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Physico-chemical and microbiological assessment of domestic water supply in Bontoc, Mountain Province, Philippines

Epiphania B. Magwilang[a,*], Annie Lourie Yawan Paredes[b], Francisco C. Armas[c], Helen Grace P. Bugnay[a] and Rose D. Dagupen[a]

[a] Research Development and Extension Office, Mountain Province State Polytechnic College, Barangay Poblacion, Bontoc Mountain Province 2616, Philippines
[b] Department of Nursing, Mountain Province State Polytechnic College, Barangay Poblacion, Bontoc Mountain Province 2616, Philippines
[c] Department of Liberal Arts, Mountain Province State Polytechnic College, Barangay Poblacion, Bontoc Mountain Province 2616, Philippines
*Corresponding author. E-mail: magwilangepiphania@gmail.com

EBM, 0000-0002-4676-2815; RDD, 0000-0001-7883-9840

ABSTRACT

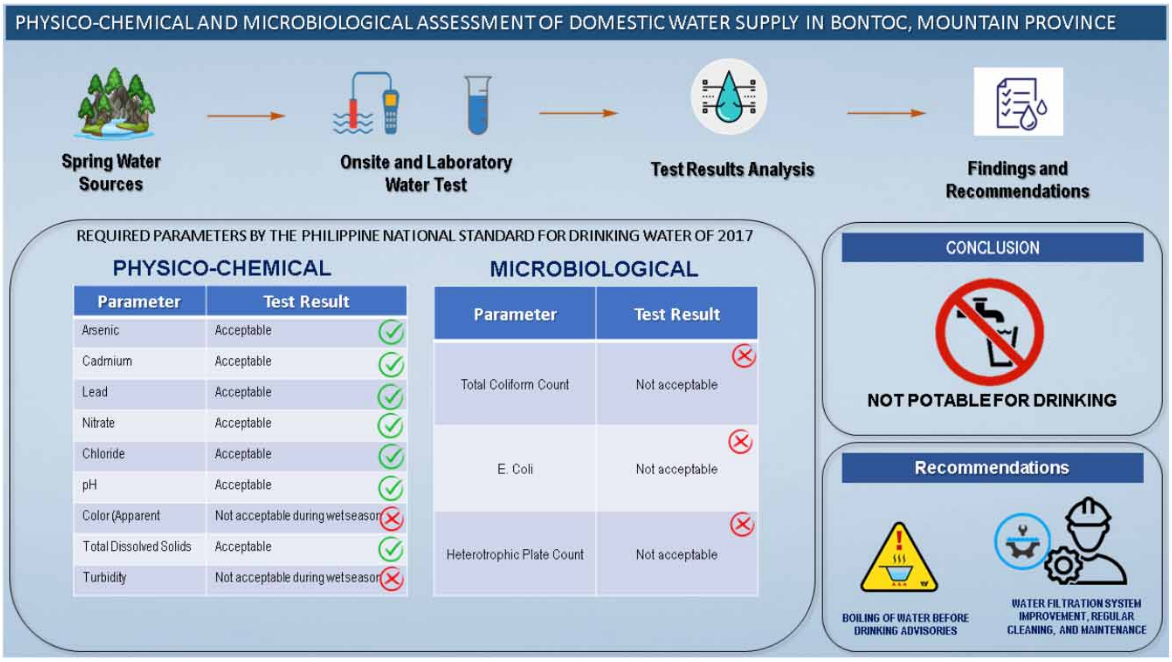
This study determined the water quality of the three major domestic water sources of Bontoc, Mountain Province, and recommended interventions to maintain water parameters within values set by the Philippine National Standards for Drinking Water (PNSDW). Results revealed that all the average values of the physico-chemical parameters measured during wet and dry seasons for the water samples from the different water sources and sampling points are within the allowable range except for turbidity and color during and just after typhoons and prolonged strong rainfalls. As to microbiological parameters, samples from the sources, storage tank, and distribution line have a very high total coliform count, and *Escherichia coli* content for both seasons. For heterotrophic plate count, only the water samples from Balabag Spring for both wet and dry seasons, from the storage tank during the wet season, and from Gakhan Spring during the dry season have acceptable values. Findings indicate the high vulnerability of the water sources to microbial contamination. Thus, water in all sources is not potable and is therefore not recommended for drinking purposes in its present condition. To address the water supply quality problems, filtration systems may be included in the water system design, the intake tanks, or a new reservoir.

Key words: domestic water supply, dry and wet season, microbiological and physico-chemical parameters, supply vulnerability, treatment system, water quality

HIGHLIGHTS

- Water from the three major domestic water sources of Bontoc, Mountain Province is not fit for drinking.
- The vulnerability of water sources to microbial contamination is high.
- A filtering system may be incorporated into the design of the water system, the intake tanks, or the building of a new reservoir to help address constraints on water quality.
- Water treatment practices in the households are encouraged.

GRAPHICAL ABSTRACT



INTRODUCTION

Water is a necessity in everybody's lives. Nobody can ever dispute that. As they say, 'water is life.' Water demand for drinking, domestic use, irrigation, or industrial purposes has increased as the population has grown and human activities shifted. So, expectedly, the need for clean and safe water has also increased and is expected to rise significantly over the coming years to meet the needs of the ever-increasing populations, growing economies, changing lifestyles, and evolving consumption patterns. Such is valid worldwide.

The demand for water is rising as a result of the human population's constant growth, which during the past two centuries has roughly approximated an exponential rate. The amount of water on Earth is, however, limited (Cassardo & Jones 2011). For optimal health, there must be a safe, dependable, economical, and easily available water supply (Hunter *et al.* 2010). Thus, water intended for human consumption must not contain pathogens or harmful chemicals.

The World Health Organization (WHO) reported that in 2020, around one (1) in four (4) people lacked safely managed drinking water in their homes (WHO 2021). This means that millions of people worldwide lack access to a reliable and safe water supply. Commonly affected are the people in rural areas with limited infrastructure. For example, 91% of the country's estimated 100.7 million people in the Philippines have access to essential water services, though highly inequitable, ranging from 62 to 100% (Buffaloe 2021). In the Cordillera, Northern Philippines, about 6 out of every 10 households were reported by the Department of Health (DOH) to have access to safe and clean water (NEDA 2018).

