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Status of the physico-chemical parameters in drinking water of Kathmandu Valley, Nepal

Siyaram Prasad Sah[1], Archana Prasad[2*]

[1,2*] Central Department of Zoology, Institute of Science and Technology,

Tribhuvan University, Kirtipur 44618, Kathmandu, Nepal.

sahsiyaram123@gmail.com * **Corresponding Author**: archanaprasad001@gmail.comContact no:+977-9841558739

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ABSTRACT

This study investigated the physico-chemical parameters of drinking water of Kathmandu Valley, Nepal, analyzing samples from tap water, tube-well water, and dug well water. A total of 720 samples were collected in 2021, comprising 240 samples each from tap water, tube well water, and dug wells water. The parameters tested included temperature, turbidity, color, pH, total alkalinity, total hardness, iron, ammonia, and chloride concentrations. The findings revealed variable water quality across different sources and seasons. Turbidity was highest in dug well water during summer (3.28±0.27 NTU) nephelometric turbidity unit and the lowest in tap water (2.07±0.32 NTU). Color intensity was greater in dug well water (2.65±0.22 TCU) true color units compared to tap water (1.3±0.25 TCU) during autumn. The pH values indicated that tube-well water was more alkaline in summer (8.2±0.28) and less in autumn (7.3±0.26). Alkalinity peaked in dug well water in summer (399.25±107.09 mg/L) and was lowest in tap water during winter (129±18.04 mg/L). Total hardness was significantly higher in dug well water during summer (294.75±169.65 mg/L) and lower in tap water in winter (135±36.72 mg/L). Iron content was substantially higher in dug well and tube well waters in summer (2.8±0.49 mg/L) compared to tap water (0.2±0.05 mg/L). Ammonia levels were alarmingly high in dug well water in winter (55.12±30.84 mg/L), but minimal in tap water during autumn and winter (0.85±0.32 mg/L). Chloride was found in high concentrations in dug well water in spring (75.86±9.45 mg/L) and lower in tap water during summer (25.16±10.98 mg/L). This study shows the variability and potential risks associated with drinking water quality in Kathmandu Valley, indicating the need for regular monitoring and water quality improvement measures.

Keywords: Alkalinity, Ammonia, Chemical, Chloride, Hardness, Maximum.

INTRODUCTION

Water is the most vital resource for all kinds of life on this planet and essential for ensuring the integrity and sustainability of the earth's ecosystems. (Adimalla 2019; Wu J et al.2020; Chen J, et al 2016). Due to increase population growth, increasing living standards in urban areas and industrialization have resulted in greater demand of quality of water on one hand, while on the other hand water pollution is continuous increasing. In this modern period, the availability and access to fresh water have been among the most critical natural resource issue in the world. Freshwater is essential to human health, for plant cultivation, for different industries and for natural ecosystem (Oişte. 2014; Giri et al. 2015; Zhang et al. 2018). Much of the health problems in the underdeveloped and developed countries are largely due to lack of adequate amount of safe drinking water. There can be no satisfactory state of community health and well being without safe water supply (Velis et al. 2017; Lu et al. 2015; Wang et al .2019). Any types of biological, physical and chemical change in water quality that has a harmful effect on plant animals and other micro-organisms or makes water unsuitable for desired use is water pollution. (Zhang et al. 2020; Umamageswari et al.2019; Su et al. 2017; Cabral et al. 2019). It is one of the most important problems which faced world. Due to lack of sanitation of water it causes different types of disease and death of them (Chen et al. 2019; He et al. 2019; Chowdhary et al. 2020; Chen et al. 2017; Lai, et al. 2017;).

Iron is an essential nutrient for living animals because it is a cofactor of many critical protein and enzymes (Fine, 2000). Iron toxicity is generated by the formation of free radicals (Adimalla et al.2019; He et al. 2020; Wu et al. 2020; Tian et al. 2019; Li et al. 2019). Currently, about two billion people in the world live without access to safe drinking water (Lai et al. 2017). Water borne diseases such as diarrhoea, typhoid, dysentery, and cholera are still major public he (Su F et al 2019; Rusiñol et al. 2015; Wu 2017;). Although threats to the people of Nepal because of contaminated water, poor, sanitation, and unhygienic living condition. According to the national demographic health survey, 8% of children below five years of age suffer from diarrheal diseases. Annually, about 3,500 children in Nepal and two million children throughout the world die to waterborne diseases (Adimalla et al. 2019; Ali et al. 2016).

The use of soap detergent and chemical fertilizers direct effect in the quality of river water. Some soap and detergent contain Nitrilotriacetic acid(NTA). It is very toxic for living life (Odiyo et al.

2018; Schullehner et al. 2018). Nitrilotriacetic acid (NTA) cause different health problem, it cause eye, skin, lungs, and kidney damage March Around 50 types of elements are categorised heavy metals which of them 17 metals are considered very toxic (Adimalla et al. 2019; Mencio et al 2016). Heavy metals cause severe health effect which which depend on type of concentration of the metal ingested. Iron and Manganese are essential for human health , however higher concentration of these metal cause various health problem (Su et al.1018). The exposure to manganese results in a decrease in fetal weight and retardation of development of the bones and internal organ (Li et al. 2014). The present study intends to assess the physico-chemical quality of drinking water from different sources, taps, tube well and dug well in Kathmandu Valley Nepal. The major goal of this research is to identify and analyze the potable water quality parameter ensure that water is good for drinking (Aryal. et. al 2012).

