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WATER SUPPLY AVAILABILITY AND ACCESSIBILITY AS DETERMINANTS OF HEALTH SERVICE DELIVERY IN HEALTHCARE FACILITIES IN UPPER NILE STATE, SOUTH SUDAN

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ABSTRACT

This study assessed the status of Water, Sanitation, and Hygiene (WASH) services and their impact on health service delivery in healthcare facilities in Upper Nile State, South Sudan. The study was guided by four objectives: to assess the availability and accessibility of water supply services; examine sanitation services; evaluate hygiene and waste management systems; and determine how WASH conditions influence healthcare service delivery. The study was conducted in 20 government healthcare facilities; including 16 Primary Health Care Centres (PHCCs) and 4 hospitals in a conflict-affected setting characterized by weak infrastructure and limited public services.A concurrent triangulation mixed methods design was employed, integrating both quantitative and qualitative approaches. Quantitative data were collected using questionnaires administered to 20 healthcare facility administrators, while qualitative data were obtained through key informant interviews with 24 health workers, 20 inpatients, and 18 lactating mothers. Observations, documentary review, and water quality testing complemented primary data collection. Quantitative data were analyzed using SPSS version 27 through descriptive statistics, Pearson correlation, chi-square tests, t-tests, logistic regression, and Structural Equation Modeling (SEM). Qualitative data were analyzed thematically using Open Code 4.02.The findings revealed that only 35% of healthcare facilities had basic water services, while 35% had no water service and 30% had limited services. Hospitals had significantly better water access than PHCCs ($p = 0.003$). Facilities lacking on-premise water supply, water quality testing, and those relying on surface water were significantly more likely to experience water shortages. Poor WASH conditions negatively affected infection prevention, maternal healthcare, patient satisfaction, and overall healthcare quality.The study concluded that inadequate and inequitable WASH services, particularly in rural PHCCs, remain a major barrier to effective healthcare delivery in Upper Nile State. The study recommends increased government and donor investment in on-premise water infrastructure, routine water quality monitoring, strengthening WASH policies, and integrating WASH into health sector planning and emergency response systems.

Keywords: Water supply, WASH services, Healthcare facilities, Health service delivery, Primary Health Care Centres (PHCCs), Infection prevention and control, Maternal healthcare.

INTRODUCTION

Access to safe and reliable water supply services within healthcare facilities remains a fundamental pillar of effective health systems globally (WHO & UNICEF, 2021). Water availability directly influences infection prevention and control, maternal and neonatal survival, surgical safety, environmental sanitation, and overall quality of healthcare delivery (WHO & UNICEF, 2021; Kayiwa *et al*., 2020; Meshi *et al*., 2022). Globally, healthcare facilities lacking continuous water supply experience compromised hygiene practices, increased healthcare-associated infections, poor waste management, and weakened emergency response systems (Cronk *et al*., 2015; WHO South Sudan, 2021). The global health architecture increasingly recognizes water security as an indispensable determinant of health system resilience and universal health coverage because healthcare delivery cannot function effectively without adequate water infrastructure (World Bank, 2022; UNICEF Uganda, 2021). Consequently, the Sustainable Development Goals, particularly SDG 3 and SDG 6, emphasize integrated investments in water and healthcare systems to enhance equitable health outcomes and reduce preventable morbidity and mortality across vulnerable populations (WHO & UNICEF, 2021; Ministry of Health Ghana, 2019; UNICEF Tanzania, 2021).

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Across Africa, inadequate water supply systems in healthcare facilities remain a persistent structural challenge that constrains effective health service delivery and weakens public health preparedness (WHO Nigeria, 2021; UNICEF Kenya, 2022; WHO South Sudan, 2021). Many African health facilities continue operating under conditions characterized by intermittent water access, poor sanitation infrastructure, and insufficient hygiene management systems, and unreliable environmental health services (Meshi *et al*., 2022; Moyo & Ncube, 2021; Chola & Banda, 2020). Such deficiencies disproportionately affect maternal healthcare, surgical procedures, infection control, and emergency healthcare interventions because water forms the operational foundation of healthcare functionality (Department of Health South Africa, 2019; Ministry of Health Tanzania, 2019). Moreover, rapid urbanization, population growth, climate variability, institutional fragility, and underinvestment in public infrastructure continue to intensify healthcare water insecurity across many African countries (UNICEF Tanzania, 2021; WaterAid Kenya, 2021; World Bank, 2022). Consequently, healthcare systems across the continent increasingly face systemic vulnerabilities that compromise equitable healthcare access and sustainable health outcomes among underserved populations (Cronk *et al*., 2015; Owusu & Mensah, 2020).

Within East Africa, water accessibility in healthcare facilities remains uneven despite substantial policy reforms and regional investments in water, sanitation, and hygiene services (Kayiwa *et al*., 2020; Maina *et al*., 2021; WHO & UNICEF, 2021). Empirical studies from Uganda,

Kenya, and Tanzania demonstrate that unreliable water supply systems continue to undermine infection prevention practices, maternal healthcare delivery, and healthcare worker performance in both rural and urban facilities (Mulogo *et al*., 2018; Omondi & Were, 2020; Meshi *et al*., 2022). In many East African healthcare settings, health workers spend considerable time coping with water shortages rather than focusing exclusively on patient care, thereby reducing operational efficiency and service quality (Isunju *et al*., 2022; UNICEF Uganda, 2021). Furthermore, disparities between urban and rural healthcare facilities remain substantial because rural facilities often lack sustainable water infrastructure, functional boreholes, piped water systems, and maintenance capacities necessary for continuous healthcare operations (Mulogo *et al*., 2018; UNICEF Kenya, 2022; Yhdego *et al*., 2015). These regional realities indicate that healthcare water insecurity remains both a public health challenge and a developmental concern requiring integrated multisectoral interventions across East Africa (Meshi *et al*., 2022; Isunju *et al*., 2022).

