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Research Article

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Effectiveness of Traditional Water Purification Methods in Preventing Waterborne Diseases such as Cholera in Kassala State

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Abstract

Background: *Access to safe drinking water is a fundamental determinant of public health, yet it remains a critical challenge in conflict-affected regions like Sudan. In rural and semi-urban communities, households often rely on Indigenous Traditional Knowledge (ITK) for water treatment. Common methods include sedimentation using clay pots (Zirs), boiling, and coagulation using natural plant derivatives such as Moringa oleifera seeds (locally known as Rauwa) to clarify turbid water. While these methods are historically rooted, they are often labor-intensive and inconsistent. For instance, boiling is frequently abandoned due to the high cost of fuel, while simple sedimentation fails to eliminate microscopic pathogens like Vibrio cholerae effectively.*

The urgency of effective water purification has escalated dramatically since the onset of the conflict. The collapse of the national water infrastructure has forced millions to rely on unregulated water trucking vendors. Consequently, Sudan declared a severe cholera outbreak in August 2024, which began in Kassala State and rapidly spread across the country. By early 2025, the Federal Ministry of Health reported over 50,000 confirmed cases and 1,350 associated deaths, with Kassala remaining a major hotspot due to the high influx of Internally Displaced Persons (IDPs).

In East/West Al-Qash, the primary challenge is not merely the source of water, but its storage. Residents heavily depend on household storage cisterns (Tanakir) to store water purchased from mobile tankers. Research indicates that even if water is sourced safely, secondary contamination often occurs within these cisterns due to biofilm formation and lack of residual chlorination. This study posits that the "Knowledge-Practice Gap" where families are aware of cholera but trust their storage tanks blindly is a leading driver of the continued epidemic in the region.

Methods: *A cross-sectional descriptive study was conducted in East/West Al-Qash, Kassala State. Data was collected from 100 participants using a structured questionnaire covering demographics, water handling practices, and disease awareness.*

Results: *The analysis revealed that 63 households rely on water tankers as their primary source. Despite a high level of educational attainment, represented by 78 university graduates, a significant 59 respondents reported not practicing any form of water purification. Among the methods utilized, boiling was cited by 41 participants, while solar disinfection*

was used by 29 others. The study identified critical barriers; specifically, 71 individuals believe their water is already safe, and 62 perceive traditional methods as too time-consuming. Furthermore, while cholera awareness is high among 96 residents, 67 confirmed witnessing cases within East/West Al-Qash.

Conclusion: *This study establishes that a critical "knowledge-practice gap" exists in East/West Al-Qash, where high health literacy is undermined by a misplaced trust in household cisterns (Tanakir) and the operational burden of traditional purification methods. The persistence of cholera in the region is likely fueled by secondary contamination within these storage units rather than a lack of awareness. Therefore, to effectively dismantle the transmission cycle, public health strategies must pivot from general education to capability enablement. It is strongly recommended to prioritize the distribution of household water filters and chlorine tablets, a solution endorsed by 77% of the community, and to implement systematic chlorination campaigns targeting residential Tanakir. These measures address the community's demand for time-efficient solutions and are essential for securing water safety at the point of use.*

Chapter One Introduction and Literature review

1. Introduction

1.1. Background

Access to safe drinking water is a fundamental requirement for human health and dignity. However, it remains a critical challenge in low-resource settings, particularly in conflict-affected regions like Kassala State, Sudan. In such areas, the collapse of infrastructure and limited access to modern water treatment have forced communities to rely on Indigenous Traditional Knowledge (ITK) and simple household water treatment (HWT) methods to mitigate the risk of waterborne diseases [1].

1.2. Common Traditional Water Purification Methods

In the context of East/West Al-Qash, communities employ various methods to treat water at the household level. Based on the analysis conducted in this study, the most prevalent methods are:

- **Boiling** (Used by 41%):
- Definition: The process of heating water to a rolling boil for at least 1–5 minutes.
- Mechanism: It is the most effective method for killing vegetative bacteria, viruses, and protozoa. However, it requires fuel and does not remove turbidity or chemical contaminants.
- **Solar Disinfection** (SODIS) (Used by 29%):
- Definition: Filling transparent plastic bottles (PET) with water and exposing them to direct sunlight for at least 6 hours.
- Mechanism: UV-A radiation and thermal heating work synergistically to inactivate pathogens. It is low-cost but limited by water turbidity and weather conditions.
- **Filtration** (Cloth/Sand) (Used by various segments):
- Definition: Passing water through a porous barrier (clean cotton cloth or sand layers) to separate particulate matter.
- Mechanism: Primarily removes suspended solids and some larger parasites (e.g., Dracunculus larvae), but is less effective against bacteria unless combined with other methods.
- **Sedimentation & Coagulation** (Traditional "Rauwa"):
- Definition: Allowing water to stand so suspended particles settle, often enhanced by natural coagulants like Moringa oleifera seeds.
- Mechanism: Clarifies turbid water by neutralizing the charge of suspended particles, causing them to clump and settle [2].

1.3. Waterborne Diseases in Kassala State

Due to the reliance on open water sources (river Gash, seasonal rainwater) and the extensive use of household storage cisterns (Tanakir), the population is exposed to a variety of waterborne pathogens. Table (1.1) summarizes the common organisms associated with water contamination in the region:

Category	Organism	Associate Disease
Bacteria	Vibrio Cholerae	Cholera (Sever Watery Diarrhea)
	Salmonella Typhi	Typhoid Fever
	Escherichia Coli	Gastroenteritis / Diarrhea
	Shigella spp.	Dysentery(Bacillary)
Protozoa	Giardia Lamblia	Giardiasis
	Entamoeba Histolytica	Amoebic Dysentery

Viruses	Rotavirus / Hepatitis A	Viral Gastroenteritis / Hepatitis

Table (1.1): Common Waterborne Pathogens in Kassala State

While multiple pathogens exist, this research specifically focuses on Cholera, given the severe outbreaks witnessed in the state recently.

1.4. Cholera: Comprehensive Profile

1.4.1. Definition and General Characteristics

Cholera is an acute diarrheal infection caused by ingestion of food or water contaminated with the bacterium Vibrio cholerae.

- Morphology: It is a Gram-negative, comma-shaped (vibrio), non-spore-forming rod.
- Motility: Highly motile due to a single polar flagellum (darting motility).
- Atmosphere: Facultative anaerobe.
- pH Tolerance: It is an alkaliphile, growing best at pH 8.0–9.5, which is a key feature used for its isolation from other gut flora.
- Halophilic Nature: Unlike other Vibrio species (e.g., V. parahaemolyticus), V. cholerae can grow without added sodium chloride (NaCl), although its growth is stimulated by trace salt [3,4].

