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ASSESSMENT OF SPRING WATER QUALITY USING WATER QUALITY INDEX METHOD – STUDY FROM UPPER SUBANSIRI DISTRICT, ARUNACHAL PRADESH, INDIA

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Abstract: Natural springs occurring in hilly areas generally serve as the main source of drinking water for neighboring population. The springs found in the study area are mostly of fracture, gravitational and contact category and belongs to the metamorphic group of rocks. Spring water samples were collected during two seasons i.e. summer and winter for water quality analysis. A total of 7 perennial springs were found on the said road section, among them one is a salt spring. The physicochemical analysis of water samples was done for parameters such as pH, Temperature, Alkalinity, Total Dissolved Solid, Potassium, Sodium, Chloride, Calcium, Magnesium and Total Hardness. Water quality index method was used to assess the spring water quality and the samples from 7 springs were found to be of potable equality. To compare any significant variation in water quality during two season descriptive statistics and paired *t*- test was performed which doesn't revealed in any significant difference in water quality of two seasons. Since all the tested samples were of excellent quality thus the water seems to be fit for human consumption, except for salt spring which needs some treatment before human consumption.

Keywords: Perennial spring, Mara Schist, Physicochemical parameters, Water Quality Index, Statistical analysis.

INTRODUCTION

The entire ecosystem and human development depend upon water resources (Tiwari, 2015). As (Krishnan et al., 2007), (Daghara et al.,2019) asserted**,** with increasing anthropogenic activity, spring ecosystems are under great threat which needs urgent attention and management plans. The increasing human population has led to urbanization and other development activity resulting in degradation of groundwater (Gupta et al., 2019). Spring water is inexpensive and high-quality which flows out to the surface due to natural gravity and hydrostatic pressure, when the spring waters interact with the surface; it undergoes through rapid contamination (Vilane et al., 2016). The springs are one of the primary sources of water in entire Himalayan region, particularly for isolated villages at higher altitude. Village population of Indian Himalayan region largely depends on spring water since time immemorial. Very few water quality assessments have been done in high altitude regions like Arunachal

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Pradesh. The study area and the surrounding topography of the springs is hilly terrain covered by thick forests and is dominated by metamorphic schist known as Mara schist (Tewari, 2001) of Bomdila group dating Paleo-Proterozoic era. The schists are trending North West and dipping towards South West. Based on lithology of the area there are three types of spring prominent and these are categorized under fracture spring, gravitational spring and contact spring. The Salt spring at Darin Suwi is a Karst spring which has unique water chemistry. The brackish property of spring-S6 (Darin Suwi) attracts the wild and domestic animals from all neighboring villages. As per the analysis, the physicochemical parameters of Salt spring are within prescribed permissible limits for human use. Storey et al. (2010) outlined that the regular monitoring of physicochemical parameters of water is an important method to detect changes in properties of water. Seasonal change in discharge of a spring may cause variation in concentration of chemicals in spring water. Most of the spring water consumed by the local community is of open source type. Therefore, regular testing and proper treatment of water is recommended for human consumption. Thus, in the present study, physico-chemical analysis for spring water was conducted adopting standard methodologies to perceive the degree of contamination/pollution. As per the analysis of the obtained results, it was found that parameters of water samples collected from all 7 perennial springs are of excellent quality without any significant difference in water quality during two seasons. The paper presents detailed analysis on chemistry of spring water and impact of country rock on spring water quality with reference to the standards of drinking water. At present, both the quantity and quality of spring water are depleting at an alarming rate due to various factors. Awareness programmes on importance of springs, conservation and rejuvenation of the spring among the local communities can help in protecting the springs in Himalaya.

STUDY AREA AND SAMPLING SITE

Arunachal Himalaya is known for its latent virgin springs which are the source of freshwater for local habitats. The springs occurring along the road section of Leya–Ripo serves the purpose of drinking water for every connecting village. Source of these springs are meteoric underground water which permeate through fractures and openings of consolidated Mara schist. Leya–Ripo section fall within the Gusar circle of Upper Subansiri district and is located in the central part of Arunachal Pradesh and lies approximately between latitude 28^{o}03'903``N and longitudes 94^{o}11'621"E at an average elevation of 390m amsl **(Fig.1)**. The region receives rainfall ranging from 2000 to 5000 mm annually (Dhar and Nandargi, 2004). The maximum rainfall occurs during the months of April to October. To mark the geographical location and altitude of the study area hand handle GPS (Garmin OREGON 650) was used. All the selected 7 seven springs were given codes from S1 to S7 (**Table 1).**