Safe and clean water refers to water of acceptable quality. Water quality is usually defined by its physical, chemical, and biological characteristics (FKNMS n.d.). Water quality concerns are often the most important component for measuring access to water sources. Acceptable water quality shows the safety of drinking water in terms of its physical, chemical, and bacteriological parameters. The WHO and national agencies in every country have established parameters to determine the biological and physico-chemical quality of drinking water. In the Philippines, the standards and procedures on drinking water quality are prescribed by Administrative Order (AO) No. 2017-0010 or the Philippine National Standards for Drinking Water (PNSDW) of 2017 to protect public or consumers' health (DOH 2017). It applies to all drinking water service providers, the general public, and all others who are involved in determining the safety of public water supplies. Periodic quality assessment of drinking water sources is necessary to guarantee the quality and security of the people's water supply. With the importance of water in everybody's life, monitoring water quality is a must. Furthermore, information on water resources and their suitability for use is mandatory for spatial planning and sustainable development.

Springs are the primary water sources for drinking and domestic purposes in the communities in Mountain Province in the Cordillera. Most of these springs are unprotected. Spring water is inexpensive as it does not require a pump to bring the water to the surface. Barangays or municipalities may have domestic water services which bring the water from the source to the communities. Water sources are directly tapped without treatment to community reservoirs or household tanks as people believe these are clean and safe. If ever treatments are employed, it is only by boiling. Although spring water is believed to be of good quality due to its filtration through rock layers, the quality is still based on specific physico-chemical and microbiological parameters.

Around the world, 2.2 billion people lack access to adequate drinking water services (WHO 2019). Hundreds of millions of these people live in mountainous areas (Messerli *et al.* 2004), including the people of the Cordillera. All these communities rely on mountain springs for their drinking and domestic water supply. As stated by Resto *et al.* (2018), springs often produce water of desirable esthetic characteristics and are generally perceived by people to be clean and free of contaminants, thus, very few studies have been conducted to study the degree of contamination of these mountain springs.

Herath (2021) assessed the microbiological and chemical quality of water from 10 springs in the Knuckles Mountain Range, Sri Lanka. Results show that bacteria were detected in all water samples tested, and the detected numbers exceeded permitted levels for drinking water. Even if all chemical parameters were within the permitted levels, the study concluded that the spring waters are not safe to drink. In the Upper Subansiri District in Arunachal Pradesh, India, physico-chemical analysis of water samples was carried out for parameters such as pH, temperature, alkalinity, total dissolved solids (TDS), potassium, sodium, chloride, calcium, magnesium, and total hardness. Samples were found to be of potable quality; thus, the researchers concluded that these are fit for human consumption (Bui *et al.* 2020).

Chitwood (2007), as cited by Resto *et al.* (2018) detected fecal contamination in water samples from mountain springs in mountainous areas in southwest China. Such contaminations were concluded by the authors to have been caused by the proximity of humans and animals to the spring sources. A similar study on *Escherichia coli* contamination of mountain springs used for drinking water and drilled well alternatives was conducted by Resto *et al.* (2018) in the Dominican Republic. Their study areas were mountain springs which provided water for many small communities. Also, such springs were surrounded by forests and agro-pastoral lands which were not adjacent to dwellings or establishments. Nevertheless, the study still found fecal contamination which could have been caused by sparse livestock grazing.

Only a few studies were conducted in the Philippines on spring water quality. In Argao, Cebu, water samples from 15 springs were tested for physico-chemical and microbiological quality. Results revealed that all 15 water samples failed in total coliform (TC) and heterotrophic plate count (HPC) tests, although they passed the fecal and *E. coli* tests (Pinote *et al.* 2014). In Damulog, Bukidnon, an assessment of the quality of water in Langahan Spring revealed that the spring's water is not safe to drink as pH, phosphate concentration, total suspended solids (TSS), TC, and *E. coli* exceeded maximum allowable levels set by the 2017 PNSDW (Arienza *et al.* 2021).

The central barangays of Bontoc, the central town in Mountain Province Philippines has two major water sources, the Sullong and the Balabag Creek. The water supply from these two sources is provided by the Bontoc Water Works Office to its consumers. Such water sources are far from urbanization and human activities but could be disturbed by wild animals and free-grazing carabaos, especially at the Sullong water source. Some consumers drink raw water from these sources or after a preliminary treatment such as boiling or filtration. However, most are not sure if such water sources are safe for drinking. Thus, many residents in Bontoc buy their drinking water from water refilling stations at a price of PhP40.00 for 16 L. The Rural Health Unit (RHU) of Bontoc has also recorded incidents of water-related diseases such as diarrhea, and amoebiasis every now and then. There is, therefore, a need to establish the quality and potability of the water supply sources of this community. This study primarily aimed to determine the water quality of the major domestic water sources of Bontoc, Mountain Province, and recommends possible interventions to maintain water parameters within values set by the PNSDW.

METHODS

Site description

The study was conducted in Bontoc, the capital town of Mountain Province (Figure 1). Bontoc is a second-class municipality located 17005′14″ N and 120°58′32″ E. It is 396 km north of the National Capital Region and

Figure 1 | Municipal study site: Bontoc, Mountain Province, Philippines.

146 km from Baguio City. It lies about 847 m above sea level and sits beside the Chico River, a main Northern Luzon river system fed by tributaries from the town barangays (ELA Bontoc 2013). It has a total land area of 396.10 km^2. Based on the 2020 census, Bontoc has registered a population of 24,000 people, most belonging to the Bontok tribe. The municipality is bounded on the north by Sadanga, northeast by Tinglayan, Kalinga, east by Barlig, south by Banaue, Ifugao, and Sabangan, west by Sagada, and northwest by Tubo, Abra. Located in the heartland of the Mountain Province, Bontoc has been the center of government, commerce, and tertiary education in the province. This explains why there are many people in the center of the municipality during school days.

The specific areas for this study were the three major water spring sources piped for use by the central barangays and being maintained by the Bontoc Municipal Water Works Office (MWWO). These are the Sullong water source, Balabag water source, and newly tapped spring, Gakhan Creek Water Source (Figure 2).

Data collection

An ocular survey of the springs was conducted. The springs' altitudes and coordinates were obtained using GPS Garmin eTrex equipment. In addition, the area's weather pattern determination was also taken from the Clime: NOAA Weather Radar Live application.

