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Challenges faced by the municipal water works management in improving water supply adequacy and distribution in Bontoc, Philippines

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Domestic water is indispensable for daily use, yet its effective management encounters numerous challenges that impact household consumers. This study aims to identify the challenges leading to supply inadequacy and uneven distribution, while proposing interventions to enhance water supply for households. The study employed surveys, interviews, and focus group discussions to gather comprehensive data on domestic water supply issues in rural communities in Bontoc, Philippines. The findings reveal two primary issues in these rural communities: supply inadequacy and unequal distribution. Supply inadequacy is attributed to factors such as wasteful water use, water scarcity during prolonged dry seasons, limited water sources, and population growth. Uneven distribution results from factors like landslides, illegal tapping, irregular water quality, insufficient monitoring of quantity and pressure, and inadequacies in the water distribution network layout. The study suggests several crucial actions for the local government unit (LGU) of Bontoc. These include augmenting water sources, implementing regular water supply monitoring, ensuring timely repairs, replacing old pipes, optimizing distribution pipeline layouts, enhancing water pressure, and rigorously enforcing municipal water ordinances. Furthermore, the study emphasizes the importance of household water management practices, such as responsible consumption, supply conservation, and recycling. The effective implementation of these interventions, through collaboration between the LGU and households, has the potential to ameliorate the constraints in domestic water supply and distribution. This collaborative approach is essential for improving supply management and addressing the current challenges faced by domestic water consumers.

KEYWORDS

water management, water supply, water distribution, municipal water works, water supply challenges, water supply adequacy, water scarcity

1. Introduction

Water scarcity and inadequate access to clean water pose critical challenges globally, especially in marginalized communities. In the context of the Philippines, a country prone to water-related issues, indigenous towns often face the brunt of insufficient water supply. Although efforts have been made to address these challenges, the unique circumstances and specific needs of indigenous communities require tailored strategies for sustainable water management.

This study aims to shed light on the challenges faced by municipal waterworks management in improving water supply adequacy in an indigenous town in the Philippines. By delving into the distinct characteristics of the indigenous community and their historical relationship with water resources, this research endeavors to bring attention to a relatively unexplored aspect of the water management discourse.

Access to clean and sufficient water is one of the Sustainable Development Goals (SDGs) that developing countries look forward to. SDG 6 aims to ensure water availability and sustainable management which is crucial in the attainment and continuity of sufficient water quantity and quality in both urban and rural communities. However, it poses the challenge to provide household services such as adequate water supply in developing countries (Briscoe, 1996). Regions with insufficient freshwater supplies to support domestic, economic development, and environmental needs are those most impacted by water constraints (Cosgrove and Loucks, 2015). Water management is therefore crucial in addressing various problems faced by the water sector, whether at the national or local level.

Water management, as defined by the Asian Development Bank (2013) is a cycle of activities involving planning, management, monitoring, and assessment. In the Philippines, the National Water Resources Board (NWRB) was established in 1974 as the leading federal agency responsible for coordinating and integrating all operations related to the management and development of water resources. Its principal goal is to ensure the scientific and orderly development and management of all the Philippines' water resources in accordance with the concepts of optimal use, conservation, and protection to meet both immediate and long-term needs (Dayrit, 2001). At the local level, water resources are managed by either water districts or municipal waterworks. The development and improvement of water supplies, maintenance and operation, and imposition of water rates, are among the functions of municipal water works to ensure the delivery of their services to consumers (Hubbard and Kiersted, 1907). Without a firm commitment to improving water resources and environmental management, the harm to the Philippines' natural resources could be irreparable, having a detrimental effect on future economic growth and societal wellbeing (Rubio et al., 2008). The same is true for municipalities if water resources are not sustainably managed.

Water as a crucial resource faces many problems which are exacerbated by various factors that continue to pose threats to water availability. Increasing water demand brought on by a rapid increase in population, contamination of water resources, droughts, flooding, and a lack of institutional support to solve these issues are the main issues with water resources being experienced as revealed by the study of Rubio et al. (2008). The Cordillera Administrative Region (CAR) which is endowed with water resources is not spared from the perils of water problems. The region's decreasing water supply indicates the need for sustainable water management to minimize water threats that may bring long-term effects to the municipal-managed water supply.

While challenges with domestic water are a common concern confronting most communities in the Cordillera region, it is imperative to understand various factors contributing to problems in supply in the local setting specifically in mountain communities. Problems with water supply vary in different settings, thus the intent of the study was to investigate scenarios and factors that contribute to water problems specifically on the adequacy and management of supply in communities with attributes different from others.

While water management is entangled in the practices of mountain indigenous communities such as in the Cordillera region, problems with water persist. Managing water resources is embedded in the culture of the region as illustrated by how the indigenous communities provide and access supply (Abansi et al., 2016). However, the management of water resources evolves due to economic activities where water supply adapts to commercial utilization like the case in Baguio City. This poses challenges in the management of water resources which relates to other rural areas such as Bontoc where supply is divided being the center of business in the province thus resulting in increasing demand and insufficiency.

Bontoc, the study area, is just one of the mountain indigenous communities in the Cordillera region that place a significant value on water resources specifically on its management and utilization. Various challenges, however, confront the municipality in sustaining the water needs of households for domestic use. Problems with water supply continue to persist despite the presence of many private water sources augmenting the supply provided by local government units (LGUs).

Bontoc which is just one among the municipalities in Mountain Province, faces various water-related problems such as supply inadequacy (Sokoken, 2022). The four central barangays of the municipality are the center for commerce and education. However, these barangays have been battling water shortages in the past decades. In 2014, the communities of the municipality were placed in a state of calamity for experiencing such (Allad-iw, 2014). The problem of insufficiency of domestic water supply persisted in 2018 where the households connected to the municipal-managed water services are not well-supplied. During the same year, the central barangays access their supply from the two major water sources managed by the LGU (Killa-Malwagay, 2018). Thus, limited supply is provided to the consumers up to the present. The LGU of Bontoc admitted that one of the contributing factors to such was the lack of funds to be appropriated for the construction of additional water supply for the central barangays (See, 2023). In addition, the growing water demand in the barangays is exacerbated by the increase of population given that these areas are the focal point for trade, commerce, and education in the municipality. These challenges contribute to the pressing need for efficient management of water in the municipality. Improved water service is thus a significant step that calls for sustainable

water management to cater to the increasing water needs of these barangays.

