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Evaluating the Sustainability of Community-Based Water Supply Systems: Insights from the Deurali-Hupsekot Urban Water Supply and Sanitation Project, Gandaki Province, Nepal

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Abstract

Sustainable water supply entails finding reliable and resilient methods to meet human water needs without depleting sources, harming the local economy, or causing environmental damage. Community-based water supply systems play a vital role in decision-making, operation, and maintenance, promoting ownership and sustainability. This research assesses the sustainability of a community-based water supply and sanitation project, focusing on technical performance, institutional arrangements, and socio-economic conditions. This study includes qualitative and quantitative research and household sampling of 230 respondents. To determine the weight of factors and subfactors influencing sustainability, the report employs the Analytical Hierarchy Process (AHP), a widely recognized decision-making tool. The project demonstrates a high level of sustainability (91.46%) in terms of technical dimension with moderate sustainability (61.19%) in the institutional and socio-economic aspects. The project achieves a sustainability rating of 69.48% in operation and maintenance. The income trends indicate potential for loan repayment and financial sustainability, while sufficient human resource ensures the smooth functioning and maintenance of the infrastructure. Overall, the project achieves a commendable sustainability rate of 79.89%. The findings from the study provide valuable insights for project implementers, policymakers, and stakeholders involved in similar community-based water supply and sanitation initiatives, promoting sustainable development and improved water access for the community.

Keywords

Analytical Hierarchy Process (AHP), Community-based water supply system, Sustainability assessment, Technical performance, Institutional arrangement, Operation and Maintenance

1. Introduction

Access to safe drinking water and proper sanitation services is fundamental for human health, well-being, and environmental preservation. They are central to sustainable development, which aims to enhance human well-being while respecting the environment's limits [1]. Sustainability is “whether or not something continues to work over time." The sustainability of community water supply and sanitation systems involves a chain of four essential links: motivation, maintenance, cost recovery, and continuing support [2]. According to the UN's Vision 2050: Water in a Sustainable World (2015), “in a sustainable world that is achievable shortly water and related resources are managed to support human well-being and ecosystem integrity in a robust economy. Sufficient and safe drinking water is available to meet every person’s basic needs, with healthy lifestyles and behaviours easily upheld through reliable and affordable water supply and sanitation services.” Community water systems rely on social cooperation and technical sufficiency for long-term sustainability. Community participation fosters ownership and sustainability through contributions, planning, and maintenance [3],[4].

A study on community-based organizations managing urban water projects revealed sustainability challenges, including technical issues, management, costs, and communication. Problems like operator training, leadership, finances, and demand estimates affect consumer satisfaction in community water supply project. To ensure sustainability, a capacity-building program and institutional solid arrangements are crucial [5],[6]. Throughout history, access to quality water in the right amount has been vital. Ancient civilizations started near water sources, and as populations grew, so did the challenge of meeting demand. This led to the transport of water to communities. Today, water supply systems include infrastructure for collecting, treating, storing, and distributing water between sources and users [7]. The piped water supply in Nepal originated in 1895 when Prime Minister Bir Sumsher introduced the first Bir Dhara system in Kathmandu. In 1972 the Nepalese government established the Department of Water Supply and Sewerage [8]. Nepal still struggles to ensure safe and sustainable drinking water and sanitation services for its people. The need of long-term, efficient access to improved water supply services is a major issue. In developing countries like Nepal, approximately 25% of water supply projects fail within two years due to socio-technical, management, financial, and community-related issues [9]. The water supply system frequently experiences breakdowns due to poor technical performance, limited maintenance, institutional gaps, and weak operation and maintenance. Moreover, Nepal’s water scarcity, leads to waterborne diseases due to poor water quality and sanitation. Providing clean and sufficient drinking water remains a government commitment, but water-related diseases significantly threaten human well-being [10],[11],[12].

Since finance is a problem in community-managed systems, it is essential to solve it. Hence, it is reported that financial management is effective if the committee can budget the income and spending over a specific time period, collect service fees, keep financial information and records, and oversee and monitor the system's financial performance [13],[14]. In addition to financial capital formation, social elements, administrative, and technical capacities are critical criteria for long-term rural water delivery systems that ensure the system functions correctly and at a reasonable cost [15]. Due to a lack of a sustainable approach and appropriate technology for the provision of water and sanitation, the percentage of the population with access to safe water and adequate sanitation has dropped, necessitating the need for appropriate and sustainable water and sanitation systems [16].

Technical aspects involve the water quality, water pressure, quantity, and reliability of the water source [17],[18]. Institutional arrangements and socio-economic conditions involve the institutions involved in the project with their clear roles, norms, and behaviours and an operational plan for the system. Also, for the potential sustainability of the system, the community must have the willingness to pay for tariffs, household satisfaction regarding tariffs, institutional behaviour, water pressure at taps, and avoidance of waterborne diseases in the community [19],[20],[21]. For the water supply system to operate and maintain successfully, the income from the various sources of the user's committee must fulfil the expenses to run the institution and system sustainably [22],[23]. These factors have been critical to the sustainability of the water supply system. Understanding the influence of these factors is important for understanding the water supply system's performance and behaviour. Hence, the main aim of this study is to focus on the Deurali-Hupsekot Urban Water Supply and Sanitation Project and analyze its sustainability in terms of its technical, operational, socio-economic, and institutional arrangements. The general objective of the study is to analyze the project's sustainability as follows: (i) to analyze the performance in terms of technical dimensions of the sustainability of the water supply system. (ii) To analyze the institutional arrangements and socio-economic conditions that sustain the water supply system. (iii) To assess the sustainability of the water supply system in terms of operation and maintenance. This research makes several noteworthy contributions. First, unlike previous literature that has focused on the social and environmental impacts of water supply and sanitation system in the case of various countries, this study explores the situation of developing country of Nepal as a case study. There is a big literature gap in Nepal so this work would bridge that gap and help to enhance the water system and sanitation situation of Nepal.

1.1 Deurali-Hupsekot Urban Water Supply and Sanitation Project

Deurali-Hupsekot is one of the community-managed water supply and sanitation systems. The user's committee is responsible for the operation and maintenance of the water supply and sanitation system. For years, the locals of Hupsekot Rural Municipality in Nawalparasi East quenched their thirst by drinking water from the wells. Now, they are supplied with clean drinking water in their taps. After the project came into operation, water has been supplied through 3,724 taps benefiting 23,000 people of Hupsekot Rural Municipality. The completion of the project as a sample project in the district, in time was hailed and the locals, especially in Ward Nos. 1, 2, 3 and 4, have been receiving enough water now. The project was completed at a cost of around Rs. 815 million of which the Nepal government covered 70 percent which is funded by Asian Development Bank. Similarly, 5 percent of the total amount was levied from the consumers while 25 percent was the loan from the Town Development Fund. Both by lifting and gravity flow of the water to the tanks and purifying it, clean drinking water is distributed 24/7 to the households. Table 1 represents the salient features of the research area.

