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Assessing physico-chemical parameters of drinking water of different districts of Nepal

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Abstract

Researchers assessed the quality of drinking water from several districts in Nepal by examining both physical and chemical properties. The physical parameters included pH, conductivity, total dissolved solids (TDS), colour, odour, and turbidity, while the chemical parameters covered hardness, ammonia, and iron. Together, these factors provided a comprehensive understanding of the region's water quality. The findings revealed an average pH of 6.65, a conductivity of 442.9 µS/cm, and a TDS of 278.3 mg/L. Hardness averaged 224.8 mg/L, ammonia 0.312 mg/L, and iron 0.39 mg/L. Turbidity was also recorded at 0.312 mg/L. The samples were clear, odourless, and free from haze. All of the measured values fell within the limits set by the Nepal Drinking Water Quality Standards (NDWQS), indicating that the drinking water in the study areas is safe and suitable for consumption.

Keywords: drinking water, iron, NDWQS, Nepal, physico-chemical parameter

Introduction

Water, a fundamental resource for life, is increasingly subjected to deterioration due to anthropogenic activities and climate change (World Health Organization, 2017).

Ensuring the standards of water for domestic, agricultural, and industrial applications are crucial for public health, environmental sustainability, and economic development (Gleick, 2000).

Water contamination is a critical global issue compounded by rapid industrial growth, urban expansion, and modern agricultural practices. The quality of water sources is increasingly degraded by various pollutants stemming from diverse human activities. Industrial processes frequently release heavy metals, organic compounds, and other contaminants into water bodies, resulting in significant environmental and health issues (Zhang et al., 2023). Similarly, agricultural practices contribute to water pollution through the excessive use of fertilizers and pesticides, which introduce harmful nutrients and chemicals into aquatic systems. Urban runoff, loaded with pollutants such as oil, grease, and heavy metals, further exacerbates the contamination of nearby water sources (Echols et al., 2009). Additionally, the discharge of untreated or insufficiently treated wastewater presents germs, nutrients, and organic materials into the environment. Compounding these issues is the impact of climate change, which alters temperature and precipitation patterns, making the management of water quality more complex (Wheeler & Hammer, 2015).

The consequence of poor water quality is vast and complex. In regions without enough sanitation and water treatment infrastructure, use or intake of contaminated water may result in serious health problems, including waterborne illnesses such as cholera and typhoid, fever, and diarrhea. These illnesses cause major public health risks, particularly in vulnerable populations (Malik et al., 2012. Moreover, poor water quality adversely affects aquatic ecosystems, decreasing biodiversity and damaging essential ecological functions such as water filtration and flood minimization. The economic impact of water pollution is also substantial, affecting sectors that rely on clean water, including agriculture, tourism, and manufacturing (Smith, Tilman, & Nekola, 2016).

To address these important challenges, it is essential to systematically assess the physicochemical properties of water. Understanding the composition and quality of water allows the identification of potential pollutants, evaluation of their health and environmental risks, and the development of effective management plans (Day & Dallas, 2011). This project aims to evaluate the physicochemical parameters of water samples collected out from hand pumps in 10 districts of Nepal. By analyzing parameters such as pH, conductivity, turbidity, colour, odor, ammonia, iron, hardness, and total dissolved solids (TDS), this research aims to give a complete overview of water conditions in this region. This assessment will help in identifying pollution sources, understanding the outcomes for public health and the environment, and guiding future efforts in water quality management and improvement. The community of different districts drinks the water from hand pumps, which serve as the main source of drinking water. Therefore, by analyzing the above-mentioned parameters and comparing them to the National Drinking Water Quality Standard (NDWQS) (Government of Nepal, 2000), we can determine whether the water is safe for drinking or not.

This project aims to analyze the physicochemical properties of water samples, including hardness, pH, conductivity, ammonia, iron, and total dissolved solids (TDS). By analyzing these parameters, we can find key insights into the water's suitability for various uses and identify potential contamination issues.

