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Assessment of the Water, Sanitation, and Hygiene(WASH) situation and identifying the implementation challenges of the water surveillance system in Dhulikhel Municipality

Safal Jung Thapa

safaljung717@student.kusms.edu.np

Kathmandu University School of Medical Science https://orcid.org/0009-0008-9233-0993

Biraj Man Karmacharya

Kathmandu University School of Medical Science

Bandana Paneru

Kathmandu University School of Medical Science

Yunika Acharya

Kathmandu University School of Medical Science

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Abstract

Background: Diarrheal diseases remain a significant public health concern, especially in U5 children, with inadequate Water, Sanitation, and Hygiene (WASH) practices contributing heavily to the disease burden. This study aimed to assess the household WASH situation with at least 1 U5 child in Dhulikhel Municipality and evaluate the barriers and facilitators of implementing a water surveillance system. Objectives included determining household U5 diarrhea prevalence, assessing caregiver WASH knowledge and practices, and identifying key barriers and facilitators for effective water surveillance.

Methodology : A cross-sectional study was conducted among 250 households with 308 U5 children in the (3-8) ward of Dhulikhel Municipality. Data were collected using "Core questions on drinking water and sanitation for household surveys" developed by the WHO and UNICEF to assess the household prevalence of diarrhea cases among children. Statistical tools (STATA 18.5) assessed WASH Knowledge practices and their association with U5 diarrhea prevalence.

Semi-structured interviews with 16 stakeholders and focus group discussions with water consumer groups explored potential barriers and facilitators of the water surveillance system. Data were analyzed using the CFIR framework to identify recurring themes.

Findings : Diarrhea prevalence among U5 children was 14.8%, exceeding national averages. Despite high awareness of practices like handwashing (96.8%) and water treatment (80%), gaps in consistent application remained. Socio-demographic factors influenced WASH practices, but no significant association with diarrhea prevalence was observed.

Barriers included low public awareness, cultural misconceptions, role ambiguity, authority unaccountability, perceived complexity, resource constraints, and political instability. Facilitators encompassed community training, technological innovations, effective leadership, partnership, and stakeholder collaboration. Advanced tools improved data accuracy, while partnerships with NGOs enhanced resource mobilization for an improved surveillance system.

Conclusion : Increasing WASH outcomes and water surveillance in Dhulikhel requires addressing systemic barriers like resource constraints and awareness gaps. Leveraging technology, community ownership, strong governance, and stakeholder collaboration can ensure safer water access, better hygiene practices, and reduced U5 diarrheal disease prevalence.

Background

1.1 Introduction

Diarrheal disease continues to be a major source of morbidity and mortality among U5 children worldwide, accounting for nearly 0.5 million deaths and 1.7 billion cases each year[1]. Over 90% of deaths in LMICs among U5 children result from diarrhea, emphasizing urgent improvements in WASH access[2]. Water surveillance helps monitor drinking water quality and prevent health risks associated with contamination [3]. Enhancing WASH dramatically lowers the number of deaths caused by diarrhea and prevents neglected tropical diseases[4]. Adhering to WHO criteria, a risk-based approach to drinking water prioritizes surveillance parameters depending on the outputs of water safety plans, thereby improving public health safety[5]. The rights to clean water, sanitation, and hygiene are essential for human development and well-being. Their absence brings on diarrhea and impacts millions of children globally[6,7]. To achieve good health, gender equality, poverty reduction, and general socioeconomic advancement, the Sustainable

Development Goals strongly emphasize the importance of water and sanitation[8]. Research in many areas emphasizes the significance of appropriate water sources, sanitation amenities, and hygiene protocols in averting illnesses and advancing communal well-being[9].

The world is facing challenges as a result of pollution-related water shortages[10]. Nearly two-thirds of the world population faces water challenges for at least one month every year [11]. Many nations' drinking water does not adhere to WHO guidelines which account for 80% waterborne disease [12]. 3.1% of deaths are attributable to dirty, low-quality drinking water[13].2.4 billion people are deprived of safely managed drinking water supply [14]. Inadequate WASH facilities contribute to an increased burden of diseases, with 90% of diarrhea-related deaths globally attributed to inadequate access to water and poor sanitation practices[6,15]. Over 2 billion people worldwide lack access to basic sanitation facilities, which makes it easier for illnesses like diarrhea to spread[16]. The majority of the diseases that cause the burden of water, sanitation, and hygiene-related illnesses are preventable, accounting for 5.7% of all diseases and 4.0% of all deaths globally [17].Nearly 110 million people in Southeast Asia are facing water challenges[18]. SEAR, including Bangladesh, India, and Sri Lanka, confronts poor WASH practices, contributing to public health concerns[19]. The prevalence of open defecation is still high in some places due to inadequate sanitation coverage[20]. Pollution and waterborne illnesses persist because of inadequate sanitation system design and upkeep, even in nations with improved sanitation coverage, such as Vietnam, Thailand, and Myanmar[21]. Water, sanitation, and hygiene (WASH) in Nepal face challenges despite being a water-abundant country [22]. WASH access inequalities across social, economic, and gender lines due to inadequate infrastructure, financial constraints, and policy issues, worsened by climate change risks, hinder reliable services [23,24].

Nepal struggles with providing basic water services to a significant population, with over 10 million lacking improved sanitation facilities [25]. Factors such as unhygienic drinking water storage systems and drainage issues have been linked with an increased risk of diarrhea in children in Nepal[26]. Bacterial coliform has been identified as a prime cause of acute diarrhea in U5 Children[27].

Addressing hygiene practices and sanitation conditions is vital in reducing the burden of infectious diseases within communities[28]. Proper water resource management is crucial to stopping waterborne illnesses, particularly infections that cause diarrhea among U5 children.