According to Rola and Francisco (2004), the regulation of water supply, management of water demand, and building of appropriate social, legal, and institutional support mechanisms for successful water management are central issues that need to be considered when dealing with water inadequacy. At this point, there is a need to look into the management of water supply and demand including interventions that are necessary in improving LGU-managed water services. For Bontoc, a water ordinance was passed by its Sangguniang Bayan to address concerns about supply management and prohibit activities that would impede inappropriate activities that may compromise supply distribution. While ordinances are a leap forward to resolving water supply constraints, further actions can still be undertaken such as conducting research for the identification of challenges and interventions that the LGU may consider for the improvement of its water supply management. As Loucks and Van Beek (2017) put it, better management arises as a need for the realization that problems and opportunities exist in the water sector. Toward this cause, this study has substantial implications for policymakers, stakeholders, and practitioners involved in water resource management and community development. Understanding the unique challenges faced by municipal waterworks management in an indigenous town will enable the formulation and implementation of targeted interventions that respect the cultural practices and heritage of the community, ensuring long-term sustainability and equitable access to clean water.

2. Materials and methods

2.1. Population of the study

Households and commercial establishments in the central barangays of Bontoc are the primary participants in the study. A stratified random sampling at 10% of the total population size was considered to ensure that respondents were proportionately distributed in the barangays. Thus, a total of 135 households served as respondents to the study survey. Selected representatives with knowledge and involvement in water-related planning, projects, and activities from the Local Government Unit (LGU) of Bontoc served as key informants for the conducted interviews. In addition, officials in the four barangays were selected for Focus Group Discussions (FGDs).

2.2. Site description

The four central barangays of Bontoc served as the study areas: Bontoc Ili, Caluttit, Poblacion, and Samoki (see Figure 1). As a center for commerce and education, these barangays experience water challenges compared with other barangays in the municipality. In 2014, the said barangays were placed in a state of calamity due to a water shortage that both affected domestic and agricultural water demand.

2.3. Data gathering tools

Survey questionnaires were used for the conducted surveys. Also, interview guides for the Key Informant Interview (KII) and FGD were used as additional data-gathering tools for the study. These instruments were pretested and validated by research consultants before utilization.

The structured survey questionnaire included open-ended and categorized questions. It was in several parts to guide the respondents: (a) current water supply and real demand in the barangays of Central Bontoc, (b) challenges and factors affecting the improvement of water supply distribution and adequacy, (c) interventions done by the Bontoc-Municipal Water Works Office (MWWO) to improve water supply distribution and adequacy, and (d) suggestions to further address water-related challenges from study participants. The same parts were prepared for the interview guides.

2.4. Data gathering procedure

An ethics clearance was obtained from the Baguio General Hospital and Medical Center (BGHMC) Research Ethics Committee, an accredited ethics committee in Baguio City, Philippines. The survey questionnaires were both distributed and administered in the four central barangays of Bontoc. Questionnaires were given to the participants to fill out. Participants with difficulties in answering were assisted by the researchers. Queries and clarifications were sought by the respondents before the completion and retrieval of the instruments. For the interviews, questions were verbally translated using the Bontoc dialect to minimize confusion and misinterpretations. The interview was conducted following a schedule set by the selected key informants. Similarly, schedules agreed upon by the barangay officials were followed to ensure their participation at their convenient time and venue for the conduct of the FGDs. The discussions were held per barangay. In addition, field observations were done to gain further insights into the current status of water supply distribution in the barangays.

Informed consent from the participants was asked before they took the survey, FGDs, and KIIs. Also, a request to conduct data-gathering activities was sought from the municipal LGU. In the same manner, letters were forwarded to the chairman of the barangays of central Bontoc.

2.5. Treatment of data

All data gathered were properly documented. Data from the survey were analyzed quantitatively. Descriptive analysis was utilized to determine the percentage and mean of responses and their statistical description. Specifically, a Likert scale was employed to determine the level of seriousness of factors contributing to the challenges encountered by the respondents. Data gathered through the key informant interviews (KIIs) and Focus Group Discussions (FGDs) were carefully transcribed. Thematic analysis

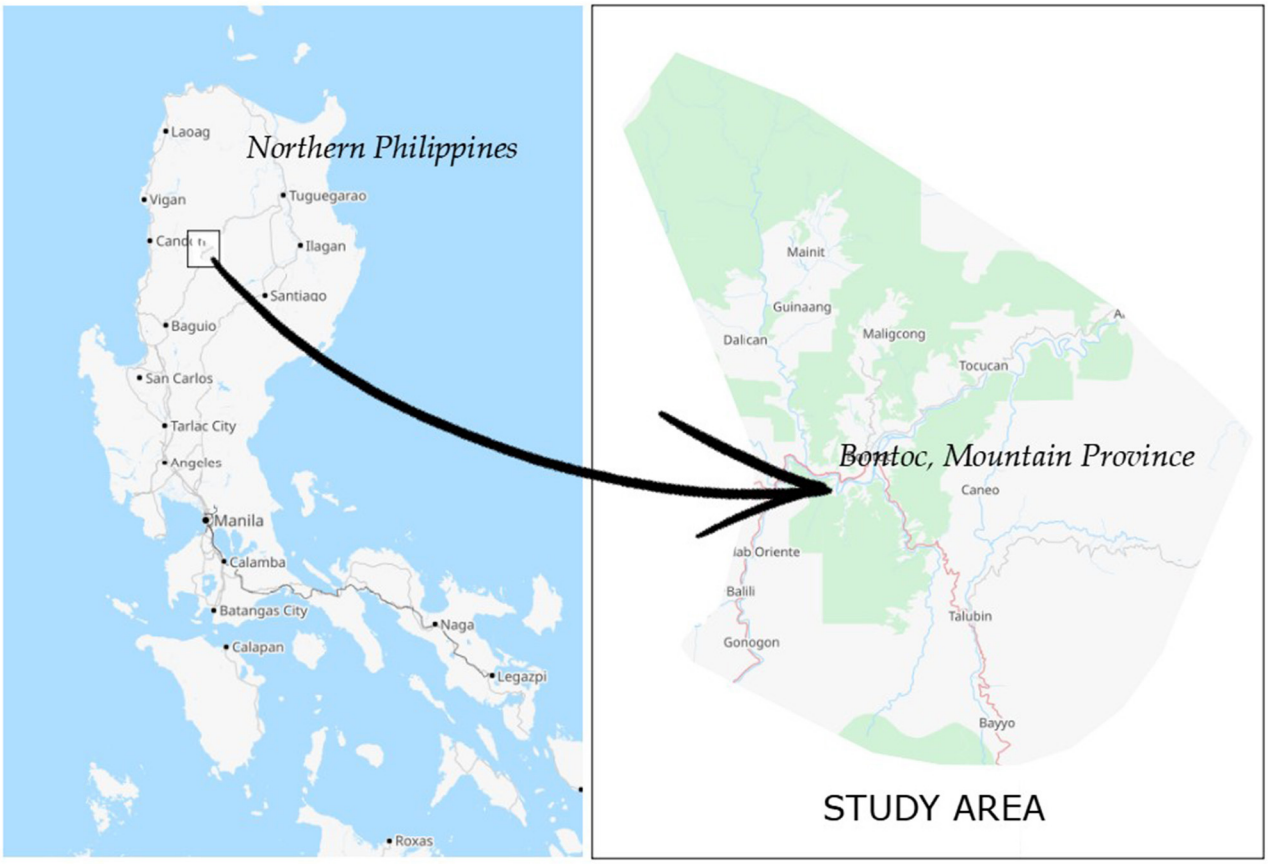

FIGURE 1
Map of the study area.

was used to determine the emerging themes from the gathered responses specifically the actions addressing the challenges to the domestic water supply of Central Bontoc. Coding was utilized for data organization.

