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**ORIGINAL RESEARCH**

# Seasonal Effect of Physico-chemical Parameters on Protozoa in Drinking Water of Kathmandu Valley, Nepal

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**ABSTRACT**

**Background:** The phrase "No life without water" emphasizes the fundamental role that water plays in sustaining life. Water is a dynamic system, consisting of living and non-living components, and it can contain various organic, inorganic, soluble, and insoluble substances. Some of protozoa found in water are *Entamoeba histolytica, Giardia lamblia, Cryptosporidium paravum, Paramecium caudatum, Amoeba proteus, Balantidium coli*. **Objectives:** Seasonal Effect of Physico-chemical Parameters on Protozoa in Drinking Water of Kathmandu Valley, Nepal. **Materials and methods:** Water samples were normally examined within 2-6 hours of collection using the centrifugation method ( 2,500 r/min for 1-2 minutes) followed by light microscope to detect cysts and oocysts of the different parasites. Direct smears were examined under the light microscope at 100x magnification. Lugol's iodine stain and Modified Ziehl-Neelson Staining were applied to conform the presence of protozoan cysts and oocysts. **Results:** The analysis of protozoa presence in water samples across different seasons reveals significant variation in their numbers and percentages throughout the year with F value 18.571 (P-value<0.001). The significant highest number of protozoa 17 (2.36%) were found in the summer season. In spring, 6 protozoa were detected, making up 0.83% of the total (P-value<0.001). In autumn, 10 protozoa were found, representing 1.38% (P-value=0.03), and in winter, 9 were detected, constituting 1.25% (P-value=0.01).These findings suggest that protozoa population fluctuate seasonally, likely influenced by environmental factors such as temperature, nutrient availability, and water conditions, which vary over the year. The analysis reveals significant seasonal variation in protozoa populations, with the highest number occurring in summer, and statistically significant difference observed across all seasons. The physico-chemical parameters were analyzed by APHA method 1992 Edison 18. **Conclusion:** The water treatment is necessary to eliminate microbial, chemical contaminants which reduce the risk of water-borne diseases.There is a need for better management of the surrounding environment of water reservoirs and feeding streams to prevent contamination. This includes implementing protective measures to reduce the introduction of pollutants into groundwater sources.

**Key Words:** Detection, Drinking, Effect, Parameters, Protozoa, Seasonal, and Water.



## INTRODUCTION

After air, water is the second most essential element for life as we know it. Water quality has therefore been thoroughly discussed in the scientific literature. "It is the physical, chemical, and biological characteristics of water" is the most widely used definition of water quality (Spellman, 2013; Alley, 2007). The state of water is measured in relation to the needs of one or more biotic species and/or to any need or goal that humans may have (Shah,2007; Chobanoglous 1985).Water is indeed one of the most critical natural resources on Earth, essential for all life forms. The phrase "No life without water" emphasizes the fundamental role that water plays in sustaining life. Water is a dynamic system, consisting of living and non-living components, and it can contain various organic, inorganic, soluble, and insoluble substances. Due to this dynamic nature, water quality can vary daily and from one source to another. Any alteration in its natural quality can disrupt the equilibrium of

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ecosystems and render the water unsuitable for its intended purposes(Ayibatel, 1992; Mishra *et al*.,2002; Gupta *et al*., 2008). The availability of water from surface and groundwater sources has become increasingly critical. Although water covers a significant portion of the Earth's surface, only a small fraction about 1% is accessible for essential human activities such as drinking, agriculture, domestic use, power generation, industrial consumption, transportation, and waste disposal. This limited availability highlights the need for careful management and conservation of this vital resource(Tahir *et al.*, 2008; Raja 2002; patil *et. al*., 2001)

In India and Nepal a significant portion of the population relies heavily on groundwater as their primary source of drinking water. Groundwater is often perceived as being cleaner and less prone to pollution compared to surface water. However, this assumption is challenged by the prolonged discharge of industrial effluents, domestic sewage, and solid waste, which increasingly contaminates groundwater, leading to severe health problems(Petrus *et al*., 2005; Lokeshwari 2006; Mossad 2006).The rapid urbanization in India has exacerbated the situation. Overexploitation of groundwater resources and improper waste disposal practices have further degraded groundwater quality. Consequently, the protection and management of groundwater quality have become crucial concerns. (Arvnabh *et al*., 2010; Elizabeth *et al*., 2005; Vijendar 2006).One of the major threats to groundwater quality is the presence of heavy metals, which are recognized as priority toxic pollutants. These pollutants significantly restrict the safe use of water for both domestic and industrial purposes. In particular, lakes, which are vital water bodies, have complex and fragile ecosystems. Unlike rivers, lakes lack the self-cleaning ability, making them prone to the accumulation of pollutants, which further deteriorates the water quality(Trivedy *et al.*, 1986; Manivaskam 2005., Khan 1985).To address these concerns, various studies have been conducted to assess the physicochemical parameters and trace metal content in water samples. For instance, research conducted in Delhi has highlighted the contamination levels in the water, underscoring the need for comprehensive measures to monitor and improve water quality.In India and Nepal the quality of water bodies has deteriorated significantly due to rapid urbanization and industrialization, making it necessary to treat water before using it for domestic purposes. Groundwater, which many rely on, often contains high concentrations of various ions, salts, and other contaminants. Consuming untreated groundwater can lead to various water-borne diseases, posing a serious public health risk(Sudhir *et al.*, 1999).

