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Assessment of groundwater quality in Gramthan rural municipality of Morang district, Nepal

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ABSTRACT

This study assesses the groundwater quality in Gramthan Rural Municipality, Morang District, Nepal, with the aim of evaluating its suitability for drinking purposes. Fifteen groundwater samples were analyzed for physicochemical parameters, including temperature, pH, dissolved oxygen (DO), nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), arsenic (As), iron (Fe), phosphate (PO_4^{3-}), total dissolved solids (TDS), total alkalinity (TA), and well depth. The results showed that most parameters were within permissible limits set by the World Health Organization (WHO), except for dissolved oxygen and iron, which were below and above the recommended thresholds, respectively, in several samples. Iron concentrations reached up to 1.5 mg/L, exceeding the WHO guideline of 0.3 mg/L. Additionally, microbial analysis revealed fecal coliform contamination in several samples, with the highest recorded value being 22 MPN/100 mL, surpassing safe drinking water limits. The presence of coliform bacteria is likely linked to poor sanitation practices, such as the absence of a concrete base around wells and proximity to contamination sources. These findings highlight the potential health risks associated with groundwater consumption in the study area and underscore the need for improved water management and sanitation infrastructure to ensure public health safety.

1. INTRODUCTION

Groundwater is one of the most essential natural resources for sustaining human health, agricultural productivity, and ecological balance. Globally, it provides drinking water to nearly 50% of the world's population and supports approximately 40% of irrigation (UNESCO, 2022). In many developing countries, including Nepal, groundwater serves as the primary source of potable water, particularly in rural and peri-urban areas where access to treated surface water is limited (Shrestha et al., 2016). Groundwater is one of the most vital natural resources in Nepal, playing a critical role in ensuring water security for domestic, agricultural, and industrial use. In the Terai region of Nepal, which includes Morang District, groundwater serves as the primary source of drinking water for the majority of the population due to its easy accessibility and relatively low cost (Shrestha et al., 2016). However, with increasing population density, urbanization, and poor sanitation practices, groundwater quality in many parts of the Terai has been increasingly compromised, posing serious public health challenges (Pant et al., 2017).

Nepal has witnessed growing evidence of groundwater contamination from both natural and anthropogenic sources. Naturally occurring contaminants like arsenic have been detected in several Terai districts, including Morang, often exceeding the World Health Organization (WHO) guideline of 0.01 mg/L (Shrestha et al., 2014). At the same time, anthropogenic activities such as the use of chemical fertilizers, improper waste disposal, and the absence of wellhead protection often leads to elevated levels of nitrates, iron, and microbial pathogens in drinking water sources (USEPA, 2006; WHO, 2017). Despite the critical role groundwater plays in rural water supply, regular monitoring of its quality is limited, especially in decentralized and rural municipalities like Gramthan. Local communities often rely on shallow tube wells without proper sanitary sealing, increasing the risk of microbial contamination from nearby latrines, septic tanks, and surface runoff (Sharma et al., 2018). The presence of fecal coliforms in drinking water is a major indicator of fecal contamination, associated with waterborne diseases such as diarrhea, cholera, and typhoid—still prevalent in many parts of rural Nepal (WHO, 1997).

Recently, different studies have been carried out to assess the groundwater quality, such as Malaysia (Hossain *et al*., 2015), Iran (Noshadi *et al*., 2016), China (Qian *et al*., 2016), Tunisia (Hassen *et al*., 2016), Uttarpradesh (Saleem *et al.,* 2016), Karnataka, India (Ravikumar *et al*., 2017), Ranchi (Tirkey *et al*., 2017), Bhagalpur, Bihar (Kumari and Choudhary, 2017; Mishra *et al*., 2017) and Biratnagar, Nepal (Das and Choudhary, 2021; Das *et al*., 2021). Given this context, the present study aims to evaluate the physicochemical and bacteriological quality of groundwater in Gramthan Rural Municipality of Morang District. By identifying contamination levels and potential health risks, this research seeks to contribute to evidence-based water safety planning and promote sustainable water resource management in the region.

