiKhola Schist	4.5	20.9	34	24.1	4.32	57.80
SM-20 ^{nf}	1066	HadiKhola Schist	4.62	21.5	66.1	47.4	6.5	77.12
SI-20 ^{nf}	1305	DhadKhola Gneiss	4	21.6	98.1	71.4	5.38	100.20
SI-16 ^{nf}	1270	DhadKhola Gneiss	3.7	21.2	119.5	78.6	5.03	62.54
SM-28 ^{nf}	1034	DhadKhola Gneiss	4.89	22.8	105.9	76.9	5.49	160.03
SM-29 ^{df}	1028	DhadKhola Gneiss	6.18	21.5	76.6	55.6	6.59	33.49
SM-9 ^{nf}	1709	DhadKhola Gneiss	4.59	18.6	40	28.7	6.18	40.77
SM-30 ^{nf}	1112	DhadKhola Gneiss	4.99	21.6	219	161	5.65	60.77
SI-23 ^{nf}	1510	DhadKhola Gneiss	4.8	19.9	13	68	5.69	84.20
SI-2 ^{fe}	1384	DhadKhola Gneiss	3.97	13.4	80.2	59	5	180.0
SM-22 ^{df}	1072	DhadKhola Gneiss	3.42	20.6	89.2	65	5.1	84.86
SM-23 ^{fe}	1057	DhadKhola Gneiss	4.16	21.9	74.4	53.8	5.42	38.57
SM-25 ^{nf}	1119	DhadKhola Gneiss	4.74	22.4	123.1	90	5.6	109.77
SM-26 ^{df}	1151	DhadKhola Gneiss	4.97	21.8	129	94	5.68	44.29
SI-17 ^{nf}	1202	DhadKhola Gneiss	4.1	21.6	142.5	105	6.1	271.43
SI-18 ^{nf}	1205	DhadKhola Gneiss	5.1	21.9	123.9	90.5	6.38	49.77
SI-21 ^{df}	1165	DhadKhola Gneiss	5.2	22.4	120.9	88.7	6.18	37.14
SI-22 ^{fe}	1164	DhadKhola Gneiss	3.79	22.4	115.1	83.8	6.07	108.57
SI-24 ^{nf}	1428	DhadKhola Gneiss	4.79	20.9	186.4	140	5.96	117.18
SM-27 ^{df}	1471	DhadKhola Gneiss	4.4	19.6	64.6	46.8	4.91	112.68
SM-10 ^{nf}	1700	DhadKhola Gneiss	5.75	14.4	20.8	14.6	2.91	35.16
SI-3 ^{df}	1865	Gyakthum Quartzite	3.7	17.4	27.5	19.4	5.1	82.86
SM-11 ^{nf}	1212	Gyakthum Quartzite	5.78	21.7	58.7	42.3	6.24	66.91
SM-7 ^{nf}	2192	Sermathang Fm.	4.75	14.4	20.8	14.6	2.91	35.16
SM-14 ^{nf}	2108	Sermathang Fm.	3.36	15	36.8	26.6	5.1	103.66
SI-5 ^{nf}	1428	Sermathang Fm.	4.07	16.5	13.63	9.23	5.7	68.86
SI-11 ^{df}	1650	Sermathang Fm.	4.72	17.4	37.9	27.2	5.68	45.71
SM-8 ^{nf}	1554	Sermathang Fm.	5.44	18.8	22.7	15.9	5.93	63.62