In rural areas, particularly where alternative water sources like dams, rivers, or canals are not available, groundwater is extensively used for agricultural purposes. However, in the past decade, there has been a marked increase in groundwater pollution, largely due to intensified human activities such as industrial discharges, improper waste disposal, and agricultural runoff.The consequences of this pollution are far-reaching, affecting not only human health but also the sustainability of agricultural practices. Contaminated groundwater used for irrigation can lead to the accumulation of harmful substances in crops, further endangering food safety and public health.To mitigate these issues, there is a pressing need for effective water treatment methods and better management practices to ensure the safety and sustainability of groundwater resources in India.Maintaining the quality of groundwater is crucial not only for human consumption but also for preserving aquatic life and supporting other essential uses. Given the importance of safeguarding groundwater, particularly in regions where it serves as the primary water source, it is vital to monitor and manage its quality effectively (Shrinivash *et al*., 2000). In light of the growing concerns over groundwater contamination, the present study was conducted to investigate the impact of groundwater quality in Kathmandu Valley, located in the Kathmandu district of the Bagmati State. The study focused on assessing the physical and chemical parameters of groundwater from various open wells and bore wells in the area(Shrinivash et al., 2000; Trivedy *et al*., 1986). The temperature (T), turbidity (NTU), color (TCU), pH ,total alkalinity (TA), iron , total hardness (TH), total alkalinity (TA), chloride ($Cl^-$).The study compared the analyzed data from tap water, tube-well water and dug well water r samples in Kathmandu valley with the standard values recommended by the World Health Organization (WHO). These comparisons are crucial for determining whether the groundwater is safe for consumption and other uses. WHO provides guidelines for various physical and chemical parameters of water to ensure its safety and suitability for human consumption. These standards include acceptable ranges for parameters such as pH, electrical conductivity, total dissolved solids (TDS), turbidity, dissolved oxygen (DO), and the concentrations of specific ions like calcium, magnesium, sodium, potassium, chloride, fluoride, nitrate, sulfate, and phosphate. By comparing the measured values from the groundwater samples with these WHO standards, the study aimed to: If the measured values exceed WHO-recommended levels, it could indicate the presence of pollutants that need to be addressed through water treatment or pollution control measures. Conversely, if the values fall within the acceptable range, it would suggest that the groundwater is generally safe for its intended uses(WHO 1993; APHA, AWWA, WEF, 1998; Arunabh 2008).

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## MATERIALS AND METHODS

### Study area

The Kathmandu Valley is located in the midland of the Himalayas, between 27°32' and 27°49' North and 85°12' and 85°32' East. It is almost round in shape, with a diameter 30 km E-W and 25 km north to south (Khanal *et al.*, 2023). Approximately 65% of the nation's economic activities takes place in Kathmandu Valley, has a population 2,517,023(CBS 2020). This study is conducted only in, Tripureshwor, Baneshwor, Bansbari and Chhetrapati ( Fig 1) of the Valley. Since Kathmandu is the urban city of country and this study sites are highly populated and at least one of this water sources is used by people of these selected sites.

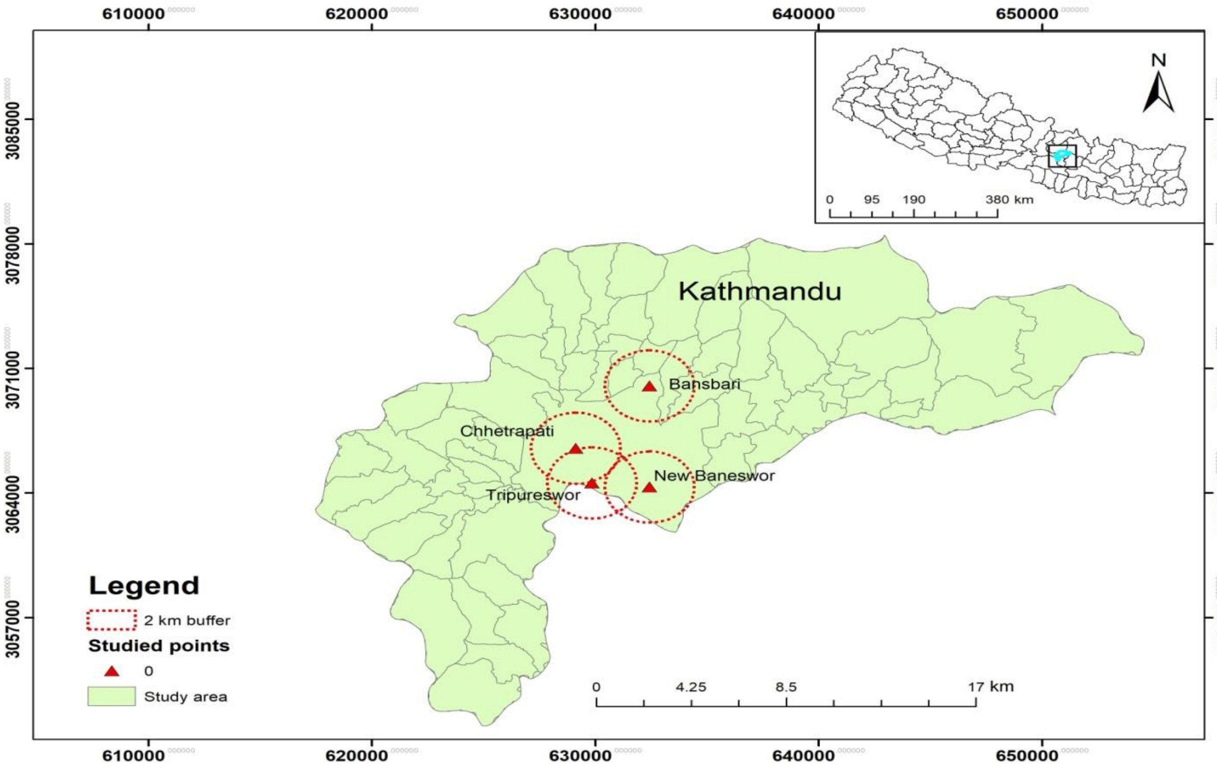


**Fig.1. Map of study area and sampling sites in Kathmandu Valley, Nepal.**

### Procedures

Water samples were taken from 720 houses in Tripureshwar, Baneshwor, Bansbari and Chhetrapati, in the Kathmandu Valley. The sample were collected from 240 taps (municipal supply) , 240 wells (2-20 m depth) and 240 deep tube-wells (10-35m depth) in 2021 covering four seasons; spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Water samples were normally examined within 2-6 hours of collection using the centrifugation method ( 2,500 r/min for 1-2 minutes) followed by light microscope to detect cysts and oocysts of the different parasites (Ritchie, 1948). Direct smears were examined under the light microscope at 100x magnification. Lugol's iodine stain and Modified Ziehl-Neelson Staining were applied to conform the presence of protozoan cysts and oocysts (Sakran *et al.*,2017). Water sample (exact 1000 ml of bottle) were used to collect for sample. The bottle were labeled properly, brought to the laboratory, and preserved properly in the refrigerator until subsequent analysis. Random sampling was conducted in laboratory of Kathmandu Valley Water Supply Management Board (KVWSMB) Sainbu, Bhaisepati, Lalitpur and Nepal environmental and scientific service private limited Kathmandu. The data were entered and analyzed in Microsoft Excel. The method which applied to analysis is given in table.1.