3. Results and discussion

3.1. Demographic profile of study participants

The participants of the study are residents of the four central barangays of Bontoc. They were selected proportionately from the barangays. A total of 234 residents served as respondents in the survey. Seventy three are males and 161 are females. One hundred fifteen are single, 103 are married and 6 are widowers. The average age of the respondents is 35 years old. One hundred forty four of the respondents live in their own houses while 90 are renting. The respondents have 4 members in their family on average. In terms of household income, as represented by the respondents, ranges from Php 10,000.00 to Php 20,000.00.

3.2. Challenges and factors affecting the domestic water supply in Central Bontoc

The Bontoc-MWWO presently manages two water sources, namely Sullong water source in Bontoc Ili and Balabag water source in Talubin, both barangays of Bontoc. These sources serve as the major source of domestic supply for the four central barangays of the municipality, specifically Bontoc Ili, Samoki, Poblacion, and Calutit. However, various challenges impede the delivery of water supply to the barangays. The survey conducted reveals two major challenges experienced in the barangays particularly, (a) water supply inadequacy; and (b) uneven distribution of supply.

3.2.1. Water supply inadequacy

The majority of the respondents connected to the municipal-managed water supply reported that they experience water inadequacy. The same response was brought up even with the presence of private water sources as an alternative. Some of the respondents mentioned that private sources are accessed when they cannot store enough supplies to use while waiting for the next schedule of collection. Such a problem is mostly experienced during the dry season. The inadequacy of supply is expected during the

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TABLE 1 Level of seriousness for factors contributing to supply inadequacy.

Factors	Mean	Descriptive equivalent
Wasteful use and misuse of water	2.88	Serious
Prolonged dry season	2.82	Serious
Limited water sources	2.76	Serious
Population growth	2.65	Serious
Pipe leakage	2.53	Moderately serious
Interruption of water supply during collections during dry season	1.83	Moderately serious
Unattended water collection/water overflow	1.80	Not serious
Overall group mean	2.47	

Scale: 4.21–5.00 Extremely Serious, 3.41–4.20 Very Serious, 2.61–3.40 Serious, 1.81–2.60 Moderately Serious, 1.00–1.80 Not Serious.

dry season as specified by 58% of the respondents (see Figure 2). Meanwhile, the supply is enough for household use during the rainy season. A total of 72% respondents noted that their supply caters to their domestic activities during the rainy season. A total of 39% respondents perceived it as moderately inadequate during the dry season (see Figure 3). On the other hand, 37% of the respondents indicated that it is not at all inadequate during the rainy season.

Most if not all the respondents recalled that the water for their domestic activities had been insufficient in the past 5 years. A total of 66% respondents have been experiencing inadequacy while 34% shared that their supply in the said period was not a problem for them (see Figure 4). In comparison, water supply was the same problem at present as represented by 57% of the respondents. Relatively, most of them perceived that supply in the coming years would remain insufficient. A total of 69% respondents thought that such a problem would persist in the future while 31% said otherwise. Accordingly, the present sources might no longer provide enough supply in the coming years with the increasing population and the urbanization of Central Bontoc including the effect of climate change.

3.3. Factors contributing to water supply inadequacy in the central barangays

Based on the data collected, the study revealed that several factors contribute to water supply inadequacy in the central barangays of Bontoc (see Table 1). From the survey, KIIs, and FGDs conducted, there are at least seven factors contributing to the inadequacy of supply to household consumers which include the wasteful use and misuse of water, prolonged dry season, limited water sources, population growth, pipe leakage, interruption of water supply during collections during the dry season, and unattended water collection or water overflow. Each of these factors was discussed in detail in the following paragraphs.

The waste and misuse of water is one of the common factors affecting supply inadequacy with a mean of 2.88 being the highest. Wastage of water is observed in the household particularly, during the schedule of collection where water tanks and other water containers are unattended causing water to overflow as commonly observed in the pathways and backyards or wherever the tanks and containers are located. Panwar and Antil (2015) noted that if such was the case, the availability of water resources would not be an assurance in water addressing inadequacy for future utilization but rather, the efficient water usage amongst consumers and maintenance of water sources.

Water inadequacy during the dry season came out as another common factor identified by the respondents. A total of 64% respondents in the central barangays said they had an inadequate supply during the summer while 34% said otherwise. A mean of 2.82 reflects that the effect of climate change such as the prolonged period of the dry season is a serious problem. Asked how climate change affects their supply, the majority of the respondents recalled the drought experienced by Bontoc which led to water insufficiency in the households. The municipality experienced drought in 2015 along with other provinces (Official Gazette, 2015). The rapid growth of the population exacerbates supply insufficiency especially during the dry season despite the presence of enough supply in the country (Philippine Environment Monitor, 2003). This is true for regions and communities experiencing water supply constraints as affected by climate change such as the central barangays of Bontoc. To cope, respondents with inadequate supply from the municipal source buy water from private sources for their daily domestic activities. Supply, on the other hand, is not a problem during the rainy season. 87% of the respondents claim that their water supply is adequate during rainy days, while 13% said otherwise.

Respondents also claimed that the limited water sources of the central barangays are considered a serious problem with a mean of 2.76. Supply from the two water sources of Central Bontoc namely, Sullong and Balabag water source is not enough to cater to the growing water demand in the central barangays, as emphasized by the majority of the respondents. The municipal LGU key informants identified potential water sources that Bontoc may develop to address the water insufficiency that is currently experienced by many consumers since no available source in the central barangays can be utilized. The limited sources even in the nearby barangays led to the difficulty in tapping additional supplies for Central Bontoc. A potential source in Maligcong, one of the barangays of Bontoc, was identified. It received funding from the Department of the Interior and Local Government (DILG) and was later continued by the municipal LGU. However, the development of the said water source failed since Maligcong, one of the barangays of the municipality, pleaded to discontinue the project for its claim that it would use the source in the future. The LGU conducted two community consultations and presented a proposal to the latter. The supply that is supposed to come from such a source was planned to supply Barangay Caluttit, especially for the Bontoc General Hospital (BGH) which consumes a significant volume of water. Yet, the limited source has become one of the reasons for the Barangay Maligcong disallowing its water source for utilization of Central Bontoc. At present, the BGH has therefore remained to be supplied by the Balabag water source.