Table 2 continued

Spring Code	Elevation (m)	Formation	Dissolved Oxygen (mg/L)	Temp. (°C)	EC (µS)	TDS (mg/L)	pH	Discharge (sec/L)
SM-12 ^{nf}	1654	Sermathang Fm.	5.95	16.8	32.5	23.1	6.1	99.34
SI-1 ^{nf}	2313	Sermathang Fm.	2.93	13.8	20.54	10.8	4.6	80.0
SI-4 ^{df}	1847	Sermathang Fm.	4.86	17.3	20.3	14.2	6.1	6.78
SM-13 ^{df}	2345	Simpani Fm.	2.86	13.4	20.1	14	4.88	260.0
SM-15 ^{nf}	1968	Simpani Fm.	4.95	21.2	89.5	65.1	5.57	35.14
SI-7 ^{df}	1570	Simpani Fm.	5.73	19.7	50.1	36	5.8	36.74
SI-6 ^{nf}	1611	Simpani Fm.	4.1	19.4	30.8	21.8	5.58	21.37
SM-17 ^{df}	1358	Simpani Fm.	5.71	18.2	45.5	32.7	2.97	61.42
SM-16 ^{nf}	1243	Simpani Fm.	6.02	21.5	51.4	37	4.4	89.78
SM-2 ^{nf}	2490	Pangang Fm.	2.96	12.4	23.6	16.9	6.15	58.26
SM-1 ^{nf}	2274	Pangang Fm.	4.21	13.7	34.8	25.1	5.81	59.37
SM-3 ^{nf}	2248	Pangang Fm.	4.38	13.8	22.9	16.3	5.96	80.06
SM-4 ^{nf}	2236	Pangang Fm.	4.05	15.2	29.5	21.1	5.36	159.37
SM-6 ^{nf}	2525	Pangang Fm.	2.77	13	27.3	19.3	5.72	89.22
SM-5 ^{df}	2045	Pangang Fm.	4.34	15.8	29.9	21.4	5.3	50.94

*Effects of Gorkha Earthquake, 2015: ^{df}decrease in flow, ^{fe} formed after earthquake and ^{nf} not affected

Table 3: Concentration of physical and chemical parameters along with standard permissible limits.

Physical Parameters	Maximum	Minimum	Average	Coefficient of Variance (%)	NDWQS, 2005	WHO, 2004
Electrical Conductivity (µS)	219	13	62.21	72.18	1500	400
Total Dissolved Solids (mg/L)	161	7.08	44.26	73.27	1000	1000
pH	6.66	2.27	5.33	17.96	6.5 – 8.5	6.5 – 8.5
Dissolved Oxygen (mg/L)	6.63	2.77	4.46	20.0	–	5 – 7
Temperature (°C)	22.8	12.4	18.91	16.01	–	12 – 35
Calcium (Ca) mg/L	19.24	4.81	10.22	53.75	200	100
Magnesium (Mg) mg/L	52.76	1.98	18.13	129.82	–	50
Sodium (Na) mg/L	12	3.2	6.86	48.79	–	200
Potassium (K) mg/L	10	8.6	9.31	5.32	–	20
Chloride (Cl) mg/L	29.82	9.23	17.04	45.38	250	250
Bicarbonate (HCO3) mg/L	25	10	15.63	42.16	–	125 – 350
Sulphate (SO4) mg/L	0.0445	0.0042	0.0302	46.83	250	250

Chemical parameters

Magnesium (Mg^{2+}) was the most abundant, followed by Calcium (Ca^{2+}) in spring water from all geologic formations. The maximum concentration of these major cations (Ca^{2+}=19.238mg/l and Mg^{2+}=52.762mg/l, *n=6*) was found at Thulichaur spring (SI-24) which lies at Dhad Khola Gneiss. The minimum concentration of Ca^{2+} was found at Churephat spring (Ca^{2+}=4.809mg/l) which lies at Simpani Formation (SM-6) and Mg^{2+} at Majhigan Spring (Mg^{2+}=1.984mg/l) which lies at Sermathang Formation (SI-1). The average of Mg^{2+} was 18.13mg/l whereas Ca^{2+} has an average of 10.22mg/l (Table 3). There was high variability in both the concentrations of Ca^{+} (CV < 55%) and Mg^{2+} (CV < 100%) within the study area. Na^{+} concentrations range lies between 3.2mg/L and 12.0mg/L, with an average of 6.86mg/l

