SUITABILITY ANALYSIS OF DRINKING WATER FROM THE SPRINGS OF DEUMAI WATERSHED ILAM, NEPAL

A PROJECT WORK SUBMITTED TO THE

DEPARTMENT OF CHEMISTRY

CENTRAL CAMPUS OF TECHNOLOGY

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY

NEPAL

FOR THE AWARD OF

BACHELOR OF SCIENCE (B.Sc.) IN CHEMISTRY

BY

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SYMBOL No: 500080023

T.U. REGISTRATION No: 5-2-8-61-2018

[MAY, 2023]

RECOMMENDATION

This is to recommend that **Priya Darshan Shrestha,** (Symbol No 500080023, T.U. Registration No 5-2-8-61-2018), has carried out project work entitled "**Suitability analysis of drinking water from the springs of Deumai watershed Ilam, Nepal"** for the requirement to the project work in Bachelor of Science (B.Sc.) degree in Chemistry under my supervision in the Department of Chemistry, Central Campus of Technology, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal.

To my knowledge, this work has not been submitted for any other degree.

He has fulfilled all the requirements laid down by the Institute of Science and Technology, Tribhuvan University, Nepal for the submission of the project work for partial fulfilment of Bachelor of Science (B.Sc.) degree.

Asst. Prof. Mr. Manoj Khanal

Supervisor

Department of Chemistry

Central Campus of Technology

Tribhuvan University

[MAY, 2023]

DECLARATION

This project work entitled "**Suitability analysis of drinking water from the springs of Deumai watershed Ilam, Nepal**" is being submitted to the Department of Chemistry, Central Campus of Technology, Institute of Science and Technology, Tribhuvan University, Nepal for the partial fulfillment of the requirement to the project work in Bachelor of Science (B.Sc.) degree in Chemistry. This project work is carried out by me under the supervision of Asst. Prof. Mr. Manoj Khanal in the Department of Chemistry, Central Campus of Technology, Institute of Science and Technology, Tribhuvan University, Nepal.

This work is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

....

Priya Darshan Shrestha

Symbol No. 500080023

T.U. Registration No. 5-2-8-61-2018

[MAY, 2023]

LETTER OF FORWAR

[Date: May, 2023]

On the recommendation of **Mr. Manoj Khanal**, this project work is submitted by **Priya Darshan Shrestha,** Symbol No 500080023, T.U. Registration No 5-2-8-61-2018, entitled "**Suitability analysis of drinking water from the springs of Deumai watershed Ilam, Nepal**" is forwarded by the Department of Chemistry, Central Campus of Technology for the approval to the Evaluation Committee, Institute of Science and Technology, Tribhuvan University, Nepal

He has fulfilled all the requirements laid down by the Institute of Science and Technology, Tribhuvan University, Nepal for the project work.

Asst. Prof. Mrs. Lalita Shrestha
Head of Department
Department of Chemistry
Central Campus of Technology
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[MAY, 2023]

BOARD OF EXAMINATION AND CERTIFICATE OF APPROVAL

This project work (PRO-406) entitled entitled **"Suitability analysis of drinking water from the springs of Deumai watershed Ilam, Nepal"** by Priya Darshan Shrestha, (Symbol No 500080023, T.U. Registration No 5-2-8-61-2018) under the supervision of Mr. Manoj Khanal in the Department of Chemistry, Central Campus of Technology, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), is hereby submitted for the partial fulfillment of the Bachelor of Science (B.Sc.) degree in Chemistry. This report has been accepted and forwarded to the Controller of Examination, Institute of Science and Technology, Tribhuvan University, Nepal for the legal procedure.

Asst. Prof. Mr. Manoj Khanal
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Priya Darshan Shrestha

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[May, 2023]

ABSTRACT

Spring is one of the major sources of drinking water in hilly and Himalayan region. The aim of this study was to check whether the water was suitable for drinking or not by studying the physicochemical properties. Springs of Deumai watershed Ilam, Nepal was investigated for water samples and the physicochemical parameters studied were TDS, pH, temperature, total hardness, alkalinity, total iron and major ion concentrations (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, NO_3^-) to describe the water's chemical characteristics. The determination of concentration of chemical parameters was performed by using spectrophotometric method, flame photometric method and titration method. According to the findings and comparison with the guidelines of drinking water given by World Health Organization (WHO) and National Drinking Water Quality Standard (NDWQS), the water quality for drinking water was found within the standards set by them. The average pH was found 7.47. And the dominance trend for major cations was $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and for anions was $Cl^- > NO_3^- > SO_4^{2-}$. All the values obtain were within the range specified by WHO and NDWQS guidelines of drinking water.

Keywords: watershed, physicochemical, spectrophotometric, pH, dominance.

शोधसार

Spring पहाडी र हिमाली क्षेत्रमा पिउने पानीको प्रमुख स्रोत हो। यस अध्ययनको उद्देश्य भौतिक रसायनिक गुणहरू अध्ययन गरेर पानी पिउनका लागि उपयुक्त छ वा छैन भनी जाँच्नु थियो। देउमाई जलाधार इलाम, नेपालका मुहानहरूको पानीको नमूनाहरूको अनुसन्धान गरिएको थियो र अध्ययन गरिएको भौतिक रसायनिक मापदण्डहरू TDS, pH, तापमान, कुल कठोरता, क्षारीयता, कुल फलाम र प्रमुख आयन सांद्रता (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, NO_3^-) थिए। रासायनिक मापदण्डहरूको निर्धारण एकाग्रता स्पेक्ट्रोफोटोमेट्रिक विधि (Spectrophotometric method), ज्वाला फोटोमेट्रिक विधि (Flame photometric method) र टाइट्रेसन विधि (Titration method) प्रयोग गरेर प्रदर्शन गरिएको थियो। विश्व स्वास्थ्य संगठन (WHO) र राष्ट्रिय खानेपानी गुणस्तर मानक (NDWQS) ले दिएको पिउने पानीको दिशानिर्देशसँग यस अध्ययनको निष्कर्षलाई तुलना गर्दा उनीहरूले तोकेको मापदण्डभित्र पिउने पानीको गुणस्तर पाइयो। । औसत pH 7.47 फेला पर्यो र प्रमुख cations को प्रभुत्वको प्रवृत्ति $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ थियो र anions को लागि $Cl^- > NO_3^- > SO_4^{2-}$ थियो। प्राप्त मानहरू WHO र NDWQS द्वारा दिईएको पिउने पानीको दिशानिर्देशहरूको निर्दिष्ट दायरा भित्र थिए।

Keywords: जलाधार, भौतिक रसायनिक, Spectrophotometric, pH, प्रभुत्वको

LIST OF ACRONYMS AND ABBREVIATION

APHA:	American Public Health Association
DO:	Dissolved Oxygen
EBT:	Eriochrome Black T.
EC:	Electrical Conductivity
EDTA:	Ethylenediaminetetraacetic acid
EI:	Electronics India
HKH:	Hindu Kush Himalaya
NDWQS:	National Drinking Water Quality Standards
pH:	Potential of Hydrogen
TDS:	Total Dissolved Solids
UV-VIS:	Ultraviolet-Visible
UN:	United Nations
USA:	United States of America
WQI:	Water Quality Index
WHO:	World Health Organization

LIST OF SYMBOLS

%	Percentage
<	less than
>	greater than
ºC	degree Celsius

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CHAPTER 1

1. INTRODUCTION

1.1 General Introduction

1.1.1 Water

Water is an important natural resource that is essential for all forms of life (Karegi et al., 2018). All the natural resources found in the earth are valuable but water resource is most valuable. Earth, also called the blue planet, gets its name from its abundance of water (Iqbal & Gupta, 2009; Maruyama et al., 2013).

1.1.2 Groundwater

One of the most precious resources is groundwater, as it concerns with many sectors of human consumption and is regarded superior than other resources. Worldwide water assets are defenseless due to the expanding drift of populace, contamination potential, and alteration of climate (Ahmed et al., 2020). Water below the ground, due to its widespread availability and good quality is an essential source for living beings. The geochemical setup of the fundamental rock strata, the recharge water standard, the soil-water interconnection process, the rocks found in the unsaturated region and their interaction with recharge water, the length of time in the aquifer, and the processes occurring in the aquifer are all factors that determine the quality of groundwater in a given area (Kaur et al., 2019). Groundwater has been widely used for drinking, irrigation, and numerous industrial applications across the world as an essential source of water supply (Baloch et al., 2021).

In the Hindu Kush Himalaya (HKH) region, a major source of water for millions of people is groundwater in the form of springs. Mountain springs address human requirements for dependable, sustainable freshwater, enhance livelihoods, and preserve environmental equilibrium. In the mid-hills of the HKH, springs contribute significantly to riverine base flows. For mountain communities, they also have a great deal of cultural significance (Dhakal et al., 2015).