Table 1: Salient features of the Deurali-Hupsekot Urban Water Supply and Sanitation Project

SN	Item	Description
1	Name of the Project	Deurali Hupsekot Urban Water Supply and Sanitation Project
2	Implementing Agency	Government of Nepal, Ministry of Water Supply
3	Executing Agency	Department of Water Supply and Sewerage Management
4	Funded by	Asian Development Bank and Government of Nepal
5	Type	Both gravity and pumping system

6	Location	
	Region/Province	Gandaki
	District	Nawalpur
	VDC/Municipality	Hupsekot Rural Municipality
	Service area	Ward No: 1, 2, 3 & 4
7	Social Status	
	Present household numbers	3724
	Present Population	21909
	Base Year Population	22786
	Design Year Population (2040)	32168
	Projected HHs in Design Year	5647
8	Type of Structures	
	Proposed Intakes	Stream intakes Gravity flow-3 Pumping System-1
	Water Treatment Plant	Rapid Mixture – Flocculator – Sedimentation - Horizontal Roughening Filter – Slow Sand Filter – Disinfection
9	Length of distribution pipeline	177.544 Km
10	Length of transmission main	14.287 Km
11	Distribution Systems	8 DMAs (District Metered Areas)

2. Methodology and Study area

The research work has been conducted on the Deurali-Hupsekot Urban Water Supply and Sanitation (Sector) Project, which is situated at Hupsekot Rural-Municipality in Nawalparasi_ District, as shown in Figure 1. Hupsekot Rural-Municipality has a total of 6 wards, which are scattered across 189 square kilometers of geographical area. The geographical location of the study area is about 27° 41′ 26″ N latitude and 84° 3′ 44″ E longitude.

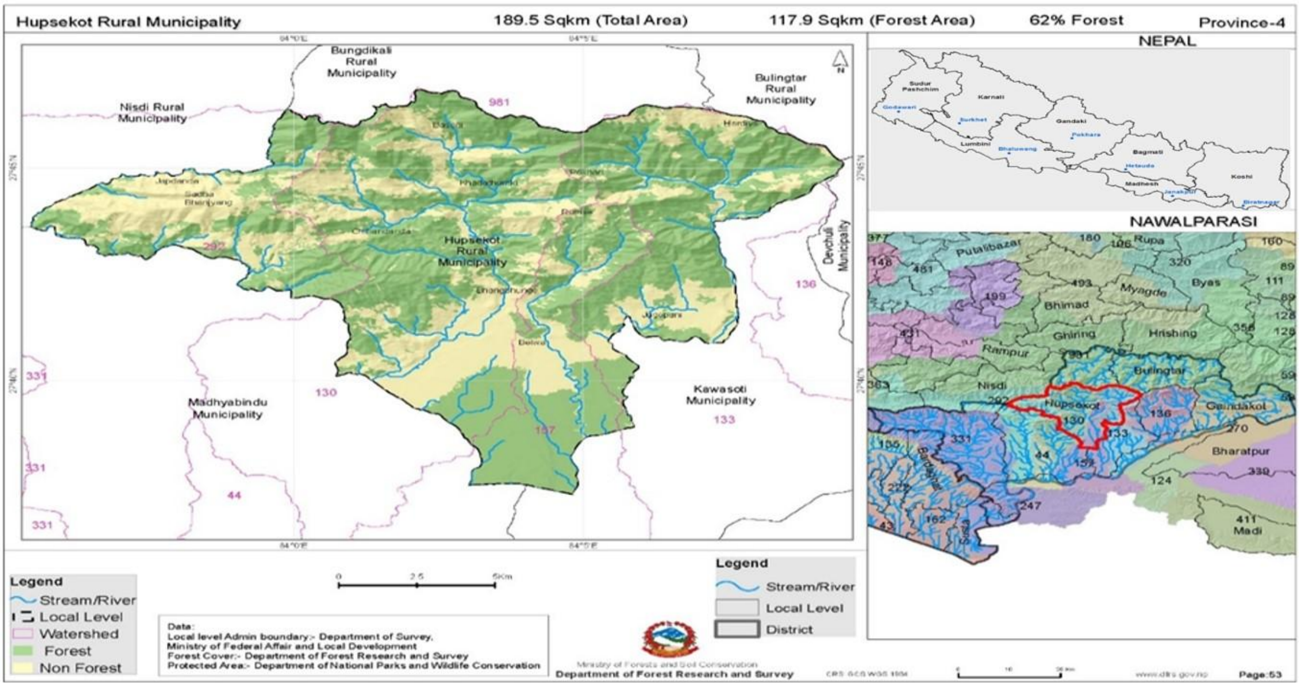

Figure 1: Map of Hupsekot Rural Municipality [24]

2.1 Methods

The research employs a case study design with a mixed strategy that integrates both qualitative and quantitative approaches, utilizing diverse research methods to achieve comprehensive insights.

2.1.1Field Observation

In this research, frequent on-site visits were made to thoroughly examine and gather observed data from the project sites.

2.1.2 Questionnaire Survey / In depth interview

A set of well-planned and relatively important questions have been prepared, printed and distributed to respondents and collected back or self-survey with questionnaire was performed. Probability sampling was applied where firstly sample size was determined and followed by stratified random sampling. The total number of beneficiaries from the system (population size) for sampling are 3724 numbers. The sample size is conducted from following formula [25].

$$n = \frac{NZ^2 * p * (1 - p)}{Nd^2 + z^2 * p(1 - p)}$$

Here,

n= sample size

N= total number of households (population size)

Z=Confidence level (at 94% level, Z=1.88)

p= estimated population proportion (0.5)

d= error limit of 6% (0.06)

A sample size of 230 households was selected, followed by proportionate stratified random sampling to determine the strata sampling size. The entire population is divided into 8 DMAs (district-metered areas). The sampling size of each DMA was obtained from the above formula. The number of households from each DMA is presented in Table 2.

Table 2: Number of households adopted for survey

DMA	Stratum Size	Strata Sample Size	Adopted
1	65	4.01	4
2	405	25.013	25
3	855	52.8	53
4	611	37.73	38
5	553	34.15	34
6	625	38.60	38
7	545	33.66	34
8	65	4.01	4
		Total	**230**

2.1.3 Focus Group Discussion

The open-ended and closed-ended questionnaires were discussed in this process. Only the interested respondents or stakeholders involved in the project were included in the discussion.

2.2 Sustainability Framework

The sustainability framework, including various factors obtained from literature review and from the consultation of expert, which has been implemented for understanding the sustainability of water supply system shown in Figure 2.

