SUITABILITY ANALYSIS OF IRRIGATION WATER FROM THE SPRINGS OF DEUMAI KHOLA 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

BIMAL KUMAR PODDAR

SYMBOL No.: 500080019

T.U. REGISTRATION No.: 5-2-8-49-2018

[MAY, 2023]

RECOMMENDATION

This is to recommend that **Bimal Kumar Poddar** (Symbol No.: 500080019 , T.U. Registration No.: 5-2-8-49-2018), has carried out project work entitled "**Suitability analysis of irrigation water from the springs of Deumai khola 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 IoST, T.U., Nepal for the submission of the project work for the partial fulfillment of B.Sc. degree.

....

Asst. Prof. Manoj Khanal
Department of Chemistry
Central Campus of Technology
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Nepal

[MAY, 2023]

DACLARATION

This project work entitled "**Suitability analysis of irrigation water from the springs of Deumai khola watershed, Ilam, Nepal**" is being submitted to the Department of Chemistry, Central Campus of Technology, IoST, T.U., Nepal for the partial fulfillment of the requirement to the project work in B.Sc. degree in Chemistry. This project work is carried out by me under the supervision of Asst. Prof. Manoj Khanal in the Department of Chemistry, Central Campus of Technology, IoST, T.U., 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.

....

Signature

Bimal Kumar Poddar

Symbol No. 500080019

T.U Registration No. 5-2-8-49-2018

[MAY, 2023]

LETTER OF FORWARD

[Date: May, 2023]

On the recommendation of **Mr. Manoj Khanal** this project work is submitted by **Bimal Kumar Poddar,** Symbol No. 500080019, T.U. Registration No. 5-2-8-49-2018, entitled "**Suitability analysis of irrigation water from the springs of Deumai khola watershed, Ilam, Nepal**" is forwarded by the Department of Chemistry, Central Campus of Technology, for the approval to the Evaluation Committee, IoST, T.U., Nepal.

He has fulfilled all the requirements laid down by the IoST, T.U., Nepal for the project work.

....

Asst. Prof. 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 "**Suitability analysis of irrigation water from the springs of Deumai khola watershed, Illam, Nepal**" by Bimal Kumar Poddar (Symbol No. 500080019 and T.U. Registration No. 5-2-8-49-2018) 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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[MAY, 2023]

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....

Bimal Kumar Poddar

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[MAY, 2023]

ABSTRACT

This study was aimed to assess the quality of groundwater from the springs of Deumai khola watershed, Ilam, Nepal, for the suitability in irrigation purposes. A total of 11 samples were gathered and examined during the PRM season. These samples were obtained from various springs. The investigation focused on determining the physicochemical characteristics, including EC, TDS, pH level, %Na, temperature, SAR, total hardness, alkalinity, total iron content, and the concentration of major ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-} and Cl^-. The ground water of the research area was somewhat alkaline to marginally acidic with average pH of 7.47. The average value of EC and TDS was observed 110.82 µS/cm and 53.73 mg/L respectively. The determination of concentration of chemical parameters was performed by using spectrophotometric method, flame photometric method and titration method. The average value of %Na and SAR was found to be 29.44 and 0.56 respectively. Also, the abundance order of major cations was; $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and that for anions was; $Cl^- > NO_3^- > SO_4^{2-}$. All of the parameters met the requirements set forth by the FAO for irrigation water.

Keywords: physicochemical, spectrophotometric, suitability, groundwater, abundance

शोधसार

यो अध्ययन सिँचाइ प्रयोजनका लागि इलामको देउमाई खोला जलाधार क्षेत्रका मुहानहरूबाट निस्कने भूमिगत पानीको गुणस्तर मूल्याङ्कन गर्ने उद्देश्यले गरिएको थियो। PRM सिजनमा कुल ११ नमूनाहरू सङ्कलन र परीक्षण गरिएको थियो। यी नमूनाहरू विभिन्न स्प्रिङहरूबाट प्राप्त गरिएका थिए। यो अनुसन्धान EC, TDS, pH स्तर, %Na, तापमान, SAR, कुल कठोरता, क्षारीयता, कुल फलाम, र Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, NO_3^{-}, SO_4^{2-}, Cl^{-} जस्ता प्रमुख आयनहरूको एकाग्रता सहित भौतिक रसायनिक विशेषताहरू निर्धारण गर्नमा केन्द्रित थियो। अनुसन्धान क्षेत्रको जमिनको पानी ७.४७ को औसत pH को साथ केहि हदसम्म क्षारीय देखि मामूली अम्लीय थियो। EC र TDS को औसत मान क्रमशः ११०.८२ μS/cm र ५३.७३ mg/L देखियो। रासायनिक मापदण्डहरूको एकाग्रताको निर्धारण स्पेक्ट्रोफोटोमेट्रिक विधि (Spectrophotometric method), ज्वाला फोटोमेट्रिक विधि (Flame photometric method) र टाइट्रेसन विधि (Titration method) प्रयोग गरेर प्रदर्शन गरिएको थियो। %Na र SAR को औसत मान क्रमशः २९.४४ र ०.५६ भेटियो। साथै, प्रमुख cations हरूको प्रशस्तता क्रम थियो; $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ र त्यो anions को लागि थियो; $Cl^{-} > NO_3^{-} > SO_4^{2-}$। सबै मापदण्डहरूले सिँचाइको पानीको लागि FAO द्वारा निर्धारित आवश्यकताहरू पूरा गर्यो।

Keywords: सिँचाइ, जलाधार, भुमिगत पानी, मुल्याङ्कन, भौतिक रसायनिक

LIST OF ACRONYMS AND ABBREVIATION

%Na	Percent Sodium
APHA	American Public Health Association
DO	Dissolved Oxygen
EBT	Eriochrome Black T.
EC	Electrical Conductivity
EDTA	Ethylenediaminetetraacetic acid
EI	Electronics India
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
HDPE	High Density Polyethylene
NDWQS	National Drinking Water Quality Standards
PH	Potential of Hydrogen
POM	Post-Monsoon
PRM	Pre-Monsoon
SAR	Sodium Adsorption Ratio
TDS	Total Dissolved Solids
UV-VIS	Ultraviolet-Visible
WHO	World Health Organization

LIST OF SYMBOLS

%	Percentage
µ	Micro
<	Less than
>	Greater than
℃	Degree Celsius
√	Square root

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CHAPTER 1

1. INTRODUCTION

1.1 General Introduction

1.1.1. Water

Water is the most valuable natural resource on the planet, surpassing all others. Because of the abundance of water on its surface, Earth is regarded as a blue planet (Iqbal & Gupta, 2009; Maruyama et al., 2013). Around 71% of the earth's surface is covered by water, but only around 3% of it is drinkable because 69% of it is frozen as ice in the two Polar Regions. The rest of the fresh water is easily accessible to people, plants, and various animal species and can be discovered in lakes, rivers, and surface aquifers. To prevent persistent resource depletion, this distribution needs to be carefully managed. (Yeazdani, 2016)

1.1.2. Groundwater

Groundwater, because of its superiority, has become a top priority in every aspect of human consumption, including irrigation and other residential consumptions (Haque, 2018). The inherent behavior of aquifers and groundwater systems leads to the emergence of springs, where water naturally flows to the surface in hilly and mountainous regions. Springs hold immense significance for the inhabitants of elevated regions in Nepal, serving as vital sources of sustenance. These invaluable resources play critical roles in ensuring human requirements, maintaining ecological equilibrium, and providing essential water flows to rivers. A spring is a spot where the aquifer's groundwater is released, causing an accessible flow on the land surface. The hydraulic head of the aquifer and the nearby land surface are situated at different elevations, which leads to the outflow (Khadka & Rijal, 2020).