1.2 Statement of the Problems

The prevalence of poor sanitation and lack of access to quality water has led to a high burden of infectious diseases[29]. Waterborne diseases result in 1.5 million deaths yearly, mainly affecting children in poor households[30]. Over 2 billion people lack access to basic sanitation services globally, which contributes to the spread of diarrhea [31]. Water-related illnesses continue to be a major cause of mortality, particularly for children under five who live in rural parts of poor countries[32]. Urbanization, poor technology, complex institutional frameworks, and the disregard for rural areas in developing nations are some of the reasons why challenges continue[33]. Waterborne illnesses like diarrhea have become more common in SEAR as a result of inadequate water sanitation and hygiene (WASH) standards, especially in nations like Nepal[34,35]. The presence of coliform bacteria in water sources indicates fecal contamination and poses a risk of diarrheal diseases[36]. Subnational disparities continue despite efforts to increase access to WASH services; obstacles include incompatibilities in policy, funding, and technological limitations[37]. The prevalence of diarrheal disease in U5 children has been reported to be around 20.8% in urban regions of Nepal [38]. Natural catastrophes like the earthquake in Nepal can worsen the situation by disrupting the clean water supply and causing

inadequate sanitation, which increases the likelihood of epidemics [39]. Water sanitation and hygiene (WASH) initiatives in Dhulikhel have been crucial due to prevalent waterborne diseases like diarrhea[40]. DDWUC reports a huge gap in supply (2.2 million liters /day) and demand (3.7 million liters/day) of drinking water.

1.3 Rationale of the Study

Preventing waterborne illnesses like diarrhea requires improving WASH[41]. The lack of access to sanitary facilities harms the environment and the lives of billions of people worldwide[42]. Ensuring human health in developing nations requires access to safe drinking water, proper sanitation, and good hygiene[43]. Achieving WASH targets is crucial because poor WASH contributes significantly to major health outcomes, including malnutrition and diarrhoea[44]. Improving access to sanitary facilities and clean water could prevent the average annual deaths of 297,000 U5 children[45]. Nepal faces WASH challenges due to infrastructure, funding, and policy issues, stressing the need for long-term strategies to enhance access and equity[46]. Enhancing sanitation and water quality is crucial because contamination can cause fatal illnesses[47]. Water surveillance protects public health by monitoring drinking water for safety and quality[48] Conducting WASH in Dhulikhel is crucial to tackling water contamination, guaranteeing fair access to WASH facilities for everyone, and advancing sustainable WASH practices in the area.

1.4 Objective of the Study

- To determine the household prevalence of diarrheal disease among U5 children in the Dhuilkhel municipality
- To assess the knowledge and practice regarding WASH among caregivers of U5 children in the Dhulikhel municipality
- To assess the association between diarrheal disease, knowledge and practice among caregivers of U5 children in the Dhulikhel municipality
- To explore barriers and facilitators of the water surveillance system in Dhulikhel municipality

Research Methodology

A multi-method study was conducted in Dhulikhel Municipality from March to mid-June 2024, employing a cross-sectional design at the household level in wards 3–8, which included households with at least one under-five (U5) child. The study aimed to measure diarrheal prevalence and assess the WASH situation at a specific point in time. Dhulikhel was selected due to the ongoing UMD project, the involvement of the Dhulikhel Drinking Water User Committee (DDWUC) in water governance for wards 3–8, and the municipality's inadequate clean water and sanitation, highlighting the need for urgent research and intervention. Eligible households were within wards 3–8, with at least one U5 child and a consenting primary caregiver available for questionnaires, while households with language barriers, caregivers with severe medical or cognitive impairments, or U5 children residing less than two weeks were excluded.

2.1 Sample Size

N = Total number of households with atleast 1 U5 child under our study

p = Prevalence of household U5 children with diarrheal cases

Where, p = 0. 1[49] and q = 1- 0.1 = 0.9

d= allowable error Where d = 4 % or 0.04

Z = 1.96 (At 95% Confidence interval)

Sample size of U5 children under our study (n^1) =(Z^2*p*q)/d^2

Number of U5 children taken to assess the WASH situation in Dhulikhel Municipality (n^1)

= 217

Non-response rate for households with atleast 1 U5 child

= 15% of 217

= 32.6 ≈ 33

Therefore, total number of households with atleast 1 U5 child under our study (N) = 217+33 = 250

2.2 Sampling Techniques

Households in wards 3–8 of Dhulikhel Municipality, where the DDWUC supplies drinking water, were purposively selected. Within these wards, households with at least one (U5) child were conveniently chosen to assess the WASH situation. A list of such households was provided by the the Municipality office, enabling assessment of both WASH conditions and U5 diarrheal prevalence.

2.3 Study Variable

Dependent Variable

Prevalence of U5 diarrheal disease = (Total U5 diarrheal disease at household level / Total U5 children household under study) * 100%

Independent Variable

1. **Socio-demographic and household characteristics**

- Age (in years)
- Sex (Male/Female)
- Level of Education(Primary/Secondary/Tertiary/Vocational)
- Marital Status(Single/Married/Divorce/Widow/Seprate/other)
- Religion(Hindu/Christianity/Islam/Buddhist/other)
- Ethnicity (Brahmin or Chhetri/ Newar /Tamang /other)
- Status of Respondent (Father/Mother/Sibling/Blood relative)
- Occupation(farmer/trader/unemployed/retired/teacher/other)
- Income (daily/monthly/weekly/not regular/not earned)
- Monthly income in Rupees

2. Knowledge & Practice on WASH

- Water
- Sanitation

- Hygiene & practice

Hand washing & latrine use

- WASH Knowledge

2.4 Sampling strategy: Household caregivers with at least 1 U5 child were selected through a purposive form of the water consumer group within the (3–8) ward households in Dhulikhel municipality**.**

2. 5 Data Collection Tools and Techniques:

a. Quantitative Phase

Technique: Face-to-face interview

Tool: Pre-structured questionnaires.

2.6 Pre-testing the Data Collection Tools: The study was conducted among 10% of the total sample size in a non-study area.

2.7 Validity and Reliability of the Study Tools

Validity

- Proper operationalization of the variables and explanation of the research title, objectives, and the tools used.
- Questionnaires were translated into both Nepali and English.
- The WASH questionnaire was adapted from *"**Core questions on drinking-water and sanitation for household surveys***" developed by the WHO & UNICEF[50].
- Sociodemographic questionnaires adopted from the NDHS report 2022.

