Abstract:-

Water samples from springs were collected from five different location across the Duga area of the East Sikkim, to understand the general distribution of elements like sodium, potassium, calcium, magnesium, sulphate, nitrate, Electrical Conductivity, Total Dissolved Solids and pH, and its variation with temperature, and verification the linear equation of Electrical Conductivity and temperature. Also understand the influence of ions concentration on Electrical Conductivity (EC). Total Dissolved Solids and Electrical Conductivity in general increase with decrease in altitude. Gypsum, Brine type rocks were found to be the main factor controlling the chemistry of the spring waters. Chemical compositions of all the spring waters are in the drinking water range.

# STUDY OF THE PHYSICAL PARAMETERS OF SELECTED SPRING WATER OF EAST DISTRICT, SIKKIM

Sudip Kumar Das[1] and Rakibul Islam[2]

[1]M. Sc , Department of Physic , Sikkim University, Gangtok .
[2]Research Scholar , Department of Geography, Sikkim University, Gangtok .

Keywords:

Spring Water Quality, Altitudes, Electric Conductivity, Temperature And Linearity.

## INTRODUCTION

Water is an important natural resource of the mother earth. Out of total area of the earth surface about 75% area cover by water, out of which near about 97% water is sea water and remaining 3% is fresh water (Stanley 2010). Within this major portion of fresh water is found in the form of glacier. Very little amount of liquid form of fresh water is available in River, streams, springs, atmospheric moisture, soil water and aquifer and natural springs. All of these are considered as the main source of fresh water. The ground water flowing to the surface as the spring throughout the year serves as the main source of water for drinking. About 80 % Sikkim's rural household are depends on spring water for supply of drinking water (Roy 2009). But the rising population and related activities such as agriculture and industry not only raises the demand of available fresh water but also pollutes the available fresh water on the earth surface. It also has impact on, spring ecosystem, aquatic flora and fauna, and also to the human health.

The Electrical Conductivity (EC) and Total Dissolved Solid (TDS) are influences by the chemical composition. Major chemicals properties of water that determined by the presence of amount of dissolved magnesium, calcium, sodium, sulphate, nitrates, chloride and they are influence by electrical conductivity.

Electrical conductivity (EC) is the reciprocal relation of electrical resistivity and measures a material's ability to conduct electric current. It is commonly represented by the Greek letter σ (sigma). In ionic liquids, electrical conduction happens not by electrons or holes but conduction occurs by ions, which carry an electrical charge. The resistivity of ionic liquids varies with the concentration of ions. Distilled water is almost an insulator and salt water is has high electrical conductivity. In biological membranes, currents are carried by ionic salts. Small holes in the membranes, called ion channels are selective to specific ions and determine the membrane resistance.

Electrical Conductivity of water refers to its ability to conduct electrical current. In water, Electrical Conductivity depends on the dissolved ions concentrations which are capable of charge carriers. The mobility of ions and electrical conductivity of water also depends on temperature. An increase in water temperature will leads to decrease in its viscosity and increase in the mobility of the ions in water and increase in the number of ions in water due to dissociation of molecules (Barron et al 2007 ).The mobility of a charged ion depends on its ionic size and charge. The EC of a fluid are depend on chemical species which are present in it and not just their concentration and mobility. The Electrical Conductivity is an indicator of Total Dissolve Solid (TDS) because ionic concentration of water is related to TDS (Masakihayashi 2004). EC of water sample is commonly used to examine the freshness of water and also estimate the physical properties (such as TDS, concentration of ions) in spring hydrograph. The major positively charged ions of spring water in Sikkim Himalaya are sodium, calcium, potassium and magnesium and the major negatively charged ions are chloride, sulphate, carbonate, and bi-carbonate. Nitrates and phosphates are minor conductor, but biologically they are very important because it play a vital role in determining quality of water.

This study attempts to understand the water quality of selected springs of East Sikkim and also try to verify linear relationship among the temperature, altitudes, TDS and EC of the spring water of sample site.