Exploitation of groundwater resources has risen fast to fulfill the rising population's agricultural, industrial, and home requirements (Noshadi & Ghafourian, 2016; Ouhamdouch & Bahir, 2017). A region's groundwater quality is influenced by activities of population or because of the geochemistry of the underlying rock stratum, the replenish water's quality, processes involving interactions between soil and gaseous phases and soil and water, rocks in the zone of unsaturation and how those rocks interact with recharge water, the aquifer's residence time, and processes occurring within the aquifer itself (Freeze & Cherry, 1977). Due to the hydrogeochemical processes, a variety of dissolved inorganic components can be present in groundwater. Ion exchange, rock weathering, and mineral dissolution are a few of these processes. Numerous variables, including the precipitation's underlying geology, the watershed's mineralogy, and the composition of the aquifers, affect the concentration and type of these inorganic elements (Karegi et al., 2018).

Mineral components' effects on soil and plants determines the suitability of groundwater for irrigation. Excessive dissolved ion concentration in irrigation water could lead to decreased production and deterioration of the soil's structure, which can also damage plants and the physicochemical characteristics of soils (Bozdağ & Göçmez, 2013; Ravikumar et al., 2010). Water quality has long been a concern in the study of groundwater. The groundwater hydrogeochemical investigation entails assessments of physicochemical measures, including pH level, temperature, TDS, EC, and DO, as well as concentrations of major cations such as calcium (Ca^{2+}), sodium (Na^{+}), potassium (K^{+}) and magnesium (Mg^{2+}), and major anions such as chlorine (Cl^{-}), bicarbonate (HCO_3^{-}), and sulfate (SO_4^{2-}). These are crucial tools and parameters for assessing the quality of the water (Bharti, 2017). By studying groundwater hydrochemistry, researchers can learn everything they need to know about the physical and chemical processes that groundwater goes through, from precipitation, runoff and root infiltration help the water reach the vadose zone, where it will eventually recharge the aquifer. (Karegi et al., 2018). This knowledge provides an in-depth understanding of ground water systems on the regional level (Zhang et al., 2017).

1.2 Rationale

The rationale of this study is to analyze and assess the suitability of water from the springs of Deumai khola watershed for irrigation purpose in that area. The quality of irrigation water is critical for crop production and health, soil productivity maintenance, and environmental protection (Vasanthavigar et al., 2013)(Vasanthavigar et al., 2013). Many factors influence ground-water chemical quality, including interaction between water and rock, rejuvenate, lithology, geological structure and geochemical activities in the aquifer (Amrani et al., 2022).

Mineral components dissolved in water can be toxic to animals and plants in high concentrations; for example, individuals who already have cardiac issues may be harmed by excessive sodium in the water. While some plants are harmful to boron in somewhat higher quantities but it is beneficial to plants in tiny amounts (*Quality*, n.d.). We fail to comprehend or prioritize groundwater issues because what's out of sight is often out of concern. We need a simplified but accurate understanding of aquifers, their features, and how they are used so that a critical mass of users and decision makers will comprehend them and act properly.

This research provided a chance to assess the pollution levels of groundwater originating from the springs within the Deumai khola watershed. A quality assessment of the irrigation water has been done, especially in locations where spring water is the primary water source. The result of this study will aid for the management of groundwater resources and the long-term utilization of these fragile sources. The outcome also gives base information that can be utilized for future reference in comparison to detect changes in water quality.

1.3. Objectives

1.3.1. General Objective

- To analyze the suitability of irrigation water from the springs of Deumai khola watershed, Ilam, Nepal.

1.3.2. Specific Objectives

- To study EC, pH, TDS, %Na, and SAR of irrigation water of Deumai khola watershed.
- To estimate the concentration of major dissolved ions viz. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_3^{-}, SO_4^{2-}, Cl^{-} in irrigation water of Deumai khola watershed.
- To estimate the total hardness of irrigation water.
- To estimate the alkalinity of irrigation water.
- To estimate the total iron content in irrigation water.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Irrigation Water

Agriculture is a vital aspect of the Nepali economy and social fabric, accounting for an estimated 27% of GDP in 2017 and employing more than 70% of the workforce. Irrigation covers around 40% of total agricultural land area (Government of Nepal, Ministry of Energy, 2020). Irrigation is the practice of artificially supplying water to soil by tubes, pumps, and sprays. In areas where rainfall is unpredictable, dry spells are forecasted, or drought is expected, irrigation is frequently used. There are various types of irrigation systems that supply water consistently to the entire field. Irrigation can utilize various water sources such as groundwater derived from springs or wells, surface water from rivers, lakes, or reservoirs, and even treated wastewater or desalinated water. As a result, farmers must secure their agricultural water source to reduce the risk of contamination. Irrigation water users must be cautious, as with any groundwater withdrawal, to avoid pumping groundwater out of an aquifer faster than it is refilled (Khadka & Rijal, 2020).

2.2. Ions in Irrigation water

An important factor in determining the water quality is the chemical makeup of the groundwater. In groundwater, major ions occur by rock weathering in unpolluted systems, and the water's quality depend on various factors, including the geology, the weathering regime, quality and amount of recharge water, and the interaction between the water and the rocks (Sethy et al., 2016). A global issue that affects both human health and the economy is groundwater contamination (World Health Organization [WHO], 1997). Because of its interactions with the atmosphere, the surface environment, the soil, and the bedrock, groundwater has the potential to dissolve a wide range of different substances. Most components in groundwaters are often present in considerably higher concentrations than in surface waters, and deep groundwaters that have long-term interaction with rock often have higher concentrations than shallow or young water. The major elements of groundwaters are normally present at concentrations between a few mg/L to several hundred mg/L (Earle, 2013).

Major ions, which can have either a positive charge (cations) or a negative charge (anions), are the most prominent dissolved substances that have been measured. Cations and anions are present in equal amounts in water due to the needs of electroneutrality, and they make up the majority of the dissolved solids in ground water. Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) are the most prevalent cations in water, while bicarbonate (HCO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}) are the most prevalent anions. The ionic composition of groundwater can be identified and its chemical quality can be assessed by measuring the amounts of these ions in groundwater samples (*Report2*, n.d.).

2.3. Electrical conductivity (EC)

Electrical conductivity (EC) is the measurement of salinity level in both drinking water and irrigation water (Ghosh et al., 2022). It is a crucial factor in separating locations at risk from salt concerns from those with good groundwater quality for irrigation. Geochemical processes such as ion exchange, evaporation, sediment dissolution, and rainwater penetration are chiefly responsible for EC levels (Saha et al., 2008). The irrigation water with high EC value affect the productivity of crops because crops could not compete with the ions in the soil for water and eventually suffer from physiological drought. Even though the soil may appear moist, very less water is available to plants due to high EC value. The EC is measured in 'µS/cm'(Bauder et al., 2011).

2.4. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS), are inorganic substances that are dissolved in water and include salts, heavy metals, and a small amount of organic substances. It displays the total amount of dissolved compounds in water. The inorganic salt commonly found in TDS are calcium, magnesium, potassium, sodium, carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS of water is affected by soil erosion, agricultural and urban runoff, overflow of the septic and wastewater system, industrial effluent and natural sources. It is measured in 'mg/L' (Rusydi, 2018).

2.5. pH in Irrigation water

The pH scale is logarithmic and represents the activity of hydrogen ions in solution negatively (Bates & Vijh, 1973).

$$pH = -\log[H^+]$$

Numerous factors, such as acid rain and pollution from a variety of sources, affect the pH of irrigation water. The carbonate equilibrium, the presence of heavy metals, and the relative ratio of nitrogen components are all impacted by the pH value, which also has an impact on soil quality and plant growth. Aluminum, magnesium, and calcium are not properly absorbed by plants in acidic water. Basic waters provide more favorable conditions for plants to absorb different metals and nutrients in comparison to this. However, calcium carbonate buildup that affects the physical makeup of water is also a result of basic waters. The preferred pH range for irrigation waters is between 7.0 and 8.0 (Simsek & Gunduz, 2007).