In South Sudan, the challenge of water accessibility within healthcare facilities is significantly exacerbated by prolonged armed conflict, institutional fragility, displacement crises, infrastructural destruction, and limited state capacity (WHO South Sudan, 2021; UNICEF South Sudan, 2022; World Bank, 2022). The country's healthcare system continues to operate under severe resource constraints characterized by damaged infrastructure, inadequate water systems, poor sanitation services, and insufficient healthcare financing (Oxfam International, 2020; WHO South Sudan, 2021). Consequently, many healthcare facilities rely on unsafe water sources, seasonal water access, or humanitarian emergency support to sustain basic healthcare functions (UNICEF South Sudan, 2022; International Rescue Committee, 2021). These conditions increase vulnerability to healthcare-associated infections, reduce patient confidence, weaken maternal and child healthcare services, and compromise emergency response mechanisms during disease outbreaks and humanitarian crises (WHO & UNICEF, 2021; UNHCR, 2021). Although humanitarian organizations continue supporting WASH interventions in healthcare facilities, sustainability challenges, insecurity, and infrastructural deterioration continue limiting long-term improvements in healthcare water systems across South Sudan (World Bank, 2022; Asmally*et al*., 2025).

Upper Nile State represents one of the most vulnerable regions within South Sudan due to recurrent conflict, population displacement, flooding, fragile infrastructure, and limited healthcare investments (International Rescue Committee, 2021; UNICEF South Sudan, 2022). Healthcare facilities in the region frequently experience severe water shortages, damaged water infrastructure, inadequate sanitation systems, and limited operational maintenance capacities that undermine effective health service delivery (WHO South Sudan, 2021; Oxfam International, 2020). The interaction between conflict-related disruptions and weak institutional support systems has significantly constrained the functionality of healthcare facilities and reduced their ability to provide safe and quality healthcare services to affected populations (UNHCR, 2021; World Bank, 2022). Furthermore, the growing burden of communicable diseases, maternal health complications, and humanitarian emergencies within Upper Nile State increasingly requires resilient healthcare systems supported by sustainable water supply services (WHO South Sudan, 2021; UNICEF South Sudan, 2022). Nevertheless, empirical evidence examining the specific relationship between water supply availability, accessibility, and health service delivery within healthcare facilities in Upper Nile State remains limited and fragmented despite the magnitude of the challenge (International Rescue Committee, 2021; Asmally *et al*., 2025).

Therefore, understanding how water supply availability and accessibility influence healthcare service delivery in Upper Nile State is critical for strengthening fragile health systems, improving healthcare quality, enhancing infection prevention capacity, and promoting sustainable public health outcomes in conflict-affected settings (WHO South Sudan, 2021; UNICEF South Sudan, 2022; World Bank, 2022). Water supply systems are not merely infrastructural components but strategic determinants of healthcare functionality, institutional resilience, and population health security because healthcare delivery fundamentally depends on environmental health conditions (Cronk *et al*., 2015; Kayiwa *et al*., 2020; Isunju *et al*., 2022). Consequently, examining the dynamics of water accessibility within healthcare facilities in Upper Nile State may provide evidence necessary for policy formulation, humanitarian planning, infrastructure investment, and health systems strengthening interventions aimed at improving equitable healthcare delivery in fragile contexts (WHO & UNICEF, 2021; Oxfam International, 2020; UNHCR, 2021).

Problem Statement

Despite global and regional commitments toward strengthening water, sanitation, and hygiene services in healthcare facilities, access to reliable water supply systems remains critically inadequate in many fragile and conflict-affected settings, particularly in South Sudan (WHO & UNICEF, 2021; WHO South Sudan, 2021). Water availability constitutes a fundamental prerequisite for infection prevention, maternal healthcare, surgical procedures, environmental sanitation, and effective emergency response. However, many healthcare facilities in Upper Nile State continue operating under conditions characterized by intermittent water access, damaged infrastructure, poor sanitation systems, and limited operational maintenance capacities (UNICEF South Sudan, 2022; International Rescue Committee, 2021). These deficiencies compromise the quality, safety, and continuity of healthcare service delivery while simultaneously increasing the risk of healthcare-associated infections and preventable morbidity among vulnerable populations (World Bank, 2022; Oxfam International, 2020).

Although humanitarian agencies and development partners have implemented WASH interventions across South Sudan, healthcare water insecurity persists due to prolonged conflict, displacement, flooding, infrastructural destruction, and weak institutional systems (UNHCR, 2021; Asmally *et al.,* 2025). Existing studies have largely focused on general WASH conditions and humanitarian responses, with limited empirical attention given to how water supply availability and accessibility specifically influence healthcare service delivery within healthcare facilities in Upper Nile State. Consequently, the absence of context-specific evidence constrains policy formulation, resource allocation, and sustainable health systems strengthening interventions in the region.

Purpose of the Study

The purpose of this study is to assess the availability and accessibility of water supply services and examine their influence on health service delivery in healthcare facilities in Upper Nile State, South Sudan.

Specific Objective

i. To assess the availability and accessibility of water supply services and determines their influence on health service delivery in healthcare facilities in Upper Nile State, South Sudan.

Research Question

1. How do the availability and accessibility of water supply services influence health service delivery in healthcare facilities in Upper Nile State, South Sudan?

Scope of the Study

The study defined its scope in terms of geographical location, content, and time. Geographically, it was conducted in healthcare facilities in Upper Nile State, South Sudan, a conflict-affected region bordered by Ethiopia, Sudan, Jonglei, and Unity States, with Malakal as its capital. The state comprises 13 counties and has experienced severe infrastructural destruction and population displacement since the 2013 conflict. Contextually, the study assessed Water, Sanitation and Hygiene (WASH) conditions in 16 PHCCs and 4 hospitals and examined their influence on health service delivery, excluding PHCUs due to their limited service scope. These facilities were selected because they provide comprehensive services requiring functional WASH systems for infection prevention and patient care. The study adopted a cross-sectional design focusing on water supply, sanitation, waste management, and hygiene practices. Temporally, it covered 2015–2023, a period marked by global and national emphasis on WASH in healthcare facilities following major SDG-related policy milestones.