From the starting, groundwater was considered as a profoundly secure asset on the soil but within the display circumstance, it has gotten to be uncouth since the defilement of squander contamination rises in groundwater (Ahmed et al., 2020).

1.1.3 Springs

Water below the ground in the higher geographical region like hills and mountains appears on the surface in the form of springs, the natural discharge features of groundwater system. People in Nepal's mountainous regions depend heavily on springs for their survival and are valuable resources that play main roles in fulfilling the requirements of human, maintaining balance in ecosystem and providing riverine base flow (Khadka & Rijal, 2020).. A spring is a place from where water below the ground is discharged creating flow which can be seen on the surface of the ground. The reason for discharge of water is due to the difference in the altitudes of aquifer's hydraulic head and the surface of land at that spot (Kresic & Stevanovic, 2009).

Although many permanent rivers originate in the Himalaya, inhabitants in the mountains and hills rely primarily on springs to supply their water demands. Communities in the HKH are experiencing record levels of water stress as a result of a decrease in spring flow. (Negi and Joshi, 2002; Tambe et al., 2012; Valdiya and Bartarya, 1989). Communities have abundant water during the monsoon season, but water scarcity is common during the dry season due to changing precipitation patterns (Dhakal et al., 2015).

1.1.4 Hydro geochemistry

Water's chemical quality is influenced by different geochemical process within groundwater and aquifer materials. Groundwater chemistry and hydrogeological regimes suggest that human actions and geological processes may influence water quality (Kumar et al. 2006; Bhat & Jeelani 2016). Hydrogeochemistry of groundwater provides an informative basis for its management and conservation for domestic, industrial, and agricultural purposes. Groundwater quality can be predicted using hydro-geochemical information. In hydrogeochemistry, the chemistry of water is used to determine where groundwater has come from and what it has experienced (Karegi et al., 2018). Additionally, it aids in water resource management by determining water's quality and suitability. We define "springshed" and emphasize the significance of springshed governance in the Nepal Himalaya. (Rijal, 2016).

Researchers can learn everything they need to know about the physical processes and chemical reactions that groundwater goes through, the roots, downpours, runoff, plus infiltration to the vadose zone, where it ultimately recharges the aquifer, thanks to groundwater hydrochemistry (Kura et al., 2018).

1.2 Significance of the study

The significance of this study lies in the analysis of water. The quality of drinking water is being deteriorate due to the unwanted activities of living beings near the water sources. The quality of drinking water must be investigated in various part of our country to know whether the water is suitable for drinking or not.

The study will offer important details about the condition of drinking water. It also gives detail about the amount of different radicals or ions present in the water. This helps in determining the usefulness of water for living beings. The result may aid for betterment of condition of drinking water as well as preservation of the source of drinking water.

In summary, the study is important to determine whether the drinking water is suitable for drinking or not. The study also helps in determining the average amount of ions present in water. The result of this study may help for further study of suitability of water and to check the change in hydro geochemistry of ground water.

1.3 Objectives

1.3.1 General Objectives

- To analyse the suitability of drinking water from the springs of Deumai watershed Ilam, Nepal.

1.3.2 Specific Objectives

- To analyse the suitability of drinking water from different springs found in that area.
- To determine the amount of anions. (SO_4^{2--}, NO_3^- and Cl^-)
- To determine the amount of cations. (Na^+, Ca^{++}, K^+ and Mg^{2+})
- To determine total hardness of water.
- To determine the alkalinity of water.
- To determine the total iron content in water.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Drinking water

Excellence of water plays an important role to determine the human health standards. Groundwater contamination is a global issue with economic and human health consequences (World Health Organization, 2004). The protection of public health is the main goal of the Drinking-water Quality Guidelines. Water is necessary for life, and everyone needs access to a sufficient (appropriate, safe) amount of it. Enhancing access to clean water for drinking can have real positive effects on health. To the greatest extent possible, a safe drinking water quality should be attained (WHO, 2011). Secure and easily accessible, whether it is utilized for drinking, residential use, food production, or recreation, water is crucial for maintaining public health. The UN General Assembly formally acknowledged the human right to water and sanitation in 2010. Everyone has the right to enough water for personal and domestic use that is available continuously, is safe, acceptable, physically accessible, and is inexpensive (WHO, 2019).

2.2 Springs and groundwater

Natural springs are main sources of freshwater in many mountainous regions. In many mountainous places, natural springs are the primary sources of freshwater. The majority of people in the Himalayan region rely on spring water for drinking, household purposes, and animal needs. Consequently, spring water is the primary supply of water that keeps people alive in mountainous areas, particularly in the Himalaya. Numerous springs in the Nepalese Himalaya have been drying out quickly in recent years, and no systematic strategy has been created to reactivate these drying springs (Rijal, 2016). A specific area's groundwater quality is a reflection of water-rock interaction, input rainfall, as well as local human operations like agriculture, home garbage, and trash from industry (Madhav et al., 2018).

Understanding the genesis of groundwater requires an understanding of how interactions between groundwater and aquifer minerals affect water quality, because the overall volumes and types of minerals dissolved from the nearby rocks determine the quality of groundwater. The pathways taken by groundwater and the interactions between rocks and water determine the concentration of dissolved ions (Khadka & Rijal, 2020).

2.3 Water and development

Due to the fact that it supports, among other things, the growth of agriculture, the production of electricity, civic and commercial applications, the development of cattle, the expansion of industry, the preservation of ecosystems, and leisure activities, water is a resource that is crucial for economic development (Kinuthia et al., 2009). Establishing the hydrogeochemical processes impacting groundwater is crucial in order to manage this finite resource properly (Zhang et al., 2017). Globally, semi-arid provinces rely heavily on groundwater for irrigation, residential, and industrial supply. According to earlier research, groundwater provides 65% of the world's home water supply, 20% of it is used for irrigation, and 15% is used for industrial reasons (Adimalla et al., 2018).

2.4 Water and its parameters

2.4.1 pH in drinking water

The negative common logarithm of the hydrogen ion activity is the pH of a solution.

$$pH = -\log (H^+)$$

The carbon dioxide-bicarbonate-carbonate equilibrium system regulates the pH of most naturally occurring fluids, which is a measurement of the acid-base equilibrium. The pH of most drinking water ranges from 6.5 to 8.5. Acid rain or a higher pH in limestone locations might cause natural waters to have a lower pH. The ideal pH range, which is typically between 6.5 and 9.5, will vary depending on the supply depending on the water's composition and the type of building materials used in the distribution system (World Health Organisation, 2007).

2.4.2 Hardness in drinking water

The conventional indicator of a water's ability to react with soap is its hardness, with hard water requiring significantly more soap to generate a lather. The amount of hardness in drinking water affects customer acceptance of the aesthetics as well as financial and operational factors. The most used way to measure hardness is in milligrams of calcium carbonate equivalent per litre (World Health Organization, 2005).

2.4.3 Sodium in drinking water

A common ion in water is sodium. Although levels can surpass 250 mg/litre in some nations, most water supplies have less than 20 mg of sodium per litre. Water can include substantial amounts of sodium through saline intrusion, mineral deposits, ocean spray, sewage effluents, and salt used for de-icing roads. Almost every food and beverage contain sodium salts. The latter normally contain less than 20 mg of sodium per litre, however in some countries, this value might be noticeably exceeded. When sodium levels are higher than 200 mg/litre, the taste of drinking water may be affected (World Health Organization (WHO), 2003).

2.4.4 Potassium in drinking water

Since potassium is a vital component of humans, it is extremely rare, if ever, to find it in drinking water at concentrations that pose a risk to healthy people. Due to the use of potassium permanganate as an oxidant in water treatment, potassium can also be found in drinking water. At this time, there is no proof that use of municipally treated drinking water, especially water treated with potassium permanganate, poses any health risks to people. Despite the fact that some health consequences of potassium may occur in those who are vulnerable, the amount of potassium in drinking water is much lower than the level at which these effects may manifest (World Health Organization (WHO), 2009).

2.4.5 Chloride in drinking water

In nature, chlorides can be found in large quantities as the salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). By using chlorine or chloride during treatment procedures, chloride levels in water may be significantly raised. The average adult human body has 81.7 g of chloride. As estimated 530 mg/day total obligatory loss of chloride, it has been suggested that people consume 9 mg of chloride per kilogram of body weight. he threshold depends on the accompanying cations, however chloride concentrations above 250 mg/litre can cause perceptible taste in water (WHO, 2011).