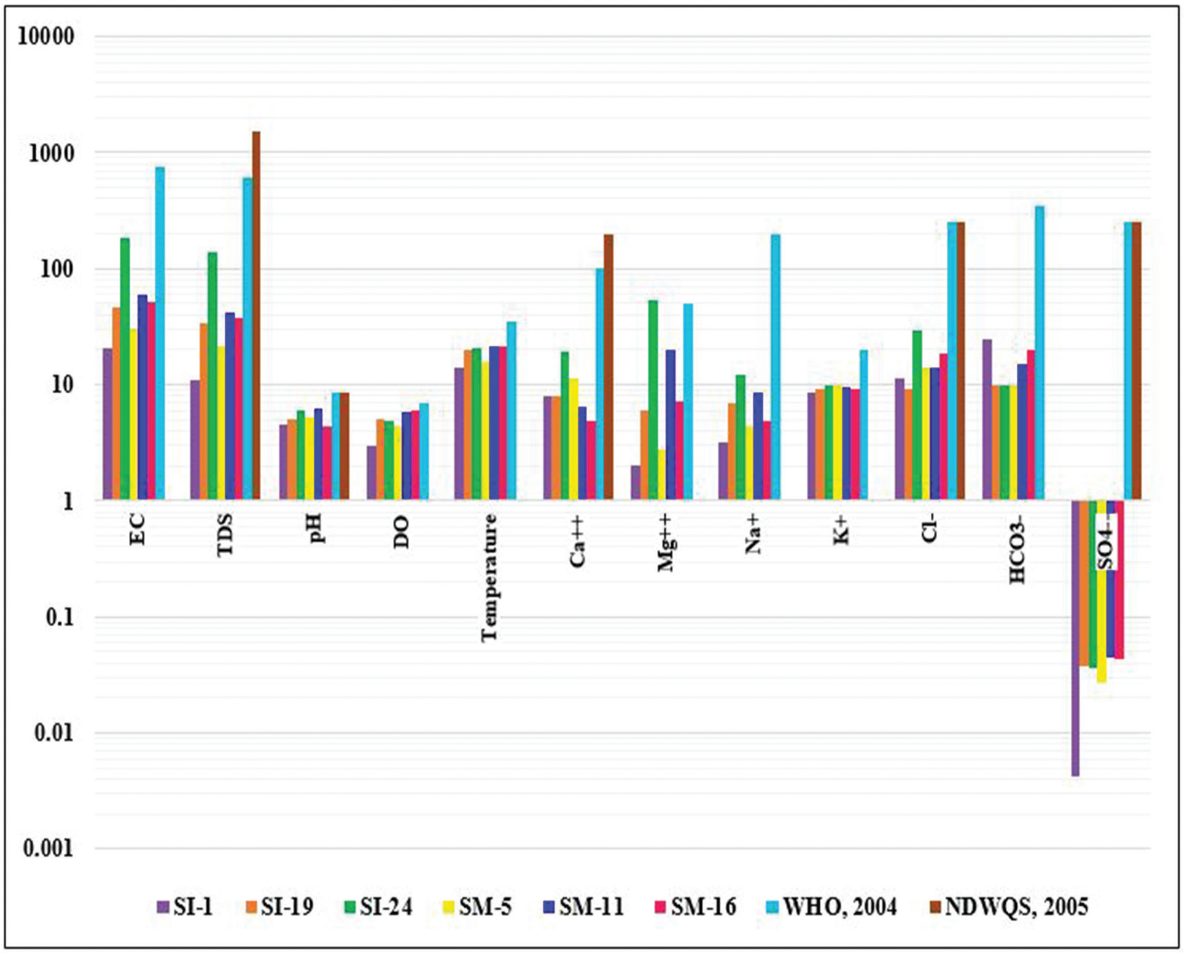

Fig. 5: Overall concentration comparison with national and international standards.

and the K$^+$ concentrations range between 8.6mg/l and 10mg/L, with an average of 9.31mg/l (Table 3). There is high variation in the spatial distribution of Na$^+$ (CV < 50%), whereas the distribution of K$^+$ was not spatially variant (CV < 6%).

