



# Water Quality and Community Perception in the Tana Delta, Kenya: Implications for Livelihoods and Public Health

Said Abdulahi Omar\*<sup></sup>, Felix L. M. Ming'ate<sup></sup>, Samuel O. Ochola<sup></sup>

Department of Environmental Studies and Community Development, Kenyatta University, Nairobi, Kenya

Email: \*abdulahiomar82@yahoo.com, mingate.felix@ku.ac.ke, ochola.samuel@ku.ac.ke

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## Abstract

Water quality is a critical determinant of public health, livelihoods, and sustainable development, particularly in communities dependent on natural water sources. This study assessed the main water sources, water quality, community perceptions, and the implications for health and livelihoods in the Tana Delta, southeastern Kenya. Household surveys, focus group discussions, and environmental assessments were conducted to evaluate water use, safety perceptions, and health outcomes. Findings indicate that households rely on rivers (42.1%), boreholes (21.7%), shallow wells (15.3%), piped systems (12.5%), and seasonal streams or oxbow lakes (20.9%). River water was widely used but perceived as unsafe due to turbidity, faecal contamination, and agrochemical runoff, while boreholes and piped water were considered safer but they faced challenges of accessibility, reliability, and occasional salinity. Waterborne diseases, particularly diarrhea, were significantly associated with unsafe sources and inadequate treatment practices. Environmental assessments further revealed wetland degradation (27%) and vegetation loss (18%), which increase contamination risks and undermine ecosystem services. Groundwater salinity combined with pollution risks from agricultural and domestic activities, limits the availability of safe drinking water, threatening both public health and livelihoods. These findings underscore the compounded vulnerability of Tana Delta communities and highlight the need for integrated interventions, including expanded access to safe water, household-level treatment, wetland conservation, climate-adaptive water management, and community education to safeguard health and sustain livelihoods.

## Subject Areas

Atmospheric Sciences

## Keywords

Water Quality, Community Perception, Hydro-Climatic Variability, Tana Delta, Groundwater Salinity, Livelihoods, Public Health

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## 1. Introduction

Water quality is a critical determinant of sustainable development, public health, and livelihood security, particularly in communities that rely on natural water sources for daily needs [1]. Poor water quality has been linked to waterborne diseases, reduced agricultural productivity, and heightened vulnerability among rural populations [2] [3]. In addition, water quality directly influences health through consumption patterns, as intake below recommended levels can cause dehydration and is linked to metabolic and functional health complications [3].

Community-based water resource management has been identified as a key approach to improving water outcomes, as local populations possess substantial indigenous knowledge regarding water availability, usage patterns, and historical changes in water resources [4]. Nevertheless, in many developing countries, water supply initiatives have historically prioritized quantity over quality, prompting calls for more attention to the safety and reliability of water sources [5].

Globally, trust in drinking water safety is declining, and perceptions of water-related risks increasingly shape household behaviors, including decisions to treat water, switch sources, or rely on bottled water [6] [7]. Divergence between perceived and actual water safety represents a major barrier to achieving universal access to safe drinking water [7]. In sub-Saharan Africa, over 400 million people still lack access to safe drinking water, with contamination remaining a leading cause of morbidity and mortality [2]. Factors such as climate variability, weak monitoring systems, and inadequate infrastructure exacerbate both water quality deficits and public mistrust [8].

Kenya reflects these global trends, particularly in arid and semi-arid counties where rural water coverage and quality remain uneven despite policy commitments [9] [10]. The Tana Delta, located in southeastern Kenya, exemplifies these challenges due to its ecological complexity, seasonal flooding, and anthropogenic pressures including irrigation, livestock grazing, and settlement expansion [11] [12]. Communities in the Delta rely heavily on rivers, oxbow lakes, shallow wells, and seasonal streams, all of which are highly vulnerable to contamination [12].