THEORETICAL REVIEW

Systems Theory

Systems Theory was originally developed by Ludwig von Bertalanffy (1968) as a general framework for understanding complex and interdependent structures. The theory assumes that any system is composed of interrelated parts that work together to achieve a common goal, and that a change in one part of the system inevitably affects the entire system. In healthcare, this implies that service delivery is not determined by a single factor but by the interaction of multiple components such as infrastructure, human resources, financing, governance, and environmental conditions. The key assumption is that systems are open and continuously interact with their environment, receiving inputs, processing them, and producing outputs with feedback mechanisms that influence performance and adaptation.

In the context of this study, Systems Theory is highly applicable because healthcare facilities in Upper Nile State function as complex systems where water supply represents a critical input that directly influences service delivery processes and outcomes. In South Sudan, where health systems are fragile due to conflict, displacement, and infrastructure destruction, disruptions in water supply create cascading failures in infection prevention, maternal care, and general patient safety. The theory is relevant because it explains how breakdowns in one subsystem (water infrastructure) destabilize the entire healthcare delivery system. However, a key criticism is that Systems Theory can be overly broad and abstract, making it difficult to operationalize specific causal relationships. Despite this limitation, its implication for healthcare service delivery in South Sudan is significant, as it emphasizes the need for integrated health system strengthening approaches rather than isolated interventions, particularly in improving water infrastructure to enhance overall healthcare performance.

2. Donabedian Model of Healthcare Quality

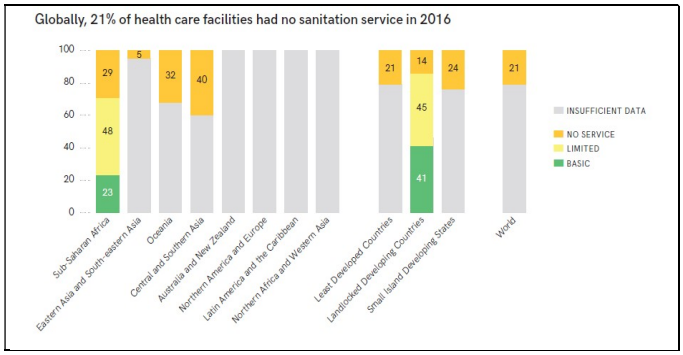
Donabedian Model of Healthcare Quality was proposed by Avedis Donabedian in 1966 as a framework for evaluating healthcare quality. The model is based on three key assumptions: (1) quality of care can be accessed through structure, process, and outcome; (2) good structural conditions increase the likelihood of good healthcare processes; and (3) effective processes lead to improved health outcomes. “Structure” refers to the physical and organizational infrastructure of healthcare, including water supply systems, equipment, and staffing. “Process” refers to how care is delivered, including hygiene practices, infection prevention, and clinical procedures. “Outcome” refers to the results of care, such as patient recovery, infection rates, and satisfaction.

In this study, the Donabedian model is directly applicable because water supply availability and accessibility represent a critical structural component influencing healthcare processes such as hand hygiene, sterilization, and sanitation in Upper Nile State. In the fragile context of South Sudan, weak infrastructure undermines safe clinical processes, leading to poor health outcomes such as high infection rates and reduced service quality. The model is highly relevant because it provides a clear analytical pathway for linking water availability to healthcare performance outcomes. However, its limitation lies in its linear assumption that structure always leads to better processes and outcomes, which may not fully capture the complexity of conflict-affected health systems where external shocks disrupt service delivery. Despite this, its implication for South Sudan is strong, as it guides policymakers to prioritize investment in structural inputs like water systems as a foundation for improving healthcare quality, safety, and overall system performance.

LITERATURE REVIEW

Availability and Accessibility of Water Sources in Health Care Facilities

Access to adequate and safe water in healthcare facilities is a fundamental requirement for effective service delivery because water supports drinking, hand hygiene, cleaning, sterilization, and clinical procedures essential for patient care (UNICEF, 2022; WHO & UNICEF, 2022; Brown & Juma, 2023). Globally, water availability in healthcare facilities remains uneven, with significant disparities in access to basic water services across regions and income groups (WHO & UNICEF, 2019; WHO & UNICEF, 2022; WHO, 2020). Although approximately four in five facilities globally had basic water services by 2021, about one in five facilities in low-income and fragile settings still lacked any service, undermining infection prevention and safe care delivery (WHO & UNICEF, 2022; Hassan *et al.,* 2022; Adams & Patel, 2021). Sub-Saharan Africa reflects these disparities, where only about half of healthcare facilities meet basic water service standards, and many still rely on off-premises or unsafe water sources (WHO & UNICEF, 2022; Cronk *et al*., 2015; UNICEF Kenya, 2022). These global inequities highlight persistent structural gaps in health infrastructure that directly affect service quality and patient safety.Despite substantial global evidence on healthcare water access, most studies remain aggregate in nature and fail to disaggregate facility-level functionality and service delivery outcomes in fragile and conflict-affected settings such as South Sudan. There is limited empirical evidence linking water availability directly to operational healthcare performance indicators such as infection control effectiveness, maternal care quality, and patient safety outcomes at facility level in such contexts.



In Africa, water supply challenges in healthcare facilities are intensified by weak infrastructure, conflict, and underinvestment in health systems, leading to frequent service interruptions and reliance on unsafe water sources (WHO Nigeria, 2021; UNICEF South Sudan, 2022; Oxfam International, 2020). Many facilities fail to meet minimum water requirements for safe healthcare delivery, resulting in compromised sanitation practices, increased infection risks, and reduced patient trust in health services (Meshi *et al*., 2022; Moyo & Ncube, 2021; Chola & Banda, 2020). Even where improved sources exist, water is often unavailable at the point of care or insufficient in quantity, affecting clinical efficiency and hygiene compliance (Isunju *et al.,* 2022; WHO & UNICEF, 2022; WaterAid Kenya, 2021). These regional disparities demonstrate that water access in healthcare facilities is not only a technical issue but also a systemic health systems constraint influenced by governance, financing, and infrastructure gaps.Although African studies highlight widespread water insecurity in healthcare facilities, they largely emphasize national or regional estimates without adequately examining how inconsistent water availability influences day-to-day clinical processes and healthcare delivery efficiency within individual facilities. Furthermore, there is limited context-specific evidence from fragile environments that explains how structural water deficits translate into measurable service delivery disruptions.