Reliability

- The questionnaire was checked, and modification of the tools was done as per the requirements after pretesting**.**

2.8 Potential Biases: Data collection timing, social desirability, and potential over- or underrepresentation may affect findings and limit their generalizability to Dhulikhel's entire population.

2.9 Limitation: The study's cross-sectional design limits causal inference, may be affected by recall bias, and only captures a specific time, missing seasonal variations. Multiple U5 children per household and a focus on selected wards may limit generalizability.

2.10 Supervision and Monitoring: The research team held regular reviews, conducted site visits, ensured data quality, analyzed findings, prepared reports, followed ethical protocols, and maintained transparency to achieve project goals effectively.

2.11 Data Management and Analysis:

Quantitative Study

- Socio-demographic characteristics, knowledge, and practices in WASH were analyzed using structured questionnaires.

- Diarrhea prevalence and WASH practice frequency and percentage,
- The WASH Knowledge Score in our study was calculated based on caregivers' responses to structured questionnaire items assessing their knowledge of safe water storage, handwashing, sanitation behaviors, and contamination risks.
- Mean Knowledge Score = (∑Individual Scores/Total number of U5 Caregiver)
- Association between knowledge and practice with diarrhea was assessed using univariate and multivariate logistic regression (reporting unadjusted and adjusted odds ratios, 95% CI, and p-value < 0.05).
- Data were collected, cleaned regularly for consistency, stored separately to maintain confidentiality ensuring anonymity, and data were destroyed after study completion.

2.12 **Expected Outcome of the Research:** WASH assessment ensured the delivery of clean and safe water to communities, safeguarding public health, and reducing the risk of waterborne diseases.

2.13 Ethical Issues and Considerations: The study received ethical approval from Kathmandu University, and participants provided voluntary verbal informed consent; a copy of the consent form is included in the annex.

2. **Qualitative Study**: We were conducting focus group discussions among homogeneous water consumer groups while in-depth interviews were done among key stakeholders.
3. **2.14 Study Unit**

The qualitative study was among Key stakeholders at various levels

- Municipal and ward Representative/Policy level,
- Water testing lab and DDWUC/Organizational level,
- FCHV / intrapersonal level and
- Water consumer group/ interpersonal level

a. Inclusion Criteria

- The study includes a water consumer group and key informants (KIs) inside Dhulikhel Municipality who were eligible participants willing to be involved in our research
- Age > 18 years

b. Exclusion Criteria

- Reluctant to participate
- Medically unfit

2.15 Sample Size Calculation

- We had conducted 16 purposive in-depth interviews with data until saturation, when no new codes/themes emerged from further interviews among key stakeholders[51]
- 3 focus group discussions (fgd) with (6-10) participants each[52], among water consumer groups to gain insights into their perspectives on implementation challenges of the water surveillance system in Dhulikhel Municipality.

2.16 Tools and Techniques for the Qualitative Phase

- Technique: In-depth Interviews, Focus Group Discussions(FGD)
- Tools: Semi-structured interview guides, focus group discussion guides.

2.17 Data management

- We conducted a CFIR Framework analysis for the implementation challenges of the water surveillance system in the municipality.
- Themes were iteratively identified and refined, providing a robust understanding of factors influencing surveillance effectiveness.

2.18 Expected outcome

- Implementing a water surveillance system for evaluating the current state of water sources and distribution networks can have a transformative impact on the Dhulikhel Municipality.

2.19 Limitations of the Study

- The quality of qualitative data is highly dependent on the skills of interviewers.
- Participant Social desirability biases.

Results

3.1 Descriptive Analysis

3.1.1 Socio-demographic characteristics of respondents

The study surveyed 250 caregivers of under-five children in Dhulikhel Municipality, with an average age of 31 years, suggesting that most were young to middle-aged adults. The majority were female (78%), reflecting the traditional caregiving role of mothers, while 94.4% were married and 78.4% identified as Hindu. Ethnically, Brahmin/Chhetri (29.6%), Tamang (28.4%), and Newar (27.2%) made up the largest groups, with smaller proportions from Magar and other ethnicities. Education levels varied, with 12% having no formal education, 30.4% completing primary school, 44.4% reaching secondary education, and 13.2% holding a university degree. Most caregivers were mothers (68%), while 32% were fathers or other relatives. Occupations included housewives (28.4%), traders (22%), farmers (19.6%), teachers (13.2%), retired individuals (9.2%), and unemployed caregivers (7.6%). More than half (59.6%) had a source of income, with an average monthly household income of NPR 14,337 (median = NPR 10,000), highlighting substantial income disparity.

3.1.2 Water-related characteristics

The study found that access to safe drinking water was limited, with 58.4% of households relying on non-piped water sources and only 41.6% having piped connections. Water availability for other uses was slightly better, with 51.6% using piped sources. Seasonal water scarcity was a major concern, as 73.6% of households reported shortages during the dry season, while 12% experienced shortages in the rainy season and 9.6% faced year-round inconsistency. Most households (72.8%) had water available inside their homes, but 20% spent more than 30 minutes fetching water, indicating accessibility challenges. Water storage practices varied, with households commonly using covered jars (44.4%), tanks (46.4%), and plastic bottles (47.2%). Although 93.6% reported clear water, 6.4% noticed discoloration, and a similar percentage reported unpleasant odors, suggesting possible contamination risks. Encouragingly, 80% of

households treated their drinking water through boiling, filtration, or disinfection, while 20% did not use any treatment method.

3.1.3 Sanitation–related characteristics

Proper sanitation is vital for preventing the spread of diarrheal diseases. The study found that 78.4% (196) of households disposed of waste by dumping it, while 21.6% (54) did not engage in waste dumping, possibly using alternative disposal methods. The proximity of dumping sites was also examined, with 39.6% (99) of households having dumping sites located more than 30 minutes away, while 38.8% (97) had sites within a 30-minute walk, and 21.6% (54) were unaware of the distance to their dumping site.

Payment for household waste management varied, with 51.2% (122) paying monthly fees for waste collection, while 48.8% (128) did not pay, suggesting that waste management services were not utilized.