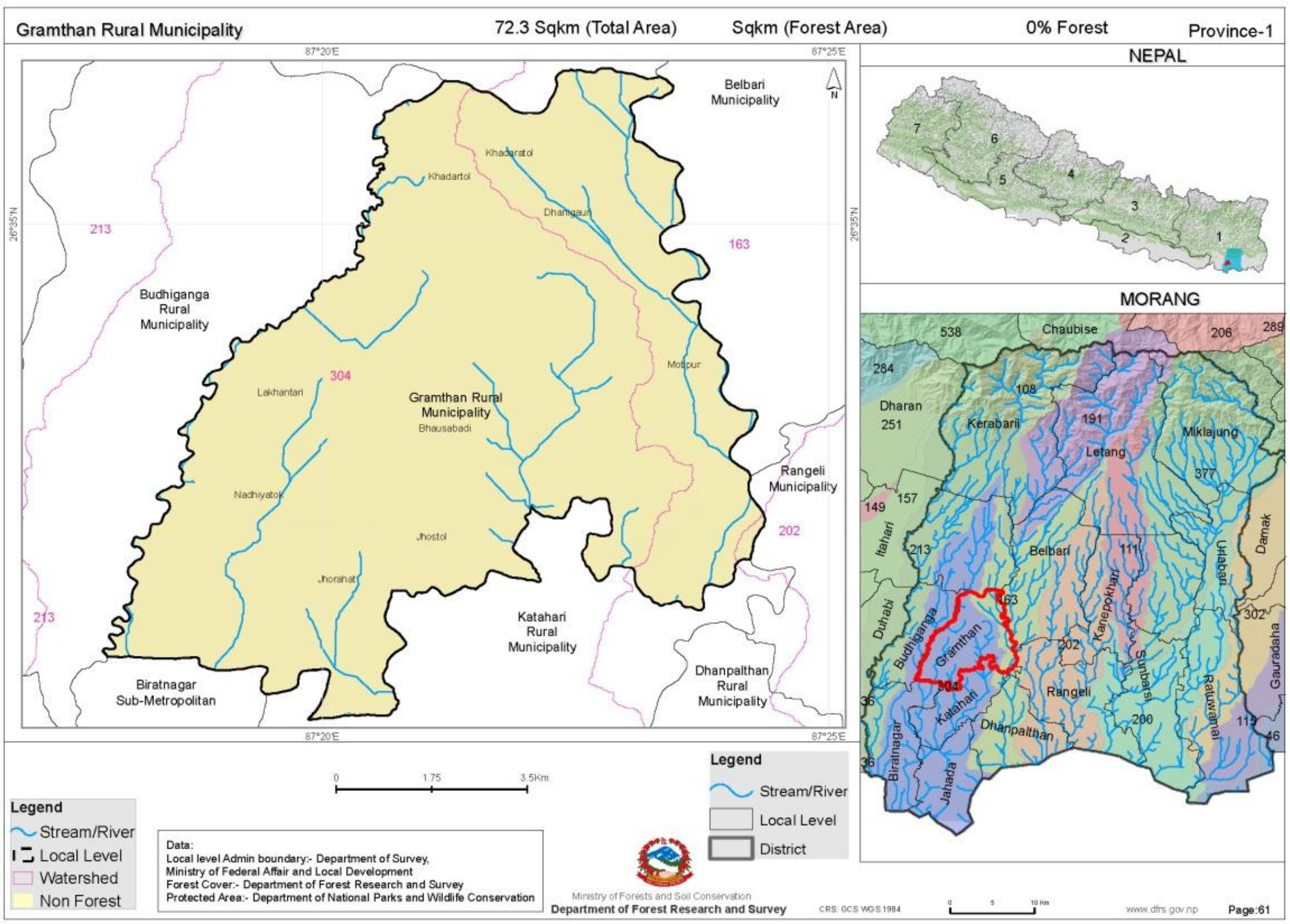

Figure 1
Map of the Gramthan Rural Municipility of Morang Nepal (Source: https://nepalindata.com).