The limited water sources cannot cater to the growing water demand in the barangays, as perceived by the respondents. As

was mentioned in the survey, they claimed that the continuous growth of the population requires higher water demand which may entail another source for the increasing consumers. The result shows that the growing population in Central Bontoc is a serious problem getting a mean of 2.65. These barangays, which serve as the center for local commerce and education, require more housing and water supply. This observation is supported by the result of the study conducted by Maina (2014) showing that inadequacy of supply is caused by factors such as rapid population growth alongside infrastructure developments, particularly residential establishments.

In addition, pipe leakage, interruption of water supply during collection, and unattended water collection or supply overflow are regarded by the respondents as other factors contributing to supply inadequacy. Pipe leakage was rated by the participants as moderately serious with a mean of 2.53. It was observed in all the barangays that leakage is one of the common causes of water wastage when left unattended. Respondents also encounter wastage due to damaged pipes in their neighborhoods or along public pathways.

Apart from the leaking pipes, the interruption of water supply during collection likewise adds up to the constraints experienced. Most of the respondents said they experience supply interruption during the dry season. The extent of supply insufficiency during the prolonged dry season was noted as moderately inadequate which likewise affects water collection. Many indicated that they experience interruption and intermittent supply during the scheduled collection. The inconsistency of supply during the scheduled collection correlates with the study result of Omarova et al. (2019) revealing that the schedule of water collection is usually interrupted and thus is unreliable during the summer season which prompts consumers to look for alternative sources.

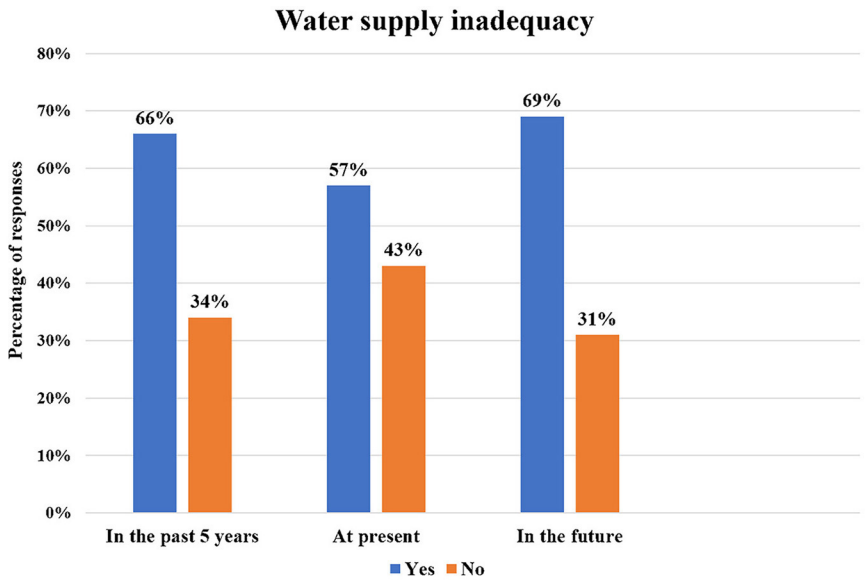

FIGURE 2
Water supply inadequacy in the central barangays.

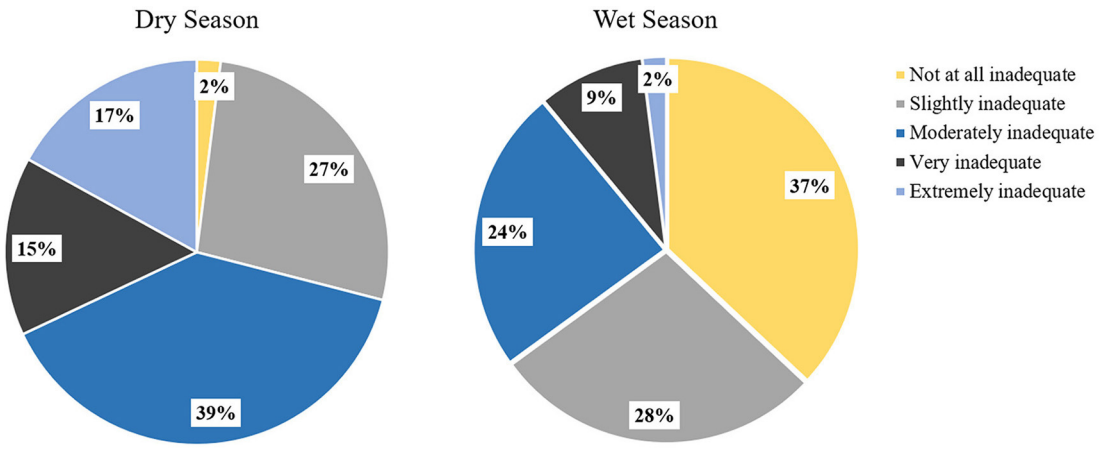

FIGURE 3
Perceived degree of water supply inadequacy during dry and rainy season.

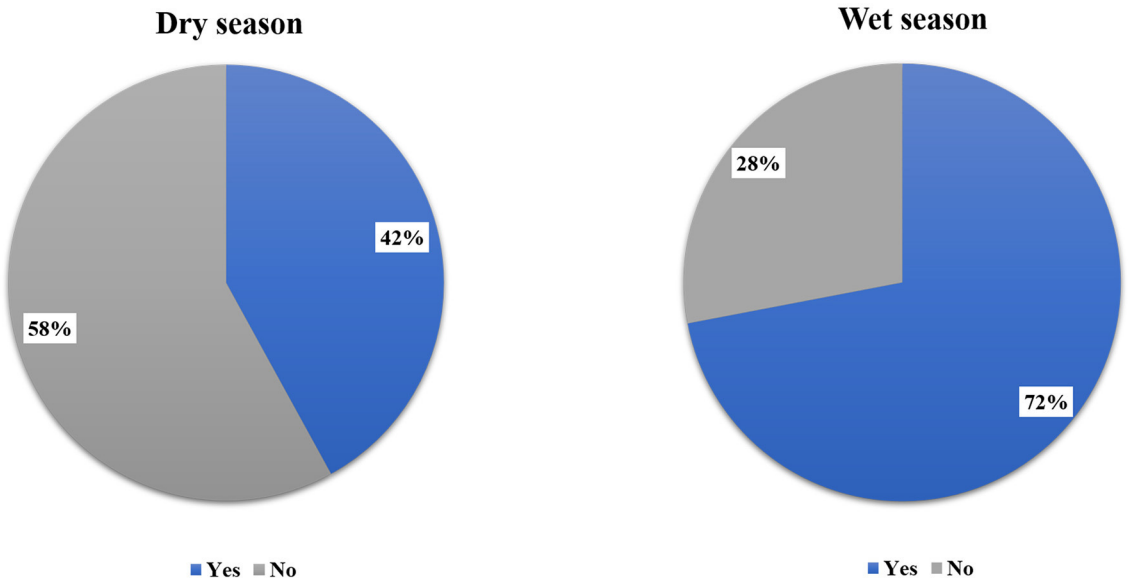

FIGURE 4
Respondent's perception of supply insufficiency.