In addition to microbial and chemical contamination, some groundwater sources in delta regions exhibit high salinity, reflecting the combined influence of natural geohydrological conditions and anthropogenic activities. Studies in the northeastern Nile Delta and the Dahab delta aquifer in Egypt have reported high levels of soil and groundwater salinity, attributed to shallow saline groundwater, seawater intrusion, and water–rock interactions. These conditions adversely affect both agricultural productivity and public health, illustrating the complex interplay of en-

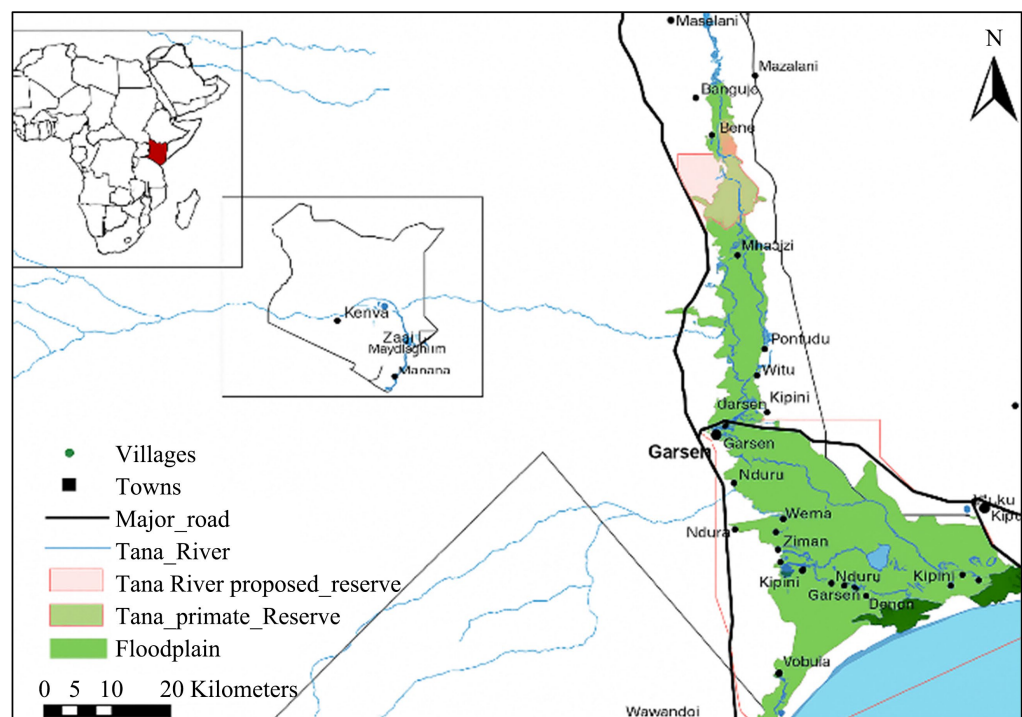
environmental and human factors in deltaic water systems [13]. High salinity, combined with microbial and chemical contamination, limits safe water availability and poses significant challenges to both livelihoods and health.

Previous research has documented considerable seasonal and spatial variability in water quality across the Tana Delta [14]; however, there remains limited investigation into how local perceptions influence water use and the consequent implications for livelihoods and public health. Addressing this knowledge gap, the present study examines: 1) the main water sources in the Tana Delta, 2) the quality of these water sources and community perceptions regarding their safety, and 3) the effects of hydro-climatic variability and climate change on water availability and public health outcomes.

## 2. Materials and Methods

### 2.1. Study Area

This study was conducted in the Tana Delta, located in Tana River County, south-eastern Kenya. The Delta is ecologically diverse and hydrologically sustained by the Tana River, Kenya's longest river. It is characterized by seasonal flooding, oxbow lakes, shallow wetlands, and an intricate mosaic of livelihood systems including farming, livestock keeping, and fishing. The study area was selected to capture varying levels of access to water sources, ecological vulnerability, and infrastructural disparities, allowing for comparative insights into water quality perceptions and exposure across differing hydro-climatic contexts [15]. See **Figure 1** below, which shows a map of the Tana Delta.



