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Sustainable Supply of Spring Water as a Social Challenge: A study of Seasonal Variations at Sikkim

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ABSTRACT- The common source of drinking water in the rural areas of east Sikkim is dhara, the natural spring. Owing to derive environmental factors such as rain water, landslide, soil erosion, waste from human and animal, it gets polluted directly or indirectly the water sources. The natural spring water from the selected areas are analysed in terms of physical parameters. Physical properties like temperature, pH, turbidity, salinity, total dissolved solids, conductivity, dissolved oxygen and hardness. The objective of the study is to determine the quality of natural spring water used for drinking and other domestic purpose in the rural areas of east Sikkim. All the observed values are compared with the Bureau of Indian Standard (BIS) guidelines. All the physical parameters are found within the permissible limit of Bureau of Indian Standard (BIS) in all the three seasons. ANOVA and Correlation matrix reflect variations across seasons and moderate correlation across two phases of the study.

Key Words: Sikkim (India) temperature, pH, turbidity, salinity, total dissolved solids, conductivity, dissolved oxygen, hardness.

I. INTRODUCTION

Water is one of the most unique and essential substances on earth which can play a vital role to meet daily need of human life. Across the world, necessity of fresh water will continue to increase considerably over the coming decades to meet the needs of rapid increased populations, growing economics, way of consumption and living style [1-2]. Around 780 million population do not get the fresh and safe water and around 2.5 billion people do not getting proper sanitation, results around 6 to 8 million people die every year due to waterborne diseases and disaster [3-4]. Hence water quality management is a great significance in many parts of the world [4-5].

Sikkim is a small state in the eastern Himalaya, India. It borders Tibet in north and northeast, Bhutan in the east, Nepal in the west and west Bengal in the south, Sikkim is also known for its biodiversity [6]. Total area of Sikkim is 7,096 sq. km with total population 6.11 Lakhs. Out of total population 25.15% people live in urban areas whereas 74.85 % people live in the rural areas [7]. Rural habitations of Sikkim are use spring water (also called as dhara) is one of the main source to meet the basic needs in daily life such as drinking and other domestic purposes. Generally it is considered that spring is natural and freshwater for drinking and other domestic purposes but steadily increase the contamination of water through various sources such as improper discharge of human and animal waste nearby water sources, leaching of drainage, runoff water, soil erosion and landslide which is common in Sikkim due to geological condition and intensity of heavy rainfall. Therefore for the good health of community and prevention of numerous waterborne diseases, consumption of water is free from bacterial contaminants. Due to heavy rainfall it may increase the pollutants load and reaches to the water bodies. The quality of water is very important to consumers, water dealers, regulators and public health authorities [8].

Study area

The study area is selected in rural areas of east Sikkim. In fact the selected spring water sources are uncovered, bushes, trees, houses near the sources even sometimes soil erosion or landslide occurs due to heavy rainfall. People residing in selected study areas are depends on natural spring water (dhara) as their main source for drinking, irrigation and other domestic purposes. In the study areas drinking water supplied from the sources directly to the individual household and is not maintained nor operated by any

of the department. In the study areas there is no restriction for discharge of human and animal waste. For the purpose of the study selection of areas are made on the basis of strength of the population. Most of the people in the study areas are unaware about the necessity of analysis before consumption to access quality and safe water in the community.

II. Literature Review

Importance of mountain streams for human beings and for the ecology in general has attracted the attention of many researchers [9-11]. The findings indicated that mountain streams account for 70% to 80% of the total channel length of a river network. The ecological capacity of downstream portion is a critical outcome of the mountain streams. They play a vital role in stocking and transmitting sediment and nutrients; provide habitat and shelter for multitudes of marine and riparian organisms. Aquatic life is greatly influenced by the quality of water and which is in turn is indicated by its physical characteristics [12].

Seasonal variations in physical characteristics of rivers and stream water has been an area of interest for many a researchers [13-24].

From the literature review it is established that mountain streams play an important ecological role for the entire river net-work and also that seasonal variation exist in the physical characteristic of water. This may influence the ecological capacity of the entire river system. Hence studies in this direction play an important role. Springs of Sikkim have not been studied in this respect and hence a study of this kind for this region is overdue. This paper explores the seasonal variations in the physical characteristics of springs of east Sikkim.

III. Materials and methods

The study is conducted in rural areas of east Sikkim, India from August 2015 - July 2017. A total of 54 spring water samples, nine sample from each area during monsoon, post-monsoon and pre- monsoon. A liter of water sample for analysis of physical parameters are collected in sterile air tight container from the selected sources. Each sample bottle is labelled with full details of the selected source of spring water at the time of sample collection. The temperature and pH values of each sample in all the three seasons were recorded in the spot with pocket size pH meter (Hanna) and thermometer and other parameter analysis is performed within 24 hours of sample collection using conductivity meter, nephelometric method, azide modification method and titrimetric method.

IV. Result and Discussion

a. General Observations

Table 1: Physical parameters (Temperature and pH) of spring water of East Sikkim.

