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Assessment of Domestic Water Use Pattern and Drinking Water Quality of Sikkim, North Eastern Himalaya, India: A Cross-sectional Study

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ABSTRACT

The present study focused on the pattern of domestic water consumption in Sikkim state of India along with the assessment of the hydro-chemical and hydrobiological characteristics of drinking water quality. The pattern of water consumption and socio-economic status were acquired through questionnaires and interview of 98 households in three major towns of Sikkim e.g. Gangtok, Ravangla and Pelling. Results showed that the hydro-chemical parameters of drinking water were less than maximum permissible limit as prescribed by the World Health Organization (WHO) and Bureau of Indian Standards (BIS). Total coliforms, *Escherichia coli, Enterococcus spp., Salmonella sp., Staphylococcus spp.* and *P. aeruginosa* were detected in 80.2, 47.5, 49.8, 55.2 and 75 percent of the drinking water samples respectively. However, a careful household survey reveals that about 43% of respondents suffered from water-borne diseases during the monsoon period. For this reason 60% of people prefer boiling or detoxify the water before drinking.

INTRODUCTION

Water is essential to life and it works as a crucial role for social and economic development of any country in the world. It is used mainly (directly or indirectly) in the domestic, agricultural and industrial based sectors. Rising population and rapid urbanisation coupled with the climate change may reduce water supply globally during the twenty-first century (Kashi and khoshab, 2015; Wheida and Verhoeven 2007). Water scarcity ultimately causes great hardship to societies, in particular women and children, who spend many hours everyday collecting water (for domestic purposes) from distant sources (Gopaldas and Gujral 1995). Safe drinking water is most important for good health and presently more than 1.2 billion people in world do not have safe drinking water. The present situation is worse in developing nation where the population growth has exceeded the ability of governments to ensure safe water supply. The World Health Organization (WHO) estimated that up to 80% of all sicknesses and diseases in the world are caused by the poor sanitation condition, miserable drinking water supply (WHO, 1997). Near about 900 million people lack access to an improved or standard water supply and 2.6 million to basic household sanitation (WHO, 2015).

Presently in India, as a result of population rise and rapid economic development, the demand for water is increasing both in urban and rural areas. The per capita average annual fresh water availability has reduced from 5,177 m^3 in1951 to 1,820 m^3 in year 2001 and it is estimated to further come down to 1,341 m^3 in the year 2025 and 1,140 m^3 in the year 2050 (Kumar et al. 2005). Decreasing availability might increase tensions and lots of disputes over sharing of water resources (Rao 1975; Shaban and Sharma 2007). A large share of population from the marginal section of the society (both in rural and urban areas) loose their precious time in collecting water for their daily domestic needs. In India, near about 85% rural population solely depends on specified groundwater sources, which is depleting at a faster rate. The high fluoride, salinity and arsenic content in groundwater are the major chemical related problems. Subsequently, the issues of sustainability and maintenance of standard quality of drinking water supplied is an area of concern for countries where groundwater is main source of drinking water.

Mountain areas in developing countries are often neglected in the provision of basic water facilities (Briscoe and DeFerranti 1988; WHO, 1992; Sharma et al. 1996). However, water is considered one of the most prime and sensitive issues in mountain areas (like Sikkim) and sub-humid climatic conditions due to very limited water resources. The majority of fresh water supplies in these regions come from streams, springs water resources etc. Communities from these regions have experienced a severe water deficit in past several decades. Moreover, future population growth and its associated water demands are expected to intensify the situation further.

Therefore, the present investigation is undertaken to figure out and describe the domestic use of water resources in different economic groups in urban region of Sikkim state in India. In this study, the physio-chemical properties and microbial characteristics of drinking water within the study area were examined to quantify the status.

MATERIALS AND METHODS

Study Area

Sikkim a northeastern state is the segment of the Eastern Himalaya has encircled by three different international boundaries, Bhutan in east, Nepal in west and China in north (Fig. 1). The study area is constituted in the major part of Lesser Himalayan low-grade metapelites (Daling Group, Proterozoic to Mesozic) and the distal parts by medium to high grade crystalline rocks of the higher Himalayan belt. The lithological units are quartzites, phyllite, schist and gneisses (Joshi, and Tiwari, 2009). The average annual rainfall of the area is about more than 2500 mm. The annual average maximum and minimum temperatures are 22ºC and 4ºC respectively. The water run-off in the state flows through various geological structures such as joints, fractures, fissures and weathered zones of the rocks. Because of the high slopes in the mountaneous region, most of the precipitation goes as surface runoff (Tiwari, 2012).