**Figure 1.** A map of Tana Delta.

## 2.2. Research Design

A mixed-methods design was adopted, integrating quantitative surveys, qualitative discussions, environmental assessments, and hydro-climatic data analysis. This approach, grounded in established methodological frameworks [16] [17], facilitated triangulation and ensured a holistic understanding of water source dynamics, community perceptions and their implications for public health and livelihoods.

## 2.3. Data Collection

### 2.3.1. Household Surveys

Household surveys were conducted across selected villages in the Tana Delta to collect quantitative data on water sources, water quality perceptions, treatment practices, and health outcomes. A total of 382 households were surveyed across the study area. Structured questionnaires were administered to household heads or their representatives, capturing demographic information, water-use patterns, frequency of waterborne diseases, and coping mechanisms during periods of scarcity or contamination.

The survey sample was proportionally distributed across villages to ensure representativeness. See **Table 1** below for the detailed household distribution by village. The overall survey response rate was 100%, as all selected households participated.

**Table 1.** Population distribution and sample allocation across selected villages in the Tana Delta.

| No. | Village Name | Geographical Zone | Estimated Households | Proportion (%) | Sampled Households |
|-----|--------------|-------------------|----------------------|----------------|--------------------|
| 1   | Mnazini      | Upper Section     | 911                  | 10.3%          | 39                 |
| 2   | Marengo      | Upper Section     | 1200                 | 13.6%          | 52                 |
| 3   | Kulesa       | Upper Section     | 500                  | 5.7%           | 22                 |
| 4   | Wema         | Upper Section     | 400                  | 4.5%           | 17                 |
| 5   | Hewani       | Upper Section     | 300                  | 3.4%           | 13                 |
| 6   | Idsowe       | Central Part      | 1061                 | 12%            | 46                 |
| 7   | Danisa       | Central Part      | 200                  | 2.3%           | 9                  |
| 8   | Ghalili      | Central Part      | 160                  | 1.8%           | 7                  |
| 9   | Kibusu       | Central Part      | 619                  | 7.0%           | 27                 |
| 10  | Ngao         | Central Part      | 440                  | 5.0%           | 19                 |
| 11  | Mandingo     | Lower Segment     | 166                  | 1.9%           | 7                  |
| 12  | Semikaro     | Lower Segment     | 446                  | 5.1%           | 19                 |
| 13  | Ozi          | Lower Segment     | 249                  | 2.8%           | 11                 |
| 14  | Kipini       | Lower Segment     | 2165                 | 24.6%          | 94                 |
|     | Total        |                   | 8817                 | 100.0%         | 382                |

### 2.3.2. Focus Group Discussions

Three focus group discussions (FGDs) were conducted in Garsen, Kipini, and Mnazini, each comprising 8 - 12 participants carefully selected to represent gender, age and livelihood diversity within the study population [18] [19]. The FGDs provided in-depth qualitative insights that complemented the household survey, particularly in capturing local knowledge, cultural perspectives, and collective experiences that cannot be quantified through structured questionnaires.

The discussions focused on cultural and experiential drivers of water quality perceptions, including traditional beliefs, water-use practices and sensory-based judgments of safety. They also explored community responses to contamination episodes such as boiling, filtering, or reliance on alternative sources and examined the perceived links between water, health, and livelihoods, with emphasis on seasonal variations in disease incidence, productivity and food security.

Additionally, the FGDs investigated adaptation and coping strategies under water scarcity or contamination, including migration, rationing, water storage and livelihood adjustments. All FGDs were audio-recorded with prior informed consent, transcribed verbatim, and analyzed thematically following established qualitative research procedures [20] [21]. Codes were generated inductively from participant narratives, grouped into categories and synthesized into key themes that informed triangulation with quantitative findings.

### 2.3.3. Environmental Assessment

Environmental assessments combined remote sensing analyses with field observations to provide a comprehensive understanding of water resources in the Tana Delta. Landsat imagery spanning 1995-2023 was analyzed using the Normalized Difference Water Index (NDWI) and the Normalized Difference Vegetation Index (NDVI) to detect changes in wetlands and vegetation cover over time [22] [23].