Areas	Temp (Phase-1)			Temp (Phase-2)			pH (Phase-1)			pH (Phase-2)		
	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST
Assam lingzey	17	15	13	19	22	15	7.34	6.5	7.54	7.29	7.24	7
Lower assam	19	16	13	17	23	14	7.84	7	7.48	7.41	7.36	7.16
Lingzey	20	16	14	21	25	16	7.58	6.5	7.72	7.63	7.4	7.02
32 mile	19	14	18	20	25	20	7.87	7.5	7.63	7.52	7.27	7
Sumin	19	13	20	19	24	22	8.07	7	7.59	8.01	7.72	7.05
Gaidhara	22	20	20	21	24	21	7.94	6.5	7.66	7.52	7.63	7.26
Joredhara	21	16	13	20	26	18	7.49	7.3	7.36	7.46	7.59	7.42
Singtam	23	20	20	20	21	21	7.99	7	7.72	7.96	7.83	7.63
Mazitar	22	21	21	20	27	23	7.83	6.5	7.62	7.75	7.91	7.84
Mean	20.2	16.8	16.9	19.6	24.1	18.9	7.8	6.9	7.6	7.6	7.6	7.3
SD	1.9	2.9	3.6	1.3	1.9	3.3	0.2	0.4	0.1	0.2	0.2	0.3

Table 2: Physical parameters (TDS and conductivity) of spring water of East Sikkim.

Areas	TDS (Phase-1)			TDS (Phase-2)			Conductivity (Phase-1)			Conductivity (Phase-2)		
	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST
Assam lingzey	94.78	56	46.4	92.36	20.26	48.2	210.8	39	92	209.2	45.15	95
Lower assam	43.2	83	50.5	44.23	44.68	62.3	96.07	83	99	95.12	99.47	97
Lingzey	48.62	47	20.5	49.73	19.08	21.8	83.15	32	41.5	84.25	42.43	49
32 mile	46.37	58	32.1	47.21	44.96	40.5	103.1	60	46	98.73	99.95	50
Sumin	81.94	113	73.3	75.99	82.9	62.8	182.4	133	148.3	179.62	184.8	121
Gaidhara	41.36	55	38	47.21	34.2	42	92.04	57	76.8	91.28	76.1	84.5
Joredhara	47.9	39	46.4	43.34	36.15	48.9	98.07	74	92.8	90.75	83.26	96.1
Singtam	61.88	38	89.4	59.28	63.15	82.6	138.1	33	182.2	129.98	141.8	174
Mazitar	53.42	66	53.6	51.12	72.13	56.3	119	71	107.3	112.53	119.82	109
Mean	57.72	61.67	50.02	56.40	46.39	51.71	124.75	64.67	98.43	120.19	99.20	97.29
SD	18.65	23.69	20.82	17.88	22.26	17.12	44.36	31.51	44.88	47.20	45.41	37.62

Table 3: Physical parameters (Turbidity and Salinity) of spring water of East Sikkim.

Areas	Turbidity (Phase-1)			Turbidity (Phase-2)			Salinity (Phase-1)			Salinity (Phase-2)		
	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST
Assam lingzey	0.53	0.44	0.81	0.52	0.41	0.48	156	36.85	43.93	166.9	38.45	50.43
Lower assam	0.11	0.48	0.33	0.93	1.64	0.15	79	76.39	37.72	74.9	79.4	43
Lingzey	0.68	0.62	0.51	0.65	0.91	0.22	81	38.52	90.63	87.08	36.4	92.01
32 mile	0.31	0.72	0.43	0.42	0.35	0.56	83	79.63	77.69	81.56	82.58	86.23
Sumin	0.46	0.72	0.64	0.51	0.5	0.63	74	65.12	131.1	139.84	148.1	98.06
Gaidhara	0.39	0.41	0.75	0.41	0.41	0.84	79	63.31	69.01	73.29	64.36	75.11
Joredhara	0.84	0.93	0.3	0.83	0.51	0.49	99	60.56	144	79.56	61.32	123.01
Singtam	0.28	0.97	0.21	0.30	0.84	0.28	95	97.85	161.4	113.6	115.5	146.53
Mazitar	0.56	0.74	0.44	0.51	0.65	0.63	98	91.63	94.62	98.33	103.8	97.12
Mean	0.462	0.67	0.491	0.598	0.6911	0.476	93.778	67.76	94.4556	100.183	81.1011	90.167
SD	0.221	0.202	0.206	0.203	0.4056	0.223	25.064	21.15	43.2926	34.5037	36.5399	32.434

Table 4: Physical parameters (Dissolved oxygen and Hardness) of spring water of East Sikkim.