Households Survey

The data was collected from three different locations viz. Gangtok,

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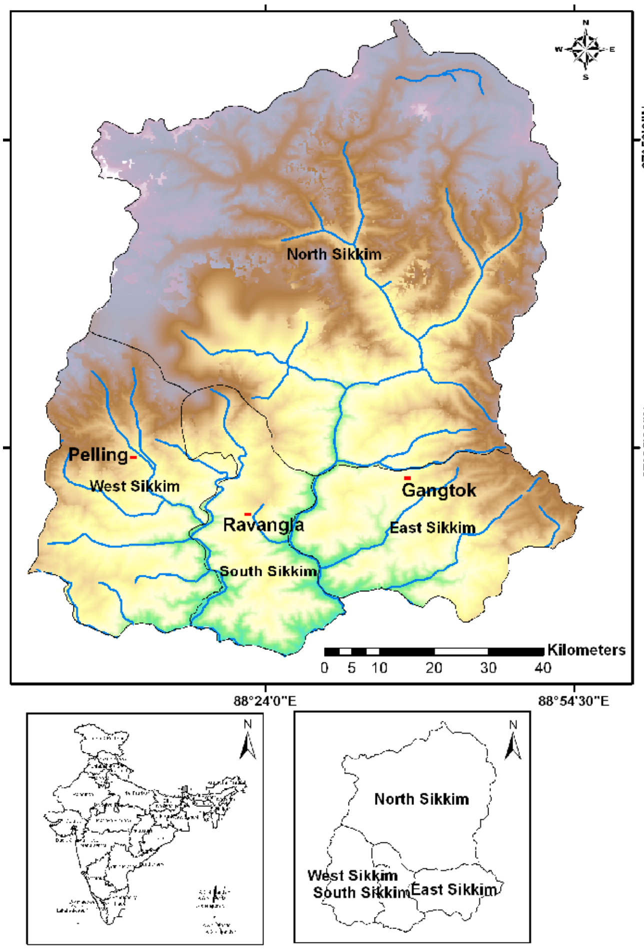

Fig.1. Location map of the study area

Ravangla and Pelling. The regular survey concerning water consumption pattern were carried out through 98 individual households (Table 1) of the three towns between 5th June 2016 and 10th June 2016 by means of structured questionnaire. It contained both closed and open ended questions. The household survey incorporated questions on daily and activity wise consumption, sources, quality, duration and frequency of water supply, distance of different sources and the level of awareness about rainwater harvesting technology in the towns. The target respondents were housewives. The administration of the questionnaire took 15–20 min per household. However, linguistic issues were faced during the survey since the questionnaire was designed in English and Hindi language.

Classification of Socio-economic Categories

The monthly household income is considered as the sole indicator for the classification of various socio-economic groups. The collected annual income data of households was classified in five socio-economic classes based on economic status of the households, like category - I (monthly income below Rs. 10,000), category II (monthly income Rs. 10,001– 20,000), category III (monthly income Rs. 20,001–30,000), category IV (monthly income Rs. 30,001–40,000) and category V (monthly income Rs. 40,001–50,000).

Table 1. Household survey sites and water samples

Sikkim State	Sampling sites	Numbers of household survey	Number of water samples
East Sikkim	Gangtok	28	9
South Sikkim	Ravangla	23	9
West Sikkim	Pelling	47	9

Water Consumption Estimation

The calculation procedures varied from per capita water consumption as the total household water consumption amount divided by the total number of household members. However, information on per capita daily drinking and bathing water amounts may be directly obtained from the participants, while information on cooking, domestic washing and other purposes may be collected on a household basis and later on it may be divided by the total number of household members.

The volume of the pots in which household's stored water was measured and the numbers of vessels of water used in different activities were ascertained. Where the running tap water was used, the duration of the tap and the quantity of water per minute coming out from the tap was also recorded. By multiplying the time with the quantity of water per minute, the volume of water used through running tap was estimated. The quantity of water used in a toilet was assessed by volume of bucket use, and flush tank capacity.

Physio-chemical Analysis of Drinking Water

A total of 16 water samples (four samples from each town) were collected from three different location of Sikkim. Pipeline / taps were operated for at least 10 minute prior to sample to collection to ensure the representative sample. The samples were collected in 500 ml sterile sampling bottles. We referred the standard ranges for different chemicals in drinking water as prescribed by WHO (1997). All water samples were kept in a cool box containing ice packs and immediately transferred to the laboratory for analysis. For each samples temperature, pH, and EC were measured using portable instruments (pH- Portable pH meter Hanna Instruments with accuracy of ± 0.1, EC and temperature). Turbidity was measure of light emitting properties of water and the test was used to indicate the quality of waste discharge with respect to colloidal matter.

Microbiological Parameters Analysis of Drinking Water

Microbiological parameters were determined in 27 drinking water samples collected from the study area (Table 1). The microbiological parameters such as, Total coliforms, *E. coli, Enterococcus spp., Salmonella sp., Staphylococcus spp.*, and *P. aeruginosa* were analyzed using the membrane filtration method as prescribed in the standard methods for the examination of water and wastewater (APHA-AWWAWEF, 1998). Analytical results were expressed in colony forming unit (cfu) per 100 ml.

Statistical Analysis

Descriptive statistics of the sample parameters were analyzed. One-way ANOVA test was done for estimation of significant observations between different aspects. A Pearson correlation co-efficient (*r*) test was performed to examine the relationship between quantity of water consumption per day and the total consumption of water for various socio-economic groups. Linear regression analysis was performed to estimate the daily water consumption in the town. The statistical analysis was performed through SPSS (v.12.0) software and Microsoft Excel Sheet v 10.1.