In addition, water points were physically inspected to document protection status, proximity to contamination sources, and infrastructure reliability. Field observations included assessments of turbidity, livestock interference and sanitation-related risks, providing complementary information to the remote sensing analyses [24]-[26].

Direct laboratory measurements (e.g., microbial testing for *E. coli* or chemical assays for salinity) were not conducted in this study. Instead, risk assessments were derived from observed physical indicators (such as visible turbidity and evidence of faecal contamination), household perceptions, and triangulation with WHO drinking water guidelines and relevant literature. This approach ensured consistency in evaluating public health risks, even in the absence of laboratory-confirmed data.

### 2.3.4. Meteorological Analysis

Historical rainfall records from 1990 to 2023, obtained from the Kenya Meteorological Department, were used to assess long-term hydro-climatic variability. Analyses focused on annual and seasonal rainfall trends, the frequency of droughts and

floods, and the correlation of rainfall anomalies with household reliance on unsafe water sources.

Household perceptions of water quality were evaluated using participatory sensory indicators, including clarity, odor, color, and taste, adapted from [27] [28]. These subjective perceptions were compared against observed environmental conditions and reported health outcomes to understand how community perceptions aligned with actual water quality.

Survey data were coded and analyzed using SPSS v26. Descriptive statistics, including percentages and frequencies, summarized household water sources and perceptions. Cross-tabulations examined the relationship between water source type, perceived safety and reported health conditions, while chi-square tests were used to assess significant differences across settlement types.

Qualitative data from FGDs were subjected to thematic content analysis to generate categories around perception drivers, coping strategies and health–livelihood narratives. NVivo software was used for coding and for triangulating qualitative findings with survey results.

Environmental and climate analyses included computation of NDWI and NDVI indices in ArcGIS 10.8 to quantify spatiotemporal changes in wetlands and vegetation. Rainfall trends were analyzed using linear regression and anomaly detection techniques to identify wet and dry cycles.

Finally, findings from household perception surveys were integrated with environmental and meteorological analyses to explain spatial and temporal variability in water risks. A perception–exposure–health framework was developed to trace causal links between water quality perceptions, behaviors, and health and livelihood outcomes.

### 3. Results

#### 3.1. Main Water Sources and Community Perceptions

Households in the Tana Delta rely on multiple water sources, each with distinct usage patterns, safety perceptions, and challenges. River water is the most frequently used source, serving 42.1% of households, yet only 28.5% of users consider it safe due to turbidity, faecal contamination and agrochemical runoff, particularly during the rainy season. Boreholes, used by 21.7% of households, were regarded as the safest source, with 68.2% perceiving the water as safe, though occasional salinity, metallic taste, long queues and equipment breakdowns reduced reliability.

Shallow wells served 15.3% of households and had moderate safety perception (35%) but proximity to latrines and surface runoff increased contamination risks. Piped water systems, accessed by 12.5% of households, were generally considered safe (72% perceiving safety), though irregular supply and infrastructure breakdowns forced some households to revert to less safe sources. Seasonal streams and oxbow lakes and swamps were used by 11.8% and 9.1% of households, respectively and were perceived as the least safe sources (22.5% and 18%), primarily due to

intermittent flow, stagnation, mosquito breeding and livestock contamination. **Table 2** below depicts the narratives.