Cl$^-$ and HCO$_3^-$ are the most abundant anions measured, ranging between 9.23mg/l (SI-19) and 29.82mg/l (SI-24) with an average of 17.04mg/l and between 10mg/L (SI-1) and 25mg/L (SI-19) with an average of 15.62mg/L (*n*=*6*) (Table 3) respectively. There is high spatial variation of both Cl$^-$ and HCO$_3^-$ concentration (CV > 40%) (Table 3). Sulphate (SO$_4^{2-}$) concentration was very low, with the maximum concentration of 0.0445mg/l (SM-11) and minimum of 0.0042mg/l (SI-1) with an average of 0.0302mg/l (Table 3).

All the physio-chemical parameters except for HCO$_3^-$, the concentration increases towards the older formation. Figure 5 shows a log plot of all parameters measured compared to the respective standards limits used for water quality. All concentrations are within the limits by WHO (2004) and NDWQS (2005).

Water Quality Index (WQI)

The WQI of each geological formation was determined using important physio-chemical parameters with compared to WHO (2004) water quality guidelines standard (Table 4).

The WQI value of six water samples ranges from 7 – 44. The results of the analysis show that four water samples (SI-1, SI-19, SM-5 and SM-16) are of excellent quality and two samples (SI-24 and SM-11) are of good quality (Table 5). From Fig. 6, the southern part of the study area which comprises Dhad Khola Gneiss and few areas of Hadi Khola Schist have good quality water. Similarly, the north-west part, where the few areas of Dhad Khola Gneiss, Sermathang Formation, Pangang Formation and nearly half of the area of Gyalthung Quartzite up to the fault area also have good quality spring water. The remaining areas of Sermathang Formation and Pangang Formationa at north, remaining areas of Gyalthung Quartzite and Dhad Khola Gneiss at north-east and all areas of Simpani Formation and remaining Hadi Khola Schist at middle of the study area have excellent quality of spring water. All spring water in this region, based on our analysis, is suitable for drinking, irrigation and industrial purposes.