Background of the Study

Water is one of our most essential natural resources, and it is a key component of life on Earth. It acts as a key factor in sustaining ecosystems, agriculture, industry, and human health. Among its various applications, the availability of safe and clean drinking water is perhaps the most fundamental (Tebbutt, 1998). The human body depends on sufficient and unpolluted water for hydration, digestion, metabolism, and other physiological processes. However, with increasing anthropogenic pressures, the safety of drinking water has become a matter of global issue (Bidaisee, 2018).

Several factors affect the quality of drinking water, such as natural geological conditions, climatic variations, and human activities (Jury & Vaux, 2007). It is analyzed based on several physical and chemical properties, commonly referred to as physicochemical parameters (Patil & Bhosale, 2019). These parameters not only determine the acceptability and aesthetic value of water but also serve as indicators of possible health risk. For example, high nitrate levels can cause methemoglobinemia in infants, while elevated fluoride levels can lead to fluorosis.

The physico-chemical characteristics of water are typically assessed through parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, alkalinity, dissolved oxygen (DO), chlorides, sulfates, nitrates, fluoride, and heavy metals, including iron, lead, arsenic, and cadmium. Each parameter provides unique information about the water’s origin, treatment history, and suitability for consumption.

Despite the formulation of national and international drinking water quality standards, in accordance with standards set by the World Health Organization (WHO), Bureau of Indian Standards (BIS), and United States Environmental Protection Agency (USEPA). Large populations across the world still rely on water sources that do not meet basic safety criteria. This is particularly relevant in developing nations where infrastructural, financial, and institutional challenges hinder the provision of safe water. The research mainly focuses on assessing the physicochemical standard of drinking water in a specified region, aiming to determine its compliance with recommended safety guidelines. The findings are expected to yield significant insights for environmental monitoring agencies, public health departments, and local communities.

Materials and Methods

In this work we have used Sample bottles (clean, sterile, and labeled), Volumetric flasks, Pipettes, Beakers, Test tubes, Graduated cylinders, Glass stirring rods, Funnels, Filter paper, Droppers, Chemicals and Reagents, Distilled water, Standard solutions, Hardness: Ethylenediaminetetraacetic acid (EDTA), TDS: known concentration of sodium chloride (NaCl) solution), Indicator solutions, Eriochrome Black T for hardness, Reagents, Ammonia: Phenol, Sodium nitroprusside, Iron: Hydrochloric acid (HCl) and Hydroxylamine, phenanthroline, Buffer solutions, Iron: Ammonium acetate, Ammonia: Oxidizing solution (Alkaline citrate solution and Sodium hypochlorite).

Study Area

The study area of different districts of Nepal and their details geographic information are given in Table 1.

Table 1: Study area and its respective coordinates and elevation.

S.N.	Sample Area	District	Province	Coordinates	Elevation
1.	Birtamod Municipality	Jhapa	Koshi	26°39′N 87°58′E	300 m (984 ft)
2.	Biratnagar Metropolitan City	Morang	Koshi	26°28′N 87°17′E	80 m (262 ft)
3.	Inaruwa Municipality	Sunsari	Koshi	26°36'N 87°09'E	75 m (246 ft)
4.	Rajbiraj Municipality	Saptari	Madhesh	26°32′N 86°45′E	76 m (249 ft)
5.	Manthali Municipality	Ramechhap	Bagmati	27°20′N 86°05′E	1218 m (3996 ft)
6.	Dhulikhel Municipality	Kavrepalanchok	Bagmati	27°37′N 85°32′E	1,550 m (5,085 ft)
7.	Bhaktapur Municipality	Bhaktapur	Bagmati	27°40′N 85°26′E	1,401 m (4,596 ft)
8.	Kathmandu Metropolitan City	Kathmandu	Bagmati	27°42′N 85°19′E	1,400 m (4,600 ft)
9.	Lalitpur Metropolitan City	Lalitpur	Bagmati	27°40′N 85°19′E	1,350 m (4,429 ft)
10.	Nepalganj Municipality	Banke	Lumbini	28°03′N 81°37′E	150 m (492 ft)

The locations of the respective districts of the study area are shown in the political map of Nepal given in Figure 1.