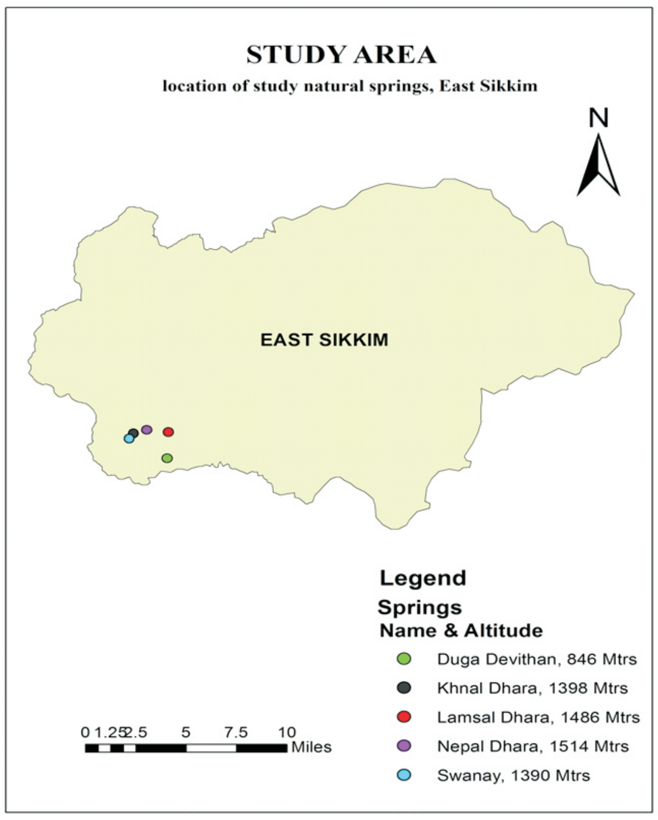
## STUDY AREA

Sikkim is the second smallest and least populous state and geographically diverse Himalayan state of India, situated between 27° 00' 46" to 28° 07' 48" N latitude and 88° 00' 58" to 88° 55' 25" E longitude with geographical area of 7,096 sq km. Being a part of Himalayas Mountain the natural elevation of the state are ranges from 300 m to 8598 m (Tambe et. al 2011). The study watershed area fall under east district of Sikkim whose natural elevation lies between from 950m at Duga to 1250m (M.S.L) at Lamsal Dhara. The study watershed region located in rain shadow zone of Sikkim therefore, these regions received relatively less amount of precipitation as compare to other parts of the state.

In terms of geology, Sikkim is best displayed in the form of Teesta gorge flowing in general from north to the south. A sequence of high grade meta-sedimentary rocks ranges from calc-granulities, schist, quartzite and gneisses to migmatites and a numbers of granitic intrusions are exposed in the Axial Zone of North Sikkim. Southern part of teesta basin is characterized by low-grade pelite-psammite assemblage belongs to the Daling formation Darjeeling gneiss and Daling Group and followed by sandstone shale-coal assemblage of Gondwana formation. The Central Crystalline rocks are separated from the gneisses and schist's belonging to Darjeeling gneiss and Daling Group.

Due to fragile nature of its landscape number of small streams, channels and snow fed rivers and natural spring are originated elsewhere in the Sikkim. Generally springs of Sikkim are classified into – hot springs; most of them are found in south, west and north district of Sikkim. The soft water springs are found in east and north Sikkim. Most of them are originates either from depression or fracture zone. From this zone aquifer water come out to the surface due gravitational force and flows out to the surface as spring.

In the Himalayan region springs are the origin of many streams and rivers. Natural springs are very significant to the mountain communities, because it is a prime source of irrigation and fresh drinking water.




## OBJECTIVE OF STUDY:

Following are main objectives of study

1)To understand the nature of natural springs of the study area.
2)To understand the interrelation among Altitude, Electrical Conductivity, Total Dissolved Solid and water pH etc.
3)To understand the interrelation among water pH, Electrical Conductivity and Total Dissolved Solid with changing temperature.
4)To verify the linear equation between Electric Conductivity and Temperature.

## METHODOLOGY

For this study natural springs from east Sikkim especially spring which located relatively rain shadow area are selected. The field survey has conducted during winter. The sample spring are randomly selected from the study area. Five natural springs namely; Duga Devithan source, Khanal Dhara, Swanay Dhara, Lamsal Dhara and Nepal Dhara are selected for this study.

GPS tool is used to know the coordinates and measure the elevation of study springs. The Arc GIS tool is used to map the study natural spring. Water samples are collected from field in polythene bottle. To avoid contamination the bottles are pre-washed and dried. After filled with water, the bottles are sealed with air tight cork and immediately brought to the laboratory for analysis.

The pH value of water samples are measured by dipping electrode pH meter. Electric Conductivity of water is determined by using electrometric method and amount of Total Dissolved Solid of samples are calculated with the help of following relation.

$TDS = K \text{ X } EC$

Where K- value varies from 0.55 to 0.85

The amount of sodium and Potassium are estimated by flame photometer using sodium chloride and Potassium nitrate solution respectively as reagent. Amount of calcium is estimated by atomic absorption spectrometry using calcium carbonate stock solution as reagent. Chloride is estimates by titration method Using silver nitrate as reagent developed by Mohr. Nitrate is estimates using Automated Colorimeter method. Specific Ion Electrode method is used to estimate the total amount of Sulphide.

The linearity of temperature, Electric Conductivity, Total Dissolved Solid is represented by Using Origin software package developed by Origin Lab Corporation. To know the influence of Cation's on the availability of Electric Conductivity and Total Dissolved Solid is verified by using Magnesium (Mg) as cation agent.

## RESULT AND DISCUSSION

**Table I: Concentration of various elements in study sample**

| Sample Name | pH value (At Room temp.) | Sodium $Na^+$ (mg/L) | Potassium $K^+$ (mg/L) | Magnesium $Mg^+$ (mg/L) | Calcium $Ca^+$ (Mg/L) | Sulphate (mg/L) | Nitrate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Nepal Dhara | 6.7 | 1.00 | 0.50 | 12.165 | 0.123 | 1.466 | 1.104 | 10.0 |
| Khanal Dhara | 6.4 | 1.25 | 0.75 | 4.396 | 0.198 | 2.345 | 0.430 | 10.0 |
| Lamsal Dhara | 7.3 | 0.50 | 0.75 | 8.779 | 0.183 | 8.054 | 3.137 | 10.0 |
| Duga Devithan Source | 8.0 | 0.75 | 0.75 | 13.313 | 0.144 | 2.520 | 5.050 | 10.0 |
| Sawnay Source | 7.3 | 2.00 | 0.75 | 11.728 | 0.107 | 1.906 | 3.540 | 10.0 |

Source: Data computed by authors 2013

From the above table it is safely stated that the pH value of water sample used to studies are lies in between 6.4 to 8.0, means approximately near about neutral point (pH 7.0) and portable and good for human health (the range of pH 6 to 8 for human health by WHO 1960). The available amount sodium in all case is lies in between 0.75 mg/l to 2.00 mg/l and highest amount of sodium is found in Sawnay Source. Potassium concentrations in all samples are lies between 0.50 mg/l to 0.75 mg/l.