1.4.2. Classification (Serotypes and Biotypes)

V. cholerae is classified based on the somatic (O) antigen into:

1. Serogroup O1: The primary cause of epidemic cholera. It is further subdivided into:
- Biotypes: Classical and El Tor (El Tor is responsible for the current 7th pandemic).
- Serotypes: Both biotypes are further divided into three serotypes based on antigenic factors (A, B, C):
- Ogawa: (Factors A, B) - The most common serotype in recent Sudan outbreaks.
- Inaba: (Factors A, C).
- Hikojima: (Factors A, B, C) - Rare and unstable.
2. Serogroup O139 (Bengal): Emerged in 1992, causes epidemics similar to O1.
3. Non-O1/Non-O139: Cause mild gastroenteritis but not epidemic cholera [5].

1.4.3. Laboratory Diagnosis and Culture

- Transport Media: Cary-Blair medium is essential for preserving the organism in stool samples.
- Enrichment Media: Alkaline Peptone Water (APW) (pH 8.6) is used to enrich Vibrio growth while inhibiting other intestinal flora.
- Selective Media: Thiosulfate Citrate Bile Salts Sucrose (TCBS) Agar.
- Appearance: V. cholerae ferments sucrose, producing large, yellow colonies against the green background of the agar.

1.4.4. Biochemical Characteristics

Vibrio cholerae is biochemically active. Table (1.2) details the specific biochemical profile used for identification.

Test	Result	Notes
Oxidase	Positive (+)	Key test differentiating Vibrios (Pos) from Enterobacteriaceae (Neg)
Indole	Positive (+)	Produces red ring; differentiates from V. parahaemolyticus (Neg)
Methyl Red (MR)	Positive (+)	Mixed acid fermentation
Voges-Proskauer(VP)	Variable	El Tor biotype is usually VP positive; Classical is VP negative
Citrate Utilization	Positive (+)	Can use citrate as a sole carbon source

Urease	Negative (-)	Does not hydrolyze urea
String Test	Positive (+)	Mucoid string forms when mixed with 0.5% sodium deoxycholate
O/129 Sensitivity	Sensitive	Inhibited by Vibriostatic agent O/129 (differentiates from Aeromonas)

Table (1.2): Biochemical Profile of Vibrio Cholerae

1.4.5. Pathogenesis

The pathogenicity is driven by the Cholera Toxin (CT), a potent AB5 enterotoxin. Upon colonization of the small intestine, the B-subunit binds to the GM1 ganglioside receptor. The A-subunit enters the cell and activates adenylate cyclase, leading to massive accumulation of cAMP. This causes the hyper-secretion of chloride ions and water into the intestinal lumen, resulting in the characteristic "rice-water stool", rapid dehydration, and electrolyte imbalance [6].

1.5. Epidemiology

1.5.1. Global Burden

Cholera remains a global threat to public health and an indicator of inequity and lack of social development. According to the World Health Organization (WHO), there are an estimated 1.3 to 4.0 million cases and 21,000 to 143,000 deaths worldwide each year [7].

1.5.2. Situation in Sudan and Kassala (2024-2025)

The conflict in Sudan has severely impacted the health system, leading to the collapse of water sanitation infrastructure.

- National Level: In August 2024, a major outbreak was declared. By early 2025, reports indicated over 50,000 cases nationwide, with a significant case fatality rate.
- Kassala State: Kassala has been a hotspot for the epidemic due to the high density of Internally Displaced Persons (IDPs) and the reliance on mobile water tankers. The link between water contamination in storage cisterns and infection rates has been a critical concern, necessitating this study to evaluate the community's purification practices [8].

1.6. Literature Review

Household water treatment methods are essential for preventing cholera, yet their effectiveness varies depending on technical, behavioral, and contextual factors. Conducted a landmark three-year field trial in Bangladesh, demonstrating that filtering surface water through four layers of old sari cloth reduced cholera incidence by 48% by mechanically removing zooplankton to which Vibrio cholerae attaches [9]. further emphasized that while cloth filtration removes particulates, secondary disinfection is necessary to eliminate free-floating bacteria [10]. In Cambodia, evaluated locally produced ceramic filters and reported a 99.99% reduction in bacterial load, but highlighted filter breakage as a major sustainability challenge in rural areas [11]. Solar disinfection (SODIS) is another low-cost intervention proven effective under optimal conditions. established the standard SODIS protocol, showing that exposing water in PET bottles to sunlight for six hours inactivates pathogens via UV-A radiation [12]. Documented a 26% reduction in severe diarrhea among Maasai children using SODIS, demonstrating its viability in African settings, while Meierhofer and Wegelin (2002) noted that shaking bottles to increase oxygen saturation enhances the photo-oxidative kill rate [13,14] Chemical and physical methods such as chlorination and boiling remain widely recommended. Conducted a meta-analysis showing that chlorination is the most cost-effective household intervention, reducing diarrhea risk by 29%, although taste-related rejection can limit adoption [15]. Noted that turbid water requires higher chlorine doses to maintain residual protection [16]. Boiling is microbiologically complete; however, reported that 40% of households recontaminate boiled water during cooling and storage due to poor hygiene [17]. Natural coagulants such as Moringa oleifera seeds have been shown to reduce turbidity by 80–99% and bacterial load by 90–99% though cautioned that treated water must be consumed within 24 hours to prevent bacterial regrowth [18,19]. Globally, cholera remains a significant public health concern, with an estimated 2.9 million cases annually, the majority in Sub-Saharan Africa [20]. Genomic sequencing has traced African outbreaks to single introduction events from South Asia, highlighting the role of global travel [21]. Conflict and war amplify outbreaks, as seen in Yemen, where over one million cases were linked to destruction of sanitation infrastructure, and in Haiti, where imported strains caused widespread infection in a naïve population [22,23]. Climate events, including El Niño, have also been correlated with cholera outbreaks in river deltas [24]. Oral cholera vaccines (OCV) are effective but insufficient without concurrent WASH interventions [25]. In Eastern Sudan, cholera outbreaks have been historically frequent. Reported over 20,000 cases during the 2006 floods, with Kassala as a major amplification hub [26]. Documented high attack rates in Aroma and Telkouk during the 2016 outbreak, linking infections to direct consumption of Gash River water [27]. The 2023–2024 crisis, driven by the influx of internally displaced persons, overwhelmed local water stations, resulting in high mortality [28,29]. Cross-border transmission and flooding from the Ethiopian highlands exacerbate

contamination [30,31]. Household storage practices significantly contribute to waterborne disease transmission. Identified secondary contamination in 60% of household Tanakir in Kassala and Port Sudan [32]. Local practices such as skipping Moringa filtration rejection of chlorine tablets due to taste and hand-dipping into clay pots leading to rapid bacterial proliferation further increase risk [33-35]. Donkey carts using unclean barrels act as mobile contamination vectors [36]. Health education improves practices temporarily, but behaviors revert without sustained interventions [37].Confirmed that time constraints are a major barrier for women in Eastern Sudan, aligning with operational challenges identified in this study [38]. Collectively, these global, regional, and local studies demonstrate that while multiple household water treatment methods are technically effective, practical, behavioral, and infrastructural barriers limit their adoption. This literature underscores the necessity of interventions that are technically sound, culturally acceptable, and operationally feasible, forming the foundation for the current study in East/West Al-Qash.