MATERIALS AND METHODS

Study area

Kathmandu Valley is located in midland of the Himalayas, and lies 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 N-S (Khanal et al. 2023). About 65 percentage of economic undertaking of the nation takes place in Kathmandu Valley, have crowded population (2,517,023 of the total population, Central Bureau of Statistic, 2012, 2020). This study is conducted only in, Tripureshwar, Baneshwor Bansbari and Chhetrapati (Fig 1) of the Valley. which is one of the most prominent and bustling areas in Kathmandu, Nepal. It is known for its vibrant atmosphere, strategic location, and diverse amenities, making it a central hub for business, education, government activities and the Parliament House (Singha Durbar) are located nearby, making it a central point for political and administrative activities.

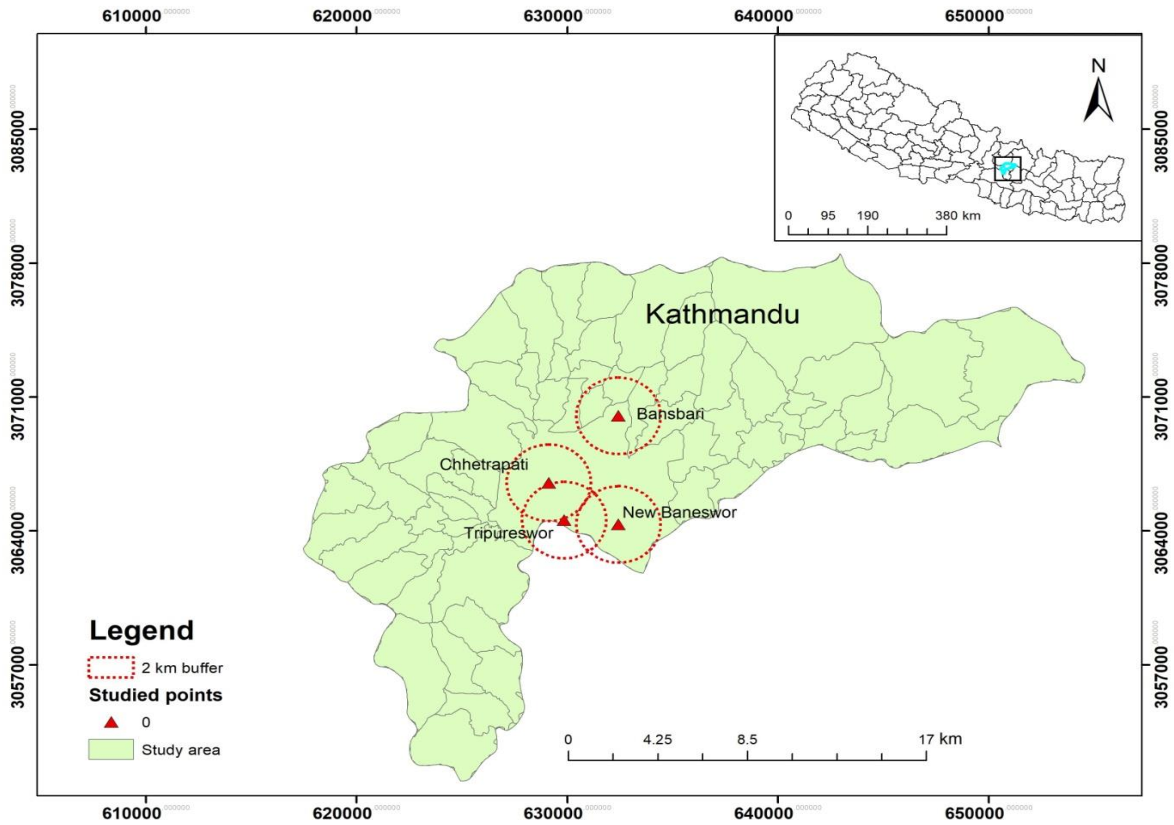

Fig 1. Map of study area and sampling sites in Kathmandu Valley, Nepal.

Methods

This study was conducted in Kathmandu valley Nepal and the total sample was 720 which of them 240 taps (municipal supply), 240 wells (2-20 m depth) and 240 from deep tube-wells (10-35m depth) water samples were taken from different houses of Chhetrapati, Baneshwor, Tripureshwar and Bansbari of Kathmandu valley. The sample was collected in 2021 at four seasons, spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). 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 was entered in excel and analyzed using SPSS. Tap water, tube-well water and dug-well water are major source of water which supply in Kathmandu district. Tap water is considered as safe for public uses because this type of water is distributed by government of Nepal and they distribute this type of water after treatment. Tap water is not available for all general public house.