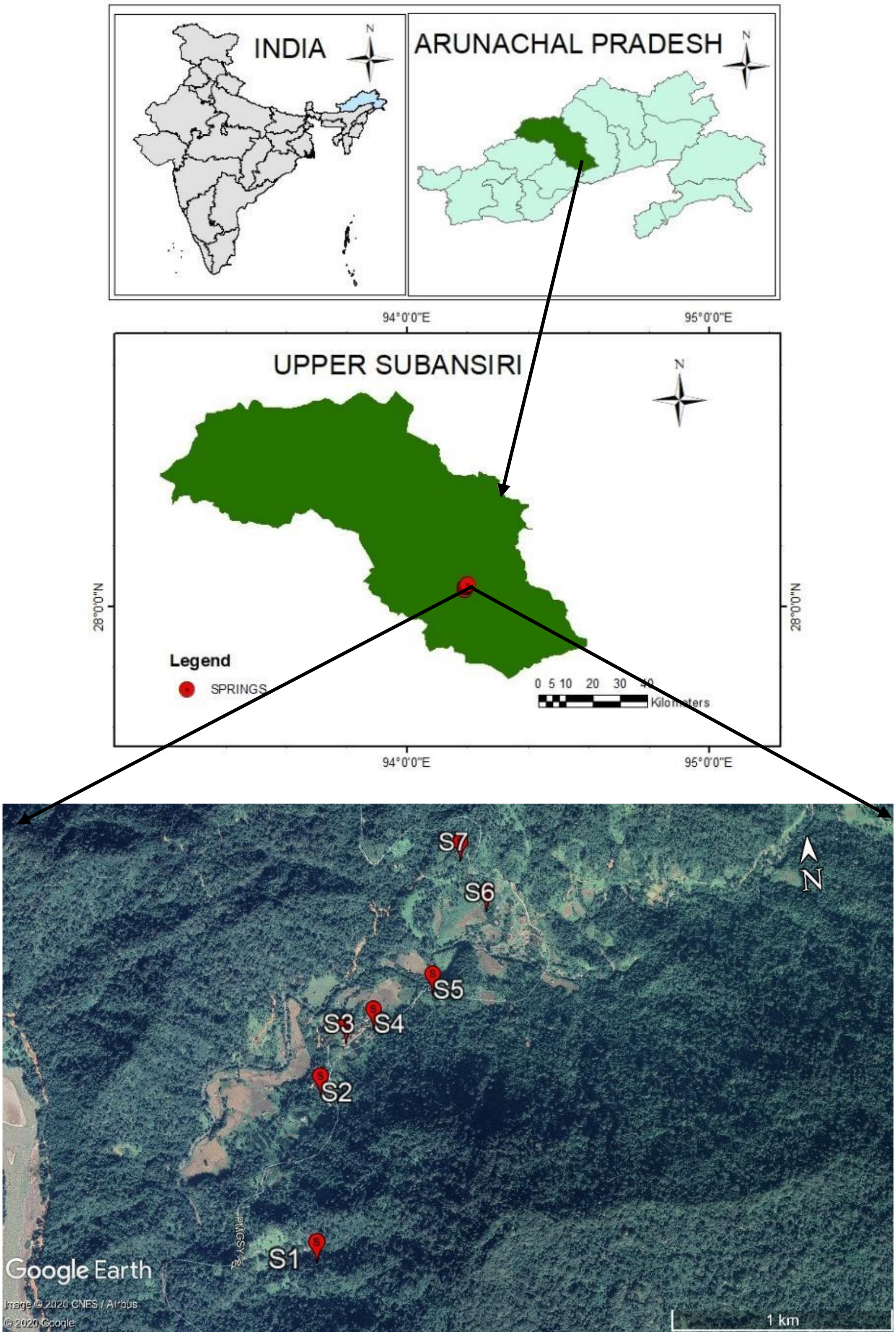

Fig.1: Sampling location map of the study area

Table 1: Location details of the selected springs

Spring Code	Spring Location	Latitude	Longititude	Altitude AMSL
S1	DeyiKro	28º3'23.22"N	094º11'30.75"E	433 m
S2	HidumKro	28º3'48.26"N	094º11'32.16"E	402 m
S3	LiyaKro	28º3'56.63"N	094º11'37.84"E	319 m
S4	Hazor Kro	28º3'58.87"N	094º11'42.40"E	392 m
S5	GhasiKro	28º4'3.28"N	094º11'53.19"E	405 m
S6	Darin Suwi	28º4'16.51"N	094º12'4.61"E	386 m
S7	RipoKro	28º4'25.36"N	094º12'0.11"E	509 m