**Table 2.** Main household water sources, usage, and safety perceptions in the Tana Delta.

| Water source            | % of households using | % perceiving as safe | Key challenges reported                                 |
|-------------------------|-----------------------|----------------------|---|
| River water             | 42.10%                | 28.50%               | Turbidity, faecal contamination, agrochemical runoff    |
| Boreholes               | 21.70%                | 68.20%               | Salinity, metallic taste, long queues, breakdowns       |
| Shallow wells           | 15.30%                | 35.00%               | Contamination from nearby latrines, surface runoff      |
| Piped/tap water systems | 12.50%                | 72.00%               | Irregular supply, infrastructure breakdowns             |
| Seasonal streams        | 11.80%                | 22.50%               | Intermittent flow, contamination during droughts/floods |
| Oxbow lakes & swamps    | 9.10%                 | 18.00%               | Stagnation, mosquito breeding, livestock waste          |

### *Sensory Perceptions of Water Quality*

Households assessed water safety using sensory indicators such as clarity, odor, color, and taste. River water was frequently brown and turbid, especially during floods, while borehole water was generally clear but sometimes salty or metallic. Shallow wells often emitted unpleasant odors, particularly when near latrines or livestock. Piped water was usually clear and tasteless, although the supply was often irregular. Seasonal streams and oxbow lakes were commonly muddy, foul-smelling and stagnant during dry periods.

These sensory perceptions strongly influenced household trust in water sources and decisions about water treatment. Water treatment practices varied across households (**Table 3**). Boiling was the most common method, followed by filtration and chlorination. Households that treated their water reported lower diarrheal incidence. Chi-square tests confirmed a significant association between household water source and diarrheal incidence ( $\chi^2 = 18.72$ ,  $df = 4$ ,  $p = 0.001$ ) and between water treatment practices and health outcomes ( $\chi^2 = 12.45$ ,  $df = 1$ ,  $p = 0.002$ ). **Table 3** gives the explanations of the findings.

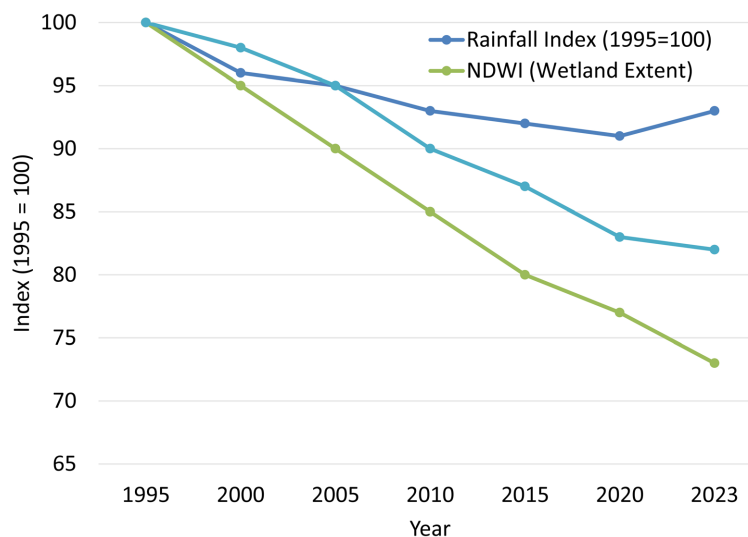
**Table 3.** Household water treatment practices and reported diarrheal incidence.

| Treatment practice | % of households using | Reported diarrheal incidence (%) |
|--------------------|-----------------------|----------------------------------|
| Boiling            | 36.40%                | 12.50%                           |
| Filtration         | 14.70%                | 15.80%                           |
| Chlorination       | 9.30%                 | 11.20%                           |
| No treatment       | 39.60%                | 28.30%                           |

### 3.2. Hydro-Climatic Variability and Its Implications on Public Health

Considerable research has examined past and projected hydro-climatic changes, including extreme events and their impacts on the water cycle globally. There is broad consensus that rising temperatures and shifts in precipitation patterns have altered both the magnitude and timing of freshwater availability worldwide.