Sampling was done every month for a year, from September 2021 to August 2022, to check for seasonal variations. During the sampling period, the months of May–October were considered the wet season when the area had received sufficient rainfall to cause runoff, and November–April was considered the dry season. The data for the study were gathered through simple field testing and laboratory-based analysis. Table 1 shows the methods used for the analysis of the different parameters, along with the instruments and units used in this study. Physical parameters gathered *in situ* include mandatory parameters as outlined in the 2017 PNSDW which are pH, color, TDS, turbidity, and nitrate. In addition, other mandatory physico-chemical parameters, such as arsenic, cadmium, and lead content, all microbiological parameters, total coliform count (TCC), *E. coli*, and HPC were determined through laboratory analysis.

Samples for the physico-chemical analysis were collected in two 1 L sterile pet bottles, sealed with plastic covers, and labeled. Samples for microbiological analysis were collected in 350 mL bottles, sealed with plastic covers, and labeled accordingly.

All the samples were placed in a cooler box filled with ice and transported to the Department of Science and Technology-Cordillera Administrative Region (DOST-CAR) Regional Standards and Testing Laboratory in La

Figure 2 | Map of major Bontoc water sources.

Trinidad, Benguet for analysis. Aside from the spring sources, samples were also tested and collected at the community outlet for the Sullong Spring and at the main storage tank for the water from Balabag Spring located at Pattig, Poblacion, Bontoc. The water from Gakhan has not really reached the community as re-piping is being done due to burst pipes, thus, no sampling was conducted at its storage facility.

For the determination of water treatment and conservation practices that could be proposed for each of the water sources, a focus group discussion and interview with barangay officials, MWWO staff, and the key players of the past and on-going water projects were carried out.

Table 1 | Water quality parameters, analytical methods, and instruments used

Parameters	Instruments/analytical methods used	Units
Mandatory parameters set by PNSDW (2017)		
Arsenic	Atomic absorption spectrophotometry after microwave digestion	mg/L
Cadmium	Atomic absorption spectrophotometry after microwave digestion	mg/L
Lead	Atomic absorption spectrophotometry after microwave digestion	mg/L
Nitrate	Ultraviolet spectrophotometric screening method	mg/L
pH	HI 98196 multiparameter meter	
Color (Apparent)	Visual comparison method	Color units (CU)
TDS	HI 98192 conductivity meter	mg/L
Turbidity	HI 93703 turbidity meter	Nephelometric turbidity unit (NTU)
Microbiological parameters		
TCC	Multiple tube fermentation technique	Most probable number/100 mL (MPN/100 mL)
E. coli	Multiple tube fermentation technique	MPN/100 mL
HPC	Pour plate	Colony forming units/mL (CFU/mL)
Other parameters		
Discharge	FP11 Flow Probe 5.5 Flow Meter	(L/s)

DISCUSSION

Balabag Spring

The four central barangays of Bontoc have only two major sources of domestic water supply. Balabag Creek is located 21.72 km away from Bontoc at an elevation of 1.08 km above sea level with coordinates 17° 3′ 25.6068″ N and 120° 3′ 39.114″ E (Figure 3). The spring is located 72 m above the main road and just below a mossy forest. Balabag Spring has an average discharge of 69.51 L/s during the rainy season and 14.42 L/s during the dry season. The highest recorded discharge was 109 L/s in the month of July as the day of collection was conducted just after a typhoon. The lowest recorded discharge was that of Balabag Creek based on the records of the MWWO with a discharge flow of 6.52 L/s for a one-time measurement during the dry season using the bucket method.

The water from the Balabag source is collected through a gravity flow type of water system in a concrete tank located at Pattig, Poblacion, Bontoc before it is distributed to customers following certain schedules.

Physico-chemical analysis (Table 2) shows that the water samples from the Balabag Spring and its storage tank in the community have no detectable arsenic, cadmium, or lead contents for either wet and dry seasons. Water samples are colorless, clear, and slightly alkaline during the time of sampling. The pH values measured are greater than 8.0 but less than the maximum allowable pH value of 8.5 during the sampling periods. Table 1 shows that all the physico-chemical parameters are within the acceptable levels given in the 2017 PNSDW. However, individual measurements of turbidity and color just after typhoons and prolonged strong rainfalls reach as high as 7.9 NTU and 12 CU, respectively. Color also becomes dirty white to brownish. This is a common experience in the central barangays of Bontoc.

Sullong Spring

Sullong Spring is located 1,170 km away from Bontoc Ili at an elevation of 861.37 m above sea level with coordinates 17° 3′ 12.2772″ N and 120° 58′ 49.044″ E (Figure 4). The water supply from Sullong is collected in a sedimentation tank, then directed to a storage tank prior to distribution through gravity flow to the community. It is connected directly to the main distribution line and serves customers from Bontoc Ili, Poblacion, and Samoki. Sullong Spring is located in Sitio Lanao, Bontoc Ili. It is 902 m away from the main. It is near agro-pastoral lands. It has an average discharge flow of 34.0 L/s during the rainy season and 7.20 L/s during the dry season. It has a much lower flow discharge than that of the Balabag Spring. Air temperature in the area during sampling ranged from 13.95 to 22.78 °C.