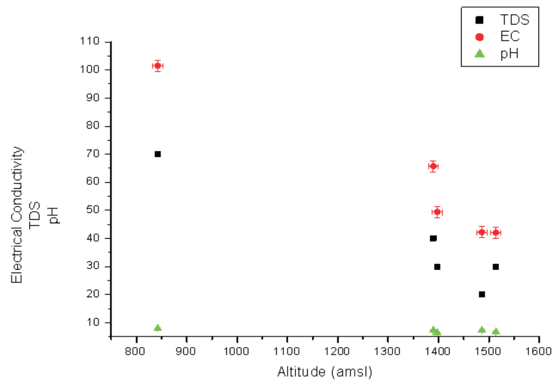
But magnesium concentrations are highly varies from sample to sample, least amount of magnesium is observed in water of Khanal Dhara that is 4.396 mg/l where as maximum amount of magnesium is recorded in water of Duga Devithan Source that is 13.313 mg/l. In case of calcium, again least amount is recorded in Sawnay Dhara that is 0.107mg/l. Again in case of sulphate concentrations are varies from one sample to another and least amount of sulphate is recorded in Nepal Dhara where as maximum amount of sulphates are found in Lamsal Dhara that is 8.054mg/l.

The presence of nitrates in all sample are falls in between 0.430 mg/l for Khanal Dhara to 5.050 mg/l for Duga Devithan Source. For Duga Devithan Source is concerned the available amount of nitrate reach beyond the permissible limit for human health recommended by World Health Organization (5mg/l, WHO 1960).

**Table II: Show the variation of EC, TDS and pH with altitude (at20$^0$C)**

| Sample Nome | Altitude (m.s.l )(±10) | EC (µS/cm)(±2) | TDS (mg/L) | pH (±0.1) |
|---|---|---|---|---|
| **Duga Devithan** | 842.5 | 101.5 | 70 | 8.0 |
| **Sawnay Source** | 1389.6 | 65.7 | 40 | 7.3 |
| **Khanal Dhara** | 1397.5 | 49.4 | 30 | 6.4 |
| **LamsalDhara** | 1486.0 | 42.2 | 20 | 7.3 |
| **Nepal Dhara** | 1514.0 | 42.1 | 30 | 6.7 |

Source: Data computerd by Authors 2013




From above results we can simply concluded that altitudes, Electric Conductivity and Total Dissolved Solid and pH are inversely related to each others. When altitude is increases then the Electric Conductivity, TDS and pH are decreases and vice versa. Because when altitude is increase then the travelling length of springs are decreases, as well as the recharge area or the source of spring is not so far from the spring. So the spring does not absorb so many minerals from the rocks of the area. It also found that at higher altitude springs water are acidic in nature as compare to springs are locates in lower altitudes.

**Table III: The influence of Cations concentration on available EC and TDS on study water sample**

| Sample Name | Cations Concentration $(mg/l)$ | TDS | Electrical Conductivity $(\mu s/cm)$ |
|---|---|---|---|
| Duga Devithan Source | 14.81 | 70 | 101.5 |
| Khanal Dhara | 5.64 | 30 | 49.4 |
| Lamsal Dhara | 13.72 | 40 | 65.7 |
| Nepal Dhara | 9.27 | 20 | 42.2 |
| Swanay Source | 13.16 | 30 | 42.3 |

Source: Data computed by Authors 2013

From the above table it is very clear that, amount of Cations concentration, amount of Total Dissolved Solid and Electric conductivity are proportionally or linearly related to each other. If the concentration of cations is increases then the amount of Total Dissolved and Electric Conductivity also rises. Here the

*The Electric conductivity and Ion factor relation*

| *Ion* | *Conductivity factor µS/cm per mg/L* |
|---|---|
| $Na^{+}$ | 2.13 |
| $,Ca^{2+}$ | 2.60 |
| $K^{2+}$ | 1.84 |
| $Mg^{2-}$ | 3.82 |
| $Cl^{-}$ | 2.14 |
| $So_4^{2-}$ | 1.54 |
| $HCo_3^{-},$ | 0.715 |
| $NO_3^{2-}$ | 1.15 |

Source: (*Barron et al TSP-07 Issue 3)*

**Table IV: The interrelation among Temperatures, Electric Conductivity, and Total Dissolved Solid and Water pH of study spring water sample**