Areas	Dissolved oxygen (Phase-1)			Dissolved oxygen (Phase-2)			Hardness (Phase-1)			Hardness (Phase-2)		
	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST	PRE	MON	POST
Assam lingzey	2.08	0.8	0.48	1.84	2	0.72	296	72	40	280	176	48
Lower assam	1.28	1.84	0.8	1.52	2	1.2	88	64	40	176	96	40
Lingzey	1.6	1.76	0.8	1.44	2.16	0.96	168	80	48	184	208	24
32 mile	1.92	1.28	0.24	1.68	1.6	0.72	96	104	40	120	200	56
Sumin	2.24	1.2	0.24	2.16	1.92	0.56	96	72	40	120	240	96
Gaidhara	2	1.92	0.4	1.84	2	0.48	64	48	40	80	168	72
Joredhara	1.28	2.32	0.8	1.44	1.6	0.88	160	56	104	160	208	72

Singtam	1.68	2.24	0.4	2.08	1.68	0.96	232	48	40	192	200	48
Mazitar	1.68	1.28	0.72	2	2.24	1.2	160	112	174	160	216	120
Mean	1.751	1.627	0.542	1.74	1.9111	0.853	151.11	72.89	62.9	160	190.222	64
SD	0.338	0.514	0.239	0.266	0.2348	0.256	75.519	22.78	46.64	59.5603	41.1393	29.665

Table 1, 2, 3 and 4 show the values of physical parameters of spring water in the present study. All the values show fluctuations in three different seasons for both the phase-I and phase-II due to various factors. Variations in temperature of water samples (Table 1) are measured between range of 13^0C and 27^0C in two phases of analysis and pH is observed above then 7 in most of the sample in both phases. During monsoon season of first phase, pH of water of some sample of areas is measured less than 7. The total dissolved solids (TDS) are the amount of organic and inorganic materials that are dissolved in water. The study shows the level fluctuate in both the phase-I and phase –II during pre-monsoon, monsoon and post-monsoon due to the presence of various minerals in water [25]. The conductivity is a measure of capacity of a solution to conduct electrical current and good indicator of total dissolved solids [26]. The study shows the fluctuations in conductivity levels may be due to domestic sewage and use of inorganic fertilizer, it may be due to bicarbonate and calcium present in the rocks near the water sources [27].

Turbidity shows the presence of materials that are suspended in the water bodies [28].The variation in the turbidity level may be due to heavy rainfall, runoff water, land slide and anthropogenic activities near the water sources. The fluctuation level in salinity during three seasons may be because of freshwater discharge by precipitation it may also due to higher solar radiation besides evaporation [29-30].

Dissolved oxygen is a measure of concentration of oxygen dissolved in water. The variation in dissolved oxygen level in spring water may be due to raise in temperature and also due to increase the microbial activity in water sources [31-32].

Variation in hardness values are observed in both phase-I and phase-II may be due to the leaching of carbonate and bicarbonate salts in water sources during rainy season [33].

In the present study all the observed values of physical parameters are found within the permissible limit of Bureau of Indian Standard (BIS) [34].

b. **ANOVA (Season):**

Is there any significant difference in the values of variables of study? To find this we performed ANOVA. The results have been provided in table. From the table we find

ANOVA (Season)		
	F-value	p-value
Temperature	4.22	0.027*
PH	27.96	0*
TDS	0.705	0.504
conductivity	4.923	0.016*
Turbidity	2.592	0.096
Salinity	2.12	0.142
Dissolved O_2	27.41	0*
hardness	7.5	0.003*
alkalinity	15.15	0*
*Significant Difference		

that out of nine variables undertaken as many as six variables differ significantly across monsoon, pre-monsoon and post-monsoon (p-value <0.05). Three variables, namely TDS, Turbidity and Salinity do not differ significantly.

c. **Correlation Coefficient across Phase-1 and Phase-2:**

Is there similarity in values of variables across two phases? This is important for the validity of the study. Table provides details of correlation coefficients across two phases. In most cases (barring Temperature, Turbidity and hardness) correlation coefficients are moderately high. This validates the first phase values. A longitudinal study comprising of 20-25 years data can help in ascertaining the trends in the values of variables under this study and will help in proposing mitigating plans if any needed. Lack of moderate correlation in time could be because temperature differs across the time of the day and perhaps ensuring collection of samples at pre-decided accurate time has not been followed. Reasons for low correlation coefficients in case of turbidity and hardness need further investigation.

Correlation (Across Phases)		
	r	p-value
Temperature	0.251	0.216
PH	0.729	0*
TDS	0.729	0*
conductivity	0.822	0*
Turbidity	0.19	0.72
Salinity	0.761	0*
Dissolved O_2	0.778	0*
Hardness	0.381	0.45
Alkalinity	0.861	0*

*Significant Correlation in Phase 1 and phase 2

V. CONCLUSION

It is affirmed that *Water and sanitation are among the most powerful preventative measures available to governments to reduce infectious disease*" (UNDP, 2006, 21). In the context of sustainable development aspirations the world espouses, access to safe drinking water, sanitation and hygiene are essential elements to be focused upon. Water supply in Sikkim mainly is through the hill streams and this is facing some major challenges, some of which could be seasonal. In the study it is observed that the physical parameters in the selected spring water of east Sikkim are found to be within the permissible limit of Bureau of Indian Standard (BIS). The necessary strategies are to be made and create for appropriate water management and hygienic system in every individual in order to prevent the existence of diseases and access quality of drinking water in the community. Water resources in Sikkim are important not just for local ecology but also for the ecology of regions far beyond the political boundaries of Sikkim and which shelters millions of people. Hence study of this nature are required to be undertaken more intensively and extensively.

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