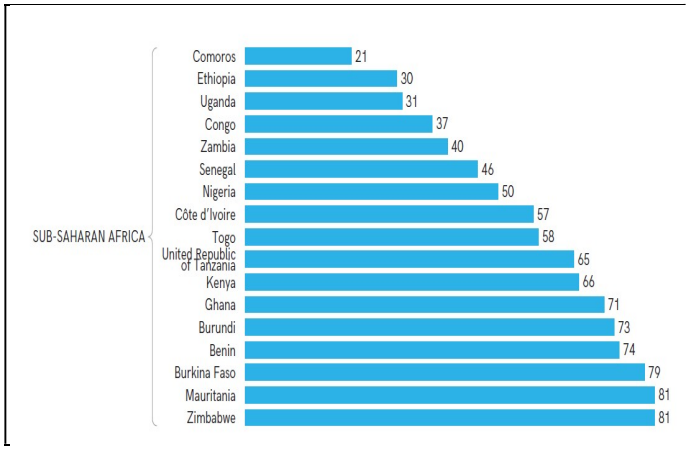


Figure 2. 1: Proportion of Health care facilities in Sub-Saharan Africa with basic water supply, Source: 2019 Global Baseline Report.

In South Sudan, and particularly Upper Nile State, water availability and accessibility in healthcare facilities are severely constrained by conflict-related destruction, weak infrastructure, and limited operational capacity (UNICEF South Sudan, 2022; WHO South Sudan, 2021; OCHA, 2022; Muzaale, 2021). Many health facilities rely on intermittent, unsafe, or distant water sources, which undermine essential healthcare functions such as infection prevention and maternal care services (International Rescue Committee, 2021; Adams *et al*., 2023; Brown & Juma, 2023). In some areas, access to improved water sources remains extremely low, with rural and conflict-affected counties experiencing near-total dependence on unprotected sources (OCHA, 2022; UNICEF, 2021; Smith *et al*., 2021). Additionally, water quality challenges persist due to contamination risks, further increasing vulnerability to waterborne diseases among patients and healthcare workers (UNICEF, 2021; Brown & Juma, 2023). Despite documented humanitarian reports on water scarcity in South Sudan, there remains a critical lack of rigorous empirical research that systematically assesses how water availability and accessibility affect health service delivery outcomes in Upper Nile State healthcare facilities. Existing evidence is fragmented, largely descriptive, and insufficient for informing evidence-based policy and health system strengthening interventions.

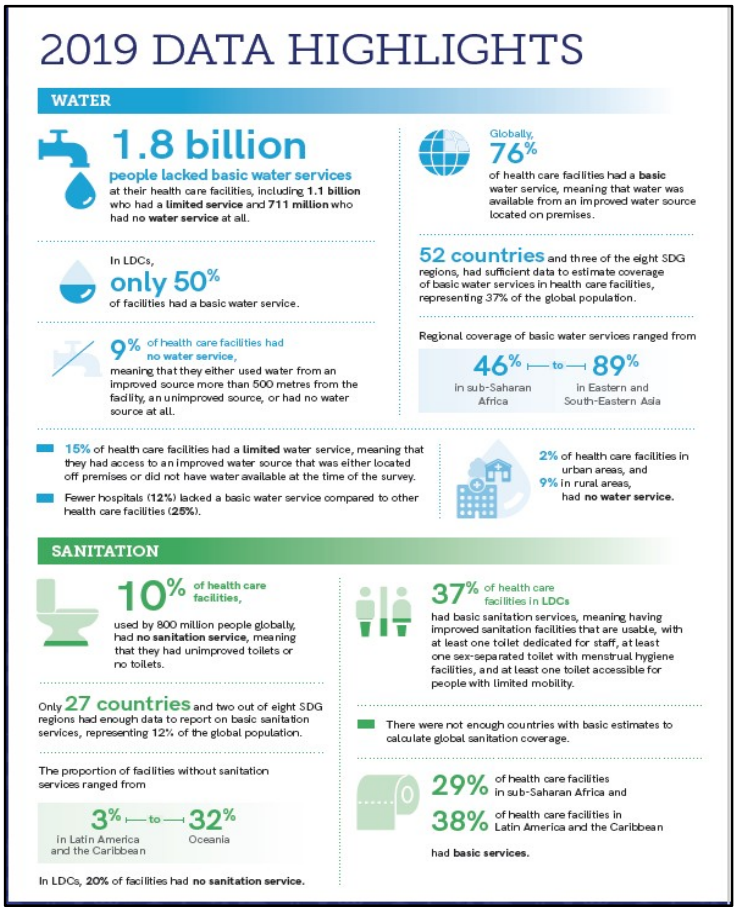


Figure 2. 2: JMP 2019 Data Highlights (WHO, 2020).

Across global, regional (Africa), East African, and South Sudanese literature, substantial evidence confirms that water supply availability and accessibility are critical determinants of effective healthcare service delivery. However, most existing studies are predominantly descriptive, policy-oriented, or based on broad national and regional estimates, with limited focus on facility-level empirical analysis. There is a consistent lack of integrated evidence linking water availability and accessibility directly to specific health service delivery outcomes such as infection prevention effectiveness, maternal and neonatal care quality, patient safety, and operational efficiency within healthcare facilities. Furthermore, very few studies have been conducted in fragile and conflict-affected contexts, particularly in South Sudan and Upper Nile State, where health systems are highly disrupted. Even where evidence exists, it is often fragmented, humanitarian-driven, and lacks rigorous quantitative assessment of causal relationships between water supply conditions and healthcare performance indicators. Therefore, a clear empirical and contextual gap exists in understanding how water supply availability and accessibility influence health service delivery in healthcare facilities in

Upper Nile State, South Sudan, limiting evidence-based planning and targeted health system strengthening interventions.