2.6. Total Hardness

The total of the calcium and magnesium contents is referred to as "water hardness". The disintegration of calcium and magnesium aluminosilicates, as well as the dissolution of limestone, magnesium limestone, magnesite, gypsum, and other minerals, contributed to the calcium and magnesium in water. This results in the soil becoming too salty, which makes it difficult for plants to adequately absorb rainwater and therefore fail to thrive as a result of this. The most important element is calcium carbonate, which is referred to as total hardness and is expressed in mg/L due to calcium and carbonate (Chhabra, 2018).

2.7. Percent Sodium (%Na)

Another crucial variable to consider when analyzing sodium risk is percent sodium (%Na). It is determined by dividing the amount of sodium and potassium by the sum of all the cationic ions present. The quality of the water for agricultural use is also determined using this method. The usage of water with high percentage of sodium for irrigation purpose inhibits the plant growth. It is an important parameter of water to compute for suitability for irrigation.

2.8. Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) is a number that represents how many sodium ions there are in comparison to how many calcium and magnesium ions there are overall in water. To be more precise, it is the Na concentration ratio to the square root of one half of the Ca + Mg concentration. In clay and loam soils, high SAR values restrict permeability of soil, which concentrates salts on the surface and inhibits growth of plants, making SAR crucial for sustaining agricultural crop production (Bell, C., Kron, 2021).

2.9. Others

Groundwater quality is significantly impacted by the geo-environmental factors (Subba Rao, 2002). Subba Rao, (2002) carried out a study for the assessment of water quality of some rural areas of Guntur district, Andhra Pradesh, India. Between May and November 1999, from 40 drilled wells in diverse sites, samples were collected and evaluated using the standard methods for principal ion chemistries (APHA 1992). The pH of water was found to be varying from 7.1 to 8.4, this indicate that the groundwater of that area was alkaline in nature. Among the cations, the concentrations of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} ions ranged from 30 to 120, 26 to 145, 95 to 586 and 12 to 71 mg/L with a mean of 55, 58, 316 and 28 mg/L, respectively. Similarly, among anions, the concentrations of CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, and NO_3^{-} ions ranged from 30 to 60, 140 to 800, 120 to 861, 12 to 370, and 13 to 56 mg/L, respectively, with 36, 352, 459, 132, and 38 mg/L as the average. From this study it was concluded that the study area’s groundwater was primarily brackish in nature due to high content of Na^{+}: Cl^{-} in comparison with seawater. This suggested meteoric origin of groundwater.

Another study conducted by Sethy et al., (2016) on the groundwater of Southern Gangetic Plain in the state of Bihar, India reported slightly acidic nature of groundwater during the POM period. The pH value was discovered to vary between 6.2 and 7.37 throughout POM and 6.7 and 7.9 during PRM. Groundwater's moderate acidity was likely caused by the generation of carbonic acid, which is created when free CO_2 and rainwater combine to change the pH of water. EC is an essential parameter for irrigation purpose, and in this study, it was found to be slightly higher in value during POM when compared to PRM. On analyzing the water samples of the study area, the concentration of major cations was found to be in order of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$. Na^{+} concentration was observed to range between 7.6 and 275.6 mg/L in the PRM and between 15.5 and 184.7 mg/L in the POM, with 124.02 mg/L as average. The maximum permissible amount, as to (WHO, 2011) guidelines, is 200 mg/L. Similarly, the concentration order of anions found in the sampled groundwater was; $HCO_3^{-} > Cl^{-} > SO_4^{-} > NO_3^{-}$.

According to Sethy et al., (2016), the elevated levels of HCO_3^- observed in groundwater samples can be attributed to agricultural runoff, where soluble carbonate minerals lead to precipitation caused by soil evaporation. This phenomenon is commonly observed in arid agricultural areas.

Karegi et al.,(2018) collected groundwater samples in February 2017 from 10 boreholes in Mbeere South Sub-County, Kenya; and analyzed for physicochemical properties along with main ions utilizing conventional analytical methods. The study area lies between latitudes-0.62, -0.68 (00 37’ 14” S, 00 40’ 50” S) and longitudes 37.53, 37.79 (370 30’4” E, 370 47’ 56” E). The analysis revealed that the groundwater samples had high pH value varied from 6.6 to 8.9. The natural pH of water is heavily influenced by the rocks and minerals in an area (geology) (Ombaka et al., 2013). The TDS was discovered to be between 12.0 and 681.0 mg/L. Also, the results showed that the cations were in order $Na^+ > Ca^{2+} > Mg^{2+} > K^+ >$ Fe and the anions were in order $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > F^-$. According to author, the observed cation order can be explained by the weathering of sodium-containing rocks, the deposition of rock salts, the dissolution of halites, and the removal of sodium by carbon and magnesium from absorbed complexes of rocks and soils(Hussien & Faiyad, 2016).

Madhav et al., (2018), in their study on the analysis of the quality of groundwater in rural sections of India's Uttar Pradesh state's Sant Ravidas Nagar (Bhadohi), revealed that the pH of groundwater in that area is neutral to slightly alkaline. Twenty (20) samples of groundwater were collected and analyzed for EC, pH, TDS and key ions; Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, F^-, SO_4^{2-}, NO_3^-. On analyzing it was found that, six of the twenty samples were excellent to good, thirteen were good to permissible, and one was only marginally inappropriate for irrigation based on %Na.

Kaur et al., (2019), studied the groundwater samples of Panipat district of Eastern Haryana, India. The study area is extended from 29°10’15’’:29°30’25’’ North to 76°38’30’’:77°09’15’’ East, covering about 1263 km^2 area. The trend of Panipat's groundwater level is continuously declining, and the region may experience a water scarcity in the near future (Kaur & Rishi, 2018). After pumping for 10 minutes from the study area during the POM season of 2015, 45 samples were collected. Clean HDPE bottles were used to collect samples. The samples were then tested for EC, pH and TDS. The sample groundwater’s pH was found to be alkaline, ranging from 7.29 to 8.89 with

8.01 as average. 260 to 2160 mg/L was the range of TDS value with 701.24 mg/L as average. On analyzing for major ions concentration in the samples, it was found that HCO_3^- and Na^+ were most abundant ions present in the samples. The mean concentration of anion was in order; $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ whereas that of cation was; $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. The average groundwater sample's total hardness was 340.58 mg/L, with a range of 64 to 750 mg/L.

Khadka & Rijal, (2020) analyzed the spring water resources around Melamchi, central Nepal. The study area is located between latitudes 26°49030″ and 27°53000″ N and longitudes 85°32030″ and 85°38000″ E. 18 samples, during POM (October 2017), were collected for the estimation of major cations and anions along with physicochemical parameters such as EC, pH, DO and TDS. The pH of water samples was found to lie within 5.5 to 7.0 range in PRM and 5.7 to 7.2 range in POM. This shows that the region's water is just mildly alkaline to slightly acidic. The EC was also seen fluctuating from 20.9 to 189.8 and 29.3 to 234 µS/cm during monsoon season. The TDS value was seen decreased during POM i.e. 10.5 to 94.9 mg/L than that in PRM i.e. 14.6 to 116.9 mg/L. Additionally, the principal cations and anions were found to be concentrated in the order: $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-}$, respectively. All physical and chemical factors of the spring waters, that were recorded are within the National Drinking Water Quality Standards (NDWQS 2005) and WHO guidelines (WHO, 2011), with exception of the fact that the majority of spring waters indicate pH levels that are lower than 6.5.

Various studies had been conducted for analyzing the suitability of groundwater for drinking as well as irrigation. Previous studies show that most of the research has been carried out on the groundwater obtained from handpumps, boreholes, wells and other sources but very few studies had been done on spring water.