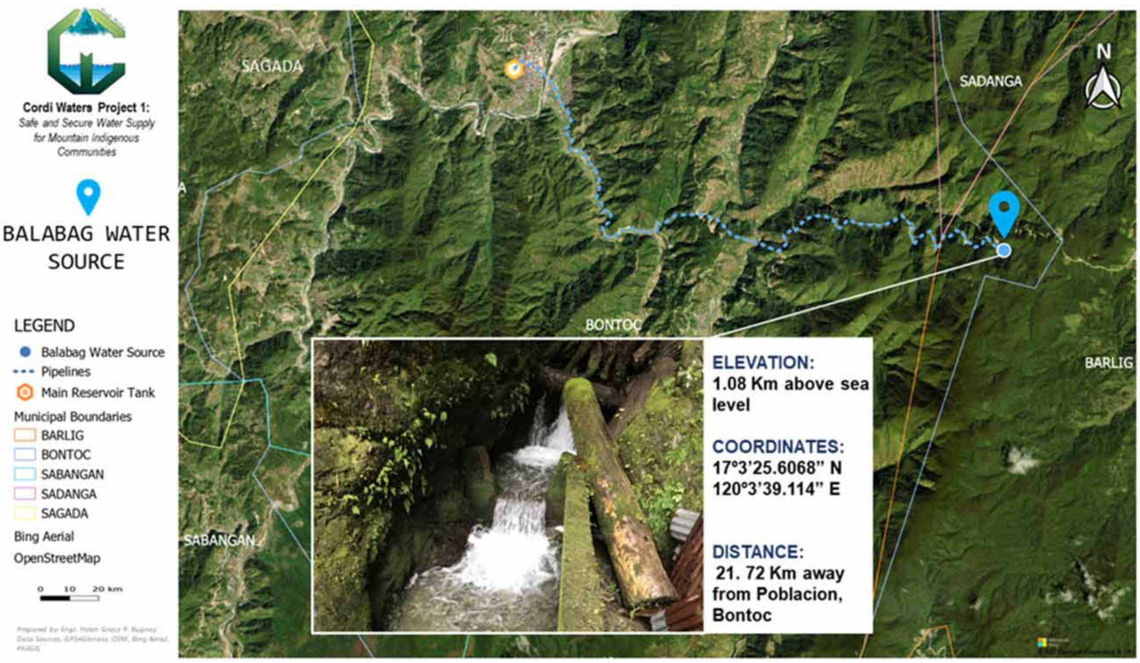


Figure 3 | Balabag water source.

Table 2 | Physico-chemical parameters of water samples from Balabag Spring and Pattig Storage Tank

Physico-chemical parameter	Maximum allowable level (PNSDW 2017)	Season	Balabag Water Source	Pattig Storage Tank
Arsenic	0.01 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Cadmium	0.003 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Lead	0.01 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Nitrate	50 mg/L	Wet season	0.182	Not detected
		Dry season	0.557	Not detected
Chloride	250 mg/L	Dry season	<LoQ (LoQ = 1.38 mg/L)	<LoQ (LoQ = 1.38 mg/L)
pH	6.5–8.5	Wet season	8.37	8.23
		Dry season	8.05	8.34
Color (Apparent)	10 CU	Wet season	6 CU	8 CU
		Dry season	3 CU	2 CU
TDS	600 mg/L	Wet season	37.55 mg/L	35.19 mg/L
		Dry season	39.28 mg/L	31.11 mg/L
Total hardness	300 mg/L	Wet season	27.25 mg/L	29.5 mg/L
		Dry season	29 mg/L	30.5 mg/L
Turbidity	5 NTU	Wet season	4.52 NTU	4.41 NTU
	(max)	Dry season	0.97 NTU	0.18 NTU

All physico-chemical parameters of water samples from Sullong source and from the distribution line as shown in Table 3 are within allowable limits set in the 2017 PNSDW. Similar to the water samples from Balabag Spring and its storage tank, the metals arsenic, cadmium, and lead were not detected. The water is clear, and not turbid, during the sampling periods. The pH values are near the maximum allowable value of 8.50 which means that the water is alkaline. Just like that of the water from Balabag, water from Sullong becomes brownish in color and

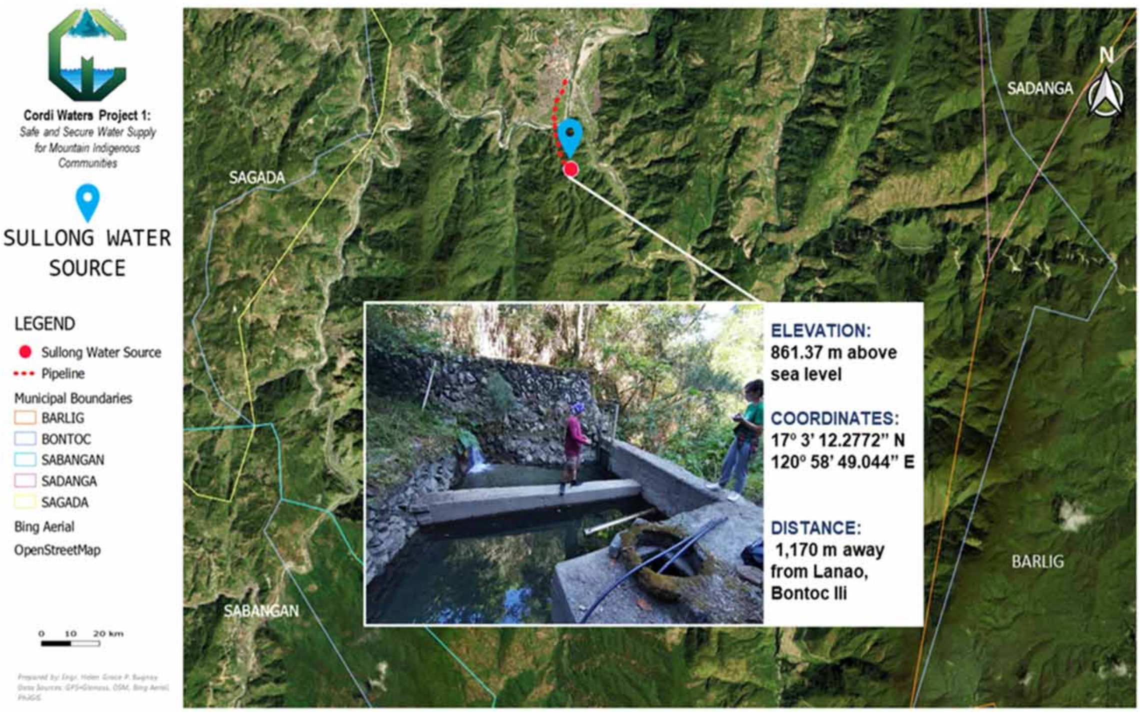


Figure 4 | Sullong water source.

Table 3 | Physico-chemical parameters of water samples from Sullong spring and at its distribution line

Physico-chemical parameter	Maximum allowable level (PNSDW 2017)	Season	Sullong Spring	Distribution Line
Arsenic	0.01 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Cadmium	0.003 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Lead	0.01 mg/L	Wet season	Not detected	Not detected
		Dry season	Not detected	Not detected
Nitrate	50 mg/L	Wet season	0.088	0.602
		Dry season	0.166	0.105
Chloride	250 mg/L	Dry season	<LoQ (LoQ = 1.38 mg/L)	<LoQ (LoQ = 1.38 mg/L)
pH	6.5–8.5	Wet season	8.47	8.50
		Dry season	8.45	8.37
Color (Apparent)	10 CU	Wet season	9 CU	8 CU
		Dry season	0 CU	0 CU
TDS	600 mg/L	Wet season	77.12 mg/L	62.55 mg/L
		Dry season	96.38 mg/L	97.82 mg/L
Total hardness	300 mg/L	Wet season	50.25 mg/L	162 mg/L
		Dry season	250.25 mg/L	251.5 mg/L
Turbidity	5 NTU (max)	Wet season	4.43 NTU	4.63 NTU
		Dry season	.546 NTU	0.17 NTU

turbid during typhoons and prolonged strong rainfalls. This could be due to the mixing of runoffs from the upper part of the mountain with the spring water.