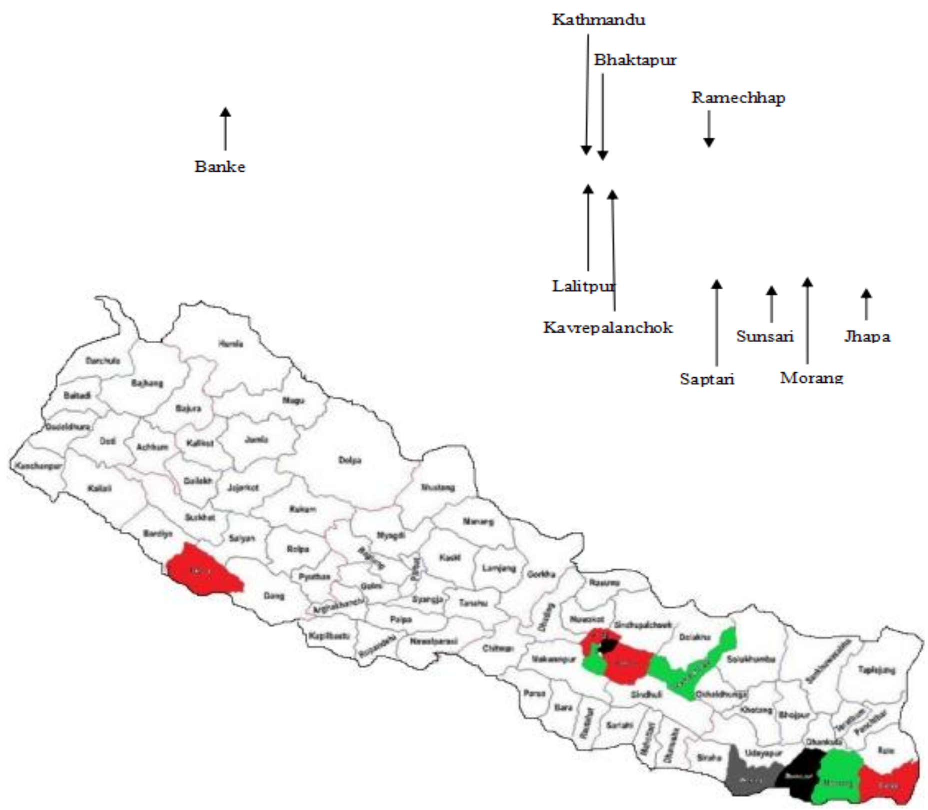

Figure 1: Political map of Nepal showing the districts of the study areas. (Highlighted areas are the respective districts of the study area).

Methods

The analysis of all the physical and chemical parameters of the water sample collected from the handpump of different locations, the study area, was done in the E.G. Labs Pvt. Ltd. situated in Pulchowk, Kathmandu, Nepal.

Field Sampling

The samples were collected to ensure coverage of the entire study area. Samples from ten locations within the study area were collected from handpumps, the community's primary source of drinking water. A clean plastic bottle was used to collect the samples for analysis. The bottles designated for storing the samples were rinsed with water before being filled with the sample water. The bottles were sealed tightly and transported back to Kathmandu by air. Subsequently, all experiments were conducted at E.G. Labs Pvt. Ltd., situated in Pulchowk, Kathmandu, Nepal.

Laboratory Analysis Water Quality Parameters

Physical Parameters: Colour and Odor were analyzed by direct observation, whereas pH, Conductivity, Total dissolved solids (TDS), and Turbidity were analyzed in the laboratory.

pH

The sample's pH was assessed using a digital pH meter. The sample was poured into a 100 ml beaker. The pH rod was rinsed with distilled water and dried using tissue paper. The pH meter was set to 'pH' mode, and the electrode was immersed in the sample to record the measurement. The procedure was conducted again for each of the ten samples.

Conductivity

The conductivity of the sample was measured using a digital conductivity meter. The sample was poured into a 100 ml beaker. The conductivity rod was cleaned with distilled water and dried with tissue paper. The conductivity electrode was immersed in the sample, and the reading was obtained by setting the button to 'conductivity 'mode. The procedure was conducted again for each of the ten samples.