1.7. General Objective

To evaluate the effectiveness of traditional water purification methods in reducing the risk of waterborne diseases, particularly cholera, in epidemic-prone areas such as Kassala State.

1.7.1. Specific Objectives

- To identify the types of traditional water purification methods commonly used in Kassala State.
- To assess the effectiveness of these methods in reducing microbial contamination, with a focus on Vibrio cholerae.
- To analyze the relationship between the use of traditional purification practices and the incidence of cholera outbreaks in Kassala.
- To compare traditional water purification methods with recommended modern techniques in terms of accessibility, affordability, and sustainability.
- To provide recommendations for integrating effective traditional purification methods into public health strategies for preventing waterborne diseases.

1.8. Research Questions

- What traditional water purification methods are commonly practiced in Kassala State?
- How effective are these traditional methods in reducing microbial contamination, particularly Vibrio cholerae?
- Is there an association between the use of traditional purification methods and the incidence of cholera outbreaks in Kassala?
- How do traditional purification methods compare with modern water treatment techniques in terms of accessibility, affordability, and sustainability?
- What recommendations can be made to improve the role of traditional purification methods in preventing waterborne diseases in epidemic-prone areas?

1.9. Justification

The urgency to conduct this research in East/West Al-Qash is driven by a convergence of critical epidemiological, environmental, and socio-economic factors currently affecting Kassala State.

- **Epidemiological Imperative (The Current Outbreak)**

Sudan is currently facing one of its most severe cholera outbreaks in decades, with Kassala State identified as a primary hotspot due to the massive influx of Internally Displaced Persons (IDPs) following the 2023-2024 conflict [8,28]. While national reports track mortality rates, there is a distinct lack of granular data regarding the behavioral drivers of transmission at the household level. This study is essential to understand why, despite widespread awareness campaigns, the infection curve remains flattened, suggesting a failure in current prevention strategies.

- **The "Secondary Contamination" Blind Spot:**

Most previous studies in Eastern Sudan have focused on the microbiological quality of source water (e.g., Gash River or Desalination Plants). However, a critical gap exists in evaluating the safety of "Point-of-Use" storage. With 63% of the population relying on mobile tankers and storing water in metal cisterns (Tanakir), there is a high probability that clean water becomes re-contaminated during storage due to biofilm formation and unhygienic handling [32]. This research is justified by the need to shift the focus from "Source Quality" to "Storage Hygiene."

- **Socio-Economic Constraints on Purification**

The current economic collapse and hyperinflation have rendered traditional purification methods unsustainable for many. The soaring cost of cooking gas and charcoal has forced families to abandon boiling, which was historically the most common method [38]. This study is crucial to document this shift and investigate low-cost, non-fuel-dependent alternatives (such as Chlorination or Solar Disinfection) that are realistic for the community's current financial capacity.

- **Addressing the Knowledge-Practice Gap**

Preliminary observations suggest a paradox in East/West Al-Qash: a highly educated population that does not practice water purification. Justifying this study is the need to scientifically dissect this "Knowledge-Practice Gap." Understanding whether the barrier is psychological (taste of chlorine), physical (turbidity of water), or economic (cost of fuel) is vital for the State Ministry of Health to design evidence-based interventions that go beyond simple "health education" to "behavioral enablement."

2. Chapter Two Methodology

2.1. Study Design

This research utilized a cross-sectional descriptive qualitative study design.

2.2. Study Areas

The study was conducted in East/West Al-Qash, located in Kassala State, Eastern Sudan, Africa. It was conducted via questionnaire online survey.

This area is characterized by its reliance on seasonal water sources and has been historically vulnerable to recurrent cholera outbreaks due to infrastructure challenges.

2.3. Study Population

The target population for this study included residents of East/ West Al-Qash.

- Inclusion Criteria: Any adult between the ages of 15 and 70 years.
- Exclusion Criteria: Non consented participants.

2.4. Sample Size and Sample Techniques

The required sample size for this study was determined using the standard statistical formula for cross-sectional studies:

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$$

Where:

- n = required sample size
- Z = Z-score (from normal distribution)
  - 1.96 for 95% confidence level
  - 2.58 for 99% confidence level
- p = estimated proportion (prevalence) from previous studies or pilot data
- d = margin of error (precision), e.g., 0.05 for ±5%

Z = 1.96 p = 0.3 D = 0.0725

Calculation:

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.1)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.01}$$

$$n = \frac{0.9604}{0.01}$$

$$n = 96.04$$

The target sample size was mathematically determined using Cochran's Formula for infinite populations ($n = Z^2pq/d^2$), assuming a prevalence (p) of 50% and a margin of error (d) of 10% due to the operational constraints in the conflict-affected zone.

The calculation yielded a baseline of 96 participants. However, to ensure better representation and account for potential non-response or incomplete questionnaires, the final sample size was rounded up to 100 participants, where each participant's response represents 1.0% of the total study population. This adjustment aligns with the study objectives and available resources, ensuring sufficient data for statistical validity.

2.5. Methods of Data Collection

A questionnaire is a methodical research tool used to gather opinions, behaviors, and specific information in a systematic way. The questionnaire was designed to be:

- Structured: Containing pre-determined closed-ended and open-ended questions.
- Objective: Focused on gathering accurate and reliable data.
- Analyzable: Responses were organized for statistical analysis.

The primary tool for data collection was the all type of (Structured, Objective, Analyzable) questionnaire.

The questionnaire covered four main areas: socio-demographic data, water source and storage, purification practices, and disease awareness.