Gakhan Spring

In 2017, the Local Government Unit was able to find another major water source for the community at the Gakhan Creek located 19.71 km away from Poblacion, Bontoc at an elevation of 1.19 km above sea level with coordinates 16° 59′ 14.47087″ N and 120° 59′ 0.1716″ E (Figure 5). This, however, is still under construction, with its pipelines being laid out, and has not yet reached the community. It has an average total discharge flow of 47.42 L/s during rainy season and 15.17 L/s during dry season. Air temperature in the area ranges from 11.67 to 20 °C.

Physico-chemical parameters of the water sample from Gakhan all have values below the maximum allowable level set by PSNDW. Similar to those of the Balabag and Sullong water sources, the metals arsenic, cadmium, and lead were not detected. The water is clear and has a pH value of 8.05 during the wet season and 8.07 in the dry season.

The results show that all the physico-chemical parameters of all the samples have values within the acceptable values set in the 2017 PNSDW. All of them have no detectable arsenic, cadmium, or lead contents.

The pH value in water indicates whether the water is acidic or alkaline. Water with a pH between 6.5 and 8.5 is generally considered by the PNSDW as satisfactory. Thus, all the water samples are satisfactory as to pH, as their values range from 8.0 to 8.5 depicting alkaline water. In a similar study in Langahan Spring in Damulog, Bukidnon, all water samples were determined to be acidic and two out of three were below the accepted lowest pH value of 6.5 (Arienza *et al.* 2021).

TDS directly affect the esthetic value of the water by increasing turbidity and can be taken as an indicator of the general water quality. The higher the TDS, the more turbid the water will be. All the samples under study have very low values of TDS and consequently acceptable turbidity.

Turbidity is the presence of particles suspended in water. Its measurement makes it possible to give visual information. All the water samples during the sampling periods in the dry season are clear but mostly turbid during the wet season. The common problem with water from these springs is that they become turbid and dirty white to brownish in color just after typhoons and prolonged strong rainfalls. This may be due to the combination of runoffs with the spring waters at the water source sites. Water samples from the Sullong Spring reached as high as 8.2

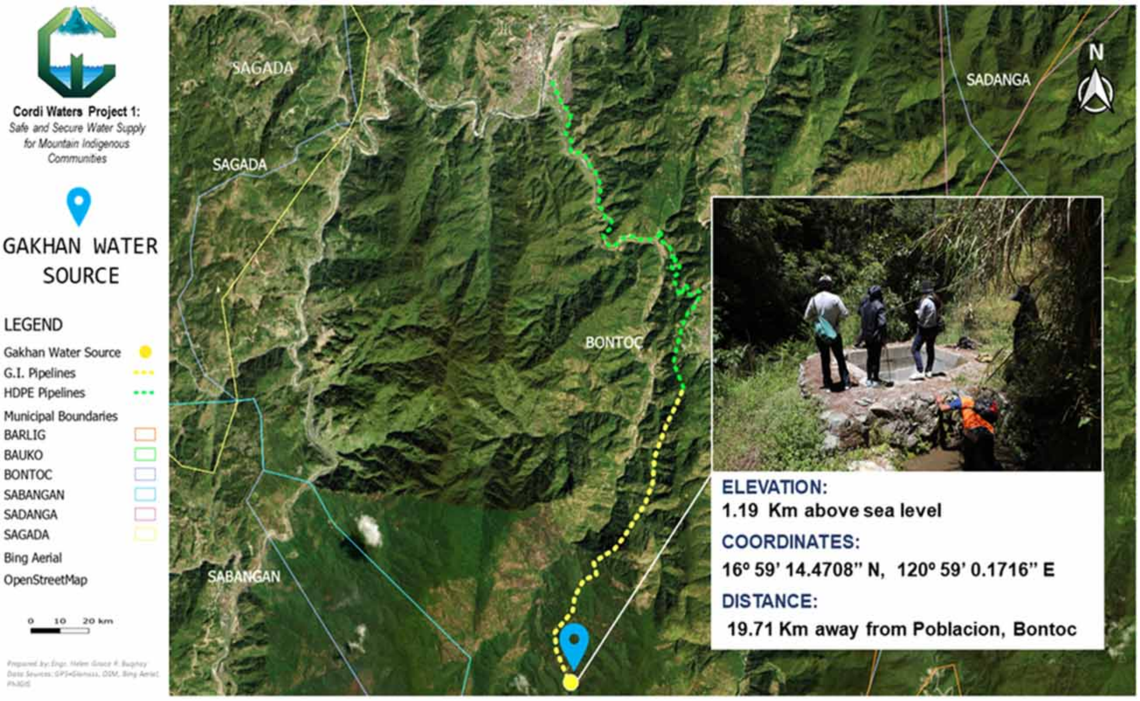


Figure 5 | Gakhan water source.

for turbidity and 12 CU for color. It should be worth noting that the community has storage tanks where water is stored prior to distribution. However, only heavier particles tend to settle down even after keeping the water undisturbed.

Low levels of nitrogen (in the form of nitrate) are said to be normal in groundwater and surface water (Reda 2015). When this is present in higher values, however, it becomes a pollutant. In all the samples in this study, nitrate content was within permissible values. This means that all the samples are safe in terms of their nitrate content.

Total hardness depends on the amount of calcium and magnesium salts or both. The maximum allowable limit for this parameter is 300 mg/L as given by the PNSDW. In the present study, values were all within the permissible limit.

All the water samples from the three water sources, from the Pattig water tank, and from the distribution point are all acceptable in terms of their physico-chemical parameters during the sampling periods. However, color and turbidity change and go beyond allowable values due to typhoons and prolonged strong rains as shown in Figure 6.

As shown in the figure above, all the values of the physico-chemical analysis indicate that the domestic water sources of the central barangays are within the PNSDW for the 12 months sampling period.

In the same way, the physico-chemical values of samples obtained from the distribution point and main storage tank are within the accepted PNSDW values as shown in Figure 7.