**Table 1. Different parameters and methods of analysis (APHA 1992 Edison18).**

| S. N. | Parameters | Units | Methods of analysis |
|---|---|---|---|
| 1. | Temperature | °C | Thermometers |
| 2. | Turbidity | NTU | Nephelometric, 2130B |
| 3. | Colour | TCU | Spectrophotomeric, 2120 C |
| 4. | pH | - | Electrometric, 4500-H+ B |
| 5. | Total Alkalinity | mg /L | Titrimetric, 2320 B |
| 6. | Total Hardness | mg /L | EDTA Titrimetric, 2320 B |

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| | | | |
|---|---|---|---|
| 7. | Total iron | mg/L | Direct Air- Acetylene AAS, 3111B |
| 8. | Total ammonia | mg/L | Direct Nesslerization, 4500 - NH3C |
| 9. | Chloride | mg/L | Argentometric Titration, 4500 –Cl− B |

## RESULTS AND DISCUSSION

The physico-chemical parameters of the above mention sites in Kathmandu Valley is described belows:

**Temperature (T) in °C:** Temperature is a critical biologically significant factor that plays a fundamental role in the metabolic activities of aquatic organisms. It directly influences enzymatic reactions, respiration rates, and overall metabolic functions, thereby affecting the growth, reproduction, and survival of aquatic species. Understanding temperature variations is essential in assessing the health and stability of aquatic ecosystems. During the study period, the temperature was observed to range between 19.75°C and 28.84°C, demonstrating significant seasonal fluctuations. The lowest average temperatures were recorded during the winter months, while the highest averages were observed during the summer season. This pattern is consistent with the typical seasonal cycle, where colder temperatures prevail in winter due to reduced solar radiation and longer nights, leading to decreased water temperatures.(Fig.2).

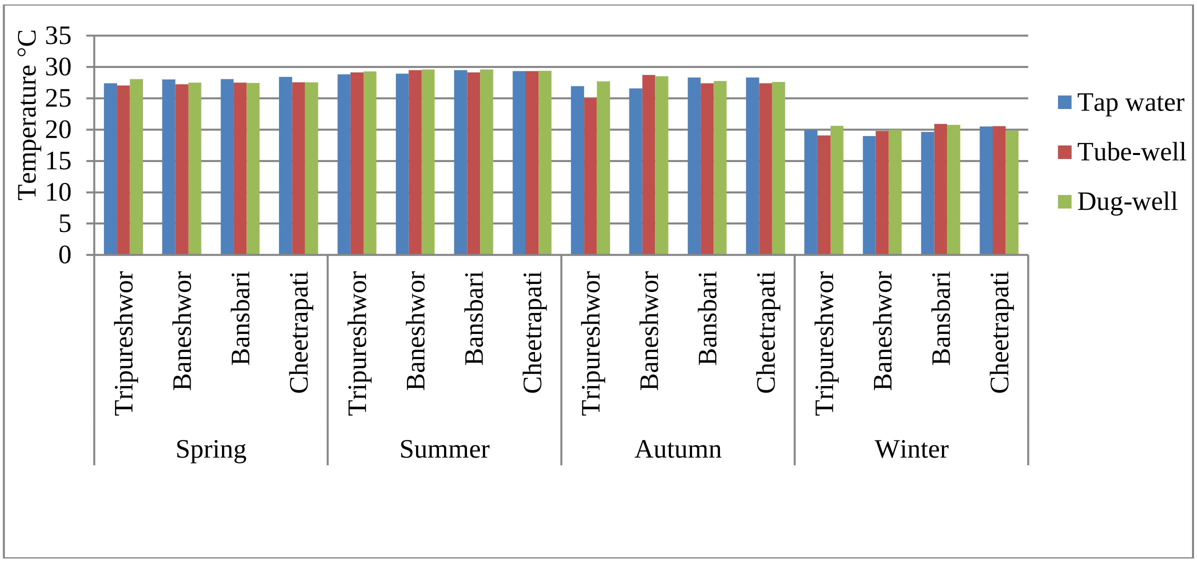


**Fig. 2. Mean value of temperature during four season from four sites.**

**pH :**The pH of water is a crucial parameter that influences the chemical composition, biological processes, and overall quality of aquatic environments. It affects the solubility of nutrients and metals, the availability of oxygen, and the functioning of aquatic organisms. Monitoring pH is vital for assessing water quality and its suitability for various uses, including drinking, agriculture, and supporting aquatic life.In this study, the pH of water samples collected from four different locations across four seasons ranged within the acceptable limits set by the World Health Organization (WHO) and the Nepal Drinking Water Quality (NDWQS) standards. The pH values observed were well within the optimal range for most aquatic organisms, indicating a stable and healthy aquatic environment.The average pH values varied slightly between seasons and sources, with the lowest average pH of 7.3 recorded in tap water during the autumn season. This slightly acidic to neutral pH suggests minimal risk of acidification, which could otherwise lead to harmful conditions for aquatic life and human consumption.On the other hand, the highest average pH of 8.2 was observed in both tube-well and dug well water during the summer season. This slightly alkaline pH is typically associated with higher biological productivity in water bodies. Alkaline conditions can promote the growth of phytoplankton and other aquatic plants, which form the base of the aquatic food web. Consequently, a higher pH in the summer months could indicate an increase in primary productivity, supporting a richer and more diverse aquatic ecosystem.(Fig.3.).

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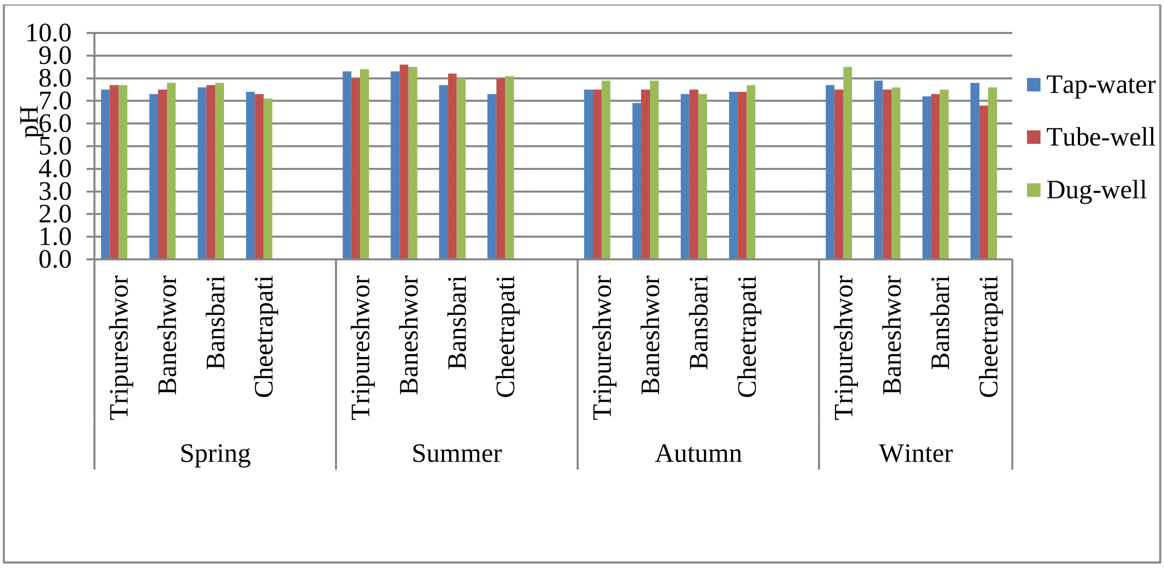