The Question of questionnaire Was:

- Gender?
- Age?
- Educational level?
- What is the main Source of income?
- What is the main water source in your home?
- How many times per day do you fetch water?
- Where you store water in your home?
- Do you purify water?
- Which of the following traditional water Purification Methods do you usually use?
- How often you treat water?
- What are the taste of water?
- Is the taste acceptable?
- If the taste isn't acceptable, Which method do you use to improve the taste of water?
- Who is usually responsible for water Purification in household?
- If you don't purify water, what is the reason?
- Have you heard about Cholera or other Waterborne Disease?
- If yes, Where did you mostly get your information from?
- To what extent do you think traditional water purification methods are effective against Cholera?
- Do your family members know the sign of Cholera (watery diarrhea, vomiting, dehydration)?
- In the last 12 months, has any family member had acute watery diarrhea?
- If yes, how many cases were there?
- Have you seen confirmed Cholera cases in the community in the past two years?
- What do you usually do if a family member has severe diarrhea?
- In your opinion, what are the benefits of boiling water?
- What are obstacles to using traditional water purification methods?
- Do you think simple intervention(health education, covered container's, sand filtration, etc) reduce the risk of Cholera infection?
- Are you willing to try new water purification methods if they are available and affordable?
- In your opinion, what is the most practical action to improve

water quality in your area?

2.6. Data Analysis

Responses gathered from the questionnaires were organized and analyzed statistically by (SPSS).

The findings are presented using frequencies and percentages, complemented by tables and figures to ensure clarity and scannability.

2.7. Ethical Consideration

Ethical approval for this study was obtained before data collection began. Informed consent was secured from every participant, ensuring they understood the purpose of the research. Furthermore, confidentiality and anonymity were guaranteed, and all data were used strictly for scientific research purposes.

3. Chapter Three Results and Data Analysis

This chapter presents the statistical results of the study conducted in East/West Al-Qash, Kassala State, based on a sample of 100 participants. The data is organized into tables and figures, followed by a descriptive analysis of each section.

Age:

Answer	Frequency	Percent
15 - 20 year	21	21.0%
21 - 25 year	36	36.0%
26 - 30 year	25	25.0%
31 - 35 year	6	6.0%
More than 35 years	12	12.0%
Total	100	100.0%

Table No (3.1): Shows the Population's Age

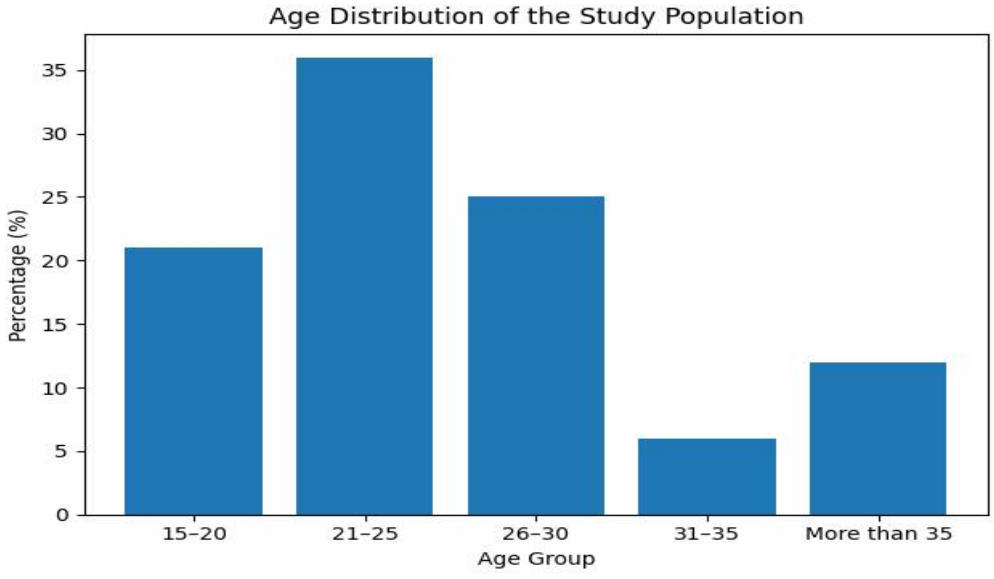


Figure: No (3.1)

- **Analysis**

The data indicates that the largest age group among respondents is 21-25 years, making up 36.0% of the sample, followed by the 26-30 years group at 25.0%. This suggests that the study captured a young and active segment of the population, which is crucial for implementing health awareness programs.

3.1. Educational level

Answer	Frequency	Percent
Uneducated	7	7.0%
Primary school	2	2%
Secondary degree	13	13.0%
University degree or above	78	78.0%
Total	100	100.0%

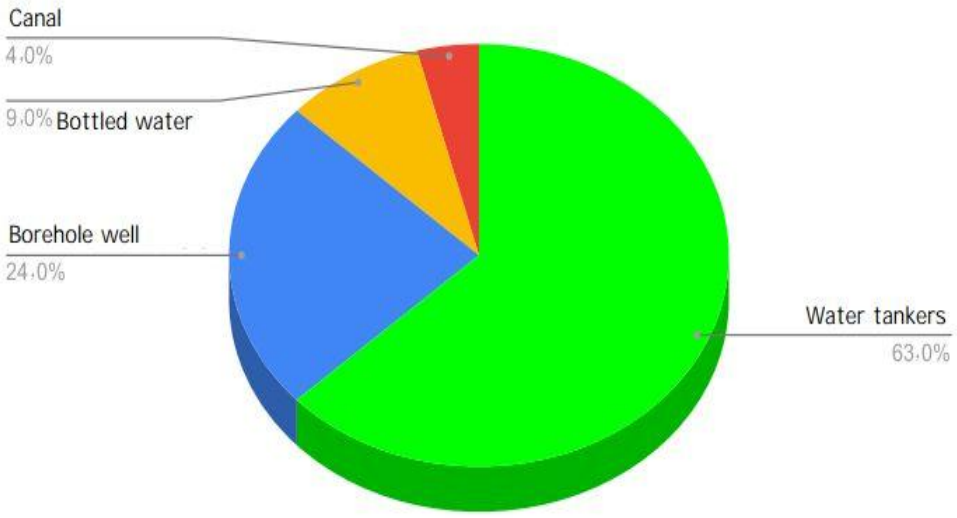
- **Analysis**

The educational level of the participants is notably high, with 78.0% of respondents holding a university degree or higher. Only 7.0% are uneducated, while 13.0% have a secondary degree. This high literacy rate among the sample is a critical factor, as it suggests that the majority of the population has the capacity to understand and implement complex health guidelines if provided with the right tools.