Microbiological parameters

According to the 2017 PNSDW, total coliforms and *E. coli* should not be detected in 100 mL of any drinking water sample or at most 1.1 MPN/100 mL and the concentration of heterotrophic bacteria should be $<$500 CFU/100 mL for water to be potable and safe for drinking.

Table 4 shows that almost all the measured values for the TCC, *E. coli*, and HPC are very high and way above the authorized standard for all the water samples. It is only the water samples from Balabag Spring for both wet and dry seasons, from the Pattig storage tank during the wet season, and from Gakhan Spring during the dry season which have passed the HPC as the values determined are below the maximum allowable limit of 500 CFU/mL. These findings indicate the high vulnerability of the water sources to microbial contamination. Thus, the water in all three water sources is not safe to drink as it could be a cause of various illnesses. Although

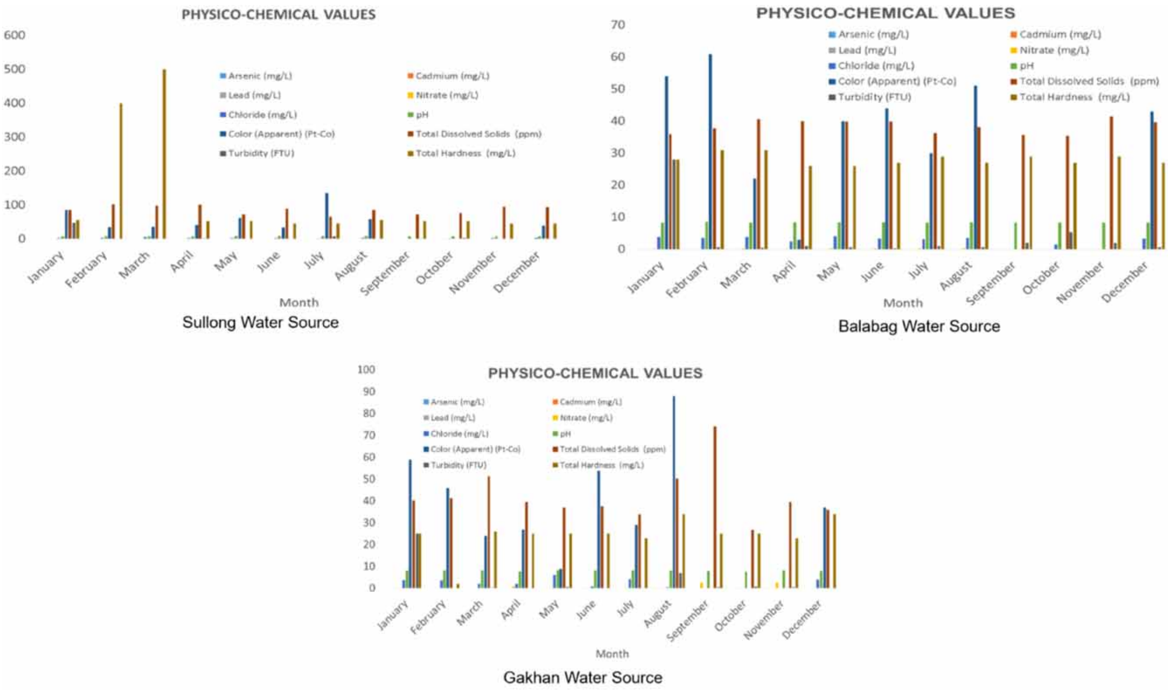


Figure 6 | Histogram of the physico-chemical values of Central Bontoc water sources.

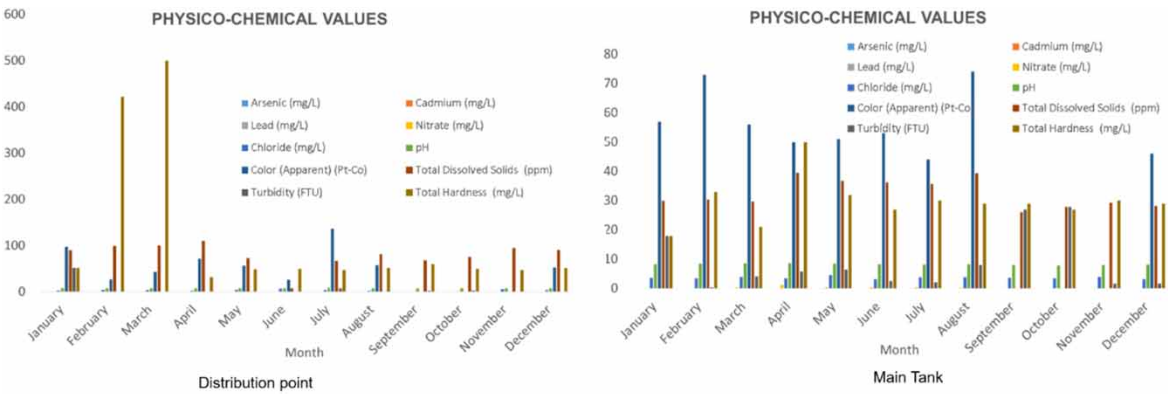


Figure 7 | Histogram of the physico-chemical values of the water distribution point and main tank.

the incidence of illnesses correlating to high HPC has not been found, still they point to favorable conditions for the growth of bacteria (LeChevallier 2003).

Water samples from four mountain springs in China failed in all the microbiological parameters but unlike in this study, such could have been caused by the proximity of humans and animals to the spring sources (Chitwood 2007, as cited by Resto *et al.* 2018). The results of this study, however, are similar to the study of Resto *et al.* (2018) which found that spring water found far from the dwellings and establishments and surrounded by forests and agro-pastoral lands in the Dominican Republic still failed the microbiological test. All the water sources of Central Bontoc are also far from dwellings and agricultural activities, thus, TC detection could be attributed to the environment where the springs are located while the *E. coli* might be traced from the feces of the animals through runoffs. Fecal contamination could have been caused by sparse livestock grazing. In Sullong spring, for instance, the area above the creek is pasturelands for cows and carabaos. It was observed that runoffs combine with the spring output during heavy rainfall. As shown in Figure 8, the microbiological parameters exceed the allowable limit in almost all sampling months. The TCC and *E. coli* are highest for Sullong and Balabag water sources