| Sample Name | Temperature ($^0$C)(±0.5) | EC(µS/cm)(±2) | TDS(mg/L) | pH(±0.1) | K-factor |
|---|---|---|---|---|---|
| Duga Devithan source | 20 | 101.5 | 70 | 8.0 | 0.686 |
| | 25 | 116.5 | 80 | 8.3 | 0.689 |
| | 30 | 127.3 | 90 | 8.5 | 0.706 |
| | 35 | 136.7 | 100 | 8.7 | 0.731 |
| | 40 | 148.2 | 100 | 8.8 | 0.674 |
| | 45 | 159.7 | 110 | 8.9 | 0.688 |
| Khnal Dhara | 20 | 49.4 | 30 | 6.4 | 0.60729 |
| | 25 | 62.3 | 40 | 6.5 | 0.69808 |
| | 30 | 72.2 | 50 | 6.6 | 0.69252 |
| | 35 | 79.1 | 60 | 6.7 | 0.75853 |
| | 40 | 89.1 | 70 | 6.8 | 0.80367 |
| | 45 | 95.1 | 80 | 6.9 | 0.84122 |
| **Lamsal Dhara** | 20 | 42.2 | 20 | 7.3 | 0.47393 |
| | 25 | 56.6 | 30 | 7.4 | 0.53097 |
| | 30 | 69.4 | 40 | 7.5 | 0.57637 |
| | 35 | 72.4 | 50 | 7.6 | 0.69061 |
| | 40 | 80.4 | 60 | 7.7 | 0.74627 |
| | 45 | 88.3 | 70 | 7.8 | 0.79275 |
| **Nepal Dhara** | 20 | 42.1 | 30 | 6.6 | 0.71259 |
| | 25 | 68.6 | 40 | 6.7 | 0.60060 |
| | 30 | 75.5 | 50 | 6.8 | 0.66225 |
| | 35 | 86.7 | 60 | 6.9 | 0.69204 |
| | 40 | 97.6 | 70 | 7.0 | 0.71721 |
| | 45 | 117.9 | 80 | 7.1 | 0.67854 |
| **Swanay Source** | 20 | 65.7 | 40 | 7.5 | 0.60880 |
| | 25 | 75.9 | 50 | 7.6 | 0.65870 |
| | 30 | 84.4 | 60 | 7.7 | 0.71091 |
| | 35 | 90.0 | 70 | 7.8 | 0.77777 |
| | 40 | 96.9 | 70 | 7.9 | 0.72231 |
| | 45 | 107.3 | 80 | 8.0 | 0.74551 |