RESULTS AND DISCUSSION

Daily Domestic Consumption of Water

The daily domestic water consumption in the summer season by the residents of Gangtok, Ravangla, and Pelling towns were estimated as 9,907 liter, 8,898 liter and 16,347 liter respectively (Fig.2). Maximum domestic water in the Pelling town was consumed by category I households followed by category II households. These two socio-economic groups in the village consumed more than 62% of the total domestic water. The high consumption under these households

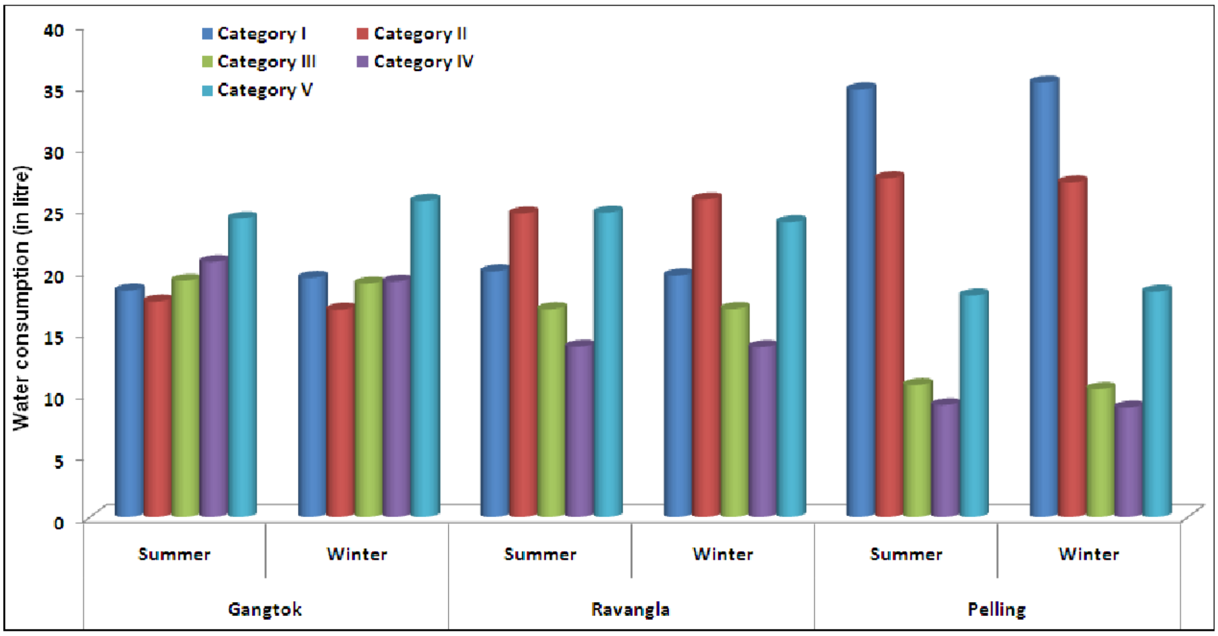

Fig.2. Water consumption across socio-economic groups in two different seasons in Sikkim

is attributed to their number in the town. Minimum domestic water consumption was made by the category IV and category III group of households, ranged between 9.09 % and 10.71% of the total water usage in the town.

Table 2 shows per household as well as per capita consumption of water in Gangtok, Ravangla and Pelling towns. It is very obvious from the table that per capita water availability in the town is not equal to the recommended standards of 150 l/day, the minimum quantity of water recommended by the WHO to fulfil urban / rural households need (Dieterich and Henderson 1963: Gleick 1996). The average per household domestic water consumption in Gangtok town is 353.82 liter whereas per capita domestic water consumption was about 90.50 l/day in summer season. There was a significant variation of per household water consumption were observed between different seasons in Gangtok (F = 11.90, p<0.01) and Ravangla (F= 24.22, p<0.002) town whereas, no significant differences were observed for the Pelling town (F=0.37, p<0.56). A significant difference of per capita water consumption in different seasons were also estimated for the Gangtok (F = 11.99, p<0.013), Ravangla (F= 17.36, p<0.005) and Pelling town (F=7.69, p<0.03).

Figure 3 indicated that the water consumption is surprisingly based on some behavioral and cultural aspects of the households. The analysis reveals significant variations in the consumption of domestic water under different socio-economic groups of the towns (*P<0.001*). The supply side discrepancy in the households of Gangtok, Ravangla and Pelling towns were responsible for high degree of variation in domestic

Table 2 Domestic water consumption and per capita per day across socio-economic groups of study areas in two different seasons