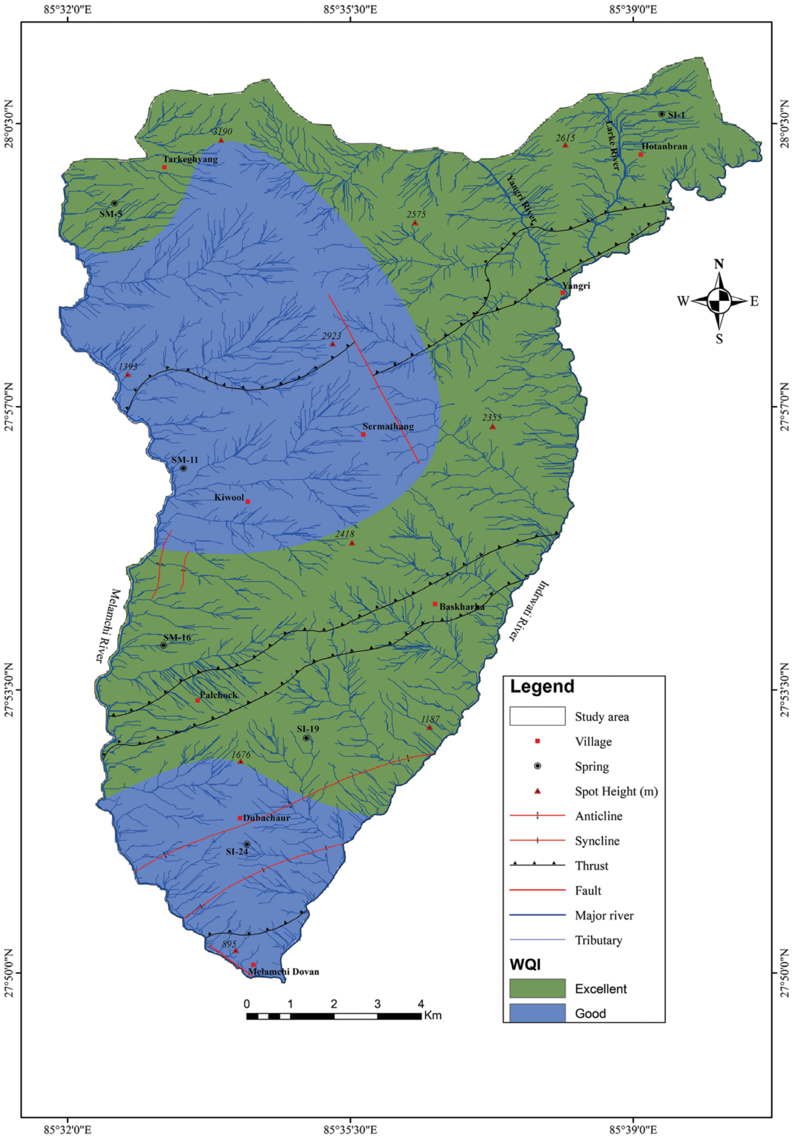

Fig. 6: Water Quality Index (WQI) map of the study area.

Table 4: Water quality parameters, their standard limits and WQI of SI - 1.

Parameters	Standard value S_i (WHO, 2004)	$1 / S_i$	Weighing factor (W_i)	Quality rating (Q_i)	Wi*Qi
EC(µS)	750	0.0013	0.003	2.739	0.00941
TDS	600	0.0017	0.004	1.80	0.00773
pH	8.5	0.118	0.303	-160.0	-48.5226
DO	7	0.143	0.368	153.553	56.54611
Temp. (^{o}C)	35	0.0286	0.074	39.429	2.90393
Ca	100	0.01	0.026	8.016	0.20663
Mg	50	0.02	0.052	3.968	0.20457
Na	200	0.005	0.013	1.60	0.02062
K	20	0.05	0.129	43.0	5.54219
Cl	250	0.004	0.010	4.544	0.04685
HCO_3	350	0.0029	0.007	7.143	0.05261
SO_4	250	0.004	0.010	0.002	0.00002
		∑ 0.3879	∑ 1.0		∑ Wi*Qi = 17.018
Overall WQI = 17.018					

Table 5: Overall WQI and water quality of selected spring samples.

Spring Sample	Overall WQI	Water quality
SI – 1	17.018	Excellent
SI – 19	16.532	Excellent
SI – 24	43.693	Good
SM – 5	25.633	Excellent
SM – 11	40.382	Good
SM – 16	7.335	Excellent

Correlation analysis

The linear correlation in Table 6 shows that there is strong positive relation between TDS and EC (*r=0.99*) and temperature and DO (*r=0.92*). Similarly, between physical and chemical parameter, TDS and EC has strong positive relation with Ca^{2+} (*r=0.83*), Na^{+} (*r=0.91*), Mg^{2+} (*r=0.98*), Cl^{-} (*r=0.92*), temperature (*r=0.51)* and SO_4^{2-} (*r=0.35 and 0.33*), which shows that these chemical concentration might be related to the increase in dissolve solids and conductivity in water. The correlation between ions shows strong positive relation between Na^{+} and Mg (*r=0.93*) and Mg^{2+} and Cl^{-} (*r=0.89*) and moderate relation between Ca^{2+} and Mg^{2+} (*r=0.79*), Na^{+} and Cl^{-} (*r=0.73*). This suggests that the contribution of major ions might be similar from different sources to each springs. Similarly, the moderate negative relation between HCO_3^{-} and pH (*r=-0.56*) shows increase in one parameter (HCO_3^{-}) has direct effect on decrease in another parameter (pH). The strong and moderate negative relation between HCO_3^{-} with K^{+} *(r=-0.79*) and Ca^{2+} (*r=-0.54*), Na^{+} (*r=-0.59*) and SO_4^{2-} (*r=-0.5*) shows the contribution of ions is variable from potential sources at each of the sampling sources (Meher et al., 2015).