Source: Data computed by author based 2013

**Graphical representation of temperature, Electrical Conductivity, total dissolved solid and water pH from sample**

**Duga Devithan Source**

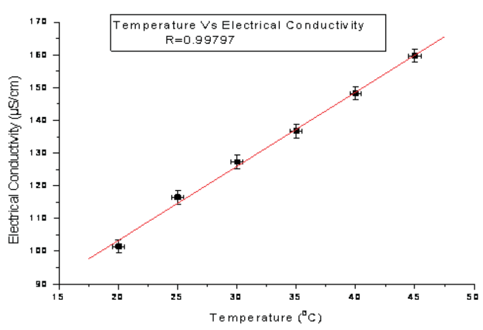


**Figure 13: Temperture vs. Conductivity graph**

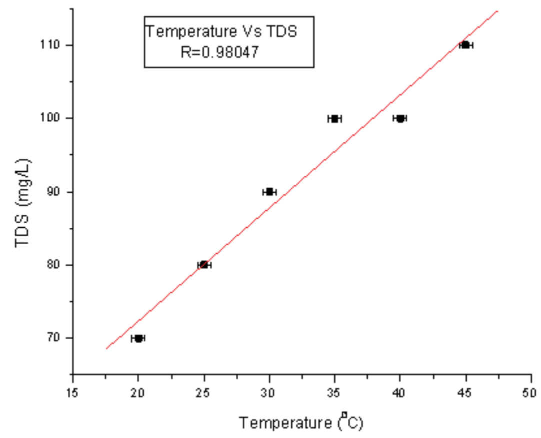



**Figure 14: Temperature vs. TDS graph**

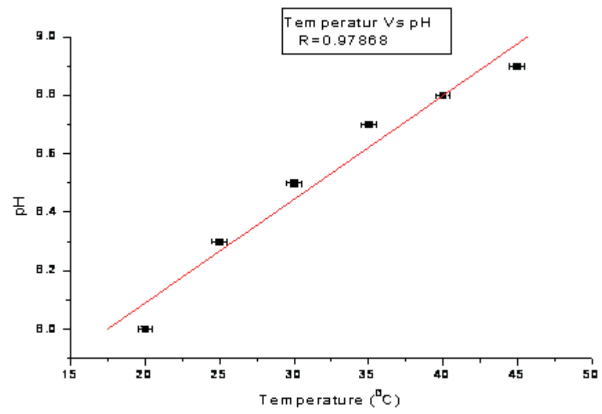



**Figure 15: Temperature vs pH graph**

**Khanal Dhara**

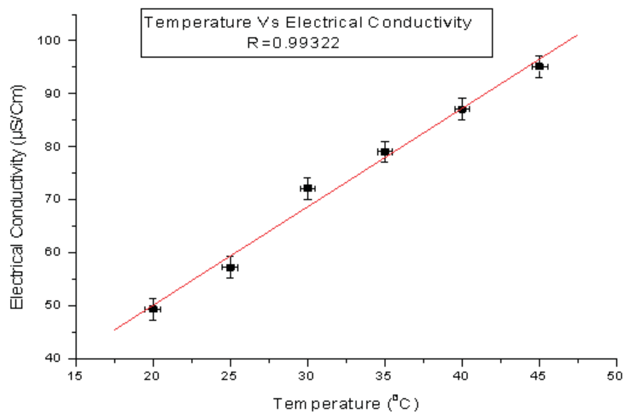



**Figure 16: Temperature vs. conductivity graph**

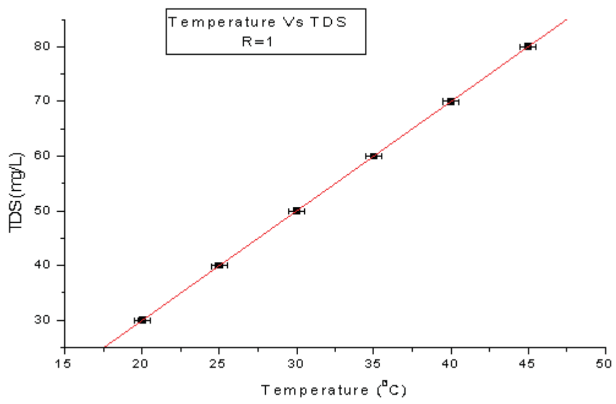



**Figure 17: Temperature vs. TDS graph.**

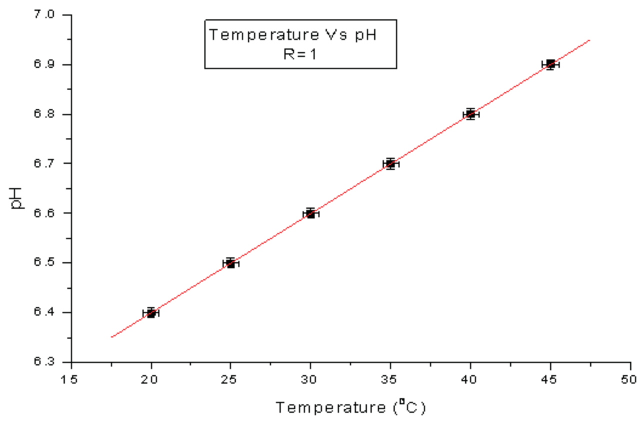



**Figure 18: Temperature vs. pH graph**

**Lamsal Dhara**

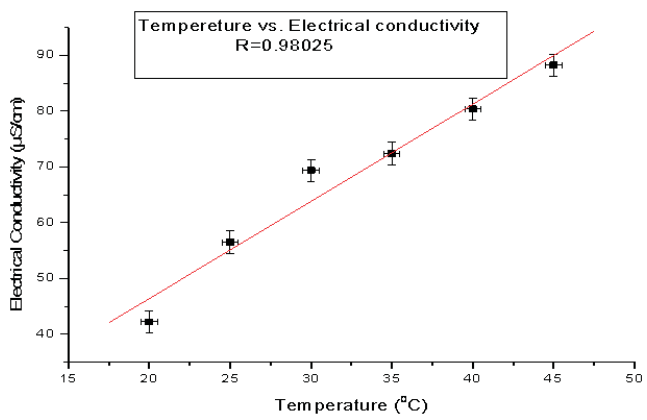



**Figure 19: Temperature vs. Electrical Conductivity.**

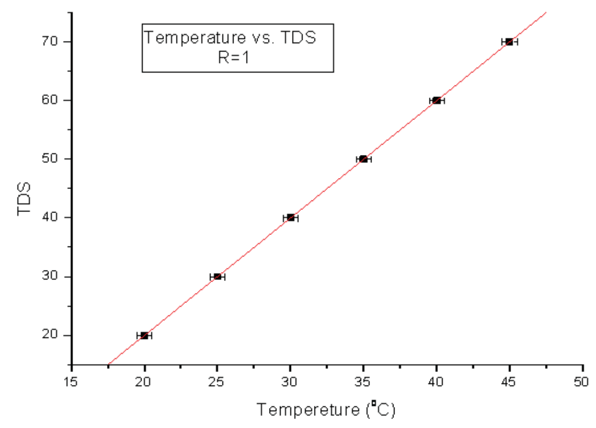



Figure 20: Temperature vs. TDS.

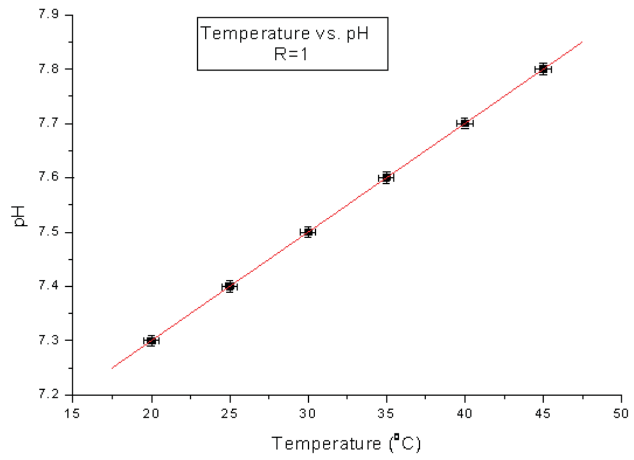



Figure 21: Temperature vs. pH

Nepal Dhara

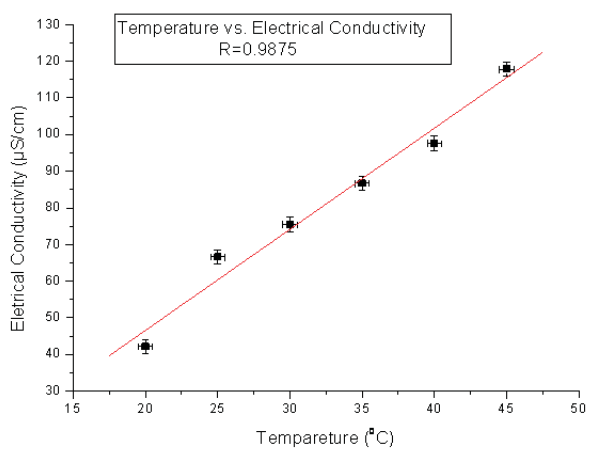



Figure 22: Temperature vs. Electrical Conductivity.