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
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

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The physico-chemical parameters including temperature, turbidity, color, pH, total alkalinity, total hardness, total iron, total ammonia, and chloride were assessed across four different sites in Kathmandu Valley, Nepal. Tripureshwor, Baneshwor, Bansbari, and Chhetrapati,. Samples were collected in each of the four seasons: Spring, Summer, Autumn, and Winter. By examining these parameters in diverse environmental contexts and climatic conditions, a more nuanced understanding of water quality dynamics in the region could be achieved. The inclusion of multiple sites and seasons allows for a more robust evaluation of potential sources of variation in water quality. Factors such as geographical location, land use patterns, and seasonal weather variations can influence the physico-chemical composition of water sources. By examining these parameters across various sites and seasons, patterns and trends in water quality can be identified, providing valuable insights for water resource management and quality improvement initiatives in the Kathmandu Valley. This multi-site, multi-season approach enhances the comprehensiveness and reliability of the study findings, enabling more informed decision-making regarding water resource management and public health interventions in the region. Turbidity: The turbidity of tap, tube well, and dug well water samples collected across four seasons in Kathmandu Valley, Nepal, exhibited varying patterns and levels. For tap water, the mean turbidity values and standard deviation recorded in spring, summer, autumn, and winter were (2.356±0.08 NTU), (2.07±0.32 NTU), (2.13±0.56 NTU) and (2.22±0.21 NTU) respectively. Although turbidity remained relatively consistent across seasons, a slightly higher level was observed in spring compared to other seasons (Figure 2). The color: The color of water serves as a crucial parameter, impacting both the aesthetic quality and perceived taste of potable water. Analysis of color measurements across different seasons revealed distinct trends and variations among tap, tube well, and dug well water sources in Kathmandu Valley, Nepal. In tap water samples, the mean values and standard deviation of color recorded for spring, summer, autumn, and winter were (1.79±0.44 TCU), (1.19±0.32 TCU), (1.3±0.25 TCU), and (1.63±0.54 TCU) respectively. Notably, the color was slightly higher in spring and winter, with a decrease observed in autumn (Figure 2 and 5). pH: pH is a critical parameter which determine the corrosive nature of potable water, was assessed across different locations and seasons in Kathmandu Valley, Nepal. The pH values of water samples collected from four locations during spring, summer, autumn, and winter were analyzed for tap water, tube well water, and dug well water sources. For tap water, the mean pH values and standard deviation were recorded as (7.5±0.1) spring, (7.9±0.48) summer, (7.3±0.26) autumn, and (7.7±0.31) winter. Maximum pH was observed during summer, while lower values were noted in autumn (Figure. 3 and 4). Total alkalinity in mg/L: Total alkalinity, indicative of water's capacity to neutralize strong acids, encompasses bicarbonate, calcium hydroxide, carbonate, sodium, and potassium compounds. Investigation of total alkalinity across various sites and seasons in Kathmandu Valley, Nepal, highlighted significant variations among tap, tube well, and dug well water sources. In tap water, total alkalinity of mean values and standard deviation were (166±16.47 mg/L) spring, (135±97.91 mg/L) summer, (164±15.04 mg/L) autumn, and (129±18.04 mg/L) winter . Notably, alkalinity peaked during summer and less in winter (Figure 3 and 5).

Total hardness in mg/L: Total hardness, influencing lather formation with soap and boiling points of water, primarily stems from magnesium or calcium salts. Examination of total hardness across various sites and seasons in Kathmandu Valley, Nepal, revealed distinct trends among tap, tube well, and dug well water sources. For tap water, mean value and standard deviation of total hardness were (220±5.44 mg/L) spring, (139±80.94 mg/L) summer, (192±21.97 mg/L) autumn and (135±36.72 mg/L) winter. Maximum hardness was observed in spring, with a decrease in winter (Figure 2 and 5). Total iron in mg/L: Total iron content in drinking water is vital for human health, aiding in oxygen transport in blood and muscle cells. However, excessive iron levels can lead to various health problems. Analysis of iron concentrations across seasons and sites in Kathmandu Valley, Nepal, revealed notable variations and potential health concerns, particularly in tube well and dug well water sources. For tap water, mean values and standard deviation) of iron were (0.3±0.05 mg/L) spring, (0.2±0.05 mg/L) summer, (0.3±0.05 mg/L) autumn and (0.3±0.08 mg/L) winter. Iron concentrations in tap water remained within the limits prescribed by the World Health Organization (WHO) and national drinking water quality standards (NDWQS). Total ammonia mg/L: Total ammonia concentration in drinking water is crucial as it can originate from industrial process wastes containing fertilizers and ammonia, potentially posing health risks. Analysis of total ammonia levels across seasons and sites in Kathmandu Valley, Nepal, revealed significant variations and potential exceedances of safety limits, particularly in tube well and dug well water sources. For tap water, mean value and standard deviation of ammonia were (0.96±0.14 mg/L) spring, (0.88±0.84 mg/L) summer, (0.85±0.32 mg/L) autumn and (0.85±0.32 mg/L) winter. While spring (Figure. 2) exhibited slightly higher levels, and other all values remained within prescribed limits. Chloride in mg/L: Chloride concentration in drinking water serves as a crucial indicator of sewage pollution, with higher levels potentially causing laxative effects on individuals. Evaluation of chloride levels across seasons and sites in Kathmandu Valley, Nepal, revealed varying patterns among tap, tube well, and dug well water sources. For tap water, mean value and standard deviation of chloride were (56.81±6.62 mg/L) spring (25.16±10.98 mg/L) summer, (50.11±11.20 mg/L) autumn and (40.93±16.14 mg/L) winte. Chloride concentrations peaked in spring, with lower levels observed in summer (Figure 2 and 4). Importantly, all values remained within prescribed limits.