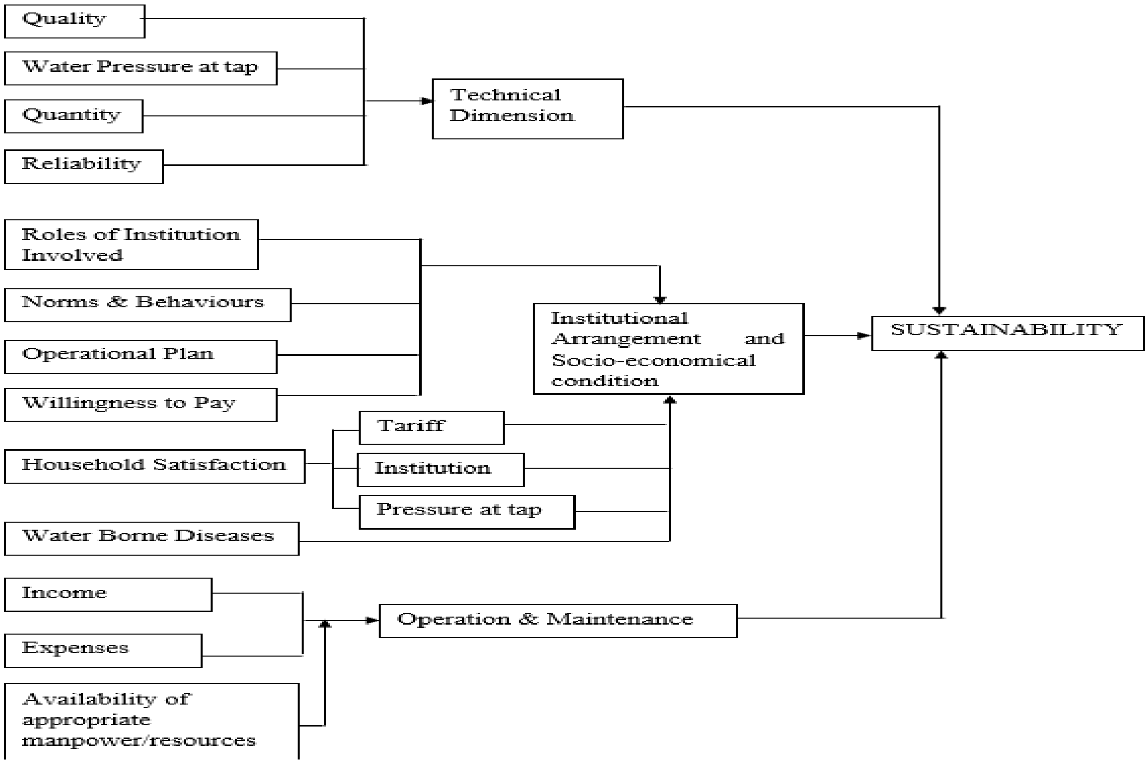

Figure 2: Sustainability Framework of the Research [17],[18],[20],[23]

2.3 Data Collection Method

The ways of different methods of data collection with respect to the sub-factors of the sustainability assessment were summarized in Table 3.

Table 3: Method of Data Collection

Factors	Sub-Factors	Data Collection Method
Technical Dimensions	Quality	WM;LT
	Water Pressure at Tap	HS;O
	Quantity	HS;SD;O
	Reliability	HS;FGD;SSI;O
Institutional Arrangement and Socio-economical condition	Roles of Institution involved	FGD;SD
	Norms and Behaviour	FGD;O
	Operational Plan	SSI;FG
	Willingness to Pay	HS
	Household Satisfaction	HS
	Water Borne Diseases	HS;FGD
Operation and Maintenance	Income	SD;FGD;SSI
	Expenses	FGD;SSI
	Availability of Appropriate Manpower	FGD;SSI;O

Note: W_f : Weight of Factors; W_s : Weight of Sub-Factors; WM: Water Monitoring; LT: Laboratory Testing; HS: Household Survey; O: Observation; FGD: Focus Group Discussion; SD: Secondary Data; SSI: Semi-Structured Interview.

2.4 Method of data analysis

After the data collection through focus group discussion, questionnaires, water quality tests, they were analysed through relevant statistical techniques of Ms-Excel. Both quantitative and qualitative data provide information to assess the level of compliance with each of the sub-factor that consisted of a five-point scale: fully met (5); met to a high degree (4); met acceptably (3); met to a low degree (2); and not met (1) corresponding to the level of hierarchy rated as scale of excellent (80-100%), good (60-79%), satisfactory (40-59%), fair (20-39%) and poor (<20%) respectively (Domínguez et al., 2019). On the basis of the evaluation of the sub-factors, rating is provided with respect to the given five-point scale. Followingly based on the weights of the factors and sub-factors obtained from pairwise comparison from AHP are multiplied with the respective ratings for sub-factors, total score is obtained for the water supply system that indicates its sustainability.

3. Results and Discussions

Weighing of factors and sub-factors: To determine the weights for the factors and sub-factors, the Analytical Hierarchy Process (AHP) was used. The weights of the different factors (W_f) and sub-factors (W_s) were established following the stages and procedures as recommended by Saaty, 1994 [26]. The factors and sub-factors identified to assess the sustainability of the water supply system with their corresponding weights and data collection methods were summarized in Table 4.

Table 4: Weightage of factors and sub-factors

Factors	W_f	Sub-Factors	W_s	Data Collection Method
Technical Dimensions	0.54	Quality	0.28	WM;LT
		Water Pressure at Tap	0.06	HS;O
		Quantity	0.52	HS;SD;O
		Reliability	0.15	HS;FGD;SSI;O
Institutional Arrangement and Socio-economical condition	0.16	Roles of Institution involved	0.24	FGD;SD
		Norms and Behaviour	0.15	FGD;O
		Operational Plan	0.42	SSI;FG
		Willingness to Pay	0.04	HS
		Household Satisfaction	0.05	HS
		Water Borne Diseases	0.09	HS;FGD
Operation and Maintenance	0.30	Income	0.52	SD;FGD;SSI
		Expenses	0.33	FGD;SSI
		Availability of Appropriate Manpower	0.14	FGD;SSI;O

3.1 Technical Dimension

3.1.1 Quality

The sample of drinking water was collected from 8 DMAs in the town. It was then taken to the water quality testing laboratory in Bharatpur, Chitwan. After the report arrived, it was compared with the National Drinking Water Quality Standard, 2079 of Nepal, and found that the value of the parameters was within the limits. Hence, the quality of drinking water in the system is satisfactory. The test results of the water obtained from the laboratory testing of water from 8 DMAs were shown in Table 5. The weighted arithmetic water quality index as shown in appendix Table A1, the result presents the good status of the quality of water on comparing the value of WQI with the classification of water [27].

Table 5: Water quality test reports of 8 DMAs

Category	Parameters	Obtained results from laboratory testing of water							
		DMA 1	**DMA 2**	**DMA 3**	**DMA 4**	**DMA 5**	**DMA 6**	**DMA 7**	**DMA 8**
Physical	Turbidity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Ph	7.97	7.95	7.9	7.82	7.8	7.97	7.88	7.75
	TDS	192	193	182	193	190	171	184	192
	Electrical Conductivity	287	289	274	289	288	257	277	287
Chemical	Iron	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Manganese	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Arsenic	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Ammonia	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Nitrate	4.5	4.3	3.6	4	4	3.5	4	4.5
	Total Hardness	110	108	102	112	108	86	92	110
	Calcium Hardness	46	45	52	49	47	40	50	46
Micro-biological	Faecal coliform E.coli	0	0	3	0	1	2	0	4

(Source: Field Study, 2023)

3.1.2 Water Pressure at Tap

A survey was done to find out if the water pressure at their domestic tap would exceed 5 meters positive head or not. The number of households showing residual pressure of water exceeding 5m head were shown in Figure 3. Result found was 92.17% of house connections have more than 5 m of positive head residual pressure of water, which is satisfactory with respect to the design of the system.