Relatively, the unattended water collection that leads to water overflow aggravates the wastage of supply and consequently leads to experiences of supply inadequacy. A mean of 1.44 shows that an unattended schedule of supply collection in households is not serious but is still regarded as a problem by some of the respondents. Accordingly, unattended collection may lead to water overflow which results in less water collection and more wasted supply. Water is also wasted if not monitored by household members during the scheduled collection. This surplus, as stated by some respondents, may have been given to neighbors with less collected supply if monitored.

3.3.1. Uneven water supply distribution

While a portion of households in the central barangays receive adequate supply, many hardly get a fair share. The disproportion of supply distribution came out in the survey, KIIs, and FGDs as the second prevailing problem as reported by the respondents. From the data collected, respondents identified 13 factors that worsen the disproportioned distribution of supply. Accordingly, these include factors such as landslide and/or soil erosion, illegal tapping, monitoring of water quality, quantity, and pressure, inappropriateness of water distribution network layout, low water pressure zones, insufficiency of standpipes or tanks in the distribution network, limited manpower, inappropriateness of main pipe layout, inadequacy of funds for maintenance, water quality degradation, political will, inefficiency control of plumber in regulating flow of supply, and water-related conflicts among household members and neighbors. These factors were discussed in detail in the following paragraphs.

The availability of additional water sources, on the other hand, does resolve water inadequacy experienced by consumers. Naiga et al. (2012) countered that developing enough water sources, however, is not always a guaranteed action if the supply remains impartially distributed and hence is not a stand-alone intervention to supply inadequacy. Their study in Isingiro, Uganda shows that despite the presence of water resources in the district, unequal distribution of water is still a problem given that a significant portion goes to farming and available sources are geographically far. This also holds true for Bontoc as attested by the household respondents and municipal LGU key informants. The presence of water supply may provide to the central barangays; however, supply distribution remains a challenge.

Findings show that water supply from the municipal waterworks is not evenly distributed to households hence adding to the problems being encountered by households connected to the municipal-managed sources (see Table 2). As experienced, most of the respondents located in the upper sitios claimed that they receive little to no supply, especially during the summer season. Various factors affect the distribution of water supply to the consumers connected to municipal waterworks such as the effects of climate change, unequal water supply distribution, illegal tapping, inefficient monitoring of water quality, quantity, and pressure, and inappropriateness of the water distribution network layout which are accounted as serious factors.

The effect of climate change on water supply has a calculated mean of 3.08 which is the highest. The respondents perceived that climate change makes the supply vulnerable when events such as a landslide or soil erosion after the onslaught of typhoons and heavy rains destroy water pipelines. The MWWO noted that they face difficulties in the repair and maintenance of pipelines in cases where these are severely hit. Interruption of supply affects distribution not until the repair is completed. Accordingly, landslides encountered in the past years are not unusual. The study shows that climate-related events compromise supply in mountain communities such as the central barangays. This finding

TABLE 2 Level of seriousness of respondents for factors contributing to uneven supply distribution.

Factors	Mean	Descriptive equivalent
Landslide/soil erosion	3.08	Serious
Illegal tapping	2.77	Serious
Monitoring of water quality, quantity, and pressure	2.73	Serious
Inappropriateness of water distribution network layout	2.61	Serious
Low water pressure zones	2.58	Moderately serious
Insufficiency of standpipes or tanks in the distribution network	2.57	Moderately serious
Limited manpower	2.55	Moderately serious
Inappropriateness of main pipe layout	2.54	Moderately serious
Adequacy of funds for maintenance	2.42	Moderately serious
Water quality degradation	2.40	Moderately serious
Political will	1.65	Not serious
Inefficiency control of plumber in regulating flow of water	1.59	Not serious
Water-related conflicts among household members and neighbors	1.52	Not serious
Overall mean	2.31	

Scale: 4.21–5.00 Extremely Serious, 3.41–4.20 Very Serious, 2.61–3.40 Serious, 1.81–2.60 Moderately Serious, 1.00–1.80 Not Serious.

thus agrees with Howard et al. (2016) providing that climate change greatly influences precipitation which poses a risk of water infrastructure damage.

In terms of pipe connections, respondents reported that some households are directly connected to the main distribution pipe getting a mean of 2.77. Illegal tapping in the distribution pipes is prohibited under the municipal water ordinance. Key Informant 1 (municipal councilor during the conduct of the interview) noted that while the ordinance is in effect, these illegal connections are not yet penalized. He, however, clarified that penalties will be strictly imposed once the distribution layout is improved. The MWWO staff conducts the removal of illegal pipe connections during the monitoring of distribution pipes and repair activities that they conduct. As observed, some illegal connections are difficult to find since they are hidden or buried. The office likewise emphasized that they inform households to apply for a connection at their office to avoid violation of the ordinance.

Respondents also shared that the pressure including the quality and quantity of their supply are factors that impede their access to enough supply. They regarded it as a problem with a mean of 2.73. Respondents implied that water quality monitoring is not given attention since they usually receive a murky water supply during the rainy season. They added that even the pressure of supply is not given appropriate action for its improvement. In an interview with the LGU, specifically, the Municipal Engineering Office and MWWO, the limited funding appropriated for water laboratory fees and funding for water system improvement is limited. The MWWO, on the other hand, clarified that daily monitoring and cleaning of the water reservoir and tanks are consistently conducted to minimize murky supply, especially during rainy days. Similarly, it was noted in the survey that water quantity is not monitored. Respondents noted that this is due to the absence of water technologies such as pressure meters for water pressure monitoring and advanced filtration and sedimentation for water quality monitoring and improvement.