2. MATERIALS AND METHODS

2.1 Study area

The study area falls under Gramthan Rural Municipality in Morang District of Nepal. Gramthan is a rural municipality located at Morang district. This rural municipality has an area of 71.84 km^2. The population as of 2017 is 32,717. The current VDC Office of the Tetariya is the office of this Gaupalika (Figure1).

2.3 Data Collection

Groundwater samples from different sampling points in different sources of drinking water were collected between 8:00 a.m. and 11:00 a.m. Groundwater samples were collected in plastic bottles rinsed with distilled water for determination of important chemical variables like Dissolved oxygen, Iron, Total Alkalinity, Nitrate-nitrogen and Phosphate-phosphorus Ammonium-ammonia. Water samples were transported to the Department of Botany, MMAM Campus, Biratnagar, Nepal. Groundwater samples for microbiological examination were collected following the protocol (APHA, 2017) and were transported to the Department of Microbiology, MMAMC Campus, Biratnagar, Nepal. Below is a methodology (table 1) summarizing the analytical methods used for each parameter assessed in your groundwater quality study.

Table 1
Methodology for Analysis of Groundwater Quality Parameters

S.No.	Parameter	Unit	Analytical Method	Instrument / Technique Used	Standard Reference
1	Temperature (Temp.)	°C	Direct Measurement	Thermometer / Multiparameter Probe	APHA (2017)
2	pH	-	Potentiometric Method	Digital pH Meter	APHA 4500-H^+ B
3	Dissolved Oxygen (DO)	mg/L	Winkler's Titrimetric Method	DO Meter / Titration	APHA 4500-O C
4	Nitrate (NO_3^-)	mg/L	UV Spectrophotometric Method	Spectrophotometer	APHA 4500-NO_3^- B
5	Nitrite (NO_2^-)	mg/L	Colorimetric Method	Spectrophotometer	APHA 4500-NO_2^- B
6	Ammonium (NH_4^+)	mg/L	Nesslerization Method	Spectrophotometer	APHA 4500-NH_3 F
7	Arsenic (As)	mg/L	Atomic Absorption Spectroscopy (AAS) / Test Kit	AAS / Arsenic Test Kit	APHA 3114 B / WHO Guidelines
8	Iron (Fe)	mg/L	Phenanthroline Method	Spectrophotometer	APHA 3500-Fe B
9	Phosphate (PO_4^{3-})	mg/L	Stannous Chloride Method	Spectrophotometer	APHA 4500-P E
10	Total Dissolved Solids (TDS)	mg/L	Gravimetric / Conductometric Method	TDS Meter / Conductivity Meter	APHA 2540 C
11	Total Alkalinity (TA)	mg/L as $CaCO_3$	Titrimetric Method (using phenolphthalein and methyl orange)	Burette and Indicators	APHA 2320 B
12	Depth of Tube Well	m	Direct Measurement	Measuring Tape	Field Observation
13	Fecal Coliform	MPN/100 mL	Most Probable Number (MPN) Method	MPN Test Kit / Multiple Tube Fermentation	APHA 9221 E / WHO (1997)

3. RESULT AND DISCUSSION

The samples were analyzed during the period of post-monsoon 2021. All the results are enumerated in the table (1 and 2) and figure (2, 3 and 4).

Temperature (20–25°C)

The values of temperature ranged from 20^0 C to 25^0C. Cool water is generally more palatable than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems. There was no any guideline value to be compared with (WHO, 2008).

pH (6.0–7.5)

The pH values ranged from slightly acidic (6.0) to neutral (7.5). According to the WHO (2017) guidelines, the acceptable range for drinking water pH is 6.5 to 8.5. Several samples were slightly below this range, indicating mildly acidic conditions which could lead to corrosion of plumbing materials, releasing metals like iron into the water. While not immediately hazardous, continued use of slightly acidic water may degrade infrastructure and influence metal solubility.