The suitability investigation of the spring water from the Deumai khola watershed in Ilam, Nepal, is the main emphasis of this project activity. In this study, parameters required for indicating quality of spring water for irrigation purpose has only been looked after. Till date no one has performed suitability analysis test for irrigation water in this region.

CHAPTER 3

3. MATERIALS AND METHODS

3.1. Materials

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

1.1.1. Chemicals and reagents

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

1.1.2. Instruments

- Conductometer
  Conductivity meter model 1601 with range of 0-200µs/cm and resolution of 0.01 µs/cm.
- Digital Balance
- Microprocessor UV-VIS Spectrophotometer
  Model-LT-291 (Single beam), Labtronics.
- Microprocessor Flame photometer
  Model: 1385, Electronics India (EI)
- pH meter
  pH meter model LT-10

3.2. Research methodology

3.2.1. Study Area

The area of study is located in the Koshi Province’s Ilam district in Eastern Nepal (Figure 1). The area is well-known for its dairy products and tea cultivation. The main sources of income for people living in rural areas are agriculture and animal husbandry. The Deumai khola watershed, located in Eastern Nepal, is a rainfed river system that flows throughout the year. It serves as a sub-watershed within the larger Kankai River

Basin. Its water is used for irrigation and also powers several hydroelectric plants. Due to less rainfall and lack of structures to conserve water, the people living in this region are highly dependent on groundwater. Hence, the analysis of groundwater is important for such regions.

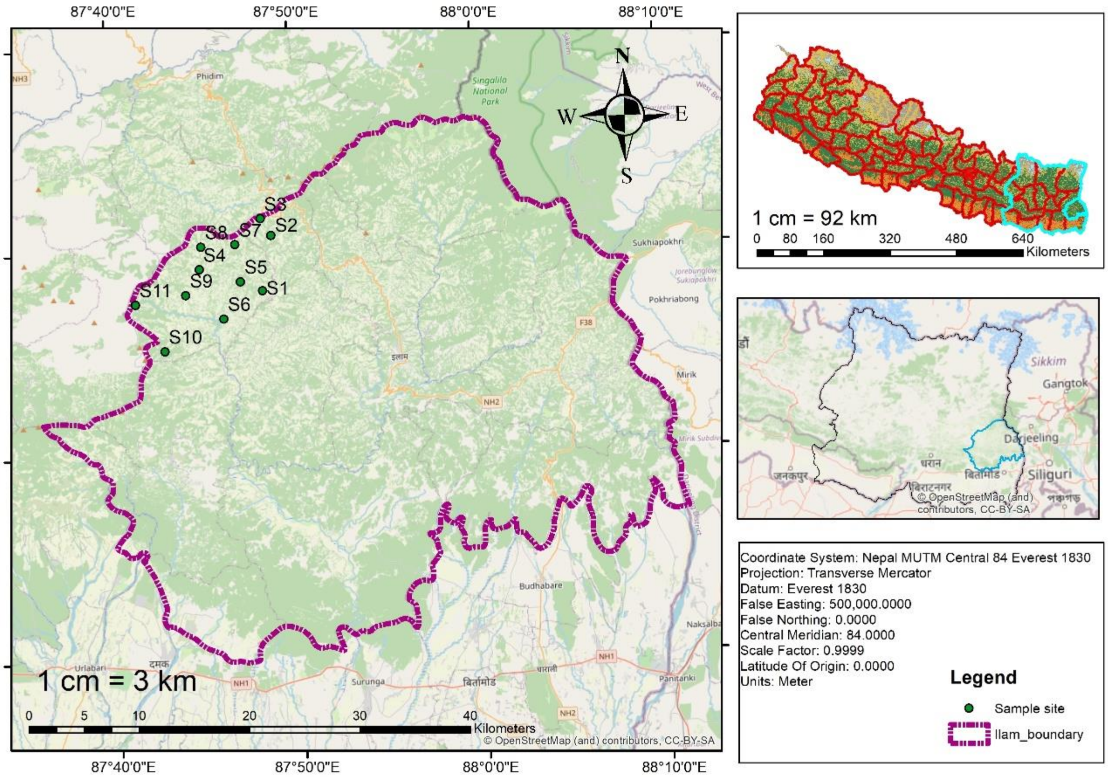

Figure 1: Sample Site (GIS Software)

3.2.2. Laboratory set up

The research work was carried out in the laboratory of Department of Chemistry and Department of Nutrition and Dietetics, Central Campus of Technology (CCT), Hattisar, Dharan.

3.2.3. Data collection and data analysis

The research data obtained from the samples were further subjected to quantitative analysis, which involved processing, tabulating, and utilizing different statistical methods such as MS-Excel 2019, IBM SPSS Statistics 25. The outcome was inferred and presented using tables and bar graphs as needed.

3.3. Methods

3.3.1. Determination of pH: (Reda, 2016)

The pH of each sample was measured with portable field pH meter model LT-10 pre-calibrated at buffer of pH 4 and 7.

3.3.2. Temperature measurement: (Oyem et al., 2014)

Temperature was immediately measured, after the sample was collected, by using glass thermometer.

3.3.3. Determination of Electrical Conductivity (EC): (Reda, 2016)

Conductivity meter model 4200 was used to measure EC. The probes were properly cleaned with distill water prior to measurement, and the conductivity of the distill water was assessed. After that, water samples were used to dip the probe, and the electrodes were moved up and down to remove any air bubbles. Finally, each sample's data was recorded.

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

Microprocessor UV-VIS spectrophotometer model-LT-291(single beam) was used to determine sulphate (SO_4^{2-}). The wavelength was set on 420 nm. First, the absorbance of standard sulphate solutions at concentrations of 1 mg/L, 5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, and 40 mg/L were measured, and a calibration curve was drawn. The probe was rinsed well with distilled water before measuring the absorbance of the other samples.

For calculation:

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

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

Microprocessor UV-VIS spectrophotometer model-LT-291(single beam) was used to determine nitrate (NO_3^-). The wavelength was set on 220 nm. First, the absorbance of standard nitrate solution at concentrations of 1 mg/L, 2 mg/L, 4 mg/L and 7 mg/L was measured, and a calibration curve was drawn. The probe was rinsed well with distilled water before measuring the absorbance of the other samples.

For calculation:

The slope and intercept of the calibration curve were determined through the application of an electronic spreadsheet, calculator, or instrument software using the method of least squares linear regression. The NO_3^- - N concentration was calculated from the following equation.

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

Where;

C = concentration

A = absorbance

I = intercept of the regression line, and

S = slope of regression line.

3.3.6. Determination of sodium (Na^+) and potassium (K^+); Flame emission photometric method

A microprocessor flame photometer model-1385 was used to measure the concentrations of sodium and potassium. To get started, standard sodium solution concentrations of 1 mg/L, 5 mg/L, 10 mg/L, 15 mg/L, and 20 mg/L were tested. The probe was thoroughly rinsed with distilled water before measuring the absorbance of another sample.

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

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

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:

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

3.3.7. Determination of iron; Phenanthroline method (APHA, 2005)

Microprocessor UV-VIS spectrophotometer model-LT-291(single beam) was used to determine total iron in water. The wavelength set on 510 nm. First, the absorbance of standard iron solution of concentration 0.1 mg/L, 0.5 mg/L, 1 mg/L, 1.5 mg/L and 2 mg/L was measured. The probe was rinsed well with distilled water before measuring the absorbance of the other samples. Standard curve was used for calculation.

3.3.8. Determination by Titration method:

3.3.8.1 Determination of total hardness

The total hardness of the water was evaluated by titrating 50 mL of sample with 0.01M EDTA. Before titrating with EDTA, 1 mL of ammonia buffer and 100–200 gram of Eriochrome indicator were added, which changed the colour of the solution to wine-red. At the end point blue colour was observed.