The inappropriateness of the water distribution network layout with a mean of 2.6 is deemed by the respondents as a factor that hampers the even distribution of supply in the sitios of the central barangays. The existing layout as regarded by some is less fitting for the different sitios. A site inspection conducted by the researchers showed that some distributions per zone were different from the usual distribution system of water works. Also, the layout was perceived by the respondents as a factor to consider for the proneness of pipes to leakage and further damage.

Moderately serious factors were also identified by the respondents such as the low water pressure, insufficiency of standpipes and/or tanks, lack of manpower, the inappropriateness of the main pipeline layout, the inadequacy of funds for maintenance, and water degradation. The low pressure of water at the tail end of the distribution system with a mean of 2.58 limits water circulation specifically to households in the upper sitios of the central barangays. Respondents shared that they do not receive the same amount as those in the lower areas given the difficulty of supply being pushed upward. Most of the time, consumers in these areas receive little to no supply during the summer period when the volume of water from the sources has decreased. This finding corroborates Nassri and Yahia (2018) in their study showing that high buildings and places lack water due to low pressure. On the contrary, high water pressure zones become a problem also. Such was the case of Gakhan Creek, a new water source for Central Bontoc. Key Informant 2 (Vice Mayor of Bontoc and the MWWO Superintendent from 2007 to 2016) emphasized that pipelines fail with uncontrolled pressure. He recalled that the PVC pipes used outbursts in high water pressure areas several times thus repair is needed to replace the damaged pipes by using galvanized iron type. This observation affirms Omotayo (2014) noting that low- and high-pressure areas cause pipe burst and demands higher cost for the repair and maintenance of pipelines. Other water infrastructures such as standpipes and/or tanks in the distribution network are necessary; however, these are limited in the central barangays. Respondents, therefore, noted that the lack of standpipes and/or tanks with a mean of 2.57 is contributory to the unproportioned supply to the barangays.

For the MWWO, its limited manpower with a mean of 2.46 is a constraint that indirectly affects the distribution of supply. Poor flow of supply is experienced during the occurrence of landslides or soil erosion where pipelines are compromised. The limited staff results in the delay in the maintenance and repair of pipes. The municipal waterworks noted that most of its staff are contractual workers thus the difficulty and delay of supply restoration in worst-case scenarios. These situations which have been experienced by the office surfaced in the interviews relate to the study of Mothetha et al. (2013) wherein the non-availability and lack of municipal waterworks staff to respond to infrastructure damage causes supply interruption which is usually encountered when pipelines are destroyed due to occurrences of soil erosion or landslide.

The inappropriateness of the main pipeline layout with a mean of 2.54 is further identified by the respondents as another factor to consider in the distribution of supply to the barangays. The existing layout faces challenges such as the geographical location of the pipelines which may make them vulnerable to the impacts of landslides. Their location makes the repair difficult and may require a longer time to be completed if parts of the pipelines are affected. Repairs could take 3 or more days to be fixed depending on the gravity of the destruction and the limited manpower of the MWWO. According to Key Informant 2, the pipes are also positioned along the roads and their alignment thus their exposure to road constructions and vehicles.

The inadequacy of funds for maintenance with a mean of 2.42 is another factor that indirectly affects the distribution of supply to consumers. The delayed action, especially in incidents where pipes are left unrepaired for weeks, is due to the limited funds necessary for maintenance activities. Inadequate funds correspond to the limited investment of the LGU to enhance the water supply and existing water facilities. While other communities with enough investment in water systems receive supply for longer hours, the case for Bontoc is different. Water collection by the consumers in the central barangays gets their supply following a two-hour schedule every other day. This scenario corresponds to the study of Lal (2014) wherein communities with limited water supply do not access supply on a 24-h basis, rather 2 h every 42 h such as the case of South Tarawa, Kiribati, a developing country like the Philippines.

In terms of water quality, the supply from the municipal source is generally clean. It, however, becomes murky during the rainy season which prompts other households to disregard the supply that comes from the municipal source and buy from private water suppliers temporarily. Water quality got a mean of 2.40, as rated by the respondents.

Other factors that are perceived to further affect the water supply distribution are mentioned during the survey and FGDs. These are not serious factors but are still considered by the respondents as contributing to the impediments that they experience. These are as follows: inefficiency of control plumbers, water-related conflicts amongst neighbors and households, political will, and delinquency and delay of water fees and water bill payments.

The inefficiency of control plumbers in regulating water flow with a mean of 1.59 is not regarded as a serious problem. However, some households shared that the period of water distribution is not consistent with their assigned schedule of water collection hence perceiving that control plumbers seem not to strictly follow schedules of opening and closing water valves. The LGU, on the other hand, pointed out the limited number of personnel in the past years which may be a factor to consider in the delay of supply collection by some households as clarified in an interview. The office furthered that their personnel are trained in their delegated activities to minimize the inefficiency of supply distribution.

In terms of water quality from the municipal source, the respondents observed that it is affected by the season. The supply is generally clean during the summertime. However, some of the respondents noted that it becomes blurry in appearance when the rainy season comes. As rated by the respondents, water quality with a mean of 1.50 is not serious but is a seasonal problem. Some respondents clarified that the murky supply during continuous rainy days could be remedied through filtration and/or by allowing the supply to settle before it is used hence is not a major concern.

Also, factors such as conflicts related to water affect supply distribution. As observed by some respondents, conflicts result in cases such as the destruction of household pipes. From interviews, cases like such may be attributed to the unequal supply received by barangay members. Conflicts that arose amongst barangay members included the uneven supply distribution. These conflicts which are attributed to receiving inequitable supply led to activities such as the destruction of other members' pipes by other barangay members. These scenarios are, however, not common. Others also mentioned political will with a mean of 1.65 as a factor that affects supply for the barangays. Some perceived that political decisions influence the water supply allocation per barangay while a few noted that the water needs of political figures are given more attention.

3.4. Interventions for improvement of domestic water supply adequacy and even distribution by the LGU

Several interventions for the reported water problems were identified during the conduct of surveys, KIIs, and FGDs by both the LGU and households in the central barangays. As pointed out by the LGU, there is a need to augment supply coming from the existing sources through additional sources, regular monitoring of water quantity and pressure, timely pipe repairs, changing old pipelines, and timely updates on water supply. In addition, households in the central barangays also suggested further actions such as the following: strict implementation of the municipal ordinance on water; improvement of the distribution pipeline layout; improvement of water pressure; regular monitoring of supply distribution; additional manpower; utilization of water technologies; and, efficient management of domestic water supply at the household level. Respondents perceived that these interventions if implemented, would ease supply inadequacy, and promote its efficient distribution. They iterated that the administrative management of the municipal water system should be complemented by the households. Below are detailed discussions of the abovementioned interventions to the challenges to domestic water supply.