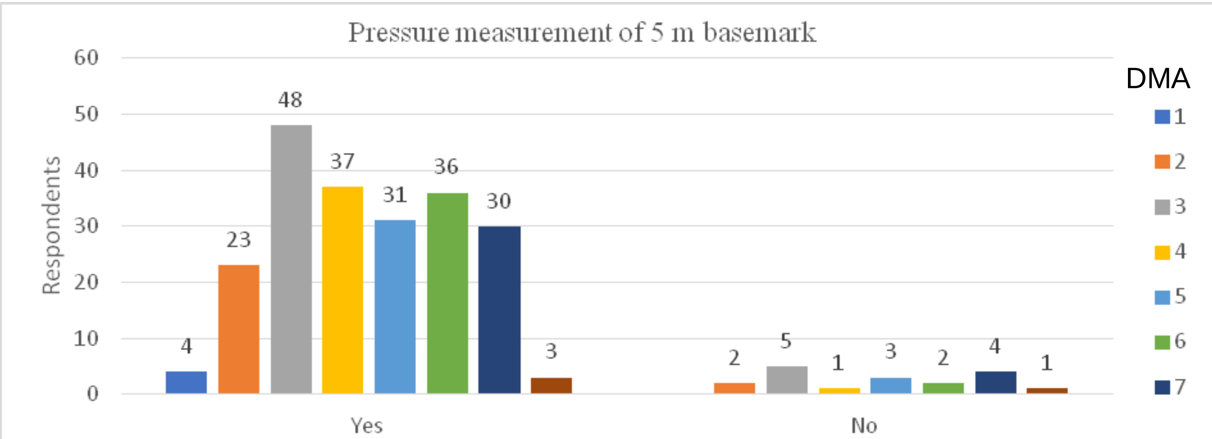

Figure 3: Number of households showing residual pressure of water exceeding 5meters head (Field Study, 2023)

3.1.3 Quantity

According to the 2019 Department of Water Supply and Sewerage Management, the maximum and minimum requirements for water are 100 lpcd and 45 lpcd, respectively. From the survey of the design team of the project, the recent population of the service area is 22786, which enumerate that their maximum demand for water with 100 lpcd is 2278600 litres per day, and in a month, it is 68358000 litres. From the report, it represents that the supply of water is sufficient to fulfil the demand of the users, as shown in Table 6.

Table 6: Supply of treated water to the consumer

Month	Monthly Production of Treated Water (litres)	Monthly Supplied Water Total of Bulk Meter (Litres)	Monthly Supplied Water total from Domestic Water Meter (Litres)	Monthly Loss of Water in Production (Litres)	Monthly Loss of Water in Distribution (Litres)
Jan-Feb	76404800	64019300	32600000	12385500	31419300
Feb-Mar	83914020	64133930	32671000	19780090	31462930
Mar-Apr	65052220	64199600	37040000	852620	27159600
Apr-May	75088470	71468820	41576000	3619650	29892820

(Source: Field Study, 2023)

From the data, production on average is 7,51,14,877.5 litres, and consumption on average is 3,59,71,750 litres in a month. Treated water production is higher than demand. Hence, treated water is washed away through the RVT overflow. Similarly, the waste water at the distribution line was caused by losses from the washout during maintenance and leakage from the joint, which was not immediately repaired by the maintenance team. Therefore, it is seen that the water supplied in the present has met the demand of the population.

3.1.4 Reliability

From the household survey, 164 respondents were confident about the reliability of the system and that it will run successfully for 20 years without any major disruptions or breakdowns, which is the design period of the water supply system. And 211 respondents were satisfied with the adequacy of the availability of water in their household territory. The responses shown in Figure 4 show that the water supply system is in very good condition in terms of its reliability.

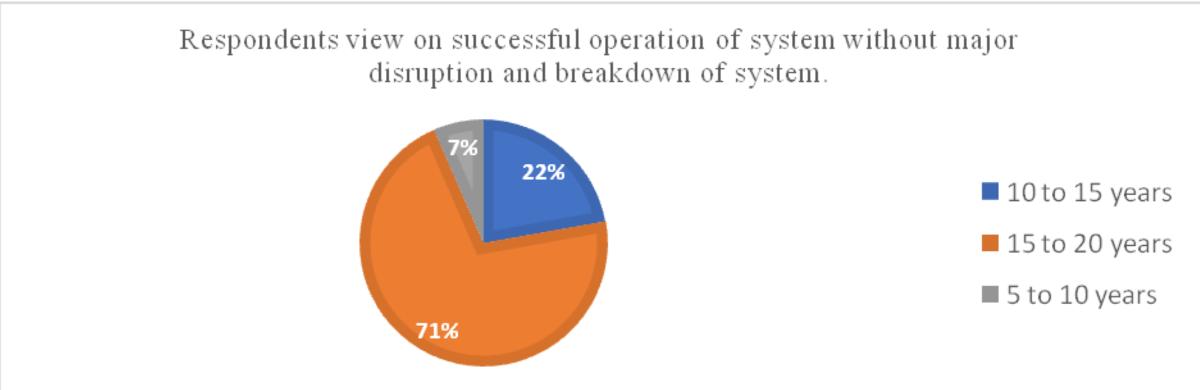

Figure 4: Respondents view on reliability of the project

3.2 Institutional arrangement and socio-economic condition

3.2.1 Roles of institutional involved

From the focused group discussion with the nine chairpersons of the user's committee, the following responses to the questionnaire were obtained: (i) The grievances of the consumers regarding the maintenance of the water supply system will be resolved as soon as possible. But there is no provision for a complaint and response book; all those complaints are reported either orally or in an application submitted by the afflicted. (ii) The Nepal government had provided technical staff with SCADA system training and financially supported the construction of the system, aided by local and town development funds. The financial contribution of the construction of water supply system shown in Table 7.

Table 7: Financial contribution of the construction of water supply system is as follows

Agency	Amount with VAT (NRs)	Amount (USD)
Water Supply Component		
ADB/ GoN Grant (70%)	561,778,083.00	4251063.814
Loan from TDF (25%)	200,635,029.7	1518237.077
WUSC Upfront Cash (5%)	40,127,005.93	303647.4153
Total	802,540,118.6	6072948.306
Sanitation Component		
GON (85%)	9,888,344.26	74826.66863
Municipality (15%)	1,745,001.92	13204.70617
Total	11,633,346.19	88031.37488
Grand Total	814,173,464.8	6160979.681

(Source: Annual Report Deurali-Hupsekot UWSSP, 2079)

Note: From the loan schedule report of TDF dated 2023/06/12, the closing amount is NRs 222,534,236.65.

Norms & Behaviour

From the focused group discussion with the nine chairpersons of the user's committee in an organization, the following responses to the questionnaire were obtained:

(i) Monthly management meetings are held regularly among committee members to address any system-related issues.

(ii) Major decisions for the system are made during the annual general committee meeting, while some other decisions are reached in the presence of the counselor during working committee meetings.

(iii) During observation, most working committee members were dedicated to their roles, although a few had other household commitments, limiting their full-time commitment to the committee.