DISCUSSION

Generally, sparse to densely vegetative area has higher water retaining capacity than the barren land surface, which provides enough time for water percolation and recharge to the aquifer, which could be one reason for greater number of springs in bush and sparse forest than barren land.

Most of the springs were locally managed and utilized on daily basis but several springs that lie in steep terrain, along roads and in cultivated land were not in use and these free flowing water have direct impact to road damage in the study area.

Based on Hussein et al. (2016), gently sloping, lower elevation regions can hold percolated and surface water for long enough to recharge local aquifers. However, steep, rocky and elevated terrain does not store water easily, leading to lower recharge into aquifer systems. Thus, we expect to see more springs along the low and gentle slopes compared to the steeper, rockier slopes. Additionally, in this study region, the geological unit of high grade metamorphic rocks at higher elevation has more variable porosity and permeability. Therefore,

Table 6: Correlation coefficient between various water quality parameters.

Parameters	TDS	Temp.	EC	DO	pH	Ca	Na	K	Mg	Cl	SO_4	HCO_3
HCO_3 (mg/L)												1
SO_4 (mg/L)											1	-0.504
Cl (mg/L)										1	0.286	-0.259
Mg (mg/L)									1	0.888	0.321	-0.408
K (mg/L)								1	0.712	0.706	0.481	-0.798
Na (mg/L)							1	0.720	0.934	0.713	0.522	-0.593
Ca (mg/L)						1	0.674	0.738	0.796	0.748	-0.086	-0.539
pH					1	0.490	0.770	0.712	0.673	0.400	0.381	-0.562
DO (mg/L)				1	0.262	-0.247	0.386	0.341	0.213	0.233	0.976	-0.314
EC (µS)			1	0.214	0.553	0.825	0.907	0.715	0.982	0.916	0.328	-0.442
Temperature (oC)		1	0.505	0.916	0.371	0.000	0.662	0.395	0.499	0.419	0.937	-0.370
TDS (mg/L)	1	0.515	0.9997	0.229	0.558	0.825	0.910	0.729	0.980	0.916	0.345	-0.460

the recharge and discharge of the springs are likely controlled by the discontinuities present in the rocks.

The presence of total concentration of ion particles, temperature and the valence of the ions and their mobility are the major factor contributing conductivity in water (Yilmaz and Koc, 2014). The less EC in water is an indicative of weakly mineralized water in the study area. This might be due to the less solute dissolution, rapid ion exchange between soil and water or due to the presence of insoluble minerals (Subramani et al., 2010; Oyem et al., 2014; Vasanthavigar; 2014). TDS also follow the same trend as EC as they are inter-related. Presence of solids in water throughout the area might be due to the removal of suspended solids by evaporation or by dryness, weathering of rocks and anthropogenic agents (e.g. Drever, 1988; Yousif and El-Aassar, 2018). Mishra and Gupta (2018) found the TDS of Melamchi river around 200mg/l, which is slightly greater than present spring data but below the standard limits. The study area consists of high grade metamorphic rocks with relatively insoluble minerals and therefore, anthropogenic agents might be another factor for the presence in solids in water. The higher standard deviation of 44.91 and 32.43 for EC and TDS respectively and very high positive correlation is indicative of heterogeneity of the hydro-chemical process within the spring water in the study area (Table 6).

pH of water is the only parameter below the standard permissible range. It plays an important role in maintaining the carbonate and bicarbonate in the solution (Singh, 2002; Spellman, 2007; Vasanthavigar, 2014; Yousif and El-Aassar, 2018). Mishra and Gupta (2018) found the Melamchi river water to be greater than permissible value (>7) but the spring water have lower pH values. This could be due to advancement of low alkalinity rainwater to the groundwater source, influence of sewers and fertilizers from agriculture or from the dissolution of carbonate minerals in water (e.g. Spellman, 2007; Todd, 2007; UNICEF, 2008; Subramani et al., 2005; Vasanthavigar, 2014; Embaby et al., 2016). Low pH values in spring water will certainly affect its quality, so regular monitoring of these springs is recommended.