**Fig. 3. Mean value of pH during four season from four sites.**

**Color TCU:**The color of water is an important aesthetic and quality parameter, often influenced by the presence of organic matter, minerals, and other dissolved substances. While color itself does not always indicate harmful contamination, it can affect the acceptability of water for drinking and other uses. In this study, the average color of water samples collected from four different sites over four seasons showed some variability. The lowest average color value was recorded in tap water during the autumn season, with an average color of 1.3. This indicates relatively clear water with minimal discoloration, likely reflecting lower concentrations of dissolved organic materials or minerals during this period. In contrast, the highest average color value was observed in tube-well water during the spring season, with an average color of 2.65. This increase in color could be due to the mobilization of organic matter or minerals from the surrounding soil into the water, which is more common during spring when there is often an increase in precipitation and groundwater recharge. The higher color values in tube-well water may also suggest a greater influence of natural factors such as soil composition and vegetation in the area. Overall, the color variations observed across different seasons and water sources are within acceptable limits and do not indicate significant water quality issues. However, the slightly higher color in tube-well water during spring might suggest the need for further monitoring to ensure that it remains within safe and acceptable levels for consumption and other uses.(Fig. 4.).

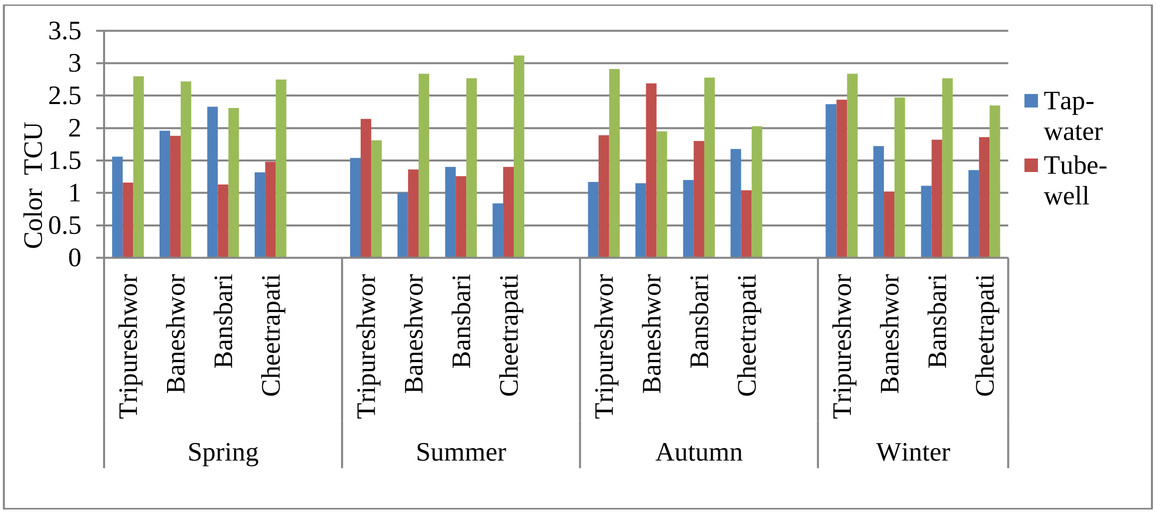


**Fig. 4. Mean value of color during four season from four sites.**

**Turbidity in NTU :**Turbidity is a measure of the cloudiness or haziness of water, primarily caused by the presence of colloidal particles and fine dispersions. It is an important parameter that can affect both the aesthetic quality and the safety of water, as high turbidity levels may indicate the presence of pathogens or other pollutants. In this study, the turbidity of water samples was measured in

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Nephelometric Turbidity Units (NTU) across various sources and seasons.The mean turbidity value recorded for tap water during the summer season was 2.07 NTU. This relatively low turbidity suggests that tap water is clearer and likely undergoes treatment processes that reduce the presence of suspended particles. On the other hand, the highest mean turbidity value of 3.28 NTU was observed in dug well water during the same summer season. This higher turbidity in dug well water could be attributed to the natural introduction of particles from soil erosion or organic matter, which are more common in unprotected or shallow water sources.Overall, the average turbidity values observed in all water samples were below the limits recommended by the World Health Organization (WHO) and the Nepal Drinking Water Quality Standards (NDWQS). This indicates that, despite some variability, the water remains within safe turbidity levels for consumption and other uses.Comparatively, the turbidity of tap water was consistently lower than that of tube well and dug well water. This difference highlights the effectiveness of treatment processes in reducing turbidity in tap water, making it a more reliable source in terms of clarity and safety. The higher turbidity in tube well and dug well water, particularly in summer, may warrant closer monitoring to ensure that it remains within acceptable limits, especially during periods of increased particle mobilization(Fig.5.).