TDS (TDS: 56 –318 mg/l)

The TDS value ranged from 56mg/L to 318mg/L and were below the allowable limit of 1000 mg/L, the palatability of drinking water can be classified according to TDS as excellent (< 300 mg/L), good (300–600 mg/L), fair (600–900 mg/L), poor (900–1200 mg/L) and unacceptable (> 1200 mg/L) (WHO, 2008). According to this categorization, most of the studied locations (14 out of 15) can be classified as excellent water class. On the other hand, the studied location (1 out of 15) falls under good water class.

Table 2
Physicochemical concentration at Gramthan rural municipality, Morang

S.No.	Temp.	pH	DO	NO_3	NO_2	NH_4	As	Fe	PO_4	TDS	TA	Depth
1	20	6.6	4.4	0.35	0.5	0	0	1.5	0	160	150	102
2	22	6.5	4.4	0.39	0.5	0	0	1.0	0	142	125	120
3	21	6.3	4	0.36	0.5	0.1	0	1.0	0	168	55	65
4	25	6.6	4	0.37	0.5	0.1	0	1.0	0	205	225	65
5	24	6.4	4.4	0.35	0.5	0.1	0	1.0	0	221	220	30
6	23	6.4	2.6	0.36	0.5	0	0	1.0	0	236	250	105
7	23	6.0	3.2	0.36	0.5	0	0	1.0	0	91	35	35
8	23	6.0	2.8	0.37	0.5	0	0	1.5	0	102	110	104
9	23	7.5	3.6	0.35	0.5	0.1	0	1.0	0	148	145	108
10	24	6.6	8.4	0.35	0.5	0	0	1.0	0	146	185	115
11	24	6.2	5.6	0.36	0.5	0.1	0	1.0	0	84	80	15
12	23	6.3	7.2	0.42	0.5	0	0	1.0	0	111	75	30
13	22	6.2	20	0.43	0.5	0	0	1.0	0	137	170	95
14	22	6.0	4.4	0.39	0.5	0.1	0	1.5	0	56	50	20
15	23	6.1	7.6	0.35	0.5	0	0	1.5	0.5	318	190	18

[Note: All the parameters are expressed in mg/L except Temperature (^{0}C), pH, Fecal Coliform (FC/100ml), and depth (feet)].