MATERIALS AND METHODS

Water samples were collected from seven perennial springs in two intervals, one during winter season (December 2018) and another in summer season (June 2019). All water samples were collected in clean 1-liter polyethylene bottles, which were thoroughly cleaned and rinsed using distilled water before sample collection. Each water sample was analyzed using standard methodologies at the laboratory of G. B. Pant National Institute of Himalayan Environment (NIHE), NERC, Itanagar. Physico-chemical analysis was done using the standard method described by (APHA, 2012) and (Tripathi and Govil, 2001) Hand-handle pH-meter and TDS meter (TDS-3, HM digital) was used for measuring pH, Temperature and Total Dissolved Solid. Alkalinity was measured using reagents such as Sulfuric acid (H_2SO_4), Phenolphthalein indicator and Methyl orange Indicator. Chloride was measured by titration of Silvernitrate ($AgNO_3$) and Potassium chromate (K_2CrO_4) whereas titration of EDTA solution, Sodium hydroxide and Murexide was used to measure the calcium. Similarly, EDTA, Ammonia buffer and Eriochrome Black –T indicator was also used to measure the Total hardness. Flame Photometry was used for measuring Sodium and Potassium.

Water Quality Index (WQI)

Water quality index was first developed by (Horton, 1965). Later, a new modified WQI similar to Horton's index was introduced by Brown (1970). To determine the suitability of spring water for human consumption we have used a weighted arithmetic water quality index method. This method is widely used by various scientist to assess water quality (Adimalla and Venkatayogi, 2018), (Aly et al. 2015), (Chowdhury etal.2012), (Balan et al., 2012), (Rao et al.2010), (Ramakrishnalah et al. 2009), (Brown et al.1972). The calculation of WQI was made by using following formula:

WQI $= \sum QiWi / \sum Wi$,

Qi and *Wi* are quality rating Scale and unit weight respectively. The (*Qi*) for each parameter is calculated by using below formula:

Qi = (Vi-Vo / Si-Vo) x100

Where, *Vi*is Estimated value of ith parameter in the laboratory analysed water, Vo is the ideal value of pure water (for all value *Vo*=0, except pH=7.0 and DO=14.6 mg/l) and Si is standard value of ith parameter.

The unit weight (*wi*) and relative weight (*Wi*) for each parameter is calculated by using the equation given below:

$Wi = wi / \sum_{i=1}^{n} wi$

The assigned weight unit for physico-chemical parameters is based on relative importance in overall water quality for drinking purposes. The assigned unit value ranges from maximum 5 to minimum 1. The mathematical calculation for both relative weight and unit weight is given (**Table. 2)**

Table 2: Relative weight for each parameter

Physicochemical Parameters	WHO(2011)	BIS(2012)	Unit Weight (wi)	Relative Weight (Wi=wi/Σwi)
pH	6.5-8.6	6.5-8.5	3	0.12
TDS	500	500	5	0.2
Total Alkalinity	200	200-600*	4	0.16
Potassium	12	12	2	0.08
Sodium	200	200	2	0.08
Chloride	250	250	4	0.16
Calcium	75	200	3	0.12
Magnesium	50	100	3	0.12
Total Hardness	100	600	3	0.12
			Σwi=29	Σ Wi=1.16

*BIS (2003)

The obtained value of WQI of all parameters were then classified according to range Value into five categories in order to determine degree of purity of spring water and its suitability for human consumption (**Table 3).**

Table 3: WQI classification range

Range	Type of Water
<50	Excellent water
50-100	Good Water
100-200	Poor water
200-300	Very Poor water
>300	water unsuitable for drinking purpose

Statistical analysis

To determine if there are any significant differences in WQI for two selected seasons (Summer and Winter) Paired *t*- test at 0.5 significant level (at 95% confidence level) was performed and mean and standard deviations were computed using Microsoft excel 2019.