(iv) Though the documentation process is done manually and computerized, not all the required data for research was obtained with a quick response from the staff members, which that the documentation is not well managed.

3.2.2 Operational Plan

The Water Supply and Sanitation User's Committee is planning to prepare the operation and maintenance manual and is recently in the preparation phase of the manual. The researcher is provided with a draft of the operation and maintenance manual. Since there is a lack of O&M manuals, there is a problem of some interruption in the regular supply of water, which leads to system breakage and delays in repair and maintenance.

3.2.3 Willingness to pay

From the household survey conducted by the researcher, among the 230 respondents, 180 had no issue with the tariff rate and were willing to pay the tariff according to the prevailing rate, but 33 respondents were not satisfied with the prevailing tariff rate and were not willing to pay. Also, 17 respondents were quite unhappy with the rate and asked for an amendment to the tariff rate. It is seen that 78.26% of the people were willing to pay the water tariff, and 21.74% of the respondents were not willing to pay the tariff or appeal for the amendment of the tariff rate, saying that it is too expensive and they have not much capacity to pay such an expensive bill amount. The detailed presentation of data showing willingness to pay obtained from the household survey is shown in Figure 5.

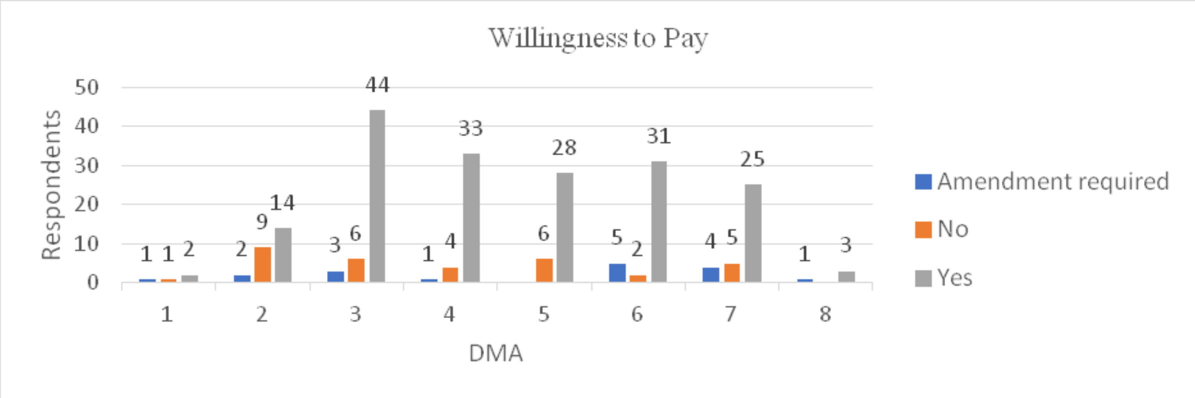

Figure 5: Number of households willing to pay the tariff of the water supply according to DMAs, Bar Graph (HS & Analysis, 2023)

3.2.4 Household satisfaction

A household survey was conducted to assess consumer satisfaction in three areas (HS & Analysis, 2023): tariff rates (Figure 6), organizational committee activities (Figure 7), and water pressure from the supply system (Figure 8). In relation to the tariff rate, out of 230 respondents, 181 were satisfied with the household water tariff (Figure 6), while 49 respondents were dissatisfied. Regarding the organization committee, the survey revealed that 194 out of 230 respondents expressed satisfaction with its activities (Figure 7), while 36 respondents were not satisfied. As for water pressure at the tap, 221 out of 230 respondents were satisfied with the water pressure from the supply system (Figure 8), while 9 respondents were not entirely satisfied.

In summary, the survey findings indicate that 84.35% of respondents were satisfied with the organization committee, 96.08% were content with the water pressure at their taps, and 78.70% were satisfied with the tariff rates for household water.

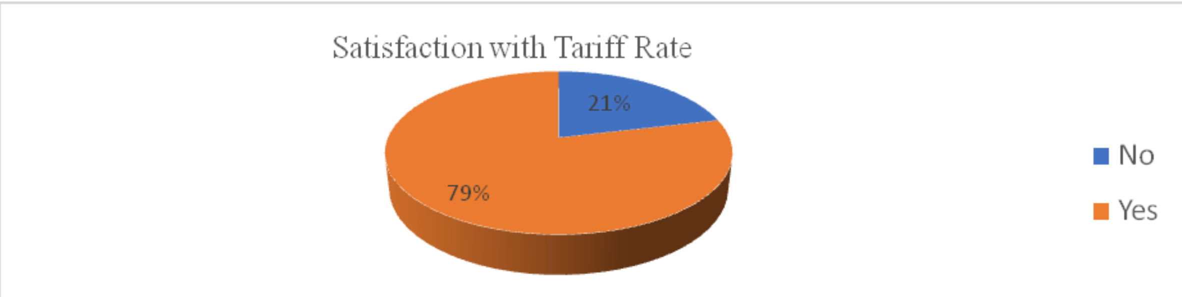

Figure 6: Satisfaction level with respect to tariff rate of water supply system

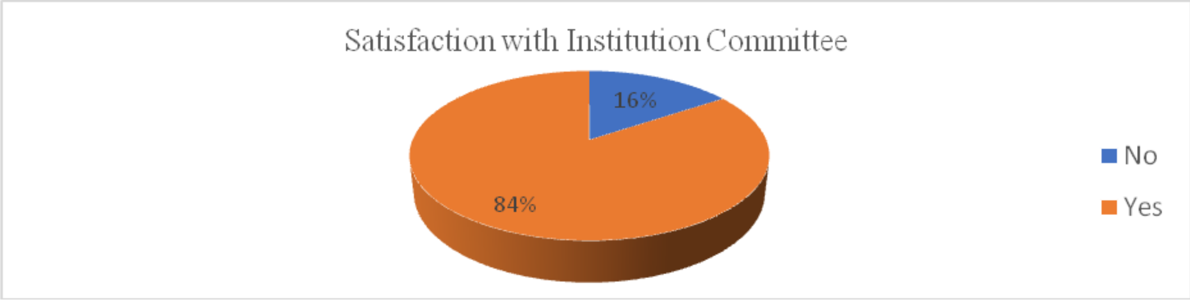

Figure 7: Satisfaction level of water user's with respect to institution committee

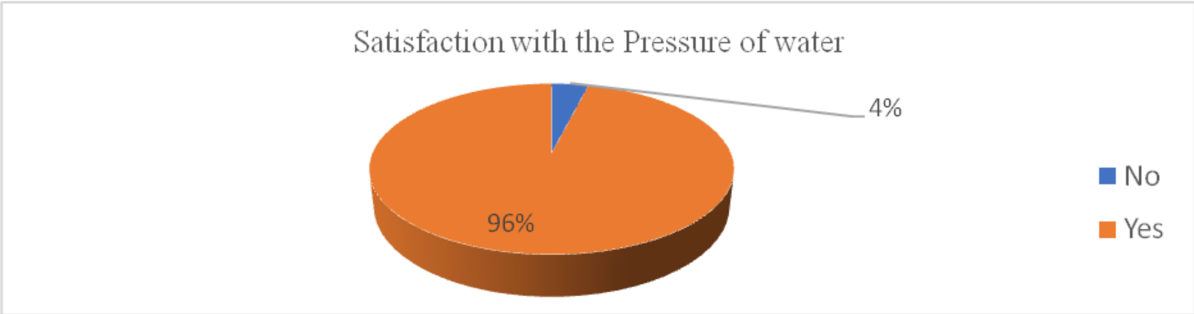

Figure 8: Satisfaction level of water user's with respect to water pressure at their tap

3.2.5 Water borne diseases

From a household survey of 230 households and discussion with the nine committee members of the water supply system, it was found that there were no cases of waterborne diseases raised yet due to the supply of water from the prevailing water supply system. Figure 9 illustrates the number of people suffering from water-borne diseases from the consumption of water, according to DMAs. None of the respondents have said that they got ill by drinking the water supplied by the system. Hence, the number of cases of waterborne diseases in the town due to this water supply system is 0%.