3.1.4 WASH Practice-related characteristics

Handwashing was widely practiced among caregivers, particularly before eating (89.2%), after eating (81.6%), and after using the washroom (79.6%), with 96.8% using soap and water. However, many did not meet the recommended handwashing duration, as 50% washed for up to 1 minute and only 7.6% for 3 minutes or more. Regarding sanitation, 86% of households had sanitary latrines, with 81.6% located inside the house, but 37.6% shared toilets with other households. Half of the households relied on public toilets, and 49.6% reported no open defecation. While hygiene awareness and sanitation access were generally high, challenges remained in handwashing duration, shared or public toilet use, and waste management, indicating areas for targeted public health interventions.

3.1.5 WASH Knowledge-related characteristics

Most caregivers had basic knowledge of safe drinking water practices, primarily filtration (75.6%) and boiling (66%), while awareness of chlorination (18.4%), sedimentation (10%), and alum use (2.8%) was limited, and 5.2% knew no method. Recognition of contamination indicators was moderate, with color change (59.2%), bad odor (50.8%), and poor taste (46.4%) identified, though 14.4% could not identify any. Open defecation (88.35%) and washing near water sources (72.29%) were widely recognized as contamination sources, while fewer acknowledged waste disposal, fertilizer use, or mining. Health risks, particularly diarrhea (96.8%), were well understood. Waste management practices included composting (90.4%), recycling (29.6%), biogas (10.4%), and landfilling (10.4%), though 8.4% lacked awareness. The main sources of WASH information were radio/TV (67.6%), health workers (52%), and information centers (49.6%).

3.2.1 Prevalence of U5 diarrhea at the household level

The findings revealed that 37(14.8%) households with at least 1 U5 child had experienced diarrhea within the two weeks before the survey, a rate higher than the national average in Nepal.

Table 1
Prevalence of household diarrhea cases among U5 children (N = 250)

Variable	Category	Frequency	%
Household Diarrhea Prevalence			
	Presence	37	14.8
	Absence	213	85.2

3.3 Inferential Analysis

3.3.1 WASH Knowledge score among household U5 children's caregivers

The Level of WASH Knowledge Score among Household U5 Children Caregivers (n = 250) was assessed based on a total possible knowledge score of 25 points. The mean knowledge score among caregivers was 11.6, with a standard deviation of 4.99. The minimum and maximum scores recorded were 4 and 25, respectively

3.3.2 Association between caregiver WASH Knowledge & U5 children diarrhea Prevalance at household level

The association between Caregiver WASH Knowledge and U5 Children Diarrhea Prevalence at the Household Level was analyzed using both univariate and multivariate logistic regression models to assess the relationship between caregivers' knowledge and the likelihood of diarrhea occurrence among under-five (U5) children.

The univariate analysis showed that the knowledge sum score had an odds ratio (OR) of 0.98 (95% CI: 0.91–1.05, p = 0.60), suggesting that an increase in WASH knowledge among caregivers had no statistically significant association with reduced diarrhea prevalence. The multivarient shows an adjusted OR 0.99(95% CI: 0.908–1.08, p = 0.64) These findings indicate that higher WASH knowledge alone does not significantly reduce diarrhea prevalence among U5 children.

3.3.3: Association between caregiver WASH Practice & U5 children diarrhea prevalence at household level

The analysis of caregiver WASH practices and diarrhea prevalence among under-five children showed no statistically significant associations across all examined variables. Children in households with unsanitary latrines, toilets located outside the home, or shared toilets had slightly higher odds of diarrhea, but these associations were not significant even after adjusting for socioeconomic and demographic factors. Similarly, water treatment practices such as boiling and filtering were linked to lower odds of diarrhea, but the results were not statistically significant after adjustment. Waste management practices, including waste dumping, also showed no meaningful association with diarrhea prevalence. Handwashing with soap appeared to reduce diarrhea risk compared to using only water, but this too was not statistically significant in univariate or multivariate models. These findings suggest that while WASH practices are important, other environmental, socioeconomic, and behavioral determinants may play a greater role in influencing diarrhea incidence among children.

Table 2
Socio-demographic characteristics of the qualitative study participants- Water Surveillance

Variable	Category	Frequency	%
Age			
	Mean/SD	44	9.13
Gender			
	Female	22	61.11
	Male	14	38.89
Residential Status			
	Permanent	30	83.33
	Temporary	6	16.67
Religion			
	Hindu	32	88.89
	Non-Hindu	4	11.11
Ethnicity			
	Brahmin/Chhetri	23	63.8
	Newar	13	36.2
Marital Status			
	Married	36	100
Education Status			
	Primary/Up to grade 8	14	38.8
	Secondary/Grade (9–12)	11	30.6
	University (Bachelor's/Master's degree)	11	30.6
Study Participant			
	DDWUC Member	3	8.3
	Municipality Representative	3	8.3
	Ward member	4	11.11
Safal717@iisc.ac.in1	Water test lab member	3	8.3
	FCHV	3	8.3
	Water Consumer Group	20	55.55

3.4.2 Facilitator and barrier of the water surveillance system using the CFIR framework in Dhulikhel municipality

The findings were categorized into key themes based on stakeholder perspectives and analyzed using the Consolidated Framework for Implementation Research (CFIR).

3.4.2.1. Barriers to Water Surveillance Implementation

4.4.2.1.1. Limited Awareness and Perceptions of Water Safety

A significant barrier to effective water surveillance was low public awareness regarding water safety and contamination risks. Several participants, including municipality representatives, water test lab members, and ward members, indicated that community members often perceive water as safe based solely on its appearance (e.g., clear water) rather than scientific testing. One municipality representative stated:

"*Many community members assume that municipal distributed water is clean without understanding the need for additional purification methods like boiling or filtration and further testing to ensure water quality at the household level."*

3.4.2.1.2. Financial Constraints and Resource Limitations

The financial burden of establishing and maintaining a water surveillance system was frequently cited as a challenge. Municipality representatives emphasized that without long-term government funding, sustainability remains uncertain. A Dhulikhel Drinking Water User Committee (DDWUC) member mentioned:

"Water testing systems are perceived as more expensive, complex and without sustained financial support, communities fear that these programs may collapse in near future"

3.4.2.1.3. Political and Institutional Challenges

Frequent political transitions and lack of accountability among concerned authorities were also identified as key barriers to the success of the surveillance system. A municipality representative highlighted:

"Frequent changes in local government and political system interrupt effective funding mechanism, program support delaying the rollout of planned water surveillance programs goal."