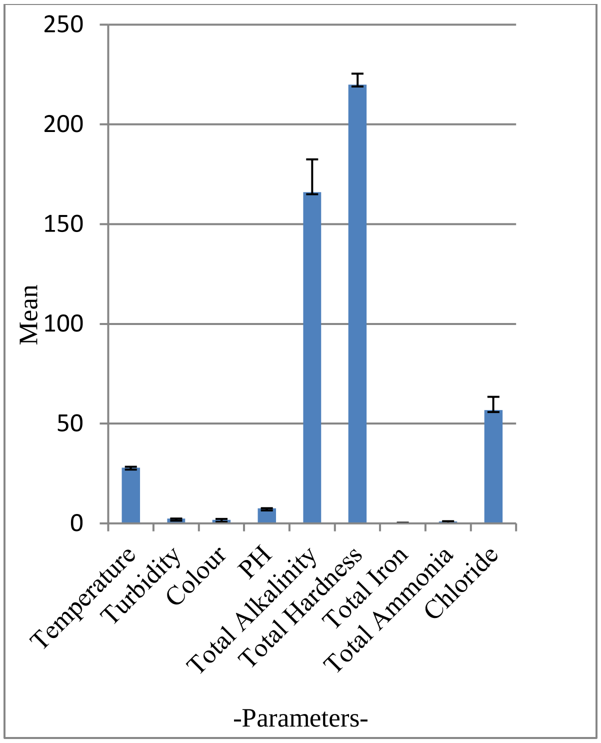


Fig 2. Mean value and standard deviation of tap water during spring.

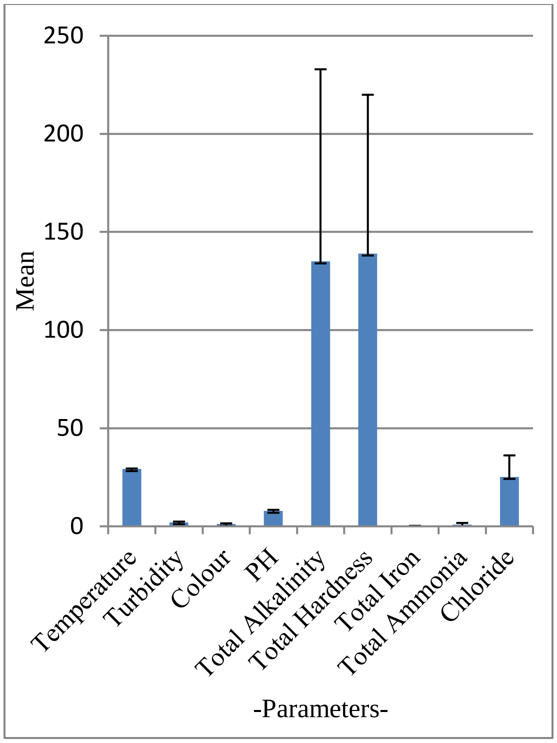


Fig 3. Mean value and standard deviation of tap water during summer.