3.1.1. What is the main water source in your home?

Answer	Frequency	Percent
Water tankers	63	63.0%
Borehole well	24	24.0%
Bottled water	9	9.0%
Canal	4	4.0%
Total	100	100.0%

Table No (3.2): Shows the Population's Storage of Water



Main water source

Figure: No ((3.2))

3.3. Storage of water

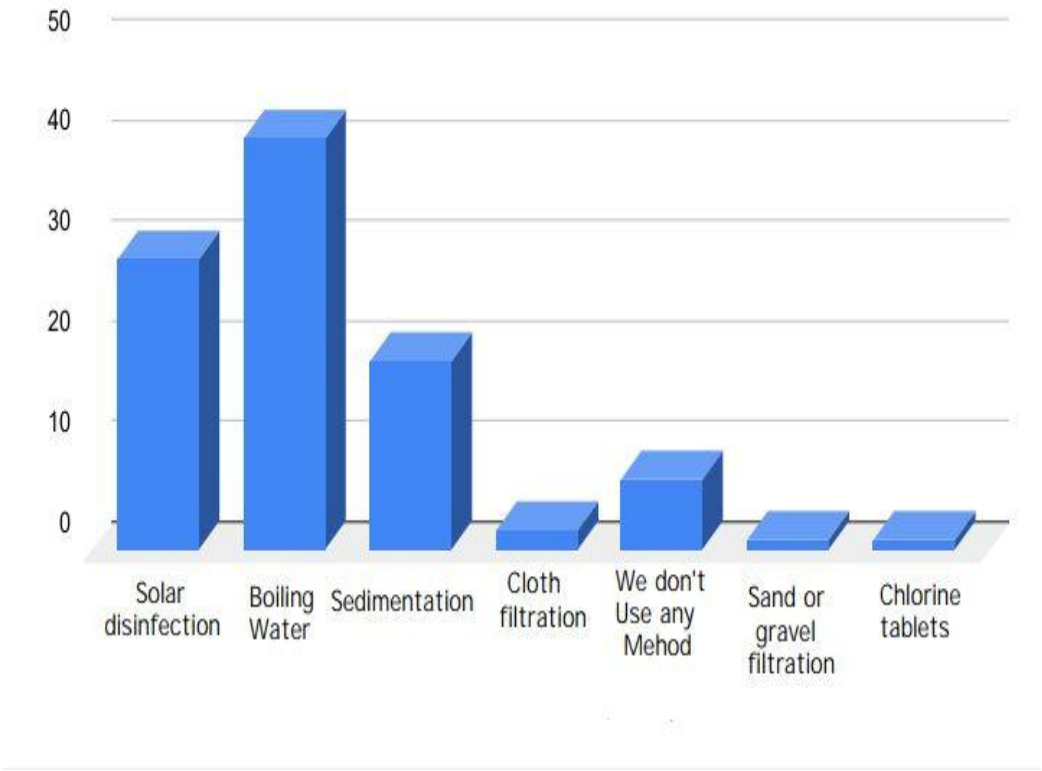
- **Analysis**

Regarding water storage, more than half of the population (56.0%) uses tanks, while 39.0% use closed containers. Although the majority use relatively safe storage methods, 5.0% still rely on open containers, which are highly susceptible to dust, insects, and external pathogens, posing a direct threat to water safety within the household.

3.3.1. Which of the following traditional methods do you usually use?

Answer	Frequency	Percent
Tank	56	56.0%
Closed container	39	39.0%
Open container	5	5.0%
Total	100	100.0%

Table No (3.3): Shows the Population's Traditional Water Purification Methods



Traditional water purification methods

Figure No (3.3):

3.4. Traditional water purification methods

- **Analysis**

Among the participants who treat their water, boiling (41.0%) is the most widely used traditional method, followed by solar disinfection (29.0%) and sedimentation (19.0%). Although these methods are culturally accepted and accessible, a small percentage uses more effective interventions like chlorine tablets (1.0%) or sand filtration (1.0%). Notably, 7.0% explicitly stated they do not use any method at all despite the availability of these options.

3.4.1. How Often You Treat Water

Answer	Frequency	Percent
Sometimes	42	42.0%
Rarely	35	35.0%
Always	23	23.0%
Total	100	100.0%

Table No (3.4): Shows the Population's Treating Water

- **Analysis**

The frequency of water treatment among respondents is highly inconsistent. While 41.0% of the population reported that they do purify water, only 23.0% of the total sample perform this task "Always". A combined 77.0% of the participants treat their water only "Sometimes" (42.0%) or "Rarely" (35.0%). This lack of consistency is a critical vulnerability during disease outbreaks, as intermittent purification does not provide continuous protection against waterborne pathogens.

3.4.2. What are the Taste of Water, and is it Acceptable?

Variable	Category	Frequency	Percent
Perceived Taste	Neutral	77	77.0%
	Salty	23	23.0%
Acceptability of Taste	Yes	84	84.0%
	No	16	16.0%
Total		100	100.0%

Table No (3.5): Shows the Population's Water Taste

- **Analysis**

Table (3.8) illustrates the physical characteristics (palatability) of the water used by the residents of East/West Al-Qash. Regarding the perceived taste, the majority of respondents (77%) described the water as neutral, while a significant minority (23%) reported it as salty. Despite the presence of salinity in some samples, the acceptability rate was notably high, with 84% of participants stating the taste is acceptable for consumption, whereas only 16% found it unacceptable.

Crucially, the data reveals a discrepancy between perception and acceptability: The percentage of people who accept the water (84%) is higher than those who find it neutral (77%). This implies that approximately 7% of the population consumes water they perceive as "salty" but still consider it "acceptable." This finding suggests a level of habituation to poor water quality among the community or a lack of alternative sources, forcing residents to lower their standards for potable water.

3.5. If You Don't Purify Water, What is the Reason?

Answer	Frequency	Percent
We believe the water is safe	71	71.0%
No time	12	12.0%
We don't know how	10	10.0%
It's expensive	7	7.0%
Total	100	100.0%

Table No (3.6) : Shows the Population's Reasons for Not Purifying Water

- **Analysis**

Among the segment of the population that does not treat their water, the overwhelming majority (71.0%) avoid it because they believe the water is already safe. Other significant barriers include a lack of time (12.0%), lack of knowledge regarding purification techniques (10.0%), and the perception that treatment is expensive (7.0%). These findings suggest that the lack of practice is largely driven by a false sense of security rather than just a lack of resources.