2.4.6 Nitrate in drinking water

The ions nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring and pervasive in the environment. Both are by products of nitrogen oxidation, which is a cycle necessary for the synthesis of complex organic compounds in all living systems. The most frequent nitrate and nitrite sources in water include agriculture (inorganic fertilizers and manure), wastewater treatment, nitrogenous human waste products, discharges from industrial processes, and motor vehicle exhaust. Most surface water and groundwater supplies in the USA contain nitrate at concentrations below 4 mg/L, with 3% of surface waters and 6% of groundwaters having concentrations above 20 mg/L. 50 mg/L of nitrate ion is the recommended level of nitrate in drinking water (WHO, 2011).

2.4.7 Sulphate in drinking water

Sulphates are found naturally in several minerals, such as gypsum ($CaSO_4.2H_2O$), epsomite ($MgSO_4.7H_2O$), and barite ($BaSO_4$). The available data do not point to a sulphate concentration in drinking water that is mostly to have a negative impact on human health. As concentrations in water rise above 500 mg/litre, there is a higher possibility that complaints may result from a detectable taste (WHO, 2004).

2.4.8 Iron in drinking water

Iron, which makes up around 5% of the earth's crust, is the second-most common metal. Since the iron ions Fe^{2+} and Fe^{3+} easily mix with substances containing oxygen and sulphur to generate oxides, hydroxides, carbonates, and sulphides, elemental iron is rarely seen in nature. Because iron (II) salts are unstable in drinking water supplies, they precipitate as soluble iron (III) hydroxide, which settles out as a rust-coloured silt. According to reports, rivers typically contain 0.7 mg/litre of iron. Iron concentrations in groundwater are are typically 0.5–10 mg/litre, but they can occasionally reach 50 mg/litre. Drinking water iron concentrations are typically less than 0.3 mg/litre, however they can be greater in some countries. Although iron concentrations of 1-3 mg/litre can be tolerable for persons drinking anaerobic well water, the taste and appearance of drinking water will typically be altered if change in concentration occurs (World Health Organization, 2003).

2.4.9 TDS in drinking water

Inorganic salts (mostly magnesium, potassium, calcium, sodium, chlorides, bicarbonates, and sulphates) and trace amounts of organic materials are dissolved in water to form total dissolved solids (TDS). TDS in drinking water comes from sewage, urban runoff, industrial effluent, and natural sources. Due to variations in the solubilities of minerals, TDS concentrations in water vary greatly among different geological locations. There are no trustworthy statistics on the potential health implications of consuming TDS in drinking water (World Health Organization, 2004).

2.5 World Health Organization

Over the course of a lifetime of usage, safe drinking water, as defined by the Guidelines, poses no significant risk to health (World Health Organization, 2004).

Table 1 WHO's standard values of different parameter for drinking water.

S.N.	Parameters	WHO Standards
1	pH	6.5-9.2
2	Sodium (Na^+)	<20 mg/L
3	Potassium (K^+)	<12 mg/L
4	Total hardness	10-500 mg/L
5	Calcium (Ca^{2+})	< 100 mg/L
6	Magnesium (Mg^{2+})	< 50 mg/L
7	Chloride (Cl^-)	< 250 mg/L
8	Nitrate (NO_3^-)	< 10 mg/L
9	Sulphate (SO_4^{2-})	< 100 mg/L
10	Iron	< 0.3 mg/L
11	Alkalinity	20-200 mg/L
12	TDS	< 1000 mg/L

2.6 Others

Madhav et al., (2018) reported the WQI values within 14.28 and 29.23 for his study area, rural areas of Sant Ravidas Nagar (Bhadohi), Uttar Pradesh. It was found that, when 20 samples were evaluated simply based on salt levels, 6 were outstanding to excellent, 13 were acceptable and 1 was unsure to unsuitable. Dhakal et al., (2015) reported a vast number of high discharges, perennial springs can be found in Godavari. Wetlands and springs are example of where groundwater is found. Godavari khola is a perennial body of water due to the springs in the Godavari watershed contributing to its base flows. In the study area, 40 springs that were located at various altitudes between 1,518–2,038 were found during the spring inventory that was conducted in June. The results show that the concentration of all dissolving ions (chemical and physical criteria) under investigation falls within the NDWQS standards set by the Nepalese government.

Kaur et al., (2019) studied the hydrogeochemical characterization of groundwater in alluvial plains of river Yamuna in northern India and found that the samples' cation-anion balance was within a range of 0-5%, which indicated that the laboratory analysis results were acceptable for the investigation. The trend followed by anions and cations for the mean concentration was $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ and $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ respectively. The various analysis results indicated majority of taken samples were freshwater.

The WHO (2011) proposed human consumption guidelines were used to estimate the WQI. When calculating WQI, ten (10) parameters were considered. The parameters were TDS. Na^+, Ca^{2+}, K^+, Mg^{2+}, SO_4^{2-}, HCO_3^-, Cl^-, NO_2^- and NO_3^-. Amrani et al., (2022) reported the value of WQI between 23.94 and 58.88 for the study area. It showed the calculated value of Na% of groundwater sample was between 5.65 and 20.07% and the average value calculated was 12.37%.

Baloch et al., (2021) explained to check the suitability of water for drinking, WQI is used. Groundwater quality was assessed using WHO guidelines because it was the most thorough way for figuring out the quality of ground water. The combined effects of several chemical factors on groundwater were carefully examined. The extensive data set was presented more effectively in the study using statistical analysis, which revealed the maximum, minimum, median, mean, standard deviation and percentiles. Observation of 17 parameters were done for ninety-five samples. The trend followed by concentration of anions were given as $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > F^-$. Similarly for cations it was $Na^+ > Ca^{2+} > Mg^{2+} > K^+$.

According to author's (Ahmed et al., 2020) study, the presence of large concentrations of certain characteristics can have a major impact on the groundwater's suitability for drinking, which is the main groundwater chemistry problem. Thirteen (13) groundwater chemical characteristics were used in this study to calculate the WQI for drinking in the study region. The finding indicates that 8.57% of the area has low groundwater quality, 51.42% has good groundwater quality and 40% has outstanding quality of groundwater. Additionally, it should be noted that the weighting of these groundwater indicators has been chosen based on their respective importance for drinking purposes. In Sagardari, the trend of cation abundance seen due to hydro-geochemistry was $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$.

Khadka & Rijal, (2020) reported, rainfall, for example, which has relatively low quantities of dissolved materials, is the source of ground water. Mineral solubility determines how slowly they dissolve in soil, sediment, and rocks. As a result, the spring water, which is at lower elevation than the others, has a high ion concentration. Major ionic species (Mg^{2+}, K^{+}, Na^{+}, Ca^{2+}, HCO_3^{-}, Cl^{-} and SO_4^{2-}) present in the water were used to characterize its type, and the hydro geochemical reactions that caused the ionic concentration were found. The spring water was mildly alkaline to slightly acidic. The general trend of order for cations were $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and for anions were $HCO_3^{-} > Cl^{-} > SO_4^{2-}$.

Many authors have examined whether water was suitable for consumption and irrigation, of different places in Nepal. The most of the analysis performed is found to be of terai region. The samples collected during the analysis are usually collected from the rivers, stream or underground water. There were only few studies that was performed by collecting the samples directly from the spring.

This study was performed for the spring water of Deumai watershed, Illam. No one had performed suitability analysis test for drinking water of this region before this study. Some comparisons between the parameters were done in this study.

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Materials

Various materials used in this study are listed in Appendix A.

3.1.1 Chemicals and reagents

Some of the chemicals and reagents used for the analysis are hydrochloric acid (HCl), EBT indicator, barium chloride ($BaCl_2$) crystals, potassium chromate indicator (K_2CrO_4), phenolphthalein indicator, ammonia buffer solution, silver nitrate ($AgNO_3$), sodium hydroxide (NaOH), etc. All other chemicals and reagents used are also listed in Appendix A.

3.1.2 Instruments

- Microprocessor UV-VIS Spectrophotometer
  Model-LT-291 (Single beam), Labtronics.
- Microprocessor Flame photometer
  Model: 1385, Electronics India (EI)
- Digital Balance
- pH meter
  pH meter model LT-10

3.2 Study Area

The study area is located in Ilam district of Koshi Province, Eastern Nepal (Fig 1). The Deumai Khola watershed is a rainfed perennial river system in Eastern Nepal. It is a sub-watershed of the greater Kankai River Basin. Its water is used for various purposes. There is presence of numerous springs in the area from where the local people utilize water for drinking and household purposes. The people living in this area highly depend on ground water for drinking as it is the natural and available source of water found in that area. Hence, the analysis of groundwater for drinking is important for such regions.

The figure 1 below shows the map of study area.