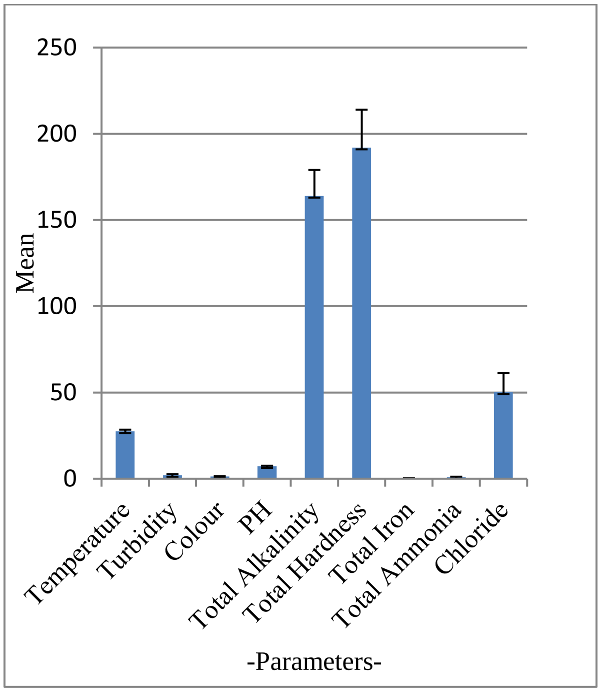


Fig 4. Mean value and standard deviation of tap water during autumn

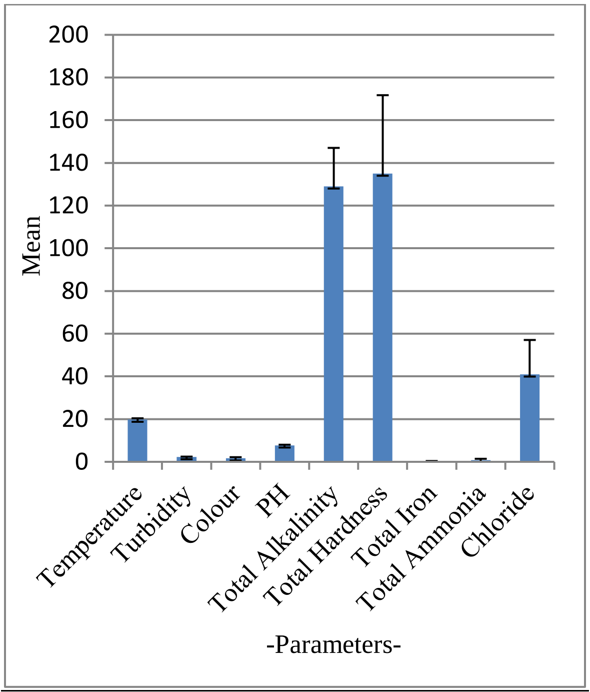
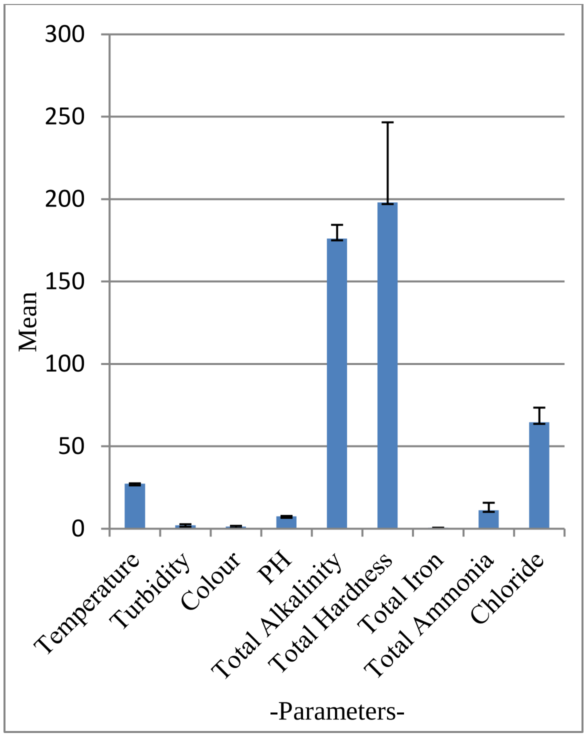


Fig 5. Mean value and standard deviation of tap water during winter

In tube well water, turbidity values fluctuated more prominently across seasons, with mean values and standard deviations noted as (2.16±0.58 NTU) spring, (2.74±0.18 NTU) summer, (2.64±0.20 NTU) autumn and (2.87±0.24 NTU) winter. Notably, turbidity was highest during winter (Figure 9). For tube well water, color measurements varied across seasons, with mean values and standard deviations noted as (1.41±0.34 TCU) spring, (1.54±0.40 TCU), summer (1.85±0.67 TCU), autumn and (1.78±0.58 TCU) winter. Interestingly, color was more pronounced in autumn compared to other seasons (Figure 8). In tube well water samples, pH values and standard deviation were ranged from (7.6±0.19) spring (8.2±0.28) summer, (7.5±0.05) autumn and (7.3±0.33) winter. The highest pH was recorded during summer, with slightly lower values in winter (Figure.7 and 9). Tube well water samples exhibited total alkalinity ranging from (176±8.40 mg/L) spring, (305.06±183.88 mg/L) summer, (181±14.72 mg/L) autumn and (221±53.05 mg/L) winter. Summer showed the highest alkalinity levels, contrasting with lower values in spring (Figure. 6 and 7). In tube well water samples, total hardness ranged from (198±48.63 mg/L) spring, (291.51±78.17 mg/L) summer, (191±49.05 mg/L) autumn and (139±5.88 mg/L) winter. Hardness peaked during summer and decreased in winter (Figure 7 and 9). In tube well water samples, mean iron concentrations ranged from (0.6±0.05 mg/L) spring, (2.8±0.49 mg/L) summer, (1±0.19 mg/L) autumn and (1.8±0.25 mg/L) winter. Iron levels peaked during summer, while autumn showed lower concentrations (Figure 7 and 8). However, iron concentrations in tube well water exceeded prescribed limits set by NDWQS and WHO across all seasons and sites.

In tube well water samples, mean and standard deviation of ammonia concentrations range were (11.22±4.54 mg/L) spring, (30.63±20.22 mg/L) summer, (13.69±3.95 mg/L) autumn and (19.46±6.38 mg/L) winter. Summer recorded the highest ammonia concentrations, with a decrease observed in autumn (Figure 7 and 8). However, both tube well and dug well water samples exceeded the limits set by the national drinking water quality standards (NDWQS) and the World Health Organization (WHO). In tube well water samples, mean value and standard deviation of chloride concentrations ranged from (64.62±8.85 mg/L) spring, (69.74±11.58 mg/L) summer, (61.77±6.69 mg/L) autumn and (59.22±1.48 mg/L) winter. Summer exhibited the highest chloride levels, indicating potential pollution sources (Fig. 7).