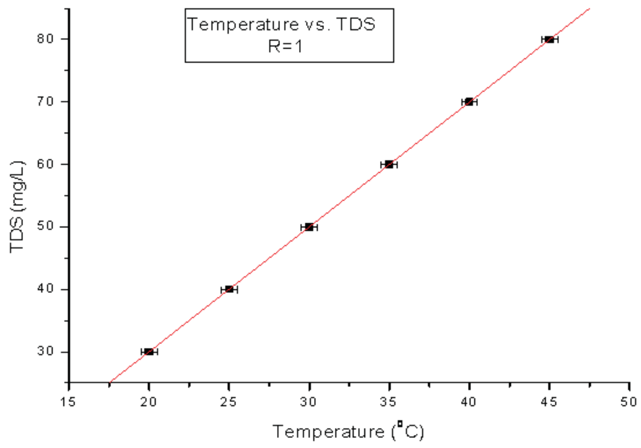



Figure 23: Temperature vs. TDS.

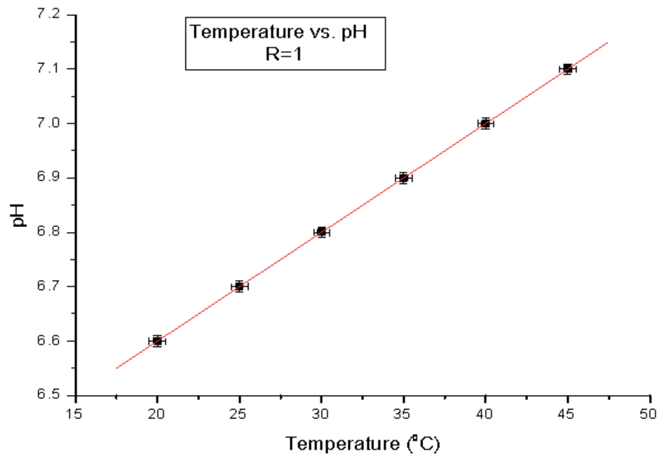



Figure 24: Temperature vs. pH

Swanay Dhara

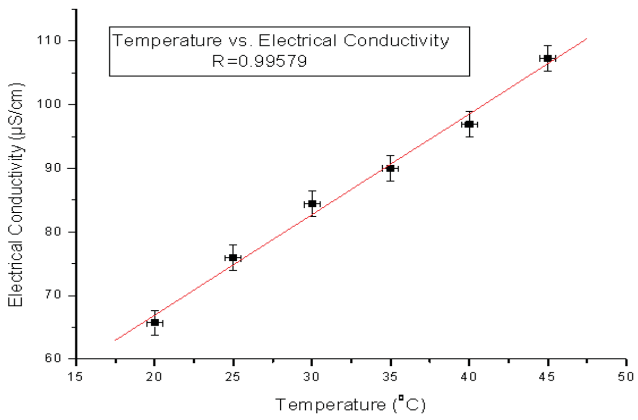



Figure 25: Temperature vs. Electrical conductivity.

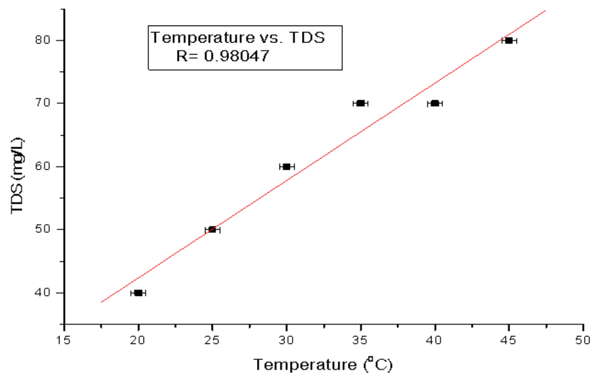



Figure 26: Temperature vs. TDS

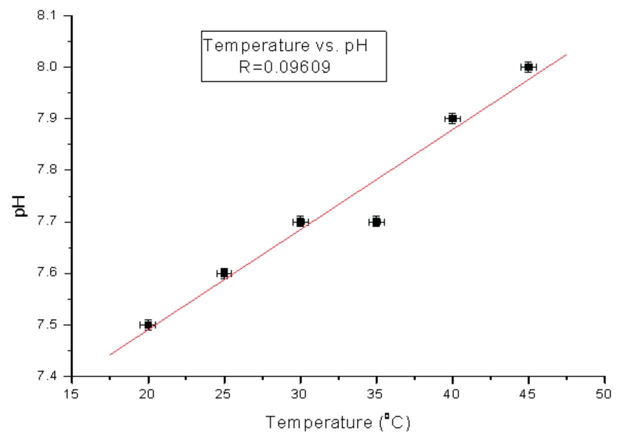



Figure 27: Temperature vs. pH.

## Verification Linear Equation of EC and Temperature

Table V: Measured and calculating value of Electrical Conductivity for study sample

| **Sample Name** | **Temperature ( °C)** | **Electric Conductivity** (µS/cm) from measured value | Electrical Conductivity (µS/cm) from Equation |
|---|---|---|---|
| **Duga Devithan** | 30 | 127.3 | 127.6 |
| | 35 | 136.7 | 138.7 |
| | 40 | 148.2 | 149.8 |
| | 45 | 159.7 | 161.0 |
| **Khanal Dhara** | 30 | 72.2 | 70.0 |
| | 35 | 79.1 | 77.8 |
| | 40 | 89.1 | 85.6 |
| | 45 | 95.1 | 93.4 |

| | | | |
|---|---|---|---|
| **Lamsal Dhara** | 30 | 69.4 | 67.8 |
| | 35 | 72.4 | 71.1 |
| | 40 | 80.4 | 78.2 |
| | 45 | 88.3 | 85.3 |
| **Nepal Dhara** | 30 | 75.5 | 72.9 |
| | 35 | 86.7 | 85.7 |
| | 40 | 97.6 | 94.3 |
| | 45 | 117.9 | 102.9 |
| **Swanay Source** | 30 | 84.4 | 83.14 |
| | 35 | 90.0 | 90.39 |
| | 40 | 96.9 | 97.64 |
| | 45 | 107.3 | 104.89 |