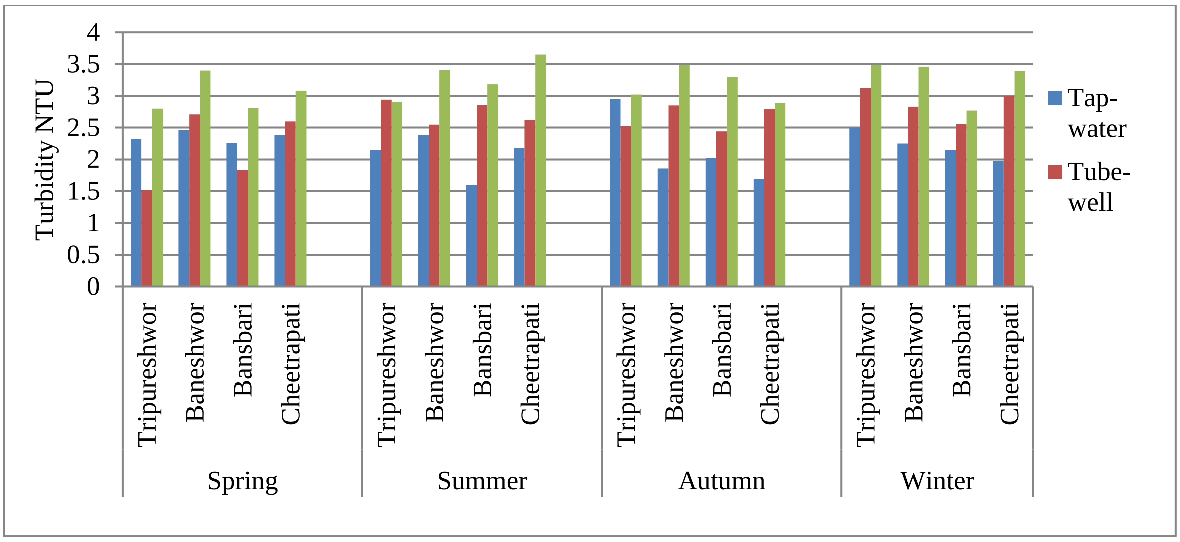


**Fig. 5. Mean value of turbidity during four season from four sites.**

**Total alkalinity (TA) in mg/L:** Total alkalinity (TA) of water refers to its capacity to neutralize strong acids, which is primarily due to the presence of bicarbonates, carbonates, and hydroxide compounds of calcium, sodium, and potassium. Alkalinity is a critical parameter that helps in maintaining the pH balance of water, providing a buffer against rapid changes in acidity, and ensuring a stable environment for aquatic life.In this study, the total alkalinity of water samples from different sources and seasons exhibited notable variations. The lowest mean value of total alkalinity was recorded at 129 mg/L in tap water during the winter season. This lower value may be attributed to reduced dissolution of minerals during colder months, as lower temperatures typically decrease the solubility of carbonates and bicarbonates.Conversely, the highest mean value of total alkalinity was observed at 399.2 mg/L in dug-well water during the summer season. The elevated alkalinity in summer could be due to increased evaporation rates, which concentrate the dissolved minerals, or greater leaching of alkaline substances from the soil into the water during this period.The mean values of total alkalinity across all studied samples were found to be within the acceptable limits set by the World Health Organization (WHO) and the Nepal Drinking Water Quality Standards (NDWQS). This indicates that the water sources analyzed in this study have a sufficient buffering capacity to resist significant pH changes, making them suitable for both human consumption and sustaining aquatic life.Overall, while there is some seasonal and source-related variation in total alkalinity, the values remain within safe and acceptable ranges. The higher alkalinity observed in dug-well water during summer suggests the need for careful monitoring to prevent potential over-alkalinity, which could impact water quality and usability(Fig.6.).

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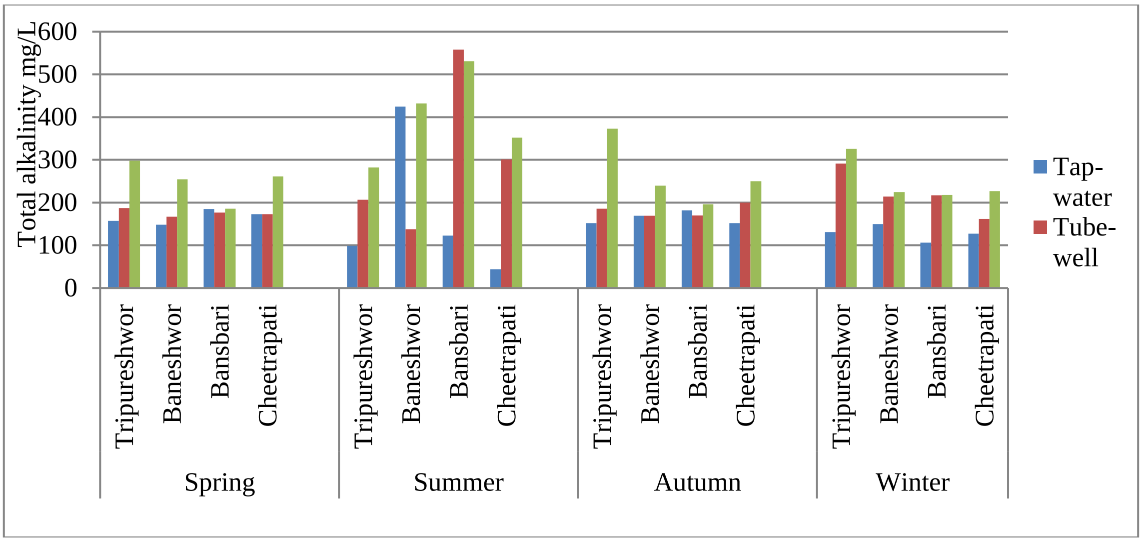


**Fig. 6. Mean value of total alkalinity during four season from four sites.**

**Iron in mg/L:** Iron is an essential nutrient for most living organisms, playing a crucial role in the formation of proteins and enzymes that are vital for various biological processes (Fine, 2000). However, excessive iron can be harmful due to its ability to generate free radicals, which are highly reactive molecules that can cause cellular damage. This toxicity arises when free iron reacts with superoxide ($O_2$) and hydrogen peroxide ($H_2O_2$), both of which are naturally produced during cellular processes (Ryan et al., 1992; McCord, 1998). In this study, the concentration of iron in water samples collected from four different locations across various seasons was analyzed. The mean iron concentration ranged from 0.2 mg/L to 2.8 mg/L. The lowest iron concentration of 0.2 mg/L was recorded in tap water during the autumn and winter seasons. This lower concentration likely reflects the effectiveness of treatment processes in reducing iron levels in municipal water supplies, ensuring that it remains within safe limits for consumption. Conversely, the highest concentration of 2.8 mg/L was observed in tube-well water. Tube wells, which draw water from deeper underground sources, may have higher iron concentrations due to the natural leaching of iron from soil and rock formations. The higher iron levels in tube-well water could pose a risk if consumed over prolonged periods, potentially leading to iron overload and the associated oxidative stress caused by free radical formation. Overall, the study found that while iron concentrations in tap water were consistently lower, tube-well water exhibited significantly higher levels of iron. Despite this variability, it is important to note that the iron concentrations observed in all samples were within the permissible limits set by health standards. However, the elevated levels in tube-well water suggest a need for regular monitoring and possible treatment to reduce iron content, particularly in areas where tube wells are a primary source of drinking water.(Fig. 7.).