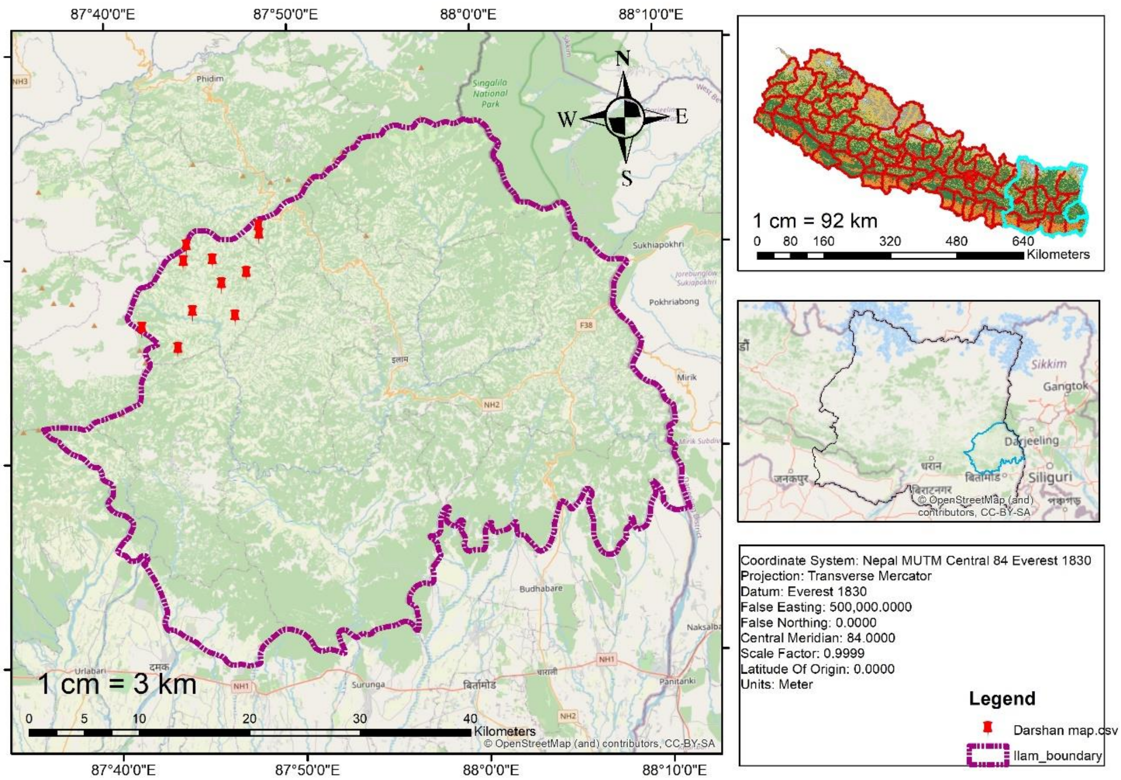

Figure 1 Map showing study area.

3.3 Methods

3.3.1 Determination of physical character

The physical character, temperature was measured immediately after sample was collected and was measured by using laboratory thermometer (Oyem et al., 2014). The pH of each sample was measured with portable field pH meter model LT-10 pre calibrated at buffer of ph 4 and 7 (Reda, 2016).

3.3.2 Determination of sulphate (SO_4^{2-}); Turbidimetric method (APHA, 2005)

Sulphate (SO_4^{2-}) was determined by using microprocessor UV-VIS spectrophotometer model-LT-291(single beam) at wavelength 420 nm. Firstly, the absorbance of standard sulphate solutions of concentration 1 mg/L, 5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L and 40 mg/L were measured and calibration curve was plotted. Before measuring the absorbance of another sample, the probe was rinsed properly with distilled water.

For calculation:

$$\text{mg } SO_4^{2-}/\text{L} = \frac{mg\ of\ sulphate\ ion \times 1000}{mL\ Sample}$$

3.3.3 Determination of nitrate (NO_3^-); Ultraviolet Spectrophotometric Screening method (APHA, 2005)

Nitrate (NO_3^-) was determined by using microprocessor UV-VIS spectrophotometer model-LT-291(single beam) at wavelength 220 nm. Firstly, absorbance of the standard solution of nitrate of concentration 1 mg/L. 2 mg/L, 4 mg/L and 7 mg/L were measured and calibration curve was plotted. Before measuring the absorbance of another sample, the probe was rinsed properly with distilled water.

For calculation:

By using a calculator, an electronic spreadsheet, or instrument software the slope and intercept of the calibration curve by at least squares linear regression was found. The following equation was used to get the NO_3^- -N concentration.

$$C = \frac{A - I}{S}$$

where:

C= concentration,

A = absorbance

I = intercept of the regression line, and

S = slope of regression line.

3.3.4 Determination of sodium and potassium; Flame emission photometric method

Both Sodium and potassium was determined by using microprocessor flame photometer model-1385. For sodium, firstly, the reading of standard sodium solution of concentrations 1 mg/L, 5 mg/L, 10 mg/L, 15 mg/L and 20 mg/L was measured. Before measuring absorbance of another sample, the probe was rinsed properly with distilled water.

Same procedure was followed to determine potassium and the standards solution used for potassium were of concentration 1 mg/L, 5 mg/L, 10 mg/L, 15 mg/L and 20 mg/L.

Calculation:

For sodium

$$\text{mg Na/L} = (\textit{mg Na/L in portion}) \times D$$

where:

$$D = \text{dilution ratio} = \frac{mL\ sample + mL\ water}{mL\ sample}$$

For potassium,

$$\text{mg K/L} = (mg\ K/L\ in\ portion) \times D$$

where:

$$D = \text{dilution ratio} = \frac{mL\ sample + mL\ water}{mL\ sample}$$

3.3.5 Determination of iron; Phenanthroline method (APHA, 2005)

Total iron in water was determined by using microprocessor UV-VIS spectrophotometer model-LT-291(single beam) at wavelength 510 nm. Firstly, absorbance of the standard solutions of iron of concentration 0.1 mg/L, 0.5 mg/L, 1 mg/L, 1.5 mg/L and 2 mg/L was measured. Before measuring absorbance of another sample, the probe was rinsed properly with distilled water. For calculation standard curve was used.

3.3.6 Determination by Titration method:

3.3.6.1 Determination of total hardness

Total hardness of water was determined by the titration of 50 mL of sample with 0.01*M* EDTA. Before titrating with EDTA, 1 mL of ammonia buffer and 100-200 gm of Eriochrome indicator was added. Which changed the colour of the solution to wine-red. At the end point blue colour was observed.

For calculation of total hardness:

$$\text{Hardness (mg/L) as } CaCO_3 = \frac{\text{ml of EDTA} \times 1000}{\text{Vol.of water (ml)}}$$

3.2.6.2 Determination of calcium

Calcium was determined by the titration of 50 mL of sample with 0.01*M* EDTA. Before titrating with EDTA, 2 mL of 0.1*N* NaOH and few mg of murexide indicator was added. Which changed the colour of the solution to pink. At the end point purple colour was observed.

For calculation of calcium,

$$Ca^{2+}\text{, mg/litre} = \frac{ml\ of\ EDTA \times 1000}{ml\ of\ sample \times 2.498}$$

3.3.6.3 Determination of magnesium

Since, the same volume of water was used for determination of total hardness as well as calcium, given relation was used for calculation of magnesium.

$$Mg^{2+}\text{, mg/litre} = \frac{ml\ of\ EDTA(for\ total\ hardness - for\ calcium) \times 1000}{ml\ oof\ sample \times 4.116}$$

3.3.6.4 Determination of alkalinity

Alkalinity of water was determined by titrating 50 mL of sample with 0.1N HCl by using phenolphthalein indicator and methyl orange. Firstly, phenolphthalein indicator was added. When colour of sample was changed then there is said to be phenolphthalein alkalinity and is titrated with HCl until the colour disappeared and the volume of HCl was noted (as X). No change in colour indicated that the phenolphthalein alkalinity was nil. After checking the phenolphthalein alkalinity, few drops of methyl orange were dropped and titration was continued till pink coloured end point. The volume of HCl was noted (as Y).

For calculation,

$$\text{Total alkalinity (mg/L) as } CaCO_3 = \frac{(X+Y) \times N\ of\ HCl \times 1000 \times 50}{ml\ of\ sample}$$

3.3.6.5 Determination of chlorine

Chloride in water was determined by titrating 50 mL of sample with silver nitrate by using 2 mL of potassium chromate indicator. The end point showed persistent red colour. Same procedure was followed for blank and it served as control.

For calculation,

$$\text{Chloride (mg/L)} = \frac{(Sample\ titer - Blank\ titer) \times N \text{ of silver nitrate} \times 1000 \times 35.5}{ml\ of\ sample}$$

CHAPTER 4

4. RESULT AND DISCUSSION

4.1 Results

The Government of Nepal published the National Drinking Water Quality Standard (NDWQS) in 2062 B.S as an effort to take step towards assuring drinking water quality. So, it is necessary to evaluate and differentiate the suitability of drinking water from the springs of Deumai watershed with National Drinking Water Quality Standard (NDWQS) and WHO.