Total Dissolved Solid (TDS)

The total dissolved solids (TDS) in the water sample were measured using a digital TDS meter. To ensure accurate readings, the meter was first calibrated using a known concentration of sodium chloride (NaCl) solution. Once calibrated, the TDS meter was used to measure the TDS content of water samples by immersing the probe in the water and recording the displayed value.

Turbidity

The turbidity of the water samples was measured using a digital turbidity meter. The sample was poured into the turbidity cuvette. It was placed inside the turbidity meter by adjusting the white line. The machine lid was closed, and the turbidity value was recorded.

Chemicalparameters: Hardness, Ammonia, and Iron were analyzed in the E.G. Laboratory and Research Center.

Hardness

To measure water hardness, 25 ml of the sample was first poured into a small conical flask. Next, 1 ml of hardness buffer (NH_4OH–NH_4Cl) and 2–3 drops of Eriochrome Black T (EBT) indicator were added. The mixture was then titrated with 0.01 N EDTA solution until the color changed from wine-red to blue. The starting and ending readings on the burette were recorded, and the hardness of the water was calculated using the appropriate formula.

$$Hardness = \frac{Initialvalue - Finalvalue}{25(volumeofsample)} x1000$$

Iron

The iron content in the water sample was determined using the Phenanthroline Method. A 50 mL portion of the sample was placed in a conical flask, after which 2 mL of concentrated hydrochloric acid (HCl) and 1 mL of hydroxylamine were added. The solution was boiled until the volume was reduced to half. Once it got cool completely, 10 ml of Ammonium acetate buffer solution and 4 ml phenanthroline solution were added. It was diluted to the mark with distilled water, and it was left for 10 minutes so that the orange colour develops. The spectrophotometer was adjusted to 510 nm in wavelength and in absorbance (A) mode. Three cuvettes were filled with distilled water, the standard solution for iron, and the prepared solution, respectively. Each value (blank and sample) was noted three times, and the mean was taken as the final value. The blank value is subtracted from the sample value. The so obtained value was entered in the Iron-curve Excel sheet, and the given values were noted as Iron content.

Ammonia

To determine the ammonia content in the water sample, the Phenate Method was used. A 25 mL sample was poured into a conical flask, and then 1 mL of phenol, 1 mL of sodium nitroprusside, and 2.5 mL of an oxidizing solution (made by combining 20 mL of alkaline citrate solution with 5 mL of sodium hypochlorite) were added. The mixture was left for 1 hour so that the blue colour develops. The spectrophotometer was adjusted to 640 nm in wavelength and in absorbance (A) mode. Three cuvettes were filled with distilled water, the standard solution for Ammonia, and the prepared solution, respectively. Each value (blank and sample) was noted three times, and the mean was taken as the final value. The blank value is subtracted from the sample value. The so obtained value was entered in the Ammonia-curve Excel sheet, and the given values were noted as Ammonia content.

Results and Discussion

Comparison of Physico-chemical Parameters of Water with NDWQS

The analysis of the water samples showed that both physical and chemical parameters fell within the ranges specified by the National Drinking Water Quality Standards (NDWQS). The physical parameters analyzed included color, odor, pH, conductivity, TDS, and turbidity, while the chemical parameters measured were hardness, ammonia, and iron. The results of the physicochemical analysis for water collected from handpumps across ten different districts of Nepal are presented in Table 2.

Table 2: Physico-chemical parameter values of water samples

Parameters	Unit	Experimental range	NDWQS
pH	-	6.3-6.8	6.5-8.5
Conductivity	µS/cm	25-743	1500
Colour	-	Clear	-
Odor	-	ND	Should not be offensive
TDS	mg/L	16-492	1000
Turbidity	NTU	1-90	≤5
Hardness	mg/L	116-428	≤500
Iron	mg/L	0.01-1.8	≤0.3
Ammonia	mg/L	0.02-0.9	≤1.5

Sample-wise variation of physicochemical parameters

pH: The mean value of the pH of all 10 districts' samples was found to be 6.65, which is in the range of NDWQS. The highest pH was of Siraha, Sunsari, Kathmandu, with a pH value of 6.8, and the lowest being of Jhapa with a pH 6.3, which is shown in **Figure 2**.