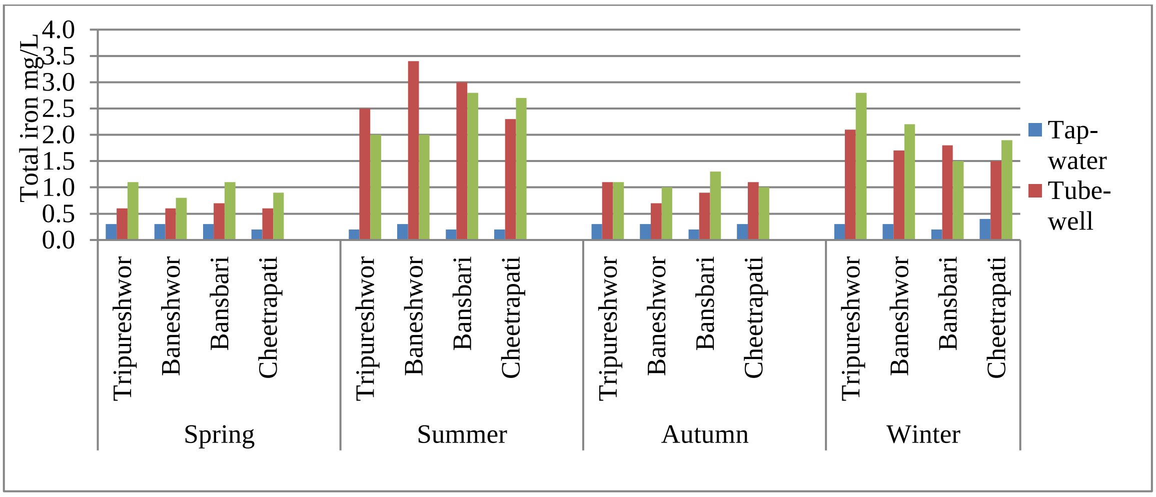


**Fig.7. Mean value of total hardness during four season from four sites.**

**Total hardness (TH) in mg/L:**Total hardness (TH) is an important characteristic of water, primarily defined by its capacity to prevent the formation of lather with soap and to increase the boiling point of water.

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Hardness is mainly attributed to the presence of dissolved calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) salts, which are common in natural water sources. In this study, the total hardness of water samples collected from various sources was measured, with mean values ranging from 135 mg/L to 295 mg/L. The lower end of this range, 135 mg/L, was observed in tap water. This lower hardness is likely due to water treatment processes that reduce the concentration of calcium and magnesium salts, making tap water more suitable for household uses, such as bathing and washing, where reduced hardness is preferable. On the other hand, the highest mean hardness value of 295 mg/L was found in dug well water. Dug wells, which often tap into shallow groundwater sources, can have higher concentrations of dissolved minerals, including calcium and magnesium, due to the water's extended contact with mineral-rich soils and rocks (APHA, AWWA and WEF 1999). The elevated hardness in dug well water suggests that it may require treatment before use in situations where lower hardness is desirable, such as in industrial processes or for washing. The variation in hardness across different water sources highlights the natural differences in mineral content, depending on the source and its surrounding geology. While the mean hardness values observed in this study fall within the acceptable limits for drinking water, it is important to consider the implications of higher hardness levels, particularly for applications where water quality is critical. Regular monitoring and, if necessary, treatment of water from sources with higher hardness, such as dug wells, may be required to ensure that the water remains within safe and acceptable levels for all intended uses( Sawyer,et.,al 2003)(Fig.8.).