3.4.1. Additional water source

In terms of water supply, most of the respondents perceived that the existing water sources may not provide enough for years to come. Therefore, they have pointed out the need to augment the existing water sources of the central barangays to improve the water supply for domestic use and to meet the increasing water demand. Some suggested that the Municipal LGU source funds to this effect.

At present, a new water source in Barangay Talubin identified as the Gakhan Creek is being developed to augment the supply coming from Balabag source and Sullong source. This water project was an initiative of the Department of Public Works and Highways (DPWH) but was later transferred to the Municipal LGU for continuation in 2016 despite the challenges encountered

during the implementation of the project. Most of the consumers in the barangay are connected to private sources. The LGU informants mentioned that the new source would significantly help in addressing water insufficiency and related challenges and conflicts related to the water supply. Key Informant 3 (municipal mayor) emphasized that insufficiency may no longer be the primary concern when a new source is developed but will be more on the management of supply to ensure fair distribution. Accordingly, the challenge would be the equal distribution of water from the new source.

Key Informant 3 hoped that the water supply services of MWWO would soon improve given the development of the additional water source for the households to have more access to water every day for at least 3 hours or more when the source is already operational. The construction of additional tanks was likewise suggested. Accordingly, there is a need to build one major tank for the community from which distribution lines will be connected. Their concept of such a project includes manifolds with valves where consumers can tap connections with installed water meters. Accordingly, it would prevent tapping on main pipes, supply pipes, and distribution lines but only on manifolds.

The Asian Development Bank (2013) (ADB) stated that one of the problems in developing communities is the lack of interest of LGU officials to handle water projects to improve supply expansion and provide better service to consumers for two reasons. Firstly, the recovery cost is uncertain and secondly, the officials have a short-term in their positions to handle water projects. However, the finding of this study counters the ADB's report. Interestingly, the interviews and FGDs conducted revealed that the LGU has been looking forward to future water projects that would alleviate water woes in Central Bontoc. The LGU emphasized that the persisting problems related to water in the central barangays served as their motivation to seek improvement on its current water supply.

While the additional source was tapped, the MWWO pointed out that timely maintenance is important in ensuring the efficiency of the existing water sources. He also noted that source rehabilitation needs prioritization if the need arises in the future. Such intervention, as pointed out by Zeraebruka et al. (2014) is relevant in the expansion of supply coverage and provision to consumers.

3.4.2. Regular monitoring of water quantity and pressure

The staff of the MWWO conducts weekly inspections of the water sources to ensure they are clean from accumulated sand and debris that may lead to pipe clogging. All the assigned staffs have their schedule for the cleaning and maintenance of the sources. They are also tasked to do inspections of the sources to prevent unauthorized individuals and activities that may compromise the water quality.

3.4.3. Pipe repairs

The repair of the distribution pipes is initiated to prevent water leakage during the distribution of supply to consumers. In the same way, the main pipelines of the sources are repaired on time in case they are damaged due to soil erosion or landslides to minimize supply interruption and shorten water unavailability.

3.4.4. Changing old pipelines

The MWWO changed old pipelines that are no longer efficient. Accordingly, old pipes are replaced with new ones to prevent corrosion and leakage of supply. Also, consumers are advised by the office to replace their aging or old pipes with new ones to avoid leakage in every schedule of water collection.

3.4.5. Timely updates on water supply

To ensure that the consumers are aware of the status of their water supply, Key Informant 4 (Municipal Government Assistant Department Head of MWWO) shared that the water works office provides timely updates via the LGU's online social platform (Facebook). Awareness of the supply minimizes the distrust between the LGU and supplied consumers. The majority of the respondents noted that they are informed of changes such as the schedule of water interruption and the time of expected supply restoration. Accordingly, the updates from the LGU help them resort to temporary sources while their supply from the municipal source is not yet restored.

3.5. Interventions for improvement of supply adequacy and even distribution as suggested by the central barangays

3.5.1. Strict implementation of the municipal ordinance on water

The strict observance of the municipal water ordinance is necessary to prevent direct connections to the distribution pipe and illegal tapping. According to officials of the LGU, consumers need to encourage owners of unregistered pipe connections to remove them. Assigned officials conduct the disconnection in cases where refusal from pipe owners is encountered. As for illegal connections, consumers are mandated to register their connections to the MWWO otherwise they will be penalized for illegal tapping. Illegal connections amongst other factors lead to inefficient supply distribution and an increase in water loss hence their removal would contribute to consistent provision of supply to registered consumers (Raymundo, 2015). Also, as stated in the ordinance, the unauthorized connection of water pumps at the distribution lines is prohibited. The MWWO stated that the connection of pumps is reported by consumers for removal.

3.5.2. Improvement of the distribution pipeline layout

In case the existing distribution line will be enhanced, Key Informant 3 suggested the tapping of consultants with expertise in pipeline lay-outing. A layout suitable for the central barangays of Bontoc would significantly improve water distribution, accordingly. Better distribution of supply is attained if the appropriate pipe layout for the water distribution system design is followed as emphasized by Adeosun (2014). For the existing

layout, Zeraebruka et al. (2014) emphasized that the rehabilitation of the distribution layout would be significant in the expansion of water services level and coverage. Their study shows that such intervention is crucial in improving the level of service delivery of water supply.

3.5.3. Improvement of water pressure

The improvement of the water pressure alongside the distribution layout is crucial for better supply service. Key Informant 4, however, admitted that water pressure is a prevailing problem in the central barangays which affects consumers located in the higher sitios. The respondents hoped that water pressure would be improved in the future should enough funding be granted. They perceived that better water pressure may help address the inequitable supply to households, pipe bursts, and leakage experienced in the barangays. These findings relate to the case studies conducted by McKenzie and Wegelin (2019) in South Africa who have proven that pressure management is significant in many ways such as the prevention of pipe bursts, leakage, wasteful consumption, and in the long run, prolonging the lifespan of the distribution system. Also, the MWWO supports the need for pressure improvement and monitoring to allow fair distribution of supply to the different sections of the central barangays. This relates to the recommendation of Nassri and Yahia (2018), wherein the monitoring of pressure through the instilment of monitoring gauges per area of distribution and the separation of the areas supplied with water into different zones may facilitate better distribution.

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3.5.4. Regular monitoring of supply distribution

In terms of water distribution to the consumers, the MWWO implements a schedule of supply distribution per sitios of the barangays. Water distribution is scheduled for 2 h every other day. The staff of the MWWO follows the schedule of opening and closing water valves in the different barangays and their respective sitios.