High DO concentrations in water do not affect water drinking quality, rather it is good for aquatic lives and sometimes speed up the corrosion of water pipes (Lomborg, 2001). There is a decreasing trend of DO level with the increase in the temperature of water towards lower elevations. This is because molecules in warm water at lower elevations moves faster than in cold water at higher elevations thereby allowing the free oxygen to escape from the water (Michaud, 1991). The other possible reason for low DO concentration at lower elevations is the presence of chemical compounds and deoxidizing agents in water which comes from nearby agricultural lands and sewers. There is a high positive correlation of temperature with EC and TDS and less with DO and pH which indicates that the springs are fed by shallow aquifer (Michaud, 1991; Lomborg, 2001; UNICEF, 2008; Oyem et al., 2014) (Table 6).

Mishra and Gupta (2018) found the concentration of major cations Ca^{2+} and Mg^{2+} in Melamchi river (2012-2013) water less than 10mg/l which is below the concentration value of spring water. Generally, the minerals presents in rocks like gneiss and schists in the study area are relatively insoluble, except for feldspar which reacts with acidic water to dissolve into clay minerals and release cations. Feldspar dissolution and rock weathering generally, is likely the source for the concentration of major cations (Ca^{2+}, Mg^{2+}, Na^{+}) in spring water. Additionally, dissolution of calcite, leaching from the fertilizers during the rainfall, cation exchange and halite dissolution are possible reasons for concentration of Na^{+} and K^{+} into water. Except for Mg^{2+} in a water sample (SI-24), all the cations are within the standard limits.

Similarly, Schist and Quartzite rocks in the study area contain hard and insoluble minerals like quartz, garnet, biotite, muscovite etc. which are almost insoluble in water. So, the concentration of anions like Cl^{-}, HCO_3^{-} and SO_4^{2-} into water might be from agricultural leachate, low pH and rainfall (halite dissolution). These anions are acidic in nature which when came in contact with hydrogen. So, lower pH into water means higher hydrogen and more acid into water. Also, higher alkalinity in water neutralizes the input acidity of water but low pH in the sample solution suggests that level of alkalinity is poor and increases the acid concentration. All these anions are below the standard limits just like cations, so considered to be good for human consumption.

Overall quality of water is “excellent” to “good” in the study area (Table 5). Fluctuation in the values of these parameters also changes the quality of water. The two water samples, (SI-24 from Dhad Khola Gneiss and SM-11 from Gyalthung Quartzite) have “good” water quality because of comparatively higher values of all physio-chemical parameters than other samples. However, the quality may change due to the changing land use practices, so regular quality assessment of water resources as well as proper water treatment plans and strategy is recommended.

CONCLUSIONS

Natural springs, rivulets and small rivers are the major sources of water for drinking, household, irrigation and other purpose in the mid-hills in Helambu area of Sindhupalchok district. The present study has focused on spring water source, classification, factors controlling spring occurrence, overall distribution of physio-chemical parameters and their quality based on their characters. Altogether, fifty-seven springs that are present in different geomorphology, rock formation, geological structures were studied. The formation of springs are mainly controlled by topography, geological structure, rock discontinuities in the study area. Out of fifty-seven springs, only six springs were tested for the chemical parameters; except for pH, all the springs has their physio-chemical parameters within the standard permissible limit. The WQI of the selected springs shows that overall area has an excellent to good quality of water for drinking, agriculture and industrial purposes. Though one time testing of water samples does not conclude that the water is excellent or good to use, but it needs several other water quality assessment, longtime experiments and monitoring.

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AUTHOR'S CONTRIBUTIONS

S. Tiwari and D. Chamlagain conceptualized the research. S. Tiwari, D. Chamlagain and A. Wood conducted field work. S. Tiwari and D. Chamlagain wrote the paper. M Sayami helped S. Tiwari to finalize the maps in Geographic Information System (GIS). All the authors discussed and approved the manuscript.

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