Socio-economic class	Summer season				Winter season			
	Per household		Per capita		Per household		Per capita	
	Mean (L)	Std. Dev. (L)	Mean (L)	Std. Dev. (L)	Mean (L)	Std. Dev. (L)	Mean (L)	Std. Dev. (L)
Gangtok town								
Category I	303.67	152.2	74.22	32.22	272.0	117.42	67.20	31.6
Category II	346.80	145.7	85.40	26.41	283.0	112.91	69.70	29.5
Category III	380.00	136.5	93.92	28.90	318.4	119.63	76.90	32.2
Category IV	410.20	148.8	102.55	25.57	321.4	110.40	80.25	30.6
Category V	342.86	136.3	111.42	27.40	308.14	115.81	81.05	27.7
Total	**353.82**	**143.9**	**90.50**	**28.10**	**300.11**	**115.22**	**72.60**	**30.32**
Ravangla town								
Category I	272.0	117.42	67.20	31.6	330.00	136.2	81.50	35.00
Category II	283.0	112.91	69.70	29.5	361.67	138.4	89.61	37.60
Category III	318.4	119.63	76.90	32.2	355.50	140.1	87.57	32.20
Category IV	321.4	110.40	80.25	30.6	386.33	135.2	95.68	31.80
Category V	308.14	115.81	81.05	27.7	402.40	133.7	100.60	30.70
Total	**300.11**	**115.22**	**72.60**	**30.32**	**365.78**	**136.72**	**91.45**	**33.46**
Pelling town								
Category I	333.82	110.2	83.42	28.2	316.71	112.2	78.92	27.5
Category II	345.92	108.4	85.18	29.6	319.00	105.4	78.95	28.6
Category III	350.00	112.6	86.75	31.5	316.80	109.7	79.06	29.3
Category IV	371.50	102.0	91.85	30.3	339.25	103.1	82.81	30.8
Category V	367.38	111.4	92.16	32.7	348.88	112.0	86.72	31.6
Total	**347.81**	**108.92**	**87.87**	**30.46**	**324.75**	**108.4**	**75.29**	**29.56**

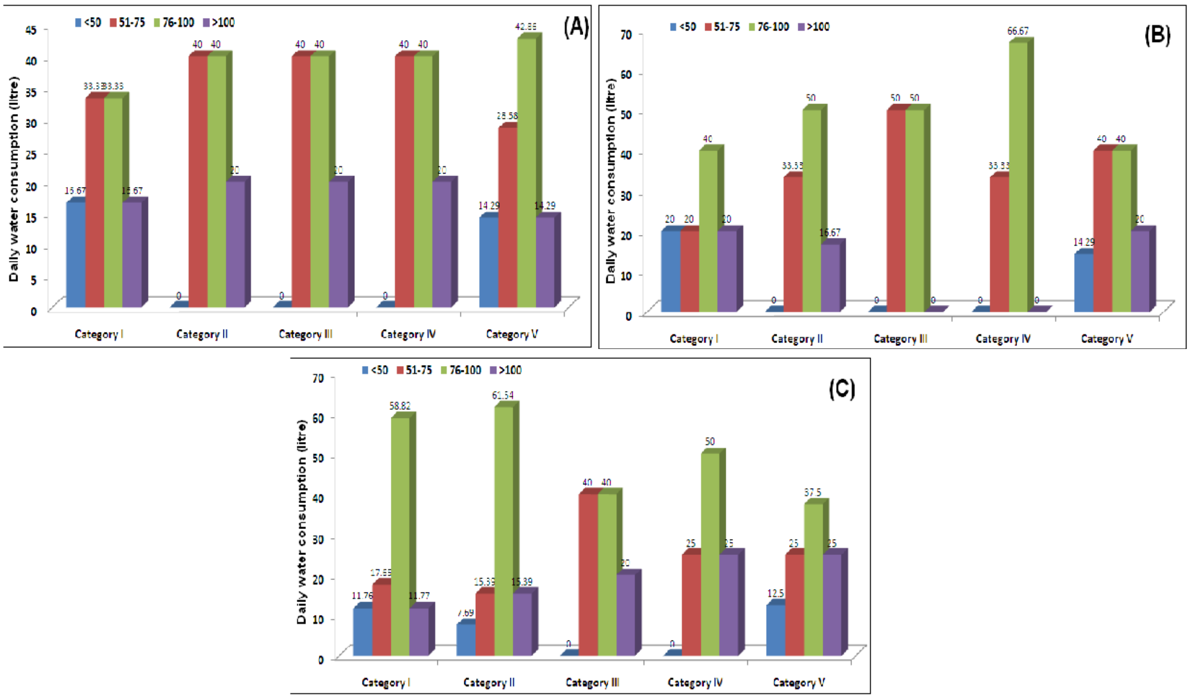

Fig.3 . Daily water consumption (Litre/day) of households across socio-economic groups (A) Gangtok, (B) Ravangla and (C) Pelling town

consumption of water. It was revealed from the analysis that Gangtok town category IV of households consume about 410.20 liter water whereas category I households consume only 303.67 liter water. Moreover, per capita average domestic water consumption were observed as highest (440 l/day) under category V households in Ravangla town whereas minimum consumption was recorded (354.8 l/day) for category I households. The outcome of the study also represented that most of the households in Pelling town consume more than 88 liter of water per day. This may be attributed to good domestic water supply system in the town. It was also observed from the analysis that about 35% households of the town consumes water less than 75 liter per day followed by 50 % households which consume 76–100 liter of water per day.