For calculation of total hardness:

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

3.3.8.2 Determination of calcium

Calcium was determined by titrating 50 mL of material with 0.01M EDTA. 2 mL of 0.1N NaOH and a little amount of the murexide indicator were added prior to titrating with EDTA. It caused the solution's color to change to pink. Purple color was seen at the end point.

For calculation of calcium:

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

3.3.8.3 Determination of magnesium

Since total hardness and calcium were determined using the same amount of water, the following relationship was utilized to calculate magnesium.

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

3.3.8.4 Determination of alkalinity

Alkalinity of water was determined by titrating 50 mL of sample with 0.1N HCl. Phenolphthalein and methyl orange were used as indicator. At starting, phenolphthalein indicator was added. When color of sample was changed then there is said to be phenolphthalein alkalinity and is titrated with HCl until the color disappeared and the volume of HCl was noted (as X). No change in color 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 colored end point. The volume of HCl was noted (as Y).

For calculation,

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

3.3.8.5 Determination of chlorine

With the use of 2 mL of potassium chromate indicator, 50 mL of the sample was titrated with silver nitrate to determine the amount of chloride present. The terminal point had a persistent red colour. The blank was treated the same way and used as a control.

For calculation,

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

3.3.9. Determination of Sodium Adsorption Ratio (SAR): (Bell, C., Kron, 2021)

The concentration of Na^{+}, Ca^{2+} and Mg^{2+} were already determined above in mg/L. Now the mg/L concentration was converted into meq/L and SAR was calculated.

For calculation:

$$SAR = \frac{[Na]}{\sqrt{\left[\frac{[[Ca]+[Mg]]}{2}\right]}}$$

Where all concentrations are expressed as meq/L.

3.3.10. Determination of % sodium (% Na): (Joshi et al., 2009)

The %Na was determined by Doneen method. First, the concentration of all the ions were determined, which was in mg/L concentration. Then the concentration was converted to meq/L and %Na was calculated.

For calculation:

$$\%Na = \left[\frac{Na+K}{Ca+Mg+Na+K}\right] \times 100$$

Where all the concentrations are in meq/L.

CHAPTER 4

4. RESULT AND DISCUSSION

Agriculture could not be sustained with limited or seasonal rainfall without irrigation. And, for irrigation, groundwater is one of the important sources. Since Ilam is a hilly region and receives very limited rainfall, so people living there highly depends on groundwater. Hence it is necessary to analyze the suitability of irrigation water from the springs of Deumai khola watershed.

This study assessed the physicochemical parameters; temperature, pH, EC, TDS, %Na, SAR, total hardness, alkalinity, total iron, Na^+, K^+, Ca^{2+}, Mg^{2+}, $NO_3^–$, Cl^- and $SO_4^{2–}$ in spring water of Deumai khola watershed.

4.1. Results

The data of parameters; temperature, pH, EC and TDS obtained from sample waters are summarized in **Table 1**.

Table 1: Temperature, pH, EC and TDS observed in water samples.

Sample Code	Temperature (°C)	pH	EC (µS/cm)	TDS (mg/L)
S1	22	6.8	87	43
S2	21	7	167	84
S3	17	7.51	95	47
S4	22.7	7.45	40	20
S5	22	8	57	26
S6	22	7.17	55	27
S7	17.5	7.18	39	19
S8	19	7.07	163	67
S9	21	7.05	152	76
S10	19.2	8.53	283	141
S11	17.2	8.41	81	41

The pH of water is a very important measurement concerning water quality. The pH of the samples that were tested ranged from 6.8 to 8.53, with 7.47 as average, indicating that the water from the spring exhibits a slightly acidic to alkaline nature. According to FAO, the normal pH range for irrigation water is from 6.5 to 8.4. The samples S10 and S11 have highest pH, 8.53 and 8.41 respectively, which is more than the normal pH range. The lowest pH is of S1 i.e. 6.8. A nutritional imbalance or the presence of harmful ions could be brought on by irrigation water with a pH that is outside of the typical range.

The spring water EC was recorded in between the range of 39 to 283 µS/cm, with 110.82 µS/cm as average. This evidence suggests there seems to be insufficient water interaction with the aquifer minerals in this area as a whole. The low TDS level is another strong indicator of this. The TDS ranges between 19 and 141 mg/L, with 53.73 mg/L as average. According to FAO, the allowable limit of EC and TDS for irrigation water are <3000 µS/cm and < 2000 mg/L respectively.

Table 2: Summary statistic of pH, EC and TDS

Statistic	**pH**	**EC**	**TDS**
Minimum	6.80	39.00	19.00
Maximum	8.53	283.00	141.00
Mean	7.47	110.82	53.73
Variance	0.35	5511.36	1335.42
Stand. deviation	0.59	74.24	36.54

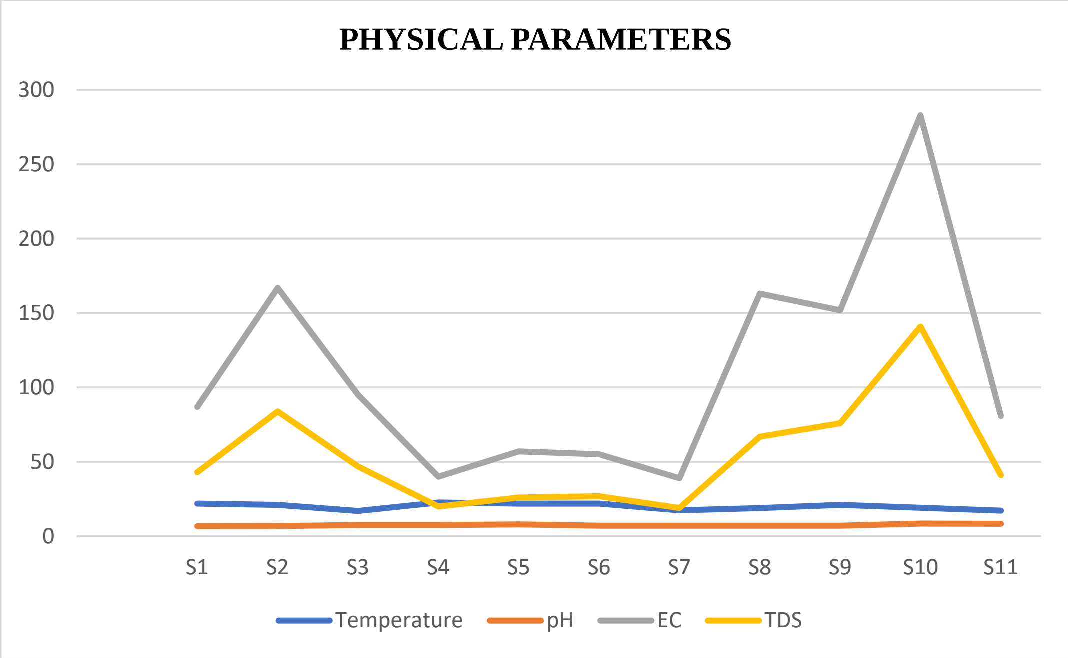

Figure 2: Curve representing the physical parameters

Table 3 lists the principal ion concentrations that were discovered through laboratory testing.

Table 3: Concentration of major cations and anions in tested samples

Sample	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	NO_3^{-} (mg/L)	SO_4^{2-} (mg/L)	Cl^{-} (mg/L)
S1	17.61	7.78	12.6	3.1	1.70	0.73	7.1
S2	40.03	7.78	11.8	1.84	7.44	0.39	18.46
S3	19.22	7.78	8	3.8	4.48	0.87	9.94
S4	4.80	2.92	9.2	1.09	1.92	0.17	5.68
S5	3.20	6.80	6.1	1.39	1.85	0.80	5.68
S6	12.81	-1.94	9.5	2.4	1.75	0.17	5.68
S7	9.61	0.00	8.4	0.64	2.12	0.33	4.26
S8	27.22	5.83	11.6	4.4	5.40	0.49	22.72
S9	25.62	5.83	13.3	3.7	10.45	0.33	19.88
S10	104.08	5.85	8.6	2.6	1.91	0.17	4.26
S11	20.82	3.89	8.9	2.2	1.80	0.59	2.84

Table 3 shows the concentration of major cations and anions observed in tested samples. The concentration of calcium and magnesium in samples were found in the range of 3.20 to 104.08 mg/L and -1.94 to 7.78 mg/L respectively. Calcium and magnesium are found in ground water that has come into touch with certain rocks and minerals, particularly limestone and gypsum.