3.5.1. Have you Heard of Cholera or Other Waterborne Diseases? :

Answer	Frequency	Percent
Yes	96	96.0%
No	4	4.0%
Total	100	100.0%

Table No (3.7): Shows the Population's Awareness of Cholera and Other Waterborne Diseases

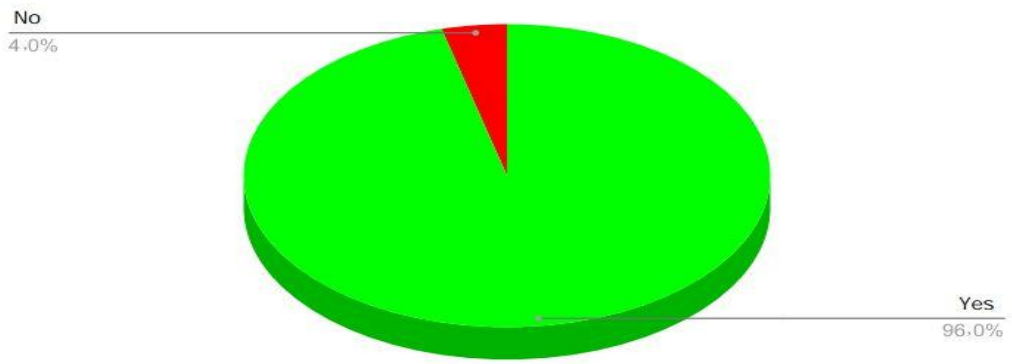


Figure No (3.7):

3.6. Awareness of Cholera and Other Waterborne Diseases

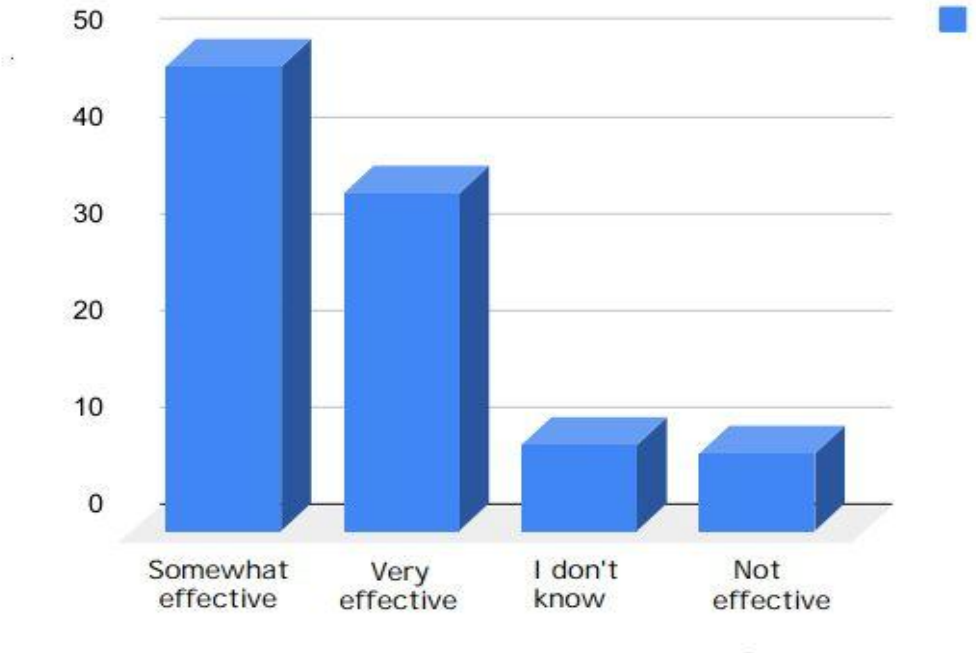
- **Analysis**

The data shows a very high level of health awareness in the community, with 96.0% of respondents stating they have heard of cholera or other waterborne diseases. Only a small minority (4.0%) reported no prior knowledge. This near-universal awareness is a positive indicator, suggesting that the population is well-informed about the existence of these health threats.

3.6.1. To what extent do you think traditional water purification methods are effective against cholera?

Answer	Frequency	Percent
Somewhat effective	48	48.0%
Very effective	35	35.0%
I don't know	9	9.0%
Not effective	8	8.0%
Total	100	100.0%

Table No (3.8): Shows Population's Perception of How Effective Traditional Water Purification Methods are Against Cholera



Perception of how effective traditional water purification methods are

Figure No (3.8):

3.7. Perception of How Effective Traditional Water Purification Methods are Analysis

The majority of respondents believe that traditional water purification methods have some level of effectiveness against cholera, with 48.0% viewing them as "Somewhat effective" and 35.0% as "Very effective". However, a combined 17.0% of the population either considers these methods "Not effective" (8.0%) or lacks sufficient knowledge to judge (9.0%). This indicates a high level of community trust in traditional practices, though it may also reflect a potential over-reliance on methods that might not provide full protection during severe outbreaks

3.8. In the Last 12 Months, has any Family Member had Acute Watery Diarrhea ?

Answer	Frequency	Percent
Yes	15	15.0%
No	85	85.0%
Total	100	100.0%

Table No (3.9): Shows the Occurrence of Acute Watery Diarrhea Among Family Members During The Past 12 Months

- **Analysis**

Regarding the health status of the households over the past year, 15.0% of the respondents reported that at least one member of their family suffered from acute watery diarrhea. Conversely, the majority (85.0%) did not experience such cases within their homes during this period. This percentage of occurrence highlight the ongoing risk of waterborne illnesses in the region despite the reported levels of awareness.

3.8.1. If Yes, How Many Cases Were There ?

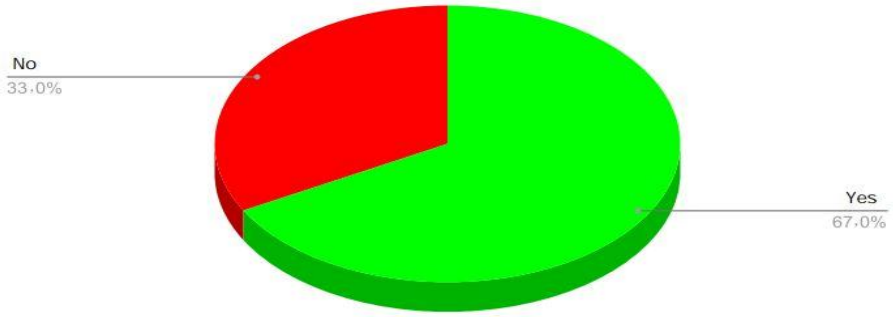
Answer	Frequency	Percent
None	86	**86.0%**
One case	8	8.0%
Two cases	2	2.0%
Three cases	4	4.0%
Total	100	100.0%

Table No (3.10): Shows the Number of Acute Watery Diarrhea Cases Reported Among Family Members

- **Analysis**

Among the households that reported cases of acute watery diarrhea, 8.0% experienced a single case, while 2.0% reported two cases, and 4.0% recorded as many as three cases within the same 12-month period. The vast majority of participants (86.0%) reported no cases, which aligns with the previous findings on disease occurrence.