About 19.59% households in the Gangtok town consume more than 100 liter water per day. It was perceived from the analysis that very less number of household consume less than 50 liter of water per day that are pertained to category I. The consumption of water by various socio-economic classes in the three towns revealed that sizeable proportion of households in all the socio-economic classes consumes water below 75 liter. The analysis demonstrated that about 50% households under category I socio-economic class consumed below 75 liter water. Consequently, 44% and 40% households of Category IV and Category V respectively consumed less than 75 liter of water during a day in Gangtok town. More than 58% households under category I consumed 76-100 liter water during a day in summer season in Pelling town. This is probably accredited to large family size in these households. Inadequate water supply in Indian villages/ towns seems to be a rule rather than an exception. Even if we take 75 liter per capita per day as the criterion for defining water deficient and sufficient households, 30% of the households in the three town viz. Gangtok, Ravangla and Pelling remain water deficient. Moreover, domestic water consumption of three town viz. Gangtok, Ravangla and Pelling households were varied due to socio-economic condition and Government water supplied policy etc (Sikkim State Tourism Policy, 2016).

Quantity of Water Consumption for Domestic Activities

Requirement of domestic water quantity at household level is dependent on a number of factors namely climate, culture, food habits, work and working conditions, level and type of development, and physiology (World Health Organization 2003). At the household level, washing of clothes consumes the highest amount of water in Gangtok, Ravangla and Pelling town, at about 23.91 %, 22.83%, and 22.74 % respectively of the total consumption. This is followed by consumption in bathing (15.02%), sanitation (12.41 %), cleaning of house (11.32 %), and washing of utensils (13.27%) in Gangtok town. On an average, less than 10 % of the total water consumption in a household is used for drinking and cooking in the three towns. Notably, lower the income level of households lower the water consumption rate under various activities and vice versa. Moreover, some of the water consumption quantity rates under different activities were verified through direct observations and measurements in the field. It is observed that average toilet use as approximately 1–2 times per day and bathing was about one time per day of the three towns. Cooking takes place 2-3 times per day.

The results of linear regression analysis as discovered in Table 3, show a strong co-efficient of determination at 95% significance level across various socio-economic groups in three different towns of Sikkim. This shows that the variables haul out are effective for elucidation of variation in domestic water use in Sikkim. The model created using nine variables (e.g., washing of utensils (dish washing), washing of cloths, bathing, cooking, drinking, sanitation, cleaning of home, gardening, any other use) shows that these constituents were strong interpreter of domestic water consumption per day in the study area.

The result of Pearson correlation co-efficient test between quantity of water consumption per day and the total consumption of water for various socio-economic groups for Gangtok town represented strong and positive correlation for Category I ($r = 0.91$, $P<0.01$), Category II ($r = 0.98$, $P<0.01$), Category III ($r = 0.98$, $P<0.01$), Category IV ($r = 0.92$, $P<0.01$), and Category V ($r = 0.90$, $P<0.01$). The results of Pearson correlation co-efficient test for the Ravangla town denoted as Category I ($r = 0.79$, $P<0.01$), Category II ($r = 0.99$, $P<0.01$), Category III ($r = 0.90$, $P<0.01$), Category IV ($r = 0.95$, $P<0.01$), and Category V ($r = 0.94$, $P<0.01$). Results of Pearson correlation co-efficient test between, quantity of water use and total consumption of

Table 3 Coefficients of the predictors of domestic water consumption across various socio-economic groups in three different towns of Sikkim

Economic class	β	Std. error	t-test	95% CI Lower	95% CI Upper	P-value	R^2
Gangtok town							
Category I	2.56	0.89	2.86	0.73	1.16	0.0005	0.94
Category II	0.30	0.62	0.48	0.92	1.20	0.0007	0.97
Category III	-0.27	1.82	-0.15	0.72	1.53	0.0002	0.86
Category IV	-1.07	1.91	-0.55	0.65	1.36	0.0002	0.85
Category V	1.83	0.62	2.93	0.80	1.04	0.0007	0.97
Ravangla town							
Category I	1.27	0.91	1.38	0.76	1.15	0.0008	0.95
Category II	0.63	0.71	0.89	0.84	1.14	0.0007	0.97
Category III	1.68	0.81	2.08	0.71	1.04	0.0006	0.95
Category IV	-0.57	0.45	-1.26	0.97	1.09	0.0008	0.98
Category V	-1.69	0.72	-2.32	0.89	1.15	0.0003	0.97
Pelling town							
Category I	0.14	1.61	0.09	0.69	1.43	0.0002	0.86
Category II	0.32	0.69	0.46	0.77	1.05	0.00006	0.96
Category III	0.99	0.51	1.95	0.82	1.04	0.0001	0.98
Category IV	0.07	0.51	0.15	0.86	1.07	0.0001	0.98
Category V	0.68	0.88	0.77	0.72	1.08	0.0006	0.95

water per day for Pelling town showed for Category I ($r = 0.95, P<0.01$), Category II ($r = 0.98, P<0.01$), Category III ($r = 0.73, P<0.01$), Category IV ($r = 0.96, P<0.01$), and Category V ($r = 0.96, P<0.01$).