Similarly, the tested water contains sodium and potassium ions in concentrations that ranges from 6.10 to 13.30 mg/L and 0.64 to 4.40 mg/L respectively. The concentration of sodium and potassium are lower and within the range of FAO guidelines. Lower levels of these ions in water are the evidence that it is very less interacted with surrounding.

The sample displays a varying range of nitrate concentration between 1.70 and 10.45 mg/L, with 3.71 mg/L as average. Nitrates in ground water is caused by malfunctioning septic tanks, sewage discharge, organic material oxidation, farming, and agricultural operations. The concentration of nitrate is in limit for the irrigation water i.e. <45 mg/L, according to FAO.

The concentration of sulphate ion in sample water ranges from 0.17 to 0.87 mg/L, which is very less as compared to FAO guidelines. Similarly, the concentration of chloride ranges from 2.84 to 22.72 mg/L, with an average of 9.68 mg/L.

Table 4: Statistical summary of major ions.

Statistic	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**NO_3^-**	**SO_4^{2-}**	**Cl^-**
Minimum	3.20	-1.94	6.10	0.64	1.70	0.17	2.84
Maximum	104.08	7.78	13.30	4.40	10.45	0.87	22.72
Mean	25.91	4.77	9.82	2.47	3.71	0.46	9.68
Variance	785.00	10.67	4.89	1.43	8.68	0.07	51.14
Stand. dev	28.02	3.27	2.21	1.20	2.95	0.26	7.15

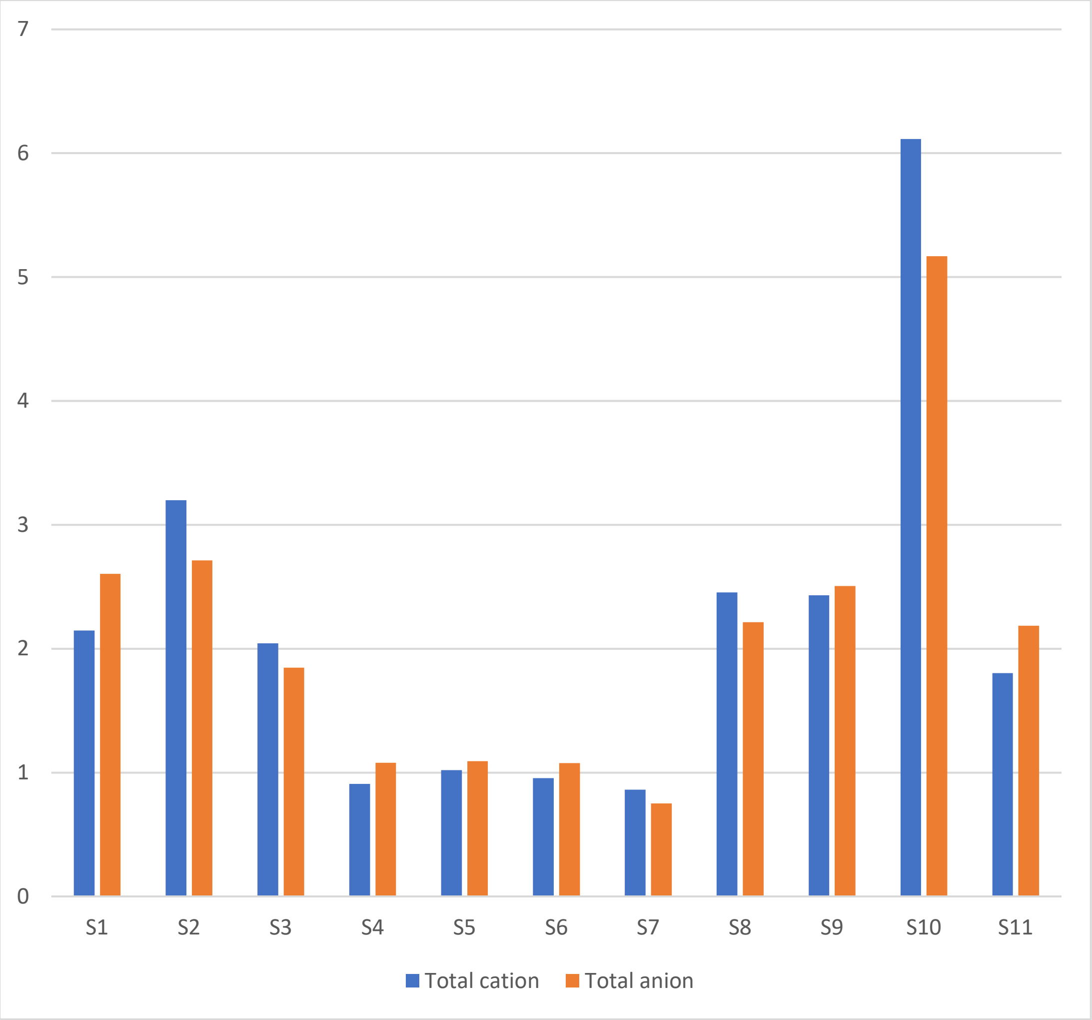

Figure 3: Graph representing total cation and anion

The graph in **Figure 3** shows the comparison of total cation and total anion present in the water samples. In most of the samples it is seen that the content of total cation and total anion are almost in equilibrium. The highest content of ion is seen in S10 sample and the lowest in S7 sample.

Table 5: Calculation values for %Na, SAR, Total Hardness, Alkalinity and Total iron for spring water in the sample area

Sample	%Na	SAR	Total Hardness (mg/L) as $CaCO_3$	Alkalinity (mg/L) as $CaCO_3$	Total iron (mg/L)
S1	29.2	0.63	25.39	144	0.147
S2	17.5	0.45	47.81	126	0.194
S3	21.8	0.39	26.99	90	0.165
S4	47.2	0.82	7.72	54	0.095
S5	29.5	0.44	10.00	54	0.15
S6	49.7	0.84	10.87	54	0.161
S7	44.3	0.75	9.61	36	0.106
S8	25.1	0.53	33.06	90	0.19
S9	27.7	0.62	31.45	108	0.09
S10	7.2	0.22	109.94	306	0.111
S11	24.6	0.47	24.71	126	0.383

Table 6: Summary statistics of %Na, SAR, total hardness, alkalinity and total iron

Statistic	%Na	SAR	Total Hardness	Alkalinity	Total iron
Minimum	7.20	0.22	7.72	36.00	0.09
Maximum	49.70	0.84	109.94	306.00	0.38
Mean	29.44	0.56	30.69	108.00	0.16
Variance	168.76	0.04	845.03	5572.80	0.01
Stand. Deviation	12.99	0.19	29.07	74.65	0.08

The study area's %Na varies from 7.2 to 49.7, with 29.44 as average. Only 3 samples (Table 5) show slightly higher value than others, but still the lies within permissible value i.e. <60. Water in the study area has a SAR value that ranges from 0.22 to 0.84, with an average of 0.56. The SAR value are also within excellent range recommended by FAO i.e. <3. The total hardness of the water is in the range of 7.72 to 109.94 mg/L.

Similarly, the alkalinity and total iron content in the water ranges from 36 to 306 mg/L and 0.09 to 0.38 mg/L respectively.