The suitability analysis of drinking water is performed using different methods and different physicochemical parameters are studied. The parameters taken into account are TDS, pH, temperature, total hardness, alkalinity, total iron, Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^- and SO_4^{2-}. These parameters will help to determine the suitability as well as WQI of drinking water.

4.1.1 Study of physical parameters

The result of physical parameters i.e., temperature and TDS is shown in Table 2. The temperature value of spring water ranged from 17.4ºC to 23ºC with an average value of 19.4 ºC. The sample with the highest temperature value of 23ºC is WS-9 and with the lowest temperature value of 17.2ºC is WS-11. All the observed sample had an average temperature and within the limit value.

TDS was another physical parameter that was studied. The TDS value of samples is ranged from 16 mg/L to 226 mg/L. The highest TDS value is 226 mg/L found in sample WS-10 and the lowest TDS value is 16 mg/L in sample WS-3. TDS value of all the observed sample is within the limit value i.e., <1000 mg/L.

4.1.2 Study of chemical parameters

Another important water quality parameter is pH. The pH of studied sample ranged from 6.52 to 8.74. The range of pH is within the value of the standard pH given by WHO i.e., 6.5-9.5. The sample WS-9 has the most acidic pH value of 6.52 falling nearer to the lower level of guidelines value given by WHO and NDWQS. The pH value 8.74 is slightly greater than the standard value range given by NDWQS 2062 B.S. However, according to WHO the pH value between 6.5 to 9.5 usually indicates good drinking water quality.

Table 2 Temperature, pH and TDS of observed water samples.

S.N.	Sample	Temperature (ºC)	pH	TDS (mg/L)
1	WS-1	20	7	66
2	WS-2	19	7	41
3	WS-3	18.2	6.8	16
4	WS-4	18.1	8.34	84
5	WS-5	20	7.92	59
6	WS-6	18	8.27	23
7	WS-7	19	6.9	23
8	WS-8	19.5	7.48	37
9	WS-9	23	6.52	53
10	WS-10	21.2	7.2	226
11	WS-11	17.4	8.74	30

Table 3 Total hardness, alkalinity and total iron of studied sample.

S.N.	Sample	Total Hardness (mg/L) as $CaCO_3$	Alkalinity (mg/L) as $CaCO_3$	Total iron (mg/L)
1	WS-1	24.42	90	0.126
2	WS-2	29.22	108	0.228
3	WS-3	26.02	90	0.107
4	WS-4	33.00	126	0.105
5	WS-5	23.11	72	0.124
6	WS-6	14.47	72	0.384
7	WS-7	22.82	72	0.245
8	WS-8	9.66	54	0.104
9	WS-9	24.42	90	0.157
10	WS-10	97.12	252	0.195
11	WS-11	18.93	90	0.09

Total hardness is measurement of the mineral content in water that is irreversible by boiling. It is determined by the concentration of cations having more than one valency.

The highest value of total hardness found is 97.12 in the sample WS-10 and the lowest value is 9.66 in WS-8. Alkalinity is the capacity of water to resist acidification. It should not be confused with basicity. In this study, the most alkaline water with highest alkalinity value of 252 is sample WS-10. Sample WS-8 has the lowest value of alkalinity and is less alkaline. The alkalinity of WS-8 is 54. The maximum value of total iron is 3.384 mg/L in WS-6 and minimum value is 0.09 mg/L in WS-10. The concentration of hardness, alkalinity and total iron is within the standards of WHO.

The Figure 2 and 3 below shows the calibration curve that is plotted for the standard solutions of sodium and potassium respectively.

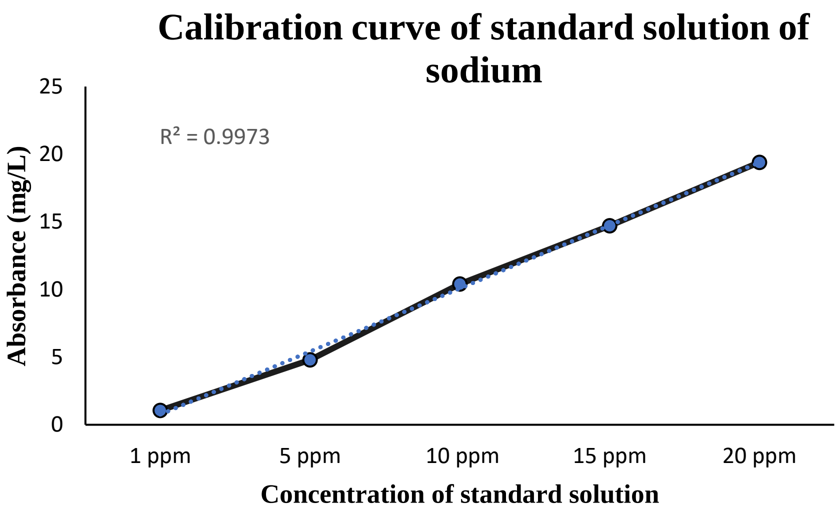

Figure 2 Calibration curve of standard solution of sodium (Na^+)

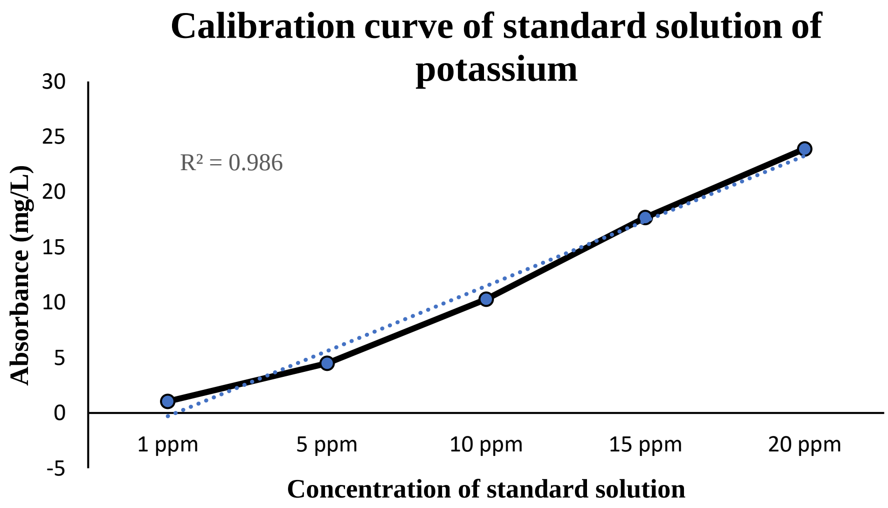

Figure 3 Calibration curve of standard solution of potassium (K^+)

Sodium (Na^+) and potassium (K^+) are one of the important cations that are present in the water. Their concentrations in drinking water are essential for suitability analysis. The Table 4 below, shows the concentration of sodium and potassium in the observed samples. The maximum concentration of sodium is found in sample WS-1 and the minimum concentration is found in WS-6 with the concentration of 15.3 mg/L and 4.9 mg/L respectively. For potassium, the maximum concentration is in WS-7 and minimum in WS-6 with the concentration of 4.4 mg/L and 0.35 mg/L respectively.

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) in water contributes for the total hardness of water. In this study, the maximum concentration of Ca^{2+} is 91.27302 mg/L in WS-10 and minimum concentration is 4.803843 mg/L in WS-8. For Mg^{2+}, maximum concentration is 6.804861 mg/L in WS-2 and minimum concentration is 0.979122 mg/L in WS-4. All the cations are within the standard limit set by WHO and NDWQS for safe drinking water.

Table 4 Concentrations of cations in the observed samples.

S.N.	Sample	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)
1	WS-1	15.3	2.7	17.61409	6.803695
2	WS-2	7.7	2.3	22.41793	6.804861
3	WS-3	12.6	4.3	19.21537	6.804083
4	WS-4	5.2	1.35	32.02562	0.979122
5	WS-5	13.8	4.4	19.21537	3.890047
6	WS-6	4.9	0.35	9.607686	4.85906
7	WS-7	15.1	5.9	16.01281	6.803306
8	WS-8	5.9	1.91	4.803843	4.857893
9	WS-9	14.8	2.3	17.61409	6.803695
10	WS-10	9.7	2.7	91.27302	5.850236
11	WS-11	5.7	2.5	16.01281	2.917924

Figure 4, 5, 6, and 7 shows the calibration curve of the standard solutions prepared for nitrate (NO_3^-), iron (Fe), sulphate (Buffer A and Buffer B) respectively.