In the Tana Delta, long-term hydro-climatic dynamics and environmental changes have significantly affected water availability and quality between 1995 and 2023 (Figure 2). Key observations include:



**Figure 2.** Hydro-Climatic Variability and its implications on public health.

- Rainfall: Annual rainfall exhibits high inter-annual variability, with recurrent droughts during 1999-2001, 2008-2011, 2016-2017 and 2020-2022, and severe floods in 1997-1998 (El Niño), 2018 and 2020. Despite episodic wet years, mean annual rainfall declined by approximately 6% over the 29-year period. This reduction has decreased both surface and groundwater recharge, heightening seasonal water stress.
- NDWI: Wetland extent declined by 27%, particularly in the lower Delta. The progressive drying of oxbow lakes and ephemeral channels during dry seasons has reduced natural water storage capacity, increasing reliance on river water and shallow wells that are frequently vulnerable to contamination.
- NDVI: Vegetation cover decreased by 18%, reflecting wetland degradation and land conversion for agriculture and grazing. Loss of riparian vegetation accelerated soil erosion and agrochemical runoff, further degrading water quality.

These combined trends declining rainfall, shrinking wetlands and vegetation loss intensify water scarcity, reduce water quality and heighten vulnerability to waterborne diseases. Consequently, communities are increasingly reliant on unsafe or intermittently safe water sources during droughts, while flood events exacerbate contamination risks, with significant implications for both public health and

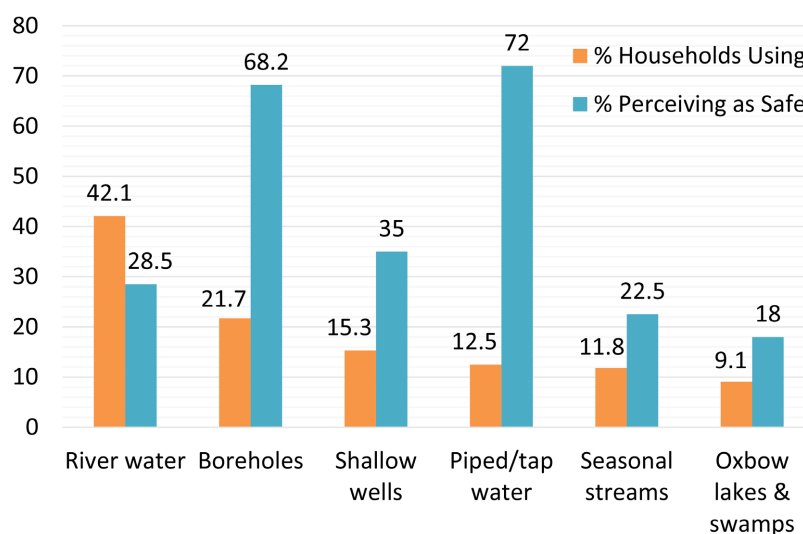
livelihoods. See the narrative in **Figure 2** below.

### 3.3. Impacts of Water Supply on Community Livelihoods

Household dependence on water sources directly affected both public health and livelihoods. River water, used by 42.1% of households, posed the highest risk of typhoid, diarrhea, dysentery and skin infections. Boreholes, though perceived as safer by 68.2% of users, were frequently overused, leading to long queues and occasional conflicts. Shallow wells and seasonal streams were unreliable during dry periods, increasing food insecurity and vulnerability. Piped systems, while safer, were inconsistent in supply, forcing households to supplement with unsafe sources.

Fluctuating water availability undermined agricultural productivity, livestock health, and household welfare. Survey data confirmed that poor-quality river water reduced crop yields and increased health risks. Qualitative narratives reinforced these findings. A farmer in Mnazini noted, “*When the wells dry up, our animals die or get weak. Without water, even the farms cannot produce enough food.*” Similarly, a participant in Garsen stated, “*Water is life here. When it is not available, people go hungry, children miss school and families lose income*”.

Field observations supported these accounts. River intake points were often unprotected and shared with livestock. Shallow wells were uncovered and located near latrines. Boreholes, though protected, were heavily overused. In Garsen, piped systems existed but were irregular, further limiting household resilience. **Figure 3** below illustrates the findings.



**Figure 3.** Household dependence on primary water sources in the Tana Delta and their implications for health and livelihoods.