4.2. Calibration graph of Sodium, Potassium, Nitrate, Iron, Buffer A and Buffer B.

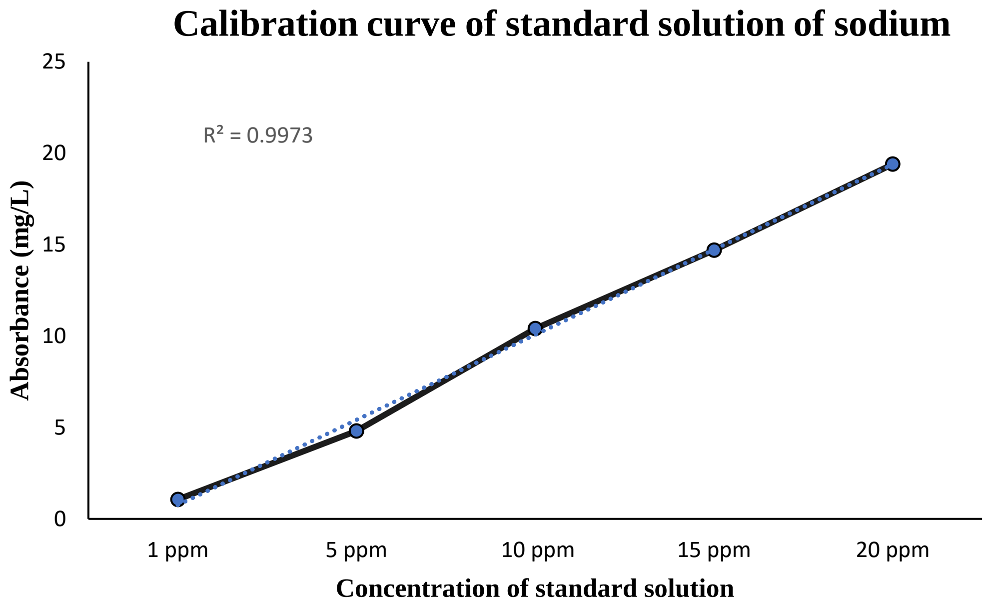

Figure 4: Calibration curve of standard solution of sodium

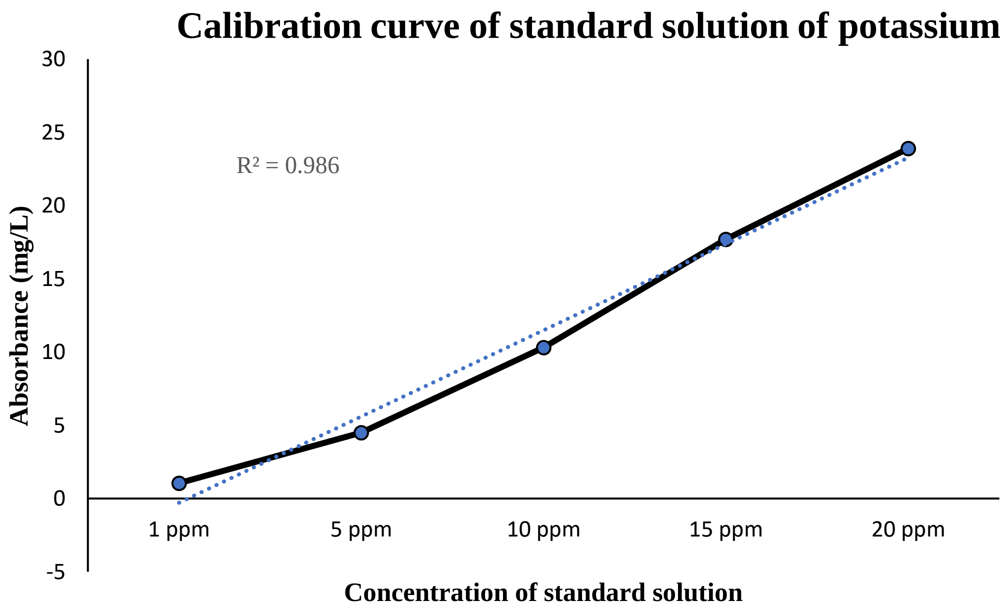

Figure 5: Calibration curve of standard solution of potassium

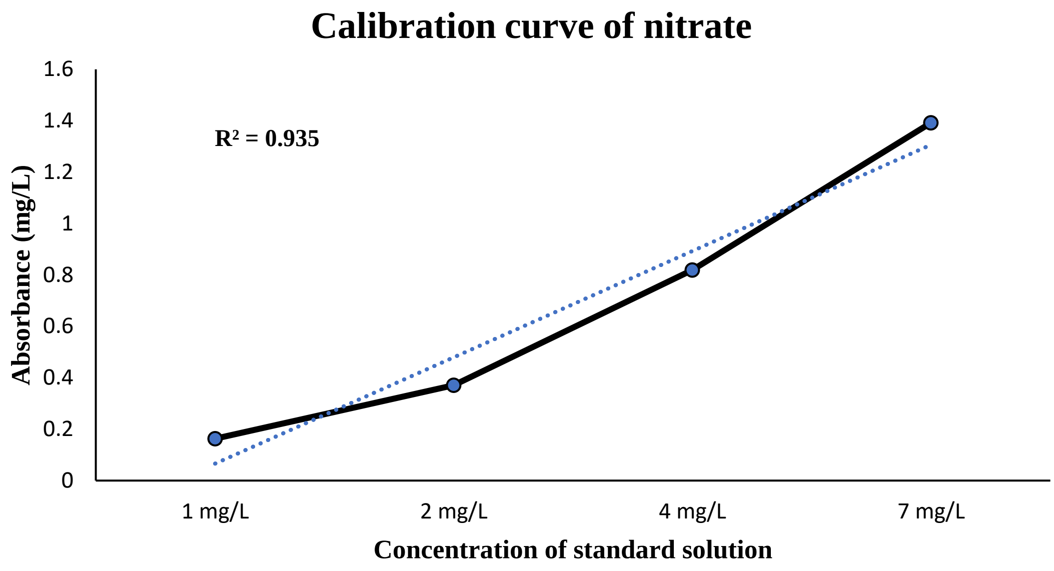

Figure 6: Calibration curve of nitrate

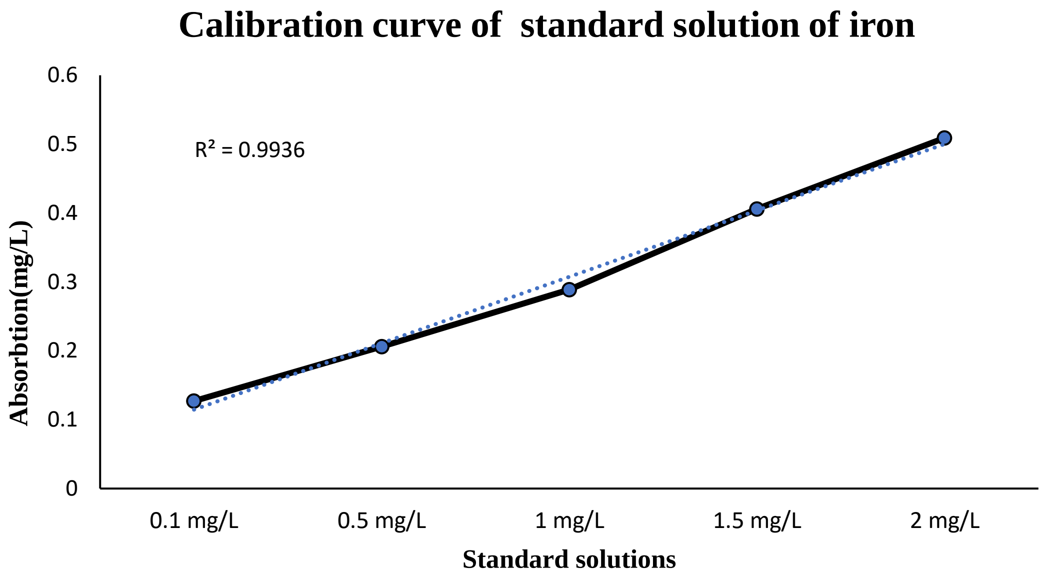

Figure 7: Calibration curve of standard solution of iron

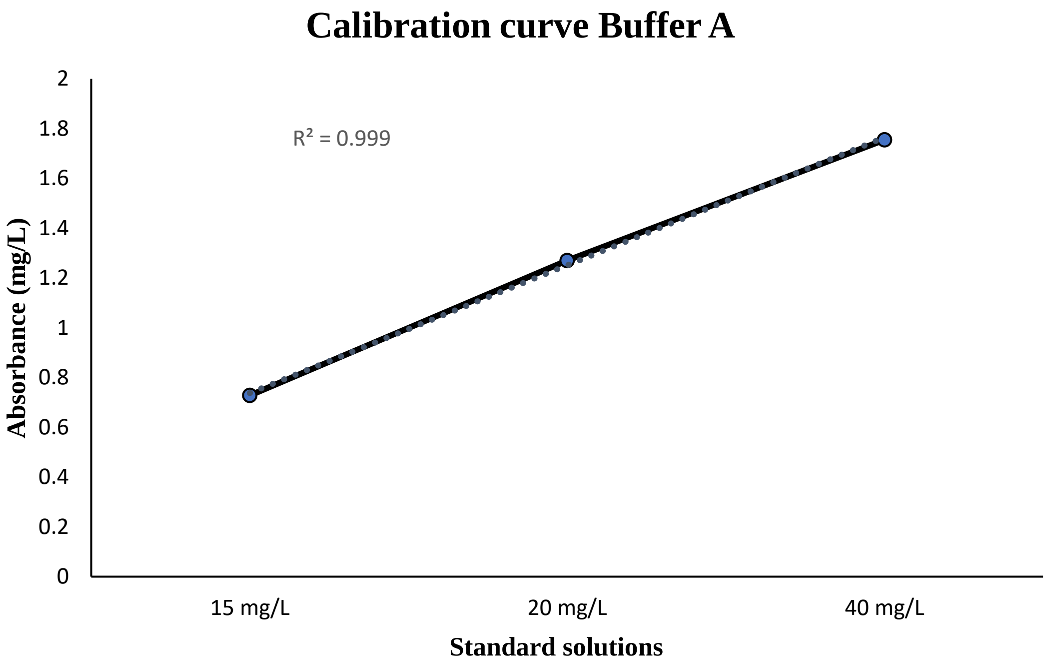

Figure 8: Calibration curve Buffer A

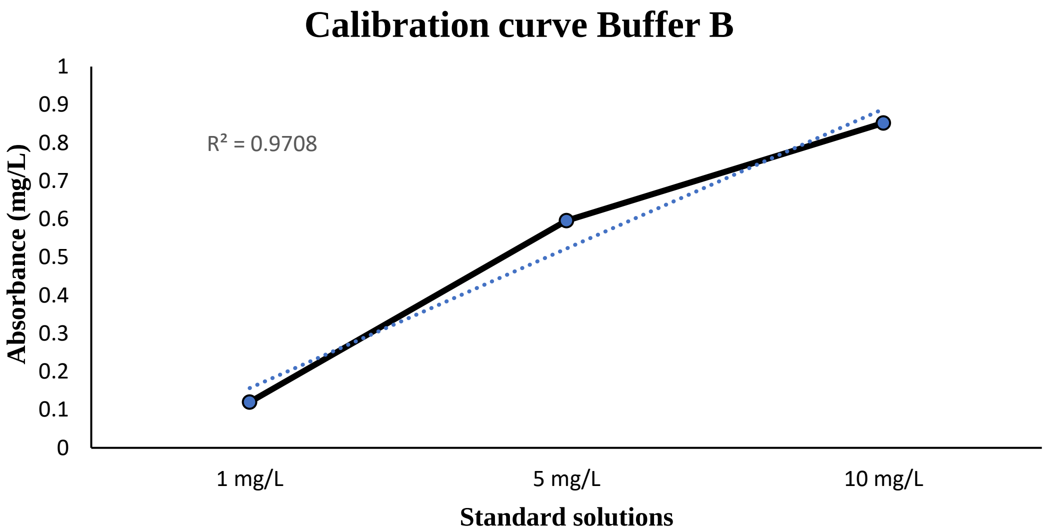

Figure 9: Calibration curve Buffer B

CHAPTER 5

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The suitability analysis of spring water for irrigation is conducted in this project work. The factors affecting the quality of irrigation water are looked after and the result is found satisfactory. The results obtained for EC, TDS, temperature, %Na, SAR, total hardness, alkalinity, total iron, Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, Cl^- and SO_4^{2-} are found to be within the permissible range recommended by FAO. But the pH of sample S10 and S11 are higher than the permissible range. The higher pH of water in this area may be due to chemicals, minerals, pollutants, soil or bedrock makeup, and any other contaminants that interact with the water supply. The concentration of cations observed is in the order; $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and anions is in the order; $Cl^- > NO_3^- > SO_4^{2-}$.

After analyzing the obtained results, it was found that the spring water of Deumai khola is suitable for the irrigation purposes. All the physicochemical parameters are found to be within the permissible range recommended by FAO.

5.2. Novelty and National Prosperity aspect of Project work

- This project work has helped to check the compatibility of spring water originated from Deumai khola watershed, Ilam, Nepal.
- This study is also helpful to make people aware about the quality and suitability of irrigation water of that area.
- Altogether, this study has provided valuable information and contributed to the national prosperity and well-being of Nepal by studying the suitability of spring water for irrigation and comparing the result with FAO guidelines.