METHODOLOGY

Research Design and Approaches

The study used a mixed-methods approach combining qualitative and quantitative techniques. Qualitative methods explored participants' experiences using interviews, while quantitative methods measured variables using questionnaires and statistical analysis to validate findings and provide a comprehensive understanding of WASH and health service delivery. A descriptive cross-sectional mixed-methods design was used to assess WASH status and its effects at a single point in time. Data was collected through primary and secondary sources, and triangulation enhanced validity by integrating qualitative and quantitative evidence for comprehensive analysis.

Study Area

The study was conducted in Upper Nile State, South Sudan, a conflict-affected region with severe WASH and health system challenges. The area experiences displacement, flooding, and weak infrastructure, making it suitable for assessing how water, sanitation, and hygiene affect health service delivery.

Unit of Analysis

The primary unit of analysis was healthcare facilities, where WASH systems are implemented and assessed. Secondary units included healthcare workers, patients, and lactating mothers, whose experiences linked institutional WASH conditions to service delivery quality, safety, and patient outcomes.

Study Population

The study population comprised 1,320,360 people within the catchment area of healthcare facilities in Upper Nile State. It included urban and rural communities using health services, enabling assessment of WASH impacts on service delivery and supporting generalizable health system planning and policy decisions. The target population was 410 respondents, including 20 health facility administrators, 120 health workers, 180 inpatients, and 90 lactating mothers. These groups were selected to capture managerial, clinical, and patient perspectives on WASH conditions and their influence on healthcare service delivery.

Sampling Frame, Size and Selection

The sampling frame included all functional government healthcare facilities in Upper Nile State (PHCCs and hospitals) and key respondents within them. It ensured inclusion of administrators, health workers, inpatients, and lactating mothers, enabling facility-level and user-level assessment of WASH services. The sample size was determined using purposive selection, information power, and data saturation principles. A total of 84 participants were included, comprising administrators, health workers, inpatients, and lactating mothers, ensuring rich, relevant, and sufficient data for understanding WASH and health service delivery. The study used a combination of purposive and simple random sampling techniques. Facilities and key respondents were purposively selected based on relevance, while lists of eligible participants were used to randomly identify respondents, ensuring representativeness, reduced bias, and reliable data collection. Health administrators, staff, inpatients, and lactating mothers were included because they directly engage with or manage healthcare services, providing informed and diverse perspectives on WASH conditions and service delivery.

Inclusion and Exclusion Criteria

Inclusion criteria covered functional public health facilities, consenting adults, and relevant service users, while exclusion criteria removed PHCUs, private facilities, critically ill patients, mentally incapacitated individuals, and non-consenting participants to ensure ethical compliance, data validity, and relevance to public healthcare WASH conditions.

Data Collection Methods

The study used mixed methods including surveys, interviews, observation, experiments, and document review. These tools collected both quantitative and qualitative data on WASH conditions and health service delivery, ensuring triangulation, validity, and comprehensive understanding of facility-level water, sanitation, and hygiene conditions.

Structured questionnaires were administered to facility administrators using KOBO Toolbox to assess WASH conditions. The survey covered water, sanitation, waste management, and hygiene indicators, supported by trained research assistants, pilot testing, and ethical approvals to ensure accurate and reliable data collection.

Key informant interviews were conducted with health workers, inpatients, and lactating mothers to capture in-depth experiences of WASH services. The method provided contextual insights into service delivery challenges and complemented quantitative data for a more comprehensive understanding of healthcare conditions.

Direct observation was used to assess real-time WASH conditions in healthcare facilities, including water availability, sanitation, hygiene, and waste management. It validated information from interviews and surveys by capturing actual practices and environmental conditions within health service delivery settings. Water quality testing was conducted using residual-free chlorine indicators and the DPD method. This standardized approach assessed safety levels of treated water in healthcare facilities, providing objective evidence on water quality and its suitability for infection prevention and health service delivery. Facility records and reports were reviewed to obtain secondary data on patient attendance, admissions, and deliveries. This helped identify trends in service utilization and linked WASH conditions to healthcare demand, providing historical and institutional context to complement primary data findings.

Data Analysis

Data analysis followed Creswell's structured process of organizing, coding, and interpreting data. Quantitative and qualitative data were analyzed separately using statistical and thematic approaches, then integrated to generate comprehensive findings on WASH conditions and their effects on healthcare service delivery. Quantitative data were analyzed using SPSS version 27 through descriptive statistics, t-tests, regression, and Chi-square. These methods assessed relationships between WASH variables and service delivery outcomes, providing statistical evidence on the impact of water, sanitation, and hygiene in healthcare facilities.Qualitative data from interviews and observations were organized into themes using Excel matrices. Responses were coded, categorized, and interpreted to identify patterns and meanings related to WASH experiences, enabling structured understanding of participants' perspectives on healthcare service delivery. Qualitative data was analyzed using Thematic analysis involved coding qualitative data into themes and

sub-themes using Open Code 4.02. Repeated coding identified patterns and relationships in WASH experiences, allowing interpretation of participants' views on how water, sanitation, and hygiene conditions influenced healthcare service delivery.

Presentation of Findings

The availability and accessibility of water supply in healthcare facilities were assessed in 20 public facilities in Upper Nile State, comprising 16 PHCCs and 4 hospitals, with data from 82 respondents (20 administrators and 62 key informants). The study recorded a high overall response rate of 97.6%, despite some loss due to conflict-related displacement in Nasir County. Respondents were mainly clinical officers (45%), doctors (25%), nurses (20%), and midwives (10%), indicating informed facility-level reporting on WASH conditions.