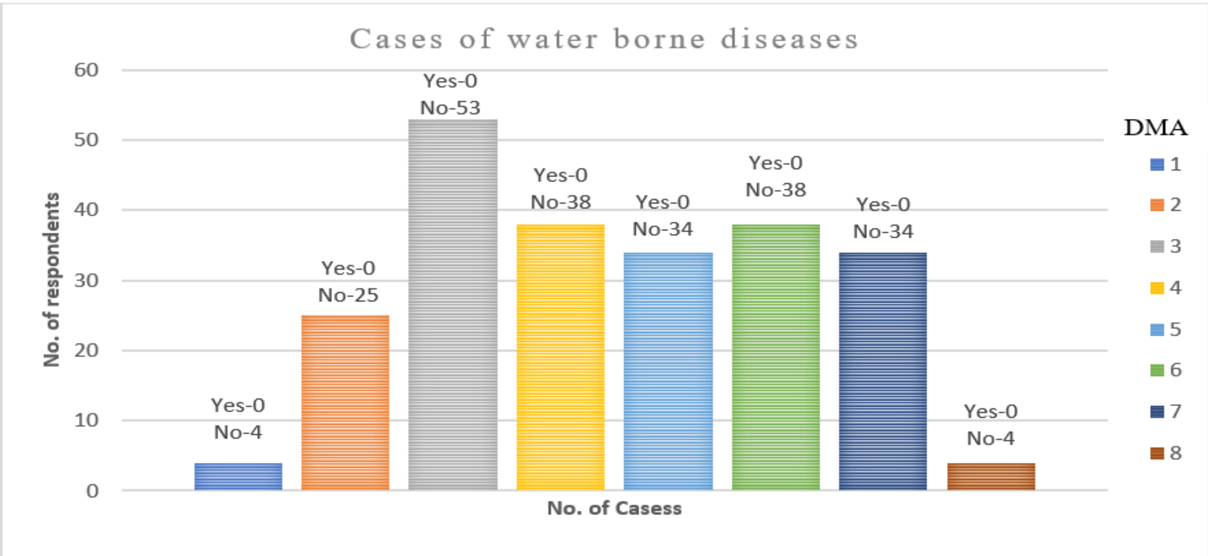

Figure 9: Number of cases of water borne diseases by supplied water from the system (Field Study, 2023)

3.3 Operation and Maintenance

3.3.1 Income

The source of income for the organization is only the tariff collected from the consumers of the water from the system, and they have not yet invested any sum that can provide a return to the organization as an income. From the agreement between WUSC and TDF on February 23, 2077, the monthly tariff rate was determined (Table 8).

Table 8: Tariff rate of Deurali-Hupsekot UWSSP (Annual Report Deurali Hupsekot UWSSP, 2079)

Units	Nepali Rupees	Remarks
0-6 units	min 150	-1 unit = 1000 litres of water -Payment within 7 days of meter reading will be given 5% discount. Within 30 days, payment as reading. Within 60 days, 10% extra fine. Within 90 days, 20% fine and 91 days onwards 30% fine.
6 - 10 units	30/unit	
11 - 15 units	45/unit	
16-25 units	65/unit	
>25 units	80/unit	

Through focus group discussions with nine committee members and semi-structured interviews with staff, it was discovered that the income from consumer tariff collections between January 2023 and May 2023 ranged from 70% to 80% of the total monthly tariff. This collection exhibited an increasing trend in those months. The organization's average monthly income over a four-month period was 8690.28 USD, and the collection of tariffs during this research period in relation to the generated amount on domestic meters is illustrated in Appendix Figure A1.

3.3.2 Expenses

From the focal group discussion with the nine committee members and the semi-structured interview with the manager and sub-engineer of the organization, various types of expenses were introduced, were summarized in Table 9.

Table 9: Types of expenses introduced in Deurali-Hupsekot UWSSP)

SN	Type of Expenses	Amounts (NRs) per month	Amount (USD)
1	Administrative expenses	200000-250000	1513.432-1891.79
2	Electricity	4000-6000	30.26-45.40
3	Telephone & Internet	12000-15000	90.80-113.50
4	Fuel & Vehicle maintenances	15000-20000	113.50-151.34
5	Chemical & Maintenance	30000-35000	227.01-264.85
6	Others / miscellaneous	20000-30000	151.34-227.01

On average, the total expenses of the organization in a month are 2,410.14 USD. The loan amount that was borrowed from the Town Development Fund for the construction of the Deurali-Hupsekot Urban Water Supply and Sanitation Project is 1,683,951.84 USD. According to their contract, the organization should pay 42,444.81 USD as interest in every 6-months' time period till date 2081/10/02, which shows that their monthly amount to repay interest is 7,074.13 USD. After the mentioned date, the organization must pay back 67,082.3 USD, including principal and interest, every 6 months' time period, according to the loan amortization schedule. Therefore, they will need to collect revenue of at least 11,180.38 USD from October 2, 2081, onward to meet this payment obligation. Hence, it is seen that the total expenses, including the payment of interest and expenses, of an organization in a month are 9,484.27 USD, as shown in Figure 10 and Figure 11 respectively.

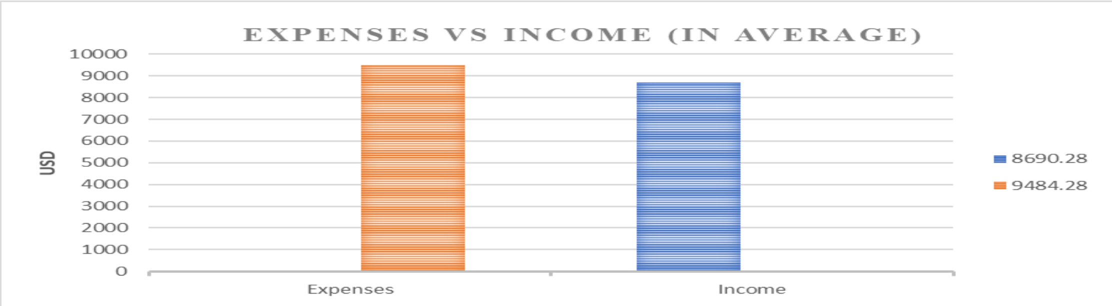

Figure 10: Total income vs total expenses of the organization (Field Study, 2023)

Figure 11: Total Income vs Total Expenses on last study month (Field Study, 2023)

3.3.3 Availability of Sufficient Manpower / resources

According to the project management and operation agreement in 2077 B.S. between the Deurali-Hupsekot Urban Water Supply and Sanitation User's Committee, the Hupsekot Rural Municipality, the Town Development Fund, and the Nepal Government, there is mentioned the required number of employees that the consumer's organization is required to appoint for the operation and maintenance of the water supply system. The availability of employees in this organization for operation and maintenance in comparison with the required number of employees according to agreement were shown in Table 10.