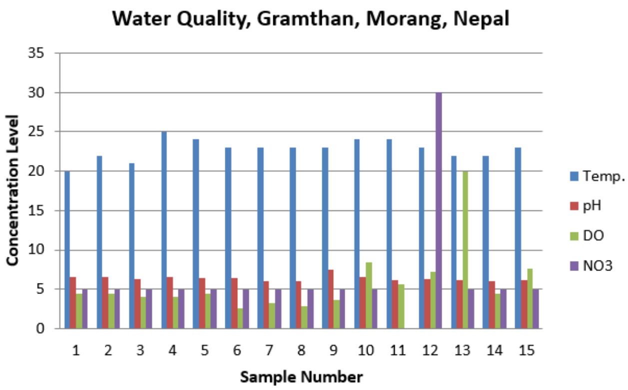

Figure 2
Concentration of Temp., pH, DO and NO_3 in Gramthan, Morang

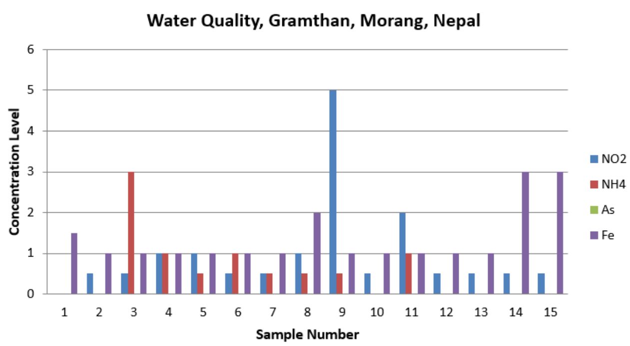

Figure 3
Concentration of NO_2, NH_4, As and Fe

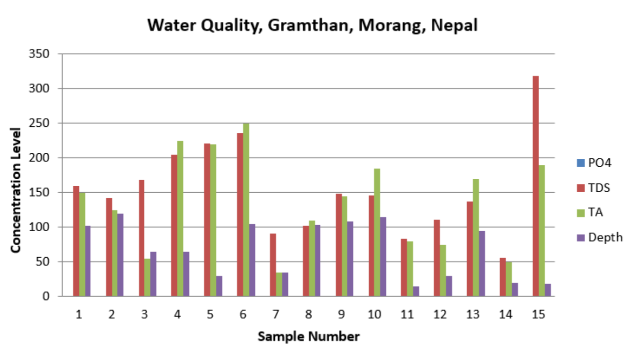

Figure 4
Concentration of PO_4, TDS, TA with Depth

Nitrate (NO_3^-: 0.35–0.43 mg/l)

The nitrates (NO_3^-) concentration ranged from 0.35 mg/L to 0.42mg/L. The concentrations of nitrate in the remaining groundwater basins were found below the permissible limit of 50 mg/L. The nitrate level above the maximum allowable limit of 50 mg/L is a potential health concern, since it may cause methemoglobinemia in infants (WHO, 2011).

Nitrite (NO_2^-: 0.5 mg/l)

The values of nitrite were constant at 0.5mg/L in all the samples which was five times higher than the WHO limit of 0.1 mg/L. This raises concern, as nitrite is more toxic than nitrate and interferes with oxygen transport in the blood (methemoglobinemia risk). Its presence may be attributed to the incomplete oxidation of ammonium or organic waste in anaerobic conditions, which aligns with the observed low DO levels (WHO, 2017). Persistent nitrite suggests biologically active contamination.

Iron (Fe: 1.0–1.5 mg/l)

The value of iron ranged from 1mg/L to 1.5mg/L. Iron levels in all samples exceeded the WHO limit of 0.3 mg/L. This suggests either natural leaching from iron-rich soils and rocks or corrosion of iron-based well components. Although not harmful at these levels, elevated iron causes aesthetic and usability issues such as metallic taste, staining, and promoting iron bacteria growth. This may explain biofilm formation or turbidity in some wells (WHO, 2017).

Dissolved Oxygen (DO: 2.6–20 mg/l)

The value of dissolved oxygen ranged from 1.6 mg /L to 2.0 mg/L. All the values were below the WHO guideline value of 5 mg/L. Low DO is often a sign of microbial activity from organic matter decomposition or poor aquifer aeration, potentially associated with sewage or runoff intrusion. Conversely, a DO value of 20 mg/L is anomalous and may indicate a sampling or equipment error, as such high values are not typical in groundwater (EPA, 2009). Persistent low DO reduces water's oxidative capacity, which can allow the survival of pathogenic anaerobic organisms.

Phosphate–phosphorus (PO_4^-P: 0–0.5 mg/l)

The phosphate values ranged from 0 to 1 mg /L. All the values were below the WHO guideline value of 0.1 to 1.0 mg/L. The guideline value is not available in NDWQS-Nepal for PO_4^-P. Phosphate is required for almost all micro-organisms and is one of the most important nutrients of aquatic systems. It is in abundance in igneous rocks and occurs in the form of 187 different minerals (Golterman, 1975). It also occurs in soluble forms in water. Phosphate is required for cellular function and skeletal mineralization but excess amounts of phosphorus intake for long periods are a strong factor in bone impairment and ageing (Takeda *et al.*, 2004).

Ammonium (NH_4^+: 0–0.1mg/l)

The values of ammonia were ranged from nil to 0.1 mg/L. Natural levels of ammonia in groundwater are usually below 0.2 mg/L. Higher natural contents (up to 3 mg/L) are found in strata rich in humic substances or iron or in forests (Dieter & Möller, 1991). Ammonia is not of direct importance for health in the concentrations to be expected in drinking-water. A health-based guideline has therefore not been derived.

Arsenic (As: 0 mg/l)

No arsenic was detected in any sample. This is encouraging, as arsenic is a major issue in many parts of the Terai region. The absence suggests the study area’s groundwater is not geogenically contaminated or that these wells tap aquifers with low arsenic-bearing sediments. However, continued monitoring is advised since arsenic distribution can be patchy and seasonal (UNICEF, 2011).