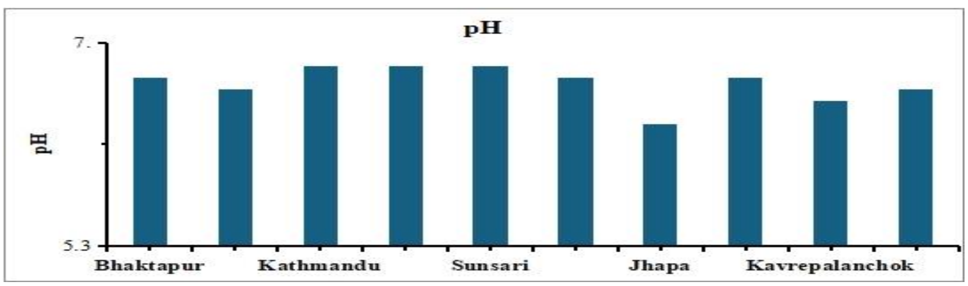

Figure 2: Sample-wise variation of pH

Conductivity

The mean value of conductivity was found to be 442.9 µS/cm. The highest being Banke with 743 µS/cm and the lowest being Ramechhap with 25 µS/cm, respectively. It is in the range of NDWQS and is shown in **Figure 3.**

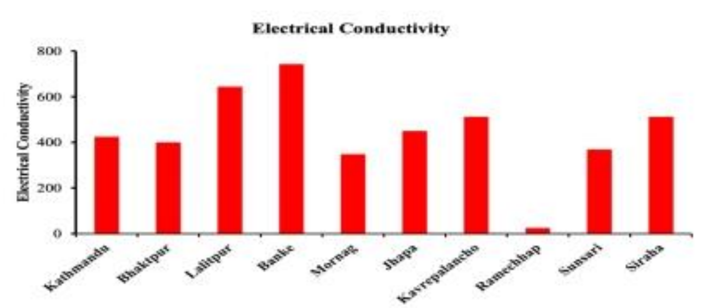

Figure 3: Sample-wise variation of Conductivity

Total dissolved solids (TDS)

The average TDS value was 278.3 mg/L, with the highest recorded in Banke at 492 mg/L and the lowest in Ramechhap at 16 mg/L. These values fall within the limits set by the NDWQS, as illustrated in Figure 4

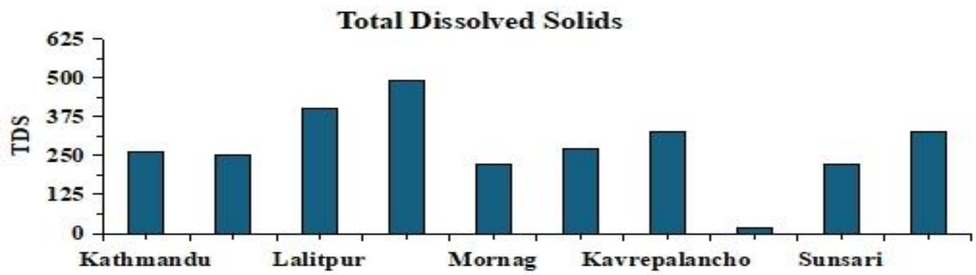

Figure 4: Sample-wise variation of TDS

Hardness

The mean value of Hardness was found to be 224.8 mg/L. The highest being Banke with 428 mg/L, and the lowest being Ramechhap with 116 mg/L, respectively. It is in the range of NDWQS and is shown in **Figure 5**.