Table 10: Availability of human resources in an organization (Field Study, 2023)

According to Agreement		**Availability in Organisation**	
Employee Detail	**Required Nos**	**Employee Detail**	**Nos**
Operations and Maintenance Engineer / Manager	1	Manager	1
Sub- Engineer	1	Sub-Engineer	1
Accountant	1	Accountant	1
Plumbing Technician	1	Plumbing Foreman/System Operator	6
Lab Technician	1	Watchman	2
Water Treatment Plant Operator	1	Store Keeper	1
Meter Reader	2	Meter Reader	2
		Driver	1

Also, the organization has sufficient availability of the resources required for the maintenance of the water supply system and was able to solve the minor breakage of the pipeline system with that equipment in a short time. In case of the unavailability of any equipment or resources for maintenance, they have easy access to the market so that necessary items can be bought easily or specific resources can be hired within one or two days. Some of the resources within the premises of the organization are shown in Appendix Table A2 and A3 respectively.

Sustainability rating of the case study in terms of technical dimension, Institutional Arrangement and Socio-economical condition and Operation and Maintenance were shown in Tables 11, 12 and 13 respectively. The overall sustainability score of the project were shown in Table 14. Hence, the total sustainability score of the work is 3.99848 out of 5 through the analysis of the judgment value of the sub-factors. The overall Sustainability score of the project were shown in Table 14.

Table 11: Sustainability rating on technical dimension of the study

Sub-Factor	**Weight (W_s)**	**Qualitative Value Judgemental**	**Data Collection Method**	**Behaviour in the study**	**Score (S)**	**W_s * S**
Quality	0.28	The value of the parameters as provided by NDWQS, 2079 BS and WQI.	WM; LT	On comparing the WQI with water quality status gives good condition of water.	4	1.126
Water Pressure at Tap	0.06	The residual pressure of water of atleast 5 m positive head at main points of house connections	HS; O	From HS, 92.17% of connections met with the judgemental value.	5	0.289
Quantity	0.52	Does the water supply meet the demand of the consumers?	HS; SD; O	The system supplies enough water to meet user demand, as indicated in the report. User satisfaction with the provided water quantity is also evident in HS.	5	2.576
Reliability	0.15	Adequacy, and successful operation of system without major breakage & disruptions within the design period.	HS; FGD; SSI; O	Very good responses from the respondents and is acceptable in terms of reliability.	4	0.582
					Sub-Total (∑Ws * S) =	4.57

(Field Study, 2023)

Table 12: Sustainability rating on institutional arrangement and socio-economical condition of the study

Sub-Factor	**Weight (W_s)**	**Qualitative Value Judgemental**	**Data Collection Method**	**Behaviour in the study**	**Score (S)**	**Ws * S**
Roles of Institution involved	0.24	Responses to the users, Training and external support, co-ordination & linkage.	FGD; SD	Slow consumer response and the absence of complaint boxes are issues. Training is provided to technical staff, and financial support is mainly allocated for project construction.	3	0.728
Norms and Behaviour	0.15	Functioning & meeting, Decision making, Ownership & activities, Documentation	FGD; O	The norms and behaviour of the organisation have met to a high degree as all the judgemental value is met except, they were unable to provide required documents in short time.	4	0.59
Operational Plan	0.42	Availability of operation and maintenance plan to run the system	SSI; FGD	Only draft of O&M manual is available and not proper implementation of even the draft manual. So, the value met to a low degree of satisfaction on the operation plan of the system.	2	0.843
Willingness to Pay	0.04	If the consumers are willing to pay the tariff in accordance with the prevailing tariff rate of consumed water	HS	From HS, 78.26% of respondents were willing to pay the prevailing rate which is a good response and met to high degree of judgemental value.	4	0.174
Household Satisfaction	0.05	Satisfaction level of consumers regarding the tariff, institution and pressure at tap	HS	From HS, more than 80% of respondents were satisfied regarding tariff, institution and pressure at tap. So, the judgemental value is fully met.	5	0.26
Water Borne Diseases	0.09	Any cases of waterborne diseases on consumer due to consumption of water from the system	HS; FGD	From HS and FGD it is seen that there were no any cases of water borne diseases neither on and survey respondents nor in system user. Hence, it is an excellent part of the system.	5	0.465
				Sub-Total (∑Ws * S) =		3.0597

(Field Study, 2023)

Table 13: Sustainability rating on the operation and maintenance of the organization

Sub-Factor	**Weight (W_s)**	**Qualitative Value Judgemental**	**Data Collection Method**	**Behaviour in the study**	**Score (S)**	**W_s * S**
Income	0.52	The total collection of tariffs out of the consumed units generated on the domestic water meter.	SD; FGD; SSI	It is seen that the total collection is 78.24% of the generated amount which met to high degree of judgemental value.	4	2.099
Expenses	0.33	Does the total income meet the overall expenses of the organization and office of the water supply system?	FGD; SSI	In the present scenario the income does not met the expenses of an organization but looking at the increasing trend of income it seems that the income will be enough to meet the expenses of the organization.	2	0.668
Availability of Sufficient Manpower/ resources	0.14	Availability of appropriate manpower required for the operation of the water supply system.	FGD; SSI; O	From the research it is seen that the organization have sufficient manpower and resources required for the operation and maintenance of the system.	5	0.708
					Sub-Total (∑Ws * S) =	3.474

(Field Study, 2023)

Table 14: Overall Sustainability Score of the Project

Factors	**W_f**	**Sub-Factors**	**Sub-Total**	**Data Collection Method**	**W_f * Sub-Total**
Technical Dimensions	0.54	Quality	4.573	WM;LT	2.46467
		Water Pressure at Tap		HS;O	
		Quantity		HS;SD;O	
		Reliability		HS;FG;SSI;O	
Institutional Arrangement and Socio-economical condition	0.16	Roles of Institution involved	3.060	FG;SD	0.50113
		Norms and Behaviour		FG;O	
		Operational Plan		SSI;FG	
		Willingness to Pay		HS	
		Household Satisfaction		HS	
		Water Borne Diseases		HS;O	
Operation and Maintenance	0.30	Income	3.474	SD;FG;SSI	1.03268
		Expenses		FG;SSI	
		Availability of Appropriate Manpower/resources		FG;SSI;O	
				Sustainability Score =	3.99848

(Field Study, 2023)

4. Conclusions and Recommendations

The technical evaluation of the water supply and sanitation project illustrates a strong sustainability rate of 91.46%. It excels at delivering high-quality water, meeting demand reliably, and promptly addressing minor issues, ensuring a satisfactory user experience. However, the evaluation of institutional arrangements and socio-economic conditions yields a moderate sustainability rate of 61.19%. Challenges in consumer responsiveness, institutional coordination, and community ownership need swift action for improved sustainability. Willingness to pay for water services remains crucial, but users can afford access to clean water, leading to satisfaction. The evaluation of operation and maintenance reveals a promising sustainability rate of 69.48%. The project generates income with the potential for future financial sustainability and has a well-equipped workforce. In summary, the Deurali-Hupsekot water supply and sanitation project has an overall sustainability rating of 79.96%, highlighting strengths and areas for future improvement. The research on the sustainability of a water supply and sanitation project yields several recommendations for improvement. These include regular testing of water quality, particularly focusing on microbiological assessments, improving water pressure management to ensure consistent flow, planning for future water demand and infrastructure upgrades, strengthening coordination among institutions for better governance, and enhancing operational plans by incorporating community needs and feedback.