Source: Data computed by Authors 2013

*Note:*
*The temperature and EC relation is not linear for natural water (millero 2001). However, the degree of nonlinearity is relatively small in a temperature range of environmental monitoring (0 –30 ?C), and a linear equation (Sorensen, J. A. And Glass G. E 1987) is commonly used to represent the relation;*

$$EC_t - EC_{25}[1 + \alpha(t - 25)]$$

*Where* $EC_t$ *the Electrical Conductivity at temperature t (* $^0C$*) is,* $EC_{25}$ *is the Electrical conductivity at temperature 25* $^0C$ *and* $\alpha$ *is a temperature compensation factor. The value of* $\alpha$ *is commonly use 0.0191 (Clesceri, et al 1998 ). The above verifications show that all the water samples are followed the EC -Temperature linear equation. The EC-temperature relation is primarily controlled by the viscosity of water (Korson, L. Hansen, D. W. & Millero F. J. 1969 ). Viscosity-based equation is given by:*

$$EC_t = EC_{25}\left(\frac{\mu_t}{\mu_{25}}\right)^{-b}$$

*Where* $\mu_t$ *and* $\mu_{25}$ *are the viscosities of pure water at temperature t and 25* $^0C$ *respectively "b" is the dimension less constant.*

*An increase in a water temperature will cause a decrease in its viscosity and an increase in the mobility of the ions in water. An increase in temperature may also cause an increase in the number of ions in water due to dissociation of molecules. As the conductivity of water is dependent on these factors then an increase in the water temperature will lead to an increase in its conductivity. If conductivity will increase then TDS also increase with increase in temperature (Barron & et al TSP -07 issue 3).*

## CONCLUSION

From the above result, Electrical Conductivity is high in sample of Duga Devithan Source whose altitude is 842.5 mts and it is very low for the sample of Nepal Dhara whose altitude is very high about 1486 meter and pH value of Duga Devithan Source is 8.0 and for Nepal Dhara is 6.7. So we concluded that, higher attitude springs have low Electrical Conductivity and the lower altitude springs have high Electrical conductivity. It shows that springs water at higher altitude are acidic and springs water at lower altitudes are basic in nature. Because water of lower altitudes springs are passed through number of rocks in their travelling way that added the minerals responsible for basic nature of water and also responsible for rising amounts of Total Dissolve Solid and also influence the K factor variation ranges from 0.55 to 0.85 (table-IV)

Electrical Conductivity, TDS, pH are linearly increase with the rising temperature. The linearity factor R is 0.99579, 0.98047 and 0.09609 respectively for Sawnay Dhara. This linearity happens because of decreasing of its viscosity and an increasing the mobility of ions in water with rising temperature. The linear equations of Electrical Conductivity -Temperature relation are verified. We also see that K-factor values are lies between 0.55 - 0.80.

Magnesium ($Mg^{2+}$, Cation) concentration is high for sample of Duga Devithan Source (13.313 mg/L) and low for sample of Khanal Dhara (4.396 mg/l). So the Electrical Conductivity is high for Duga Devithan Source (101.5µS/L) and low for Khanal Dhara (49.4µS/L) due to the high conductivity factor of $Mg^{2+}$ (3.82µS/cm per mg/L) in case Duga Devithan Source and Khanal Dhara.

Nitrate ($NO_3^-$) concentration in Duga Devithan Source is high (5.505 mg/L) among the study sample. So this spring water act as natural source of nitrates for the soil. The chemical compositions of the entire samples are lies in the drinking water range except nitrate concentration for Duga Devithan Source it is little bit higher the permissible limit. So people can use this spring water for drinking and other purpose.

## ACKNOWLEDGEMENT

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## REFERENCES


1.Atkins, P. Paula D. J (2006) Atkins' Physical Chemistry (8thedition) in OXFORD UNIVERSITY PRESS

2.Atekwana, A. E. Rowe, S. R. Werkema, D. D. Legall, F. J. D & et al (2004) The relationship of total dissolved solids measurements to bulk electrical conductivity in an aquifer contaminated with hydrocarbon, in Journal of Applied Geophysics, Vol. 56, pp. 281– 294

3.Brian, A. Pellerin, W. M. Xiahong F. & Charles, J. V (2007) The application of electrical conductivity as a tracer for hydrograph separation in urban catchments; Hydrological Process in John Wiley & Sons, Ltd.

4.Coder, K. D & Warnell, B. D (1999) Basic Water Properties: Attributes and Reactions Essential for Tree Life, in School of Forest Resources, University of Georgia, U.S.A

5.Canadian Council of Minister of Environment (2011) Protocols Manual for Water Quality Sampling in Canada, Canada

6.David, R. H. Susan, S (1993) Electrical Conductivity in Science Activity, Spring Vol.30

7.Dahlena, J. Karlssona, S. Mattias, B. Jessika, H. Pettersson, H (2000) Determination of nitrate and other water quality parameters in groundwater from UV/Vis spectra employing partial least squares regression, in Chemosphere Vol. 40, pp. 71-77

8.Dekker A. J (1958) Solid state physics (1st edition), Macmillan publisher India ltd, New Delhi

9.Department of Health and Community Services Environmental Public Health Division (2011) Drinking Water Manual: Bacteriological Water Quality Public and Private Water Supplies, in New Foundland Laboratory, Canada