RESULTS AND DISCUSSION

The analysis of physico-chemical parameters includes pH, Temperature, Alkalinity, Total Dissolved Solid (TDS), Potassium, Sodium, Chloride, Calcium, Magnesium and Total Hardness. Temperature of spring water is influenced by the surrounding atmospheric and weather conditions. The temperature of spring water was recorded higher during summer with mean temperature of 25.6 ^{0}C and the lowest during winter 19 ^{0}C.pH values from all the spring sites were found to be within desirable limits except from thespring-S7 which was reported slight acidic during winter. Dissolve solid consists of ‘anion’ compounds such as chlorides and nitrates whereas ‘cations’ include potassium, magnesium, calcium, and sodium. During the both seasons (Winter and Summer) maximum amount of TDS was reported from a spring-S6(132 mg/L and 320 mg/L). However, all the values were within the permissible limits of BIS (2012) and WHO (2011). Alkalinity in water is due presence of dissolved minerals such as carbonate, bicarbonate and hydroxide. The total alkalinity value of all the spring water was lower than the permissible limits. Based on the prescribed limit of (WHO,2011) and (BIS,2012) difference in potassium concentration has been reported during two seasons. Summer month recorded the highest value of potassium at spring site S6 (13.4mg/L) exceeding the permissible limit. Possible sources for higher concentration of potassium at spring site S6 might be due chemical weathering of carbonate host rock and agricultural activity practiced within the catchment area. However, the potassium value of all other spring water samples falls within the permissible limit. Presence of sodium in low concentration was also been detected in all the spring water samples (lower than the permissible limit of 200mg/L). Salinity of water is mainly due to presence of sodium chloride (NaCl) in water. During the two seasons higher values of sodium and chloride were detected at spring-S6. The presence of significant amount of chloride might be the possible reason for the saline taste of spring S6. The spring water of Darin Suwi (S6) which is popularly called as 'Salt spring' locally. Salt spring attract the animals from the adjacent forest area and neighboring villages due to its saline property. Comparatively, chloride concentration in spring-S6 was found to be higher during winter but these values are within the permissible limit prescribed by (WHO, 2011) and (BIS, 2012). Springs site S3 and S6 with abundant carbonate rocks in the catchment are showing higher calcium and magnesium concentration. These ions are formed when water reacts with surrounding carbonate rock. Seasonal variation in calcium and magnesium concentration is significant. During the winter season the highest concentration of magnesium recorded was, 57.24 mg/l at spring site S1 which is beyond the permissible limit prescribed by (WHO, 2011) **(Table. 2).** However, the values of magnesium in all other spring water samples are within the permissible limit during two seasons. The concentrations of calcium and magnesium in all the water samples were within the permissible limit. Hardness in spring water is due to the presence of a high amount of calcium and magnesium ions. Higher value of total hardness was recorded for both winter and summer seasons. During winter, the hardness values of all the spring sites were found to be above (WHO, 2011) the prescribed limits, except at spring-S5. Similarly, higher values of total hardness were also found in the spring-S1, S3, and S6 during the summer season. However, all the hardness value of spring water were within (BIS, 2012) acceptable limit. The reason for higher value of total hardness could be attributed to anthropogenic activity and weathering action of host carbonate rock.

In general, parameters of all the spring water samples were found to be in potable and excellent water (**Table. 3)**), except the water sample of Darin Suwi spring (Spring-S6), which tastes saline and as a result the water is not being used by the people. In order to know the degree of purity of spring water and its suitability for human consumption, a weighted arithmetic WQI method was applied. WQI values for all the water samples of springs for two seasons is shown table **(Table. 4)**. All the spring value falls below the 50, range indicating “excellent” class for drinking purposes.

Table 4: WQI and Paired *t* -test analysis (at 0.05 Significance level)

Spring Code	WQI (Winter 2018)	WQI (Summer 2019)
S1	23.38	28.46
S2	13.39	7.995
S3	35.45	27.73
S4	28.57	26.86
S5	20.64	8.01
S6	22.8	39.13
S7	7.49	27.69
t Stat	-0.442	
P value one-tail	0.337	
t Critical one-tail	1.943	
t Critical one-left tail	-1.943	

The paired *t* -test analysis was carried out at 0.05 significance level and 95% confidence level. These were calculated to compare the variation change in WQI during two seasons. Computation of paired *t*-test results shows that ‘p’ value (p = 0.337) is greater than significant value 0.05. Similarly, the critical value is also greater than measured *t statistics* value -0.442 which is within the acceptable range. This revealed that the difference in WQI of winter and summer season is insignificant.

The overall results revealed that, water quality of most of the springs is of potable and excellent quality without any significant variation in water quality during two seasons. However, spring-S6 needs to undergo further treatment for household use.

CONCLUSION

The quality of spring water also depends on its surrounding country rock (Michalik, 2007) (Dwivedi, 2017). All the spring sites of the study area belong to a metamorphic group of rocks dominated by Mara schist. The saline nature of spring water (spring-S6) might be due to the presence of carbonate host rock. Water samples collected during the winter season exhibited lower pH value in spring -S7 and higher concentration of magnesium in spring-S1. Similarly, during summer season a higher amount of potassium was observed in spring-S6which exceeded the prescribed limit of (WHO, 2011) and (BIS, 2012), this, may be due to weathering of host rock and extensive agriculture activity within the periphery of spring site leading to deposition of salt, soil and fertilizer residue. The overall WQI of all the springs were found to be potable and of excellent quality. Additionally, there is no significant difference in WQI for all spring water during two seasons. In the present scenario Himalayan springs are gradually turning non-perennial. The anthropogenic activities within the catchment of springs are also significantly affecting the water quality. Water quality and discharge of the springs need to be checked at regular intervals particularly during the rainy season as many water borne diseases are prevalent during this season. Weathering activity also gets intense during the summer season which dissolves many minerals increasing their concentration in water**.** Patil et al., (2012) studied that the presence of excessive amounts of alkalinity, pH and hardness can turn water into a toxic substance. In future, more studies should be conducted on monitoring of discharge and water quality of springs in Himalayan region. Awareness and capacity building of local community members is also needed to rejuvenate the Himalayan springs.

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