Qualitative respondents were largely aged 31–40 years (40%), female (55%), and married (78%), reflecting active service users and caregivers. Most health staff had higher education (100%), while inpatients (60%) and lactating mothers (72%) had no formal education, highlighting vulnerability to WASH-related risks.

Most facilities were PHCCs (80%) and located in rural/peri-urban areas (80%), yet hospitals handled most patients (78%), showing imbalance in service demand and WASH pressure.

Table 1: Response Rate of the Study

Type	Tool	Target	Actual	Response Rate
Quantitative	Questionnaire	20	20	100%
Qualitative	KII	64	62	96.9%
Total		**84**	**82**	**97.6%**

The response rate was very high at 97.6%, indicating strong participation and reliable data collection. All quantitative questionnaires (100%) were completed by facility administrators, showing full institutional engagement. Qualitative responses also achieved 96.9%, with only slight loss due to conflict-related displacement. This high response rate strengthens the validity, credibility, and representativeness of the study findings on WASH and healthcare service delivery in Upper Nile State.

Table 2: Designation of Questionnaire Respondents

Designation	Number	%
Doctor	5	25
Clinical Officer	9	45
Nurse	4	20
Midwife	2	10
Total	**20**	**100%**

Most respondents were Clinical Officers (45%) and Doctors (25%), followed by Nurses (20%) and Midwives (10%). This distribution shows that the data was mainly provided by highly trained clinical personnel directly involved in healthcare service delivery. Their dominance enhances the reliability of responses, as they possess technical knowledge of WASH systems, infection prevention, and facility-level service performance.

Table 3: Characteristics of Health Facilities

Category	Type	%
Facility level	PHCC	80%
	Hospital	20%
Location	Rural/Peri-urban	80%
	Urban	20%
Patient load	Hospitals	78%
	PHCCs	22%

The findings show that most facilities were PHCCs (80%), while hospitals constituted only 20%, indicating a primary healthcare–dominated system. Most facilities were located in rural/peri-urban areas (80%), highlighting limited urban health infrastructure. However, hospitals handled the majority of patients (78%), suggesting higher service pressure and greater WASH demand at higher-level facilities compared to PHCCs.

Empirical Findings

The results are based on question items extracted from the primary dataset, including indicators such as level of water service (basic, limited, or none), main sources of water supply (e.g., boreholes, surface water, piped systems), and operational conditions such as on-premises availability and water quality testing practices.

Descriptive Analysis on Water Availability in Healthcare Facilities
To assess the availability and quality of water in healthcare facilities, descriptive statistics were generated using key variables extracted from the dataset. The analysis focused on two main aspects: the level of water service and the source of water available at each facility. The variable corresponding to water service levels was derived from responses to the question: "What is the level of water service in your facility?" with response options including No Water Service, Limited Water Service, and Basic Water Service. In addition, data on water sources were drawn from the question: "What is the main source of water used by the facility?", which included responses such as Tube Wells/Boreholes, Surface Water (River/Lake), Piped Water (Inside/Outside Building), Water Trucking, and No Water Source.These variables were selected due to their central role in understanding the foundational readiness of healthcare settings to deliver safe services, particularly in fragile and conflict-affected regions like Upper Nile State. The descriptive results presented in Table 4 provide insight into the distribution and frequency of water access across facilities, revealing critical infrastructure gaps.

Table 4: Distribution of Water Service Levels and Main Water Sources in Healthcare Facilities

Category	Indicator	Frequency (n)	Percentage (%)
A. Water Service Level	No Water Service	7	35
	Limited Water Service	6	30
	Basic Water Service	7	35
B. Main Source of Water	Tube Wells/Boreholes	7	35
	Surface Water (River/Lake)	5	25
	Piped Water (Outside Building)	3	15
	Piped Water (Inside Building)	2	10
	No Water Source	2	10
	Water Trucking	1	5

Source: Author's Computation from Primary Dataset, 2025.

Table 4 shows that 35% of the healthcare facilities reported having no water service, while another 30% had limited service and 35% had basic water service, and. This means that only about one-third of the facilities had reliable water access, which is essential for safe healthcare delivery. The average number of facilities, with a standard deviation of 2.46, showing a moderate spread in water availability

across facilities. This means that on average, each water indicator was observed in about 4 to 5 facilities, and the number varied moderately across indicators (±2.46 facilities from the mean).

Regarding water sources, the most common source was tube wells or boreholes (35%), followed by surface water like rivers or lakes (25%). Piped water, both outside and inside the building, was only available in 25% of the facilities combined. The mean percentage across all sources is 22.2% with a standard deviation of 12.3%.

Plate 1: Piped Water storage tank in the compound in Malakal Teaching Hospital.

Source: Author (2025)

Plate 2: Piped Water storage taps outside the building in Malakal Teaching Hospital.

Source: Autho (2025)

This finding supports the purpose of the study, showing that many facilities lack safe and reliable water. Without water, it becomes difficult to maintain hygiene, conduct deliveries, and offer quality health services, especially in rural or conflict-affected areas.

Additionally, water quality assessment in the healthcare facilities revealed notable gaps. Only one facility reported testing its water and confirmed that residual chlorine levels met WHO standards. This indicates that regular water quality monitoring is largely absent across most facilities. In terms of quantity, half of the healthcare facilities reported having an insufficient water supply, with the issue being more common in remote Primary Health Care Centres (PHCCs). This suggests that both the safety and availability of water remain major challenges, particularly in hard-to-reach areas, and directly affect the ability of healthcare workers to maintain hygiene standards during health service delivery.

T-Test for Comparing Water Service Access between PHCCs and Hospitals

To assess whether the level of water service access differs significantly between facility types, an independent sample t-test was conducted using data extracted from responses to the question: "*What is the level of water service in your facility?*" Respondents were asked to categorize water service levels as either No Water Service, Limited Water Service, or Basic Water Service, which were then coded numerically for analysis. Facility types were also identified through the item: "*What type of facility is this?*", with options including Primary Health Care Centres (PHCCs) and Hospitals.