3.4.2.1.4. Limited Access to Advanced Testing Equipment

The lack of modern laboratory facilities and reliable testing kits limits the accuracy and scope of water quality monitoring. A water testing laboratory member noted:

"Without proper tools or water testing kits, we rely on outdated tools that are slow, unreliable, and less effective in detecting potential water contamination."

3.4.2.1.5. Environmental Challenges

Natural disasters such as landslides, earthquakes, and seasonal floods pose a risk to water infrastructure, especially in slope regions, making consistent surveillance difficult and increasing potential water contamination risks. A ward member stated:

"During monsoon, many water pipelines break down, leakage in slope area and there is no immediate action to repair them, leading to potential contamination cause several health risk."

3.4.2.1.6. Poor Inter-Agency Coordination

Weak collaboration between municipal authorities, health agencies, and ward and local water consumer groups has led to fragmented efforts in water surveillance implementation. A ward member emphasized:

"Different concern agencies work in isolation, poor communication which results in delayed response and uncoordinated actions at the time of epidemic"

3.4.2.1.7. Trust Issues Regarding the Surveillance System

Inconsistent water testing results due to poor equipment maintenance have led to skepticism among community members in the system, which ultimately reduced trust among consumer groups from concern agencies (Water testing lab, DDWUC, Municipality). A water consumer stated:

"We receive conflicting reports on water quality, leading different water quality result across different testing labs inside Dhulikhel, which makes it hard to trust the efficiency of water Surveillance system."

3.4.2.1.8. Cultural Misconceptions About Water Quality

Traditional beliefs that untreated water is natural and safe for drinking purposes without contamination risk contribute to resistance against modern water testing and purification practices in the community. An FCHV noted:

"People usually believe that boiling water changes its original taste and quality, leading them to consume untreated or untested water considering them safe from their health."

3.4.2.1.9. Delayed Implementation During Outbreaks

Delays caused by complicated procedures and logistical challenges make it difficult to implement water safety measures quickly during disease outbreaks. A Municipal officer explained:

"By the time we gather the necessary resources and take action during an outbreak, the harm has already occurred in the community in an unmanageable manner due to epidemic."

3.4.2.1.10. Lack of Community Engagement

The limited involvement of local communities in decision-making processes has led to weak compliance with surveillance guidelines. A Ward member noted:

"When community people are not included in planning and not well informed about the importance of the surveillance system, they do not feel responsible for water safety-related issues in the community."

3.4.2.1.11. Lack of Standardized Testing Protocols

Inconsistent testing protocols across different monitoring agencies hinder the reliability of surveillance efforts. A municipal health officer stated:

"Different agencies use varied testing tools and techniques, lacking uniformity leading to inconsistencies in water quality test reports across different water testing site."

4.4.2.1.12. Weak Law Enforcement on Water Quality Standards

Despite proper regulations for the surveillance system, enforcement remains weak, resulting in continued contamination issues. A water test lab member emphasized:

"Without strict enforcement, industries and households fail to comply with water safety guidelines, failing the surveillance system."

4.4.2.2. Facilitators for Effective Water Surveillance

4.4.2.2.1. Community Training and Awareness Programs

Community-based training programs and awareness campaigns have played a crucial role in improving water surveillance. A Female Community Health Volunteer (FCHV) noted:

"We conduct training programs in the community to teach safe water handling practices, the importance of water testing including boiling and proper filtration methods."

3.4.2.2.2. Technological Innovations in Water Testing

The use of modern digital water quality monitoring tools has improved efficiency and data accuracy, enabling early detection and rapid response to contamination events. A water testing laboratory member stated:

"Modern digital tools provide more reliable testing, helping us detect contamination early and take preventive measures quickly and more accurately."

3.4.2.2.3. Stakeholder Collaboration and Policy Initiatives

Collaborations between municipal authorities, NGOs, and water user groups have strengthened implementation efforts, ensuring better resource allocation and surveillance sustainability. A DDWUC member emphasized:

"Strong partnerships with concerned stakeholders and support have allowed us to secure more

funding and technical support from concerned agencies."

3.4.2.2.4. Government Commitment and Financial Support

Financial support from central and local governments has helped sustain water surveillance programs in the municipality. A municipal official stated:

"Government funding ensures that necessary water testing resources are available at the local level and sustainable for a surveillance system."

3.4.2.2.5. Leadership and Governance

The involvement of ward representatives and local leaders has ensured regular monitoring, timely interventions, and improved accountability in water quality management. A ward leader mentioned:

"Strong Political leadership drives effective water surveillance and ensures community participation, ownership, and support for water surveillance action."

3.4.2.2.6. Integration of Water Surveillance with Public Health Programs

The integration of water surveillance with broader public health initiatives has enhanced disease prevention strategies and improved hygiene practices within communities. A Municipal officer stated:

"Linking water surveillance with Public health programs from municipal level leadership has reduced the incidence of waterborne diseases in present days."

3.4.2.2.7. Capacity Building and Training for Health Workers

Training programs for local authorities, health workers, and community members have strengthened technical competencies related to water surveillance. A water lab technician noted:

"Continuous training and capacity building action helps ensure that concerned laboratory personnel and health workers are well-equipped to handle water quality monitoring effectively."

3.4.2.2.8. Increased Community Participation in Water Governance

The active engagement of local communities in decision-making processes has fostered a sense of ownership, ensuring the long-term sustainability of water surveillance efforts. A water consumer stated:

"When the community people are involved in the decision-making process, people take ownership and motivate themselves to keep water sources safe, ensuring the success of water surveillance system goal."

3.4.2.2.9. Use of Mobile and Digital Data Collection Systems

The implementation of mobile-based water quality reporting tools and digital data collection systems has improved data accessibility and enhanced real-time monitoring capabilities. A DDWUC mentioned:

"Mobile data collection systems or use of modern technology have made tracking water quality issues more efficient and transparent manner ensuring reliable and valid test result"

3.4.2.2.10. Infrastructure Improvements

Upgrades in the water supply network and sanitation infrastructure have facilitated better monitoring and reduced contamination risks. A municipal engineer noted:

"Municipal Investments in WASH-related infrastructure and supply networks have led to a more consistent and safer water supply system for Dhulikhel residents."