3.5.5. Additional manpower

It was commonly suggested that manpower for the MWWO be added to cater to technical needs such as weekly inspection of the main pipelines and distribution pipes, changing of old pipes, removal of illegal connections, and other relevant tasks that may arise such as repairs and supply restoration. According to respondents these activities, if conducted efficiently would be necessary to provide a fair distribution of water supply to the households. The MWWO has increased the number of its staff in 2021 and thus is hopeful that they will perform better with the addition of their manpower. However, the tendency that manpower becomes a problem may be possible given that many of the present staffs are non-permanent employees. Hiring is usually dependent on fund availability.

3.5.6. Utilization of water technologies

To mention further interventions, the result of the survey indicates that respondents are willing to utilize water technologies to help improve the quantity and quality of water they receive from the municipal water source such as the use of water meters in households and sedimentation and filtration in the storage tank. At present, water metering is not yet implemented to regulate the supply and consumption amongst households in the barangays but most of the respondents are open to the use of water meters. Only a small portion of respondents from Barangay Samoki, on the other hand, is not. The MWWO recounted the destruction of installed water meters which were pilot tested for their efficiency in the past years which may show the resistance of some to water metering. Accordingly, these were destroyed by consumers who were not in favor of water metering. This finding agrees with the study of Tantoh (2021) who examined that water metering in the piped community-based water supply is challenged by factors such as misinformation and wrong notion about the utilization of water meters. The survey and in-depth interviews he conducted revealed that metering is not viable if the technology is understood as a money-making venture of the government. His findings showed community resistance and the destruction of meters. Relative to this case, the MWWO pointed out that the dissemination of information about the water metering process and its advantages would be relevant to addressing misconceptions about the use of the technology.

As rated by the majority of the respondents, water metering is an "acceptable" technology for household use. This was even suggested by some in the barangays of Bontoc Ili and Caluttit during the conduct of FGD, which according to them will regulate water consumption at the household level, minimize waste of water, and develop water conservation habits of household members. Relative to the acceptance of the many in water metering, the MWWO emphasized the need to educate consumers on the utilization and advantages of such technology to prevent part experiences such as the destruction of installed meters. Informing consumers about metering is significant in promoting the responsible and efficient use of water. As substantiated by the study findings of Koop et al. (2021), the message tailoring technique is a major predictor of respondents' motivation to accept and encourage the use of water metering, which also provides a promising strategy for promoting water conservation. The study assessed public attitudes toward digital water meters for domestic use which yielded positive responses from households. Should the water metering be implemented in the future, the key

informants pointed out that the water meters should be shouldered by the consumers so that they will be responsible for taking care of them.

Water quality is also considered a factor that may affect supply adequacy and inadequacy. Some respondents noted that supply from one of the sources, specifically Sullong water source is not utilized when supply becomes murky during continuous rainy days. Undesirable supply, as respondents defined it, indirectly influences supply adequacy. It was found out that some throw their murky supply since they do not practice filtration hence causing inadequacy of stored supply at their households while waiting for the next schedule of water collection. Another reason for wasting murky supply is the inconvenience of using it when it is supposed to be used immediately. The majority of the respondents thus agree with the use of sedimentation and filtration in storage tanks to address concerns about the quality of water used for domestic activities. In the same way, they agree to the utilization of other necessary purification methods in households to minimize the wastage of supply. The majority have rated the use of sedimentation as acceptable while they regarded the utilization of filtration in the storage tank and households as very acceptable.

3.5.7. Efficient management of domestic water supply at the household level

Apart from the role of the LGU in addressing challenges to the water system, the households likewise play a significant role in complementing the LGU management of water. Survey respondents regarded responsible water consumption and conservation practices to be important in minimizing further problems with water supply. Most households have experienced water supply insufficiency in the past 5 years or at present. Thus, most of the survey respondents stated that efficient water consumption at the household level is significant in dividing the supply to the different household activities requiring water use. In the same way, most of the respondents avoid water overflows by monitoring the schedule of water collection and closing pipes when water is not in use to conserve supply. The household members remind each other to monitor their tanks during fetching schedules to avoid water overflow.

Others recycle gray water, especially during the dry season when an insufficiency of supply is experienced. Gray water collected from dishwashing and laundry is used to flush the toilet, clean the yard, and water plants. Others collect rainwater through their houses' gutters to be used for cleaning activities instead of using their stored supply. Recycling of gray water and rainwater collection is practiced by most households residing in higher sitios of the barangays, especially when their supply did not arrive at their scheduled collection. The lack of water pressure affects the distribution of supply in these areas thus households have practiced recycling and rainwater collection to suffice their supply. Most respondents perceived that gray and rainwater are convenient alternatives when they are available.

In addition, respondents who experience water inadequacy tend to connect to private sources either as an alternative source of supply or for augmentation. 19 respondents revealed that they are both connected to municipal and private sources. Households with more members are permanently connected to a private source while those with fewer members tend to access supply from private water sources only during the dry season when they experience collecting scarce supply for weeks or if the need arises.

4. Conclusions

The central barangays of Bontoc deal with two primary problems specifically the inadequacy of domestic water supply and uneven distribution to households with access to the municipal-managed water services. Various factors contribute to these major problems which evidently show the current state of domestic water supply until to the present.

The Bontoc LGU noted several measures such as the augmentation of existing water sources, timely monitoring of water quantity and pressure, timely pipe repairs, changing old pipelines, and timely updates on water supply. Additional actions were suggested by the households such as tapping additional water sources, improvement of distribution layout and water pressure, water recycling, and conservation measures at the households. These, if efficiently implemented by the LGU coupled with the cooperation of households, would contribute to relieving the prevailing challenges on the domestic water supply and its distribution. Other interventions such as the utilization of technologies like water metering were regarded as "acceptable" while sedimentation and filtration as "very acceptable". These technologies may further improve the existing quality of supply and its distribution to households if incorporated into the municipality's water supply distribution system. The findings of this study may give the municipality wider perspectives on necessary actions that may ease water constraints and enhance its supply services. Identification of these challenges serves as a starting point in determining opportunities for the further improvement of water service delivery in mountain indigenous communities considering various factors that impede supply sufficiency and equitable distribution to households.

In conclusion, this study represents a novel exploration of the challenges faced by municipal waterworks management in enhancing water supply adequacy in an indigenous town in the Philippines. By amalgamating interdisciplinary perspectives, incorporating cultural nuances, and emphasizing the unique circumstances of the indigenous community, this research aims to make a valuable contribution to the existing literature and support the development of sustainable water management practices in marginalized areas in communities while considering their capacity to improve supply and distribution to consumers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Baguio General Hospital and Medical Center Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors participated in the monthly field collection of data in the different sites, worked together in the preparation, finalization of the manuscript, and have also agreed to the manuscript content for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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