Analysis of Hydro-chemical Quality of Drinking Water

The hydro-chemical quality of drinking water varied drastically among different sites of Sikkim. The drinking water samples were free from color, odor and turbidity. The pH of all sampling sites ranges from 6.7 to 8.4. The mean ranges of pH for drinking water was 7.1 (Gangtok) to 8.1 (Ravangla) in studied localities (Table 4). Though pH has no direct effect on human health, but it shows close relations with some other chemical constituents of water. EC values signify the amount of total dissolved salts, which in turn indicates the inorganic pollution load of water. There were large variations in EC values not only in the samples collected from different sites, but also in the samples collected from the same location. The EC of drinking water varied from 20.3 (Gangtok) to 185 µs (Ravangla). The higher EC may be the attributed to high salinity and high mineral content at the sampling site. Sun et al., (2015) concluded that the higher EC of the water is result of ion exchange and solubilisation in the aquifer. TDS further indicates the salinity behaviors of drinking water. TDS values for drinking water were between the ranges 132 (Ravangla) and 14.7 ppm (Gangtok) in different locations.

Total Dissolved Solids (TDS)

Water has the capability to melt a varied range of inorganic and several organic minerals or salts such as calcium, potassium, bicarbonates, chlorides, magnesium, sodium, sulfates etc (Mohsin et al., 2013). These minerals formed un-wanted taste and diluted color in presence of water. The water with high TDS value indicates that water is highly mineralized. Desirable limit for TDS is 500 mg/l and maximum limit is 1000 mg/l which prescribed for drinking purpose (Fadaei and Sadeghi, 2014). The concentration of TDS in present study was observed in the range of 14.7 and 132.0 mg/l (Table 4). The mean total dissolved solids concentration in Gangtok was found to be 41.98 mg/l, and it is within the limit of WHO standards. Similar results were obtained at Pelling and Ravangla. High values of TDS in ground water were generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases (Kumar and Puri, 2012). Water containing high solid may cause laxative or constipation effects.

Electrical Conductivity (EC)

Increase in ions concentration enhances the electrical conductivity of water (Singh et al., 2013). Generally, the amount of dissolved solids in water determines the electrical conductivity. According to WHO standards, EC value should not exceeded 400 µS/cm. The current investigation indicated that EC value ranges from 20.5 – 185 µS/cm with an average value of 92.23 µS/cm. These results clearly indicate that water in the study area was not considerably ionized and has the lower level of ionic concentration activity due to small dissolve solids (Table 4).

pH of Water

pH is an important parameter in evaluating the acid–base balance of water. WHO has recommended maximum permissible limit of pH from 6.5 to 8.5. The current investigation ranges were 6.70–8.40. The overall result indicates that the three town viz. Gangtok, Ravangla and Pelling water source is within the desirable and suitable range. Basically, the pH is determined by the amount of dissolved carbon dioxide (CO_2) which forms carbonic acid in water. Present investigation is similar to the study of Sarda and Sadgir (2015).

Table 4. Physio-chemical parameters of drinking water

Location	Water samples ID	Fe (ppm)	Mg (ppm)	Ca (ppm)	Na (ppm)	EC (µs)	TDS (ppm)	Sulfate (ppm)	pH
Gangtok	GDWS1	0.048	0.169	1.481	3.095	132.2	83.20	0.81	7.1
	GDWS2	0.007	0.074	0.133	4.520	20.3	14.70	1.49	7.4
	GDWS3	0.009	0.138	0.672	3.60	51.20	36.6	1.02	8.1
	GDWS4	0.057	0.061	0.172	4.170	46.30	33.40	0.64	8.3
Ravangla	RDWS1	0.053	0.349	0.666	5.045	100.2	71.20	0.80	7.4
	RDWS2	0.029	0.098	0.299	2.15	74.90	53.4	0.55	7.2
	RDWS3	0.056	0.650	0.308	0.400	90.90	64.00	0.70	7.6
	RDWS4	0.025	1.700	1.627	7.03	185.0	132.0	0.80	7.9
Pelling	PDWS1	0.006	0.183	3.09	3.545	165.20	118.0	0.58	7.7
	PDWS2	0.023	0.159	0.536	3.825	60.7	43.60	0.60	6.7
	PDWS3	0.118	0.144	1.820	2.700	101.3	73.20	0.92	8.4
	PDWS4	0.064	0.126	0.560	4.750	66.40	47.30	0.40	7.8

GDWS= Gangtok Drinking Water Sample; RDWS= Ravangla Drinking Water Sample; PDWS = Pelling Drinking Water Sample

Sulfate

Sulfate is derived from the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies. High concentration of sulfate may be due to oxidation of pyrite and mine drainage etc (Sarda and Sadgir, 2015). The WHO has established 250 mg/l as the highest desirable limit of sulfate in drinking water. In the study area, concentration of sulfate ranges from 0–1.49 mg/l in Gangtok town, and the mean value of SO_4 was 0.99 mg/l. The results exhibit that concentration of sulfate in Gangtok town was lower than the standard limit and it may not be harmful. Other towns' viz. Ravangla and Pelling was found to have similar results.