10.Deshpande, L - Water Quality Analysis Laboratory Methods, National Environmental Engineering Research Institute (NEERI), Nagpur, Council of Scientific & Industrial Research, New Delhi, Govt. of India

11.Ela, W. P (2007) Introduction to Environmental Engineering and Science, (3rd edition) Prentice Hall Publication

12.Eisenberg, D. & Kauzmann, W (1969) The Structure and Properties of Water, in Oxford University Press, Oxford, London

13.Fetter, C. W (1990) Applied hydrogeology, in Charles E. Merril Publ. Co. USA

14.Freese, S. D. Trollip, D.L & Nozaic, D. J (2003) Manual for Testing of Water and Wastewater Treatment Chemicals, Water Research Commission, Pietermaritzburg, Russia

15.Hiscock, K. M. Dennis, P. F. Saynor, P. R. & Thomas, M. O (1996) Hydro-Chemical and stable isotope evidence for the extent and nature of the effective Chalk aquifer of north Norfolk, U.K, in J. Hydrology, vol. 180, pp. 79- 107

16.Henderson, L. J (1913) The Fitness of the Environment: An Inquiry in to the Biological Significance of the Properties of Matter, in Macmillan, New York

17.Hounslow, A (1995) Water quality data: analysis and interpretation (1st edition), in Lewis publisher

18.IAPWS (2007) Thermodynamic Properties of Water and Steam in International Association for the Properties of Water and Steam, Lucerne, Switzerland

19.John, J. B. & Ashton, C (2011) The Effect of Temperature on Conductivity Measurement, in TSP-07 Issue 3. www.reagecon.com.

20.Jeelani, G. H. Nadeem, A. B. Shivanna, K & et al ( 2011) Geochemical characterization of surface water and springwater in SE Kashmir Valley, western Himalaya: Implications to water–rock interaction, in J. Earth Syst. Sci. Vol. 120, No. 5, October, pp. 921–932

21.Jeffrey, M. Donald, I. Siegel W. P. McKenzie, D. J. et al (2001) A geochemical survey of spring water from the main Ethiopian rift valley, southern Ethiopia: Implications for well-head protection, in Hydrogeology Journal Vol. 9 pp. 265–272

22.Kobayashi, D (1986) Separation of a snow melts hydrograph by stream conductance, in J. Hydrology, vol. 84, pp. 157- 165

23.Kumar, S. P. J (2013) Interpretation of groundwater chemistry using piper and chadha´s diagrams: a comparative study from perambalur taluk, in Elixir Geoscience, Vol. 54, 12208-12211.

24.Korson, L. Hansen, D. W. & Millero F. J (1969) Viscosity of water at various temperatures, in J. Phys. Chem. Vol. 73, pp. 34- 39

25.Keller, G. V. And Frischknecht, F. C (1966) Electrical Methods in Geophysical Prospecting, in Pargamon Press, Oxford

26.Kaustubh, M. and Himanshu, K (2012) Groundwater resources and spring hydrogeology in South Sikkim with special reference to climate change, govt. of Sikkim, Gangtok
27.L. S. Clesceri, L.S. A. E. Greenberg, A. E. Eaton A. D (1998) Standard Methods for the Examination of Water and Wastewater in 20th ed., American Public Health Association, Washington, D. C
28.Masakihayashi (2004) Temperature - electrical conductivity relation of water for environmental monitoring and geophysical data inversion, in Environmental Monitoring and Assessment, vol. 96 pp. 119–128
29.Millero, F. J (2001) The Physical Chemistry of Natural Waters, Wiley-Interscience, New York
30.Moore, R. D. Richard, G. & Story, A (2008) Electrical Conductivity as an Indicator of Water Chemistry and Hydrologic Process, in Streamline Watershed Management Bulletin (spring) Vol. 11, No. 2
31.Negi, G. C. S. and Joshi, V (2002) Drinking Water Issues and Development of Spring Sanctuaries in a Mountain Watershed in the Indian Himalaya, in Mountain Res. Dev. Vol. 22, no. pp. 29 – 31
32.Pisal, A (2010) Water and environmental analysis, in PerkinElmer, Inc
33.R. A. Robinson, R. A. and Stokes, R. H (1965) Electrolyte Solutions, in Butter worth's, London, U.K
34.Sorensen, J. A. & Glass, G. E (1987) Ion and Temperature Dependence of Electrical Conductance for Natural water in Analyt.. Chem. Vol. 59, pp 1594- 1597
35.SubhraSuchi, S. Ali, A. M. Bhattacharya, G. De, S. P. Roy, B. C. Nambiar, K.V. & Kkan, I. K. (2012) Geology and mineral resources of Sikkim, in GEOLOGICAL SURVEY OF INDIA (GSI) Govt. of India
36.Stanley, E. M (2010) Environmental Chemistry in CRC press, Taylor & Francis group, U.S.A
37.Sharap, A. K (2001) Water: Structure and Properties in Encyclopedia of Life Sciences, John Wiley & Sons, Ltd. USA
38.Tambe, S. Arrawatia, M. L. Bhutia, N. T & Swaroop, B (2011) Rapid cost-effective and high resolution assessment of climate-related vulnerability of rural communities of Sikkim Himalaya, India in Current Science vol. 101, no. 2, 25th July.
39.U.S. Environmental Protection Agency (2010) Learning about Lakefront Property in Office of Wetlands, Oceans, and Watersheds 1200 Pennsylvania, Washington, DC 20460
40.http://www.epa.gov/acidrain/education/site_students/phscale.html