## 4. Discussion

This study demonstrates that access to safe and reliable water in the Tana Delta is shaped by a complex interaction of household perceptions, hydro-climatic variability, and livelihood needs. While river water remains the dominant source,

households consistently perceive it as unsafe, whereas boreholes and piped systems inspire greater trust but are undermined by salinity, irregular supply, and infrastructure failures. These findings confirm that water use decisions are not only a matter of availability but also of sensory perceptions clarity, odor, color, and taste that strongly influence household behavior and treatment practices.

The significant association between untreated water and diarrheal incidence highlights how reliance on unsafe sources translates directly into health risks. At the same time, the limited uptake of treatment methods, despite awareness of contamination, points to structural barriers such as affordability, fuel availability for boiling, and inconsistent supply of chlorine. These behavioral and infrastructural constraints amplify health vulnerability.

Hydro-climatic variability further compounds these risks. Declining rainfall, recurrent droughts, and flood events have reduced both surface and groundwater reliability while accelerating wetland and vegetation loss. This degradation has increased turbidity, agrochemical runoff, and exposure to contamination. As a result, communities are frequently pushed toward less safe sources in dry periods and face heightened contamination during floods.

Livelihood impacts are equally pronounced. Water stress disrupts agriculture, livestock, and fishing, undermining food security and household income. Borehole queues, crop losses, and livestock mortality illustrate how water insecurity translates into social and economic strain. Such cascading effects contribute to missed school attendance, reduced labor productivity, and heightened vulnerability during prolonged water stress.

Taken together, these findings highlight that water quality concerns in the Tana Delta cannot be addressed through water supply interventions alone. They must be considered alongside environmental conservation and climate adaptation strategies. The study's unique contribution lies in linking household perception data with hydro-climatic evidence and livelihood outcomes. This integrated perspective demonstrates that sensory judgments of water, climate-driven variability and livelihood insecurity are mutually reinforcing drivers of vulnerability.

## **5. Conclusion & Recommendations**

This study concludes that households in the Tana Delta face persistent challenges in accessing safe and reliable water, with significant implications for public health and livelihoods. River water, although the most widely used source, is consistently unsafe due to contamination, while boreholes and piped systems though safer are constrained by salinity, irregular supply, and infrastructure breakdowns. Hydro-climatic variability, including droughts and floods, further exacerbates water scarcity and contamination, undermining agriculture, livestock, fishing, and overall community well-being.

There is a need to expand access to safe and reliable water sources while ensuring effective water treatment and environmental conservation. Communities remain highly vulnerable to recurrent waterborne diseases and livelihood disruptions unless comprehensive measures are taken.

## 6. Recommendations

Based on the findings and identified gaps of this paper, the following recommendations are proposed:

### 1) Water Sources

- Expand safe water infrastructure, including boreholes, piped schemes, and protected wells, to reduce reliance on unsafe surface sources.
- Ensure regular maintenance and monitoring of water systems to improve reliability and sustainability.

### 2) Water Quality and Community Perception

- Introduce low-cost, community-friendly water treatment technologies such as filtration and chlorination.
- Strengthen public health education programs to address cultural and sensory-based perceptions that shape water-use practices.
- Enhance trust and accountability in water governance institutions to encourage community participation in water management.

### 3) Hydro-Climatic Variability and Public Health

- Promote climate adaptation strategies, including water harvesting, storage facilities, and drought-resilient infrastructure.
- Implement watershed and wetland conservation programs to reduce erosion, agrochemical runoff and contamination risks.
- Integrate early warning systems for floods and droughts to safeguard public health and livelihoods.

Overall, a comprehensive approach integrating improved water supply infrastructure, water quality management, and climate adaptation strategies is essential to secure safe water access, strengthen resilience, and protect the health and livelihoods of communities in the Tana Delta.

## 7. Limitations

This study relied on self-reported household health data, which may be subject to recall or reporting bias. In addition, the absence of microbiological testing limited the ability to validate perceived water safety with laboratory-confirmed contamination. Future studies should incorporate microbial and chemical analyses to strengthen causal inferences. Limitations

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## Conflicts of Interest

The authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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