Total Alkalinity (TA: 35–250 mg/l)

Alkalinity, a measure of water's buffering capacity, varied significantly. Samples with higher alkalinity (e.g., 250 mg/L) suggest the presence of bicarbonates, often from carbonate rock dissolution. While high alkalinity is not harmful, it can contribute to scale formation. Lower values (<50 mg/L) indicate limited buffering and potential vulnerability to acid inputs (Chapman, 1996).

Coliform Examination (0–22 MPN/100ml)

Coliforms were detected in several samples, with one exceeding 22 MPN/100 ml, violating the WHO standard of 0 MPN/100 ml for safe drinking water. The likely causes are poor well construction, lack of sealed platforms, and proximity to latrines or septic tanks. This poses serious health risks, especially for children, and highlights the urgent need for sanitary improvements (WHO, 1997).

Here is the simplified correlation matrix Table 3 (values range from -1 to +1), showing the strength and direction of relationships between groundwater quality parameters:

Table 3

Correlation Matrix Table

	Temp	pH	DO	NO_3	NH_4	Fe	PO_4	TDS	TA	Depth
Temp	1.00	0.07	-0.08	-0.15	0.24	-0.39	0.04	0.15	0.36	-0.25
pH		1.00	-0.14	-0.29	0.27	-0.34	-0.20	0.16	0.35	0.50
DO			1.00	0.62	-0.28	-0.14	0.12	-0.00	0.14	0.06
NO_3				1.00	-0.24	-0.14	-0.22	-0.39	-0.24	-0.02
NH_4					1.00	-0.18	-0.22	-0.10	-0.10	-0.38
Fe						1.00	0.44	0.04	-0.11	-0.12
PO_4							1.00	0.66	0.21	-0.35
TDS								1.00	0.75	0.02
TA									1.00	0.35
Depth										1.00

The correlation analysis of groundwater quality parameters in Gramthan Rural Municipality revealed several notable relationships. Dissolved oxygen (DO) showed a moderate negative correlation with temperature and total dissolved solids (TDS), indicating that higher temperatures and increased mineral content may reduce oxygen availability in water. A moderate positive correlation was observed between DO and total alkalinity (TA), suggesting that more alkaline conditions may support better oxygen levels. Iron (Fe) exhibited a negative correlation with DO, implying that elevated iron levels might be associated with oxygen depletion. Meanwhile, pH and DO were inversely related, which is typical in groundwater systems where acidic conditions often accompany lower oxygen levels. These correlations highlight the interconnected nature of groundwater parameters and underscore the need for integrated monitoring to ensure safe drinking water quality.

4. CONCLUSION

The assessment of groundwater quality in Gramthan Rural Municipality, Morang District, Nepal, reveals that most physical and chemical parameters, such as pH, nitrates, nitrites, and ammonia, fall within acceptable limits prescribed by the World Health Organization (WHO, 2017). However, the presence of elevated iron (Fe) concentrations in many samples, along with the detection of fecal coliform in some locations, raises significant concerns about both chemical contamination and microbial safety. Notably, fecal coliform levels exceeding 22 MPN/100 ml indicate potential contamination from human or animal waste, likely due to poor sanitary infrastructure and the proximity of tube wells to sources of pollution.

The correlation analysis highlights important interrelationships among water quality parameters. A moderate negative correlation was found between dissolved oxygen (DO) and both temperature and iron, suggesting that higher iron levels and warmer temperatures may contribute to oxygen depletion. Positive correlations between DO and total alkalinity (TA) as well as phosphate (PO_4^{3-}) suggest some buffering and nutrient effects on oxygen levels. These findings are consistent with other regional studies that emphasize the importance of iron, temperature, and organic matter in shaping water quality dynamics (Sharma et al., 2021; Paudel & Raut, 2019). In conclusion, while groundwater in the study area is generally of acceptable chemical quality, microbial contamination and high iron concentrations demand urgent attention. Public health risks could be mitigated through improved sanitation, construction of protective well platforms, regular monitoring, and community awareness programs.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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