Table 4 | Physico-chemical parameters of water samples from Gakhan Creek

Physico-chemical parameter	Maximum allowable level (PNSDW 2017)	Season	Gakhan Spring
Arsenic	0.01 mg/L	Wet season	Not detected
		Dry season	Not detected
Cadmium	0.003 mg/L	Wet season	Not detected
		Dry season	Not detected
Lead	0.01 mg/L	Wet season	Not detected
		Dry season	Not detected
Nitrate	50 mg/L	Wet season	0.602
		Dry season	0.225
Chloride	250 mg/L	Dry season	<LoQ (LoQ = 1.38 mg/L)
pH	6.5–8.5	Wet season	8.05
		Dry season	8.07
Color (Apparent)	10 CU	Wet season	0 CU
		Dry season	0 CU
TDS	600 mg/L	Wet season	43.31 mg/L
		Dry season	41.32 mg/L
Total hardness	300 mg/L	Wet season	26.75 mg/L
		Dry season	19.5 mg/L
Turbidity	5 NTU (max)	Wet season	1.65 NTU
		Dry season	0.17 NTU

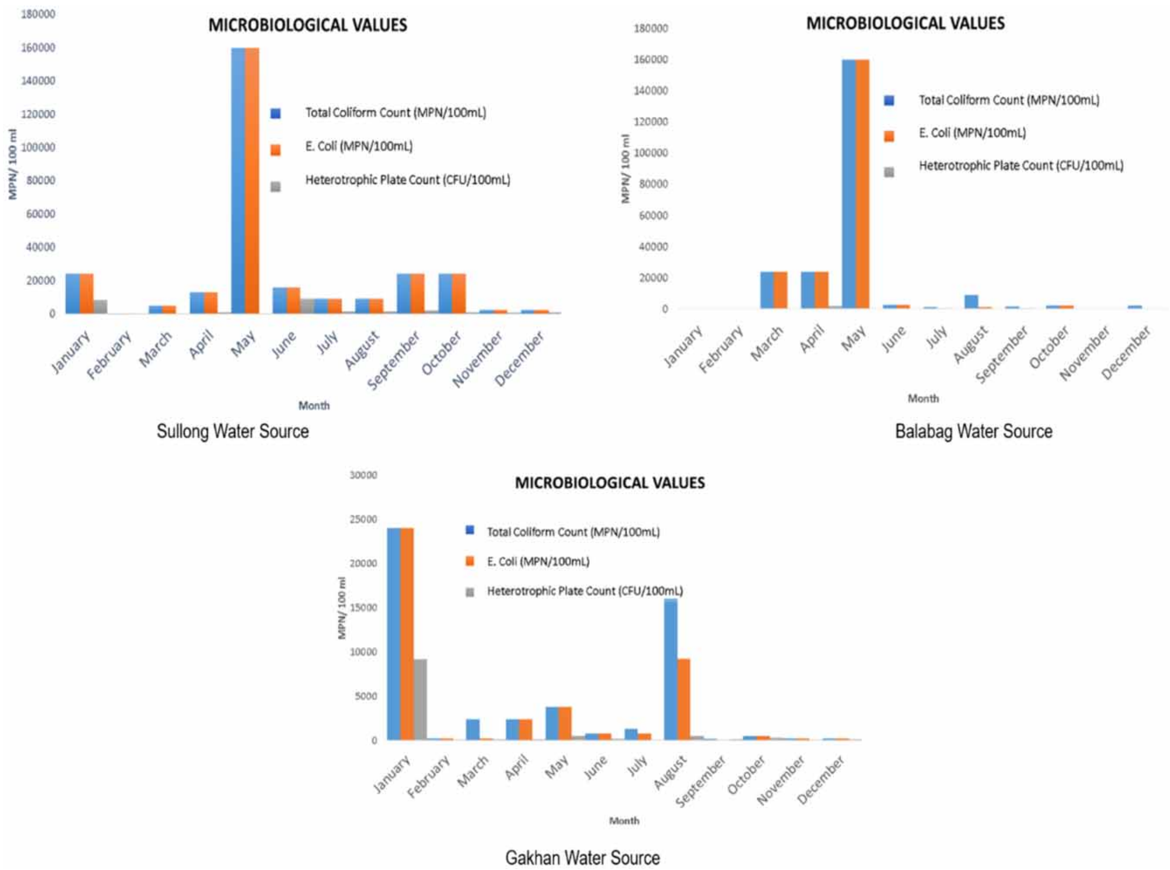


Figure 8 | Histogram of the microbiological values of Central Bontoc water sources.

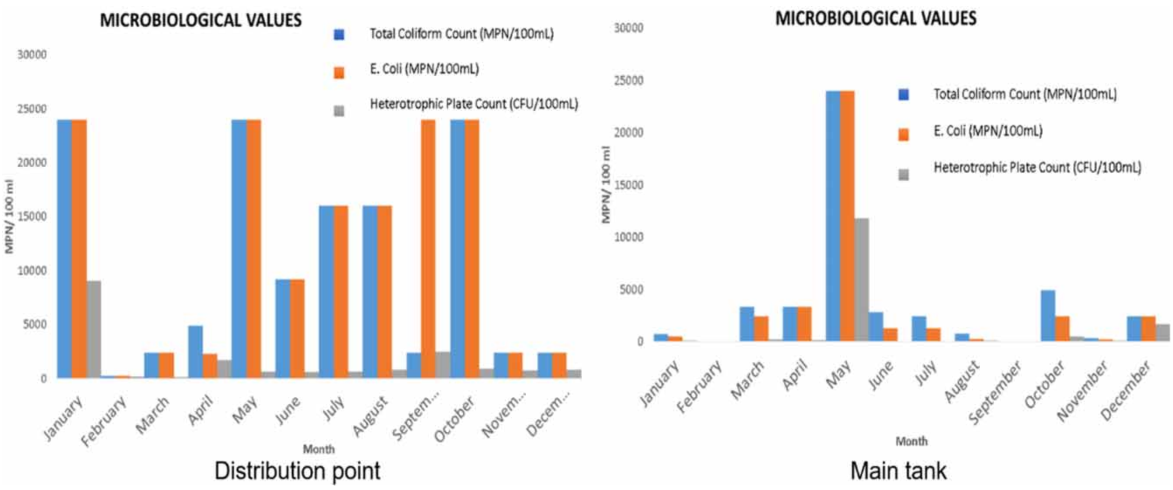


Figure 9 | Histogram of the microbiological values of the water distribution point and main tank.

during the month of May which is the start of the rainy season. It is expected that during the first strong rains, the runoff from the mountain side that combines with the water source takes all contaminants along its way. The community people using water from the sources are actually aware of the condition of the water sources, but as they say, those who have been drinking such might have already developed immunity to the bacteria.