Magnesium (Mg)

Magnesium is crucial for living organisms and found in minerals like dolomite, magnetite etc. Human body comprises about 25 g of magnesium (e.g., 60 % in bones and 40 % in muscles and tissues) (Garg et al. 2009). According to WHO standards, the permissible range of magnesium in water should be 50 mg/l. In the study areas magnesium ranges from 0.65 to 1.70 mg/l in Ravangla and the mean value of magnesium in water is 0.70 mg/l (Table 4). Similar values were also recorded at Gangtok and Pelling town in drinking water. The results exhibit that concentration of magnesium in Sikkim state was lower than the standard limit of WHO.

Calcium (Ca)

Calcium is very important for human cell physiology and bones. About 95% of calcium in human body is stored in bones and teeth. According to WHO (2011) standards, its permissible range in drinking water is 75 mg/l. In the study areas, results show that the concentration of calcium ranges from 0.172 to 3.09 mg/l in selected sites with an average value of 0.947 mg/l (Table 4).

Sodium (Na)

Sodium is found in less quantity in water. In most of the countries, majority of water supply bears less than 20 mg/l, while in some countries the sodium in water exceeded from 250 mg/l (WHO 1987). According to WHO standards, concentration of sodium in drinking water is 200 mg/1. In the present study, the finding shows that sodium concentration ranges from 0.40 to 7.03 mg/1 with an average value of 3.74 mg/1 (Table 4).

Estimation of Microbiological Study of Drinking-water Quality

Microbiological parameters were determined in 27 drinking water samples collected from the study area (Table 5). The results of bacteriological analysis of drinking water in the selected towns showed contamination with total coliform, *E. coli, Salmonella spp*., and *Enterococcus spp*. The bacterial colony counts were all above the WHO guideline and standard limit of zero (0) cfu/100 ml for drinking purposes. Total coliforms, *E. coli, Enterococcus spp., Salmonella sp., Staphylococcus spp*., and *P. aeruginosa* were detected in 80.2, 47.5, 49.8, 55.2 and 75 % of the drinking water samples, respectively (Fig.4). The result shows significantly higher bacteriological count in the wet season in mountain area (Table 4). This result indicates a higher risk of waterborne diseases in the wet season.

Perception of Water Quality

The majority of households in the three town viz. Gangtok, Ravangla and Pelling depend on government water supply for their daily needs. It was revealed from the analysis that as high as 90% of the households in town were using government water supplies for domestic use, and the remaining 10% of source of water supply was coming through running springs. According to Sheat (1992), perception may very well become more important than reality, especially when it

Table 5. Microbiological load of drinking water collected from selected sites [positive (present), negative (absent)]

Selected area	Sample identification no.	Enumeration of bacteria Isolated bacterial population MPN coliform/100 ml	Isolated bacterial population			
			Escherichia coli	*Salmonella spp.*	*Staphylococcus aureus*	*Pseudomonas aeruginosa*
East Sikkim (Gangtok)	GDWS1	240	Positive	Positive	Positive	Positive
	GDWS2	130	Positive	Negative	Positive	Negative
	GDWS3	91	Positive	Negative	Negative	Positive
	GDWS4	170	Positive	Negative	Negative	Positive
	GDWS5	80	Positive	Negative	Positive	Negative
	GDWS6	98	Negative	Positive	Negative	Positive
	GDWS7	52	Positive	Negative	Negative	Positive
	GDWS8	109	Negative	Positive	Negative	Negative
	GDWS9	118	Positive	Negative	Negative	Positive
South Sikkim (Ravangla)	RDWS1	101	Positive	Negative	Positive	Positive
	RDWS2	86	Positive	Positive	Negative	Negative
	RDWS3	83	Negative	Positive	Positive	Positive
	RDWS4	104	Positive	Negative	Negative	Positive
	RDWS5	94	Negative	Positive	Positive	Positive
	RDWS6	113	Positive	Positive	Negative	Positive
	RDWS7	107	Negative	Positive	Negative	Positive
	RDWS8	250	Positive	Negative	Negative	Positive
	RDWS9	170	Negative	Positive	Negative	Negative
West Sikkim (Pelling)	PDWS1	14	Positive	Negative	Negative	Positive
	PDWS2	80	Negative	Positive	Negative	Negative
	PDWS3	240	Negative	Negative	Negative	Negative
	PDWS4	78	Positive	Negative	Positive	Positive
	PDWS5	120	Positive	Positive	Negative	Positive
	PDWS6	135	Positive	Negative	Negative	Positive
	PDWS7	64	Negative	Positive	Negative	Negative
	PDWS8	60	Positive	Negative	Negative	Positive
	PDWS9	76	Positive	Positive	Positive	Negative

GDWS= Gangtok Drinking Water Sample; RDWS= Ravangla Drinking Water Sample; PDWS = Pelling Drinking Water Sample