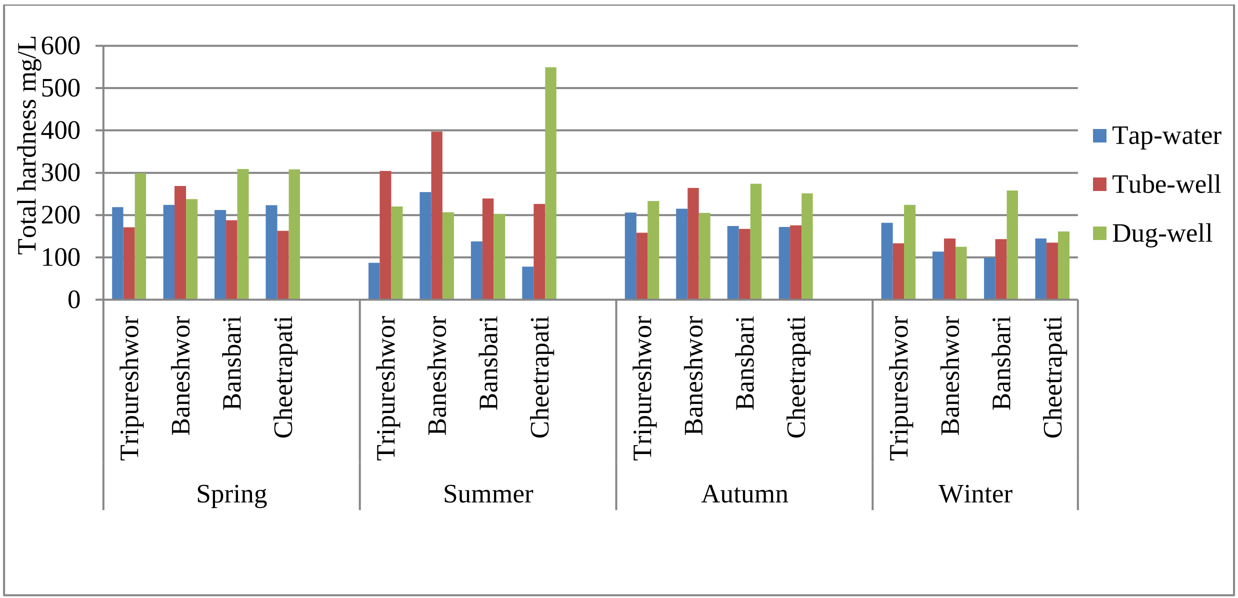


**Fig.8. Mean value of total hardness during four season from four sites.**

**Total ammonia (TA) in mg/L:** Ammonia in natural freshwater systems primarily originates from the breakdown of organic waste matter and the weathering of nitrogen-containing minerals. It is an important parameter to monitor, as elevated levels of ammonia can be toxic to aquatic life and may indicate pollution from agricultural runoff, sewage, or industrial discharges. In this study, the concentration of total ammonia (TA) in water samples collected from four different locations over four seasons varied significantly, ranging from 0.85 mg/L to 55.12 mg/L. The lower end of this range, 0.85 mg/L, was observed in tap water, indicating minimal contamination and suggesting that the water treatment processes effectively reduce ammonia levels to within safe limits for human consumption. In contrast, the highest concentration of 55.12 mg/L was recorded in dug well water. This elevated level of ammonia could be due to the infiltration of organic waste or agricultural runoff into the groundwater. Dug wells, which are often less protected from surface contamination compared to other water sources, are more susceptible to such pollution, leading to higher ammonia concentrations. The observed variation in ammonia levels across different water sources and seasons highlights the influence of environmental factors and land use practices on water quality. While tap water consistently showed lower ammonia concentrations, making it a safer choice for drinking and household use, the higher levels in dug well water could pose a risk to both human health and aquatic ecosystems if left unmonitored. Regular monitoring and management strategies, such as reducing agricultural runoff and protecting water sources from contamination, are essential to maintaining safe ammonia levels in all water sources, particularly in more vulnerable areas like dug wells(Fig.9.).

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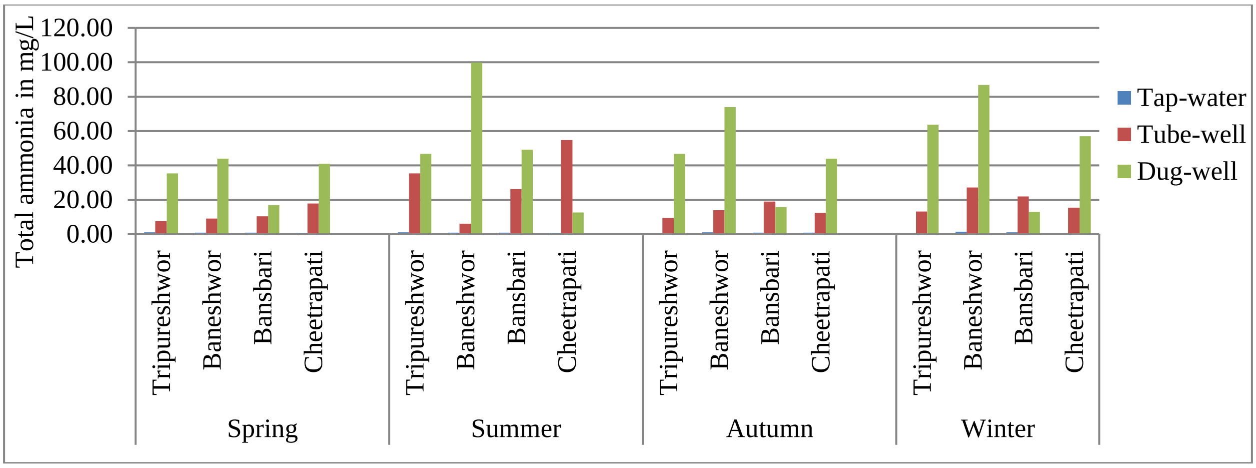


**Fig.9. Mean value of total ammonia during four season from four sites.**

**Chloride ( Cl ) mg/L:** Chloride concentration in water is an important indicator of possible pollution, particularly from sewage or other wastewater sources. Elevated chloride levels can be harmful, as they may lead to laxative effects in individuals who are accustomed to high-chloride water. Monitoring chloride levels is therefore crucial for assessing water quality and ensuring it remains safe for consumption.In this study, the chloride concentration in water samples collected from four different sites across four seasons varied between 25.16 mg/L and 75.86 mg/L. The lower concentration of 25.16 mg/L was observed in tap water, suggesting effective treatment processes that limit the chloride content in municipally supplied water, keeping it well within safe limits for daily use.On the other hand, the highest chloride concentration of 75.86 mg/L was found in dug well water. The elevated levels in dug wells may be attributed to the infiltration of sewage or other forms of pollution, which can introduce chloride into groundwater sources. This higher concentration highlights the vulnerability of dug wells to contamination, particularly in areas where sanitation practices are not well-managed.Despite the variability in chloride levels, the mean values of all the sampled water sources were found to be within the limits prescribed by the World Health Organization (WHO) and the Nepal Drinking Water Quality Standards (NDWQS). This suggests that, while some sources like dug wells may require closer monitoring and potential remediation efforts, the overall chloride levels in the studied areas remain within safe boundaries for human consumption.Continued monitoring of chloride levels, particularly in more susceptible water sources like dug wells, is recommended to prevent potential health risks and to ensure water quality remains compliant with international and national standards(Sawyer et al., 2003; WHO.,2017 and Nepl Government., 2005)( Fig.10.)

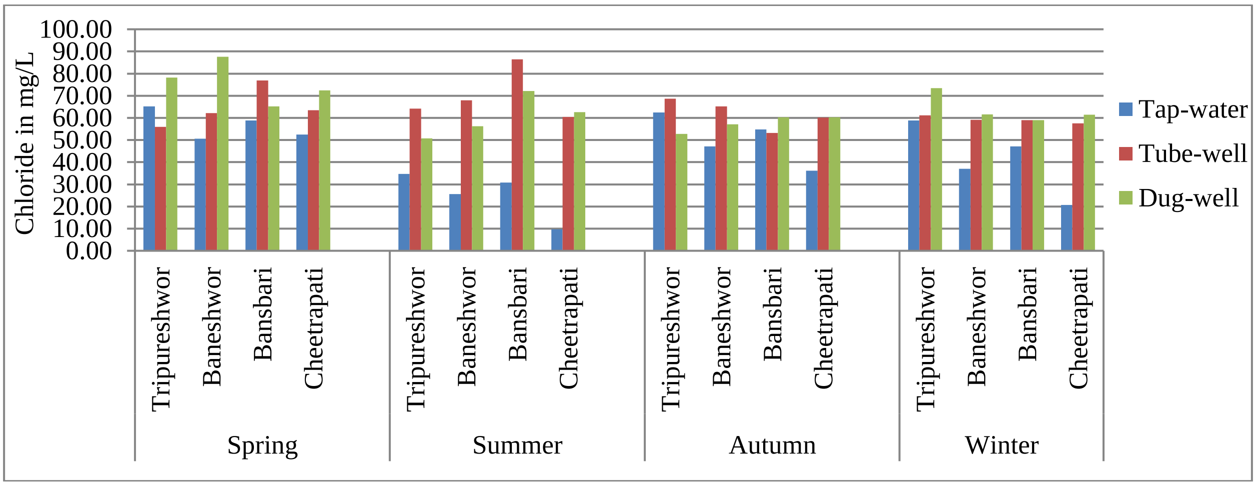


**Fig.10. Mean value of chloride during four season from four sites.**

**Microbiological analysis of Protozoa:**Based on the data provided, you analyzed the presence of protozoa in water samples across different seasons and locations. The results indicate variability in the number and percentage of protozoa detected throughout the year. Below is a summary and discussion of your findingsThe microbiological analysis of protozoa in water samples across different seasons and sites revealed noticeable seasonal variations. In spring, 6 protozoa were detected,