In the same manner, Figure 9 indicates high values of TCC, *E. coli*, and heterotrophic count that exceeded the acceptable values all year round for both the distribution point and the main tank.

Water from all three sources is not potable and is therefore not recommended for drinking purposes in its present condition.

Proposed water treatment and conservation practices

As the physico-chemical parameters are within allowable limits set in the 2017 PNSDW, attention should be directed to preserving such parameters while improving the microbiological aspect (Table 5). The effects of typhoons and strong rains on color and turbidity should, however, be considered. This needs the attention of the Local Government Unit (LGU) and the RHU. Advisories on boiling water prior to drinking have been released every now and then by the RHU. The survey results show that 67% of the respondents mentioned that advisories are necessary for their convenience in utilizing their domestic supply.

Based on the results of focus group discussions conducted by the researchers, it was determined that 158 of the respondents do not drink from the municipal water supply especially during the rainy season as accordingly, water seems murky. As observed in this study, the residents' claims during rainy seasons indeed are valid. Many do not consider it safe for drinking. Water for drinking is usually bought or delivered from private sources like water refilling stations. About 80% of the residents in Bontoc buy their drinking water from water refilling

Table 5 | Microbiological parameters of water samples from the different sources

Test	Standard (PNSDW 2017)	Season	Balabag water source	Gakhan water source	Sullong water source	Sullong water source – distribution point	Pattig main tank
TCC	< 1.1 MPN/ 100 mL	Wet	29,550 MPN/ 100 mL	3,758 MPN/ 100 mL	46,640 MPN/ 100 mL	15,120 MPN/ 100 mL	6,978 MPN/ 100 mL
		Dry	8,519 MPN/ 100 mL	4,920 MPN/ 100 mL	7,865 MPN/ 100 mL	6,057 MPN/ 100 mL	1,681 MPN/ 100 mL
E. coli	< 1.1 MPN/ 100 mL	Wet	27,972 MPN/ 100 mL	2,525 MPN/ 100 mL	45,280 MPN/ 100 mL	19,440 MPN/ 100 mL	5,858 MPN/ 100 mL
		Dry	8,139 MPN/ 100 mL	4,560 MPN/ 100 mL	7,448 MPN/ 100 mL	5,623 MPN/ 100 mL	1,476 MPN/ 100 mL
HPC	< 500 CFU/mL	Wet	127 CFU/mL	281 CFU/mL	2,822 CFU/mL	1,063 CFU/mL	2,503 CFU/mL
		Dry	440 CFU/mL	1,600 CFU/mL	1,861 CFU/ mL	2,106 CFU/mL	384 CFU/mL

stations (Marrero 2018). Nevertheless, households that drink water from the municipal district practice water treatment at home. A total of 148 participants mentioned that they treat their domestic water before it is utilized for drinking: 118 of them practice boiling water before drinking, following the advice of the RHU to boil before drinking; 54 use water filters, while 44 strain water through a cloth wrapped around the faucet. During the rainy season, people let the collected turbid water settle and clear out before these are used. The Bontoc MWWO has tried out chlorination as an intervention. However, this was not accepted by the residents, because of fear of other illnesses that may be caused by the residuals. Indeed, chlorination has been used widely because of its removal efficiency and cost-effectiveness in killing or inactivating microbiological organisms, but the disinfection process may create several kinds of disinfection by-products (DBPs) in the treated water which may also be harmful to health (Srivastav *et al.* 2020). For this reason, it is a good idea to install some additional filtration and protection for the community water source. The majority of the participants noted that filtration is a must.

With the unacceptable results of the microbiological examinations, filtration must be included in the process. A reservoir or two equipped with appropriate filtration systems might be able to help make the water from these community sources potable and totally acceptable for drinking and other domestic use. A ceramic water filter and an intake box should be considered in the design of the reservoir to address both the problems of turbidity and microbiological parameters. A study by Arienza *et al.* (2021) of the Langahan Spring in Bukidnon, Philippines has recommended, as an intervention to the unacceptable microbiological results, the construction of a reservoir with ceramic filter, intake box, and riprap. Most ceramic filters are effective at removing bacteria and the larger protozoans, but not at removing viruses (Michen *et al.* 2013). Studies have shown adequate removal of bacterial pathogens in water filtered through high-quality locally-produced or imported ceramic filters in developing countries (Household Water Treatment Options in Developing Countries: Ceramic Filtration 2008).

The Bontoc MWWO has also tried installing a simple filtration system at the Sullong water source using stones, sand, and charcoal but was later removed due to the hardening of the charcoal due to collected contaminants. This simple filtration system may still be appropriate for the filtration of the water from Sullong and Balabag although the charcoal will be replaced with ceramic plates. This could be installed in the intake tanks or a new reservoir be constructed that includes the filtration system. Also, regular cleaning and maintenance of the water sources, the intake tanks, and storage tanks should be undertaken by the MWWO to ensure the cleanliness of the water.

CONCLUSION

The study revealed that all the average values of the physico-chemical parameters measured during wet and dry seasons for the water samples from the different water sources and sampling points are within the allowable range set by the PNSDW. Except for being turbid and cloudy during and just after typhoons and prolonged strong rains, all the physico-chemical parameters of the water samples are below the maximum allowable limit set in the 2017 PNSDW. This result implies that the water samples are acceptable for domestic use in their state during the sampling periods. However, there is a need for interventions to address turbidity and color during and just after typhoons and heavy rains.

All the water samples from the three major sources, the storage tank, and from the distribution line have very high TCC, and *E. coli* content for both wet and dry seasons. For HPC, only the water samples from Balabag Spring for both wet and dry seasons, from the Pattig storage tank during the wet season, and from Gakhan Spring during dry season have acceptable values. These findings indicate the high vulnerability of the water sources to microbial contamination. Thus, the water in all three water sources is not safe to drink as it could be a source of various illnesses. Water from all three sources is not potable and is therefore not recommended for drinking purposes in its present condition.

To address the problems with the quality of the community water supply, a simple filtration system with stones, sand, fine screen mesh, and ceramic plates may be installed in the intake tanks or included in the construction of a new reservoir. The design of the intake tanks may also be revised to avoid the combination of runoffs with the spring water. Further, regular cleaning and maintenance of the water sources, intake tanks, and storage tanks should be undertaken by the MWWO to ensure the cleanliness of the water.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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