These two variables, including water service level (as the dependent variable) and facility type (as the grouping variable) were used to test for statistically significant differences in mean water service scores. This comparison is critical in identifying disparities in infrastructure between lower-tier PHCCs and more centralized hospitals, especially in resource-constrained settings like Upper Nile State. By comparing the mean scores of each facility type, the test provides insight into how facility classification influences access to basic water services, which are essential for hygiene, patient care, and service delivery. The results are summarized in Table 5.

Table 5: Independent Sample T-Test Comparing Water Service Access Between PHCCs and Hospitals (N = 20)

Facility Type	Sample Size (n)	Mean Water Service Score	Std. Deviation	Mean Difference	p-value (Sig.)
PHCCs	16	1.75	0.775		
Hospitals	4	3.00	0.000	**1.25**	**0.003***

Note: *p < 0.05 indicates a statistically significant difference between facility types.*

Source: Author's Computation from Primary Dataset, 2025.

Table 5 shows that hospitals had a higher mean score (3.00) for water service levels compared to PHCCs (1.75). The mean difference of 1.25 and a significance value (p = 0.003) indicate a statistically significant difference in water access between the two facility types. This suggests that hospitals are better equipped with functional water sources, while PHCCs continue to struggle with limited or no water service. The lack of consistent water supply in PHCCs affects basic hygiene, infection control, and service provision, especially during deliveries and outpatient treatments. These results align with the study's objective of assessing water availability and accessibility, confirming that rural and lower-level facilities remain most affected. This variation stresses the urgent need for equitable water infrastructure development across all healthcare facilities in Upper Nile State.

Table 7: Logistic Regression Analysis Showing Predictors of No Water Service in Healthcare Facilities in Upper Nile State

Predictor Variable		Freq	Sig.(p)	Exp(B)/OR
Facility Type	Hospital	4	0.041*	2.589
	PHCC	16		
Surface Water	Otherwise	15	0.018*	3.099
Source	Uses surface water	5		
No On	On-premise supply	3	0.006*	4.398

Premise	available			
Supply	No on-premise supply	17		
No Water	Testing done	6	0.028	2.090
Quality Test	No testing of water quality	14		

Source: Author's Computation from Primary Dataset, 2025.

Table 7 indicates that several structural and operational factors significantly predicted the likelihood of a healthcare facility having no water service. Facilities classified as PHCCs had higher odds (Odds Ratio (OR) = 2.589, p = 0.041) of lacking water service compared to hospitals. Similarly, those relying on surface water such as rivers or lakes were over three times more likely to report no water service (OR = 3.099, p = 0.018). The strongest predictor was the absence of an on-premise water supply, where facilities without water within the compound were 4.398 times more likely to lack water (p = 0.006). Facilities that did not conduct any water quality testing also had higher odds of no water service (OR = 2.090, p = 0.028). The average odds ratio across the predictors was 3.04, with a standard deviation of 0.94, showing a consistent pattern of risk among all factors.

These findings align with the study's objective, which sought to assess the availability and accessibility of water sources in healthcare facilities across Upper Nile State. The data suggest that lack of infrastructure such as on-site water supply and safe, reliable sources like boreholes, as well as limited operational practices like repair of water systems, significantly influence whether facilities can provide basic water services. Improving these factors could enhance service delivery and health outcomes in conflict-affected regions.Many lactating mothers reported the absence of clean water during delivery and postnatal care. One mother from Fashoda PHCC recounted the hardship she faced, saying:

> *"I had to bring water from home in a jerrycan. There was nothing to use after delivery, not even for washing the baby. The nurse tried her best, but how can she help with no water?"(KII 12 – Lactating Mother, OrinyPHCC)*

In Baliet PHCC, the only option available to one mother was untreated river water:

> *"I had to boil river water. That's the only option the facility had. No clean water, no taps, nothing."(KII 07 – Lactating Mother, Baliet PHCC)*

These responses reflect how water scarcity impacts maternal care, aligning with the regression finding that PHCCs and facilities using surface water are at significantly higher risk of having no water service.

Inpatients described unreliable access to water for basic hygiene and care. One patient in Longochuk PHCC explained:

> *"There was one tap outside, and it was dry most of the time. We had to wait or ask caretakers to go to the river."(KII – Inpatient, Longochuk PHCC)*

Others raised concerns over personal hygiene and medical care:In more equipped facilities like Renk Hospital, availability was still inconsistent:

> *"The hospital in Renk had tanks, but sometimes there was no fuel to pump water."(KII 40 – Inpatient, Renk Hospital)*

These narratives show the real effects of lacking on-premise water supply also identified in the regression model as the most significant predictor of poor water service.

Health workers, often the frontline implementers of hygiene and infection prevention measures, described how water shortages compromise both their professional capacity and the dignity of the services they provide.

Health staff repeatedly highlighted how water shortages limit their ability to deliver care:

> *"Chronic water shortages are disrupting daily operations and greatly limiting our ability to deliver safe and dignified care. Without reliable access to clean water, the provision of essential tasks such as hygiene care, infection prevention work and caring for patients' basic needs become extremely difficult, if not impossible. We are forced to delay treatments, reduce services and to work in settings that threaten not only patient safety, but also their professional standards." (KII 55 – Health Staff, Chotbora PHCC)*

Health workers' testimonies echo and validate the regression findings, illustrating that water-related challenges are not abstract constraints, since they are daily operational barriers that directly affect the safety, timeliness, and quality of patient care.The above question items directly relate to the quantitative predictors identified through logistic regression specifically: facility type, reliance on surface water, absence of on-premise water supply, and lack of water quality testing. The rich, lived experiences shared by informants revealed how these predictors manifest in practice, affecting not just infrastructure but also dignity, safety, and the quality of care.