Figure 5: Sample-wise variation of Hardness

Ammonia

On average, the ammonia level in the water samples was 0.312 mg/L. The highest concentration was found in Bhaktapur at 0.9 mg/L, while the lowest was recorded in Sunsari, Jhapa, and Morang at just 0.02 mg/L. All these values fall within the safe limits set by the NDWQS, as shown in **Figure 6.**

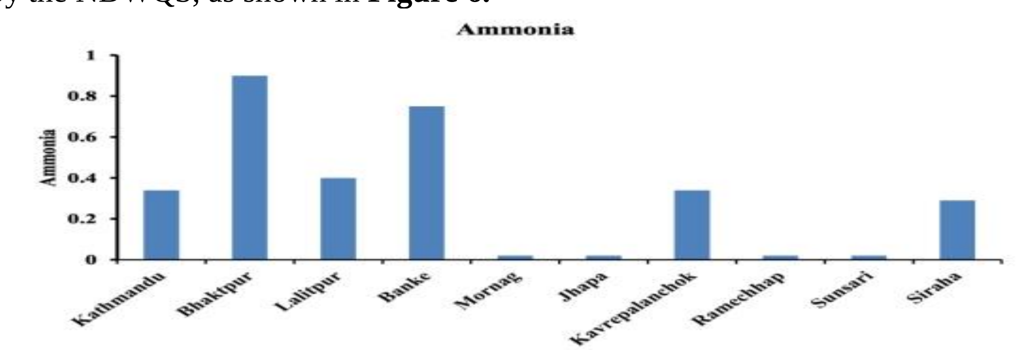

Figure 6: Sample-wise variation of Ammonia

Turbidity

The average turbidity of the water samples was 18 mg/L. The highest turbidity was recorded in Sunsari at 90 mg/L, while the lowest was found in Ramechhap, Jhapa, and Siraha at just 1 mg/L. All these values fall within the safe limits set by the NDWQS, as shown in **Figure 7.**

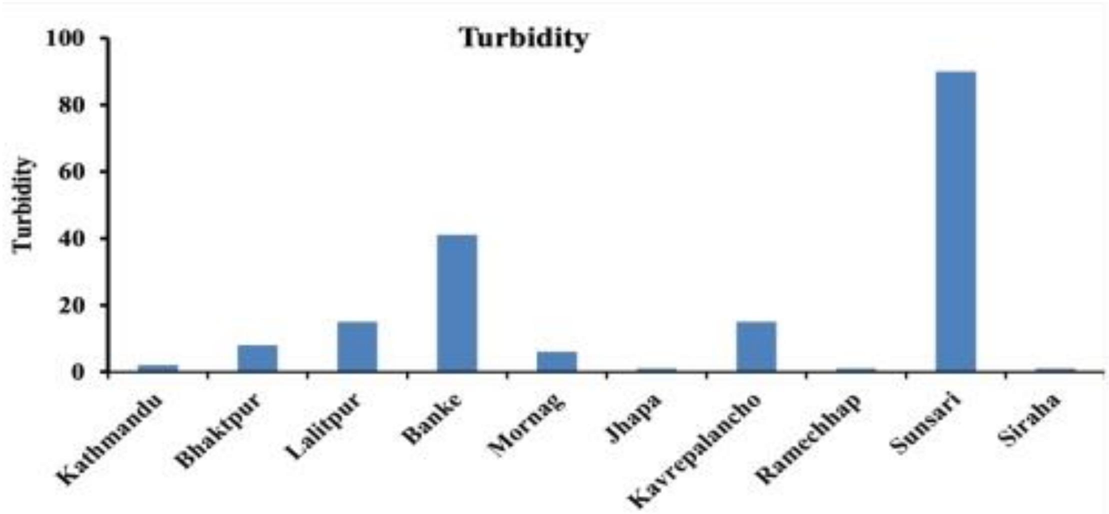

Figure 7: Sample-wise variation of Turbidity

Colour

The mean value of Colour was found to be 0.58 mg/L. The highest being Ramechhap, Kavrepalanchowk, with 1 mg/L, and the lowest being Siraha, Jhapa, with 0.1 mg/L, respectively. It is in the range of NDWQS and is shown in **Figure 8.**