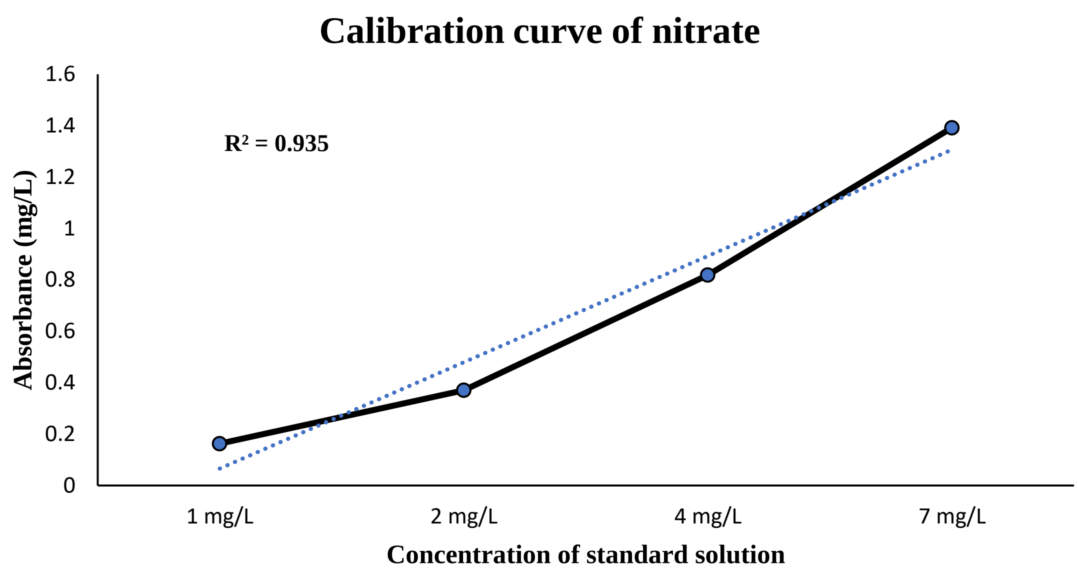

Figure 4 Calibration curve of nitrate (NO_3^-)

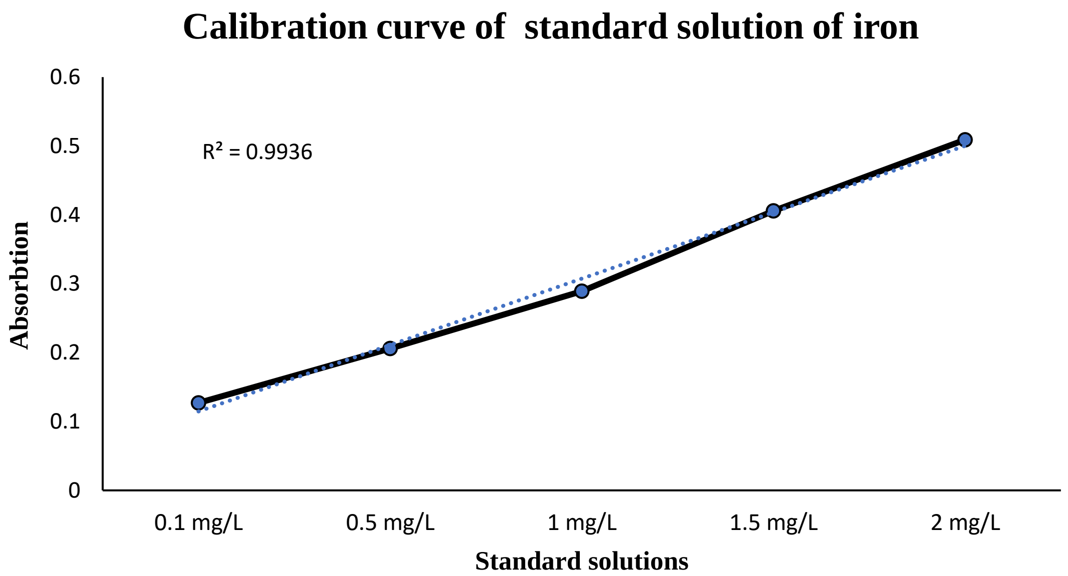

Figure 5 Calibration curve of Iron (Fe)

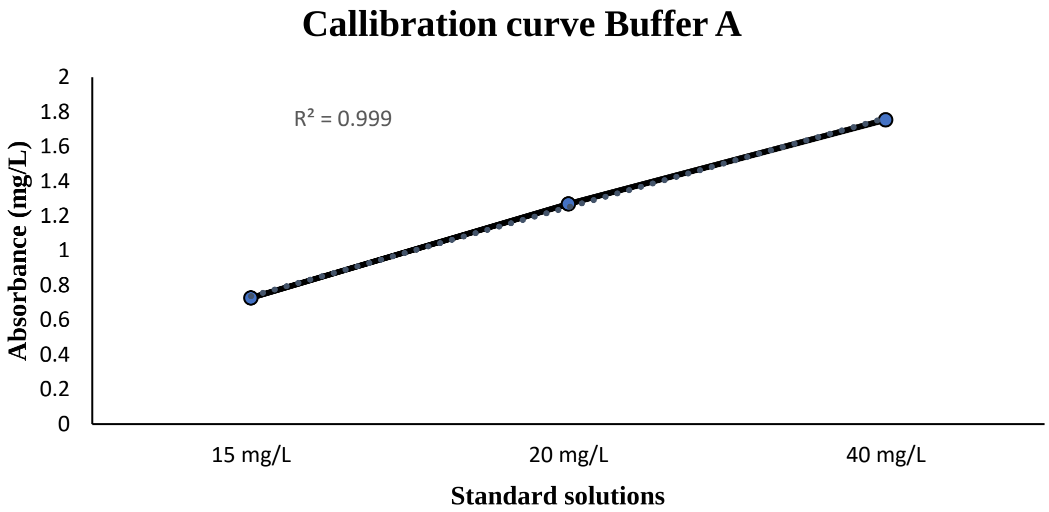

Figure 6 Calibration curve of sulphate (Buffer A for concentration > 10 mg/L)

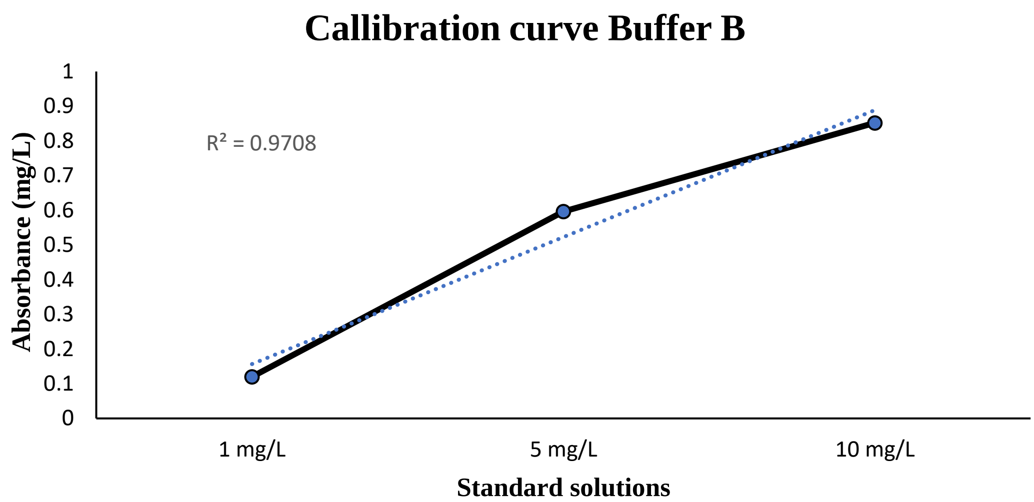

Figure 7 Calibration curve of sulphate (Buffer B for concentration < 10mg/L)

Anions are another important factor to determine the suitability of drinking water. In this study, the anions studied were chloride (Cl^-), nitrate (NO_3^-) and sulphate (SO_4^{2-}). The quantity of anions in the observed samples are given in Table 5 below.

The maximum value of chloride ion in observed samples is 24.14 mg/L in WS-7. In the both sample WS-6 and WS-8 the concentration of chloride is 2.84 mg/L which is the minimum value observed. Similarly, the maximum and minimum value for nitrate is 4.811451 mg/L (WS-5) and 1.632774 mg/L (WS-8). For sulphate, the maximum concentration is 2.765727 mg/L in WS-3 and minimum concentration is 0.173536 mg/L in WS-8.

Table 5 Concentrations of anions in the observed samples.

S.N.	Sample	Chloride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)
1	WS-1	8.52	2.363277	0.791757
2	WS-2	4.26	1.805528	0.780911
3	WS-3	14.2	2.639684	2.765727
4	WS-4	4.26	2.412636	0.531453
5	WS-5	12.78	4.811451	0.542299
6	WS-6	2.84	1.770977	0.175346
7	WS-7	24.14	3.898322	0.401302
8	WS-8	2.84	1.632774	0.173536
9	WS-9	9.94	1.662389	0.357918
10	WS-10	21.3	2.531096	0.260304
11	WS-11	1.42	1.820336	0.336226

The calculation of mean, standard deviation, variance and coefficient of variation is done for all parameters and the result is shown in Table 6 below.