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Conflicts of Interest Statement

The author declares no any conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix A1

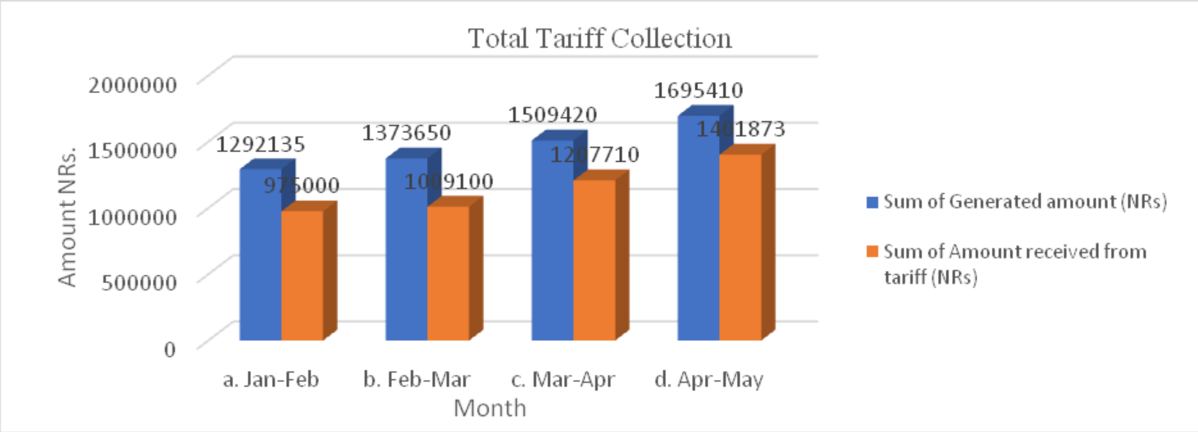

Figure A1: Collection of tariffs from the consumer vs amount generated (Tariff report: Deurali-Hupsekot UWSSP)

Table A1: Calculation of water quality index

Parameter	**NDWQS, 2079 (Sn)**	**$1/S_n$**	**$K=1/\sum(1/S_n)$**	**Wi = K/Sn**	**Ideal Value (V_o)**	**Mean concentration value (V_n)**	**$(V_n-V_o)/(Sn-V_o)$**	**$Q_n=(V_n/S_n)*100$**	**W_n * Qn**
Turbidity	5.0	0.20	0.033	0.01	0.0	0.20	0.04	4.00	0.03
pH	7.5	0.13	0.033	0.00	7.0	7.88	1.76	176.00	0.78
TDS	1000	0.00	0.033	0.00	0.0	187.13	0.19	18.71	0.00
Electrical Conductivity	1500	0.00	0.033	0.00	0.0	281.00	0.19	18.73	0.00
Iron	0.30	3.33	0.033	0.11	0.0	0.20	0.67	66.67	7.37
Manganese	0.20	5.00	0.033	0.17	0.0	0.10	0.50	50.00	8.29
Arsenic	0.10	20.00	0.033	0.66	0.0	0.01	0.10	10.00	6.63
Ammonia	1.50	0.67	0.033	0.02	0.0	0.10	0.07	6.67	0.15
Nitrate	50.0	0.02	0.033	0.00	0.0	4.05	0.08	8.10	0.01
Total Hardness	500	0.00	0.033	0.00	0.0	103.50	0.21	20.70	0.00
Calcium Hardness	200	0.01	0.033	0.00	0.0	46.88	0.23	23.44	0.00
Faecal coliform E.coli	1.3	0.80	0.033	0.03	0.0	1.25	1.00	100.00	2.65
	$\sum(1/Sn)$	30.16		1.00					25.9

Table A2: Equipment and Tools available for maintenance of the water supply system.

S.N.	Descriptions	Unit	Nos.
A	**Electrofusion Welding Machine and Accessories**		
1	Welding unit KWS-500, 230V	Set	1
2	Hand Scraper - 2 ½" Blade	Set	2
3	Eclipse Saw 63 mm-315mm	Set	2
4	Ratchet Cutter (Pipe Shear) Size:0-63mm	Set	2
5	Multi Alignment 2 Way, KT04-2340 Sizes 63,75,90,110,140 mm	Set	2
6	Top Loading Clamp D63-315	Set	2
7	Saddle Clamp. Strap Style-AT07-0040 Size 63 to 500mm	Set	2
8	Drilling tool for cutting hole in electrofusion tapping saddle 1/2',3/4"& 1" dia	Set	2
9	Generator -petrol operated - 5 KVA	Set	1
B	**Other Tools**		
1	Adjustable Wrench - 8"	Nos.	2
2	Adjustable Wrench - 10"	Nos.	1
3	Monkey Pliers - 10"	Nos.	2
4	Pipe Wrench - 14"	Nos.	2
5	Pipe Wrench - 18"	Nos.	2
6	Pipe Wrench - 24"	Nos.	2
7	Pipe Wrench - 36"	Nos.	2
8	Chain Pipe Wrench - 4"	Nos.	1
9	Chain Pipe Wrench - 6"	Nos.	2
10	Screw Driver	Set	2
11	Ball Pan Hammer - ½ Kg	Nos.	2
12	Ball Pan Hammer - 1 Kg	Nos.	2
13	Ratchet Die ½" - 2"	Nos.	2
14	Hacksaw frame with 24 number extra blades.	Set	2
15	Pick	Nos.	5
16	Shovel	Nos.	8
17	Tractor with carrier	Nos.	1
18	4WD pickup vehicle	Nos.	1

Table A3. Apparatus or Equipments required for laboratory testing of water (Field Study, 2023)

S.N.	Apparatus or equipments	Unit	Nos.
1	pH meter	Nos	1
2	Thermometer for water temperature measuring	Nos	1
3	Turbidity meter	Nos	1
4	Jar test set	Set	1
5	Ammonia comparison desk	Nos	1
6	Iron test set	Set	1
7	Electric Conductivity Test meter	Nos	1
8	Free Residual Chlorine test set	Set	1
9	Weighing machine for chemical dosing 20kg,10kg,5kg	Nos	1