3.8.2. Have You Seen Confirmed Cholera Cases in the Community in the Past Two Years ?



Reports of confirmed cholera cases in the community during the past two years

Figure No (3.10):

3.9. Reports of Confirmed Cholera Cases in the Community During the Past Two Years

- **Analysis**

A significant majority of the participants (67.0%) reported having seen confirmed cholera cases within their community over the past two years. Only 33.0% stated they had not witnessed such cases. This finding confirms that cholera is a highly visible and prevalent health threat in East/West Al-Qash, emphasizing the urgent need for effective water safety interventions.

3.9.1. In Your Opinion, What are the Benefits of Boiling Water?

Answer	Frequency	Percent
Kills germs	94	94.0%
Improve taste	2	2.0%
Removes turbidity	2	2.0%
No benefit	2	2.0%
Total	100	100.0%

Table No (3.11) : Shows the Perceived Benefits of Boiling Water Among the Population

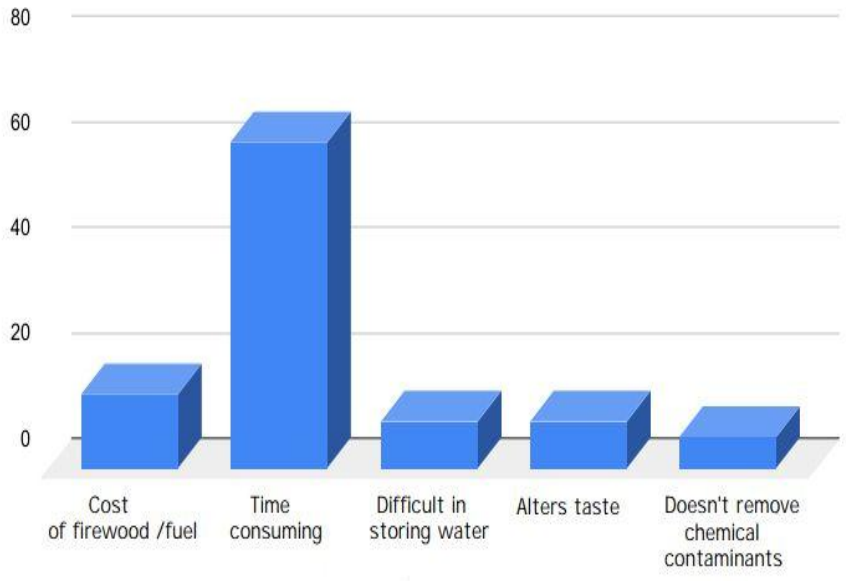
- **Analysis**

The vast majority of the population (94.0%) recognizes that the primary benefit of boiling water is its ability to kill germs. Only a small fraction of respondents associated boiling with improving taste (2.0%) or removing turbidity (2.0%), while another 2.0% believed it offered no benefit at all. This high level of understanding regarding the microbial safety provided by boiling serves as a strong foundation for public health campaigns.

3.9.2. What are Obstacles to Using Traditional Water Purification Methods?

Answer	Frequency	Percent
Time consuming	62	62.0%
Cost of firewood/fuel	14	14.0%
Difficulty in storing water	9	9.0%
Alters taste	9	9.0
Doesn't remove chemical contaminants	6	6.0%
Total	100	100.0%

Table No (3.12): Shows the Obstacles Faced By the Population When Using Traditional Water Purification Methods



The obstacles faced by the population when using traditional water purification methods

Figure No (3.12):

3.10. The Obstacles Faced By the Population When Using Traditional Water Purification Methods

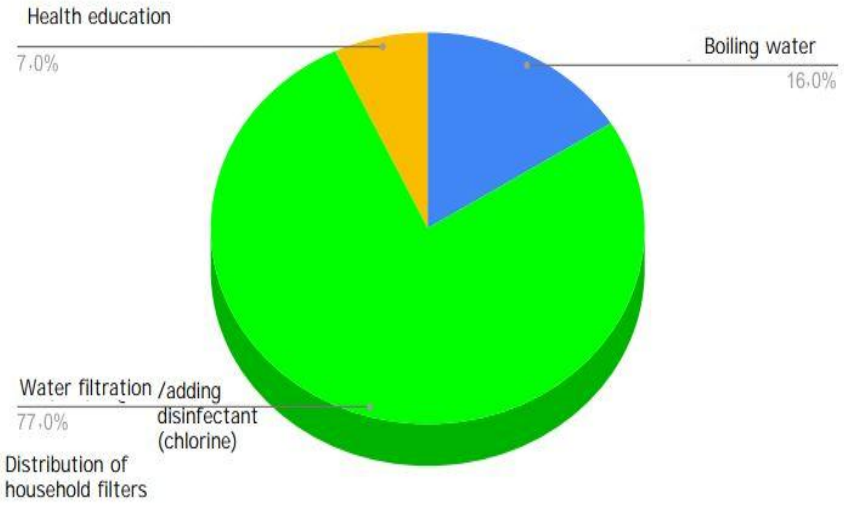
- **Analysis**

The most significant obstacle to the use of traditional purification methods is that they are time-consuming, as reported by 62.0% of the participants. Other noted barriers include the cost of firewood or fuel (14.0%), difficulties in storing treated water (9.0%), and the perception that these methods alter the taste of the water (9.0%). A smaller group (6.0%) expressed concern that traditional methods do not remove chemical contaminants. These results suggest that for water treatment to be more widely adopted, it must be made more efficient and less resource-intensive for the user.

In your opinion, what is the most practical action to improve water quality in your area?

Answer	Frequency	Percent
Boiling water	16	16.0%
Health education	7	7.0%
Water filtration/distribution of household filters/adding disinfectant(chlorine)	77	77.0%
Total	100	100.0%

Table No (3.13): Shows the Population's Opinion on the Most Practical Action to Improve Water Quality in Their Area



Population's opinion on the most practical action to improve water quality in their area

Figure No (3.13):

3.11. Population's Opinion on the Most Practical Action to Improve Water Quality in their Area

- **Analysis**

When asked to identify the most practical solution for their community, the majority of respondents (77.0%) prioritized household-level technical interventions, specifically water filtration, the distribution of filters, or the addition of disinfectants like chlorine. 16.0% viewed boiling water as the most practical step, while a small segment (7.0%) emphasized health education. This distribution reflects a strong community preference for tangible, immediate solutions that can be managed within the home to ensure water safety.