Table 6 Value of mean, standard deviation, variance and coefficient of variation for all parameters.

Parameters	Mean	Stand. deviation	Variance	Coeff. of variation
TDS	59.818	58.891	3468.164	98.450
pH	7.47	0.735	0.540	9.840
Temperature	19.4	1.623	2.634	8.366
Sodium	10.06	4.336	18.803	43.088
Potassium	2.79	1.547	2.393	55.405
Calcium	24.16	23.287	542.284	96.367
Magnesium	5.22	1.956	3.826	37.500
Chloride	9.68	7.721	59.612	79.746
Sulphate	0.65	0.734	0.539	113.511
Nitrate	2.49	1.014	1.027	40.765
Total hardness	29.38	23.38	546.571	79.57
Alkalinity	101.454	53.561	2868.873	52.794
Total Iron	0.170	0.089	0.008	52.284

Ca^{2+} is present in larger quantity in comparison to other cations and Cl^{-} is present in larger quantity among anions. The mean TDS, pH, and temperature is 59.818 mg/L, 7.47 and 19.4ºC respectively.

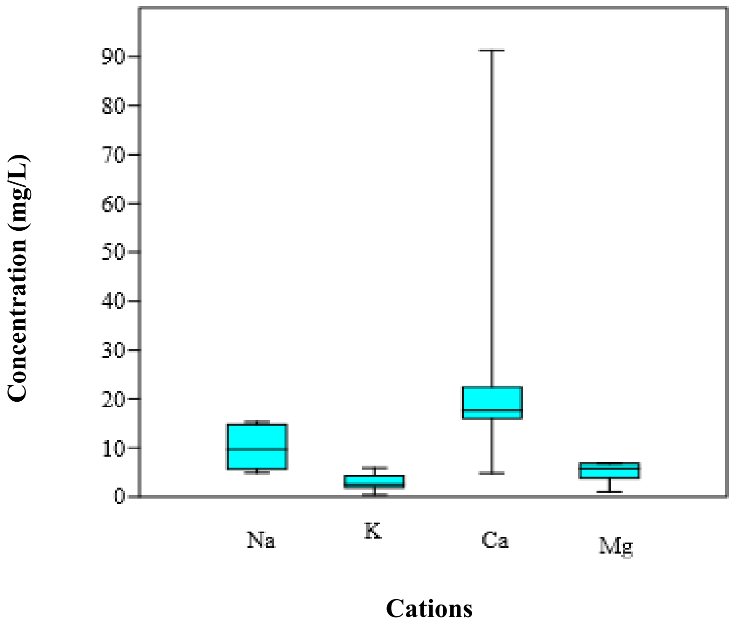

Figure 8 Box plot for cations

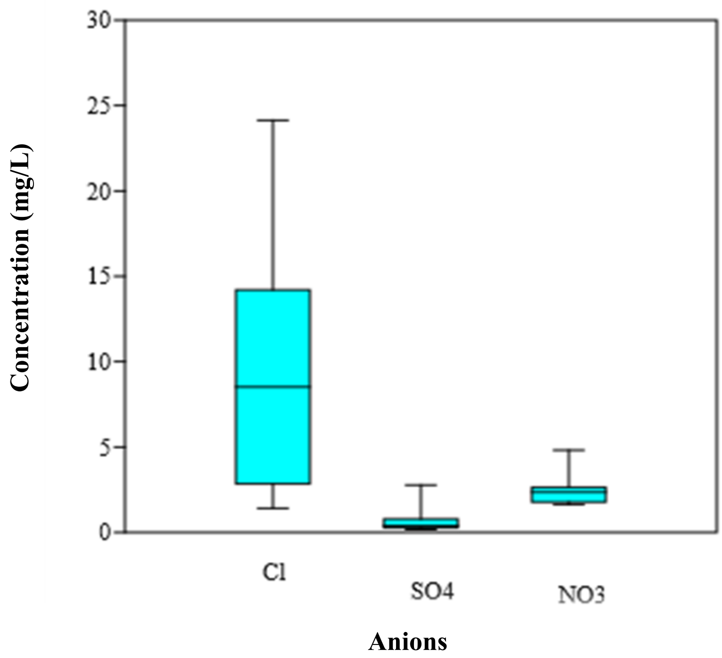

Figure 9 Box plot for anions.

The Fig 8 and 9 above shows the box plot for the concentration of cations and anions in the water sample respectively.

And, the fig 10 shows the comparison of cations within each water sample and fig 11 shows the comparison of anions in each water sample.

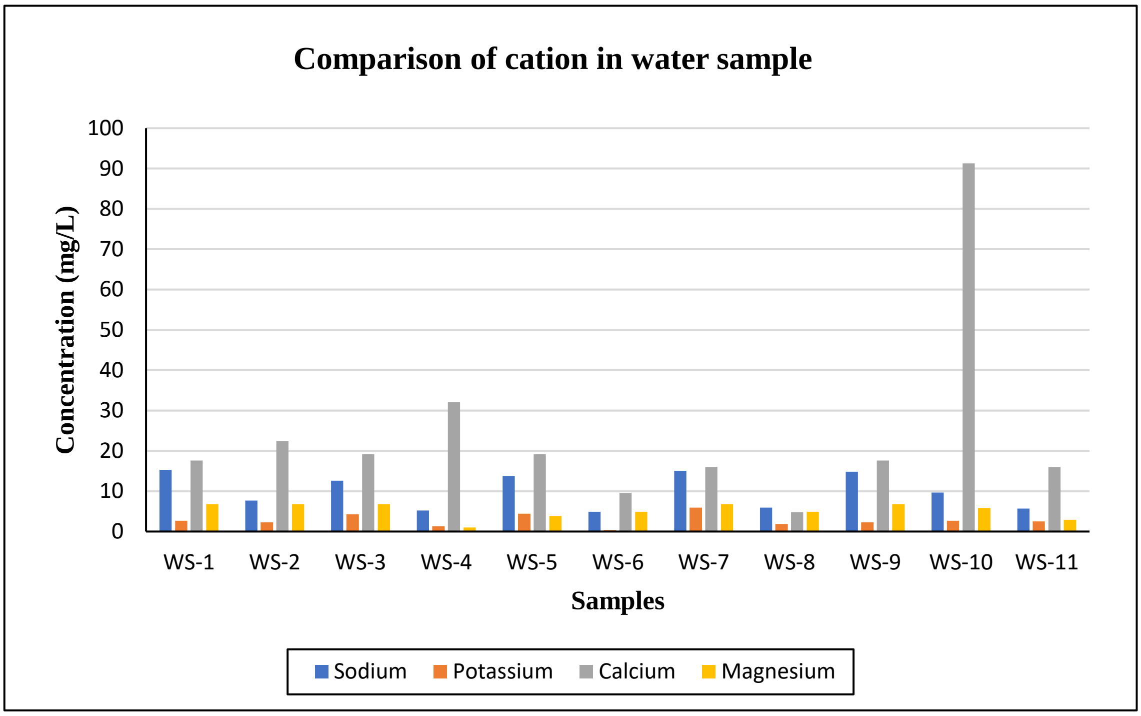

Figure 10 Comparison of concentration of cations within each water sample

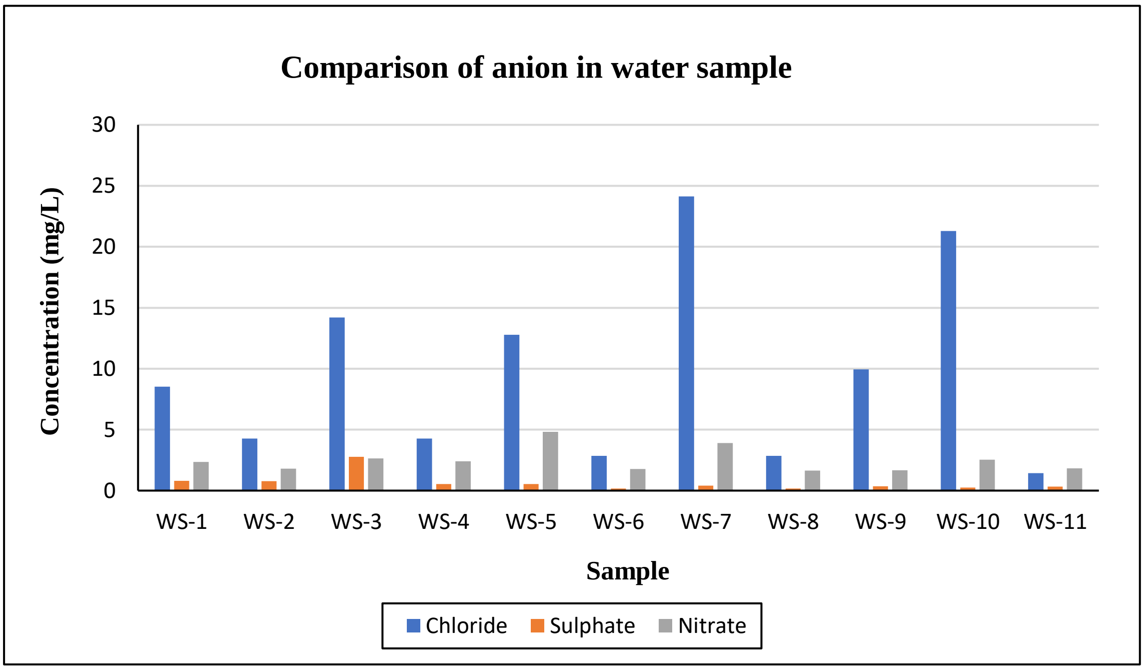

Figure 11 Comparison of concentration of anions within each water sample

The bar graph (Fig 10) indicates that the concentration of Ca^{2+} is maximum among cations in all the water sample. Whereas, the bar graph (Fig 11) indicates that the concentration of Cl^{-} is maximum among anions in all water sample except WS-11.