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comprising 0.83% of the total. During summer, the number increased to 17, accounting for 2.36%. In autumn, 10 protozoa were found, making up 1.38%. In winter, 9 species were detected, representing 1.25%. These findings suggest that protozoa populations fluctuate seasonally, likely influenced by environmental factors such as temperature, nutrient availability, and water conditions, which vary throughout the year(Fig.11.).

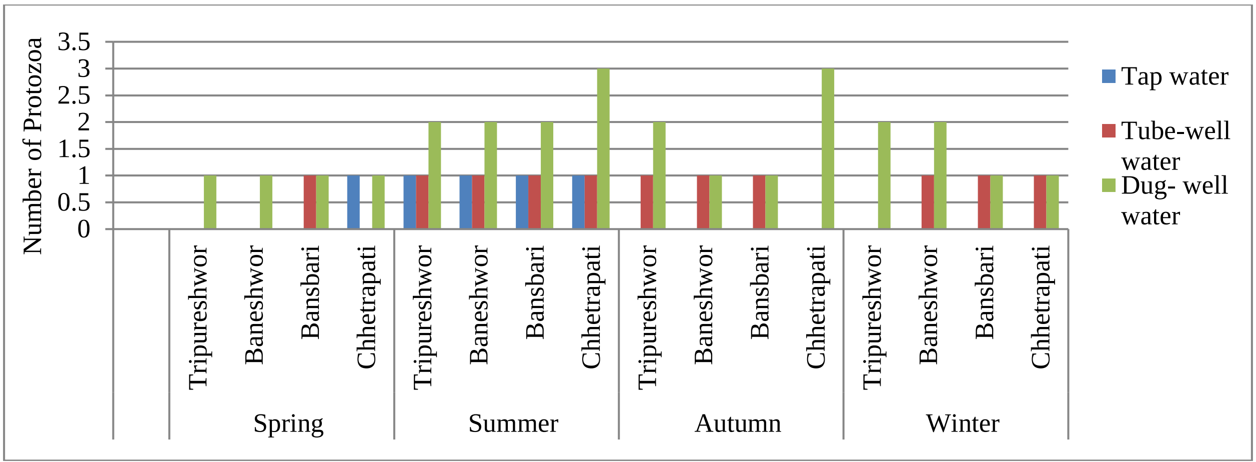


**Fig.11. Seasonal detection of protozoa in four season and four site.**

**Statistical analysis**

The analysis of protozoa presence in water samples across different seasons reveals significant variation in their numbers and percentages throughout the year with F value 18.571 (P-value<0.001). The significant highest number of protozoa 17 (2.36%) were found in the summer season. In spring, 6 protozoa were detected, making up 0.83% of the total (P-value<0.001). In autumn, 10 protozoa were found, representing 1.38% (P-value=0.03), and in winter, 9 were detected, constituting 1.25% (P-value=0.01).These findings suggest that protozoa population fluctuate seasonally, likely influenced by environmental factors such as temperature, nutrient availability, and water conditions, which vary over the year (Fig.11). The analysis reveals significant seasonal variation in protozoa populations, with the highest number occurring in summer, and statistically significant difference observed across all seasons.

**CONCLUSION**

The study conducted on the tap water, tube well water and dug well water quality in Kathmandu Valley, reveals important insights regarding the safety and suitability of water from various sources. Despite the improper management of the surrounding environment of reservoirs and their feeding streams, most of the physico and chemical parameters analyzed were found to be within the acceptable limits set by the World Health Organization (WHO) and the National Drinking Water Quality Standards (NDWQS).Physical and Chemical Parameters. The majority of the physical and chemical properties of the tap water samples, such as temperature (T), turbidity (NTU), color (TCU), pH , total alkalinity (TA), iron , total hardness (TH), total alkalinity (TA), chloride ($Cl^-$), were within the permissible limits. This suggests that, from a chemical standpoint, the water is generally safe for use of general people.Microbial Contamination: However, the study also uncovered a significant concern regarding microbial contamination, specifically the presence of protozoa. Protozoa are microscopic organisms that can cause water-borne diseases if ingested. Their presence indicates that, while the chemical quality of the water may be acceptable, there is a biological risk associated with consuming this water without proper treatment.The tap water, likely treated at a municipal facility, was found to be safe for public consumption. This safety can be attributed to the treatment processes that remove or neutralize contaminants, including microbial pathogens.Tube-Well and Dug Well Water: In contrast, water from tube wells and dug wells was not considered safe for public consumption without significant treatment. The microbial contamination detected in these sources poses a health risk, particularly if the water is consumed without adequate disinfection.Intense Treatment Required: Given the presence of protozoa, it is essential that water from tube wells and dug wells undergo intense treatment with disinfectants before it is deemed safe for drinking and other domestic uses. This treatment is necessary to eliminate microbial contaminants and reduce the risk of water-borne diseases.Improved Water Management: There is a need for better management of the surrounding environment of water reservoirs and feeding streams to prevent contamination. This includes implementing protective measures to reduce the introduction of pollutants into groundwater sources.Regular Monitoring: Continued monitoring of groundwater quality is crucial to ensure that both chemical and microbial parameters remain within safe limits, and to detect any emerging threats to public health.Overall,

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while the chemical quality of the tap water in Kathmandu Valley is largely satisfactory, the study underscores the importance of addressing microbial contamination to ensure the water is safe for consumption.The seasonal detection of protozoa in water samples shows a clear pattern, with higher concentrations during the summer and lower during the spring. This information is crucial for understanding the ecological role of protozoa in aquatic systems and for managing water quality in different seasons. Further research could focus on the specific environmental factors driving these seasonal variations and on the site-specific differences in protozoa populations.

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