3.4.2.2.11. Standardization of Water Quality Testing

The adoption of uniform testing protocols has improved the consistency and reliability of water quality data. A municipal officer noted:

"Availability of the standardized water testing kits ensures that we have comparable data across different regions."

3.4.2.2.12. Strengthened Regulatory Frameworks

Enhanced water safety policies, guidelines, and stricter enforcement mechanisms from municipalities have improved compliance with water quality standards. A municipal official noted:

"With stricter regulations and penalties provision regarding water testing, and quality control we will see fewer violations of water safety guidelines."

Discussion

4.1 Prevalence of U5 children's diarrhea at the household level

In Nepal, the Prevalence of U5 diarrheal cases ranges from 10.2% to 13.6% [53], which is quite lower than our finding of 14.8%. This is because our data were collected during rainy seasons, leading to more chance of water contamination, rather than in other seasons.

Studies from Bangladesh and India report similar prevalence rates of 13.9% and 15.5%, respectively, indicating that U5 diarrheal disease remains a significant public health concern in the South Asia region [54,55]. Similar seasonal variations in diarrheal prevalence have been reported in other studies in South Asia, with an average seasonal diarrhea prevalence of 15.2% in Southeast Asia [56,57]. Research from Cambodia and Vietnam indicates seasonal peaks reaching 16.8% and 17.2%, respectively, further emphasizing the influence of environmental factors on diarrheal disease prevalance [58,59].

4.2 WASH Knowledge & practice among U5 children caregiver

The study highlights the critical deficiencies of WASH–related knowledge among caregivers, such as improper handwashing & unsafe water storage leading to diarrheal disease [60–62]. Studies in Ethiopia and Bangladesh have shown that knowledge gaps in water handling and sanitation practices significantly increase the risk of waterborne diseases [63,64]. Additionally, research in Kenya found that only 45% of caregivers demonstrated proper handwashing techniques, correlating with higher diarrheal prevalence among children [65]. A study conducted in India showed that inadequate knowledge regarding safe water storage and open defecation significantly contributed to the persistence of diarrheal diseases in rural areas[66]. Similarly, findings from Cambodia and Vietnam emphasize the role of educational interventions in improving sanitation behaviors and reducing diarrheal disease burden[67,68].

In our study, limited awareness about sanitary practices among caregivers leads to a higher prevalence of diarrheal cases in comparison to the national average [69]. The research emphasizes the need to address broader environmental factors that influence WASH Practice [23,24]. Limited resources, such as financial constraints for water purification methods or improper sanitation facilities, increased the risk of diarrheal disease[42,75] .

4.3 Association between U5 diarrhea cases with knowledge score & practice among caregiver

Although WASH knowledge and practice are crucial components of effective interventions, their lack of significant association with diarrhea prevalence in this study underscores the need for a multifaceted approach. Studies in Ethiopia and India have similarly found that improved WASH knowledge alone does not always translate into lower disease prevalence, as environmental and infrastructural factors play a crucial role [70,71]. Other studies have also suggested that while individual behaviors play a role, broader environmental, socio-economic, and cultural factors exert a greater influence on WASH-related health outcomes [72]. A study in Bangladesh demonstrated that factors such as water source contamination and seasonal variations had a more significant impact on diarrheal prevalence than hygiene practices alone [73]. Similar research from Sub-Saharan Africa and South Asia has emphasized the importance of improving water infrastructure and sanitation facilities rather than relying solely on behavioral interventions [74,75]. Evidence from developing countries supports this view, showing that investments in clean water access and improved sanitation facilities significantly reduce diarrhea cases, independent of individual hygiene behaviors[76,77].

4.4 Barrier and facilitator of water surveillance system in Dhulikhel Municipality

4.4.1 Barriers to the Water Surveillance System

Key barriers include limited public awareness, where many individuals assume that clear water is safe for consumption without recognizing the potential for microbial contamination. This aligns with findings from Hunter et al. and Bartram & Cairncross, who emphasize that public misconceptions about water safety contribute to increased health risks [74,75]. Many regions lack access to modern testing equipment, resulting in delays in detecting and addressing waterborne contamination. Mara et al. highlight that outdated tools provide inaccurate results, reducing the efficiency of surveillance mechanisms[78]. Environmental challenges, such as seasonal fluctuations, natural disasters, and climate change, also contribute to inconsistent water quality. Levy et al. found that climate-related factors influence waterborne disease outbreaks, stressing the need for adaptive surveillance strategies[79]. These findings align with previous studies conducted in Nepal and other LMICs, where financial and technical constraints have hindered water quality monitoring efforts [78,79].

4.4.2 Facilitator to the Water Surveillance System

Conversely, leveraging technological advancements, innovative water testing methods, and stakeholder participation can significantly enhance surveillance effectiveness. Stakeholder collaboration, including partnerships between government agencies, non-governmental organizations (NGOs), and community water user groups, strengthens implementation efforts. Hunter et al. stress that multi-sector coordination improves resource allocation, ensuring a more systematic and sustainable approach to water quality monitoring [74]. The use of digital monitoring tools and automated water quality sensors allows for real-time detection of contaminants. Bartram & Cairncross highlight that technology-driven approaches enhance data accuracy and enable quicker response times to potential health threats[75]. Prendergast & Humphrey found that well-funded programs are more likely to implement long-term surveillance strategies that address both emerging and existing water quality concerns[77]. Strong leadership at the local level ensures regulatory compliance and effective enforcement of water safety measures. Mara et al. argue that proactive governance structures lead to better adherence to water quality standards, ultimately benefiting public health[78] .Educational initiatives help inform communities about safe water handling, contamination risks, and preventive measures. Velleman et al. emphasize that participatory approaches foster greater community ownership, encouraging individuals to take proactive steps in water safety[80]. Research from Bangladesh and India suggests that community engagement and decentralized water monitoring systems improve water quality outcomes and public health indicators [80,81] .