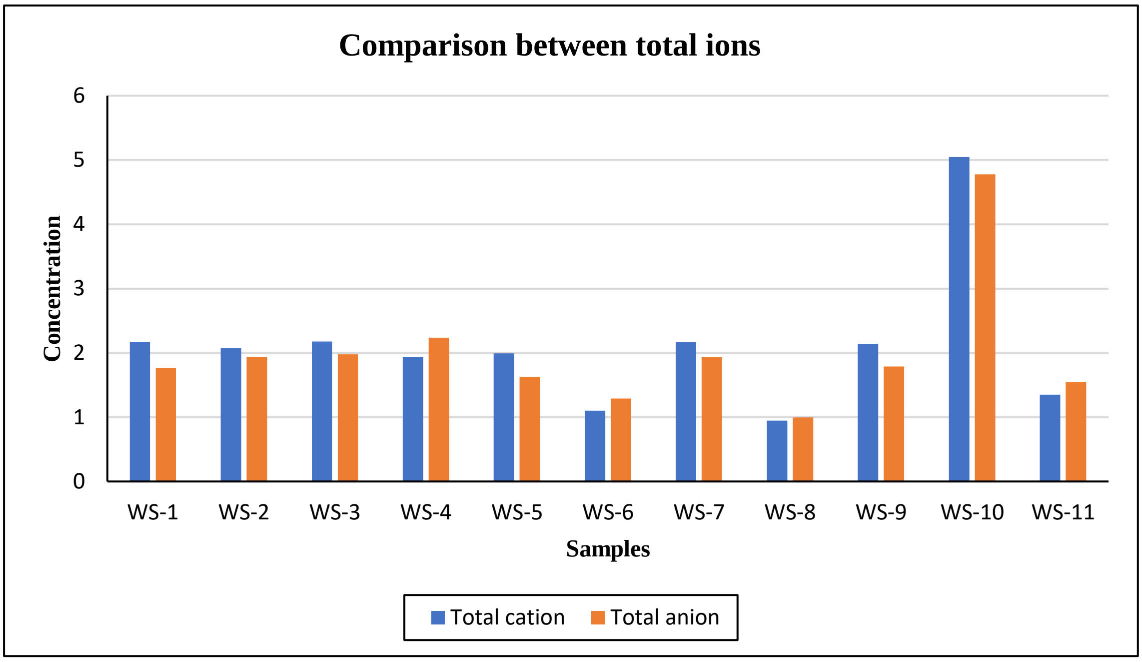

Figure 12 Comparison between total cation and anion within each water sample

Fig 12 above shows the comparison between total cation and anion within each water sample. The data plotted in the bar graph gives the information that 7 samples out of 11 has higher concentration of cation and rest are dominated by anions. The sample WS-10 contain the highest concentration of cation and anion among all the water sample.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusions

In this study, the suitability analysis for drinking water is done. All the results obtained for TDS, pH, temperature, total hardness, alkalinity, total iron, Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}, SO_4^{2-} and NO_3^{-} are found within the standard guidelines of drinking water given by WHO. The result also satisfies the guidelines of drinking water given by NDWQS. The average values of pH, temperature and TDS are 7.47, 19.4ºC and 59.818 mg/L respectively. The average value of total hardness and alkalinity found are 59.818 mg/L and 101.454 mg/L respectively. For total iron the average concentration was 0.17 mg/L. The general order of dominance of major cations in this study was $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$. For anions the order of dominance is $Cl^{-} > NO_3^{-} > SO_4^{2-}$.

By observing the concentration value of parameters in all the water sample and comparing it with the drinking water guidelines given by WHO and NDWQS, the values are found within the guidelines set for the drinking water.

5.2 Novelty and National Prosperity aspect of Project work

- The project work on suitability analysis of drinking water from the springs of Deumai watershed Ilam, Nepal has contributed to check the suitability of drinking water.
- This study provides useful information and helps the local people to know about the quality of drinking water.
- Overall, the project work has provided valuable information and contributed to the national prosperity and well-being of Nepal by studying the various parameter of drinking water and comparing it with the guidelines given by World Health Organization (WHO) and guidelines given by National Drinking Water Quality Standard (NDWQS).

5.3 Limitation of the study

- The study was only done for the water sample collected in Pre-Monsoon.
- The study of microbiological quality of water was not performed.

- Some of the parameters couldn't be studied due to unavailability of instrument and chemicals during the time of study.

5.4 Recommendation for further work

Further study of other parameters like DO, CO_3^{2-}, PO_4^{3-}, EC might be helpful for determining the quality more precisely. The study of microbiological quality of water is recommended for the further study to determine whether the water is suitable for drinking or not in the perspective of microbiology. Study of water for the irrigation purposes can also be performed in future. Also, one can check the history of hydro geochemistry of water of that place.

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APPENDIX A

MATERIALS REQUIRED

Glassware

Volumetric flask	Borosilicate
Conical flask	Borosilicate
Beakers	Borosilicate
Pipette	–
Burette	–
Glass tube and glass rod	–
Glass funnel	–
Measuring Cylinder	Borosilicate

Chemicals and reagents

Sodium acetate (CH_3COONa)	Thermo Fisher Scientific
Magnesium chloride ($MgCl_2.6H_2O$)	Central Drug House (CDH) P. Ltd.
Potassium nitrate (KNO_3)	Qualigens Fine Chemicals
Sodium sulphate (Na_2SO_4)	Qualigens Fine Chemicals
Magnesium sulphate ($MgSO_4.7H_2O$)	NICE
Phenolphthalein indicator	Qualigens Fine Chemicals
Methyl orange indicator	s.d Fine-Chem Pvt Ltd
Ammonium chloride (NH_4Cl)	NICE
Sodium chloride (NaCl)	Centrat Drug House (CDH) P Ltd.
Silver nitrate ($AgNO_3$)	Centrat Drug House (CDH) P Ltd.
Potassium chromate (K_2CrO_4)	NICE
Potassium chloride (KCl)	Qualigens Fine Chemicals

Sodium hydroxide (NaOH)	Centrat Drug House (CDH) P Ltd.
1,10-Phenanthroline ($C_{12}H_8N_2$)	Thermo Fisher Scientific
EDTA ($C_{10}H_{16}N_2O_8$)	s.d Fine-Chem Pvt Ltd.
Hydrochloric acid (HCl)	Thermo Fisher Scientific
Acetic acid (CH_3COOH)	Labort Fine Chem Pvt. Ltd

APPENDIX B

Sample	Sample site name	East	North
WS-1	Dokane Mul	26.94841	87.77933
WS-2	-	27.01467	87.8035
WS-3	School dada Muhan, Maidane	27.02134	87.80314
WS-4	Panch Puncho Dharo	27.00703	87.73697
WS-5	Sim Dhara	26.97501	87.76781
WS-6	Tiwa Khola Mul	26.9835	87.79067
WS-7	Bohara Khanepani, Khambang tol, PKT-1	26.99472	87.76011
WS-8	Devithan Sim, PKT-1	26.99412	87.7337
WS-9	Bhotekhet Muhan, salleri, Simal tol, PKT-3	26.95295	87.74061
WS-10	Dhade Muhan, Lumde, PKt-5	26.92322	87.72647
WS-11	Sabiako Muhan, Mahimba, PKT-4	26.94072	87.69414

APPENDIX C

Photo Gallery

Fig: Flame Photometer

Fig: Water samples

Fig: Glasswares

Fig: Standard solutions for iron

Fig: Result of titration

Fig: Laboratory work