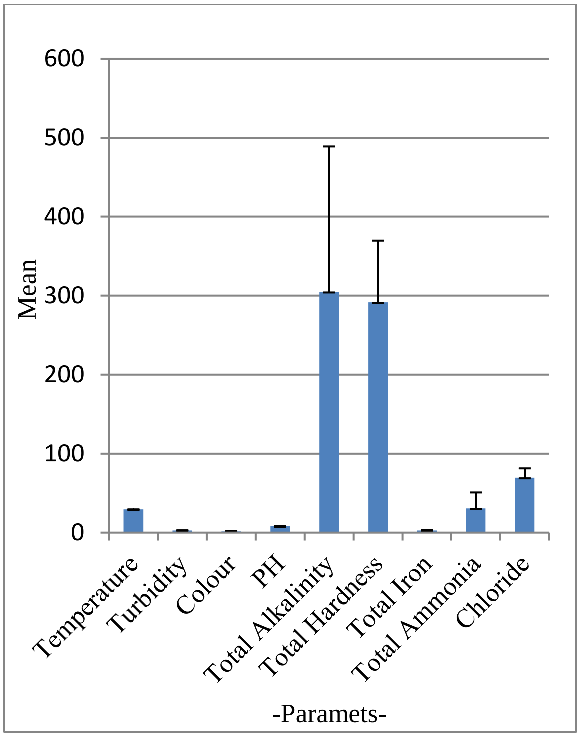
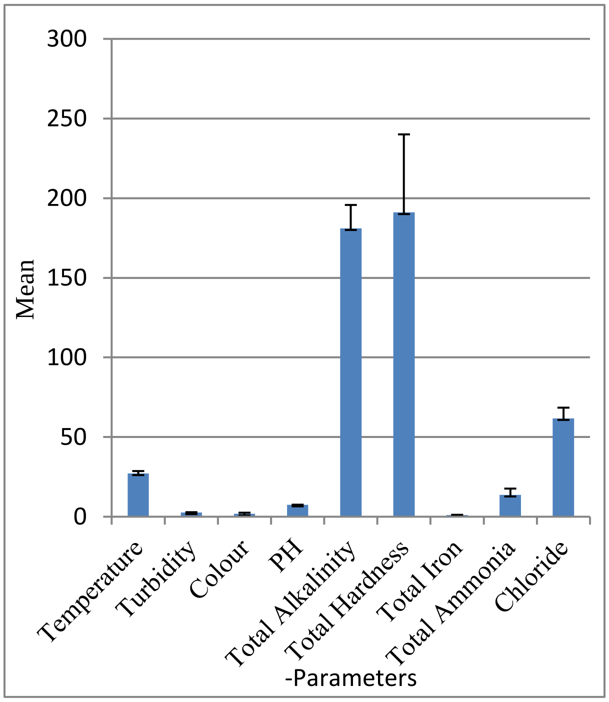


Fig 6. Mean value and standard deviation of tub-well water during spring.

Fig 7. Mean value and standard deviation of tub-well water during summer.



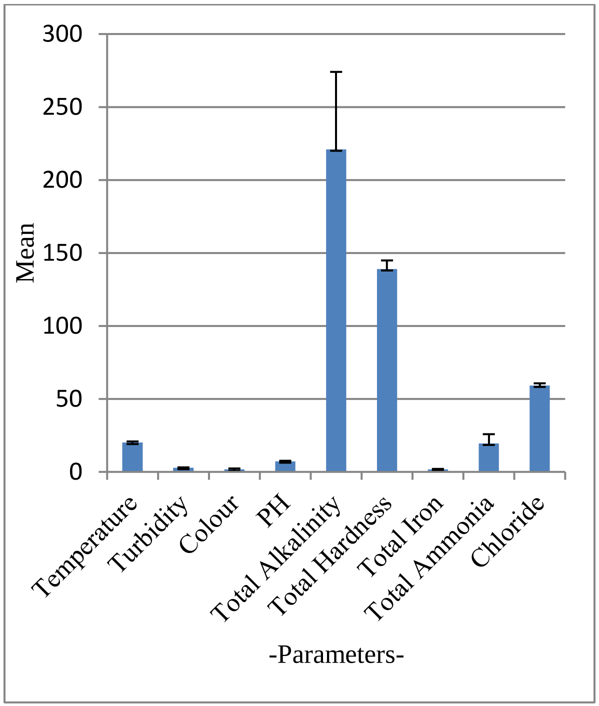


Fig 8. Mean value and standard deviation of tube well during autumn.

Fig 9. Mean value and standard deviation of tub-well water during winter

Dug well water exhibited the highest turbidity levels among the three water sources, with mean values and standard deviations recorded as (3.02±0.28 NTU) spring (3.28±0.27 NTU) summer (3.02±0.27 NTU) autumn and (3.27±0.34 NTU)winter. Particularly, turbidity was notably higher in summer compared to other seasons (Figure 11). Dug well water exhibited consistently higher color values across all seasons, with mean values and standard deviations recorded as (2.65±0.22 TCU) spring, (2.63±0.57 TCU) summer, (2.41±0.49 TCU) autumn and (2.6±0.23 TCU) winter. Although spring showed slightly higher values, the color of dug well water exceeded that of tap and tube well water throughout the year (Figure 10-13). Similarly, dug well water exhibited pH values and standard ranging were (7.6±0.33) spring, (8.25±0.23) summer, (7.7±0.28) autumn and (7.8±0.46) winter. Dug well water displayed total alkalinity values spanning (250±47.71 mg/L) spring, (399.25±107.09 mg/L) summer, (265±75.78 mg/L) autumn and (249±51.47 mg/L) winter. Dug well water exhibited total hardness values spanning (289±33.96 mg/L) spring, (294.75±169.65 mg/L) summer, (241±29.14 mg/L) autumn, and (192±60.08 mg/L) winter. Summer showed the highest hardness, with a decline in winter (Figure 11 and 13). Similarly, dug well water exhibited mean value and standard deviation of iron concentrations ranging were (1.0±0.15 mg/L) spring, (2.37±0.43 mg/L) summer, (1.1±0.14 mg/L) autumn and (2.1±0.54 mg/L) winter. Similarly, dug well water exhibited mean and standard deviation of ammonia concentrations ranging from (34.36±12.09 mg/L) spring (52.06±36.00 mg/L) summer, (45.10±23.76 mg/L) autumn and (55.12±30.84 mg/L) winter. Similarly, dug well water exhibited mean value and standard deviation of chloride concentrations were (75.86±9.45 mg/L) spring (60.46±9.16 mg/L) summer (57.61±3.58 mg/L) autumn and (63.83±6.46 mg/L) winter .