A comprehensive approach incorporating elements like increased investment, advanced technology, stronger governance, and community ownership is crucial for ensuring sustainable improvements in water quality and public health outcomes in Dhulikhel Municipality.

Conclusion & Recommendation

WASH knowledge gaps and a 14.8% diarrhea prevalence among U5 children are driven by water scarcity, poor infrastructure, and limited resources. Community participation and technology can facilitate improvements, but barriers like low awareness and political constraints remain.

Enhance WASH knowledge through workshops, promote handwashing, waste management, and household water treatment, and strengthen collaboration among authorities and communities. Invest in infrastructure, adopt digital water monitoring, and enforce water safety regulations to ensure safe, reliable water for all.

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Tables

a. Quantitative study on Ward-wise distribution of households with at least 1 U5 Children caregiver (N=250)

Dhulikhel ward number	Frequency	%
3	53	21.20
4	32	12.80
5	26	10.40
6	44	17.60
7	73	29.20
8	22	8.800

Table 1: Sociodemographic Information of household with U5 children caregiver (N=250)

Variable	Category	Frequency	%
Age in years			
	Mean/SD	31	8.35
Gender			
	Male	55	22
	Female	195	78
Education Level			
	None/Uneducated	30	12
	Primary(Upto 8)	76	30.4
	Secondary(9-12)	111	44.4
	University(Bachelor/Master)	33	13.2
Marital Status			
	Single/Unmarried	14	5.6
	Married	236	94.4
Religion			
	Hinduism	196	78.4
	Non hindu	54	21.6
Ethnicity			
	Brahmin/Chhetri	74	29.6
	Tamang	71	28.4
	Newar	68	27.2
	Magar	19	7.6
	Other (Dalit/Gurung/Rai/Limbu)	18	7.2
Household U5 Size			
	One	194	77.6
	Two	54	21.6
	Three	2	0.80
Relation to U5 Children			
	Mother	170	68
	Other (Father/Sibling/Blood Relative)	80	32
Respondent Occupation			
	Housewife	71	28.4

	Trader	55	22
	Farmer	49	19.6
	Teacher	33	13.2
	Retired	23	9.2
	Unemployed	19	7.6
Earning			
	Yes	149	59.6
	No	101	40.4
Income in Rupees			
	Mean (SD)	14337	31735
	Median (IQR)	10000	20000

Table 2: Water-related characteristics of households with U5 children (N=250)

Variable	Category	Frequency	%
Water Source for Drinking Purposes			
	Non-Pipeline	146	58.6
	Pipeline	104	41.6
Water Source Other than drinking purposes like Cooking, washing, etc			
	Non-Pipeline	121	48.4
	Pipeline	129	51.6
Water Scarcity Seasons			
	Dry	184	73.6
	Rainy	30	12
	Inconsistency	24	9.6
	Don’t Know	19	7.6
Water assessability			
	Inside House	182	72.8
	>30 min distance	50	20
	<30 min distance	18	7.2
Water Storage			
	Covered in Water Jar	110	44.4
	Tank	116	46.4
	Plastic Bottle	118	47.2
Water Apperance			
	Clear	234	93.6
	Colored	16	6.4
Water-Odor			
	Don’t Smell	234	93.6
	Smell	16	6.40
Water treatment in the household			
	No	50	20
	Yes	200	80

Table 3: Sanitation characteristics of households with U5 Children (N= 250)

Variable	Category	Frequency	%
Household refuses disposal method			
	Dumping site	196	78.4
	Non-dumping site	54	21.6
Dumping site distance from house			
	Not Known	54	21.6
	>30 min Walk distance from house	99	39.6
	<30 min Walk distance from house	97	38.8
Payment for household Waste management			
	Don't Pay	122	48.8
	Pay Monthly	128	51.2

Table 4: WASH Practice characteristics of households with U5 Children (N= 250)

Variable	Category	Frequency	%
Handwashing time by a household member (Multiple Responses)			
	Before eating	223	89.2
	After eating	204	81.6
	After use of Washroom	199	79.6
	Before cooking food	165	66
	Arrival at the house from a new place	165	66
Hand washing use			
	Soap and water	241	96.8
	Water Only	8	3.2
Handwashing time			
	Upto 1 min	125	50
	Upto 2 min	106	42.4
	Upto 3 min	19	7.6
Household latrine type			
	Sanitary latrine	215	86
	Open pit latrine	35	14
Toilet location			
	Inside Compound	46	18.4
	Inside House	204	81.6
Household toilet Condition			
	Single	156	62.4
	Shared	94	37.6
Defecate Outside			
	Never	124	49.6
	Use a Public toilet	126	50.4

Table 5: WASH Knowledge characteristics of household U5 children caregiver (N = 250)

Variable	Category	Frequency	%
Way to make drinking water safe			
	Filtration	189	75.6
	Boiling	165	66
	Chlorination	46	18.4
	Sedimentation	25	10
	Alum	7	2.8
	Don’t Know	13	5.2
Water Contamination Identification			
	Poor taste	116	46.4
	Color Change	148	59.2
	Bad odor	127	50.8
	Don’t Know	36	14.4
Human activity causes water contamination			
	Mining	34	13.65
	Washing clothes/vehicles near water sources	180	72.29
	Open defecation	220	88.35
	Mixing Chemical fertilizer near water source	98	39.36
	Industrial/Household waste	125	50
Water Contamination Health Effects			
	Diarrhea	242	96.8
	Stomach ache	194	77.6
	Head ache	109	43.6
	Vomiting	124	49.6
	Cholera	131	52.4
	Skin Rashes	70	28
	Other(Typhoid/Hepatitis/Dysentry)	6	0.24
Household waste management			
	Recycling	74	29.6
	Biogas	26	10.4
	Compost manure	226	90.4

	Land filling	26	10.4
	Not Known	21	8.4
Source of WASH-related health information			
	Newspaper	45	18
	Radio/Television	169	67.6
	Information Center	124	49.6
	Health worker	130	52
	Acquaintance	73	29.2

Table 6: Level of WASH Knowledge Score among household U5 children caregiver (N=250)