4. Chapter Four Discussion

The findings of this study reveal a pronounced knowledge–practice gap in household water safety in East/West Al-Qash. Despite high educational attainment (78.0%) and near-universal awareness of cholera (96.0%), the majority of households (59.0%) reported not treating their drinking water. This confirms earlier findings from Kassala State that health literacy alone is insufficient to produce sustained behavior change in settings affected by poverty, fuel scarcity, and protracted conflict [34]. The high recognition of cholera symptoms (90.0%) and the fact that 67.0% of respondents had witnessed cholera cases likely reflect the intense visibility of recent outbreaks in Sudan since 2024, driven by infrastructure collapse and mass displacement, rather than effective preventive engagement [28].

Risk perception emerged as a critical determinant of practice. Most households relied on water tankers and household storage cisterns (Tanakir) (63.0%), and among non-practicing households, 71.0% perceived these sources as safe. This misplaced confidence is particularly concerning given longstanding evidence from Eastern Sudan demonstrating high microbial contamination in household storage due to secondary contamination [32]. Earlier studies in Kassala and Port Sudan identified Tanakir as a critical transmission point, suggesting that cholera risk is often generated within the domestic environment rather than at the original water source [32]. The present findings reinforce this interpretation and highlight household storage as a "silent vector" sustaining transmission.

Traditional purification methods were widely acknowledged but inconsistently practiced. Although boiling was recognized by 94.0% of participants as an effective method, its routine use was limited, with 62.0% citing time consumption and fuel scarcity as major barriers. While boiling is microbiologically complete, previous studies have shown that up to 40% of households recontaminate water during cooling and storage, further reducing its protective value in real-world settings [17,35]. Similarly, solar disinfection (SODIS), which has demonstrated effectiveness in African contexts when applied correctly, requires low turbidity and consistent exposure time—conditions that may not be reliably met in Al-Qash, particularly during floods and periods of displacement [12].

The limited reliance on traditional filtration methods observed in this study contrasts with findings from Bangladesh, where cloth filtration significantly reduced cholera incidence by removing zooplankton-associated Vibrio cholerae [9]. However, subsequent research has demonstrated that filtration alone is insufficient unless followed by secondary disinfection to eliminate free-floating bacteria [10]. This may explain why filtration-based approaches such as cloth or Moringa seed use—although locally known—are often perceived as inefficient in Al-Qash. While Moringa has been shown to substantially reduce turbidity and bacterial load, improper filtration and delayed consumption can allow bacterial regrowth, limiting its protective impact under household conditions [33].

Beyond structural and technical barriers, behavioral factors also influenced water safety practices. A small but notable proportion of participants (7.0%) described their water as having an altered taste, such as salinity, yet still deemed it acceptable for consumption. This suggests a process of sensory habituation, whereby chronic exposure to poor water quality normalizes risk and diminishes motivation to seek safer alternatives. Such behavioral nuances are rarely captured in conventional KAP studies but may play an important role in sustaining unsafe practices despite high awareness [34].

In contrast to the low uptake of labor-intensive methods, the study revealed strong receptivity to modern, household-level interventions. A large majority of respondents (89.0%) expressed willingness to adopt new and affordable technologies, with 77.0% identifying household filtration and chlorine-based treatment as the most practical options. This preference aligns with global evidence identifying chlorination as the most cost-effective household water treatment method, particularly in emergency and conflict-affected settings [15]. Although taste-related rejection of chlorine has been reported in Eastern Sudan, its speed, affordability, and residual protection make it more compatible with the community's expressed need for convenience and time efficiency. These findings are consistent with Global WASH Cluster reports emphasizing that time constraints—particularly for women—are a primary barrier to safe water practices in the region [38].

5. Chapter Five Conclusion and Recommendation

5.1. Conclusion

This study demonstrates a substantial knowledge–practice gap in household water safety in East/West Al-Qash. Although awareness of cholera is high, safe water practices remain limited due to misperceived source safety and practical barriers such as time and fuel constraints [34,38]. Reliance on tanker water and household storage increases the risk of contamination, highlighting the need for interventions beyond health education alone [32]. The strong community willingness to adopt affordable, household-level solutions particularly filtration and chlorine-based treatment—underscores the importance of point-of-use water treatment strategies to effectively reduce cholera transmission in conflict-affected setting [15,28].

Recommendation

To address the knowledge–behavior gap in water safety in East/West Al-Qash, this study recommends shifting from awareness-based approaches to practical, enabling interventions [34,38]. For the State Ministry of Health and Policy Makers , Efforts should prioritize subsidizing household water filters and chlorine tablets to overcome time and cost barriers. Regulatory enforcement of mandatory chlorination for commercial water tankers at filling points is essential, alongside routine monitoring of water quality at the household storage level (Tanakir) to detect secondary contamination [32]. For Humanitarian Organizations Interventions should focus on safe household water storage by promoting Tanakir hygiene through the provision of cleaning supplies and protective covers. The distribution of zero-energy filtration systems should be

prioritized to provide effective treatment options without reliance on fuel or electricity [38]. For the Community, Households should be encouraged to adopt combined treatment approaches by pairing traditional filtration methods with secondary disinfection, such as chlorination or solar disinfection [10]. Regular cleaning and disinfection of household storage tanks are also essential to reduce contamination risks [32]. For Future Research: Further microbiological investigations are needed to assess contamination levels and characterize Vibrio cholerae in household storage tanks in Al-Qash.

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Dedication

First of all, we would like to thank Allah, without his guidance we would never have been able to accomplish this.
We dedicate this humble work...
To our beloved parents, the pillars of our strength, whose endless prayers, sacrifices, and unwavering belief in our potential have paved the way for our success. Your love is the light that guided us through the darkest hours of our academic journey.
To the resilient people of Sudan, especially those in Kassala State, who continue to show immense strength in the face of epidemics and hardships. This work is a tribute to your perseverance, and we hope it serves as a stepping stone toward a healthier, disease-free future.
To our mothers, the primary guardians of health in our households, whose dedication to the safety of their families inspired the core of this study.
To the souls of those we have lost to preventable waterborne diseases, and to the health workers on the front lines fighting for every life.
To the spirit of knowledge and scientific inquiry, for which we have dedicated our years of study at Al-Madain College.

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