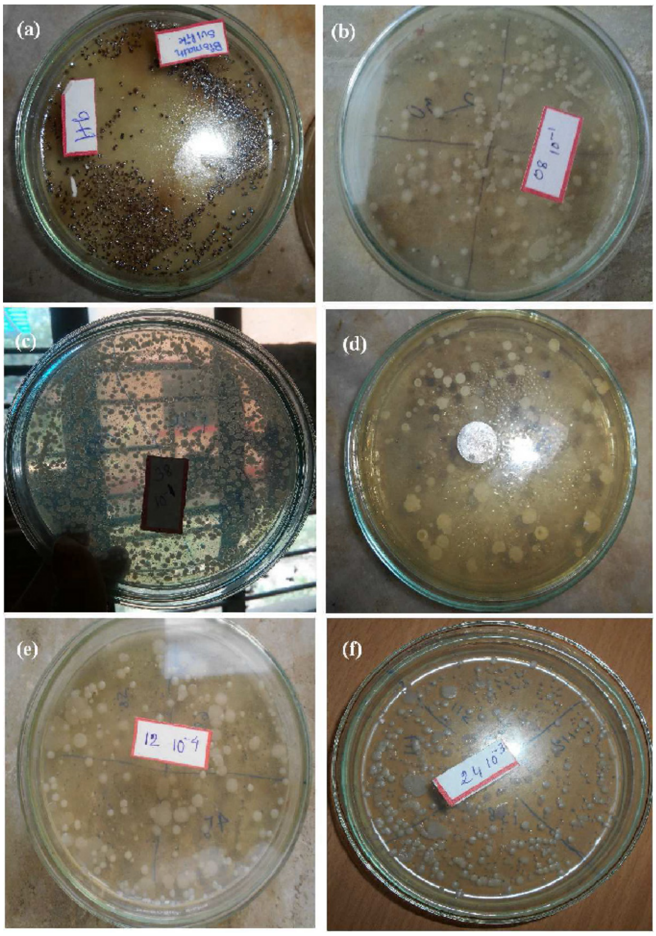

Fig.4. Microbiological study (a and b) PDWS5 and 6; (c and d) Samples- GDWS4 and 3; (e and f) Samples- RDWS1 and 8

comes to the quality of drinking water for town planners. However, the household survey reveals that about 43 % of respondents suffered from water-borne diseases during the monsoon period. So, the large numbers of people (more than 60%) in this region prefer boiling the water before drinking (Table 6). Later, it was confirmed that boiling the water samples not only kills the microbes present, but also lowers the basicity of water to an acceptable level.

CONCLUSION

Water conservation is important to ensure a sustainable future for mountain households especially in Sikkim state, India. High water consumption is associated with the economic activities and population growth which is responsible for declining per capita water availability. Lepchas, Bhutias and Nepalis in Sikkim having different culture, religion, customs and traditions of other communities of people living in Sikkim constitute a heterogenous blend and these communities' undergone differential uses of domestic waters. Increased consumption by the privileged class likewise, puts further pressure on these diminishing natural hydrological resources. Overall, the major observations drawn from the study represents women are the principal water collectors in the study areas of Sikkim state. The availability and mode of use of water varied across the numerous socio-economic classes for each town viz. Gangtok, Ravangla, and Pelling. Water consumption in Sikkim state is far lower than the norms laid down by WHO standards. The lower domestic water consumption pattern is presumably attributed to deficient water supply which is not keeping step with population growth and increasing need of users. The study reveals that very few households in the Gangtok town get 24 h water supply. The erratic and limited duration of supply of water in the

Table 6. Response of Purification techniques use for drinking water

Location of the sample sites	Purification method of drinking water					
	Boiling	%	Filtration	%	Raw	%
Gangtok	15	53.57	7	25.00	6	21.43
Ravangla	14	60.87	4	17.39	5	21.74
Pelling	31	65.96	5	10.64	11	23.40
Average		60.13		17.68		22.19

Ravangla and Pelling is a common phenomenon. This has forced the peoples to rely on other sources of water supply namely, private vendors who supply water through tankers. This in turn is leading to emerging water markets in the town and these private water vendors have their hey-days during the summer season.

For sustainable urban water management, qualitative aspects also pay an important role. An integrated management of wastewater has to be taken into account for effective water resource management in future. Specialized focused should be given for rooftop rainwater harvesting and consequently the local people may be aware about the proper use and conservation of rooftop rainwater. Remarkably, the rainwater harvesting methods, which have a large potential to solve emerging water crises are not known to a majority of people in the study areas. The water collected from rooftop should be properly treated before superior use for drinking purposes. The analysis also revealed that more than 90% of respondents admitted that they had never been instructed on the judicious use of water, and therefore do not consciously practice any form of conservation. The insinuation of the consequences here is that policy architectures in urban water supply planning should integrate such components as revealed here in water supply scheduling for its sustainability. Therefore, an awareness campaign about the judicious use of water highlighting various domestic activities can play a big role in conserving water. The local panchayat body, NGOs, Governmental organization should take purposeful initiative to aware the confined people in proper ways in water conservation. The major limitation of the study is the small sample size; therefore, an extensive study is required in future. Finally, it is also important to find more hygienic ways of storing water will reduce the prevalence of water-related diseases in Sikkim state. Water desalination, drinking water treatment, wastewater treatment, water resources planning, investigation and management is urgently needed for brighter future.

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