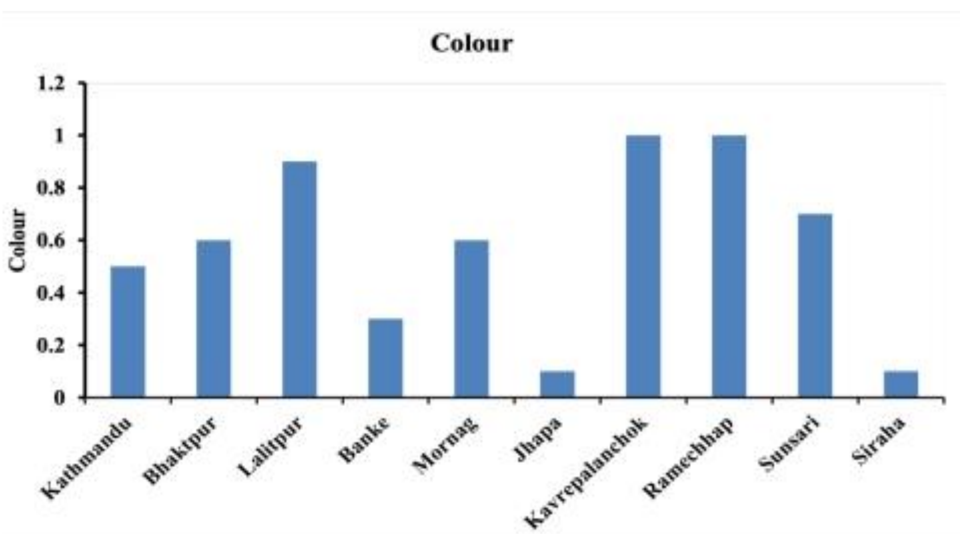

Figure 8: Sample-wise variation of Colour

Iron

The average iron content in the water samples was 0.39 mg/L. The highest level was observed in Sunsari at 1.8 mg/L, while the lowest was recorded in Siraha at just 0.01 mg/L. All these values are within the safe limits set by the NDWQS, as illustrated in Figure 9.

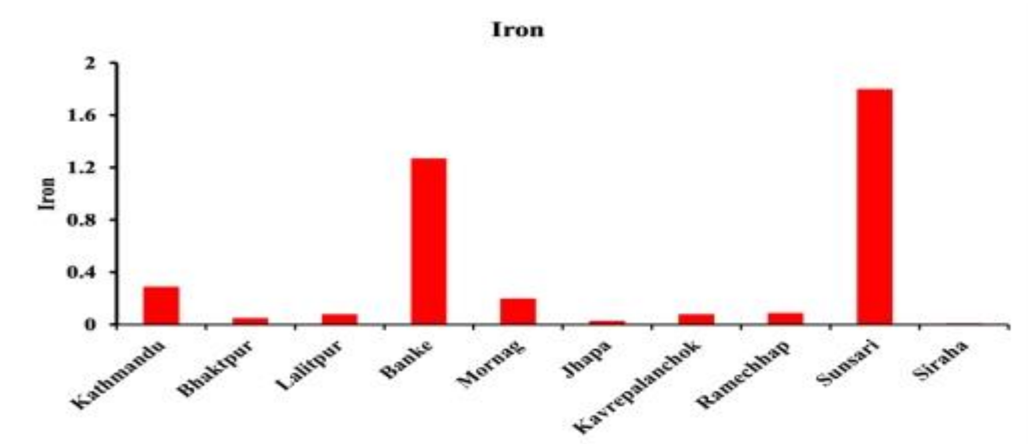

Figure 9: Sample-wise variation of Iron

Conclusion

The analysis of different physicochemical parameters on drinking water quality, such as pH, conductivity, hardness, turbidity, colour, odor, TDS, Ammonia, and Iron, resulted in a range of values within the NDWQS. The mean values of Hardness, pH, Conductivity, and TDS are 224.8 mg/L, 6.65, 442.9 µS/cm, and 278.3 mg/L, respectively. Ammonia and Iron were detected in any of the water samples, being 0.312 mg/L, 0.39 mg/L.This implies that there is contamination from sewage or agricultural runoff. There was turbidity observed being 18, whereas the colour was clear with no odor. In conclusion, the findings of this work revealed that the observed parameters are an optimum level in accordance with NDWQS. Maintaining each parameter within an optimal range is crucial for ensuring good quality drinking water.

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