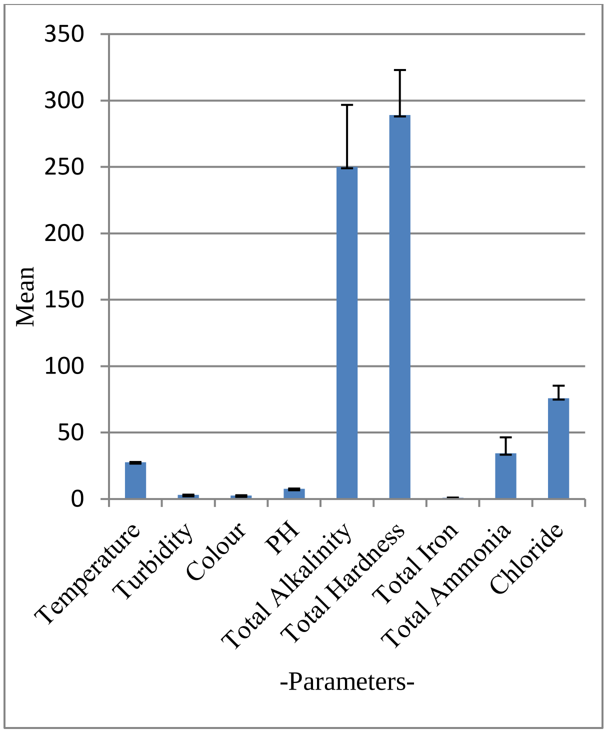


Fig 10. Mean value and standard deviation of dug-well water during spring.

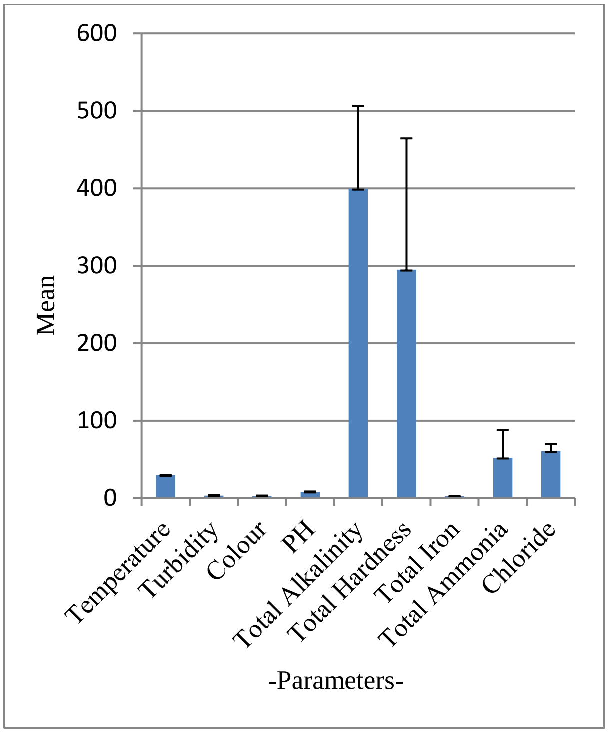


Fig 11. Mean value and standard deviation of dug-well water during summer.

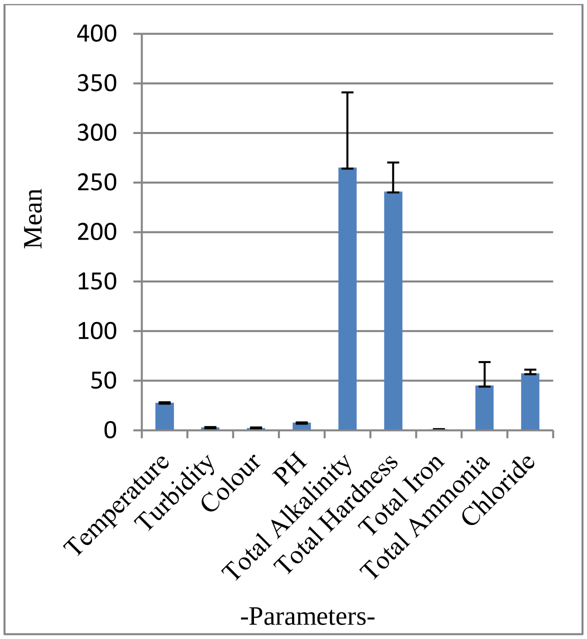


Fig 12. Mean value and standard deviation of dug-well water during autumn.