Variable	Category		
WASH Knowledge Score			
	Mean/SD	11.6	4.99
	Max/Min	25	4
Total WASH Knowledge Score =25			

Table 7: Association between caregiver WASH Knowledge & U5 children diarrhea Prevalance at household level (N=250)

	Univariate			Multivariate		
Characteristics	**OR**	**95% CI**	**P Value**	**aOR**	**95% CI**	**P Value**
Knowledge Sum Score	0.98	0.91-1.05	0.6	0.99	0.908-1.08	0.64
Adjusting for all sociodemographic variables (Age , Gender , Education , Marital status , Religion , Ethnicity , Relationship status , Occupation , and Income)						

Table 8: Association between caregiver WASH Practice & U5 children diarrhea Prevalance at household level (N=250)

Characteristics	Univariate			Multivariate		
	OR	95% CI	P Value	aOR	95% CI	P Value
Latrine type						
Sanitary/ref						
Unsanitary	1.22	0.67-0.47	0.67	1.22	0.44-3.38	0.95
Toilet location						
Outside home/ref						
Inside home	1.19	0.46-3.05	0.711	1.20	0.46-3.10	0.73
Toilet using household						
Single/ref						
Shared						
	1.15	0.4-9.68	0.64	1.13	0.55-2.34	0.80
Water treatment						
No treatment/ref						
Treatment	0.74	0.32-1.69	0.4	0.78	0.33-1.81	0.96
Household waste management						
No dumping/ref						
Dumping						
	1.25	0.45-3.45	0.64	1.27	0.43-3.70	0.26
Handwashing						
Soap &water/ref						
Water Only	1.97	0.417-0.38	0.44	2.07	0.39-11.03	0.87

In Multivariate Analysis

 # Latrine type has adjusted variables such as Income, Education, and Ethnicity

Toilet location has adjusted variables such as Age, Gender, and Marital Status

Toilet-using household adjusted for Income, education, and Water Source

Water treatment has adjusted for variables such as Education, Income, and Religion

Household waste management has adjusted for variables such as Income, Education, and Marital Status

Handwashing has adjusted for variables such as Education, Age, and Income

Figures

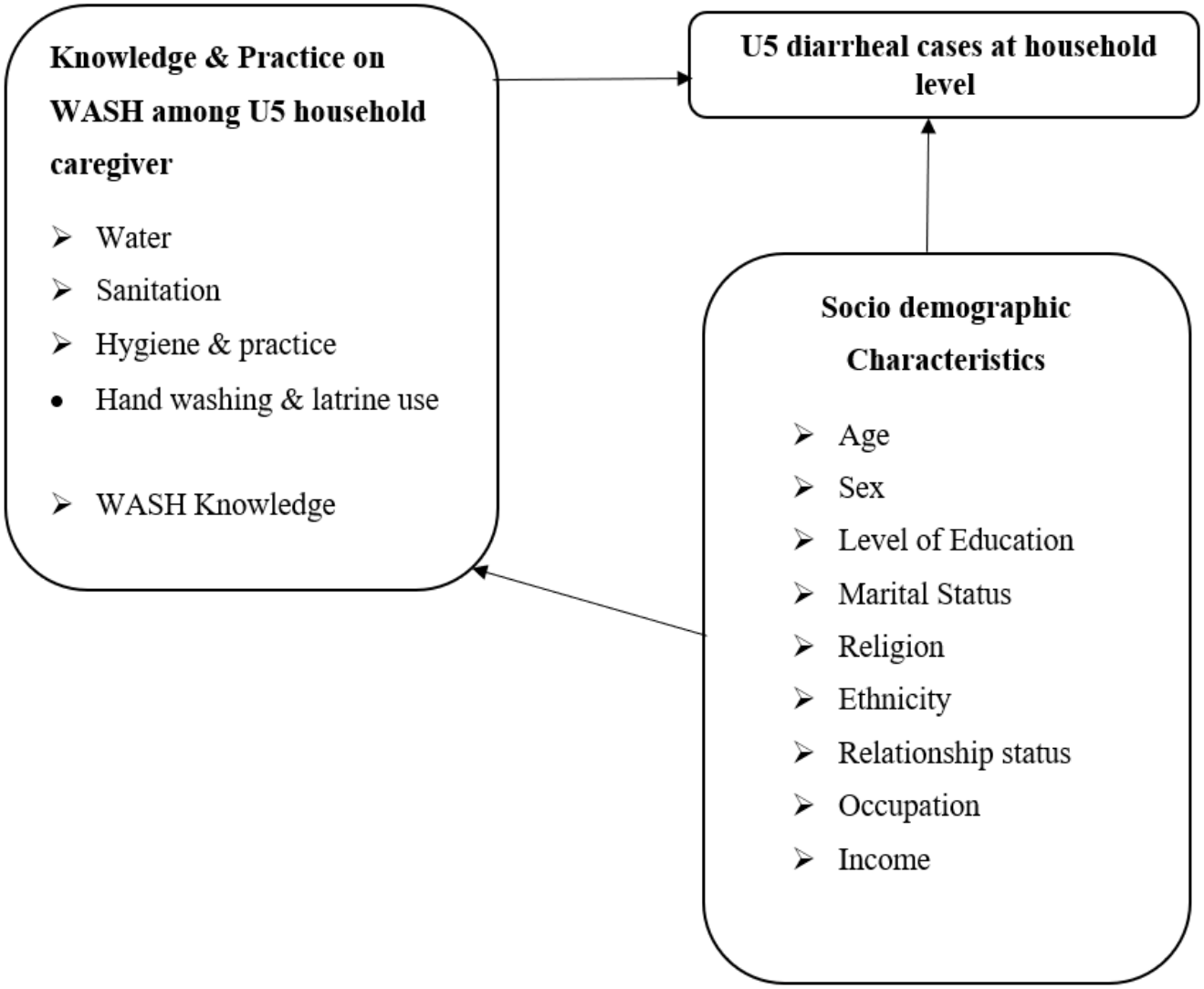


Figure 1

Conceptual framework showing household U5 Caregiver knowledge and practice, its association with U5 diarrhea Prevalance

Supplementary Files

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- Question.docx