DISCUSSION

The current study found that hospitals in Upper Nile State had significantly better water service access than PHCCs, confirming a persistent inequality in WASH infrastructure between higher-level and lower-level health facilities. These findings agree with Cronk and Bartram, who reported that rural and lower-tier facilities in fragile settings frequently experience inadequate or intermittent water supply. Similarly, the findings corroborate World Health Organization and United Nations Children's Fund (2019), which concluded that conflict-affected health systems suffer from severe disparities in WASH investment, especially in decentralized facilities. The higher water service scores observed in hospitals compared to PHCCs therefore confirm global evidence that centralized hospitals receive greater infrastructural investment, supervision, and operational support than peripheral healthcare units. However, the findings slightly disagree with the decentralization principles of primary healthcare systems, which advocate equitable resource allocation across all levels of care. This demonstrates that despite policy intentions, PHCCs in fragile settings remain disproportionately underserved, limiting their capacity to provide safe maternal care, infection prevention, and quality health services.

The study further revealed that only 35% of healthcare facilities had basic water services, while 35% had no water service and 30% had limited service, confirming the widespread inadequacy of safe water access in conflict-affected healthcare settings. These findings strongly agree with the WHO/UNICEF Joint Monitoring Programme (2021), which reported that nearly half of healthcare facilities in sub-Saharan Africa lacked basic water services. The findings also corroborate Adane *et al.,* (2019), who found that healthcare facilities depending on surface water and unprotected sources were more vulnerable to waterborne infections and failed to meet WHO safety

standards. Similarly, the findings confirm Blanton *et al.,* (2010), who observed that reliance on rivers and lakes increased exposure to cholera and diarrheal infections within healthcare environments. The current study extends these earlier findings by demonstrating that facilities relying on surface water were over three times more likely to have no water service. This therefore strengthens existing evidence that unsafe and unreliable water sources significantly compromise infection prevention, patient safety, and healthcare utilization in fragile contexts.

Qualitative findings from health workers, patients, and mothers further demonstrated that unreliable water supply negatively affected infection prevention, maternal healthcare, and staff performance within healthcare facilities. These findings agree with Kayiwa *et al*., (2020), who established that absence of on-premise water supply limited consistent hygiene practice and emergency healthcare delivery in Ugandan health facilities. The findings also corroborate Bouzid *et al*., (2018), who reported that inadequate water services forced health workers to improvise with unsafe water sources, thereby compromising infection control standards and staff morale. Furthermore, the findings strongly confirm Velleman *et al*., (2014), who observed that women avoided health facility deliveries where water and sanitation conditions were poor. In Upper Nile State, many mothers preferred home deliveries because PHCCs lacked reliable water and hygiene services, increasing maternal and neonatal health risks. These converging findings therefore demonstrate that water supply is not merely a supporting utility, but a fundamental requirement for safe, dignified, and trusted healthcare delivery in conflict-affected settings.

CONCLUSION

The study concludes that water supply services in healthcare facilities in Upper Nile State are critically inadequate, unreliable, and unevenly distributed, particularly in Primary Health Care Centres (PHCCs) located in rural and conflict-affected areas. Most facilities lacked basic water services, depended on unsafe water sources such as rivers and surface water, and rarely conducted water quality testing. Statistical analysis confirmed that PHCCs, absence of on-premise water supply, use of surface water, and lack of water testing were major predictors of water scarcity. These deficiencies significantly compromise infection prevention and control, maternal and neonatal healthcare, hygiene practices, patient safety, and overall quality of healthcare service delivery. The study therefore establishes that inadequate water infrastructure is a major structural barrier to effective healthcare delivery in Upper Nile State.

The study further concludes that inequalities in WASH investment between hospitals and PHCCs have created a two-tier healthcare system where rural populations remain disproportionately exposed to poor healthcare conditions and preventable infections. Qualitative evidence from health workers, patients, and lactating mothers confirmed that unreliable water access delays treatment, increases dependence on unsafe coping mechanisms, and discourages utilization of maternal and child healthcare services. The findings demonstrate that improving healthcare outcomes in conflict-affected settings cannot be achieved without strengthening water supply systems, ensuring routine water quality monitoring, and integrating WASH services into healthcare planning, financing, and emergency response mechanisms.

Recommendations

The National Ministry of Health, in collaboration with the State Ministry of Health, should develop and enforce a comprehensive WASH-in-Healthcare Facilities policy framework that prioritizes equitable water infrastructure investment in PHCCs and rural healthcare facilities. The government should allocate dedicated budget lines for installation of on-premise water systems, solar-powered boreholes, piped water connections, water storage facilities, and regular water quality monitoring systems in all public healthcare facilities. In addition, the Ministry of Health should integrate WASH indicators into routine health facility performance monitoring and national healthcare accreditation systems to ensure accountability and sustainability.

Humanitarian organizations, development partners, and international agencies such as World Health Organization, United Nations Children's Fund, and non-governmental organizations operating in Upper Nile State should support emergency and long-term rehabilitation of WASH infrastructure in healthcare facilities, particularly in conflict-affected and hard-to-reach areas. These partners should provide technical assistance, emergency water treatment supplies, mobile water systems, and capacity-building programs for healthcare workers on water safety management and infection prevention practices. They should also support operational research and digital monitoring systems to strengthen evidence-based WASH planning and emergency preparedness.

Healthcare facility administrators and county health departments should establish routine facility-level WASH management committees responsible for water safety planning, infrastructure maintenance, water quality testing, and emergency response coordination. Facility managers should ensure continuous availability of safe water within healthcare premises, strengthen preventive maintenance systems for boreholes and storage tanks, and improve reporting mechanisms for WASH service interruptions. Furthermore, health workers should be regularly trained on infection prevention and control protocols, rational water use, and emergency hygiene measures to minimize healthcare-associated infections during periods of water shortage.

Local governments, community leaders, and community-based organizations should actively participate in protecting community water sources, supporting maintenance of healthcare water infrastructure, and promoting public awareness on safe water handling and hygiene practices. Communities should be engaged through participatory WASH governance structures to strengthen accountability and sustainability of healthcare water services. In addition, policymakers should mainstream WASH interventions into post-conflict recovery and health sector reconstruction programs to ensure that rural and underserved populations have equitable access to safe and reliable healthcare services.

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