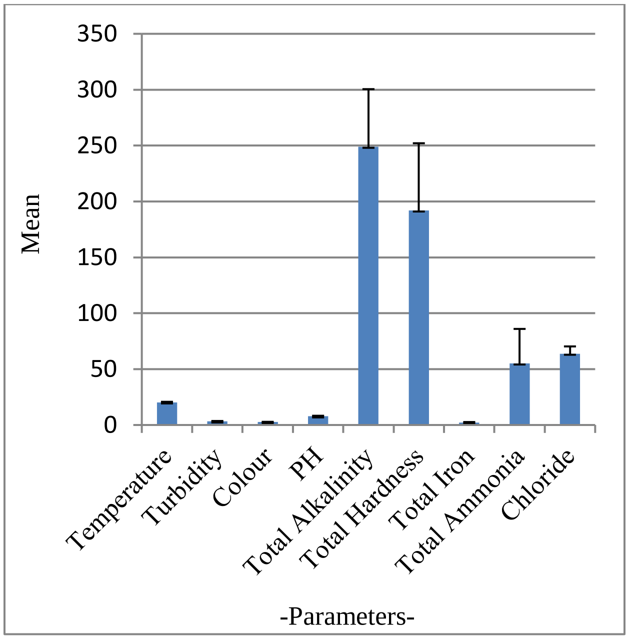


Fig 13. Mean value and standard deviation of dug-well water during winter.

These findings underscore the variability in turbidity levels across different water sources and seasons in Kathmandu Valley. They suggest potential differences in water treatment efficacy, susceptibility to environmental influences, and seasonal variations in sedimentation and runoff. Effective management strategies are crucial to mitigate turbidity-related concerns and ensure the provision of safe drinking water to the population (Chalise et al. 2023). (Figure 13 and 10). These findings underscore potential health risks associated with elevated ammonia concentrations, particularly in tube well and dug well water sources. Urgent measures are required to address ammonia contamination and ensure safe drinking water provision in Kathmandu Valley (Thapa et al. 2023). Spring recorded the highest chloride concentrations, highlighting potential sewage contamination (Figure 10). Despite seasonal variations, chloride values across tap, tube well, and dug well water sources were within the limits prescribed by both the World Health Organization (WHO) and national drinking water quality standards (NDWQS). However, continued monitoring and mitigation efforts are necessary to prevent potential health risks associated with chloride contamination (Rai et al. 2023) These findings highlight the significant variability in water color across different sources and seasons in Kathmandu Valley. The higher color values observed in dug well water indicate potential sources of organic or inorganic contaminants contributing to water discoloration. Effective water treatment and management strategies are essential to address color-related concerns and ensure the provision of aesthetically pleasing and safe drinking water to the population (Shrestha et al. 2023). The pH was highest during summer, consistent with other water sources (Figure 11). Importantly, all pH values for tap water, tube well water, and dug well water samples remained within the limits prescribed by national drinking water quality standards (NDWQS) and the World Health Organization (WHO). This indicates that the water pH in Kathmandu Valley is within acceptable ranges for safe drinking water (Gurung et al. 2023). Summer exhibited the highest alkalinity, with a decrease in autumn (Figure 11 and 12). Notably, all investigated water samples from tap, tube well, and dug well sources exceeded prescribed limits by the national drinking water quality standards (NDWQS) and the World Health Organization (WHO) across all seasons and locations. This highlights potential water quality challenges necessitating appropriate treatment measures for safe drinking water provision (Maharjan et al 2023; Sharma et al. 2023). Crucially, all water samples from tap, tube well, and dug well sources across all seasons and sites fell within the limits prescribed by the national drinking water quality standards (NDWQS) and the World Health Organization (WHO). This suggests that water hardness in Kathmandu Valley remains within acceptable ranges for safe consumption.(Rai et al.2023).

Summer witnessed the highest iron concentrations, whereas spring showed comparatively lower levels (Figure 11 and 10). Iron concentrations in dug well water samples also exceeded NDWQS and WHO limits. These findings underscore potential health risks associated with elevated iron concentrations in tube well and dug well water sources. Effective water treatment measures are necessary to mitigate iron-related health concerns and ensure safe drinking water provision in Kathmandu Valley (Sharma et al. 2023). Winter showed the highest ammonia concentrations, whereas spring exhibited lower levels.

CONCLUSION

Nepal underscores the critical importance of access to safe and clean water for human health and well-being. Despite water being essential for life, many people, particularly in developing countries like Nepal, continue to face challenges in obtaining microbiologically and chemically safe water. Inadequate quality control and sanitation measures in water systems contribute to the dissemination of pathogenic microorganisms, originating from human or wildlife feces, posing significant health risks to consumers. The provision of safe drinking water is a fundamental requirement, yet it remains a challenge in regions where infrastructure and resources are limited. Despite considerable efforts to improve water quality globally, a staggering 1.1 billion people worldwide still consume water contaminated with fecal microorganisms. This highlights the persistent gap in access to safe water and the urgent need for comprehensive solutions to address this issue. Developing standard, reproducible microbial water quality tests is crucial for effectively monitoring and ensuring the safety of drinking water supplies. Such tests enable accurate detection of waterborne pathogens, facilitating timely interventions to mitigate health risks and safeguard public health. In conclusion, the findings underscore the ongoing importance of prioritizing investments and efforts to improve water quality management, particularly in regions facing significant challenges like Kathmandu Valley, Nepal. Addressing the complexities of waterborne pathogen detection and implementing robust quality control measures are essential steps toward achieving the universal goal of providing safe and clean drinking water for a

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