5.3. Limitation of the study

- The study was only conducted on the water samples collected in PRM season.
- The size of sample taken in this study is small because of remote study area and difficulty in transporting large number of samples.
- The study of microbiological quality of water was not performed due to time limitation.
- Due to unavailability of some instruments and chemicals during the time of study, few parameters couldn't be studied.

5.4. Recommendation for further work

Beside parameters studied in this project work, other parameters such as DO, concentration of lithium, silicon, bromine, iodine, copper, cobalt, fluorine, boron, lead, phosphate and organic matter should also be studied. This will help to evaluate the quality of irrigation water more effectively. The microbiological quality of water is also recommended for further study because micro-organisms also plays a vital role in agriculture. The study for drinking water quality can also be carried out. And, the hydro-geochemical characterization of that area can be investigated.

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APPENDIX A

MATERIALS REQUIRED

Glassware

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

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 Site

Sample Code	Sample Site	District	North Coordinate	East Coordinate
S1	Hiti Kholsa	Illam	87.80502443	26.96772474
S2	Simsar Mul	Illam	87.81424513	27.01272186
S3	–	Illam	87.80480852	27.02657998
S4	Timsina Kholsa	Illam	87.74807902	26.98636556
S5	Thulo Kholsi, Sepegau	Illam	87.78509936	26.97564643
S6	Kattusaini Mul, Pelewa	Illam	87.76905507	26.94558081
S7	Gurung Kholsi, Putalikharka, PKT-2	Illam	87.78108682	27.00597609
S8	Dharmadwar, PKT-1	Illam	87.75000442	27.00469149
S9	Aamchowk, PKT-3	Illam	87.73502502	26.96561525
S10	Jankanya Mandir, Lumde-7	Illam	87.71449716	26.92025449
S11	Saptami, simkharka	Illam	87.68902887	26.95880548

Note: S1, S2, ……S11 are the water samples.

PHOTOGRAPHS

Photograph 1: Flame photometer

Photograph 2: Water Samples

Photograph 3: Samples for testing

Photograph 4: Buffer solutions with standard SO_4^{2-} solutions

Photograph 5: Titration for total hardness